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Sustainable Paper Production from Sugarcane Bagasse: An Innovative Approach to Mitigate Wood Fibre Dependence and Promote Eco-friendly Alternatives

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Abstract: Even though the usage amount of traditional wood fiber paper has been greatly reduced by recycling or some other methods, the demand for paper is still enormous. As many global issues start to influence our daily life, people begin to pay attention to sustainable development. This report was focused on the production of paper from sugarcane bagasse. In a bid to achieve this, sugarcane bagasse was obtained, dried and then made to undergo the following sequence of steps; cooking, pulp washing puip screening and cleaning pulp thickening, pulp bleaching. pulp thickening blending. After which the pulp was then pressed into paper using the appropriate equipment/materials. The paper was then obtained after sufficiently drying the pressed pulp (now paper). The paper produced weighed 42.6 % had an area of 0.341 m and its thickness was 1.0 mm. From the analysis made, the paper had a grammage of 124.9 g/m*, bulk of 8.01 cm/%. Based on physical examination, the paper produced was also stift. By comparing the properties of the paper produced with the acceptable standard, based on ISO, a paperboard grade of paper was produced. Paper can be produced from sugarcane bagasse as an alternative to paper from woods. The grade of paper that can be obtainable from sugarcane waste is dependent on what the paper is to be used for in order that the appropriate additives may be added to improve its properties thereby, bringing it up to the standard for which it is to be used.

Keywords: Sugarcane Bagasse, Paper, Recycling, Eco-friendly
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1. INTRODUCTION

Global paper consumption was around 300 million tons in the mid-1990s and has been projected to increase above 500 million tons by 2030 due to a continued rise in demand for paper products worldwide (Sharma & Ahuja, 2019). This increasing demand has placed significant strain on conventional forest resources traditionally used in pulping processes, prompting a search for alternative raw materials. Agricultural residues, such as cereal straw, bagasse, and other non-wood sources, are gaining interest as sustainable raw materials, helping to alleviate pressure on forests and support environmental sustainability (Li et al., 2019; Ahmed et al., 2021). These residues have become essential to supplement dwindling forest resources and meet the expanding needs of the pulp and paper industry (Goswami & Rathi, 2022). Sugarcane (Saccharum officinarum) bagasse, the fibrous residue left after sugar extraction, is produced in large quantities by sugar industries and is now being explored extensively as an alternative raw material for paper manufacturing across various regions, including India, Brazil, and China, where forest-based raw materials are scarce (Singh et al., 2021; Patel et al., 2020). Nigeria faces similar challenges, with growing demand for paper products, limited pulp mills, and high costs of paper, highlighting the potential of bagasse as a solution (Dutta et al., 2021; Adebayo & Adesina, 2022).

Recent studies have demonstrated that bagasse pulp can produce high-quality paper with excellent smoothness, formation, and strength properties. It is suitable for a variety of grades and applications, from newsprint to fine paper, which aligns with the sustainability goals of reducing dependence on wood-based pulps (Mishra et al., 2022). Bagasse composition typically includes about 46–52% moisture, 43–49% fiber, and 2–6% soluble solids, with its high cellulose content (around 45%) making it viable as a fibrous raw material (Silva et al., 2020; Ahmed & Khan, 2019). Furthermore, the fuel value of bagasse is largely due to its fiber content, containing approximately 45% cellulose, 28% pentosans, and 20% lignin (Sharma & Bhattacharya, 2021). The advantages of non-wood fibers, such as those from bagasse, have been emphasized by international organizations like the World Intellectual Property Organization, which encourages the use of agricultural waste to alleviate environmental issues and deforestation. Such initiatives promote the development of "green technologies" that minimize chemical usage and focus on waste materials to meet industrial needs without compromising the environment (Dutta et al., 2021; Thakur et al., 2023). Bagasse, with a similar cellulose, hemicellulose, and lignin content as wood, can potentially replace conventional forest resources and support sustainable industry practices (Pandey & Singh, 2021; Goswami & Rathi, 2022).

