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Organic Production and Characterization of Paper from Banana Pseudostem Fiber for Ecofriendly and Concrete Benefits

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Abstract: ***In a world, increasingly conscious of sustainability and eco-friendly alternatives, banana fiber paper (BPF) has emerged as a fascinating and innovative solution. This article delves into the world of BFP. BFP offers countless benefits that set it apart from traditional wood pulp paper. The natural strength of banana fibers results in a paper that makes them durable, long-lasting, biodegradable, eco-friendly, and usable for various applications. A study was conducted to develop organic paper from banana pseudostem fiber with negligible use of chemicals. Tensile strength analysis of banana pseudostem fiber paper clarifies that a maximum peak load of 20.18 N was observed at the speed of 100 mm/min. The minimum peak load of 5.50 N was observed at the speed of 40 mm/min. According to the observation, the average peak pressure the paper can withstand in the pouch burst test is 0.548 kg/cm^2. The water contact angle of the paper was assessed using the sessile drop method with a Drop Shape Analyzer (DSA25-KRUSS GmbH). A water droplet (20 µL) was deposited onto the sample surface at ambient temperature. The contact angle was less than 90 showing the hydrophilic nature of paper, the lower the contact angle higher the wettability. BFP is an eco-friendly which can be used for food packaging, preserving old documents, and printing.***

Keywords: Banana fiber, cellulosic paper, tensile strength, pouch burst strength, contact angle

1. Introduction

Banana is one of the important fruit crops grown in almost every state of India. Apart from fruit, it generates a huge quantity of biomass as waste in the form of pseudostem. Banana pseudostem can be utilized for the preparation of charcoal, the banana fiber paper etc [1]. Banana pseudostem central core flour (BPF) is rich in dietary fiber and minerals. The more ash content and dietary fiber it is used to control various health issues like constipation, lowering blood cholesterol, control obesity, diabetes, kidney stones etc. So, the partial substitution of BPF for wheat flour presents a feasible option for the utilization of banana pseudostem waste simply and effectively [2].

Banana pseudostem fibers are used for chemical-free handmade paper production. Enzymatic refining process utilized for paper preparation from banana fiber. High-strength natural fiber suitable for various applications and can be blended with other fibers to create compound materials [3]. Paper made from banana waste for environmental protection and study feasibility of commercializing paper made from banana fiber [4]. Chemical pulping through cow dung and banana fibers with the addition of pectin and hydrogen peroxide ameliorates paper properties. Banana fiber and cow dung paperboard show astonishing properties for packaging. The incorporation of cow dung increased tensile and burst strength with efficient antimicrobial activity [5]. Mechanical extraction process used for eco-friendly handmade paper production. Waste banana fiber is characterized and pulped for paper production. Tensile, burst, and tear indices of WBF were lower than extracted banana fiber, but still acceptable for handmade paper [6].

Banana stem waste can be used to produce Kraft paper due to its majestic properties. Banana stems have low lignin content and long cellulose fibers reduce the demand for chemicals and energy in processing. The chemical and physical treatment used for the fiber extraction process [7]. Production costs are reduced by utilizing banana stem fiber in the paper. Mixing banana stem fiber primary pulp with waste paper pulp for preparation of banana stem fiber compound kraft paper to reduce the production cost, imparts high toughness and good water resistance in prepared kraft paper [8]. Banana fiber is suitable for wrapping paper production with optimal mix ratios. Optimal mix percentages for minimal weight loss are 20-40% wastepaper and 10-30% bagasse. Banana fiber was used with sugarcane bagasse and wastepaper to produce paper in different ratios. Banana paper has high tensile and bursting indexes. Banana paper shows superior water absorbency compared to wastepaper [9]. Banana fibers are environmentally safe and biodegradable and break down into the water and carbon dioxide. Environmentally safe, low density, lightweight, strong tensile strength. Banana fibers have excellent strength characteristics similar to glass fiber [10].

