Journal of Tropical Forest Science 18(4): 236–242 (2006)

CHARACTERIZATION OF BAMBOO *GIGANTOCHLOA SCORTECHINII* AT DIFFERENT AGES

H. Norul Hisham[1,*], S. Othman[2], H. Rokiah[2], M. Abd. Latif[1], S. Ani[1] & M. Mohd. Tamizi[1]

[1]*Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia*
[2]*Bioresource, Paper & Coating Technology, School of Industrial Technology, Universiti Sains Malaysia, 11800 Penang, Malaysia*

Received August 2005

NORUL HISHAM, H., OTHMAN, S., ROKIAH, H., ABD. LATIF, M., ANI, S. & MOHD. TAMIZI, M. 2006. Characterization of bamboo *Gigantochloa scortechinii* at different ages. The anatomical, physical and chemical properties of *Gigantochloa scortechinii* from different ages of 0.5, 1.5, 3.5, 5.5 and 6.5 years were investigated. The bamboo culm from the sixth internode above ground was studied. This study suggests that *G. scortechinii* is in its growing, development and maturation phases at ages 0.5, 1.5 and 3.5 years respectively. The higher content of inorganic nutrients in bamboo showed its potential as chewing sticks. Bamboo from 3.5 years of age was suitable for any utilization purpose.

Keywords: Age, description, anatomical properties, physical properties, chemical properties

NORUL HISHAM, H., OTHMAN, S., ROKIAH, H., ABD. LATIF, M., ANI, S. & MOHD. TAMIZI, M. 2006. Pencirian buluh *Gigantochloa scortechinii* pada umur berlainan. Ciri-ciri anatomi, fizikal dan kimia *Gigantochloa scortechinii* pada umur berlainan iaitu 0.5 tahun, 1.5 tahun, 3.5 tahun, 5.5 tahun dan 6.5 tahun dikaji. Kulma buluh daripada ruas ke-6 dari aras tanah dikaji. Kajian ini mendapati bahawa buluh berada pada fasa-fasa pertumbuhan, perkembangan dan matang masing-masing pada umur 0.5 tahun, 1.5 tahun dan 3.5 tahun. Kandungan nutrient tak organik yang tinggi menunjukkan ia berpotensi sebagai kayu kunyah. Buluh daripada umur 3.5 tahun dan ke atas sesuai untuk sebarang tujuan penggunaan.

INTRODUCTION

Characterization of bamboo in relation to its anatomical, physical, mechanical and chemical properties helps to determine the maturation age towards better processing and utilization. Liese (1997) reported that properties and utilization of bamboos are influenced by structural changes brought about by ageing. The relation between bamboo ageing and maturation was reviewed by Liese and Weiner (1996). Researchers such as Zhou (1981), Espiloy (1987, 1994), Widjaja and Risyad (1987), Abd. Latif *et al.* (1990) as well as Sattar *et al.* (1994) are in general agreement that bamboo culm matures at two to three years, reaching its maximum strength. However, this general agreement did not include overall properties of individual bamboo species. In subtropical countries such as China, bamboo properties have been reported to differ with species, age, location and external factors (Anonymous 2001). In a tropical country such as Malaysia, Abd Latif and Phang (2001) reported that the mechanical properties of bamboo vary significantly with location, but the differences are relatively small. Liese (1997) reported that more than 1000 bamboo species world-wide have different physical and mechanical properties, resulting in different methods in processing and product quality. Therefore, information on the overall properties and systematic measurement of these properties on individual bamboo species at different ages from one specific location is required.

Gigantochloa scortechinii (buluh semantan) is the most abundant bamboo found in Peninsular Malaysia and globally. It is one of the most easily available resources to supplement local wood.

*Current address: Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia. E-mail: h_noroul@putra.upm.edu.my

Therefore, studies on its anatomical, physical and chemical properties should be geared towards harvesting bamboo at the most suitable age to ensure superior quality. Systematic characterization of these properties would help the industry in terms of utilization.

