INVESTIGATING THE POTENTIAL OF CORN STALK BAMBOO COMPOSITES FOR SUSTAINABLE NEWSPRINT PAPER

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Abstract

The bamboo and corn stalk and samples were collected in Min Hla Township (Lower Myanmar), Bago Region, prepared, and chipped. The physicochemical properties such as pH, solubility, moisture, lignin, holocellulose, cellulose, silica, and ash of raw bamboo (RB) and raw corn stalk (RC) were determined. Pulp was prepared from corn stalk chips by using Kraft pulping process chemical ratio of 16% of NaOH and 18% of Na_2S, chips to liquor ratio (1:4), and cooking time (90 min). Pulp was prepared from bamboo chips by the Kraft pulping process using a chemical ratio of 18% NaOH and 20% Na_2S, chips-to-liquor ratio (1:4), and cooking time (120 min). Chemical properties of pulps such as moisture, lignin, residual alkali, pulp consistency, °SR (schopper degree), fiber length, pulp yield, and Kappa number were determined by the Technical Association of the Pulp and Paper Industry (TAPPI) test methods. The pulps were bleached with NaOCl. Composite papers were prepared using 50% bamboo and 50% corn stalk (BC-1) and 30% bamboo and 70% corn stalk (BC-2). Mechanical properties such as thickness, breaking length, tensile strength, folding, tear index, moisture, water absorption, and basis weight of corn stalk, bamboo, and BC-1, BC-2 were determined by the Technical Association of the Pulp and Paper Industry (TAPPI) test methods. The corn stalk, bamboo, and BC-1, BC-2 were characterized by an optical microscope.

Keywords*:* cornstalk, bamboo, Kappa number, composites, pulps, Kraft process

Introduction

Paper is one of the most significant inventions and is produced in all regions of the world. Up to now, paper is more than just a substrate for writing, printing, and packaging. Recent scientific research has established its potential as a biodegradable, renewable, inexpensive, and flexible polymer substrate. Pulp and paper are manufactured from raw materials containing cellulose fibers, generally wood, non-wood plants, recycled paper, and agricultural residues. Wood, as the main raw material in global pulp and paper production, hugely contributes to the depletion of forest resources, hence triggering an adverse impact on the environment (Amidon, 1999). In this research work, corn stalks and bamboo will be used as sources of pulp for preparing paper. Firstly, the samples will be cooked with the Kraft pulping process in order to separate the fibers. The effect of cooking variables such as working time, temperature, and sodium hydroxide and sodium sulfide concentrations will be examined on the pulp properties. The physicochemical properties of paper, such as moisture content, ash content, lignin content, and kappa number, will be determined by Tappi test methods (Pe Kyaw Htin et. al. 1987). The mechanical properties of paper, such as basic weight, folding, thickness, tear index, tensile strength, and moisture, are determined by the Tappi Test methods. The prepared paper will be characterized by Fourier transform infrared spectroscopy (FT IR), and an optical microscope was prepared. (Zhuang, J. S., et al. 2020). The prepared paper will be applied.

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Botanical Aspects of Corn Stalk

Kingdom	Plantae
Order	Poales
Family	Poaceae
Genus	*Zea*
Species	*mays*
botanical name	*Zea mays* L.
English name	corn(maize)
Myanmar name	Pyaung-bu
Part used	stalk

Figure 1 Corn stalk (Pyaung-bu)

Botanical Aspects of Bamboo

Kingdom	Plantae
Order	Poales
Family	Poaceae
Genus	*Bambusa*
Species	*polymorpha*
botanical name	*Bambusa polymorpha* Munro.
English name	Bamboo
Myanmar name	Kyathaung-wa
Part used	stalk

Figure 2 Bamboo (Kyathaung-wa)

Materials and Methods

The bamboo and corn stalk samples were collected, prepared, and chipped in Min Hla Township (Lower Myanmar), Bago Region. Sodium sulphide (Na_2S) sodium hydroxide (NaOH), sodium hypochlorite (NaOCl), acetic acid (CH_3COOH), hydrochloric acid (HCl) and sulphuric acid (H_2SO_4), potassium permanganate ($KMnO_4$), sodium thiosulphate ($Na_2S_2O_3$), potassium iodide (KI) were supplied by Department of Chemistry, University of Yangon and Dagon University, Myanmar.

