
Variation in density and its relation to anatomical properties in bamboo culms, *Bambusa bambos* (L.) Voss

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Abstract: The study was mainly focused on the distribution of tissue proportion and its influence on density in the culms of *Bambusa bambos* (L.) Voss. For this study the culms or the portions of the culms were collected and analyzed such as outer, mid and inner portions of the culm wall, base, mid and top portions of the culm. The result shows that the anatomical properties as well as physical properties varied in relation to different portions of the culm wall, height levels and age of the culm. In addition to these the anatomical properties such as percentage of tissues proportions may influence the physical properties. Age is one other important factors influence the density. Physical properties changes up to a particular age of the culm and then the change was negligible or stabilized.

Keywords: Parameters, Analyzed, Proportions, Distribution

1. Introduction

Bamboo is a viable alternative to wood. In fact, bamboo is also one of the oldest building materials used by mankind (Abd. Latif *et al.*, 1990). In many densely populated countries of the tropics, certain bamboos supply at least one suitable material that is sufficiently economical and plentiful to meet the extensive need for economical housing (McClure, 1966). Earlier studies on anatomical properties have attempted to assist taxonomical characterization of different species. Further studies on bamboos mainly aimed at the establishment of the structure-property correlations or to analyze growth, maturation or ageing phenomena in bamboos. As is common to any woody material, utilization of bamboo for various applications is governed by its properties. However, these properties vary between species. Since the parameters like physical and anatomical properties ultimately influence the utilization of bamboo resources, the present study has been chosen to look into these facts and relationships in a more systematic way. Anatomical methods have been adopted for investigation in order to provide a precise insight into the observations recorded on such physical features.

2. Materials and Methods

2.1. Collection of Material

The culms of the species were collected by cutting at the base. When samples were collected from forest area, age of the culm was ascertained based on the procedure described by Waheed Khan (1962) and Banik (1988). After felling, the samples were collected from three height levels; base, middle and top for different analyses such as physical properties and anatomical structure.

2.2. Quantification of Tissue Proportions

From FAA fixed material transverse as well as longitudinal sections of 30-50 µm thickness were cut on a sliding microtome. The sections were stained with tannic acid and ferric chloride for 15-20 minutes. The material was washed and stained with safranin (Foster, 1934). Stained sections were washed thoroughly with distilled water and dehydrated. After passing through xylene the sections were mounted in DPX mountant.

The abundance of fibro-vascular bundles was estimated by counting the bundles per mm². The tissue proportions across the culm wall were estimated by tracing the cross-sectional views on a tracing film and calculating the area occupied by each tissue.

2.3. Photomicrographs

Photomicrographs were made with the help of Nikon-photomicroscope (NIKON DIGITAL CAMERA – CoolPiX 4500, Microscope – ECLIPSE EE 200) and Leica Image Analysis System

2.4. Physical Properties

2.4.1. Basic Density

The volume of culm samples was determined by water displacement (ASTM, 2002). The samples were kept in a hot air oven at 105°C for about 48 hours (ASTM, 2002) for drying. After cooling the samples in a desiccator, the oven-dry weight was determined. Basic density was calculated using the formula,

$$\text{Basic density} = \frac{\text{Oven dry weight(kg)}}{\text{Green volume(m}^3\text{)}}$$

2.4.2. Statistical Analysis

One-way Analysis of variance (ANOVA) was used to compare the difference in structure and properties between age, height levels, and radial positions. For some parameters site-wise comparison was also done. If the F-value of ANOVA was found to be significant pair-wise comparison was done using least significant difference (LSD) to find out which pairs were significantly different.

3. Results and Discussion

3.1. Variation in Size and Distribution of Fibro-Vascular Bundles across the Culm Wall

The distribution of fibro – vascular tissue varied in different parts of a culm. Towards the mid-portion of the culm wall, the size of the vascular bundles increased (Table 1). Table 1 show that the size of vascular bundles significantly differed from outer to inner portion of culm wall at three height levels in the species. The LSD showed that the vascular bundles at outer portion of the culm wall were significantly smaller than those from the middle and inner portions of the culm wall at three height levels in the species (Table 1).

