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Quality class of Betung Bamboo fiber (*Dendrocalamus Asper*) from West Sumatra and its Potential as a Raw Material for Paper

Sri Mutiar [a] *, Malse Anggia, Yogi Riyanda Putra [a], Nurul Aini [a]

[a] Study Program of Agricultural Technology, Dharma Andalas University, Padang, Indonesia

Abstract. *Betung bamboo is one of the Non-Timber Forest Products referring to the Minister of Forestry Regulation P.35 / MENNUT-II / 2007. In Indonesia, betung bamboo (Dendrocalamus asper) is included in the type of large bamboo which has a very wide potential for pulp and paper raw materials. Identification information of betung bamboo from Agam district, West Sumatra is important to know. Bamboo characteristics include the characteristics and dimensions of bamboo fibers based on bamboo stem sections. The purpose of this study was to determine the characteristics and physical properties of betung bamboo based on bamboo stem section. The research method used in this study uses observation and experimental research methods. The results showed that the water content of betung bamboo showed that the base had a higher water content than the top. While the density, thickness and diameter of the bamboo at the base is higher than the middle and top of the bamboo.*

Keywords: *characteristics; fiber; bamboo betung; paper.*

Type of the Paper: Regular Article

1. Introduction

Society's need for paper products in Indonesia is expected to increase for domestic consumption and export needs. The increasing trend of e-commerce transactions, resulting in the need for brown paper will continue to increase. The global pulp and paper industry grew 1.07% to reach US$387.54 billion or around Rp6,058.2 trillion in 2023. While paper consumption in Indonesia is currently still low at around 32.6 kg per capita, when compared to several other countries, paper consumption per capita in the United States reaches around 324 kg, Belgium around 295 kg, Denmark around 270 kg, Canada around 250 kg, and Japan around 242 kg [1]. This condition shows that there are still large opportunities for the development of the paper industry in Indonesia, this is also supported by the increasingly limited use of plastic as a packaging material and packaging. High demand for paper is an opportunity for the pulp and paper industry in Indonesia to increase production capacity. This is also balanced with the availability of adequate raw materials. The raw materials used by the paper industry generally come from pulp made from wood or virgin pulp [2].

Bamboo is a non-timber forest product that can potentially replace wood with raw materials for various processed forest products. Bamboo production is also abundant in Indonesia with a

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* First corresponding author
Email: srimutiar@unidha.ac.id

diversity of species [3]. According to Gintings [4] 160 bamboo species are found in Indonesia and 122 species are endemic to Indonesia out of a total of 1000 bamboo species in 80 countries. Bamboo is used for various purposes and preparations because it has properties, straight, flat, hard, easy to process, easy to shape, and lightweight [5]. However, bamboo has several disadvantages including susceptibility to termite attack and dry wood powder, considerable variability in physical properties between the base, center, and ends, and limited diameter [6]. Therefore, bamboo has more potential as a raw material for paper.

The chemical components of bamboo are similar to wood, consisting of cellulose (33.8-52.01%), hemicellulose (24.5-33.4%), lignin (24.84-32.65%), and extractive substances [7–9]. Bamboo is a potential biomaterial for various products as a substitute for wood, such as bio composites [10–13], bamboo-oriented strand boards [6,14,15], bamboo zephyr board [6] pulp dan paper [16–19] dan nanocelluloses [20,21] The abundant availability of bamboo raw materials in Indonesia may encourage the possibility of using bamboo as a raw material for pulp and paper.

One type of bamboo that has the potential to be developed as a pulp raw material is betung bamboo. Betung bamboo can be used as raw material for pulp and paper. This is because betung bamboo has a wall thickness of 10-30 mm. bamboo has a hemicellulose content of 12.49%, lignin 10.15 and cellulose 73, 83% [22]. Utilization of betung bamboo as pulp raw material can save the use of wood, the potential utilization of non-timber forest products and forest sustainability.

