FIBRE MORPHOLOGY AND CHEMICAL PROPERTIES OF *GIGANTOCHLOA SCORTECHINII*

Abd. Latif Mohmod, K.C. Khoo,

Forest Research Institute Malaysia (FRIM), Kepong, 52109 Kuala Lumpur, Malaysia

Jamaludin Kasim & Abd. Jalil Hj. Ahmad

School of Applied Sciences, Mara Institute of Technology (ITM), 40450 Shah Alam, Selangor, Malaysia

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ABD. LATIF MOHMOD, KHOO, K.C., JAMALUDIN KASIM & ABD. JALIL HJ. AHMAD. 1994. Fibre morphology and chemical properties of *Gigantochloa scortechinii*. The chemical composition and fibre morphology of 1-y-old, 2-y-old and 3-y-old *G. scortechinii* were determined. In general, the fibre dimensions (except for fibre wall thickness and the Runkle and L/D ratios) increased with age, and fibre wall thickness and the Runkle ratio decreased with height. The long fibre (3.24 - 5.03 *mm*) and high L/D ratio (105 - 171) of *G. scortechinii* are attractive features of the species for papermaking. The chemical composition, correlated insignificantly with age (except for the cold water solubles content) and height (except for the hot water, alkali and alcohol-benzene solubles contents). The contents of the chemical components generally increased with age (except for alpha-cellulose and hot water solubles contents) and height (except for the lignin and cellulose contents). Regardless of age and culm height, the high cellulose content of this species (together with its fibre characteristics) indicates its good potential as a raw material for pulp and paper.

Key words: *Gigantochloa scortechinii* - one to three-year-old - culms - fibre morphology - chemical composition

ABD. LATIF MOHMOD, KHOO K.C., JAMALUDIN KASIM & ABD. JALIL HJ. AHMAD. 1994. Morfologi gentian dan ciri-ciri kimia *Gigantochloa scortechinii*. Komposisi kimia dan morfologi gentian *G. scortechinii* yang berumur 1 tahun, 2 tahun dan 3 tahun telah ditentukan. Pada umumnya, dimensi gentian (kecuali tebal dinding gentian dan nisbah Runkle dan nisbah L/D) meningkat dengan umur manakala tebal dinding gentian dan nisbah Runkle menurun dengan ketinggian batang buluh. Gentian *G. scortechinii* yang panjang (3.24 - 5.03 *mm*) dan nisbah L/D yang tinggi (105 - 171) merupakan ciri-ciri spesies ini yang menarik untuk pembuatan kertas. Komposisi kimia tidak berhubung kait secara ketara dengan umur (kecuali kandungan terlarut air sejuk) dan ketinggian batang buluh (kecuali kandungan terlarut air panas, alkali dan alkohol-benzin). Kandungan komponen kimia pada keseluruhannya meningkat dengan umur (kecuali alfa - selulosa dan kandungan terlarut air panas) dan ketinggian batang buluh (kecuali kandungan lignin dan selulosa). Kandungan selulosanya yang tinggi (bersama-sama dengan ciri-ciri gentian) menunjukkan bahawa spesies ini mempunyai potensi yang baik sebagai bahan mentah untuk pulpa dan kertas, tidak kira umur dan ketinggian batangnya.

Introduction

The importance of fibre morphology and chemical properties of bamboo cannot be overlooked, especially if it is to be used for pulp and fibre-based products. Fibre length, for example, influences the physical and mechanical properties of the material and is thus often associated with its toughness, workability and durability (Parameswaran & Liese 1976, Espiloy 1987). It is one of the factors controlling the strength properties of paper, since the length of an individual fibre is associated with the number of bonding sites between fibres (Wangaard & Woodson 1973).

Lignin, on the other hand, influences the woody structural rigidity by stiffening and holding the fibres together (Hale 1969). From the pulping point of view, a high level of lignin content consumes chemicals in pulping and can also affect the beating quality of pulp resulting in lower strength of paper produced (Robinson 1980, Jalaluddin *et al.* 1989).

