

## Characteristics of Kraft Pulp and Paper Made from Betong Bamboo (*Dendrocalamus Asper*)

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### Abstract

This study is conducted to evaluate the potential and suitability of Malaysian Betong bamboo (*Dendrocalamus Asper*) as an alternative non-wood-based papermaking material. This study is to investigate the production of pulp and paper from Betong bamboo by Kraft pulping technique. Bamboo pulp was produced with 20% alkali concentration (NaOH), 25% sulphidity, 6:1 liquor to fibre ratio, 170 C cooking temperature and 2 hours cooking time. 120 gsm linerboard was produced and tested according to TAPPI and MS ISO standards. The pulp's moisture content was 73%, its drainage time was 5.03 seconds, and its Canadian Standard Freeness (CSF) was 705 millilitres, according to the data. The paper's physical properties included a density of 0.44 g/cm<sup>3</sup>, a thickness of 280.8 μm, and a grammage of 122.38 gsm. The mechanical properties included a folding endurance of 9, a burst index of 2.69 kPa·m<sup>2</sup>/g, a tear index of 7.63 mN·m<sup>2</sup>/g, and a tensile index of 1.11 Nm/g. The burst index met the minimal specifications for commercial linerboards in Malaysia (9). The burst index pass the minimum requirements of Malaysia commercial linerboard. This study shows that Malaysian Betong bamboo has a potential quality as an alternative non-wood based raw material for Kraft packaging paper applications.

## 1. Introduction

The growing interest in non-wood materials, such as bamboo, as alternatives to conventional wood-based resources, is a result of the pulp and paper industry's need for sustainably acceptable and sustainable alternatives. Betong bamboo (*Dendrocalamus Asper*), a species that grows quickly and is widely distributed in Malaysia, is the subject of this study because it may be used as a raw material to make Kraft pulp and paper. Betong bamboo is a viable answer to the problems of raw material shortages and environmental sustainability because of its high cellulose content and strong mechanical qualities. Previous studies have shown that bamboo can lower greenhouse gas emissions and energy consumption when compared to traditional wood pulping methods [1-2]. To show the potential and potential for improving sustainable practices in the paper industry, this study intends to create Kraft pulp and paper from Betong bamboo, study its mechanical and physical

characteristics, and contrast it with other bamboo-based goods and commercial products. The need for sustainable raw materials has been brought to light by the pulp and paper industry's increasing need for sustainable practices substitutes. Overuse and environmental concerns strain traditional wood-based resources, so non-wood alternatives are being investigated. Betong bamboo (*Dendrocalamus Asper*) is a potential substitute, defined by its quick growth, high cellulose content, and flexibility. This bamboo variety, mostly found in Southeast Asia, especially Malaysia, has several benefits over traditional wood pulping methods, including lower energy use and greenhouse gas emissions. This study makes the rising need for high-quality, sustainable paper solutions by investigating Malaysian Betong bamboo's mechanical and physical characteristics and potential for Kraft pulp and paper manufacturing. This research aims to produce Kraft pulp and paper from Betong bamboo, examine its mechanical and physical characteristics, and compare them with previous bamboo-based studies and commercial goods. Under TAPPI and MS ISO standards, the study uses the Kraft pulping process in a controlled laboratory setting to analyze properties such as bulk density, tensile strength, and folding endurance. While limitations are set at laboratory-scale production and do not include industrial-scale examinations, the scope consists of producing 120 gsm paper sheets and assessing pulp qualities including freeness and draining time. The project handles environmental issues and develops innovation in the paper industry by examining the potential of using Betong bamboo as a sustainable raw material.