According to Grosser and Liese (1971), the vascular bundles of the inner zone differ with the species and with the portion on the culm. They also reported that the larger vascular bundles are present in the middle zone. Similarly Kumar and Dobriyal (1992) measured the variation in size of vascular bundles in relation to different portions (outer to inner) of the culm wall of *D. strictus*. Thier study shows that the size of vascular bundles varied from outer to inner portions of the culm wall. According to their study the maximum size of the vascular bundles is observed in the inner part of the culm wall

followed by middle and outer portions.

Table 1. Size of vascular bundle at different portions in different height levels of *B. bambos*

Species	Height levels	Radial position			F-value
		Outer	Middle	Inner	
<i>B. bambos</i>	Base	6.10 ^B	15.09 ^A	15.97 ^A	10.178**
	Middle	6.01 ^B	13.25 ^A	14.98 ^A	8.086**
	Top	4.16 ^B	8.96 ^A	11.04 ^A	9.413**
	F-value	0.939 ^{ns}	2.948 ^{ns}	2.122 ^{ns}	

Note: Means with same small letter as superscript within a column are homogeneous

Means with same capital letter as superscript within a row are homogeneous

* - significant at 5% level; ** - significant at 1% level; ns - non- significant at 5% level

3.2. Variation in Size and Distribution of Fibro-Vascular Bundles along Culm Height

The size of vascular bundles varied in relation to the height level of the culm in the species investigated. Generally the largest vascular bundles were observed in the basal height level of the culm (Table 1). There was a decreasing trend from base to top height levels although; the variation in size of vascular bundles was not consistent in all cases (Table 1). However, the smaller vascular bundles are observed at top height level as compared to base and mid height levels of the culm (Table 1). In *B. bambos* the height levels does not significantly influence on size of the fibro-vascular bundles even in all the radial positions.

3.3. Anatomical Properties

3.3.1. Frequency of Vascular Bundles

The frequency of vascular bundles as estimated from number of bundles/mm² in the culm wall at different height levels of the species is given in Table 2. The result of ANOVA showed significant difference from outer to inner portions of the culm wall in the species. The mean values at different portions showed a decrease in frequency of vascular bundles from periphery to inner portions of the culm wall in the species.

Frequency of vascular bundles also varied with height levels (Table 2). The overall picture was that there was an increase in frequency of vascular bundles from basal height level to top height level in the species. This may due to the decrease in wall thickness at top height level of the culm. The high density of vascular bundles at the top height level of the culm is due to the decrease in the wall thickness of the culm (Grosser and Liese, 1971). They also reported that the size of vascular bundles in the culm is not directly correlated with age, but decreases with height of the culm.

Abd Latif and Tamizi (1993) have found that the concentration of vascular bundles varies with height levels of the culms and species. The highest mean concentration of vascular bundles at top height level and the lowest in the mid-height level of the culm, which is confirmed in this study.

Table 2. Abundance of vascular bundles at different portions in different height levels of *B. bambos*

Species	Height levels	Radial position			F-value
		Outer	Middle	Inner	
<i>B. bambos</i>	Base	4.18 ^A	1.57 ^{bB}	1.35 ^{bB}	30.099**
	Middle	3.36 ^A	1.99 ^{abB}	1.53 ^{bB}	12.307**
	Top	4.37 ^A	2.45 ^{aB}	2.12 ^{aB}	17.175**
	F-value	1.915 ^{ns}	3.947*	3.876*	

Note: Means with same small letter as superscript within a column are homogeneous

Means with same capital letter as superscript within a row are homogeneous

* - significant at 5% level; ** - significant at 1% level; ns - non-significant at 5% level

3.3.2. Variation in Percentage of Fibro-Vascular Tissues

Mean percentage of fibro-vascular tissue for different radial positions and height levels of the species is provided in Table 3. The mean value increased from inner to outer portion of the culm wall.

Espiloy (1987), Wu and Hsieh (1991) found that the diameter of the vessels decreases from sixth internode towards the top for *Dendrocalamus latiflorus*, but a slight increase in the species of *Phyllostachys edulis*.

