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(RESEARCH ARTICLE)

Utilization of lemongrass and switchgrass in pulp and papermaking

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Abstract

The increasing demand for paper and concerns over deforestation has led to the exploration of non-wood fibres as alternative raw materials for papermaking. Lemongrass (*Cymbopogon citratus*), a genus of Asian, African, Australian, and tropical island plants in the grass family and switchgrass (*Panicum virgatum*), a perennial warm-season bunchgrass native to North America, are promising alternatives to traditional wood-based pulp in paper manufacturing. This study examines the potential of these grasses by analyzing their fibre properties, processing conditions, and the quality of the resulting paper. A range of pulping techniques was employed to maximize fibre extraction and sheet formation. The findings reveal that specific ratios of lemongrass and switchgrass fibres produce paper with distinct properties, making them suitable for various applications, such as printing and packaging. The papers produced were of varying feel, appearance, lustre, and quality. This research highlights the importance of non-wood fibre sources in promoting environmentally sustainable paper production.

Keywords: Lemongrass; Switchgrass; Non-wood fibres; Deforestation; Paper-making

1. Introduction

Paper is the basic material used for written communication and the dissemination of written information. Additionally, paper and paperboard provide materials for hundreds of other uses, such as wrapping, packaging, toweling, insulating, and photography. However, the global paper industry heavily relies on wood-based pulp, leading to deforestation, biodiversity loss, and environmental degradation [1, 2]. As demand for paper products continues to rise, there is an increasing need to explore alternative, sustainable fibre sources to offer a sustainable and renewable source of cellulose for papermaking. Non-wood plants, including grasses, have gained attention due to their fast growth rates, abundant availability, and high cellulose content [3,4]. Lemongrass and switchgrass, in particular, have shown potential as alternative raw materials for pulp and paper production due to their favourable chemical and structural properties [5, 6]. This study evaluates the effectiveness of these grass species in pulp production, focusing on their chemical composition and contribution to reducing dependence on wood fibres. Additionally, the environmental and economic benefits of non-wood fibre utilization are discussed, as research indicates that non-wood fibres can lower production costs while enhancing sustainability [7, 8, 9].

Previous research has explored using non-wood fibres such as bamboo, kenaf, and bagasse in paper manufacturing. Studies indicate that non-wood fibres generally contain lower lignin content than wood, making them easier to pulp with reduced chemical inputs. However, fibre strength and bonding properties vary significantly among sources. Research by [10] demonstrated the potential of switchgrass for nanocellulose extraction, while [11] highlighted the challenges of achieving desirable paper properties from alternative fibres. Understanding the properties of these fibres is essential for determining their viability in commercial papermaking applications. This present study expands existing research by evaluating the combined use of lemongrass and switchgrass.

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a: Lemongrass | b: Switchgrass

Figure 1a and b Lemon grass and Switchgrass respectively

The study aims to evaluate the suitability of lemongrass and switchgrass in papermaking by analyzing their fibre composition, pulping efficiency, and mechanical properties. The research addresses the following objectives:

- To determine the chemical composition of lemongrass and switchgrass fibres
- To determine the most effective pulping conditions for optimal yield and paper quality
- To assess the physical and mechanical properties of the paper produced from these fibers
- To evaluate and compare the environmental and economic impact of grass-based paper production with conventional wood pulp methods

2. Materials and Methods

2.1. Raw Materials

Lemongrass and switchgrass were harvested, dried, and processed to extract fibres. The lignin content, cellulose composition, and fibre morphology were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM). A comparative analysis of these fibres against conventional wood pulp was conducted to evaluate the feasibility of these alternative fibres.

2.2. Pulping Process

Chemical pulping was performed using sodium hydroxide (NaOH) and the kraft process to break down lignin and isolate fibers. The primary reaction involved is represented as:

$$C_6H_{10}O_5 + NaOH \rightarrow NaC_6H_9O_5 + H_2O$$

where $C_6H_{10}O_5$ denotes cellulose, while sodium hydroxide aids in delignification.

The fibres were washed, screened, and refined using a Hollander beater to achieve uniform consistency.

The fibre yield percentage was determined using:

$$Yield = \frac{Mass\ of\ dried\ pulp}{Mass\ of\ raw\ material}\ x\ 100$$

To enhance fibre bonding, the pulp underwent bleaching with hydrogen peroxide (H_2O_2) and mechanical refining.

2.3. Paper Formation and Testing

The processed pulp was diluted and evenly distributed onto a wire mesh screen to form paper sheets through a controlled sheet-forming process using a mould and deckle. The sheets were then pressed and dried under standardized conditions to achieve optimal consistency. The resulting paper was tested for tensile strength, burst index, tear index, brightness, opacity, and flexibility.

Tensile Strength Test: Measured using a universal testing machine, where force was applied until the paper sample fractured. Tensile strength was determined using:

$$Tensile\ Strength\ = \frac{F}{A}$$

where F is the applied force and A is the cross-sectional area of the paper sample.

Burst Index Test: The burst index was determined by measuring the pressure required to rupture the paper surface:

$$Burst\ Index\ Test\ = \frac{P}{A}$$

where P is the applied burst pressure and A is the sample area.

Tear Resistance Test: The Elmendorf tearing tester was used to evaluate the resistance of the paper to tearing forces. The tear index was calculated using:

$$Tear\ Resistance\ = \frac{T}{G}$$

where T is the tearing force required, and G is the grammage of the paper.

Brightness and Opacity Analysis: A spectrophotometer was used to measure brightness and opacity based on light reflectance. The brightness () was determined using the formula:

$$Brightness\ = \frac{Rs}{Ro}\ x\ 100$$

Where R_S is the sample reflectance and R_0 is the standard reflectance.