## 2. Material and Methods

### 2.1 Material Preparation

Because of its high cellulose content and suitability for papermaking, Betong bamboo (*Dendrocalamus Asper*), collected from Putuo Village, Kulai, Johor, Malaysia, is the main raw material used in this study. After being collected, the bamboo culms were manually cut into chips with a hand saw. To maintain consistency and convenience of handling throughout the Kraft pulping process, these chips were chopped into regular proportions of around 3 cm in length, 3 cm in width, and 6 mm in thickness. Chip size equality is crucial for successful cooking, consistent chemical penetration, and good fiber separation. Figure 1 shows the Betong Bamboo chips that have been prepared.



*Fig. 1:* Betong Bamboo chips

### 2.2 Kraft Pulping

Table 1 shows the cooking condition of the Betong bamboo pulp produced using the Kraft Pulping method in this study.

**Table 1:** Cooking conditions of the Betong bamboo process

Pulping condition	unit	Value
Cooking temperature	°C	170
Cooking time	minutes	120
Active alkali = Sodium Hydroxide (NaOH)	%	18
Sulphidity = Natrium Sulphite (Na <sub>2</sub> S)	%	25
The ratio of fiber to liquor	-	1: 6

After being mixed in the rotary digester, the bamboo chips were cooked for 120 minutes at 170 °C. After 120 minutes, the pulp was removed from the rotary digester and sent to the washing and screening process to remove the black liquor and produce a fine pulp. Following that, the pulp went through a spin-drying process to remove the water. My supervisor provided the cooking conditions listed in the above table, which I used to carry out my investigation utilising the kraft pulping process. Finally, the pulp was dispersed to separate it. Lastly, the bamboo pulp was kept at 6 °C in the chiller until further hand sheet making.

### 2.3 Paper Making Process

To create the hand sheets, the Technical Association of the Pulp and Paper Industry (TAPPI) T-205 "Forming Handsheets for Physical Tests of Pulp" was used. First, a certain output weight is needed to create a paper that weighs 120 gsm (2.44 g). In the next step, a disintegrator machine is used to break up the pulp and separate it evenly. The Betong bamboo hand sheet was then made using a hand sheet machine. TAPPI T-221 "Drainage Time of Paper Pulp" was used to calculate the drainage time, while TAPPI T-227 "Freeness of pulp (Canadian standard technique)" was used to establish the freeness value. The resulting sheets were dried and conditioned for a minimum of 24 hours.

### 2.4 Physical and Mechanical Characteristics of Hand Sheet

Following TAPPI and the Malaysian International Organisation for Standardisation (MS ISO), the mechanical and physical characteristics of 120 gsm Betong bamboo hand sheets were examined. By TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products," TAPPI T-220 "Physical Testing of Pulp Handsheets" was applied to evaluate the mechanical and physical characteristics of these papers in a temperature and humidity-controlled setting. The thickness and grammage tests were performed using TAPPI T-411 and MS ISO 536, respectively. Tensile index, tear index, burst index, and folding endurance (double fold) were determined according to MS-ISO 1924-2:2010, MS-ISO 1974:1999, MS-ISO 2758:2007, and MS-ISO 5626:1999, respectively.

### 2.5 Paper Surface Analysis

The paper surface morphology was also examined using a Field Emission Scanning Electron Microscope (FESEM). Before testing, double-sided conductive a piece of tape was used to attach gold-coated paper samples to the specimen mounts.

## 3. Results and Discussions

### 3.1 Betong bamboo (120gsm) paper and Pulp Characteristics

The Betong bamboo 120 gsm Kraft liner board that has been produced in this study is shown in Figure 2



**Fig. 2:** Betong bamboo 120 gsm Kraft paper

Table 2 shows the Betong bamboo Kraft pulp properties. The moisture content of the Betong bamboo (*Dendrocalamus asper*) Kraft pulp shows a value of 73%. In CSF Freeness, bamboo Kraft pulp reaches the average CSF value of 705 ml. The bamboo Kraft pulp also shows an average drainage time of 5.03 seconds.

