CARBOHYDRATES IN SOME NATURAL STAND BAMBOOS

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ABD. LATIF MOHMOD, KHOO, K.C. & NOR AZAH MOHD. ALI. 1992. Carbohydrates in some natural stand bamboos. The starch and total sugar (total carbohydrate) content of one- to three-year-old Malaysian bamboos, namely *Bambusa blumeana* (buluh duri), *B. vulgaris* (buluh minyak) and *Gigantochloa scortechinii* (buluh semantan) were analysed at various culm heights. The results indicate that the 3-y-old (oldest) culm gave the most amount of starch while no clear trend was observed in the distribution of the total sugar content with age. *G. scortechinii* was observed to contain the highest amount of total carbohydrates in all age and height levels (except for the butt portion of the 3-y-old *B. vulgaris*)

Key words: Carbohydrates - starch - free sugars - Malaysia - wild bamboos

Introduction

In Malaysia, bamboo is found in abundance although widely scattered in about 5% of the total forest reserves (Abd. Latif 1987, Abd. Razak & Abd. Latif 1988). Until recently, it has, however, received relatively little attention as far as research is concerned. Due to the current demand for disposable bamboo products, the bamboo industries, which were traditionally established to supplement the needs of handicraft and agriculture, have been suddenly tailored to machine-intensive type (Abd. Latif & Roslan 1989). As a result, bamboo, which was once considered a weed in forestry practice (Medway 1973, Ng 1980), has been extensively exploited to meet the demand from consumer countries, particularly Japan, the Republic of Taiwan and Korea. Although the number of mills has increased, many reports have been received on the poor quality and durability of the locally-made bamboo products produced for export. This industrial set-back was mainly related to indiscriminate harvesting of bamboo without proper attention given to its properties and final usage (Abd. Latif *et al.* 1990).

The selection of bamboo for industrial use and structural purpose is closely related not only to the physical and mechanical properties but also to the chemical composition (particularly starch and free sugars) of this material. This is important as the properties could be associated with age and culm heights which thus affect the final use of the bamboo (Abd. Latif 1987, Abd. Latif *et al.* 1990). Furthermore, the carbohydrate content of a woody material plays an important role in its durability and service life. Many scientists have confirmed its relationship to mold and fungal stain (Liese 1985) and borer attacks (Plank 1951, Purusotham *et al.* 1953).

From the usage point of view, a high level of starch and sugar contents can also influence the quality of cement-bonded particle board produced (Schwarz & Simatupang 1984). This is due to the fact that the sugars and starch contain hydroxyl groups which could retard the absorption rate of H_3O^+ ion on the cement mineral surfaces and thus slow down the setting reaction (Rahim *et al.* 1989).

In this study, the carbohydrate content of some wild Malaysian bamboos was examined as a guide to their potential uses, predicting their behaviour towards biodegrading agents and promoting their acceptance in commercial application.

Materials and methods

Source of materials

Three species of bamboo, *viz Bambusa blumeana* (buluh duri), *B. vulgaris* (buluh minyak) and *Gigantochloa scortechinii* (buluh semantan) were used in this study. Samples of the bamboos (one- to three-year-old), the growth of which has been recorded since their sprouting stages, were obtained from wild clumps in the grounds of the Forest Research Institute Malaysia (FRIM). Each bamboo sample was divided into three portions, namely the butt, middle and top at an interval length of 4 *m*.

Determination of starch content

The method devised by Humphrey and Kelly (1960) was adopted to determine the starch content through the basic reaction of the starch present with iodine and measuring the absorption of the colour developed by a colorimeter.

Bamboo samples were first ground to pass through a 200-mesh sieve. Triplicate samples of 0.4 *g* each were dried for 72 *h* in a desiccator oven containing concentrated sulphuric acid and then analysed.

The starch content was then calculated by applying the formula:

$$\% \text{ starch} = \frac{0.368 \text{ x (E reading} + 0.008)}{\text{Oven-dry weight of sample}} \times \frac{50}{100} \times 100,$$

where E = difference of absorption between sample and blank.

