

Extractives, Holocellulose, α -Cellulose, Lignin and Ash Contents in Cultivated Tropical Bamboo *Gigantochloa brang*, *G. levis*, *G. scortechinii* and *G. wrayi*

¹Razak Wahab, ²Mohd Tamizi Mustafa, ³Mahmud Sudin, ⁴Aminuddin Mohamed,

¹Shafiqur Rahman, ²Hashim W. Samsi and ¹Izyan Khalid

¹Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli, Kelantan, Malaysia

²Forest Research Institute Malaysia, Kepong 52109 Kuala Lumpur, Malaysia

³Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia

⁴Universiti Teknologi MARA Pahang, 26400 Bandar Tun Abdul Razak Jengka Pahang, Malaysia

Abstract: This paper studied the chemical composition of cultivated 3 year-old tropical bamboo *Gigantochloa brang*, *G. levis*, *G. scortechinii* and *G. wrayi* especially in the extractives, holocellulose, α -cellulose, lignin and ash contents. The comprehensive knowledge of the chemical components in the bamboo species will facilitate the use of the materials in the forestry industrial sector and help to enhance their utilization in the chemical and bio-chemical related industry. The chemical compositions in cultivated 3 year-old bamboo culms of these species were studied. The chemical compositions of bamboo were determined in accordance with the standards outlined in TAPPI test methods. The culms exhibited different chemical composition in the contents of extractives, holocellulose, α -cellulose, lignin and ash between the bamboo species, location in the culms and position at the nodes and internodes. The extractives content of *G. brang*, *G. levis*, *G. scortechinii* and *G. wrayi* were 8.30, 9.23, 8.00 and 8.62%, respectively. The holocellulose content for *G. levis* were 85.08%, *G. wrayi* 84.53%, *G. brang* 79.94% and *G. scortechinii* 74.62%. The α -cellulose were higher in *G. brang* (51.58%), followed by *G. scortechinii* (46.87%), *G. wrayi* (37.66%) and *G. levis* (33.80%). The lignin contents were higher in *G. scortechinii* (32.55%), *G. wrayi* (30.04%), *G. levis* (26.50%) and lowest in *G. brang* (24.83%). The ash content were 2.83% in *G. scortechinii*, 2.83% in *G. levis*, 1.29% in *G. brang* (1.25%) and 0.88% in *G. wrayi*.

Keywords: α -cellulose, ash contents, bamboo genus *Gigantochloa*, extractives, holocellulose, lignin

INTRODUCTION

The bamboo cell walls consist of between 90 to 98% hemicellulose, cellulose and lignin, while the other 2 to 10% are mainly of extractives, resins, tannins, waxes and inorganic salts (Razak *et al.*, 2009; Liese, 1985, 1992; Tomalong *et al.*, 1980). Some variation, however do occurred in the main chemical constituent as the bamboo culms matured and it also depend on the type of bamboo species.

The hemicellulose and cellulose are actually made of the carbohydrate polymers which consisting of simple sugars monomer and lignin from phenylpropane (Browning, 1975). Lignin acts as the bonding agent that binds the cells in bamboo. Bamboo has been known difficult to work with as they blunt the cutting tools and deteriorate easily (Razak, 1998). Information on the chemical constituents of the bamboo culms will help the industry in overcoming this problem. Comprehensive knowledge of the chemical components in the bamboo species will facilitate the use of the materials in the forestry industrial sector and help to

enhance their utilization in the chemical and bio-chemical related industry.

This paper studied the chemical composition of cultivated 3 year-old bamboo *Gigantochloa brang*, *G. levis*, *G. scortechinii* and *G. wrayi* especially the extractives, α -cellulose, lignin and ash contents.

MATERIALS AND METHODS

Raw material preparation: Cultivated tropical bamboo *G. levis*, *G. scortechinii* and *G. wrayi* were used in this study. The 3 year-old bamboo culms of all the (4) species were selected and harvested from the bamboo trial plots located in the Forest Research Institute Malaysia (FRIM), Kepong, Selangor, Malaysia.