Historically, non-wood materials like bagasse, rice husks, and cereal straws were central to paper production, especially in Asia, long before the industry shifted to wood-based pulp (Jha et al., 2022; Li et al., 2019). With the rise of industrialization and the invention of printing in the 15th century, demand for paper surged, but wood-based pulping only became widely adopted in the 19th century. Today, the pulp and paper industry is increasingly focused on developing alternative raw materials, as wood resources are facing depletion and environmental concerns have intensified (Singh & Gupta, 2021). The potential of bagasse, especially when integrated with other pulping technologies, allows it to fulfill quality standards for paper production with less environmental impact (Ahmed et al., 2021; Patel et al., 2020).

Bagasse-based paper production has several benefits, including low cost, low energy requirements, good sheet formation, and recyclability, all of which align with the global shift towards sustainable practices. Its ability to meet quality standards for various paper types and its recyclability, similar to wood pulp, make it an attractive resource (Kumar & Mehta, 2022; Sharma & Bhattacharya, 2021). Additionally, recent technological advances in pulping processes are helping to improve bagasses' quality for paper production. For instance, hybrid chemimechanical pulping techniques have shown promise in producing high-grade pulps with lower environmental impact (Thakur et al., 2023; Zhang et al., 2021). Bagasse is also being utilized in integrated pulp and paper mills, where the pulp produced is directly transferred to paper mills, saving significant energy costs typically associated with drying and transporting pulp (Pandey & Singh, 2021; Li et al., 2019). Hybrid pulping methods that combine mechanical and chemical techniques have shown to reduce the need for harmful chemicals, aligning with environmental goals (Jha et al., 2022). This shift to alternative pulping methods supports cleaner production processes, as traditional chemical pulping degrades a considerable amount of cellulose and hemicelluloses, leading to more waste (Silva et al., 2020; Goswami & Rathi, 2022).

The use of bagasse for paper production not only provides economic advantages but also addresses environmental challenges by transforming agricultural waste into valuable resources, contributing to both wealth creation and waste management. The future of the paper industry likely includes a more diverse raw material base, with bagasse and other agricultural residues playing an essential role in sustaining resources and meeting rising paper demands (Singh et al., 2021; Dutta et al., 2021).

2. MATERIALS AND METHODS

The materials used in the present study are blender, wood frame/ deckle, sugarcane, plastic containers, bag sieve, cooking vessel, sodium hydroxide, hydrogen peroxide, calcium hypochlorite. The following procedures were taken in producing the paper from sugarcane waste involved four stages: (i) Sampling (ii) Preparation of bagasse (iii) Pulp milling (iv) Paper milling.

The sample sugarcane bagasse used was obtained then and dried sufficiently under sunlight for 7 days. Thereafter, it was cut into smaller pieces using a pair of scissors before taking it to the next stage.

2.1 Pulp milling stage

The pulp milling stage involved the following five sub-stages: Cooking, Pulp washing, Pulp screening and cleaning, Pulp thickening and Bleaching

2.2.1 Cooking

The dried bagasse (already prepared) was then cooked using a solution containing calculated amount of sodium hydroxide (NaOH) for a period of 45 minutes under a temperature of 90 °C. At the end of cooking, the product obtained known as the pulp and a solution of black liquor were then prepared for the next stage.

2.2.2 Pulp Washing

Here, the cooking product was then washed gradually using sufficient amount of water by first transferring the product into the sieve and the rinsing the content of the sieve with water till the black liquor was almost gone.

2.2.3 Pulp Screening and Cleaning

At this stage the product obtained after washing was then screened and cleaned to remove particles like grits, stones that would otherwise have negative impact on the process in the long run.

2.2.4 Pulp Thickening

Here the product obtained was further rinsed and more water was removed from the pulp, thereby making the pulp thicker.

2.2.5 Pulp Bleaching

At this stage, the now thickened pulp which had a brownish colour was then bleached in order to brighten and whiten its colour. This was done by adding calculated amounts of calcium hypochlorite, hydrogen peroxide and sodium hydroxide to the already thickened pulp obtained carlier and then leaving the system undisturbed for a period of 5 hours.