Table 3. Proportion of fibro-vascular tissue at different portions in different height levels of *B. bambos*

Species	Height levels	Radial position			F-value
		Outer	Middle	Inner	
<i>B. bambos</i>	Base	48.52 ^A	36.93 ^{bB}	29.92 ^{bC}	16.792**
	Middle	46.02 ^A	43.95 ^{aA}	36.73 ^{aB}	5.477**
	Top	53.34 ^A	49.79 ^{aA}	40.20 ^{aB}	7.636**
	F-value	2.796 ^{ns}	8.341**	4.726*	

Note: Means with same small letter as superscript within a column are homogeneous

Means with same capital letter as superscript within a row are homogeneous

* - significant at 5% level; ** - significant at 1% level; ns - non-significant at 5% level

The mean values (Table 3) show that there was a decrease in percentage of fibro-vascular tissues from top to basal height level of the culm in the species. This may be due to variation in wall thickness. The wall thickness at basal height level was higher as compared to other height levels. This indicates the wall thickness of culm may influence the percentage of fibro-vascular tissues. Based on this observation thin walled bamboo culm may have higher percentage of fibro-vascular tissue as compared to thick walled culms. This variation may affect the physical and mechanical properties of bamboos.

3.3.3. Variation in Percentage of Fibrous Tissues

The outer portion of the culm wall had significantly higher fibrous tissue than the other two portions in the species (Table 4). Overall there was a decrease in percentage of fibrous tissues from periphery to inner

portions of the culm wall at three height levels of the species.

Table 4. Proportion of fibrous tissue at different portions in different height level of *B. bambos*

Species	Height level	Radial position			F-value
		Outer	Middle	Inner	
<i>B. bambos</i>	Base	40.78 ^A	28.78 ^{bB}	21.80 ^{bC}	19.222**
	Middle	37.18 ^A	30.65 ^{bB}	25.12 ^{abC}	12.419**
	Top	40.73 ^A	36.39 ^{aA}	28.27 ^{aB}	9.330**
	F-value	0.716 ^{ns}	4.249*	4.387*	

Note: Means with same small letter as superscript within a column are homogeneous

Means with same capital letter as superscript within a row are homogeneous

* - significant at 5% level; ** - significant at 1% level; ns - non-significant at 5% level

The percentage of fibrous tissue also varied along with culm height. The percentages of fibrous tissue in *B. bambos* in relation to height levels of the culm are given Table 4. The percentage of fibrous tissue was comparatively higher in top height level than base and mid-height levels in the species. However, the difference was statistically not significant. Such variation in proportion of fibro-vascular percentage may affect the physical properties of bamboo culm. The maximum density was observed at the top height level as compared to other height levels. Similarly the percentage of fibrous tissue increases from base to top height levels. This indicates that higher basic density of the top height level of bamboo culm may be attributed to the presence of higher sclerenchymatous fibrous tissue at this height level. This result also supports the earlier findings of Espiloy (1987) and Janssen (1981).

3.3.4. Variation in Percentage of Ground Tissues

Proportion of ground tissues holds an inverse relationship with proportion of fibro-vascular tissue. The data on proportion of ground tissues at different portions of culm wall at three height levels of the species are presented in Table 5. Proportion of ground tissues in the inner portion of the culm wall was significantly higher than that at other portions of the culm wall at all height levels of the culm of *B. bambos*.

Table 5. Proportion of ground tissue at different radial positions in different height level of *B. bambos*

Species	Height level	Radial position			F-value
		Outer	Middle	Inner	
<i>B. bambos</i>	Base	51.48 ^C	63.07 ^{aB}	70.08 ^{aA}	16.792**
	Middle	53.97 ^B	55.45 ^{bB}	63.27 ^{bA}	5.868**
	Top	46.66 ^B	50.21 ^{bB}	59.80 ^{bA}	7.636**
	F-value	2.787 ^{ns}	8.576**	4.726*	

Note: Means with same small letter as superscript within a column are homogeneous

Means with same capital letter as superscript within a row are homogeneous

* - significant at 5% level; ** - significant at 1% level; ns - non-significant at 5% level

There was also variation in percentage of ground tissues with different height levels of the culm of the species of *B. bambos* (Table 5). The maximum percentage of ground tissue was observed at the basal height level of the culm it decreased from base to top height level of the culm in the species.