The chemical constituents of the bamboo were determined following the standard outlined in the TAPPI test method T257 (Anonymous, 1993). The bamboo samples were segregated according to their species. Each species were then grouped according to location of the samples taken at the outer, middle and

inner position of the nodes and internodes in the bamboo culms. The samples were chipped and dried in an oven at 50°C for three (3) days. The dried samples were ground into powder with Willey mill in order to pass BS 40-mesh (425 µm) sieve and retained on BS 60-mesh (250 µm) sieved. The size of the samples must be small to make sure the reaction reagent and fibres are occurring with optimum during the analysis. The chemicals composition analysis was used on the bamboo fibre. This method were divided into five (5) stages namely, the material preparation, determination of extractive, holocellulose, α-cellulose, lignin and ash contents.

Determination of organic and ash: The major chemical constituents of bamboo from genus *Gigantochloa* were determined. These include holocellulose, lignin, α-cellulose and extractives. The chemical characteristics of bamboo were determined in accordance with the standards outlined in TAPPI test methods. The determination of extractive content were carried out in according to the T2 04 cm-88 and T2 64 cm-88 methods (Anonymous, 1999). The procedure for the ethanol-benzene solubility followed T204 cm-97 (Anonymous, 2002) for 6 h. Holocellulose were determined following the procedure of Le *et al.* (1946) and α-cellulose base by T203 cm-74 (Anonymous, 1999). The lignin content was carried out following the T222 cm-88 method (Anonymous, 2002). The inorganic constituent of lignocelluloses material (referred to its ash content) was considered being the residue remaining after combustion of the organic matter at a temperature of 525±25°C. The ash content

was determined by followed the procedure outlined in T 211 cm-93 method (Anonymous, 1999).

RESULTS AND DISCUSSION

Extractive content: Table 1 show the results of the extractive content for various bamboo species at different location (internodes and nodes) and different position (inner, middle and outer position of the culm). The extractive content in four (4) species of *Gigantochloa* bamboo ranged between 8.30 to 9.23%. Hisham *et al.* (2006) obtained the extractive content of *G. scortechinii* from 3.4 to 5.8%. Mahanim *et al.* (2008) in their study on *G. scortechinii* and *G. lagulata* obtained the extractive content ranging from 3.74 to 4.45% and 2.95 to 3.20% respectively. The result obtain from this study was higher compared with previous studies. Softwoods constitute 3% and the hardwoods 5% extractives (Thomas, 1977). The extractive content of *G. brang*, *G. levis*, *G. scortechinii* and *G. wrayi* were 8.30, 9.23, 8.00 and 8.62%, respectively (Table 1). The extractive may constituted roughly from 5 to 30% of wood substance in wood, depending on factors such as species, growth conditions and time of year when the tree were cut.

Results of the studies shows that the extractive content in bamboo were less than 10% and were higher than those found in softwoods and hardwoods. The Analysis of Variance (ANOVA) on extractive content (Table 2) showed significant differences on extractive content within the various bamboo culms. The extractive content was noted to be higher in *G. levis*

Table 1: Extractive content various species genus *Gigantochloa*

Sample location	Position	<i>G. brang</i>	<i>G. levis</i>	<i>G. scortechinii</i>	<i>G. wrayi</i>
Inter-node	Outer	4.42 (±0.34)	4.76 (±0.38)	3.62 (±0.16)	4.54 (±0.47)
	Middle	5.16 (±0.05)	9.89 (±0.27)	6.58 (±0.28)	9.57 (±0.19)
	Inner	12.32 (±0.24)	14.03 (±0.40)	14.17 (±0.18)	12.40 (±0.48)
	Average	7.30 (±0.21)	9.53 (±0.35)	8.16 (±0.21)	8.80 (±0.38)
Node	Outer	5.25 (±0.04)	5.90 (±0.80)	4.72 (±0.30)	6.66 (±1.19)
	Middle	6.27 (±0.42)	7.53 (±0.47)	7.01 (±0.15)	5.71 (±0.88)
	Inner	16.41 (±0.25)	13.27 (±0.20)	11.91 (±0.18)	12.88 (±2.61)
	Average	9.31 (±0.24)	8.93 (±0.49)	7.80 (±0.21)	8.41 (±1.56)

The data presented were average values of at least 6 samples

Table 2: Summary result for Analysis of Variance (ANOVA) for chemical composition between species, location and position