MATERIALS AND METHODS

Materials

Gigantochloa scortechinii ranging from 0.5, 1.5, 3.5, 5.5 and 6.5 years were studied. The bamboos were obtained from a natural stand in Nami, Kedah (northern Peninsular Malaysia). The culm age was determined by monitoring the growth starting from new shoots that emerged from the ground. The shoots were recorded, tagged and marked with coloured paint when they have reached the targeted age. From one clump, one bamboo culm from each age class was harvested and immediately coated with wax before being transferred to the laboratory. Only the sixth internode above ground level was used. Their basic characteristics are given in Table 1.

Determination of anatomical properties

Samples from the outer, middle and inner zones were boiled with distilled water for two to three hours and sliced with a microtome to thickness of 15–20 mm. The specimen was rinsed with distilled water three times and dried for 2 min each. Two drops of safranin-o solution were applied on the specimen and dehydrated with 80, 90 and 100% (three times) ethanol series. A total of 60 vascular bundles were measured for radial length/tangential diameter ratio and tangential diameter of metaxylem vessel.

Only the middle zone of the bamboo culm was selected for measurement of fibre and parenchyma dimensions. The section was mixed with hydrogen peroxide (30%) and absolute acetic acid mixture, and heated at 40 °C for 72 to 96 hours. A total of 150 single fibre and parenchyma cells were measured for length, wall thickness and lumen diameter.

Determination of physical properties

Initial moisture content and oven-dry density were measured in accordance to TAPPI Standard Method (Anonymous 1978) and TAPPI Standard Method T-18 (Anonymous 1978) respectively.

Determination of chemical properties

Major

Bamboo matchsticks were oven dried at 60 °C for 24 hours, ground with a grinding machine and air dried for 48 hours for chemical analysis. The methods used are summarized in Table 2.

Minor

Bamboo matchsticks of 0.2 g, from the middle zone, were heated with hydrogen peroxide (30%) and absolute nitric acid mixture until completely dissolved. The solution was then cooled in room temperature and its final volume

Table 2 Methods used for major chemical analysis

Chemical property	Method
Alcohol/toluene extractive	TAPPI T 6m-59 (Anonymous 1978)
Holocellulose	Wise *et al.* (1946)
α-Cellulose	TAPPI T 9m-54 (Anonymous 1978)
Lignin	TAPPI T 13m-54 (Anonymous 1978)
Ash	TAPPI T 211om-85 (Anonymous 1978)
Silica	TAPPI T 244 os-77 (Anonymous 1978)
Starch	Humprey & Kelly (1961)

Table 1 Basic characteristics of the sixth internode of bamboo culm

Characteristic	Age (years)				
	0.5	1.5	3.5	5.5	6.5
Internode length (cm)	32.5	35.2	49.5	32.3	40
Internode diameter (cm)	14.8	10.5	11.5	17.8	16
Culm wall thickness (mm)	8	6	7	8.5	6.5

measured. The solution was diluted further to 5 ml with distilled water and the final concentration measured. It was then analysed with inductive couple plasma machine. Each element content present was calculated using the following formula:

$$\text{Element content (ppm)} = \left[\frac{\text{Fv} \times \text{C}}{\text{W}}\right]\text{DF}$$

where
Fv = Final volume
C = Concentration
W = Oven-dried weight of bamboo matchsticks
DF = Dilution factor
ppm = Part per million

RESULTS AND DISCUSSION

Anatomical properties

Radial length/tangential diameter ratio of vascular bundle

The ratio varied with culm zone and age (Table 3). In all age classes, the ratio increased from the inner zone towards the outer zone. Similar trend was reported in sympodial bamboo, *Phyllostachys pubescens* (Wenyue *et al.* 1981). This indicates that a vascular bundle is longest and smallest at the outer zone but shorter and bigger towards the inner zone. This finding is in agreement with that of Liese (1985). The ratio also differed with age particularly at the middle zone. Smaller vascular bundles tend to be denser in distribution than the bigger ones. Therefore, density and mechanical strength are greater at the outer zone than at the inner (Liese 1985, Zhou 2000). Primary tissue or parenchyma cells gradually increase from the outer towards the inner zones (Liese 1985, Anonymous 2001). Lignification, which indicates maturation of fibre and ground parenchyma, begins from outside and proceeds inwardly (Itoh & Shimaji 1981). Regardless of culm zone, the ratio increased from the youngest age of 0.5 years (1.25) to a maximum at the age of 1.5 years (1.28), but remained significantly unchanged beyond the age of 3.5 years. However, Abd. Latif and Mohd. Tamizi (1992) reported no significant correlation in the ratio between 1- and 3-year-old *G. scortechinii.*

