PHYSICAL ATTRIBUTES, PHYSICAL AND CHEMICAL PROPERTIES OF BAMBOO (*GIGANTOCHLOA SCORTECHINII*)

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JAMALUDIN, K., ABD. JALIL, A. & ABD. LATIF, M. 2000. **Physical attributes, physical and chemical properties of bamboo (*Gigantochloa scortechinii*).** The physical attributes, physical and chemical properties of *Gigantochloa scortechinii* harvested from FRIM bamboo plantation were studied. For the physical attributes, regardless of age, the culm basal diameter varied from 7.4 to 11.7 cm, culm wall thickness from 1.1 to 3.2 cm, culm weight from 11.2 to 26.4 kg and volume from 11 841 to 21 790 cm^3. Effects of age on the culm basal diameter, weight and volume were found to be significant except for culm wall thickness. The culm basal diameter, weight and volume correlated positively with age. The top portion of 3-y-old culm showed the highest oven-dry density (0.8 g cm^{-3}) while the basal portion of 1-y-old culm the lowest (0.5 g cm^{-3}). Highest initial moisture content (131.4%) was observed in the basal portion of 1-y-old culm while the lowest at the top portion of 3-y-old culm (58.0%). The oven-dry density and initial moisture content were affected by age and culm portion. The initial moisture content was negatively correlated with age and culm portion while the oven-dry density was positively correlated. All the chemical properties varied significantly with age (except for holocellulose) and culm portion (except for ash and lignin content).

Key words: *Gigantochloa scortechinii* - physical attributes - physical-chemical properties

JAMALUDIN, K., ABD. JALIL, A. & ABD. LATIF, M. 2000. **Sifat-sifat fizikal, ciri-ciri fizikal dan kimia buluh (*Gigantochloa scortechinii*).** Sifat-sifat fizikal, ciri-ciri fizikal dan kimia *Gigantochloa scortechinii* yang ditebang dari ladang buluh FRIM diselidiki. Bagi sifat-sifat fizikal buluh, tanpa mengira umurnya, garis pusat bahagian bawah buluh berada antara 7.4 hingga 11.7 cm, ketebalan dinding dari 1.1 ke 3.2 cm, berat batang dari 11.2 ke 26.4 kg dan isi padu dari 11 841 ke 21 790 cm^3. Kesan umur terhadap garis pusat bahagian bawah buluh, berat dan isi padu adalah ketara kecuali ketebalan dinding. Garis pusat bahagian bawah buluh, berat dan isi padu berkait secara positif dengan umur. Bahagian atas buluh berumur 3 tahun menunjukkan ketumpatan ketuhar kering tertinggi (0.8 g cm^{-3}) manakala bahagian bawah buluh berumur 1 tahun terendah (0.5 g cm^{-3}). Kandungan lembapan awal yang tertinggi (131.4%) terdapat di bahagian bawah buluh berumur 1 tahun manakala yang terendah pada bahagian atas buluh berumur 3 tahun (58.0%). Ketumpatan ketuhar kering dan kandungan lembapan awal dipengaruhi oleh umur dan bahagian buluh. Kandungan lembapan awal berkait secara negatif dengan umur dan bahagian buluh manakala ketumpatan ketuhar kering berkait secara positif. Kesemua ciri-ciri kimia berbeza ketara dengan umur (kecuali holoselulosa) dan bahagian buluh (kecuali abu dan kandungan lignin).

Introduction

In Malaysia, more than 50 bamboo species are being found in cultivation or grown wild in the forest (Wong 1995). However, only 12 species of bamboo are being commercially exploited for their culms and shoots. Bamboos are associated with traditional and rural lifestyles, normally used as housing materials or for making of home utility items. Bamboo shoots are gathered and used as food supplement. *Gigantochloa scortechinii* is used extensively for making poultry cages, blinds, barbecue sticks, vegetable baskets, chopsticks, incense sticks and tooth picks (Abd. Latif & Abd. Razak 1994).

Bamboos vary considerably in size depending on the species, locality and vigour of the clump (Krishnaswamy 1956). Wong (1982) reported that stem size and wall thickness influence the range of bamboo usage. Studies on the physical attributes of local bamboos are limited (Azmy *et al.* 1991, Azmy 1993, Abd. Latif *et al.* 1995, Abd. Latif 1996). The fibre and chemical properties of *G. scortechinii* have been investigated by Abd. Latif *et al.* (1994). The highly variable properties of bamboo present many problems during processing and utilisation (Abd. Latif *et al.* 1990). Since bamboo is normally harvested without due consideration given to their characteristics and final use (Abd. Latif & Abd. Razak 1994), future improvements should be geared towards harvesting bamboo of suitable age, quality and species for intended uses. This paper discusses the physical and chemical properties and physical attributes of *G. scortechinii* with reference to the effects of age and culm portion on the properties. The findings are important in yield determination and utilisation.