In this study, the variation in fibre morphology and chemical composition of the most commonly utilized bamboo species in Peninsular Malaysia, *i.e., Gigantochloa scortechinii* (buluh semantan) sampled from natural stands were determined. The inter-relationship of age and height in relation to the properties studied were evaluated as a guide to their potential application.

Materials and methods

Ten culms each from 1-*y*-old, 2-*y*-old and 3-*y*-old *Gigantochloa scortechinii* were obtained from Panson, Ulu Langat, Selangor, for this study. Each bamboo culm was divided equally into three portions, basal, middle and top. Measurements of the fibre dimensions were carried out using the method outlined by Wilson (1954).

From the fibre measurements, the Runkle ratio, coefficient of suppleness and Felting Power or L/D factor (Runkle 1952, Anonymous 1955) were calculated as follows:

$$\text{Runkle ratio} = \frac{2w}{l}$$

$$\text{Coefficient of suppleness} = \frac{l \times 100}{D}$$

$$\text{Felting Power or L/D ratio} = \frac{L}{D}$$

where,

w = fibre wall thickness (μm)
l = lumen diameter (μm)
D = fibre width (μm)
L = fibre length (mm)

Proximate chemical analysis was conducted on air dry milled bamboo samples according to the following standard methods:

a. Hot water solubles	: TAPPI T 207 (Anonymous 1978)
b. Cold water solubles	: TAPPI T 207 (Anonymous 1978)
c. 1% NaOH solubles	: TAPPI T 212 (Anonymous 1978)
d. Alcohol-benzene solubles	: TAPPI T 204 (Anonymous 1978)
e. Lignin	: TAPPI T 222 (Anonymous 1978)
f. Alpha-cellulose	: TAPPI T 203 (Anonymous 1978)
g. Holocellulose	: Wise *et al.* (1946)
h. Ash	: TAPPI T 15 (Anonymous 1978)

Results and discussion

Fibre morphology

The fibre dimensions of *G. scortechinii* of the three age groups and at different portions of the culm are presented in Table 1. The respective summary of analyses of variance and Duncan Multiple Range test are given in Tables 2 and 3. Table 4 gives the correlation coefficients of different fibre dimensions with age and height of the bamboo.

Table 1. Fibre dimensions of *G. scortechinii*

Age (*y*)	Portion	Fibre length L (*mm*)	Fibre width D (μ*m*)	Fibre lumen l (μ*m*)	Fibre wall thickness w (μ*m*)	Runkle ratio	Coefficient of suppleness (%)	L/D ratio
1	Basal	3.83	27.60	9.42	8.69	1.84	34	138.9
	Middle	3.48	32.41	9.61	11.39	2.36	30	107.5
	Top	3.24	19.62	6.69	6.44	1.86	34	165.3
2	Basal	3.95	23.09	11.82	5.61	0.95	51	171.0
	Middle	3.78	30.82	11.79	9.51	1.61	38	122.8
	Top	3.71	25.25	9.54	8.85	1.64	38	146.9
3	Basal	5.03	38.99	25.05	6.97	0.55	64	129.0
	Middle	4.40	28.44	14.47	6.98	0.97	51	154.8
	Top	3.32	31.51	16.12	7.69	0.95	51	105.4

The fibre length of *G. scortechinii* obtained in this study varied significantly with age, height and interaction of age and height. In general, it increased with age ($r = 0.56$ at $p < 0.05$) but decreased significantly with increase of culm height ($r = -0.65$ at $p < 0.01$). The lowest and highest mean fibre lengths were observed in the top portion of the 1-*y*-old culm (3.24 *mm*) and the basal portion of the 3-*y*-old culm (5.03 *mm*) respectively. As reported by many researchers, the fibre length within and between culms may vary as the individual characteristics of the bamboo itself (Grosser & Liese 1971, Pattanath 1972, Espiloy 1987).