Determination of total available sugar content

The method developed by Simatupang as reported by Rahim and Khozirah (1988) was adopted in determining the sugars in the bamboos based on 0.4 *g* of each ground bamboo sample that had passed through a 200 - mesh sieve.

The amount of sugar was detected by Reactive Index Detector (Model 1037A) of a High Performance Liquid Chromatography (HPLC) system using Aminex HPX-87P column at 0.48 *ml* min^{-1} flow rate with double distilled water as the mobilizer. Sucrose, fructose, glucose, xylose and arabinose (analytical Reagent D+) were used as standards.

Results and discussion

The carbohydrate contents of the three bamboo species are given in Table 1. The respective summary of analysis of variance and Duncan Multiple Range Test are given in Tables 2 and 3.

Table 1. Carbohydrate contents (%) of bamboo

Species	Nutrient	1-year			2-year			3-year		
		Butt	Middle	Top	Butt	Middle	Top	Butt	Middle	Top
B. vulgaris	Starch	0.09	0.57	0.08	0.92	5.37	1.78	5.69	8.66	5.39
	Sucrose	0.33	1.25	1.04	0.26	0.17	0.18	0.38	0.15	0.88
	Glucose	0.36	1.06	0.83	0.12	0.08	0.08	0.93	0.55	1.23
	Fructose	0.44	1.21	1.17	0.20	0.07	0.13	1.10	0.63	1.34
	Xylose	t	0.01	0.03	t	t	t	t	t	t
	Arabinose	t	t	0.03	t	t	t	t	t	t
	Total sugars	1.13	3.53	3.10	0.58	0.32	0.39	2.41	1.33	3.45
	Total carbohydrates	1.22	4.10	3.18	1.50	5.69	2.17	8.10	9.99	8.84
B. blumeana	Starch	0.13	0.09	0.07	0.10	0.23	0.80	1.14	4.50	3.12
	Sucrose	1.34	1.69	2.01	0.81	2.19	2.16	1.50	5.18	3.52
	Glucose	1.34	0.24	0.28	t	0.02	0.08	t	0.10	0.04
	Fructose	0.38	0.34	0.26	t	0.03	0.29	t	0.08	0.05
	Xylose	t	t	t	t	t	t	t	t	t
	Arabinose	t	t	t	t	t	t	t	t	t
	Total sugar	3.06	2.27	2.55	0.81	2.24	2.53	1.50	5.36	3.61
	Total carbohydrates	3.19	2.36	2.62	0.91	2.47	3.33	2.64	9.86	6.73
G. scortechinii	Starch	0.77	0.51	1.28	0.66	7.69	0.29	5.25	8.38	5.56
	Sucrose	1.67	1.82	1.78	0.96	1.98	2.03	0.73	1.79	1.67
	Glucose	1.03	1.10	1.24	1.19	0.36	1.83	t	0.40	0.27
	Fructose	1.01	1.15	1.12	1.60	1.40	1.74	1.79	1.55	1.51
	Xylose	t	t	t	t	t	t	t	t	t
	Arabinose	t	t	t	t	t	t	t	t	t
	Total sugars	3.71	4.07	4.14	3.75	3.74	5.60	2.52	3.74	3.45
	Total carbohydrates	4.48	4.58	5.42	4.41	11.43	5.89	7.77	12.12	9.01

Note: t= trace amount

Table 2. Analyses of variance of carbohydrate contents of *B. vulgaris*, *B. blumeana* and *G. scortechinii*

Source of variation	Df	Mean squares and statistical significance				
		Carbohydrates contents of bamboo				
		Starch	Total sugar	Sucrose	Glucose	Fructose
Species	2	69.96**	24.39**	13.59**	1.79**	7.53**
Age	2	18.68**	93.83**	1.28**	1.05**	0.62**
Portion	2	208.39**	36.82**	4.37**	0.12*	0.10**
Species × age	4	1.14*	3.75**	2.16**	1.13**	0.73**
Species × portion	4	24.70**	4.82**	0.87**	0.17**	0.06**
Age x portion	4	0.34ns	10.12**	0.40**	0.14*	0.08**
Species × age × portion	8	1.84ns	2.20**	0.71**	0.40**	0.13**

