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Research On Microwave-Assisted Pulping And Eco-Friendly Paper Production

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Abstract

This study presents an eco-friendly, microwave-assisted process for producing biopaper using three common agricultural residues: sugarcane dry waste (spazzato), wheat straw, and cotton. The process integrates an innovative combination of bleaching and fiber-softening agents including citric acid, hydrogen peroxide, and baking soda to enhance whiteness, while plasticizers such as glycerol, sorbitol, and polyethylene glycol (PEG-400) were added to improve paper flexibility and usability. This approach highlights a sustainable alternative to wood-based paper, ensuring a cost-effective, fast, and green paper fabrication method that promotes circular economy principles.

Keywords : Biopaper, Agricultural Waste, Microwave Synthesis, Hydrogen Peroxide, Citric Acid, Plasticizers, Glycerol, PEG-400, Sorbitol

1.INTRODUCTION

Paper production has traditionally relied on wood pulp, contributing to deforestation and environmental degradation. With the rising demand for sustainable alternatives, agricultural waste presents a promising raw material due to its abundance, cellulose content, and biodegradability. However, challenges such as fiber separation, adequate bleaching, and flexibility in final paper products need to be addressed. In this research, we developed a microwave-assisted, chemical-free approach to produce paper from a blend of sugarcane spazzato, wheat straw, and cotton. Citric acid and hydrogen peroxide were used as eco-friendly bleaching agents, while baking soda helped improve fiber softness and whiteness. The use of natural and synthetic plasticizers—specifically glycerol, sorbitol, and PEG-400—helped improve the final paper's flexibility, smoothness, and durability, making it suitable for various applications including wrapping and packaging.

2. Materials :

2.1 Raw Materials

- Sugarcane Dry Waste (Spazzato) – 4 g
- Wheat Straw – 3 g
- Cotton (Hospital grade or absorbent) – 3 g

2.2 Chemicals and Plasticizers

- Citric Acid ($C_6H_8O_7$) – 1 g
- Hydrogen Peroxide (H_2O_2, 30%) – 5 mL
- Baking Soda ($NaHCO_3$) – 1 g
- Glycerol (Natural plasticizer) – 1 mL
- Sorbitol (Natural plasticizer) – 1 mL
- PEG-400 (Synthetic plasticizer) – 1 mL

- Distilled Water – As needed (~500 mL)

2.3 Equipment

- Microwave Oven (600W)
- 500 mL Beaker
- Blender or Grinder
- Fine Mesh Sieve
- Weights (2-3 kg)
- Oven (optional)
- Glass Rod, Measuring Spoons, Timer, Filter Paper

3. Procedure

3.1 Pre-Treatment of Agricultural Waste

1. Size Reduction & Cleaning
   All agricultural residues were cut into ~1–2 cm pieces and washed with warm distilled water to remove surface impurities.
2. Soaking
   All residues were soaked in 200 mL of distilled water for 10 minutes to soften the fibers.

3.2 Alkaline Treatment

1. Baking Soda Solution Preparation
   Dissolve 1 g of baking soda in 200 mL distilled water.
2. Microwave Pre-Treatment
   The soaked residues were added to the baking soda solution and microwaved at 600W for 5 minutes. The solution was allowed to rest for 15 minutes.
3. Rinsing
   The residues were drained and rinsed with distilled water to remove excess alkali.

3.3 Pulping Process

1. The treated residues were mixed with 150 mL distilled water and microwaved for 15 minutes (5-minute cycles x 3 with stirring in between).
2. The softened fibers were blended with 100 mL water for 2–3 minutes until a smooth, uniform pulp was obtained.

3.4 Bleaching and Softening

1. A bleaching solution was prepared using:
   - 1 g citric acid
   - 5 mL hydrogen peroxide
   - 50 mL distilled water
2. The solution was mixed into the pulp and microwaved for 5 minutes at 600W. The mixture was left to react for 30 minutes at room temperature.

3.5 Plasticizer Addition

To improve softness and flexibility, the following plasticizers were added to the bleached pulp:

- 1 mL Glycerol (natural)
- 1 mL Sorbitol (natural)
- 1 mL PEG-400 (synthetic)

They were stirred well into the pulp for 3 minutes using a glass rod.

3.6 Sheet Formation

1. The final pulp was poured onto a fine mesh screen and evenly spread using a glass rod.
2. Filter paper was placed on both sides, and the wet sheet was pressed with 2–3 kg weight for 30 minutes.

3. The sheet was dried in a hot air oven at 50°C for 30 minutes or air-dried under a fan for 45–60 minutes.

3.7 Finishing

- The dried sheet was optionally rolled with a glass bottle for smoothness.
- It was then kept under a light press for 30 minutes to ensure uniformity.

4. Results and Discussion

4.1 Visual Characteristics

- Color: Bright white due to the synergistic bleaching action of citric acid, hydrogen peroxide, and baking soda.
- Surface: Smooth texture with minimal grain due to fine blending and plasticizer use.
- Thickness: Uniform across sheet; average ~0.2–0.3 mm.

4.2 Physical Properties

Parameter	Observation
Tear Resistance	Good (similar to notebook paper)
Flexibility	Excellent (due to plasticizers)
Drying Time	30 min (oven), ~45–60 min (air)
Whiteness Level	High

4.3 Role of Plasticizers

- Glycerol: Enhanced softness and surface feel.
- Sorbitol: Improved fiber bonding and flexibility.
- PEG-400: Increased mechanical strength and elasticity.

The combination led to a durable, foldable paper with minimal cracking, ideal for packaging, wrapping, or writing use.

5. Conclusion

This study demonstrates a low-cost, efficient, and eco-friendly method for producing white, flexible biopaper from mixed agricultural residues. The microwave-assisted synthesis method significantly reduces energy and processing time. The use of hydrogen peroxide, citric acid, and baking soda resulted in effective bleaching, while plasticizers like glycerol, sorbitol, and PEG-400 enhanced the softness, usability, and strength of the biopaper. This method can be a scalable alternative to conventional wood-based paper production with industrial potential.

6.Real-World Applications

1. Biodegradable Packaging
   - This paper could be further tested for use in food wrapping, seed packets, or herbal product labels.
2. Handmade Stationery / Art Paper
   - Add small amounts of natural dyes or petals for artistic papers used in greeting cards or eco-packaging.
3. Educational Kits
   - This method can be used for science education in rural schools to demonstrate sustainability and chemistry.

7.Sustainability & Environmental Relevance

1. Utilization of Agricultural Waste
   - Converts non-edible residues like spazzato, wheat straw, and cotton waste into high-value products.
   - Reduces open burning, which contributes to air pollution (PM2.5), especially in rural India.
   - Encourages circular bioeconomy by converting farm waste into paper, reducing deforestation.
2. Eco-Friendly Process
   - No use of chlorine, sulfates, or strong alkalis like NaOH – hence, zero discharge of toxic effluents.
   - Hydrogen peroxide and citric acid are biodegradable and food-safe.
   - Water used can be filtered and reused after simple neutralization

8. Refrence

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