Production and characterization of paper made from banana stem fiber, optimizing its density using response surface methodology and Box-Behnken design. The quadratic model best fits density response, with blending time and banana stem fiber amount as significant terms [11]. Cellulose fibers extracted from banana pseudostem using sodium hydroxide and hydrogen peroxide. Alkaline treatment resulted in

higher yield and more fibrillous material [12]. The Organosolv process is optimized for pulp yield and quality, based on a mixture of formic acid, acetic acid, and water. Papers with higher tensile index and tear index compared to other non-wood fibers [13]. Mechanical and biological methods of banana fiber extraction provided similar yields. Fibers collected from biological methods are darker than those collected by mechanical methods. Banana fiber is an environmentally friendly alternative to synthetic fibers and highlights the potential of banana fiber in textile and paper industries [14]. Natural fibers can be used as alternative noise-absorbing materials. Banana fibers have good sound-absorbing properties and can be used in bio-composites. Synthetic fibers like asbestos cause health and environmental risks Natural fibers are a sustainable alternative to synthetic fibers for acoustic absorbing materials [15]. Banana-based paper can be commercialized make good use of resources and offer a better use of natural resources and lower environmental impact [16].

Greaseproof paper made from banana pseudostem fiber for packaging butter. Kraft pulp was beaten to 60°SR and 70°SR for handsheets. Handsheets produced with 70ºSR pulp freeness in combination with 3% carboxymethyl cellulose coating seem to be more efficient and can be used for packaging butter [17]. The Soda Anthraquinone pulping process used for the production and characterization of pulp from banana pseudostem with high-strength mechanical properties and good surface properties of paper [18]. Banana fiber is a natural and sustainable bioresource. It has various industrial applications such as textiles and construction materials. It shows excellent biochemical and mechanical properties [19]. Kraft process is used for pulping banana stems with a blend ratio of 20-80% banana stem pulp and commercial bagasse pulp used for high-quality paper production. Banana stem pulp can successfully replace softwood pulp for high-quality writing and printing paper [20]. The significance of this study is to utilize banana fiber for organic, nongod paper production to meet the demand for paper in the world economically. Choosing banana fiber paper is not just a choice, but a statement of commitment to sustainability and environmental responsibility.

2. Materials and Method

Raw materials

Fibers from the banana pseudostem were obtained from the Tapti Valley Banana Processing and Products Co-Op. Society Ltd. located in Faizpur, Jalgaon, Maharashtra, and the experimental procedures took place at Yashprabha Eco Agri. Products, Jalgaon, Maharashtra, India.

Pulping

Banana fibers were cut into small pieces of 4-5 cm. About 500 g of cut fibers were placed in the rotary digester. Kraft pulping was carried out with 3% sodium hydroxide, 2% hydrochloric acid and 3% alum. Alum was added to maintain the pH in the range of 6-6.5. Thereafter, the fiber was cooked for approximately 4-5 hours. The cooked fibers were filtered using a fine mesh. After filtration, the left one was a brownie-cooked fiber (pulp with residual lignin). The cooked fiber after digestion was thoroughly washed with water to remove black liquor and excess alkali. The fibers were beaten for about 4-5 hours so as to achieve a pulpy consistency and separate the fibers in the solution. The pulp was passed through a fine mesh and made ready for rinsing. The pulp was passed through a fine mesh and made ready for rinsing. The pulp was rinsed thoroughly with water to remove excess lignin.

Paper preparation

In the first step, 40 g of the beaten pulp was weighed and prepared for papermaking. The pulp mixture was poured into a silk screen in a tub 2/3 filled with water. The pulp was stirred using fingers to spread the fibers. Then, the silkscreen was removed from the tub and the water was allowed to drain completely. Once it was done, the pulp was placed on a Pellon or felt material and was pressed to remove excess water. Thereafter, the Pellon or felt material was removed and the semi-dried pulp was transferred to a whiteboard to let dry in the sunlight. Lastly, the dried paper was peeled from the drying board shown in Figure 1.

Figure 1: Pictorial view of BFP

Paper analysis

Banana fiber paper, a versatile material known for its strength and flexibility, is used in various applications. Banana fiber paper has a significantly lower environmental impact compared to traditional wood-based paper. Utilizing a natural byproduct like banana fiber helps to reduce deforestation and promotes sustainable practices in the paper industry. Analysis of paper not only ensures the quality of the products but also helps in enhancing and reducing costs. BFP analysis was done in the National Chemical Laboratory (NCL) venture centre, in Pune, Maharashtra, India.