Collection, Preparation and Determination of Raw Materials

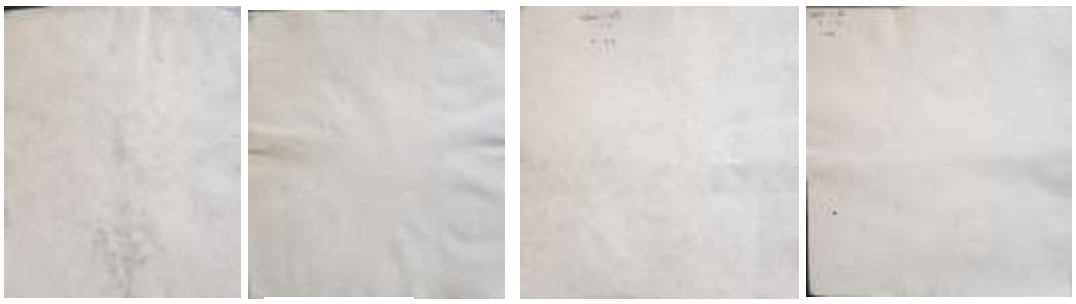
In this research, the bamboo and corn stalk samples were collected, and chipped in Min Hla Township (Lower Myanmar), Bago Region. The bamboo and corn stalk samples were washed and cleaned with water to remove extraneous matter. The bamboo and corn stalk samples were dried in an open air for one week. Dried cornstalk and bamboo were cut into 1-2 cm with a knife and stored in sealed bottles and zip bags. These samples prepared therefrom were evaluated by the Technical Association of the Pulp and Paper Industry (TAPPI) test methods.

Pulping and Paper Making from Cornstalk and Bamboo

The corn stalk and bamboo samples were cut into small pieces for easier processing, and the sample (1000 g) was placed in each large container. Various chemical ratios of 16% NaOH, 18% Na2S, and 18% NaOH and 25% Na_2S were prepared for each sample, respectively. The corn stalk and bamboo were added with NaOH and Na_2S using a chips-to-liquid ratio of 1:4, and then the digester was heated until 165 °C to boiling in 90 min and 120 min, respectively. After the boiling, the mixture was filtered to get the residue, which was thoroughly washed with distilled water to remove excess NaOH and Na_2S impurities and to obtain the pulp. The obtained pulp was bleached with NaOCl and then washed with distilled water. The bleached pulp was blended with a blender until the fibers were broken down into a thick slurry or pulp.

Sheet Forming Process

Pulp solution (mixed as well as unmixed) was placed into the mold, then distilled water was added to the solution. Then a roller was used to smooth out the pulp. After that, the water was removed from the mold by tap. The wet pulp sheet was taken from the mold and pressed with a roller to remove the traces of water. After pressing, the wet paper sheet was obtained. This paper was dried at 110 °C and 0.05 MPa by a sheet-forming machine. Finally, the smooth product of paper was obtained. Figure 5 shows the papers produced from the process. Then, the non-composites and composite paper sheets were tested for mechanical properties according to the TAPPI standard methods.



(i)B (ii)C (iii) BC-1 (iv) BC-2

B = Bamboo paper sheet

C = Corn Stalk Paper sheet
BC-1 = 50% Bamboo and 50% Corn stalk paper sheet
BC-2 = 30% Bamboo and 70% Corn stalk paper sheet

Figure 3. Prepared paper sheets

Characterization of Prepared papers

In a pulp and paper mill, microscopes are essential tools used for quality control and analysis. Bamboo and cornstalk are uniform fibers that contribute to the strength and smoothness of the paper. The surface morphology of four different prepared paper were shown in figure 5.

Results and Discussion

Physicochemical Properties of Raw Samples

The pH during pulping affects the efficiency of lignin removal, the quality of the pulp, and the strength properties of the final paper product. It was found that all of the values ranged

around 8. This result indicates that alkaline conditions are used to break down lignin, which binds cellulose fibers together.Moisture content is a critical factor in various stages of paper production and directly influences the efficiency, quality, and cost-effectiveness of operations in a paper mill. Solubility contents of raw samples were determined by TAPPI standard method. Cold water solubility, hot water solubility and 1 % NaOH solubility of raw powder samples were between 8.24% and 13.43 %. There was a direct relation between Kappa number and lignin content in the pulp. Higher Kappa number indicates more lignin is present, while lower Kappa number indicates less lignin remained. The content of cellulose and holocellulose in paper mill processing varies depending on the type of wood or plant material used and the pulping process. Cellulose content was found to be 73.43 % for Bamboo and 39.60 % for corn stalk. Holocellulose content was found to be 85.00 % for Bamboo and 81.50 % for corn stalk. These contents will vary based on the pulping method (chemical vs. mechanical) and the specific requirements for the paper being produced (Table 1).

