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Chemical and anatomical properties cultivated bamboo (*Dendrocalamus membranaceus* munro) culms.

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A B S T R A C T

In the present study anatomical and chemical properties of *Dendrocalamus memberceus* Munro species results are shows that number of vascular bundle frequency and vessel diameter is more at top portion. But there were no much variations in fiber length fiber width and lumen diameter from bottom to top level of the bamboo culm. Whereas the chemical composition results shows that higher level of hot water solubility at top portion as the vessel diameter is also more. This indicates that chemical composition varies from base to top at different height level of the bamboo culm.

Introduction:

Bamboo is a fast growing species and a high yield renewable resource. Bamboo growth depends on species, but generally all bamboo matures quickly. The suitability of bamboo for structural composite products is demonstrated by its physical properties. These properties are the results of genetic design, as well as the effect of the climate and soil condition. The anatomical, chemical and physical-mechanical properties of bamboo exhibit no basic differences among genera and species compare to wood. Also, growth conditions and aging have apparently no significant effect on composition and structure of the bamboo tissue. In brief, the total culm comprises of about 60% parenchyma, 40% fibers and 10% conducting tissue (vessels and sieve tubes) (Razak et al., 2009; Liese, 1992, 1985). 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).As is common to any woody material, utilization of bamboo for various applications is governed by its properties. The gross anatomical structure of a transverse section of any culm internode is determined by the shape, size, arrangement and number of the vascular bundles.

As the morphology, structure and chemical components of bamboo differ from those of timber, the methods, technology and equipment for timber processing cannot be applied indiscriminately to bamboo utilization. Being a biological material, it is subjected to greater variability and complexity due to various growing conditions such as moisture, soil and competition (Latif *et al*. 1993).Many factors, such as culm height, topography and climate, affect the properties of bamboo to a great extent and thus its utilization (Soeprajitno *et al*. 1988). Information on physical and mechanical properties of bamboo is necessary for assessing its suitability for various end products (Sattar *et al*. 1992). The appropriate use of any material depends on its properties to a large extent. Being a universal raw material, the properties of bamboo need to be evaluated. The important physical properties include density, specific gravity, and shrinkage in diameter and wall thickness. On the other hand, mechanical properties include bending strength, tensile strength, compressive strength, shear strength, nail withdrawal resistance perpendicular to the face of the culm and fracture resistance. However, these properties vary between species. Since the parameters like chemical 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. This study was aimed at evaluating some important chemical and anatomical properties of *Dendrocalamus memberceus* Munro bamboo species to identify proper utilization of bamboo for different applications.

Material and methods:

In the present investigation six culms of four (4) year old cultivated bamboos species namely *Dendrocalamus memberceus* Munro was collected from bamboo Arboratum of BIAF (Bharatiya Agro Industries Foundation), S. Lakkihalli near Tiptur taluk of Tumkur district, Karanataka. After felling, the bamboo culms unusable parts of the culm bottom (the crooked portion with very short internodes) and culm top (with very low diameter and thin wall) was removed.

Determination of anatomical properties:

Sample blocks for anatomical study were taken from internodal portions of the *Dendrocalamus memberceus* Munro bamboo species. The anatomical studies on vascular bundles concentration, vessel diameter, fibre length, fiber width and lumen diameter were carried out using the technique used by Latif and Tamizi (1993) with some modification.

Bamboo sample blocks were cut into square sections of size 10 mm × 10 mm × culms wall thickness and boiled in distilled water for four hours to soften the hard bamboo culm. These were then sliced into 45 µm thick transverse sections by sledge microtome with a 15 degree knife angle.

Slide preparation:

Each section was stained with 4 drops of aqueous safranin-O for 4 minutes on the slide. They were washed with 50% ethanol then dehydrated through alcohol series of 70, 80, 90 and 95%, and 3 changes of absolute ethanol for 1 minute, mounted with drop of Glycerine by cover slip. Observations for anatomical structure were made using light compound microscope, attached digital camera with image analysis software.

Second method:

In the present study we followed a new technique to study the anatomical characters like vascular bundle concentration by taking the live bamboo sample's images using stereo zoom microscope attached with image analysis software. Bamboo sections of *Dendrocalamus memberceus* Munro species were made a sharp cut with the help of a knife at cross section of the bamboo culm. The sharp cut bamboo sample was placed under the objective lens to view image on computer screen. Vascular bundle distribution was measured using the image analysis software system attached with the microscope.

Determination of Fibre morphology:

Fiber morphology studies like Fiber length, width and fiber lumen diameter were studied using bamboo maceration technique.