Tangential diameter of metaxylem vessel

The vessel diameter increased from the outer zone towards the inner zone in all age classes (Table 4). Liese (1985) also reported a similar trend. Vessel diameter was significantly larger with age at the outer and inner zones, but this was not observed at the middle zone. The diameter gradually increased from the youngest age of 0.5 years (0.51 mm) to a maximum

Table 3 Mean radial length/tangential diameter ratio of vascular bundle

Age (years)	Zone			
	Outer	Middle	Inner	Mean
0.5	1.72^{a}	1.40^{b}	0.64^{a}	1.25^{ab}
1.5	1.64^{ab}	1.41^{b}	0.79^{a}	1.28^{b}
3.5	1.61^{ab}	1.35^{ab}	0.63^{a}	1.20^{a}
5.5	1.68^{ab}	1.29^{a}	0.63^{a}	1.20^{a}
6.5	1.56^{a}	1.50^{c}	0.62^{a}	1.22^{a}

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

Table 4 Mean tangential diameter of metaxylem vessel

Age (years)	Zone			
	Outer	Middle	Inner	Mean (mm)
0.5	0.17^{a}	0.62^{b}	0.75^{ab}	0.51^{a}
1.5	0.24^{b}	0.65^{b}	0.73^{a}	0.54^{b}
3.5	0.28^{c}	0.65^{b}	0.79^{c}	0.57^{c}
5.5	0.46^{d}	0.60^{b}	0.80^{c}	0.62^{d}
6.5	0.22^{b}	0.50^{a}	0.78^{bc}	0.50^{a}

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

diameter at the age of 5.5 years (0.62 mm). The vessel diameter was also smaller compared with that of *P. pubescens*, which has an average of 0.98 mm as reported by Zhou (2000). Liu *et al.* (1998) mentioned that larger vessel diameter in laminated bamboo made of *Dendrocalamus latifflorus* could probably cause its lower glue bond strength compared with *Phyllostachys edulis*.

Fibre and parenchyma dimensions

The youngest culm at 0.5 years had the shortest fibre (Table 5). Culm at age 1.5 years had the longest fibre but fibre length then decreased with age. Fibre diameter did not differ with age and the mean was 26 μm. The widest fibre lumen diameter was observed in the youngest culm of 0.5 years old (10 μm) and the diameter remained unchanged beyond age 1.5 years. The fibre wall was thinner at the early age of 0.5 years (8 μm) but thickened as much as 1 μm at age of 1.5 years. Liese and Weiner (1996) as well as Murphy and Alvin (1997) also reported a thicker fibre wall in older bamboos. However, Abd. Latif and Mohd Tamizi (1992) reported that fibre wall thickness in *G. scortechinii* is not affected by age. The fibre morphology also contradicts the observation made by Abd. Latif *et al.* (1994). This is probably due to the fact that bamboo properties are characterized by its own individual characteristics (Liese 1985).

Almost all parenchyma dimensions were lower at the youngest age of 0.5 years, except for wall thickness. The parenchyma length, diameter and lumen diameter values increased with age and reached maximum dimensions at 3.5 years old. The parenchyma wall thickness was not significantly different with age.

Physical properties

The oven-dry density significantly increased with age but the initial moisture content showed a reverse trend (Table 6). Highest oven-dry density and lowest initial moisture content were observed in the oldest culm of 6.5 years. Their means were 680 kg m^{-3} and 48.6% respectively. Jamaludin *et al.* (2002) also found similar trend in 1- to 3-year-old *G. scortechinii*. The increase of density with age was probably due to the thicker lamellated fibre walls and parenchyma cells in older culms (Espiloy 1987, Liese 1987, Abd. Latif *et al.* 1996). However, anatomical properties such as fibre and parenchyma wall thickness remained unchanged beyond the age of 3.5 years. Therefore, the total amount of chemical constituents probably influences greater density in the oldest bamboo. Liese (1985) stated that bamboo has about more than 50% of holocellulose content. The density trends seen in this study contradicted that