	Chemical composition				
	Extractive	Holocellulose	α-cellulose	Lignin	Ash
Species					
<i>G. brang</i>	8.30 ^b	79.70 ^b	51.58 ^a	24.83 ^c	1.26 ^{cb}
<i>G. levis</i>	9.23 ^a	84.52 ^a	33.81 ^d	26.50 ^c	1.30 ^b
<i>G. scortechinii</i>	8.00 ^b	74.63 ^c	46.87 ^b	32.55 ^a	2.84 ^a
<i>G. wrayi</i>	8.62 ^{ab}	84.53 ^a	37.66 ^c	30.04 ^b	0.88 ^c
Location					
Internode	8.46 ^b	80.03 ^b	42.22 ^a	32.19 ^a	1.54 ^b
Node	8.63 ^a	81.66 ^a	42.74 ^a	24.76 ^b	1.60 ^a
Position					
Outer position	4.99 ^c	82.99 ^a	49.07 ^a	33.43 ^a	1.52 ^b
Middle position	7.21 ^b	80.89 ^b	41.28 ^b	21.98 ^c	1.28 ^c
Inner position	13.42 ^a	78.65 ^c	37.09 ^c	30.03 ^b	1.89 ^a

Means followed by the same letter in a column is not significant different at 0.05 probability level

Table 3: α -cellulose content genus *Gigantochloa*

Sample location	Position	<i>G. brang</i>	<i>G. levis</i>	<i>G. scortechinii</i>	<i>G. wrayi</i>
Inter-node	Outer	56.94 (± 0.41)	36.96 (± 0.54)	61.31 (± 0.43)	44.20 (± 0.90)
	Middle	48.98 (± 0.27)	32.87 (± 1.25)	41.59 (± 0.73)	38.10 (± 1.42)
	Inner	46.34 (± 0.63)	25.54 (± 0.52)	39.16 (± 0.49)	34.62 (± 1.37)
Node	Outer	57.98 (± 0.79)	46.46 (± 0.68)	50.02 (± 0.76)	38.72 (± 2.39)
	Middle	52.71 (± 1.06)	32.02 (± 0.20)	46.18 (± 0.48)	37.80 (± 2.70)
	Inner	46.54 (± 0.43)	29.00 (± 0.47)	42.95 (± 0.23)	32.55 (± 1.40)

The data presented were average values of at least 6 samples

Table 4: Holocellulose content of genus *Gigantochloa*

Sample location	Position	<i>G. brang</i>	<i>G. levis</i>	<i>G. scortechinii</i>	<i>G. wrayi</i>
Inter-node	Outer	80.05 (± 0.93)	89.80 (± 0.92)	75.35 (± 0.21)	84.49 (± 1.45)
	Middle	78.29 (± 0.48)	83.83 (± 2.55)	71.41 (± 0.45)	82.75 (± 0.76)
	Inner	76.64 (± 0.34)	84.08 (± 0.68)	70.67 (± 0.27)	82.98 (± 1.34)
Node	Outer	83.72 (± 0.55)	84.13 (± 0.81)	77.84 (± 0.28)	88.55 (± 0.77)
	Middle	81.97 (± 1.00)	83.33 (± 0.21)	77.26 (± 0.41)	88.28 (± 1.98)
	Inner	77.53 (± 0.51)	81.97 (± 0.71)	75.24 (± 0.29)	80.11 (± 1.84)

The data presented in this report are average values of at least 6 samples

(9.23%), followed *G. wrayi* (8.62%), *G. brang* (8.30%) and lowest in *G. scortechinii* (8%). At the internodes, the extractive content was 8.46%, while at nodes was 8.63% for all species. This showed a significant difference between the internodes and nodes in the bamboo culm.

Both the internodes and the nodes have higher extractives content in the inner position compared to the outer position of the bamboo. The inner position of the internodes contain about 12.32 to 14.17% and the nodes at 11.90 to 16.41%, compared with *Phyllostachys pubescens* (Moso bamboo) at inner position at 5.78%. Middle position for the internodes was from 5.15 to 9.74% and for nodes at 5.71 to 7.57%. Compared to *P. pubescens* at middle position was 4.25%. For the outer position for internodes was from 3.65 to 4.75% and for nodes was 4.71 to 6.66%, compared with *P. pubescens* at outer position was 3.15% (Li *et al.*, 2007). The extractive contains for different position shows significant differences between the bamboo positions for all species (Table 2). The highest extractive content was at 13.42% inner position, 7.21% at the middle position and 4.99% at outer position. A similar trend of extractive content at inner, middle and outer position in bamboo culm was reported by Li *et al.* (2007). It showed that the extractive compositions between sympodial and monopodial type of bamboo exhibit the similar trend. Li *et al.* (2007) noted that the inner position has higher extractive content due to wax like materials attached to the inner position and may have contributed to higher extractive content, compared with the middle and outer position.