2. Materials and methods

2.1 Sample preparation

Betung bamboo for this study was collected in February 2025 from the Bamboo Forest of Agam Regency, West Sumatra, Indonesia. The bamboo culms taken were 3 years old. The sampling procedure refers to Li [23]. Bamboo longitudinal section Fig. 1. Starting with the second internode from the lowest position. The culm was divided into three sections with the same number of long segments (bottom, bottom, middle and top). The second and third segments of each section were selected for the determination of physical and mechanical properties.

2.2 Characteristic of bamboo betung

Determination of moisture content [24], density, diameter, thickness of bamboo, macroscopic images of bamboo according to transverse, radial and tangential sections. Determination of bamboo fiber quality class determination of fiber quality class, namely: 1) Provision of wood samples, 2) Provision of fibers, 3) Measurement of fiber dimensions, 4) Calculation of fiber dimension derived values, 5) Calculation of the total value of fiber dimension derived values. 6) Determination of fiber quality class

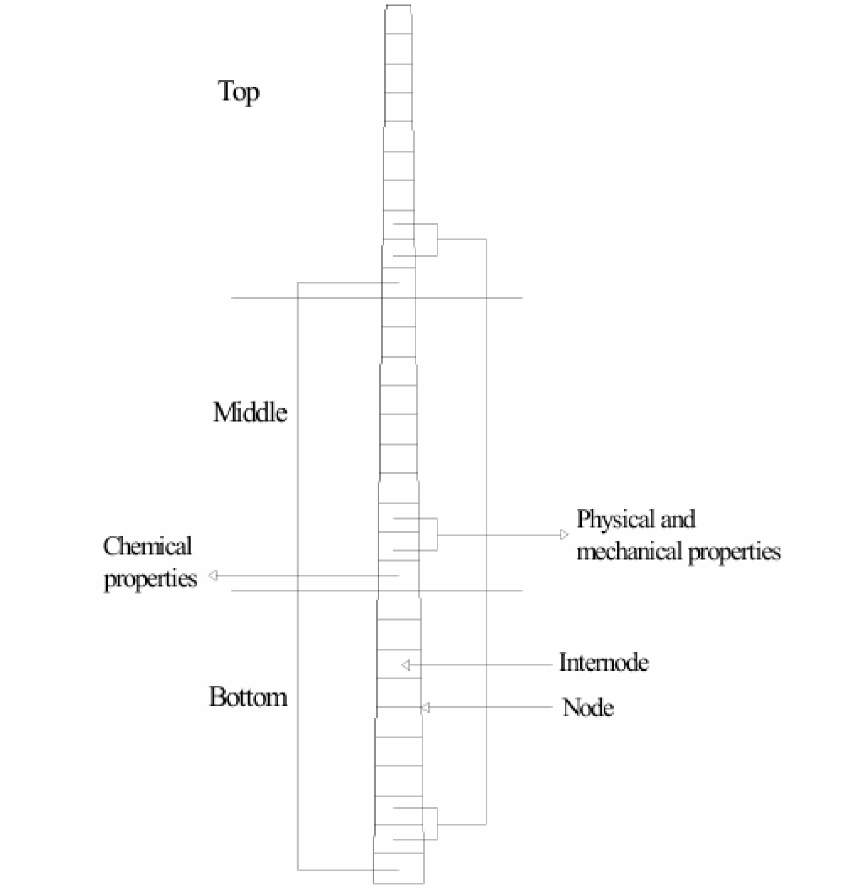

Fig. 1. Chematic diagram of sampling technique from bamboo culm.

1. Fiber provision

Bamboo measuring 15 x 2 x 2 mm3 is taken randomly and then put into a test tube. add a few grains of KClO3. Add 50% HNO3 solution until the bamboo pieces are submerged. Heat the test tube and its contents until a yellowish white color is seen and there are decomposed fibers. Heating is done in an acid chamber. Then cooled to room temperature. The material was washed over a sieve until acid free. The fibers were transferred to Petridis and given safranin or fuksin dye. Staining is to facilitate the measurement of fiber dimension. Soaking can be done 6 - 8 hours if the substance is documented. And wash the fiber until it is clean. and can be soaked in alcohol. Add Xylol for easy separation between fibers.