Table 1. Physicochemical Properties of Raw Bamboo and Raw Corn stalk

No.	**Properties**	Raw cornstalk	Raw bamboo
1	Moisture (%)	16.60	20.00
2	Solubility – 1 % NaOH	9.49	8.24
	Solubility – Hot water	13.43	10.39
	Solubility – Cold water	10.35	9.19
3	pH	7.50	8.02
4	Lignin (%)	23.05	25.80
5	Holocellulose(%)	81.50	85.00
6	Cellulose(%)	39.60	73.43
7	Ash (%)	4.59	1.59
8	Silica(%)	1.80	0.90

Chemical Properties of Prepared Pulps

Kappa number approximately indicates the amount of lignin left after delignification of pulp. The Kappa number of these samples is around 20, and the lignin content is nearly 3%. Pulp yield in a paper mill refers to the amount of usable fiber obtained from raw materials (such as wood or recycled paper) during the pulping process. The pulp yield is found to be 40.10% for bamboo and 37.9% for cornstalk. During the papermaking process, controlling the moisture content is crucial for consistent quality and efficiency. The moisture content is found to be 6.24% for bamboo and 6.76% for cornstalk. Residual alkali is usually measured in terms of grams of NaOH per liter of solution. The residual alkali is found to be 5.74 g/L for bamboo and 3.10 g/L for corn stalk. Generally, for Kraft pulping, a residual alkali concentration in the range of 5–15 g/L is often targeted to balance effective lignin removal and minimize chemical usage. A pulp capacity of 0.8 means that the mill is operating at 80% of its maximum pulp production capacity. Freeness is a measure of how quickly water can drain from a pulp sample. It is expressed in Schopper-Rieglar degree (°SR). A lower °SR value is preferred to make stronger, smoother paper, and a higher °SR to make porous and absorbent paper. The fiber length is found to be 1.92 mm for bamboo and 1.11 mm for corn stalk (Table 2).

Table 2. Chemical Properties of Prepared Pulps

No.	Chemical Properties	Bamboo Pulp	Corn Stalk Pulp
1.	Kappa number	22.70	19.30
2.	Lignin content (%)	3.51	2.99
3.	Residual alkali (g / L)	5.74	3.10
4.	Pulp yield (%)	40.10	37.90
5.	Pulp consistency	0.8	1.90
6.	Schopper- Rieglar degree (°SR)	21	39
7	Fiber length (mm)	1.92	1.11
8	Moisture (%)	6.24	6.76

FT IR spectroscopy

FT IR experiments were carried out to investigate the interaction between bamboo pulp, corn stalk pulp, and composite pulps. The spectrum of bamboo pulp, corn stalk pulp, and composite pulp, the peaks at 3332, 3338, 3337, and 3341 cm^{-1} correspond to O-H stretching vibration, the peaks at 2912, 2915, 2893, and 2894 cm^{-1} correspond to asymmetric and symmetric C-H stretching vibration of sp^3 hydrocarbons, and the peaks at 1031, 1025, 1030, and 1029 cm^{-1} correspond to asymmetric stretching of C-O-C in the cellulose and hemicellulose. The spectra of mixed pulps appeared to show an additive effect of the two unmixed pulps, and no significant interaction is observed at this stage (Figure 4).