**Table 2:** Betong bamboo Kraft pulp characteristics

Properties	Average values
Moisture Content (%)	73
Freeness (ml)	705
Drainage Time (s)	5.03

### 3.2 Paper Physical Characteristics

The grammage, thickness, and bulk density of the paper made from Betong bamboo pulp are shown in Table 3. The physical characteristics of the paper, including its thickness, grammage, and bulk density, were evaluated. To determine the average thickness of a single sheet of paper, the thickness of five areas was measured. The average thickness of a single sheet of paper is 280.8  $\mu\text{m}$ . The actual number of 120  $\text{g}/\text{m}^2$  is not far from the grammage value of 122.38  $\text{g}/\text{m}^2$ . The density in bulk was 0.44  $\text{g}/\text{cm}^3$ .

**Table 3:** The physical properties of Betong bamboo hand sheet paper

Properties	Average value
Bulk Density ( $\text{g}/\text{cm}^3$ )	0.44
Thickness ( $\mu\text{m}$ )	280.8
Grammage ( $\text{g}/\text{m}^2$ )	122.38

### 3.3 Mechanical Characteristics

The mechanical properties of paper, including tearing, tensile, and bursting indexes as well as the folding endurance of the Betong (*Dendrocalamus Asper*) bamboo paper sheet, are listed in Table 4.

**Table 4:** Mechanical properties of Betong bamboo hand sheet paper

Properties	Average Value
Burst Index ( $\text{kPa}\cdot\text{m}^2/\text{g}$ )	2.69
Tensile Index ( $\text{Nm}/\text{g}$ )	1.11
Tear Index ( $\text{mN}\cdot\text{m}^2/\text{g}$ )	7.63
Folding endurance (double fold)	9

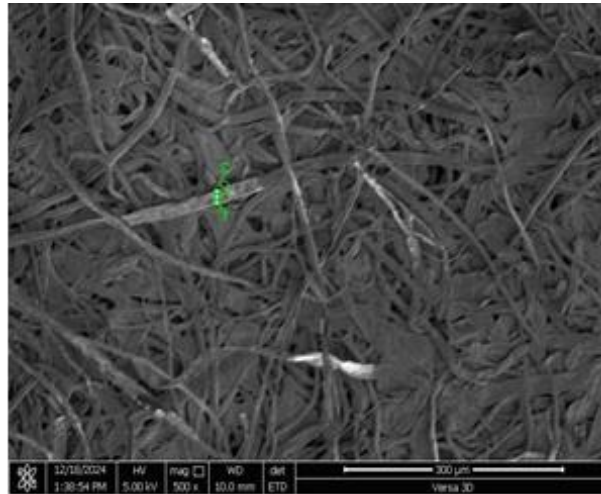
The burst index shows how much pressure a sheet of paper can bear perpendicularly before bursting. The burst index that was measured was 2.69  $\text{kPa}\cdot\text{m}^2/\text{g}$ . During the bursting test, the device's pressure gauge calculates the bursting pressure needed to break the paper. Tensile breaking strength and bursting strength are strongly connected, and fiber properties and papermaking methods that increase tensile breaking strength also typically increase bursting strength [3]. A tensile test was used to calculate the maximum elongation and ultimate tensile strength of Betong bamboo paper. Additionally, the relative contributions of inter-fiber bonding and individual fiber strength were determined, with a comparable tensile index of 1.11  $\text{Nm}/\text{g}$ .

Betong bamboo paper has a tearing index of 7.63  $\text{mN}\cdot\text{m}^2/\text{g}$ . This demonstrated that paper made with long fibers is reportedly far more resistant to ripping than paper made with short fibers. Additionally, the length and diameter of the raw material fibers can have good effects on several pulp and paper mechanical properties, including the tensile and tear indices [4].

Folding endurance is an empirical test that determines how many folds a paper can withstand before its tensile strength falls below a certain threshold [5]. Finding the paper's falling apart and the maximum number of folds it could withstand before folding were the goals of the folding test. The average folding endurance (double fold) for Betong Bamboo Kraft pulp shows the value of 9.