2. Fiber dimension measurement

The number of fibers measured is at least 20 pieces. Magnification 75x for Length, 500x for fiber wall thickness, fiber diameter, lumen diameter, Measurements are made on intact fibers and in a straight position, Measure fiber length (L) from both ends, Measure fiber diameter (d) at the widest place, Measure fiber wall thickness (w), Calculate the lumen diameter value (l) using the formula (1) below:

$$L = d - 2w \quad (1)$$

Calculation of fiber dimension derived values 1) Runkel Ratio (RR), 2) Felting Power (FP), 3) Muhlsteph Ratio (MR), 4) Flexibility Ratio (FR), 5) Coefficient of Rigidity (CR) using the formulas (2)-(6) below.

$$RR = \frac{2w}{1} \tag{2}$$

$$FP = \frac{L}{d} \tag{3}$$

$$MR = \frac{d^2 - l^2}{d^2} \tag{4}$$

$$FR = \frac{l}{d} \tag{5}$$

$$CR = \frac{w}{d} \tag{6}$$

3. Calculation of total value of fiber dimension derived values
   The total value of fiber dimension derived values is the value given to the fiber dimension derived values and added to the value of fiber length based on Table 1. By referring to Table 1, each value of fiber derived values: fiber length, runkel ratio, felting power, muhlsteph ratio, flexibility ratio, coefficient of rigidity to obtain a nominal value.
4. Calculation of total value
   Calculation of total value of fiber dimension derived values. The total value of fiber dimension derived values is the value given to the fiber dimension derived values and added to the value of fiber length based on Table 1. By referring to Table 1, each value of fiber derived values: fiber length, runkel ratio, felting power, muhlsteph ratio, flexibility ratio, coefficient of rigidity to obtain a nominal value.
5. Determination of fiber quality class
   The determination of fiber quality class is based on Table 1 where to obtain fiber quality class using the following figures:
   Quality class I with a range of 451 – 600
   Quality class II with a range of 301 – 450
   Quality class III with numbers ranging from 151 – 300
   Quality class IV with a range of ≤150

Tabel 1. Parameters of Dimension, Derivative, and Class of Fiber [25]

Derived dimensions	Class I		Class II		Class III		Class IV	
	Standard	**Value**	**Standard**	**Value**	**Standard**	**Value**	**Standard**	**Value**
fiber length	>2,200 µ	100	1,600 – 2,200 µ	75	900 – 1, 600	50	900µ	25
Runkel ratio	<0.25	100	0.25 – 0.50	75	0.50 – 1.00	50	1.0	25
Felting power	>90	100	70 – 90	75	40 – 70	50	40	25
Muhlsteph ratio	<30%	100	30 – 60%	75	60 – 80%	50	80%	25
Flexibility ratio	>0.80	100	0.60 – 0.80	75	0.40 – 0.60	50	0.40	25
Coeff. Of rigidity	<0.10	100	0.10 – 0.15	75	0.15 – 0.20	50	0.20	25
Jumlah nilai		600		450		300		150
	(451 – 600)		(301 – 450)		(151 – 300)		(150)	

3. Results and Discussion

Bamboo plants are a family of grasses with the classification as *Bambusoidea*, can grow more than 30m tall in a few months and are able to survive the harshest climatic conditions such as frost and drought [26]. The bamboo image used as a sample is presented in Fig. 2. Bamboo is also categorized as an annual plant that does not require replanting after planting, does not require maintenance costs, does not require pesticides or fertilization [27]. According to Huang [28] Bamboo fibers are arranged in parallel on the inside of the lignin matrix in the form of a hollow internal tube like a tube between their bonds in the longitudinal, radial and tangential directions of the bamboo is shown in Fig. 2. According to Bahtiar [29] Bamboo has an axial plane and the stiffness of bamboo has a gradation that decreases from the edge to the outside of the bamboo. Furthermore, in bamboo there is a close relationship between the density of vascular bonds and mechanical properties. So that bamboo has strength and rigidity according to its layer from the density of its vascular bonds.