Table 6 Mean oven-dry density and initial moisture content

Age (years)	Physical property	
	Density (kg m^{-3})	Moisture content (%)
0.5	530[a]	90.5[a]
1.5	590[b]	67.7[b]
3.5	610[c]	65.4[c]
5.5	630[d]	59.5[d]
6.5	680[e]	48.6[e]

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

Table 5 Mean fibre and parenchyma dimensions

Dimension	Age (years)			
	0.5	1.5	3.5	5.5
Fibre				
Length (mm)	2.23[a]	2.63[a]	2.50[bc]	2.38[ab]
Diameter (μm)	26[a]	26[a]	26[a]	26[a]
Wall thickness (μm)	8[a]	9[b]	9[b]	8[b]
Lumen diameter (μm)	10[a]	9[b]	8[b]	9[b]
Parenchyma				
Length (μm)	98[a]	103[ab]	113[b]	103[ab]
Diameter (μm)	41[a]	43[a]	47[b]	46[b]
Wall thickness (μm)	4[a]	3.8[a]	3.7[a]	3.5[a]
Lumen diameter (μm)	33[a]	36[a]	40[b]	39[b]

Means followed by the same letter(s) in the same row are not significantly different at the 0.05 probability level.

observed by Satar *et al.* (1994). They reported that the density of bamboo reaches its maximum value at 3 years with no further increment at 4 and 5 years. Hamdan and Abd. Latif (1992) reported that maturity has a major effect on the machining properties of bamboos. They found that physical and anatomical properties of bamboos do not affect the recovery rate and quality of bamboo products, but processing of immature culms generally results in low grades and fibrous products.

Chemical constituents

Major

Almost all the major chemical constituents were relatively low in percentage at the youngest age of 0.5 years (Table 7). Starch content was low at the age of 1.5 years (0.6%) but increased to 3.5% at the age of 3.5 years and remained unchanged towards the later years. This is probably due to the fact that no further increase of parenchyma length and lumen diameter occurred beyond the age of 3.5 years. The starch granule is situated or stored in vertically elongated cells of ground parenchyma (Liese & Weiner 1996). The authors reported that younger bamboo culms of 1 year old do not contain any starch during the growing phase, since all the nutrients must be utilized immediately for metabolic processes. However, Abd. Latif *et al.* (1992) reported minor trace of starch content (0.8%) at the basal portion of 1-year-old *G. scortechnii.* Lignin content drastically increased at the age of 1.5 years (14.5%) but gradually increased thereafter.

No specific trend for alcohol/toluene extractive was observed, but it was high at age of 0.5, 3.5 and 6.5 years. The α-cellulose content remained unchanged, but the holocellulose content slightly increased beyond 3.5 years. Abd. Latif *et al.* (1994) indicated no clear trend between holocellulose and α-cellulose contents in 1- to 3-year-old *G. scortechinii.* Ash and silica contents drastically increased at age 1.5 years but slightly changed beyond 3.5 years. High density in old bamboos probably causes greater contents of holocellulose, lignin, ash and silica. Espiloy (1983) reported a positive correlation between silica content and density of *Bambusa bluemena.*

Minor

Minor inorganic nutrients varied with age and those detected can be segregated into three groups (Table 8). The nutrients were potassium, calcium, sodium and aluminum, which were in abundance. These were followed by magnesium, phosphorus, zinc and ferrous. Lastly by nickel, boron, manganese and copper, which were hardly detected. Almost all the inorganic elements were high in content at 0.5, 3.5 and 6.5 years old but relatively low at 1.5 and 5.5 years. This shows that the oldest bamboo still has the ability to take up the nutrients from soils. However, in monopodial bamboo, Chen *et al.* (1987) reported that certain elements such as copper, zinc, cobalt, phosphorus, iron and potassium decrease when a bamboo gets older (7 years) compared with younger ones (1 year).