Holocellulose content: The result of the chemical analysis shown in Table 3 indicated only a small difference exist in the holocellulose content between the bamboo species. The highest was *G. levis* (85.08%) followed by *G. wrayi* (84.53%), *G. brang* (79.94%) and *G. scortechinii* (74.62%), respectively. Tomalong *et al.* (1980) and Chen *et al.* (1985) reported that the

holocellulose content in bamboo normally consists about 50-70%. The Analysis of Variance (ANOVA) on holocellulose are tabulated in Table 2 showed that there exist significant different between species. The highest holocellulose content was 84.53% found in *G. wrayi* and 84.52% in *G. levis*, *G. brang* 79.70% and *G. scortechinii* has the lowest value at 74.62%. Hisham *et al.* (2006) found the holocellulose content of *G. scortechinii* was in the range of 78.60 to 82.30%. Ireana (2010) reported that the holocellulose content in *B. blumeana* was 74.56%. Li *et al.* (2007) in their study on *P. pubescens* bamboo showed that the holocellulose content was 63.14 to 69.94%. The value of holocellulose content in bamboo fiber was higher compared to holocellulose content in *P. pubescens* bamboo and almost similar to softwood fiber (60-80%) (Tsoumis, 2006; Ashori, 1991).

The holocellulose content in bamboo was 74-85% and it higher than softwood (67%) and also similar and higher than hardwood (75%). The holocellulose content for *G. levis* was the higher 85.08% followed by *G. wrayi* (84.53%), *G. brang* (79.94%) and *G. scortechinii* (74.62%). The holocellulose content does not show much significant differences at the internodes and nodes of the bamboo culms between the various bamboo species. The content of holocellulose at internodes was 73.48 to 86.74% and for the nodes 76.76 to 85.65%. The holocellulose content were higher at the outer position and its lower in inner position of the bamboo culms (Table 4).

Outer position for the internodes possess about 75.36 to 91.13% and for the nodes was 77.80 to 88.55% of holocellulose, compared with *P. pubescens* at outer position 69.94%, middle position for internodes were from 71.40 to 84.92% and the nodes at 77.26 to 88.29% (Li *et al.*, 2007). For the inner position of internode were 70.69 to 84.17% and at node was 75.23 to 81.97%. At the inner position the holocellulose content were 64.54%, the outer position has 82.99%, middle position 80.89% and the inner position 78.65%.

Table 5: Lignin content of genus *Gigantochloa*

Sample location	Position	<i>G. brang</i>	<i>G. levis</i>	<i>G. scortechinii</i>	<i>G. wrayi</i>
Inter-node	Outer	38.75 (±0.45)	35.98 (±0.42)	43.68 (±0.47)	38.90 (±0.20)
	Middle	15.72 (±0.41)	20.34 (±0.98)	28.68 (±0.40)	22.39 (±0.44)
	Inner	35.60 (±0.66)	33.32 (±0.43)	33.57 (±0.22)	39.40 (±1.12)
Node	Outer	21.01 (±0.66)	25.42 (±0.84)	33.33 (±0.19)	30.34 (±2.43)
	Middle	18.28 (±0.53)	21.67 (±0.37)	27.61 (±1.04)	21.04 (±0.83)
	Inner	19.69 (±0.62)	22.30 (±0.10)	28.42 (±1.04)	28.15 (±3.80)

The data presented were average values of at least 6 samples

Similar trend of holocellulose content at the inner, middle and outer positions in the monopodial type of bamboo culm was observed by Li *et al.* (2007). This shows that the holocellulose composition between sympodial and monopodial bamboo exhibit similar trend. The outer position possess higher holocellulose content due to heavy distribution of vascular bundle compared to the inner positions.