Table 2. Summary of analyses of variance on fibre dimensions of *G. scortechinii*

		Mean squares and statistical significance						
Source of variation	Df	Fibre length	Fibre width	Fibre wall thickness	Fibre lumen width	Runkle ratio	L/D ratio	Coefficient of suppleness
Age	2	0.80**	84.97**	3.97**	161.88**	2.15**	445.10**	784.75**
Height	2	2.16**	46.08**	7.86**	34.99**	0.44**	490.29**	185.96**
Age × height	4	1.25**	64.02**	6.76**	19.25**	0.07**	1784.76**	30.17**

Note: ns: not significant at $p < 0.05$; *: significant at $p < 0.05$; **: highly significant at $p < 0.01$.

Table 3. Duncan Multiple Range test on the effects of age and culm height on fibre morphology

	Age			Height		
Property	1	2	3	Basal	Middle	Top
Fibre length	3.52a	3.81b	4.25c	4.27c	3.89b	3.42a
Fibre width	26.55a	26.39a	32.98b	29.89b	30.56b	25.46a
Fibre wall thickness	8.84b	7.99ab	7.21a	7.09a	9.30b	7.66a
Fibre lumen width	8.57a	11.05b	18.55c	10.78a	11.96b	15.43c
Runkle ratio	2.02c	1.40b	0.83a	1.12a	1.65c	1.49b
L/D ratio	137.27b	146.93c	129.75a	146.33c	128.38a	139.23b
Coefficient of suppleness	32.62a	42.41b	55.42c	49.86b	39.58a	41.01a

Means followed by a common letter(s) in the same row are not significantly different at $p < 0.05$.

Table 4. Correlation coefficients of different fibre dimensions with age and height of bamboo

Characteristic	Age	Height
Fibre length	0.56*	- 0.65**
Fibre width	0.49*	- 0.34ns
Fibre wall thickness	- 0.38ns	0.13ns
Lumen width	0.79**	- 0.37ns
Runkle ratio	- 0.88**	0.27ns
L/D ratio	- 0.14ns	- 0.13ns
Coefficient of suppleness	0.87**	- 0.34ns

Note: ns: not significant at $p < 0.05$; * : significant at $p < 0.05$;
**: highly significant at $p < 0.01$.

The effects of age and height on fibre wall thickness were significant (Table 3). The fibre wall thickness, however, tended to be thinner with age but thicker with culm height (r= - 0.38 and 0.13 at $p < 0.05$ respectively). This could be associated with the increase and decrease in fibre lumen with the increase of age and height (r = 0.79 and - 0.37 respectively). The average fibre wall thickness of *G. scortechinii* observed in this study, nevertheless, ranged from 5.61 to 11.39 μm.

The variation in Runkle ratio, as expected, follows a somewhat similar trend with the fibre wall thickness. They correlated negatively with age (r = - 0.88 at $p < 0.01$) but positively with culm height (r=0.27 at $p < 0.05$). The lowest and highest mean Runkle ratios were observed in the basal portion of the 3-y-old culm (0.55) and the middle portion of the 1-y-old culm (2.36). Duncan's Multiple Range test (Table 3) further revealed that the Runkle ratio was lowest in the basal than the middle and top portions (1.12, 1.65 and 1.49 respectively); and was lower in older than the younger culms (0.83 and 2.02 respectively). The Runkle ratio from 50 fibres of each age and culm height obtained in this study ranged between 0.55 and 2.36. Those portions of the bamboo having Runkle ratio less than 1 would be more suitable for papermaking (Tamolang *et al.* 1957). Compared to Malaysian hardwoods [heavy-hardwoods, more than 1.87; medium-hardwoods, 0.67; light-hardwoods, 0.34 (Peh *et al.* 1986)], the 2-y-old culm (limited to the basal portion) and 3-y-old culms of *G. scortechinii* appear to be a good material for paper.