### 3.4 Field Emission Scanning Electron Microscope (FESEM)

The Kraft of Betong bamboo has a long fiber structure, but there were also decay and wrinkles along the surface that may be improved by a future beating process, according to the results of the paper surface determination applying FESEM equipment through a 500x magnifying lens (Figure 3).



**Fig. 3:** The surface of Betong bamboo Kraft paper in 500x magnification

### 3.5 Comparison with Previous Study

The mechanical and physical characteristics of Betong bamboo, various components of Betong bamboo, waste bamboo powder, and Malaysian commercial liner boards are all compared in this study (Table 5). The present investigation reveals a tensile index of 3.96 Nm/g, tear index of 7.63 mN·m<sup>2</sup>/g, burst index of 2.69 kPa·m<sup>2</sup>/g, grammage of 122.38 g/m<sup>2</sup>, freeness of 705 ml, and bulk density of 0.44 g/cm<sup>3</sup>. The fold number is 9. Except for fold number and tensile index, which are lower than waste bamboo powder, Betong bamboo performs better than the middle and upper parts in several measures are shown in Table 5. It can be seen present Kraft pulp performs better in bulk density, tensile, tear and burst compared to soda pulp [7-8]. Betong bamboo Kraft paper has a lower bulk density and competitive burst strength when compared to commercial liner boards. It exceeds SANYEN and TRIO boards (1.49–1.87 kPa·m<sup>2</sup>/g) and matches Pascorp IL and GSPP IKL samples (burst index 2.00–3.12 kPa·m<sup>2</sup>/g), making it fit for moderate to high-strength applications. The data comparison with commercial linerboard are shown in Table 6.

**Table 5:** Comparison of bamboo pulp and paper with previous study

Pulp Properties	Present Study Betong Bamboo (Kraft)	Waste Bamboo Powder (Kraft) [6]	Middle section Betong Bamboo (soda pulp) [7]	Top section of Betong Bamboo (Soda Pulp) [8]
Freeness (ml)	705	-	725	691.5
Bulk Density (g/cm <sup>3</sup> )	0.44	-	0.212	0.225
Grammage (g/m <sup>2</sup> )	122.38	-	126.1	130
Tensile Index (Nm/g)	3.96	4.99	0.717	1.581
Tear Index (mN·m <sup>2</sup> /g)	7.63	2.96	1.32	1.817
Burst Index (kPa·m <sup>2</sup> /g)	2.69	0.30	1.541	1.730
Fold Endurance(double fold)	9	-	13	1.758

**Table 6:** Bulk density and burst index comparison for Malaysian commercial liner board

Paper Type	Bulk Density (g/cm <sup>3</sup> )	Burst Index (kPa·m <sup>2</sup> /g)
Betong Bamboo	0.44	2.69
GSPP [9]		
GSPP IKL 1	0.68	3.12
GSPP IKL 2	0.73	3.12
GSPP IKL 3	0.79	2.85
GSPP IKL 4	0.72	2.70
GSPP IL 1	0.68	2.09
GSPP IL 2	0.72	2.09
GSPP IL 3	0.79	1.80
GSPP IL 4	0.79	1.80
GSPP IL 5	0.74	1.80
GSPP IL 6	0.81	1.80
Pascorp [9]		
Pascorp IL 1	0.71	2.00
Pascorp IL 2	0.70	2.09
Pascorp IL 3	0.71	2.09
Pascorp IL 4	0.72	2.00
Pascorp IL 5	0.71	2.00
Pascorp IL 6	0.70	2.00
SANYEN [10]		
SANYEN 6	-	1.49
SANYEN 13	-	1.51
SANYEN 20	-	1.55
SANYEN 26	-	1.58
SANYEN 40	-	1.56
SANYEN 50	-	1.87
TRIO 2006 [10]		
TRIO 25	-	1.71
TRIO 45	-	1.67
TRIO 50	-	1.75