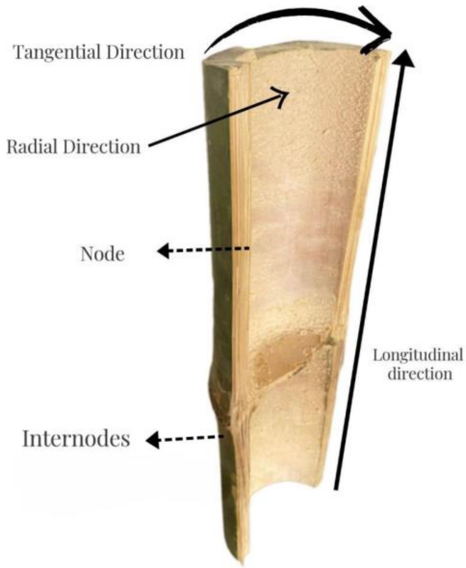

Fig. 2. Plant and Structure of Bamboo

Table 2. Results of Bamboo Measurement

Caracteristic bamboo	Top	Middle	Bottom
Water Conten (%)	31.88	37.49	41.13
Density (b/v)	1.14	1.01	1.02
Diameter (mm)	10	12.5	14.5
Thickness (mm)	12.3	16.4	28.6
Average of fiber length (mm)	2.83	2.63	2.53
Average of Diameter fiber (µm)	22.8	22.5	21.6

The results of the measurement of bamboo betung on the physical, mechanical and chemical properties of bamboo have the potential to be used as raw materials as well as wood for sources of cellulose and construction materials. The results of observation and measurement of bamboo are presented in Table 2.

Bamboo is in the form of a hollow cylinder in the form of segments connected by books. Bamboo betung has different diameters and thickness based on the base, middle and top. This size can vary more according to the age of the bamboo to be harvested. Wulandari [30] Reporting the results of the study, the characteristics of betung bamboo have a length of 39.4-45.8 cm at the base, 46-49 cm in the middle and 46.4-57 cm in the length of the tip; the diameter of the bamboo stem at the base is 6.69-9.25 cm, the middle part is 5.79-8.32 cm and the tip is 5.06-7.99 cm; The thickness of the stem wall at the base is 1.62-2 cm, the middle part is 1.16-1.57 cm and the bamboo tip is 0.85-1.09 cm. Eskak [31] It is also reported that Betung bamboo has the largest size among other types of bamboo with a thickness of 1 – 3 cm. The drawing of the measurement of the diameter of the bamboo by the part of the bamboo stem is presented in Fig. 3.

Bottom Middle Top

Fig. 3. Bamboo diameter measurement based on bamboo stem part

Table 3. Dimensional value of the derivative of betung bamboo fiber

Dimensional	Top	Middle	bottom
fiber length	100	100	100
Runkel ratio	75	75	75
Felting power	40	40	40
Muhlsteph ratio	25	25	25
Flexibility ratio	100	100	100
Coeff. Of rigidity	100	100	100
Value	440	440	440

Based on the results of the measurement of the length of bamboo fibers, it shows that betung bamboo is included in quality class II. The quality class II fiber group is a group of fibers with medium to long, with thin cell walls and slightly wide lumens. The fibers will easily flatten when milled and the fiber bonds well. This type of fiber is expected to produce sheets with high tear, cracking and tensile strength [32]. According to Wahab [9] that long fibers into class I, are suitable materials for pulp and paper making. Meanwhile, the results of observation of bamboo betung are based on Runkel ratio, Felting power, Muhlsteph ratio, Flexibility ratio and Coeff. Of rigidity bamboo betung belongs to class II. The results of the observation of bamboo fiber are presented in Table 3 dan figure fiber of bamboo are presented in Fig. 4.