For tensile strength analysis five samples of BFP viz. AS01, AS02, AS03, AS04 and AS05 were prepared. All five samples shown in Figure. 2 were tested on Tensile Strength Tester Model No: GP 10 DX. Table 1 shows the test results and graphical representation in Figure. 3. The Bursting strength test is a measure of resistance to rupture when subjected to controlled hydraulic pressure. Preparation of BFP pouches A1, A2, and A3 were prepared and a small hole in the pouch was made and stuck to the probe as shown in Figure 4 and the analysis results are given in Table 2. The water contact angle (WCA) of the dry samples was assessed using the sessile drop method with a Drop Shape Analyzer (DSA25-KRUSS GmbH). A water droplet (20µL) was deposited onto the sample surface at ambient temperature.

3. Results and Discussion

Tensile Strength Test

Banana stems have the highest tensile strength of 7.04262 MPa as compared to other natural fibers. Alkaline treatment improved the tensile strength of single banana fibers [21]. Alkaline treatment conditions, paper frame technique used for single fiber tensile test [22]. Waste banana fiber can be

used to produce handmade paper. The tensile strength of waste banana fiber paper is 23.7 N/mg. A Study compares the tensile strength of sisal, false banana, and banana fibers. False banana fiber has good physical, mechanical, thermal, and chemical properties with the highest tensile strength [23]. The tensile strength of the banana stem and leaf paper laminated with banana film shows improved strength with a 1:1 ratio of mixed stems and leaves. Wet lamination improves tensile strength and elongation [24].

The maximum peak load of 20.18 **N** was observed at the speed of 100 mm/min. The minimum peak load of 5.50 **N** was observed at the speed of 40 mm/min.

Table 1: Tensile strength test samples at different speed

Sr. No.	Sample	Speed (paper stretching speed in mm/min)	Peak load (N)	Deviation (Stretched length of the sample before breaking in mm)
1	AS01	120	9.47	1.4
2	AS02	100	20.18	1.7
3	AS03	80	16.36	1.8
4	AS04	60	17.74	2.2
5	AS05	40	5.50	1.5