#### 4. Conclusion

This study has successfully shown the potential and quality of Malaysian Betong bamboo (*Dendrocalamus asper*) as a sustainable raw material for Kraft pulp and paper production. Betong Bamboo virgin Kraft linerboard burst index satisfies Malaysian linerboard industry requirements. The virgin Betong bamboo Kraft pulp and paper shows moderate better characteristic with the Kraft pulping process compared to previous soda pulping. However, it is proposed to improved the Betong bamboo virgin Kraft pulp physical and mechanical characteristics by beating and the addition of dry strength agent (DSA). By showing the sustainability advantages of Betong bamboo, such as its quick growth and low impact on the environment, it also addressed the environmental issues of deforestation and limited resources. These results lay a strong basis for increasing the manufacturing usage of bamboo material in commercial pulp and paper applications to reduce the environmental impacts. This study has shown the potential quality of Betong bamboo as non-wood based raw material for papermaking.

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## References

- [1] Mohd Shamsuri, M. I. S., And Che Pa, N. F. (2023). The potential of *Dendrocalamus Asper* (Betong Bamboo) leaves as natural coagulant for wastewater treatment agent. *Progress in Engineering Application and Technology*, 4(1), 74-83.
- [2] Chen, H., Wang, Y., Qiu, J., Song, J., Wang, J., Liu, M., Wo, Q., Jiang, L., and Yang, T. (2022). Properties and application of kraft pulp prepared from waste bamboo powder, *BioResources*, 17(4), 6262-6276.
- [3] Caulfield D. and Gunderson, D. (1988), Paper testing and strength characteristics, In: TAPPI Proceedings of the 1988 Paper Preservation Symposium: 1988 October 19-21; Washington, DC. Atlanta, GA: TAPPI Press, pp. 31-40.
- [4] Sharma, A.K., Anupam, K., Swaroop, V., Lal, P.S., and Bist, V. (2015), Pilot scale soda-anthraquinone pulping of palm oil empty fruit bunches and elemental chlorine free bleaching of resulting pulp, *Journal of Cleaner Production*, 106, 422-429, <https://doi.org/10.1016/j.jclepro.2014.03.095>.
- [5] N. H. M. Hassan, S. Muhammed, and R. Ibrahim (2013) Effect of soda-anthraquinone pulping conditions and beating revolution on the mechanical properties of paper made from *Gigantochloa scortechinii* (Semantan bamboo), *The Malaysian Journal of Analytical Sciences*, 17(1), 75 - 84
- [6] Chen, H., Wang, Y., Qiu, J., Song, J., Wang, J., Liu, M., Wo, Q., Jiang, L., and Yang, T. (2022) Properties and application of kraft pulp prepared from waste bamboo powder, *BioResources* 17(4), 6262-6276.
- [7] Mohamad Khair, F. N., & Masrol, S. R. (2022) The Characteristics of Pulp and Paper Made from Top Section of Betong (*Dendrocalamus Asper*) Bamboo by Soda Pulping Method. *Progress in Engineering Application and Technology*, 3(1), 849-857.
- [8] Amri, F. Z. & Masrol. S.R. (2022) Characteristic of Pulp and Paper made from Middle section of Betong Bamboo (*Dedrocalamus Asper*) by soda pulping method. *Progress in Engineering Application and Technology*, 3(1), 691-702.
- [9] Main, N. M., Talib, R. A., Ibrahim, R., Abdul Rahman, R., and Mohamed, A. Z. (2015) Linerboard made from soda-anthraquinone (soda-AQ) treated coconut coir fiber and effect of pulp beating, *BioResource*, 10(4), 6975-6992.
- [10] Rushdan, I. (2007) Commercial-scale production of soda pulp and medium paper from oil palm empty fruit bunches. *Journal of Tropical Forest Science (JTFS)*, 19(3), 121-126. Retrieved from <https://jtfs.frim.gov.my/jtfs/article/view/738>