3.4. Physical Properties

3.4.1. Basic Density

3.4.1.1. Density Variation across the Culm Wall

The highest density was observed in the outer portion of the culm wall, gradually decreasing to the inner region of the culm wall (Table 6). The mean values showed a definite uniform trend in the species. The higher basic density of the outer portion of the culm wall may be attributed to the presence of higher number of vascular bundles and higher proportion of fibrous tissue at this portion (Tables 2, 4). And this reason supports the earlier findings of Espiloy (1987), Janssen, (1981) and Liese, (1998). According to their reports the variation in basic density in bamboo culms may be attributed to proportion of vascular bundles and proportion of fibrous tissue.

Table 6. Mean density (kg / m^3) content at outer, middle and inner portions of the culm wall of the species

Portions	<i>B. bambos</i>	
	Density	SD
Outer	789.955 ^a	20.0889
Middle	589.095 ^b	20.8526
Inner	542.485 ^b	32.7178
F - value	54.357**	

Note: ** - significant at 1% level; ns - non significant at 5% level

3.4.1.2. Variation in Density in Relation to Height Levels of the Culm

The basic density of the culm increased with increasing height levels of the culms in (Figure 1). Other investigators also noted the increase in specific gravity or density with increasing height levels of the culm (Espiloy, 1987; Liese, 1986). The reason for higher basic density of the top height level of bamboo culm may be attributed to the presence of higher proportion of fibrous tissue and higher frequency of vascular bundles at top height level (Tables 2, 4). And this reasons support the earlier findings of Espiloy (1987), Janssen (1981) and Liese (1998). Espiloy (1987) studied the variation in density of selected Philippine bamboos *B. blumeana* and *Gigantochloa levis*. He observed significant increase in density from base to top height levels in a culm and there was no variation among species, where density value increased toward the top for both species. Abd. Latif and Mohd. Zin Jusuh (1992) reported that the density of the culms varies with species. Similar observations have been made in a number of studies (Sattar *et al.*, 1992; Liese, 1998; Bhat, 2001; 2003). According to Liese (1998) the reason of the higher density at top height level of the culm

is due to the higher frequency of vascular bundles.

Density variation in relation to anatomical properties was studied by Janssen (1981), Espiloy (1987), Widjaja and Risyad (1987). Their studies showed that the density of bamboo culms is closely related to the relative proportion of vascular bundles and ground tissues.

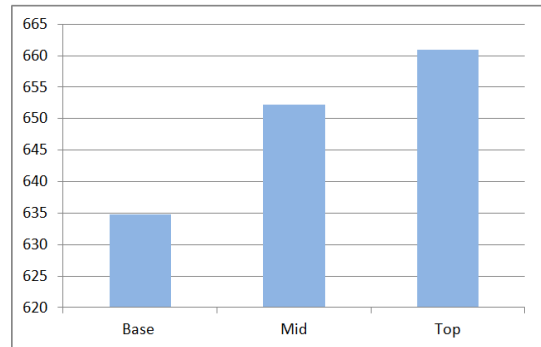


Figure 1. Variation in density (kg / m^3) at different height levels of *B. bambos*

4. Conclusion

The anatomical properties also varied with positions of the culm wall and different height levels of the culm in the species. The size of the fibro-vascular bundles increased from outer to inner positions of the culm wall but decreased with increasing height of the culm. The percentage of parenchyma tissues, fibrous tissues, vascular tissue and frequency of vascular bundles varied with different height levels and different positions of the culm wall. The frequency of vascular bundles decreased from outer to inner position of the culm wall and increased with increasing height level of the culm. The result of the present study shows that a definite uniform trend was noticed in distribution of tissues and its influence on physical properties.

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References

- [1] Abd. Latif, M., Mohd. Tamizi, M. 1993. Variation in anatomical properties of three Malaysian bamboos from natural stands. *Journal of Tropical Forest Science* 5(1): 90-96.