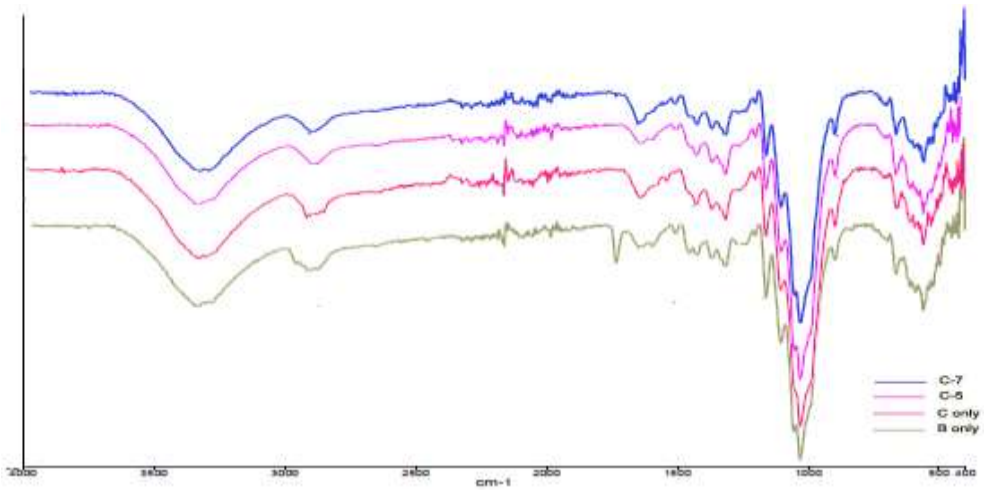


Figure 4. FT IR spectra Bamboo (B only), Corn stalk (C only), 50% Bamboo and 50% Corn stalk(C-5) and 30% Bamboo and 70% Cornstalk BC-2(C-7)

Mechanical Properties of Prepared Papers

The mechanical properties are influenced by the type of pulp used, the pulping process, and the papermaking process. The mechanical properties were determined such as the thickness of bamboo, corn stalk, BC-1 and BC-2 (0.211, 0.142, 0.195, and 0.179) mm, breaking length of bamboo, corn stalk, BC-1 and BC-2 (311.1, 737, 572.6, and 572.6) m, tensile strength of bamboo, corn stalk, BC-1 and BC-2 (0.2, 0.4, 0.34, 0.33) kN/m, and tearing strength of bamboo, corn stalk, BC-1 and BC-2 (3.7, 4, 4.1, and 4.1) mN/g, folding time of bamboo, corn stalk, BC-1 and BC-2 2 times, moisture of bamboo, corn stalk, BC-1 and BC-2 (10.5, 11.8, 11.6, and 6.3) percent, water absorption of bamboo, corn stalk, BC-1 and BC-2 (440, 280, 290, 280) g/m^2, basis

weight of bamboo, corn stalk, BC-1 and BC-2 around 60 g/m^2, respectively. Superior values of tensile strength, breaking length, and tear index in cornstalk paper relative to bamboo paper may be due to the lower lignin content in the former and also its shorter fiber length. If freeness values of 39 °SR may also be nearer to their optimum values. It also is observed to be less bulky with respect to paper thickness (Table 3).

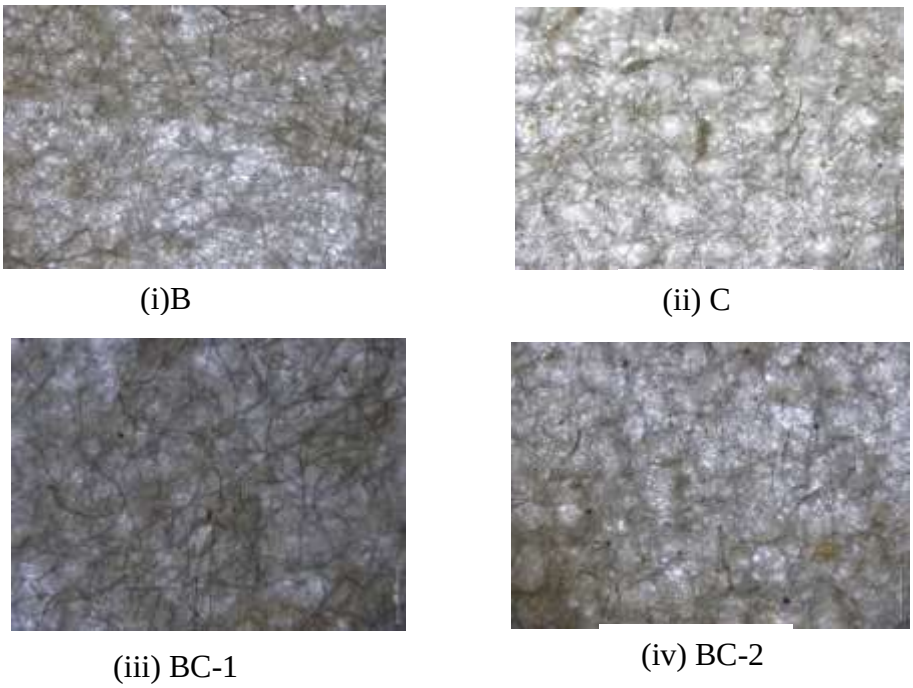
Table 3. Mechanical Properties of Prepared papers

No.	Mechanical Properties	Bamboo	Corn stalk	BC-1	BC-2
1.	Basic weight (gsm)	66.7	60	60	60
2.	Folding (times)	2	2	2	2
3.	Thickness (mm)	0.211	0.142	0.195	0.179
4.	Tensile strength (kN/m)	0.2	0.4	0.34	0.33
5.	Tear index (mNm^2/g)	3.7	4	4.1	4.1
6.	Moisture of paper (%)	10.5	11.8	11.1	6.3
7.	Water absorption (g/ m^2)	440	280	290	280
8.	Breaking Length (m)	311.1	737	572.6	572.6

Microscopic Examination of Prepared Papers

Microscopes are used to examine the characteristics of wood fibers, which are the primary raw materials in paper production. This analysis helps in understanding the type, length, and quality of fibers, ensuring they are suitable for the desired paper product (Figure 5).