α -cellulose content: The Analysis of Variance (ANOVA) on α -cellulose content is showed in Table 2. Significant difference was noted in the α -cellulose content between the various bamboo species. The highest α -cellulose content were observed in species *G. brang* (51.58%) followed by *G. scortechinii* (46.87%), *G. wrayi* (37.66%) and *G. levis* (33.80%). The α -cellulose is one of the chemical constituents in the holocellulose. A similar pattern was obtained by Mahanim *et al.* (2008) reported that the α -cellulose contents in bamboo *G. scortechinii* and *G. lagulata* consists about 46.14-46.53 and 48.4-56.45%, respectively. Other studies on the α -cellulose content of *G. scortechinii* was in the range of 63.30 to 64.60% (Hisham *et al.*, 2006). Ireana (2010) reported that the α -cellulose content in bamboo (*Bambusa blumeana*) consist of 58.72%. Li *et al.* (2007) on their study on *P. pubescens* bamboo showed that the α -cellulose content was 41.71 to 49.02%. The value of α -cellulose content in bamboo fiber studied was similar compared to α -cellulose content in *P. pubescens* bamboo and almost similar to softwood fiber (42%) (Thomas, 1977). The α -cellulose content in bamboo (33.79-51.76%) were higher than softwood (42%) and hardwood (45%).

The α -cellulose content at difference location internode and node in bamboo culm for this genus, did not shows much difference between internodes and nodes. The content of α -cellulose at inter node was 31.76 to 50.82% and for the node 33.79 to 51.76%.

The ANOVA in Table 2 shows no significant difference in α -cellulose content between the internodes and nodes. The value of α -cellulose content at internodes was 42.22% and for the nodes was 42.74%.

The outer position for the internodes contains 36.99 to 61.24% and for the nodes at 38.74 to 58.15%, compared with *P. pubescens* (Moso bamboo) which has 49.02% at outer position (Li *et al.*, 2007). At the middle position the α -cellulose content for inter-node was from 32.72 to 49.08% and for node was 32.06 to 53.33%, compared with *P. pubescens* at middle position was

45.08%. The inner position, the α -cellulose content for internodes was from 25.56 to 46.32% and for the nodes was 28.95 to 46.61%, compared to 42.84%. in inner position of *P. pubescens*.

Lignin content: The Klason lignin or acid insoluble lignin values are shown in Table 5. The results show the lignin content of various bamboo species under genus *Gigantochloa* at difference location (inter-node and node) and difference position (inner, middle and outer position) of the culm. The lignin content in four (4) species of *Gigantochloa* bamboo is in the ranged of 24.84 to 32.65%. Hisham *et al.* (2006) and Mahanim *et al.* (2008) on their study on *G. scortechinii* observed that the lignin content was 16.12-12.48% and *G. lagulata* 12.02-11.69%. Ireana (2010) reported that the lignin content in bamboo (*B. blumeana*) consist of 28.86%. Data obtains from Ireana (2010) study almost comparable with result from this study. Lignin constitutes 23 to 33% of wood substance in softwood and 16 to 25% in hardwoods, although lignin occurs in wood throughout the cell wall, it is concentrated toward the outside of the cells and between cells.

The Analysis of Variance (ANOVA) on lignin contents (Table 2) shows significant differences between the bamboo species. The results showed the highest value in *G. scortechinii* i.e., 32.55%, *G. wrayi* i.e., 30.04%, *G. levis* i.e., 26.50% and lowest value in *G. brang* i.e., 24.83%. The lignin contents in bamboo were almost similar with that of the softwood and hardwood. The lignin content at internodes was 15.72 to 43.68%, while at nodes was 18.28 to 33.33% for all species. The lignin content at the inter-node was 32.19% and at the node was 24.76%. There was a significant different between location in bamboo culm. It's clear that inter-node content higher lignin amount compare to node.

The inner position for the inter-node contains about 29.88 to 35.36% and for the node at 19.66 to 29.93%. In comparison with *P. pubescens* at inner position of internodes was 22.57%, the middle position at 15.70 to 39.40% and for the nodes was 18.28 to 27.74%, the middle position was 21.79%. The outer position for the internodes was from 35.98 to 43.68% and for the nodes was 21.01 to 33.33%, compared with *P. pubescens* at outer position was 24.30%. The Analysis of Variance showed there was a significant difference of lignin content between positions of bamboo culm thickness. The value was highest at outer position which was

Table 6: Ash content genus *Gigantochloa*

Sample location	Position	<i>G. brang</i>	<i>G. levis</i>	<i>G. scortechinii</i>	<i>G. wrayi</i>
Inter-node	Outer	0.78 (±0.04)	1.19 (±0.14)	1.50 (±0.11)	0.97 (±0.12)
	Middle	0.84 (±0.06)	1.26 (±0.18)	2.04 (±0.06)	0.97 (±0.13)
	Inner	1.38 (±0.12)	1.41 (±0.11)	3.35 (±0.23)	1.41 (±0.18)
Node	Outer	1.26 (±0.24)	1.66 (±0.26)	2.80 (±0.14)	0.72 (±0.14)
	Middle	0.83 (±0.06)	1.03 (±0.02)	2.63 (±0.11)	0.66 (±0.12)
	Inner	1.13 (±0.11)	1.24 (±0.15)	4.70 (±0.28)	0.53 (±0.24)