These tests provided quantitative data to compare the physical and mechanical properties of the grass-based paper with conventional wood pulp paper.

3. Results and Discussion

Fiber Composition and Pulping Efficiency

The chemical analysis revealed that lemongrass and switchgrass contain high cellulose content, making them suitable for papermaking [12]. Lemongrass contained lower lignin content (15-18%), facilitating easier pulping, while switchgrass fibres provided structural strength due to their higher hemicellulose and lignin content (20-25%). However, the pulping efficiency varied, with switchgrass requiring a higher chemical input due to its slightly higher lignin content. The paper produced from lemongrass exhibited good brightness and smoothness, while switchgrass-based paper demonstrated higher tensile and tear strength [13, 14]. The combination of both resulted in improved paper quality with an optimal balance of durability and flexibility suitable for printing and packaging applications. Scanning electron microscopy images revealed well-formed fibre networks with minimal defects [14, 15].

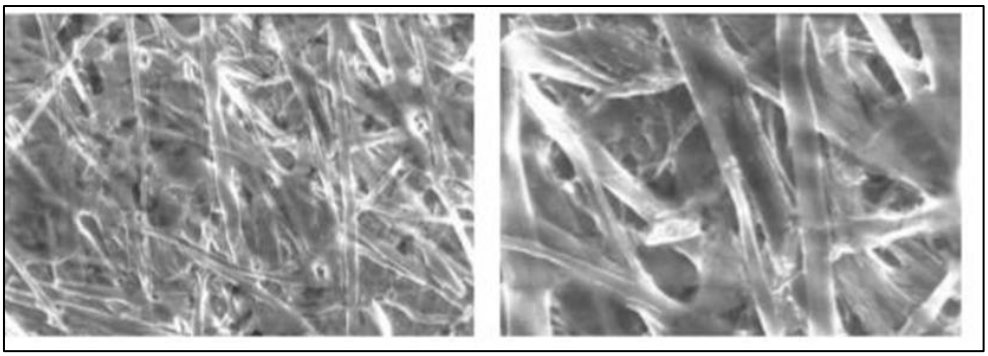

Figure 2 SEM image of lemon grass fibre surface and formation

3.1. Mechanical and Chemical Properties

Paper samples from various fiber ratios were subjected to mechanical testing, the results of which are summarized in Table 1.

Table 1 Mechanical testing of various ratios of Paper samples

Sample	Tensile Strength (MPa)	Burst Index ($kPa \cdot m^2/g$)	Tear Index ($mN \cdot m^2/g$)
Sample A (100% Lemongrass)	20.5	1.5	8.2
Sample B (30% Lemongrass, 70% Switchgrass)	24.1	1.8	9.6
Sample C (50% Lemongrass, 50% Switchgrass)	27.3	2.2	10.8

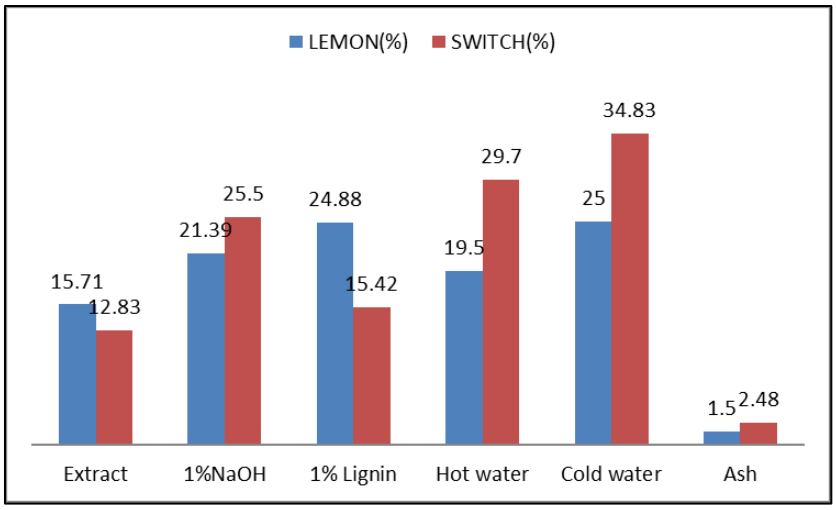

Figure 3 Plot of % Chemical Analysis of Lemon Grass and Switch Grass

3.2. Environmental and Economic Considerations

Using lemongrass and switchgrass in papermaking reduces reliance on wood-based pulp, thereby mitigating deforestation [16]. Additionally, these grasses are fast-growing and require minimal agricultural inputs, making them cost-effective alternatives. Carbon footprint analysis indicates that grass-based paper production generates 30% lower CO_2 emissions than traditional wood pulp processes [5]. Additionally, water consumption in pulping was reduced by 25% due to the lower lignin content of the grasses. The study suggests that non-wood fibres can contribute to a more sustainable paper industry.

4. Conclusion

This research confirms that lemongrass and switchgrass are viable raw materials for pulp and paper production. These non-wood fibres provide an eco-friendly alternative to conventional wood pulp and offer the potential for diverse industrial applications. Further studies should optimize pulping conditions, improve fibre bonding, and explore large-scale manufacturing potential. While challenges remain in fibre refining and bonding optimization, enhancements in fibre processing and mechanical refining can further improve the competitiveness of these alternative fibres. Additionally, exploring hybrid fibre blends with other non-wood sources could enhance paper strength and expand its industrial applications. Finally, economic feasibility studies should be conducted to determine the cost-effectiveness of implementing grass-based paper production on a commercial scale.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declared that are no conflict of interest as regards this work

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