Materials and methods

Physical attributes

Plantation-grown bamboos established in FRIM plots were used. Twenty culms each from 1-, 2- and 3-y-old bamboos were selected randomly. Details of freshly cut merchantable culms (10 m) were obtained: (a) diameter of the first internode; (b) culm wall thickness of the base and top portions; (c) bamboo culms were cut into three equal parts and from each portion, the culm wall thickness, fresh weight and solid volume were determined. The solid volume of each section was calculated using the following formula (Tandug & Torres 1985).

$$V = \frac{-(Ba - Bh) + (bs - bh)}{2} \times L$$

where

V = solid volume of the section (cm^3)
Ba = area at the large end of the section (cm^2)
Bh = area at the large end of the hollow portion (cm^2)
bs = area at the small end of the section (cm^2)
bh = area at the small end of the hollow portion (cm^2)
L = length of the section (cm)

The total weight in kg was derived by summing up the values obtained for each section.

Physical properties

Ten bamboo culms with dimensions of 2 × 3 cm × thickness taken from the middle section of the first internode were selected randomly for sampling. The initial moisture content was determined by weighing the initial weight followed by oven drying in an oven at 105 ± 2 °C for 24 h and then taking its final weight. Difference between the two divided by the oven-dry weight multiply by 100 gave the initial moisture content. The oven-dry density was determined by dividing the oven-dry weight by its green volume.

Chemical properties

The proximate chemical analysis was conducted on air-dried milled bamboo samples according to the following standard methods:

Hot and cold water solubles	: TAPPI T 207 (Anonymous1978)
1% NaOH solubles	: TAPPI T 212 (Anonymous1978)
Alcohol-benzene solubles	: TAPPI T 204 (Anonymous1978)
Lignin content	: TAPPI T 222 (Anonymous1978)
Holocellulose content	: Wise *et al.* (1946)
Ash content	: TAPPI T 15 (Anonymous1978)

Results and discussion

Physical attributes

Table 1 shows the physical attributes of culms of 1-, 2- and 3-y-old *G. scortechinii* and their variations. These values (except for culm wall thickness) were significantly affected by age (Table 2). The correlation coefficients (Table 3) further revealed that culm diameter (r = 0.39), weight (r = 0.36) and volume (r = 0.43) increased significantly with age. The bigger basal diameter of older bamboo culms as compared to younger ones could be explained by the fact that younger bamboos have less nutrients for their growth. Abd. Latif (1996) also reported that older bamboo have bigger basal diameter. The increase in culm weight and volume with maturity is associated with the increment in basal diameter. The effect of age on culm wall thickness was insignificant (r = -0.07). According to Liese (1985) this is true since for bamboo there is no secondary thickening as found in dicotyledons.

Table 1. Physical attributes of *Gigantochloa scortechinii*

Age (y)	Culm diameter (cm)	Culm wall thickness (cm)	Culm weight (kg)	Culm volume (cm^3)
1	7.42–10.06 (8.82)	1.25–2.90 (2.07)	11.20–22.70 (17.37)	11 841–19 529 (14 757)
2	7.44–10.21 (8.99)	1.20–2.69 (1.95)	13.30–26.60 (18.85)	11 943–20 696 (15 363)
3	7.43–11.74 (9.75)	1.14–3.19 (2.06)	14.50–26.40 (20.27)	12 301–21 790 (17 699)

Numbers in parentheses are mean values.

Table 2. Summary of the analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) on the physical attributes of *Gigantochloa scortechinii*

Source of variation	Degree of freedom	Culm diameter	Culm wall thickness	Culm weight	Culm volume
Age	2	4.92 **	0.10 n.s.	42.05 *	48246183 **
DMRT		Culm diameter (cm)	Culm wall thickness (cm)	Culm weight (kg)	Culm volume (cm^3)
1		8.821 b	2.07 a	17.37 b	14 757 b
2		8.990 b	1.95 a	18.85 ab	15 363 b
3		9.752 a	2.06 a	20.27 a	17 699 a

n.s. = Not siginificant, * = significant ($p < 0.05$), ** = highly significant ($p < 0.01$).
Means in the same column followed by the same letter are not significantly different ($p > 0.05$).

Table 3. Correlation coefficients of culm characteristics with age

Culm characteristic	Age
Diameter	0.394 **
Wall thickness	- 0.074 n.s.
Weight	0.364 **
Volume	0.434 **

n.s. = Not significant ($p > 0.05$), ** = significant ($p < 0.01$).