Bamboo obtains inorganic nutrients from soil or rain (Austin *et al.* 1974). Therefore, nutrient uptake in bamboo probably is dependent on species, soil, climate and other external factors. Elements such as potassium, aluminum, sodium, magnesium, manganese, ferrous, nickel and zinc were much higher than those reported by

Table 7 Mean of major chemical constituents

Constituent (%)	Age (years)				
	0.5	1.5	3.5	5.5	6.5
Alcohol/toluene extractive	5.8	3.4	5.3	3.5	5.6
Holocellulose	78.6	80.1	80.6	81.5	82.3
α-Cellulose	64.6	64.1	64.6	63.3	64.4
Lignin	23.4	26.8	27.8	28.7	29.0
Starch	0.5	0.6	3.5	3.4	3.4
Ash	1.9	2.5	2.8	3.0	3.5
Silica	0.6	1.1	1.7	2.2	2.0

Table 8 Mean minor inorganic nutrients

Element (ppm)	Age (years)				
	0.5	1.5	3.5	5.5	6.5
Potassium (P)	5029	4133	5368	3530	5402
Calcium (Ca)	822	499	740	917	1157
Sodium (Na)	732	468	529	710	888
Aluminum (Al)	219	820	180	247	270
Magnesium (Mg)	174	156	424	306	966
Phosphorus (Ph)	88	59	60	60	69
Zinc (Zn)	83	19	34	63	76
Ferrous (Fe)	40	25	21	34	21
Nickel (Ni)	0.8	5	1	2	9
Boron (Bn)	0.2	10	6	9	3
Manganese (Mn)	–	3	16	7	14
Copper (Co)	–	1	0.4	–	–

– not traceable

Akande and Yamamoto (1998) in seven African chewing sticks.

CONCLUSIONS

Bamboo properties differed with age. Therefore, properties should be classified according to the bamboo's growing, development or maturation phase. These studies suggest that *G. scortechinii* culms are classified as growing, developing and maturation phases at 0.5, 1.5 and 3.5 years respectively. Bamboo from 3.5 years of age is suitable for any purpose.

REFERENCES

ABD. LATIF, M., ARSHAD, O., JAMALUDIN, K. & MOHD. HAMAMI, S. 1996. Chemical constituents and physical properties of *Bambusa heterostachya*. *Thailand Journal of Forestry* 15: 14–25.

ABD. LATIF, M., KHOO, K. C., JAMALUDIN, K. & ABD. JALIL, H. A. 1994. Fiber morphology and chemical properties of *Gigantochloa scortechinii*. *Journal of Tropical Forest Science* 6: 397–407.

ABD. LATIF, M., KHOO, K. C. & NOR AZAH, M. A. 1992. Carbohydrates in some natural stand bamboos. *Journal of Tropical Forest Science* 4(4): 310–316.

ABD. LATIF, M. & MOHD. TAMIZI, M. 1992. Variation in anatomical properties of three Malaysian bamboos from natural stand. *Journal of Tropical Forest Science* 5(1): 90–96.

ABD. LATIF, M. & PHANG, M. T. 2001. The mechanical properties of *Bambusa vulgaris* and *Gigantochloa scortechinii* grown in Peninsular Malaysia. *Journal of Tropical Forest Products* 7(1): 111–125.

ABD. LATIF, M., WAN TARMEZE, W. A. & FAUZIDAH, A. 1990. Anatomical features and mechanical properties of three Malaysian bamboo. *Journal of Tropical Forest Science* 2: 227–234.

AKANDE, J. A. & YAMAMOTO, K. 1998. Inorganic elements in common tropical chewing sticks. *Journal of Tropical Forest Products* 4(2): 146–152.

ANONYMOUS. 1978. *TAPPI Testing Procedures*. Technical Association of the Pulp and Paper Industry, Madison.

ANONYMOUS. 2001. *Cultivation and Integrated Utilization on Bamboo in China*. China National Bamboo Research Center, Hangzhou.

AUSTIN, R., EUDA, K. & LEVY, D. 1974. *Bamboo: its Growth and Cultivation*. Weatherhill, New York.