Bamboo maceration:

The bamboo splits of size 20mm x 10mm x thickness were cut tangential from each portion of bottom, middle and top into a match stick size with a sharp knife and transferred into Jeffrey's solution (50:50 mixture of 15% nitric acid and 10% chromic acid) to macerate the fibers. A period of 48 hours was allowed to soften the splints (Abd. Latif and Mohd Tamizi 1993; Razak et al., 2007). At the end of the maceration period, the softened splints were carefully washed with distilled water. A drop of slurry solution was placed on glass slide and drops of safranin-O were introduced to contrast the fibre's images.

Observations:-Fifty (50) undamaged or unbroken fibers were measured for their length (l) widths (d) lumen diameter (l) using Olympus microscope equipped with image analysis software and the images was measured at 4x magnification for (length), 10x magnification for (width) and 40x magnification for (lumen diameter).

Determination of chemical composition:

The chemical composition of bamboo samples were determined in accordance with the standards outlined in ASTM test methods as shown in Table 1. Six culms were selected and divided into bottom, middle and top for chemical analysis study.

Sample Preparation:

Bamboo samples were chipped by drilling machine to convert into power form 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) sieve. The size of the sample was taken 2g during the analysis.

Table: 1. List of ASTM standards for chemical analysis of Bamboo

Property	Standard
Alcohol-toluene solubility	* ASTM D 1107-56 (Reapproved 1972)
Hot-water solubility	ASTM 1110-56 (Reapproved 1977)
Lignin	ASTM D 1106-56 (Reapproved 1977)
Holocellulose	ASTM D 1104-56 (Reapproved 1978)
Alpha-cellulose	ASTM D 1103-60 (Reapproved 1978)
Ash Content	ASTM D 1102-84 (Reapproved 1990)

Each test was conducted using 3 replications. It was necessary to conduct additional experimentation when analyzing for alcohol-toluene extractive content and holocellulose content. The alcohol-toluene test is the starting material for many of the other experiments. Both the lignin and holocellulose content test are performed with extractive-free bamboo that is derived from the alcohol-toluene extractive test. Additionally, holocellulose is a necessary preparatory stage in order to determine the alpha-cellulose content.

Results:

The vascular bundle distribution and vessel diameter results of *Dendrocalamus membranaceus*

Munro, species are presented in Table-2.The transverse section of *Dendrocalamus membranaceus* Munro species internode exhibit Type IV vascular bundle, which consists of three parts; the central vascular strand with small sclerenehyma sheaths and two isolated fibre strands located at the phloem and protoxylem side (Fig.1).

Table: 2. Anatomical properties of *Dendrocalamus membranaceus*

Anatomical structures/ Portions	*Dendrocalamus membranaceus*				
	Vascular bundle Frequency (no/mm^2)	Vessel diameter (µm)	Fiber length (mm)	Fiber width (µm)	Fiber lumen diameter (µm)
Bottom	48.00	23.50	5.80	38.14	9.70
Middle	45.00	26.40	5.30	37.50	8.01
Top	55.00	30.05	6.30	38.40	8.30
Mean	**49.33**	**26.65**	**5.80**	**38.01**	**8.67**

From the above table it is found that highest number of vascular bundle frequency per mm^2 is observed 55 bundles per mm^2 at top portion and lowest number of 45 bundles per mm^2 at middle portion with an average of 49.33 bundle/ mm^2 throughout the height of the bamboo culm. Similarly highest vessel diameter is observed 30.05µm at top portion and lowest 23.5µm at bottom portion of the bamboo culm with an average of 26.65 µm respectively (Fig.5). From the above results highest number of vascular bundle frequency found in top and bottom portion and lowest at middle portion (Fig.2). The vessel diameter results also showing highest vessel diameter at top and middle portion but lower at bottom portion.

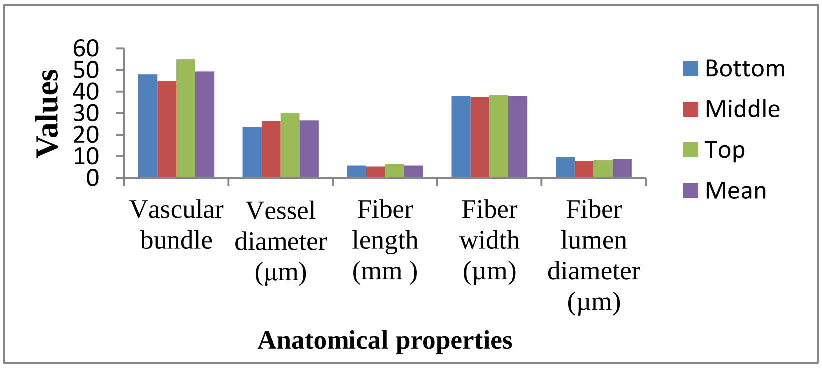

Fig. 2: Anatomical properties of *Dendrocalamus membranaceus*

Fibre morphology:

The morphology of fibre length, fibre width and fibre lumen diameter results are presented in (Table 2.). The highest fibre length 6.3 mm is observed at bottom portion of the *Dendrocalamus membranaceus* Munro, species and lowest fiber length of 5.3 mm at top portion with an average fiber length of 5.8 mm respectively. Similarly the higher lumen diameter is observed 9.70 µm at bottom portion and lowest lumen diameter 8.01µm with an average of 8.67µm lumen diameter is observed.