The data presented were average values of at least 6 samples

33.43%, inner position 30.03% and the lowest at middle position which was 21.98%. Similar trend were obtained by Li *et al.* (2007) on lignin content at inner, middle and outer position in bamboo culm. There was a clear relationship between the lignin content with the fiber length. The middle position has a long fibre. The outer and inner positions having short fibres possess higher lignin content. Lignin is often called the cementing agent that binds individual cells together.

Ash content: Table 6 showed the ash content for various bamboo species under genus *Gigantochloa* at difference location (internodes and nodes) and difference position which is inner, middle and outer position of the culm. Hisham *et al.* (2006) found that the ash content of *G. scortechinii* was the ranged of 1.90 to 3.50%. Ireana (2010) reported that the ash content in *B. blumeana* consist of 1.67%. Both results obtained are comparable with the result obtained from this study.

The highest value of ash content was 2.83% for *G. scortechinii*, follow by *G. levis* 1.29%, *G. brang* 1.25% and the lowest for *G. wrayi* 0.88%. Several common wood species have ash contents ranging from 0.43% (aspen) to 0.87% (white oak) (Mishra *et al.*, 2004). The bamboo genera *Gigantochloa* had significantly higher ash content than these common wood species, but similar with kenaf form 1.6-22% (Ashori, 2006).

Comparison of chemical composition: The inorganic components of wood are generally expressed as percentage of ash, based on dry weight of the sample. The normal levels of occurrence appear to be from approximately 0.1% to about 0.5% ash, for most domestic timbers. Scurlock *et al.* (2000) reported that *Phyllostachys nigra*, *P. bambusoides*, *P. bissetii* bamboo species from 1 to 4.5 years old have ash content 0.41 to 0.87%, 0.53 to 0.84% and 0.78 to 1.14%, respectively.

The results in Table 6 showed the ash contents at internodes was 1.00 to 2.32%, while at nodes was 0.88 to 2.86% for all species. There is no significant difference of ash content between the internodes and nodes in the culm.

The ash contents at the inner position for the internode were about 1.38 to 3.39% and for the node was 0.53 to 4.79%, compared with *Phyllostachys pubescens* (Moso bamboo) at inner position was 0.88%, At the middle position for the inter-node was from 0.86 to 2.03% and for the node was 0.64 to 2.62%

Table 7: Correlation coefficients of different chemical composition with moisture content and specific gravity genera *Gigantochloa*

Properties	Species	MC	SG
Extractive	<i>G. brang</i>	0.69*	-0.77*
	<i>G. levis</i>	0.75*	-0.83*
	<i>G. scortechinii</i>	0.84*	-0.83*
	<i>G. wrayi</i>	0.50*	-0.73*
Lignin	<i>G. brang</i>	0.09 ⁿ	0.24*
	<i>G. levis</i>	0.01 ⁿ	0.18*
	<i>G. scortechinii</i>	0.09 ⁿ	0.38*
	<i>G. wrayi</i>	0.09 ⁿ	0.22*
Holocellulose	<i>G. brang</i>	-0.77*	0.79*
	<i>G. levis</i>	-0.34*	0.48*
	<i>G. scortechinii</i>	-0.61*	0.49*
	<i>G. wrayi</i>	-0.39*	0.56*
α-cellulose	<i>G. brang</i>	-0.83*	0.94*
	<i>G. levis</i>	-0.71*	0.81*
	<i>G. scortechinii</i>	-0.70*	0.78*
	<i>G. wrayi</i>	-0.43*	0.74*
Ash	<i>G. brang</i>	0.35*	-0.16*
	<i>G. levis</i>	0.20*	-0.22*
	<i>G. scortechinii</i>	0.38	-0.24*
	<i>G. wrayi</i>	0.25*	-0.08 ⁿ

MC: Moisture content; SG: Specific gravity; * = significant at 95% probability level, n = not significant

compared with *P. pubescens* at middle position was 0.65%. For the outer position for the inter-node was from 0.78 to 1.53% and for the node was 0.71 to 2.80%, compared with *P. pubescens* at outer position was 0.54%. Li *et al.* (2007) from their study showed the similar trend of ash content at inner, middle and outer position in bamboo culm. It's showed that the ash composition between sympodial and monopodial type of bamboo, has a similar trend.