Note: ns - not significant at P<0.05 ; * - significant at P<0.05 ; ** - significant at P<0.01

The results indicate that the starch contents of the bamboos differ significantly with species, age, culm height and the interactions of species with age and culm height. The starch contents of the bamboos, regardless of age and culm height, vary between 0.29 and 8.38%, 0.08 and 8.66%, and 0.07 and 4.50% in *G. scortechinii*, *B. vulgaris* and *B. blumeana*, respectively. The results (Tables 1 and 3) further show that the highest amount of starch was generally present in the middle portions, particularly in the 3-y-old *B. vulgaris*, *G. scortechinii* and *B. blumeana* (8.66, 8.38 and 4.50%, respectively). This is probably due to the middle portion containing less vascular bundles (Espiloy 1987, Abd. Latif *et al.* 1990) and more thick-walled parenchyma cells where the food storage of the living plant is concentrated. Parameswaran and Liese (1980) disclosed that the cytoplasmic organisation of the parenchyma cells in early stages of development consists of a nucleus, mitochondria, plastids and ribosomes. The plastids develop starch in maturing parenchyma cells, the fine structure of which has revealed the presence of a polylamellate construction of the walls. Furthermore, older bamboos have more matured tissues which are involved in the photosynthetic process than the younger culms which rely mainly on food supplement from the rhizome of the maternal plant (Anonymous 1962).

The total sugar contents of the bamboos differ significantly with age, species, culm height and their interactions (Table 2). As mentioned by Liese (1985), the chemical composition varies according to the individual characteristic of the species, its growing condition, age and part of the culm.

The composition of the free sugars is also shown in Table 1. Sucrose is the main free sugar in all the bamboo samples followed by glucose and fructose. While the levels of sucrose, glucose and fructose in *B. blumeana* were observed to be in the range of 0.81 to 5.18, 0.02 to 1.34, and 0.03 to 0.38%, respectively, those in *B. vulgaris* were in the range of 0.15 to 1.25, 0.08 to 1.23, and 0.07 to 1.34%, respectively. *G. scortechinii* had 0.73 to 2.03 of sucrose, 1.01 to 1.79% of fructose and only traces and up to 1.83% of glucose.

The highest value of the total sugars from this study was found in *G. scortechinii* (5.60%), followed by *B. blumeana* (5.36%) and *B. vulgaris* (3.53%). This is probably due to the smaller radial/tangential ratio and less dispersion of the vascular bundles [higher distribution of parenchyma cells in *G. scortechinii* compared to both the *Bambusa* species (Abd. Latif *et al.* 1990)].

Further regression analysis on the relationship of carbohydrate contents with age and height of the culm is given in Table 4.

While the amount of total sugars in all the bamboo species increases insignificantly with age ($r = 0.008$ at $P<0.05$), it is, however, correlated significantly with the increment of culm height, particularly in *B. blumeana* and *G. scortechinii* ($r = 0.480$ and 0.577, respectively). This could be related to the photosynthetic process which takes place in the leaves, that is, the higher portion of bamboo culm (Anonymous 1962).

Table 3. Mean values of carbohydrate contents of bamboos at different age and height levels (% by weight of oven-dry material)