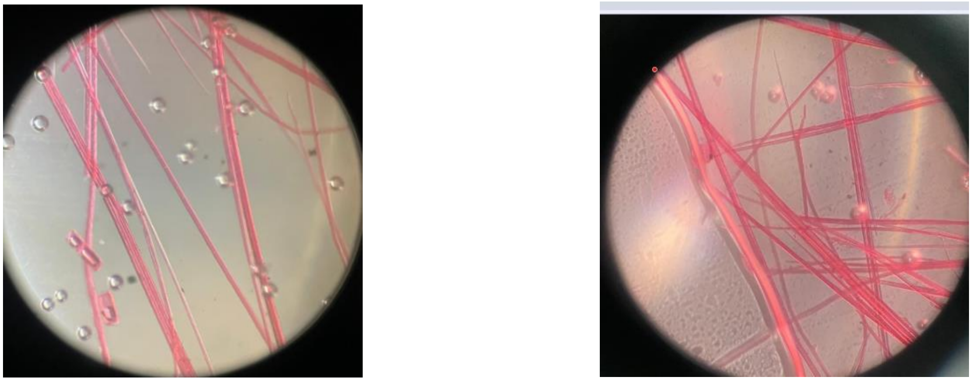

Fig. 4. Microscopy bamboo fiber length magnification: a)75x for Length; b) 500x for fiber wall thickness, fiber diameter, lumen diameter.

The potential of bamboo betung as a raw material for pulp and paper is very large. One of the requirements for raw materials to be made into paper is that it contains cellulose in the form of fiber and hemicellulose [33,34]. Pulp can be make wood and non-wood [35]. Akinlabi et al. [36] reported the chemical content of bamboo cellulose (70%), hemicellulose (12%) and lignin (10%). Another study was reported on the chemical analysis of various types of bamboo and one of them was bamboo with a holocellulose content of 70% [37]. According to Li et al. [23] reported that five-year-old Phyllostachys pubescens grown in Louisiana, United States, had a holocellulose content of about 69.94% and alpha-cellulose of about 46.08%. High levels of holocelose and alpha cellulose were also found in *Gigantochloa scortechinii* from Kedah, Malaysia, 81.4% holocellulose and 55.2% alpha cellulose. Meanwhile, in the research Mokeramin et al. [22] the chemical content of bamboo hemicellulose is 12.49, lignin content is 10.15% and cellulose content is 7383% Where bamboo has a high fiber size and tensile strength after alkaline treatment.

Alkaline or mercerization treatment is a treatment that is often applied to natural fibers to help break down or break fiber bonds. The pulping process on biomass is usually carried out by Kraft, sulfite, soda, and alkali methods with low concentrations. Strong alkalis such as NaOH are commonly used in the pulping process for Kraft and alkali methods. Strong alkali can promote the degradation of lignin and increase cellulose yield. Report on the results of the study Chen et al. [19] about the effect of the application of sodium hydroxide (NaOH) on bamboo of various concentrations, namely concentrations of 6, 8, 10, 15 and 25% soaked in a 1:1 solution ratio resulting in tensile strength and the modulus of bamboo fibers decreases along with the increase in NaOH concentration due to greater damage to bamboo fine fibers, this indicates that this process is suitable for pulp processing.

Kaur et al. [38] alkaline treatment of bamboo with alkali aged 2-3 years with concentrations of 5%, 10%, 15%, 20% and 25% Na2SO3 and 0.5% Lissapol D with a time of 45 minutes showed that there was a decrease in the levels of lignin and non-cellulose materials so as to increase the cellulose content in the material. More research by Hong. [39] several alkaline treatments such as NaOH, HNO3+ KClO3, Sodium hopoclolite, NaClO, H2O2 + HAC on bamboo of *Neeeosinocalamus affinis* produced a tensile strength of 1.78GPa.

4. Conclusions

The conclusion of this study is that betung bamboo is included in the fiber quality class class II. With medium to lenght size fibers. The results of the study showed that the moisture content of betung bamboo showed that the base had a higher moisture content than the top. The density, thickness, length and diameter of the base of the bamboo are higher than the middle and top of the bamboo stem.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Sri Mutiar: Conceptualization (lead), Methodology (lead), Writing – Original Draft (lead), and Editing (equal). **Malse Anggia**: Data Curation (lead) and Editing (equal). **Yogi Riyanda Putra**: Formal Analysis (equal). **Nurul Aini**: Visualization- desain (equal).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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