Moisture content and oven-dry density

Highest moisture content (MC) was observed in the basal portion of 1-y-old bamboo (131.4%) while the lowest was at the top portion of the 3-y-old bamboo (58.0%) (Table 4). The Duncan's multiple range test (DMRT) showed that MC decreased with age and height of culm (Table 5). Further correlation analysis (Table 6) revealed that the MC decreased significantly with age (r = -0.40). Abd. Latif *et al.* (1996) reported that this could be related to its growth establishment such as the development of branches and leaves. The MC also decreased significantly with culm portion (r = -0.76). The lower MC at the top portion could be associated with the decrease in percentage of parenchyma cells, the site of water storage (Liese 1987, Abd. Latif & Mohd. Zin 1992) while the higher MC at the basal portion is probably due to the thin wall fibres and lower concentration of vascular bundles distributed in the immature tissues of the younger bamboo (Abd. Latif & Mohd. Tamizi 1992).

Table 4 shows that 3-y-old bamboo (top portion) has the highest oven-dry density (0.8 g cm^{-3}) while 1-y-old bamboo (basal portion) has the lowest density (0.5 g cm^{-3}). The correlation analysis (Table 6) revealed that the density increased significantly with age (r = 0.55) and culm portion (r = 0.73). Espiloy (1987) and Jamaludin *et al.* (1992, 1993) also found a similar pattern of density variation. Liese (1987) stated that this behavior is due to the decrease in parenchyma cells and a higher frequency of vascular bundle distribution. Since 3-y-old bamboo has higher density, it is expected that older bamboo has better processing qualities.

Table 4. Initial moisture content and oven-dry density according to age and culm portion

Age (y)	Culm portion	Initial moisture content (%)	Oven-dry density (g cm^{-3})
1	B	131.38	0.48
	M	89.75	0.60
	T	69.71	0.72
	B	117.48	0.53
2	M	87.70	0.64
	T	68.07	0.73
	B	85.42	0.66
3	M	74.33	0.75
	T	58.00	0.83

B = basal portion, M = middle portion, T = top portion.

Table 5. Summary of DMRT on the effect of age and culm portion on the initial moisture content and oven-dry density

Age (y)	Initial moisture content (%)	Oven-dry density (g cm^{-3})
1	96.94 a	0.60 c
2	91.08 b	0.63 b
3	72.58 c	0.75 a
Portion	**Initial moisture content**	**Basic density**
Basal	111.42 a	0.55 c
Middle	83.93 b	0.66 b
Top	65.26 c	0.75 a

Means in the same column followed by the same letter are not significantly different at the 0.05 probability level.

Table 6. Correlation coefficients of moisture content and density with age and culm portion

Property	Age	Portion
Moisture content	-0.404 **	-0.761 **
Density	0.551 **	0.733 **

** = Significant ($p < 0.01$).

Chemical properties

The cold water (CW) and hot water (HW) contents, regardless of age and culm portion, varied from 1.1 to 8.3% and 3.3 to 10.3% respectively (Table 7). The HW solubles content is within the range of Malaysian hardwoods (Khoo & Peh 1982). The CW and HW variations were significantly different between the age groups and also between culm portions (Table 8). The correlation analysis showed that CW increased significantly with age ($r = 0.59$) and culm portion ($r = 0.47$). The HW solubles were positively correlated with age ($r = 0.54$) but the increase with culm portion ($r = 0.44$) was not significant.

Irrespective of age and bamboo portion, the alcohol benzene solubles (AB) varied from 2.5 to 7.9% (Table 7). Three-year-old bamboo had the highest amount of AB content while 1-y-old bamboo the lowest. The DMRT analysis showed that the AB content differed significantly with age and bamboo portion (Table 8). The correlation analysis further revealed that the AB content increased significantly with age ($r = 0.78$) but was not significant with bamboo portion ($r = 0.11$).

Table 7. Chemical properties of *Gigantochloa scortechinii* according to age and culm portion

Age (y)	Culm portion	Cold water solubles (%)	Hot water solubles (%)	1% NaOH solubles (%)	Alcohol benzene solubles (%)	Ash content (%)	Lignin content (%)	Holo-cellulose content (%)
1	Basal	1.12	3.25	11.23	2.49	1.12	26.05	65.15
	Middle	4.17	5.60	15.49	2.60	1.09	25.38	65.61
	Top	3.03	3.84	18.45	2.89	1.32	23.71	65.83
2	Basal	5.75	6.48	18.17	2.98	1.11	25.50	68.12
	Middle	7.03	7.87	21.33	3.02	1.39	26.08	67.11
	Top	8.25	10.32	23.64	3.45	1.38	26.50	67.83
3	Basal	4.37	6.01	18.30	7.05	0.98	26.50	68.52
	Middle	5.76	6.60	20.90	7.60	0.98	25.00	70.95
	Top	7.62	8.32	23.12	7.92	1.18	28.88	69.55

Values are means of three determinations.