The coefficients of suppleness is a general term used as a guide for assessing the degree of fibre bonding of the paper made from a particular woody material (Anonymous 1955). The higher the coefficient, the greater is the tensile and bursting strengths, due to the good inter-fibre bonding (Tamolang *et al.* 1957). Although the coefficient of suppleness varied significantly with age and height, the slightly lower values observed in this study (about 30 to 64 %) are expected to produce an average strength bonded papers compared to light hardwoods with coefficients of 77% (Peh *et al.* 1986).

The L/D ratio of *G. scortechinii* varied significantly with age and culm height. In general, they decreased insignificantly with age and culm height (r = - 0.14 and

-0.13 at $p < 0.05$ respectively). The Duncan's Multiple Range tests (Table 3) further revealed that the L/D ratio in the bamboo was highest in the basal than the top portions (about 146 and 139 respectively); and was highest in the 2-y-old culm than the 1-y-old and 3-y-old culms (about 147, 137 and 130 respectively). Compared to Malaysian timbers, the bamboo species with higher L/D ratio would produce paper with better tearing resistance than the heavy, medium and light-hardwoods with mean L/D ratios at 59, 47 and 35 respectively (Peh *et al.* 1986). Linear relationship between L/D ratio and the various paper properties, however, is hardly found. Dadswell and Watson (1962) argued that even though the L/D ratio has some effects on paper properties, its influence is small if compared to the effects of fibre length and fibre wall thickness.

Chemical properties

Table 5 shows a comparison of the proximate chemical composition of *G. scortechinii* from the three age groups and at different portions of the culm. The summary of analyses of variance and Duncan Multiple Range test are presented in Tables 6 and 7 respectively. Table 8 gives the correlation coefficients of the chemical composition with age and culm height.

The results indicate that the contents of all the chemical components of *G. scortechinii* differed insignificantly with age (except for the lignin and cold-water solubles contents) and height (except for the hot water and alcohol-benzene solubles contents). The contents, however, generally increased with age (except for the alpha-cellulose and hot water solubles contents) and culm height (except for lignin, alpha- and holocellulose contents).

Table 5. Proximate chemical analysis of *G. scortechinii*

Age (y)	Portion	Ash (%)	Lignin (%)	Cellulose (%) Holo-	Cellulose (%) Alpha-	Hot water solubles (%)	Cold water solubles (%)	1% alkali solubles (%)	Alcohol-benzene solubles (%)
1	Basal	1.09	25.5	66.1	40.4	6.0	4.0	18.8	2.9
	Middle	1.11	26.7	66.9	40.7	6.3	4.4	19.9	3.2
	Top	1.11	25.0	67.4	41.3	6.5	4.5	20.0	3.5
2	Basal	1.09	25.4	68.8	41.0	5.3	4.1	17.9	2.9
	Middle	1.11	24.9	67.3	41.6	5.9	4.5	19.7	3.2
	Top	1.12	24.4	67.2	41.6	6.4	4.7	19.9	3.5
3	Basal	1.11	28.8	69.0	42.2	4.7	5.1	18.5	3.2
	Middle	1.13	28.0	67.6	41.3	5.7	5.2	20.0	3.5
	Top	1.18	27.2	67.2	37.9	5.9	5.5	20.4	3.7

Table 6. Summary of analyses of variance on chemical analysis of *G. scortechinii*

Source of variation	Df	Mean squares and statistical significance							
		Ash	Lignin	Cellulose		Hot water solubles	Cold water solubles	1% NaOH solubles	Alcohol-benzene solubles
				Holo-	Alpha-				
Age	2	2.37ns	4.39*	0.54ns	4.16ns	3.69ns	5.20*	0.26ns	1.93ns
Height	2	2.21ns	0.60ns	0.25ns	3.70ns	5.19*	1.10ns	3.72ns	6.65*
Age × height	4	0.42ns	0.17ns	0.32ns	11.80**	0.30ns	0.06ns	0.08ns	0.01ns

Note: ns: not significant at $p < 0.05$; *: significant at $p < 0.05$.