Chemical compostion:

The analysis of lignin, holocellulose, alpha cellulose are the main constituents which determines the real chemical properties of a bamboo culm. The ash content, hot water solubles, and Alcohol- Toluene Solubility extractives are minor factors affecting the bamboo chemical characteristic Table.3.

Table.3: Chemical composition at different heights

Bamboo portions	**Bottom**	**Middle**	**Top**
Alcohol- Toluene Solubility (%)	1.70	1.61	2.09
Hot-Water Solubility (%)	11.66	13.03	13.42
Lignin (%)	20.41	21.70	19.02
α- Cellulose (%)	47.72	44.11	46.66
Ash content (%)	1.44	1.36	1.48
Holocelluose (%)	67.0	68.12	63.48

Alcohol toluene and Hot water extractions:

The Alcohol–Toluene solubility of bamboo three bamboo species are consists of the soluble materials not generally considered part of the bamboo substance, which are primarily the waxes, fats resin and some gum along with some water soluble substances. The highest alcohol-toulene 2.09% was found 1.50% at top portion where lowest 1.61% at middle portion of the culm. Similarly higher hot water solubility was observed 13.24% at top portion and lowest 11.66% at bottom portion of the culm respectively (Fig.3).

Holocellulose and Alpha-cellulose:

Holocellose includes α–cellulose and hemicelluloses. From the results the highest holocellose content 68.12% was observed at middle portion whereas lowest holocellose content 63.48% at top portion of the culm. Similarly the highest alpha cellulose content 47.72% was observed at bottom whereas lowest 44.11% at middle portion of the bamboo culm respectively. 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- ellulose content was 41.71 to 49.02%. The α-cellulose and holocellulose content at difference location internode in bamboo culm did not shows much difference between internodes .

Lignin content and Ash content:

The lignin present in bamboos is unique. From the results the highest lignin content of 21.70% was found in middle portion and lowest 19.02% is found at top portion of the culm. Razak Wahab,et al (2013) reported that lignin content in the four species of *Gigantochloa* bamboo ranged between 24.84 to 32.65% respectively.

The ash content results was found that , highest Ash content of 1.48% is observed at top portion whereas lowest 1.36% ash content at middle portion of the culm (Fig.3). From the present studies it is found that the chemical composition of the bamboo species showing not much significant distribution throughout the culm at different location, because of full maturation of the culm and chemical composition tend to remain constant. The amount of water soluble material is influenced by season which is higher in the dry season and lower in rainy season.

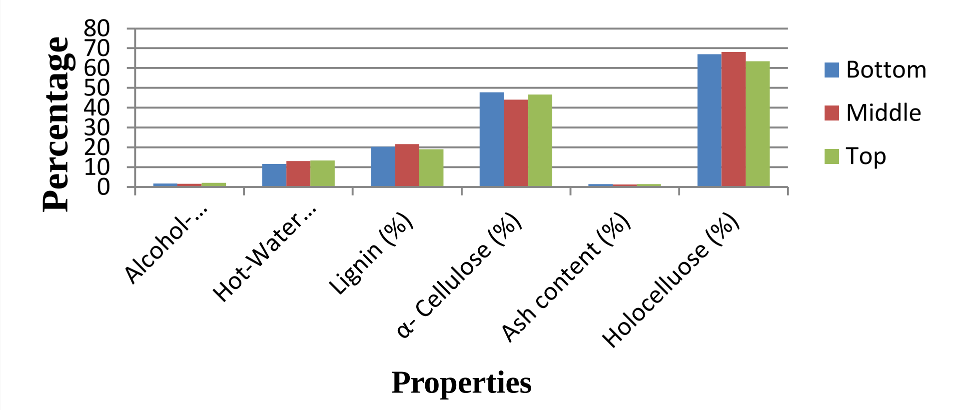

Fig. 3: Chemical composition at different heights.

Conclusion:

Based on the analysis of chemical composition, anatomical characteristics and fiber analysis of *Dendrocalamus membranaceus* higest number of vascular bundle frequency and vessel diameter at top portion. As the vascular bundle and vessel diameter Alcohol- Toluene Solubility (%) and Hot-Water Solubility (%) was found higher at the top portion of the culm. The fiber length and fiber width also higher at top portion, whereas fiber lumen diameter was lower at top portion. Similarly lignin content and other chemical content was found to be more at top portion but ash content was lower at top portion. This indicates that both chemical and anatomical properties are comparatively showing not much variations from bottom to top portion of the bamboo culm.

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