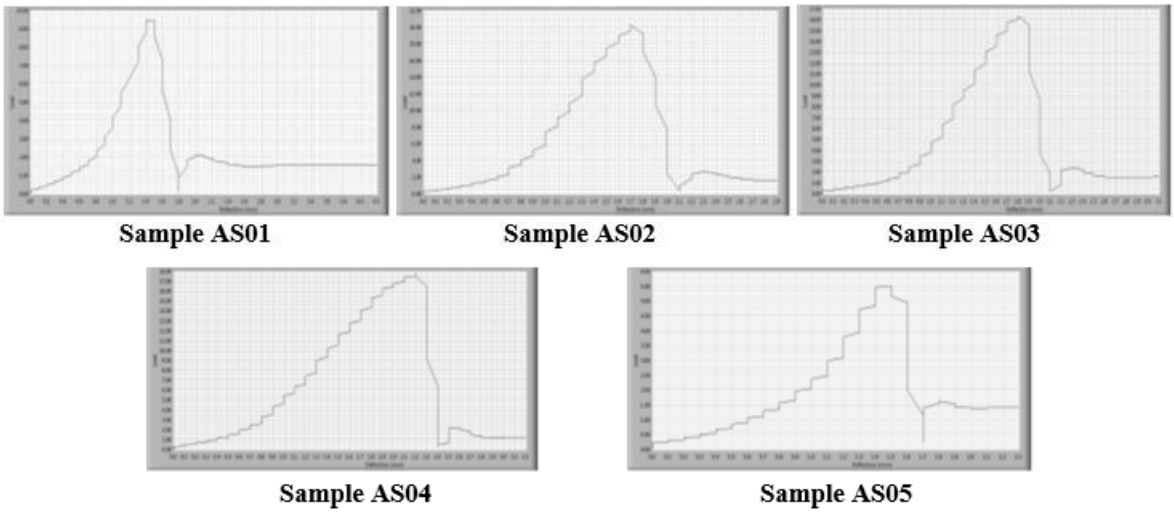

Figure 3: Graphical representation of tensile strength test

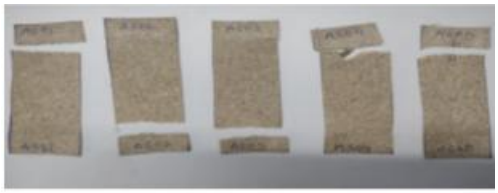

Figure 2: Tensile strength test samples

Table 2: Pouch burst test of BFP

Sr. No.	Sample	Peak pressure (Kg/cm^2)
1	A1	0.512
2	A2	0.484
3	A3	0.648
Average value		0.548

According to the observation, the average peak pressure the paper can withstand in the pouch burst test is 0.548 kg/cm^2.

Pouch Burst test

Bursting strength and water contact angle of biobased fiber papers coated with cellulose nanofibers and polyvinyl alcohol, enhancing mechanical and surface properties for packaging. Coating fluting papers with cellulose nanofibers and polyvinyl alcohol improves tensile properties and grease resistance, and coating with alkyl ketene dimer improves water contact angle [25]. The bio-based fiber papers exhibited high bursting strength, with banana tree pseudostem showing superior mechanical properties [26].

Figure 4: BFP pouch A1, A2, A3

Contact Angle Measurement

The water contact angle of banana fiber papers can vary with the specific fabrication methods and surface treatments applied. Research by Zhang et al. demonstrated the creation of a pH-responsive aerogel using banana nanocellulose fibers, showing a contact angle of 135° under certain conditions [27]. Additionally, Li et al developed super hydrophobic paper by precipitating carnauba wax on cellulose fibers, achieving a water contact angle of 157° through optimized treatment conditions [28]. Moreover, Xi et al. focused on all cellulose paper composites with underwater superoleophobicity, achieving water contact angles higher than 150° in a neutral environment, slightly decreasing under acid and alkali conditions, showcasing good separation performance for oil in water emulsions [29]. X-ray diffraction studies showed that the treated cellulose prepared by chemical treatment like alkali and bleaching

treatment were more crystalline than the untreated banana fibers [30]. These studies highlight the potential for achieving high water contact angles with banana fiber papers through various fabrication techniques and surface modification.

Three independent measurements were conducted and the average values along with the standard deviation are 86.9°, 85.7°, 87.4° and an average of 86.67° shown in Figure. 5.

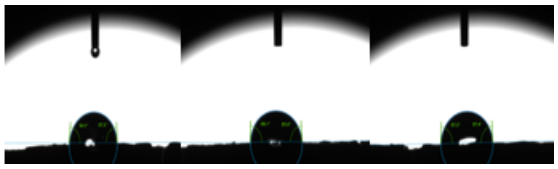

Figure 5: Contact angle measurement of BFP

The water contact angle is a crucial parameter that describes the wetting behavior of a surface. When a water droplet comes in contact with a solid surface, the angle formed between the droplet's surface and the solid surface is known as the water contact angle. When water droplets come in contact with fiber paper, their behavior can provide valuable information about the paper's characteristics. The contact angle of BFP was less than 90 showing the hydrophilic nature of paper, the lower the contact angle higher the wettability.

4. Conclusion

BFP is a sustainable alternative to wood pulp paper, as banana plants are fast-growing and require minimal resources to cultivate. Preparation of organic paper by using negligible chemicals opens up various applications in food packaging, printing, medical and educational fields. The present study analysis result explains good tensile strength, pouch burst strength and contact angle measurements show the wettability of BFP. As consumers and industries alike strive to adopt more sustainable practices, BFP stands out as a shining example of innovation and eco-friendliness. With its robust properties, versatility, and biodegradability, BFP is revolutionizing the way we think about paper products. Embracing this green alternative not only benefits the environment but also opens up endless possibilities for creative and sustainable solutions. Let's continue to explore and support eco-friendly alternatives like BFP to create a brighter and greener future for generations to come.