CHEN, Y., QIN, W., LI, X., GONG, J. & NIMANNA. 1987. The chemical composition of ten bamboo species. Pp. 110–113 in Rao, A. N. *et al.* (Eds.) *Proceedings of the International Workshop*. 6–14 October 1985, Hangzhou.

ESPILOY, Z. B. 1983. Variability of specific gravity, silica content and fiber measurements in *Bambusa bluemena*. *NSTA Technology Journal* 8(2): 42–47.

ESPILOY, Z. B. 1987. Physico–mechanical properties and anatomical relationships of some Philippine bamboos. Pp. 257–264 in Rao, A. N. *et al.* (Eds.) *Recent Research on Bamboo. Proceedings of an International Workshop*. 16–14 October 1985, Hangzhou.

ESPILOY, Z. B. 1994. Effect of age on the physio–mechanical properties of some Philippine bamboo. Pp. 180–182 in FORSPA No. 6. IDRC/FAO/UNDP.

HAMDAN, H & ABD. LATIF, M. 1992. Effects of physico-anatomical characteristics on machining properties of Malaysian bamboos. *Bamboo Journal* 10: 57–65.

HUMPREY, F. R. & KELLY, J. 1961. A method for determination of starch. *Wood Analytical Chemistry Acta* 24: 66–70.

ITOH, T. & SHIMAJI, K. 1981. Lignification of bamboo culm *(Phyllostachys pubescens)* during its growth and maturation. Pp. 104–110 in Higuechi, T. (Ed.) *Bamboo Production and Utilization. Proceedings of XVII IUFRO Congress Group*. Kyoto.

JAMALUDIN, K., ABD. JALIL, A. & ABD. LATIF, M. 2002. Variation of moisture content and density with age and height level in *Gigantochloa scortechinii*. *Journal of Tropical Forest Products* 8(1): 112–114.

LIESE, W. 1985. Anatomy and properties of bamboo. Pp. 13–

126 in *Bamboos, Biology, Silvics, Properties, Utilization.* Deutsche Geselschaft fiir Technische Zusanimenarbeit (GTZ), Eschborn.

Liese, W. 1987. Anatomy and properties of bamboo. Pp. 196–208 in Rao, A. N. *et al.* (Eds.) *Proceedings of the International Bamboo Workshop.* 6–14 October 1985, Hangzhou.

Liese, W. 1997. Structural research issue on bamboo. Special Focus. *INBAR* 5(1&2): 27–29.

Liese, W. & Weiner, G. 1996. Ageing of bamboo culms. A review. *Wood Science and Technology* 30: 77–89.

Liu, C. T., Li, W. J. & Wang, Y. H. 1998. Properties and utilization of laminated bamboos. *TFRI Extension Series* 96: 507–514.

Murphy, R. J. & Alvin, K. L. 1997. Fiber maturation in the *Gigantochloa scortechinii. IAWA Journal* 18(2): 148–156.

Sattar, M. A., Kabir, M. F. & Battacharjee, D. K. 1994. Effect of age and height position of Muli *(Melocanna baccifera)* and Borak *(Bambusa balcooa)* bamboos on their physical and mechanical properties. Pp. 183–187 in FORSPA No. 6. IDRC/FAO/UNDP.

Wenyue, H., Shiyi, Q. & Youfen, L. 1981. The anatomical structure of culms of *Phyllostachys pubescens* Mazel exh. de Lehaie. *Bamboo Research* 1: 58–65.

Widjaja, E. A. & Risyad, Z. 1987. Anatomical properties of some bamboo utilized in Indonesia. Pp. 224–246 in Rao, *et al.* (Eds.) *Recent Research on Bamboo. Proceedings of an International Workshop.* 6–14 October 1985, Hangzhou.

Wise, L. E., Murphy, M. & D'addieco, E. E. 1946. Chlorite holocellulose, its fractionation and bearing on summative wood analysis and on studies on the hemicelluloses. *Paper Trade Journal* 122(2): 35.

Zhou, F. 1981. Studies on physical and mechanical properties of bamboo woods. *Journal Nanjing Technology College of Forestry Product* 2: 1–32.

Zhou, F. 2000. *Selected Works of Bamboo Research.* Nanjing Forestry University, Nanjing.