Table 7. Duncan Multiple Range test on the effects of age and culm height on chemical composition

Property	Age			Height		
	1	2	3	Basal	Middle	Top
Ash	1.10a	1.11a	1.14a	1.10a	1.11a	1.13a
Lignin	25.7a	24.9a	28.0b	26.6a	26.5a	25.5a
Cellulose:						
a. Holo-	66.7a	67.8a	67.9a	68.0a	67.2a	67.2a
b. Alpha-	40.7a	41.41a	40.4a	41.1a	41.1a	40.3a
Solubles:						
a. Hot water	6.3a	5.9a	5.4a	5.3a	6.0ab	6.3b
b. Cold water	4.3a	4.4a	5.3b	4.4a	4.7a	4.9a
c. 1% NaOH	19.6a	19.2a	19.6a	18.4a	19.8ab	20.1b
d. Alcohol-benzene	3.2a	3.2a	3.5a	3.0a	3.3ab	3.6b

Means followed by a common letter(s) in the same row are not significantly different at $p < 0.05$.

The holocellulose and alpha-cellulose contents, regardless of age and height, varied from about 66 - 69 % and 38 - 42 % respectively. The results (Table 5) also reveal that the increase in holocellulose content within and between age and culm height was commonly accompanied by a decreasing amount of hot and cold water solubles contents. Norazah and Azmy (1991) in their study on 2-y-old culm of four Malaysian bamboo species also found a similar trend.

The variation in the holocellulose content might be accompanied by a similar change in the alpha-cellulose content within the woody material (Escolano 1973). The results, however, indicate no clear trend between the holocellulose and alpha-cellulose contents within and between the age and culm height. As reported by Liese (1985), the chemical composition may vary according to the individual characteristics such as species, its growing condition, age and the part of the culm, and external factors such as topographical and seasonal effects. By comparing the cellulose contents of *G. scortechinii* (66 - 68% and 37 - 42% of the holocellulose and alpha-cellulose contents respectively) with those of 59 - 85% holocellulose and 35 - 54% alpha-cellulose contents in Malaysian timbers (Khoo & Peh 1982), this bamboo, nevertheless, indicates its potential as an excellent material to be used in pulping.

Table 8. Correlation coefficients of chemical composition with age and height of bamboo

Composition	Age	Height
Ash	0.58ns	0.63ns
Lignin	0.64ns	-0.30ns
Cellulose:		
a. Holo-	0.56ns	-0.37ns
b. Alpha-	-0.26ns	-0.19ns
Solubles:		
a. Hot water	-0.62ns	0.72*
b. Cold water	0.83**	0.41ns
c. 1% NaOH	0.03ns	0.88**
d. Alcohol-benzene	0.42ns	0.88**

Note: ns: not significant at $p < 0.05$;
* : significant at $p < 0.05$; **: highly significant at $p < 0.01$.

The amount of lignin in bamboo increased insignificantly with age (r=0.64 at $p < 0.05$) but decreased slightly or insignificantly from basal to the top portion (r=-0.30 at $p < 0.05$). The highest and lowest mean lignin contents were observed in the basal (28.8%) and top (24.4%) portions of the 3- and 2-year-old culm respectively. The Duncan's Multiple Range test (Table 7) revealed that the amount of lignin decreased from 25.7 % in the 1-y-old culm to 24.9% in the 2-y-old culm but increased in the older culms (28.0%). This could be due to the fact that the full lignification of the bamboo culm is completed within one growing season with no further significant ageing effects (Liese 1987). The amount of lignin tended to decrease slightly from the basal (26.6%) towards the tip (25.5%). A similar pattern was also observed in bamboos from China (Chen *et al.* 1987). As mentioned by Liese (1985), this reflects the individual characteristics of the bamboo itself. The average lignin content of about 24 to 28% in *G. scortechinii*, nevertheless, is within the range of that of four Indian bamboos that are widely used for papermaking (Subash & Sathapathy 1990).