- [2] Abd. Latif, M., Wan Tarmeze, W.A. and Fauzidah, A. 1990. Anatomical features and mechanical properties of three Malaysian bamboos. *Journal of Tropical Forest Science* 2(3):227-234.
- [3] Abd. Latif, M., Zin Jusuh 1992. Culm characteristics of *Bambusa blumeana* and *Gigantochloa scortechinii* and its effect on physical and mechanical properties. In Zhu, S., Li, W., Zhang, X., Wang, Z. (eds.). *Bamboo and its use*. Proceedings of the International symposium on Industrial use of bamboo, Beijing, China, 7–11 December 1992. International Tropical Timber Organization; Chinese Academy of Forestry, Beijing, China. 118–128.
- [4] ASTM (American Society of Testing Materials). 2002. Standard Test Methods for specific gravity of wood and wood – based materials. Designation: D 2395 – 02. ASTM. International, West Conshohocken, PA., USA., 8pp.
- [5] Banik, R.L. 1988. Investigation on the culm production and clump expansion behaviour of five bamboo species of Bangladesh. *Indian. For.* 114(9): 576-583.
- [6] Bhat, K.V. 2001. Anatomical changes associated with culm maturation in *Bambusa bambos* (L.) Voss and *Dendrocalamus strictus* Nees KFRI, Res. Rep. No. 216. Kerala Forest Research Institute, 18pp.
- [7] Bhat, K.V., 2003. Anatomical Changes during maturation in *Bambusa bambos* (L.) Voss and *Dendrocalamus strictus* Nees *Journal of Bamboo and Rattan* 2: 153–160.
- [8] Espiloy, Z. B. 1987. Physico – mechanical properties and anatomical relationship of some Philippine bamboos. In Rao, A.N., Dhanarajan, G., Sastry, C.B. (eds.). *Recent Research on Bamboo*. Proceedings of the International Bamboo workshop, Hangzhou, China, 6 – 14 October 1985. Chinese Academy of Forestry, Beijing, China; International Development Research Center, Ottawa, Canada. 257-264.
- [9] Foster, A. S. 1934. The use of tannic acid iron chloride for staining cell walls in meristematic tissue. *Stain Technol.* 9: 91-92.
- [10] Grosser, D.; Liese, W. 1971. On the anatomy of Asian bamboos, with special reference to their vascular bundles. *Wood Sci. Technol.* 5: 290-312.
- [11] Janssen, J.J.A. 1981. The relationship between the mechanical properties and the biological and chemical composition of bamboo. In Higuchi, T. (ed.). *Bamboo production and Utilization*. Proceedings of the congress group 5.3. A. Production and Utilization of bamboo and related species XVII IUFRO World congress, Kyoto, Japan, September, 6-17, 1981, 27-32.
- [12] Kumar, S., Dobriyal, P.B. 1992. Treatability and flow path studies in bamboo. Part. I. *Dendrocalamus strictus* Nees. *Wood and Fiber Science.* 24(2): 113–117.
- [13] Liese, W. 1986. Characterization and utilization of bamboo. Pro. IUFRO 18th World congress on Bamboo production and Utilization, 7-21 September, Ljubljana, Yugoslavia, 11-16.
- [14] Liese, W. 1998. The Anatomy of Bamboo Culms. Technical Report No. 18, International Network for Bamboo and Rattan, Beijing China. 208pp.
- [15] McClure, F.A. 1966. *Bamboos: a fresh perspective*, Harvard University press. Cambridge, Massachusetts, USA. 347pp.
- [16] Sattar, M.A., Kabir, M.F, Bhattacharjee, D.K. 1992. Physical and mechanical properties of six important bamboo species of Bangladesh. “Bamboo and its use” international symposium on industrial use of bamboo. Beijing China, 7 – 11, December, 1992. International Tropical Timber Organization, Chinese Academy of Forestry, 112–117.
- [17] Waheed Khan, M.A. 1962. Determination of culm age in bamboo. *Indian. For.* 88 (8): 533-542.
- [18] Widjaja, E.; Risyad, Z. 1987. Anatomical properties of some bamboo utilized in Indonesia. In Rao, A.N., Dhanarajan, G. and Sastry, C.B. (eds.). *Research on Bamboos* proceedings of International bamboo workshop, Hangzhou, China, October, 6–14, 1985, 244-246.
- [19] Wu, S.C., Hsieh, J.S. 1991. Anatomical characteristics of Taiwan giant bamboo and moso bamboo. In *Bamboo in Asia and the Pacific*. Proceedings of the 4th International workshop, Chiangmai, Thailand, 27 – 30 November 1991. International Development Research Center, Ottawa, Canada, Forestry Research Support programme for Asia and the Pacific, Bangkok, Thailand, 193–198.