References

[1] Patil, D., & Wani, S. (2023). A Review on Banana Pseudostem Waste Utilization and Processing. Journal of Interdisciplinary Cycle Research. DOI:18.0002.JICR.2023.V15I7.008301.3171237345161

[2] ShitalWani, DipakPatil. Nutritional Composition of Grand-9 Tender Banana Pseudostem Wheat Flour Biscuits, (2024).doi:10.61350/TJ5379

[3] Ms., Akanksha, Mote., Mr., Aniket, Gavade., Mr., Santosh, Bandgar., Mr., Avinash, Narute. Handmade Paper from MUSA Accuminata (Banana) Stem.International Journal of Advanced Research in Science, Communication and Technology, (2023).doi: 10.48175/ijarsct-7897

[4] Cabezas, W., Davila, D., Freire, C., Hernandez, S., & Morales, A. (2022). Manufacture of Banana-Based Paper. *Athenea Engineering Sciences Journal*, *2*(6), 15-21. https://doi.org/10.47460/athenea.v2i6.29

[5] M., Vishnuvarthanan., R., Dharunya., S., Jayashree., B., Karpagam., R., Sowndharya. Environment-friendly packaging material: banana fiber/cowdung composite paperboard. Environmental Chemistry Letters, (2019).doi: 10.1007/S10311-019-00879-9

[6] Kmy, Arafat.,Jannatun, Nayeem., Ariful, Hai, Quadery., M., A., Quaiyyum., M., Sarwar, Jahan. Handmade paper from waste banana fiber.Bangladesh Journal of Scientific and Industrial Research, (2018). doi: 10.3329/BJSIR.V53I2.36668

[7] Ramprasad, Nigudkar.,Shubham, Kalan., Prashant, A., GIri. Experimental Investigation of Kraft Paper Making from Banana (Musa Sapientum) Stem Fibers and Study of Advancements in Fiber Extraction Process.Journal of emerging technologies and innovative research, (2018).

[8] Xiong, Yulin. Preparation method of banana stemfiber compound kraft paper. (2018)

[9] Amit, Ramdhonee.,Pratima, Jeetah. Production of wrapping paper from banana fibers..Journal of environmental chemical engineering, (2017).doi: 10.1016/J.JECE.2017.08.011

[10] Organic Production of Banana Fibers for Pollution-free and Environmental Benefits. (2022). doi: 10.9734/bpi/cpafs/v1/3554c

[11] Vianney, Andrew, Yiga., Michael, Lubwama., James, Opio., Emmanuel, Menya., Denis, Nono., Harriet, Nalubega, Lubwama. Production and Characterization of Paper from Banana Stem Fiber: Optimization Using Box-behnken Design (BBD). Journal of Natural Fibers, (2023).doi: 10.1080/15440478.2023.2192019

[12] Alba, N., Ardila-Arias., Hely, Johana-Restrepo., Johan, Steven, Valencia-Duarte., Erasmo, Arriola-Villaseñor., Santiago, Bedoya-Betancur., Juan, David, Valencia-González. Evaluation of the extraction of cellulose fibers from banana pseudostems with potential use in the paper industry. (2022). doi: 10.56845/rebs.v3i1.33

[13] Pannala, N.M.., Karunarathne, P.K.D.M.C..Utilization of Waste Banana Pseudostem for Paper Production via OrganosolvPulping.Proceedings of the International Forestry and Enviroment symposium, (2022).doi: 10.31357/fesympo.v26.5691

[14] Aslam, Ali. Banana Fiber: Environmental Friendly Fabric: A way to Health and Wealth. International Journal for Science Technology And Engineering, (2022). doi: 10.22214/ijraset.2022.45071

[15] Pruktivud, Chattaviriya.,Dusanee, Supawantanakul., Ratsamee, Sangsirimongkolying., Gritsada, Sua-iam. Banana Fibers as Sustainable Acoustic Absorbing Materials: A Review. Trends in Sciences, (2022).doi: 10.48048/tis.2022.4498

[16] William, Cabezas., Daniel, Davila., Carlos, Freire., Alexander, Morales. Manufacture of Banana-Based Paper. (2022). doi: 10.47460/athenea.v2i6.29