Comparison between chemical composition with moisture content and specific gravity:

Moisture content were proportional to the extractive content. The higher the moisture content, the higher the extractive content. Lignin content does not show significantly correlation with moisture content. The correlation was rather weak and the moisture content has no direct relationship with lignin content in bamboo. Holocellulose and α-cellulose content has significant correlation with moisture content. They correlate quite well where the location and position with high moisture content, it related directly with low contents of holocellulose and α-cellulose.

The ash content has a positive correlation with moisture content. This means that the location and position that contains a high moisture content, ash directly a rate that is higher. Water contents were most

likely contained minerals or inorganic materials. Ash was an indicator of the presence inorganic materials in the lignocellulose material.

Table 7 shows correlation between chemical compositions with specific gravity. Extractive content has a significant correlation with specific gravity of bamboo. This shows the inverse relationship which a higher specific gravity, extractive content was low.

Lignin content has a significant correlation with specific gravity. This means that the location and position has a high specific gravity, the lignin content was relatively high. It shows the role of lignin as cement for cell bonding. This clearly shows a weak correlation between specific gravity and lignin content.

Holocellulose and α -cellulose has a significant correlation with specific gravity. This shows a strong and positively relationship, meaning a high specific gravity, which was attributed to the presence of a high holocellulose and α -cellulose. The ash content with specific gravity relationship is not consistent and not significant.

CONCLUSION

The extractive content in four (4) species of *Gigantochloa* bamboo was in the range of 8.30 to 9.23%. The extractive content of *G. brang*, *G. levis*, *G. scortechinii* and *G. wrayi* were at 8.30, 9.23, 8.00 and 8.62%, respectively. The extractive content was higher in *G. levis* (9.23%), followed *G. wrayi* (8.62%), *G. brang* (8.30%) and lowest in *G. scortechinii* (8%). The extractive content at internodes was 8.46%, while at the nodes was 8.63% for all species. Inner position for the internodes the extractives contains were 12.32 to 14.17% and for the nodes were 11.90 to 16.41%. The middle position for internodes were from 5.15 to 9.74% and nodes were 5.71 to 7.57 %. The extractive content was at 13.42% (inner position), 7.21% middle position and 4.99% outer position).

The holocellulose content for *G. levis* was 85.08%, *G. wrayi* 84.53%, *G. brang* 79.94% and *G. scortechinii* 74.62%. The holocellulose content for the cultivated bamboo genus *Gigantochloa* were 74 to 85%. The content of holocellulose at internodes was 73.48 to 86.74% and for the nodes 76.76 to 85.65%. The holocellulose content was highest at internodes (81.65%) compared to the nodes (80.02%).

The highest was *G. brang* (51.58%) followed by *G. scortechinii* (46.87%), *G. wrayi* (37.66%) and *G. levis* (33.80%). Based from the result, the average of α -cellulose content for the cultivated bamboo genus *Gigantochloa* were 33.79 to 51.76%. The α -cellulose content at difference location internodes and node in bamboo culm for this genus, showing not much differences between internodes and nodes. The content of α -cellulose at internodes was 31.76 to 50.82% and for the nodes 33.79 to 51.76%. The average value of α -cellulose content at internodes was 42.22% and for the nodes was 42.74%.

The lignin content in the four (4) species of *Gigantochloa* bamboo ranged between 24.84 to 32.65%. The highest were obtained in *G. scortechinii* (32.55%), *G. wrayi* (30.04%), *G. levis* (26.50%) and lowest in *G. brang* (24.83%). The lignin content at the internodes were 15.72 to 43.68%, while at nodes were 18.28 to 33.33% for all species.

The ash content in four species of *Gigantochloa* bamboo ranged between 0.88 to 2.86%. The ash content was highest in *G. scortechinii* (2.83%) follow by *G. levis* (1.29%), *G. brang* (1.25%) and the lowest in *G. wrayi* (0.88%). The ash content at internodes ranged from 1.00 to 2.32%, while at nodes was 0.88 to 2.86% for all species. The ash content was higher at nodes compared to internodes. The ash contents at the inner position for the internodes ranged between 1.38 to 3.39% and the nodes was 0.53 to 4.79.

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