The ash content of *G. scortechinii* which ranged from 1.09 to 1.18% falls within the ranges of those of Malaysian hardwoods (0.1 to 2.5%) (Khoo & Peh 1982) and bamboos from India, Japan, Burma, Indonesia and Philippine (0.8 to 9.7%) (Semana *et al.* 1967). In particular, the ash content observed in this study resembles those values of 1.1 - 1.2% in *Phyllostachys pubescens* (Liese 1985), the commonly used monopodial bamboo for making machine-intensive products such as skewers and chopsticks in Taiwan and China. Since the ash content is commonly associated with the amount of silica in a material like bamboo, thus affecting its working properties (Lee & Lopez 1968, Wong 1976), the selection of this species with its relatively low silica content for specific machine-intensive products such as skewers and chopsticks is significant. By comparing the respective ash contents of about 4.4% and 3.8% in *G. levis* and *G. aspera* of the Philippines (Tamolang *et al.* 1980), which are also commonly found in Malaysia, the lower ash content in *G. scortechinii*, may explain for its wide preference in the making of incense-sticks in Peninsular Malaysia (Abd. Latif & Abd. Razak 1991), especially in the locality where the bamboo samples are collected.

The hot and cold water water solubles are important in the evaluation of water soluble extractives such as tannin, starch, sugar, pectin and phenolic compounds within the woody materials (Janes 1969). Higher concentrations of these water soluble extractives (4.7 - 6.5% and 4.0 - 5.5% for hot and cold water solubles respectively) may influence the durability of the bamboo materials (Plank 1951, Purusotham *et al.* 1953). Generally, the portion of the culm in each age group with lower lignin content contained higher cold and hot water solubles but those portions with higher holocellulose contents had lower cold and hot water solubles.

The alcohol-benzene solubles of *G. scortechinii* varied between 2.9 and 3.7%, *i.e.*, within the range for various bamboo species (Semana *et al.* 1967, Chen *et al.* 1987, Nor Azah & Azmy 1991) and Malaysian timbers (Khoo & Peh 1982, Jalaluddin *et al.* 1989).

The highest and lowest mean percentages of alkali solubles were observed in the top portion of the 3-y-old culm (20.4%) and basal portion of the 2-y-old culm (17.9%) respectively. In general, they do not vary significantly with age (19.6, 19.2 and 19.6% for the respective 1-, 2- and 3-y-old culms) but correlate significantly with culm height (18.4 to 20.1% from basal to the top portions). High alkali solubles could be associated with high degradation of cellulose and high polyphenol content (Clayton 1969, Tadena & Villaneuva 1971). Compared to Malaysian hardwoods (Khoo & Peh 1982), this bamboo appears to have high alkali solubility. The lower yield from chemical pulping of the material as a result of this property could, however, be compensated for by its high holocellulose content.

Conclusion

There is wide variation in the fibre dimensions as well as the proximate chemical composition within the culms of the same age group and between culms of different age groups of the 1-y-old, 2-y-old and 3-y-old *Gigantochloa scortechinii* samples studied. As expected of bamboos, the fibres are long (3-5 *mm*) but are relatively thick-walled. Although the Runkle ratio is correspondingly high (0.55 - 2.36), this bamboo is expected to be a good pulping material to produce paper with high tear resistance (on account of the high L/D ratio). The older culms and basal portions of the culms are particularly attractive for pulping.

This potential pulping property of the bamboo is generally supported by the proximate chemical analysis which gives a high cellulose content and an ash content that is considered relatively low for a siliceous material like bamboo. The moderately high alkali solubility may, however, affect the yield in chemical pulping.

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