When the comparison studied non-composites and composite papers with ink, the corn stalk sample allowed the ink to spread more easily compared to other samples. Bamboo is the least conductive to ink spreading, while the remaining composites exhibit similar behavior. Finally, other printing qualities such as stamp and water color were tested, and four different papers exhibited similar results (Figure 6).

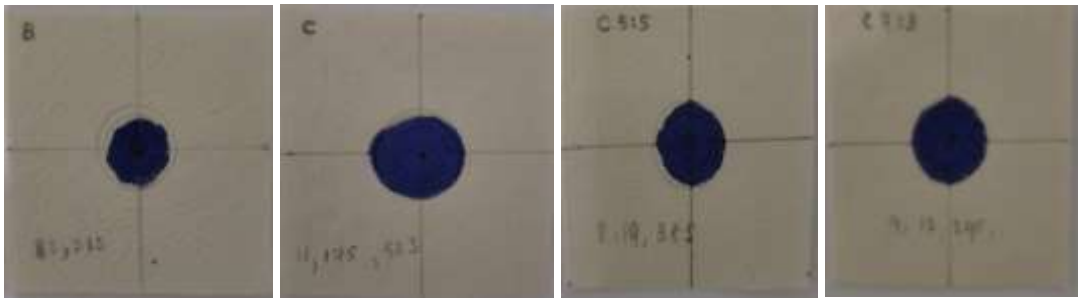


(i)B (ii) C

(iii) BC-1 (iv) BC-2

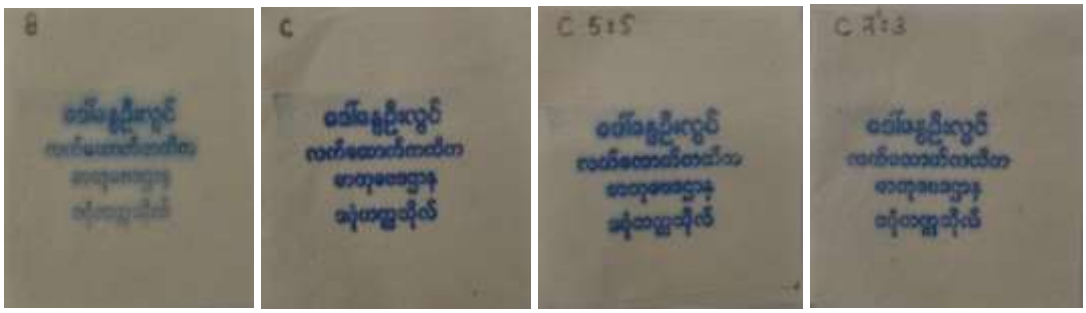
Figure 5. Microscopic examination of prepared paper

(a)Tested with ink



(i)B (ii) C (iii) BC-1 (iv) BC-2

(b)Tested with stamp



(i)B (ii) C (iii) BC-1 (iv) BC-2

(c)Tested with watercolor

(i)B (ii) C (iii) BC-1 (iv) BC-2

Figure 6 Photographs of printing on prepared papers

Conclusion

In this research work, the papers were prepared from corn stalk and bamboo. Firstly, the samples were collected, prepared, and chipped from Min Hla Township (Lower Myanmar), Bago Region. Producing a good-quality composite paper for newsprint by mixing bamboo pulp with corn stalk pulp is feasible, as demonstrated by the assessed quality factors such as mechanical properties and printing properties. This reduced use of bamboo has a favorable environmental impact by reducing deforestation; on the other hand, a value-added product was made from the old waste cornstalk. The use of cornstalk also has less pollution on the environment as it employs fewer chemicals in the Kraft process. The corn stalk pulps thus prepared also have a higher lignin content than the bamboo pulp; the lower Kappa number also means less energy consumption in pulp refining. Further study on sizing composite paper may improve the paper quality for newsprint.

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