The highest and lowest alkali solubles were observed at the top portion of the 2-y-old bamboo (23.6%) and basal portion of 1-y-old bamboo (11.2%) respectively (Table 7). The alkali solubles varied significantly with age and bamboo portion (Table 8) and were significantly correlated with age (r = 0.61) and culm portion (r = 0.62) (Table 9). Tadena and Villaneuva (1971) reported that high alkali solubles are associated with high degradation of cellulose and high polyphenol content.

The ash content of *G. scortechinii* ranged from 1.0 to 1.4% (Table 7). The highest ash content was in the middle portion of 2-y-old bamboo while the lowest was in the basal and middle portions of 3-y-old bamboo (Table 7). The ash content was not affected by age and culm portion (Table 8). The ash content decreased insignificantly with age (r = -0.26) but increased insignificantly with culm portion (r = 0.44). Abd. Latif (1996) also found a similar pattern on the effect of age and culm portion on the same species of bamboo. The increase in ash content at the top portion could be attributed to the greater number of vascular bundles within this region, associated with the decreasing ability of the bamboo to absorb nutrients (Espiloy 1983, Chen *et al.* 1987). Since ash content is commonly related with the amount of silica, the selection of bamboo of suitable age with low silica content for specific products is very important.

The lignin content varied from 23.7 to 28.9%, regardless of age and culm portion (Table 7). Table 8 shows that the lignin content is not affected by either age or bamboo portion. Table 9 shows that the lignin content increase with age (r = 0.46) and culm portion (r = 0.09) is not significant.

The holocellulose content of *G. scortechinii* varied from 65.2 to 71.0% (Table 7). The highest value was observed in the middle portion of the 3-y-old culm while the lowest value at the basal portion of the 1-y-old culm. The DMRT analysis showed that the holocellulose content varied significantly with age but was not significant with the culm portion (Table 8). The holocellulose content correlated positively with age ($r = 0.83$) but was uncorrelated with culm portion ($r = 0.03$) (Table 9).

Table 8. Summary of DMRT on the effect of age and culm portion on chemical properties

Property	Age			Portion		
	1	2	3	Basal	Middle	Top
Cold water	2.77 c	7.01 a	5.92 b	3.75 b	5.65 a	6.30 a
Hot water	4.23 c	8.23 a	6.98 b	5.25 c	6.69 b	7.54 a
1% NaOH	15.06 b	21.05 a	20.77 a	15.90 b	19.24 a	21.74 a
Al-benzene	3.42 b	3.15 b	7.52 a	4.17 b	5.17 a	4.75 a
Ash	1.18 a	1.29 a	1.05 a	1.07 a	1.16 a	1.29 a
Lignin	25.05 a	26.03 a	24.78 a	26.02 a	25.48 a	26.36 a
Holocellulose	65.87 b	67.69 ab	69.68 a	67.60 a	67.89 a	67.74 a

Means in the same column followed by the same letter are not significantly different at the 0.05 probability level.

Table 9. Correlation coefficients of chemical properties with age and portion

Property	Age	Portion
Cold water	0.59 *	0.47 *
Hot water	0.54 *	0.44 n.s.
1% NaOH	0.61 **	0.62 **
Al-benzene	0.78 **	0.11 n.s.
Ash	-0.26 n.s.	0.44 n.s.
Lignin	0.46 n.s.	0.09 n.s.
Holocellulose	0.83 **	0.03 n.s.

n.s. = Not significant ($p > 0.05$), * = significant ($p < 0.05$), ** = highly significant ($p < 0.01$).

Conclusion

The physical attributes of *G. scortechinii* except for the culm wall thickness were significantly affected by bamboo age. Three-year-old culm showed the largest diameter, heaviest culm and greatest volume. The physical attributes (except for culm wall thickness) correlated positively with age. Oven-dry density increased while the initial moisture content decreased significantly with age and culm portion.

Age showed positive correlations with all the chemical properties (except for ash and lignin content). Culm portion had positive correlations with cold water and alkali solubles. In conclusion, *G. scortechinii* with its good physical attributes, acceptable physical and chemical properties should be exploited as an industrial material and geared for specific products. Three-year-old culm with the highest total mass, culm volume as well as high density, is expected to have better processing qualities than those of lower age groups.

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