Species	Parameter	Means percentage				
		Starch	Total sugars	Sucrose	Glucose	Fructose
B. vulgaris	Age					
	1	0.25a	2.76c	0.88c	0.77b	0.97b
	2	2.69b	0.43a	0.20a	0.11a	0.13a
	3	5.39c	2.40b	0.49b	0.91c	1.09b
	Portion					
	Butt	0.94a	1.38a	0.32a	0.52a	0.60a
	Middle	4.87c	1.73b	0.54b	0.55a	0.65a
	Top	2.52b	2.48c	0.71c	0.72b	0.94b
B. blumeana	Age					
	1	0.10a	2.28b	1.68a	0.65b	0.36a
	2	0.98b	1.86a	1.75a	0.06a	0.15a
	3	2.92c	3.50c	3.26b	0.23a	1.16a
	Portion					
	Butt	0.46a	1.46a	1.21a	0.46a	0.16a
	Middle	1.61c	3.29c	2.91c	0.26a	0.24a
	Top	1.33b	2.90b	2.56b	0.21a	0.27a
G. scortechinii	Age					
	1	0.85a	3.95b	1.82b	1.27b	1.23a
	2	2.88b	4.37c	1.69ab	1.22b	1.58b
	3	6.40c	3.24a	1.50a	0.33a	1.71b
	Portion					
	Butt	2.23a	3.33a	1.19a	0.81a	1.51a
	Middle	5.53b	3.84b	1.96c	0.82a	1.50a
	Top	2.38a	4.40c	1.88b	1.20b	1.51a

Note: Means followed by a common letter(s) are not significantly different at $P<0.05$

The highest total sugar content in each of the three bamboo species occurred at the top portion of the 2-y-old *G. scortechinii* (5.60%) and middle portions of the 3-y-old *B. blumeana* (5.36%) and *B. vulgaris* (3.53%), respectively. The amount of total sugars, however, was observed to be lowest at the middle portion of the 2-y-old *B. vulgaris* (0.32%), followed by the basal portion of the 2-y-old *B. blumeana* (0.81%) and *G. scortechinii* (2.52%). This could be related to the process of culm maturity which might have begun within the second growth year. Within this growth year, furthermore, bamboo establishes its rooting system and starts to branch (Abd. Razak Othman, personal communication). A 1-y-old culm normally relies on food supplement from the rhizome of the maternal plant but a 2-y-old bamboo starts to use all the carbohydrate contents, particularly sugar, for the development of its culm. It might be the point where bamboo starts to synthesize its own food requirement.

Table 4. Correlation coefficients of carbohydrate contents with age and culm height

Carbohydrate	Species	Age	Height
Starch	a	0.729 **	0.223 ns
	b	0.761 **	0.235 ns
	c	0.722 **	0.020 ns
	Average	0.662 **	0.127 ns
Total sugars	a	0.341 ns	- 0.110 ns
	b	0.399 ns	0.480 *
	c	- 0.385 ns	0.577 *
	Average	0.008 ns	0.352 **
Sucrose	a	- 0.395 ns	0.390 ns
	b	0.546 *	0.473 *
	c	- 0.313 ns	0.647 **
	Average	0.113 ns	0.317 *
Glucose	a	0.134 ns	0.203 ns
	b	- 0.421 ns	- 0.256 ns
	c	- 0.674 **	0.280 ns
	Average	- 0.308 *	0.089 ns
Fructose	a	0.099 ns	0.267 ns
	b	0.277 ns	- 0.503 *
	c	0.791 **	0.003 ns
	Average	0.087 ns	0.096 ns

Note: a : *B. vulgaris*; b: *B. blumeana* ; c: *G. scortechinii* ; ns: not significant at P<0.05 ;
* : significant at P<0.05; **: significant at P<0.01

From usage point of view, most of the bamboo samples which contained more than 0.6% total sugar (except the 2-y-old *B. vulgaris*) would probably produce low quality cement-bonded particleboard unless treated (Weber 1985). As the high carbohydrate content could also attract borer and fungal attacks (Liese 1985, Sulthoni 1987), bamboos should be treated adequately. Nevertheless, the variation in both the starch and total sugar contents within and between the culms of bamboo species and their relationship with biodeteriorating agents should be further investigated to classify their natural durability.

Conclusions

The starch content of bamboo was significantly correlated with species and age while the total sugar content was observed to correlate significantly with the increment of culm height (except in *B. vulgaris*). The variability that exists within the height and species of bamboo may probably be due to the age of the culm, the photosynthetic process which takes place predominantly at the upper portion, and the inherent characteristics of the individual bamboo species with special reference to the distribution, shape, size and arrangement of parenchyma cells along the culm length. *G. scortechinii* was observed to possess the highest amounts of starch and total sugars in almost all the three age groups at different height levels in relation to both the *Bambusa* species.

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