2.2.6 Blending

Here, the bleached pulp was then blended using the blender for minutes ensuring that it was not too smooth.

2.3 Paper Milling Process

The bleached, blended pulp obtained after blending is pressed to allow for moisture passage and form the pulp into appropriate shape using the deckle (the default shape was the shape of the deckle). The deckle is positioned in a water bath at room temperature with the side of the deckle possessing the sieve in contact with the water while the other part of the deckle is placed on the deckle. Then the blended pulp is transferred in moderate quantity with respect to the size of the deckle into the deckle. The deckle is then adjusted until the pulp becomes evenly distributed over the surface of the deckle. After this, the deckle is removed from the water bath, then a clean piece of towel spread on a smooth surface. The side of the deckle conveying the pulp is then turned over to the surface of the towel. Then the other part of the deckle was taken off and another piece of clean towel is spread at the back of the deckle conveying the pulp and water left in the pulp is soaked off. Thereafter, the deckle was taken off the pulp (now on the rag on the smooth surface). The pressed pulp was then left to dry sufficiently after which the paper was obtained. Figure 1 shows the steps involved in processing Bagasse in the pulp milling section.

Figure 1: Bagasse processing in the pulp milling section.

3. RESULTS AND DISCUSSION

At the end of the experimental work, the aim of the experiment was achieved. Paper was produced. Table 1 shows the properties obtained from the characterization of the three paper samples.

Table 1. Properties of the Paper Samples

Weight (g)	Thickness (mm)	Thicknes (μm)	Area (cm^2)	Area ($m^{2)}$)	Grammage (g/m^2)	Bulk (cm^3/g)
42.6	1.0	1000	341	0.341	124.9	8.01

Weight of sugarcane bagasse = 546g, Molar mass of NaOH = 39.9971g/mol, Molar mass of $Ca(OCl)_2$ =142.98g/mol
250g NaOH was dissolved in Slitres of distilled water for the cooking stage.
Cooking Temperature = 100 °C
Cooking time- 25 minutes.
Composition of bleaching compounds;
(i) 150 g $Ca(OCl)_2$, (ii) 30 g H_20_2 (iii) 50 g NaOH
Bleaching time = 5 hours
Grammage / basis weight = weight (g)/Area (m^2)
Bulk = Thickness (mm)* 1000/Basis weight/grammage (g/m^2)

Achieving the result started off from the stage where the lignin was dissolved by cooking with sodium hydroxide. This made the fibers very much softer, and the lignin were removed. The bleaching carried out on the fibres had a very significant effect on the whiteness of the paper; the fibres became white after addition of the bleach compounds. This in the end, gave the paper produced its whiteness. The paper produced weighed 42.6 g, had an area of 0.341 m' and its thickness was 1.0 mm. Since this project was only interested in the production of paper, no step was taken to improve any property of the paper such as strength or opacity of the paper other than bleaching.

The grammage the Basis weight of paper which is the weight per unit area of the paper was found to be 124.9 g/m^2. It was found that the paper produced had a bulk value of 8.01 cm/g. With respect to stiffness, the paper produced was stiff. By comparing the properties of the paper produced with the acceptable standard, based on ISO, the grade of paper having such characteristics such as that of the paper produced is a paperboard. Hence, a paperboard grade of paper is produced.

4. CONCLUSION

From the analysis made to determine some of the properties of the paper produced, the results obtained are as follows: The paper produced weighed 42.6 g, had an area of 0.341 m^2 and its thickness was 1.0 mm. The grammage/the Basis weight of paper which is the weight per unit area of the paper was found to be 124.9 g/m^2. It was found that the paper produced had a bulk value of 8.01 cm' with respect to stiffness, the paper produced was stiff. After comparing the properties of the paper produced with the acceptable standard, based on ISO, the grade of paper having such characteristics such as that of the paper produced is a paperboard. Hence, a paperboard grade of paper was produced. Based on the results of this study, paper can be produced from sugarcane waste as an alternative to paper from woods and the physical properties of the paperboard grade of paper produced, compared well the ISO standard for paperboard grade paper.

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