[17] Priyanka, Sakare., A., K., Bharimalla., Jyoti, Dhakane-Lad., P., G., Patil. Development of Greaseproof Paper from Banana PseudostemFiber for Packaging of Butter.Journal of Natural Fibers, (2021).doi: 10.1080/15440478.2019.1710652

[18] Emiru, Yidnekew, Melesse.,Tesfaye, Kassaw, Bedru., B.T., Meshesha. Production and Characterization of Pulp from Banana Pseudo Stem for Paper Making via Soda Anthraquinone Pulping Process.International Journal of Engineering Research in Africa, (2022).doi: 10.4028/www.scientific.net/JERA.58.63
[19] Sanjeev, Balda.,Aarjoo, Sharma., Neena, Capalash., Prince, Sharma. Banana fiber: a natural and sustainable bioresource for eco-friendly applications. Clean Technologies and Environmental Policy, (2021).doi: 10.1007/S10098-021-02041-Y
[20] Mohamed, Abdallah, Ali.,Mamduh, Nassar., Ebrahim, Esmail, Ebrahim., Hisham, Sherif. Optimization of Banana Stem Pulp to Substitute SoftWood Pulp for High Quality Paper.The Egyptian Journal of Chemistry, (2020).doi: 10.21608/EJCHEM.2020.46294.2954
[21] Sri, Mutia. The Effect of Natural Fiber Percentage on the Tensile Strength of Paper Using ANOVA.International Journal of Engineering, Science and Information Technology, (2023).doi: 10.52088/ijesty.v3i2.448
[22] Tensile strength of single banana fibers (SBFs) improved by novel alkaline treatment. IOP conference series, (2022).doi: 10.1088/1757-899x/1244/1/012001
[23] Endalkachew, Gashawtena., Addis, Kidane., Belete, Sirahbizu. A Comparative Study on the Tensile Strength of Single Natural Fibers. (2024). doi: 10.21203/rs.3.rs-3824763/v1
[24] Natcharee, Jirukkakul. Physical Properties of Banana Stem and Leaf Papers Laminated with Banana Film. (2018). doi: 10.48048/WJST.2019.3471
[25] Quim, Tarrés., Helena, Oliver-Ortega., Paulo, Ferreira., M., Àngels, Pèlach., Pere, Mutjé., Marc, Delgado-Aguilar. Towards a new generation of functional fiber-based packaging: cellulose nanofibers for improved barrier, mechanical and surface properties. Cellulose, (2018).doi: 10.1007/S10570-017-1572-7
[26] Bárbara, Maria, Ribeiro, Guimarães., Mário, Vanoli, Scatolino., Maria, Alice, Martins., Saulo, Rocha, Ferreira., Lourival, Marin, Mendes., José, Tarcísio, Lima., Mário, Guimarães, Junior., Gustavo, Henrique, Denzin, Tonoli. Bio-based films/nanopapers from lignocellulosic wastes for production of added-value micro-/nanomaterials..Environmental Science and Pollution Research, (2021).doi: 10.1007/S11356-021-16203-4
[27] Meiling, Zhang., Wenhui, Hu., Ningting, Guo., Peiming, Wu., Huiying, Su., Min, Li., Zhan, Gang, Wang., Yaolin, Yang., Muhammad, Yousif., Xupin, Zhuang. Amino-modified banana nanocellulose aerogels with quick Ph-responsive switchable wettability for oil–water separation.Journal of Applied Polymer Science, (2024).doi: 10.1002/app.55722
[28] Pan, Li., Hui, Li., Jin, Yang.,Yahong, Meng. Facile Fabrication of Superhydrophobic Paper with Excellent Water Repellency and Moisture Resistance by Phase Separation.Bioresources, (2016).doi: 10.15376/BIORES.11.3.6552-6565
[29] Jianfeng, Xi., Shan, Jiang., Yanling, Lou., Hongqi, Dai., Weibing, Wu., Weibing, Wu. Underwater superoleophobic all-cellulose composite papers for the separation of emulsified oil.Cellulose, (2021).doi: 10.1007/S10570-021-03768-Z