

Utilization Of Sisal Plant and Water Hyacinth in Pulp and Paper Making

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Abstract- *The growing global demand for paper products, coupled with deforestation and the dwindling availability of wood-based pulp sources, has encouraged the investigation of alternative fibrous raw materials. This study evaluates the suitability of water hyacinth (*Eichhornia crassipes*) and sisal plant (*Agave sisalana*) for pulp and paper making, emphasizing their chemical composition, fibre morphology, and mechanical properties. Pulping processes were conducted following TAPPI standards, and several physical tests were applied, including tensile strength, tear resistance, abrasion resistance, and grammage. Results showed that blends of these non-wood fibres can yield paper with varying mechanical and physical qualities appropriate for diverse applications such as packaging and craft paper. These findings support the viability of both plants as sustainable sources of pulp and offer insight into environmentally conscious alternatives for traditional paper making industries.*

Index Terms- *Water-Hyacinth, Chemical Composition, Fibre Morphology, Mechanical Properties, Pulp And Paper, Paper Making*

I. INTRODUCTION

The pulp and paper industry plays a significant role in the global manufacturing and communication sectors [1]. However, its dependence on wood as the primary raw material has raised sustainability concerns. The extensive harvesting of forest trees contributes to deforestation, loss of biodiversity, and increased carbon emissions, prompting the need for alternative sources of fibrous material [2].

In this context, non-wood plants such as agricultural residues, fast-growing grasses, and aquatic weeds present promising opportunities [3]. Water hyacinth (*Eichhornia crassipes*), an invasive aquatic plant known for its aggressive spread in tropical and subtropical regions, is widely regarded as an

environmental nuisance. Its rapid growth clogs waterways, hampers aquatic ecosystems, and impedes transport and fishing activities. However, its fibrous structure and high cellulose content suggest that it could be repurposed into value-added applications like papermaking [3].

Similarly, the sisal plant (*Agave sisalana*) is a drought-resistant perennial with thick, fibrous leaves traditionally cultivated for rope and twine. Sisal fibres are long, strong, and durable, making them suitable for reinforcement and packaging applications. In Nigeria, where both water hyacinth and sisal are abundant and underutilised, their valorisation could create new economic opportunities and reduce environmental waste [1,3].

This research aims to explore the feasibility of using *Eichhornia crassipes* and *Agave sisalana* as pulp sources for papermaking by analysing their chemical and physical properties and testing the performance of paper made from their fibres. Through this, the study contributes to the advancement of sustainable paper production technologies in developing regions [2].

II. LITERATURE REVIEW

Several studies have examined the potential of non-wood fibres in the pulp and paper industry. According to [4], non-wood raw materials offer advantages such as lower lignin content, shorter fibre length, and faster renewability compared to hardwood and softwood trees. These features make them easier to process and bleach, resulting in reduced chemical usage and environmental impact [5].

Water hyacinth, despite its reputation as an ecological burden, contains a significant amount of cellulose, hemicellulose, and extractives, making it a viable raw material for bio-based applications. Research has shown that its fibre can be processed into biofuel, compost, animal feed, and paper pulp. [3, 5] confirmed that water hyacinth fibres, when pulped under suitable conditions, can yield paper with acceptable tensile and optical properties.

Sisal, a traditional fibre crop, has been extensively studied for its strong lignocellulosic composition. The plant's fibres contain high levels of α -cellulose and offer excellent strength characteristics, which are beneficial in producing high-quality paper and board products [3, 6]. The combination of these two raw materials; sisal for strength and water hyacinth for flexibility, presents an opportunity for developing composite papers with tailored properties [6, 7, 8].

Despite this potential, the utilisation of these plants in papermaking remains limited, particularly in Africa, where they are largely treated as waste [6, 8]. This study therefore seeks to bridge the gap by providing empirical evidence on the chemical and mechanical suitability of water hyacinth and sisal as alternative pulp sources

III. MATERIALS AND METHODS

3.1 Raw Materials

Water hyacinth was harvested from Majidun Awori in Ikorodu, Lagos State, where it occurs as a persistent aquatic weed. Sisal leaves were obtained from cultivated fields in Ikorodu, Lagos. The collected materials were cleaned to remove dirt and contaminants, then air-dried under natural sunlight to reduce their moisture content before further processing

3.2 Chemicals and Equipment

Chemicals used include ethanol, acetone, sodium hydroxide (NaOH), sulfuric acid (H_2SO_4), and distilled water. Equipment included Soxhlet extractors, ovens, pulping digesters, valley beaters, abrasion resistance testers, a scanning electron microscope (SEM), and an INSTRON 5980 series universal testing machine.

3.3 Sample Preparation and Pulping

The dried samples were chipped and ground into fine particles. The pulping process involved alkaline digestion using NaOH to remove lignin and separate cellulose fibres. The process followed TAPPI standard methods to ensure reproducibility and accuracy.

3.4 Chemical Analysis

3.4.1 Extractive Content (T204 om-88)

The extractive content was determined using Soxhlet extraction for six hours:

$$\text{Extractives}(\%) = \frac{W_i - W_f}{W_i} \times 100$$

where W_i and W_f are the initial and final dry weights.

3.4.2 1% NaOH Solubility (T212 om-92)

This test indicates the amount of low-molecular-weight carbohydrates and degraded lignin:

$$\text{Solubility}(\%) = \frac{W_i - W_f}{W_i} \times 100$$

3.4.3 Lignin Content (T222 om-88)

Lignin was precipitated using sulfuric acid and dried:

$$\text{Lignin}(\%) = \frac{W_i - W_f}{W_i} \times 100$$

3.4.4 Water Solubility (T207 om-93)

Measured at room temperature and at 100°C:

$$\text{Solubility}(\%) = \frac{W_i - W_f}{W_i} \times 100$$

3.4.5 Ash Content (T211 om-93)

Represents the inorganic residue:

$$\text{Ash}(\%) = \frac{W_{\text{ash}}}{W_{\text{original}}} \times 100$$

3.5 Physical Testing

3.5.1 Abrasion Resistance

Assessed using a Martindale tester at 9kPa for 500 cycles:

$$\text{Abrasion}(\%) = \frac{(W_i - W_f)}{W_i} \times 100$$

3.5.2 Tear Strength

Samples were notched and tested on the INSTRON machine

3.5.3 Tensile Strength

$$\text{Tensile Strength (MPa)} = \frac{F}{A}$$

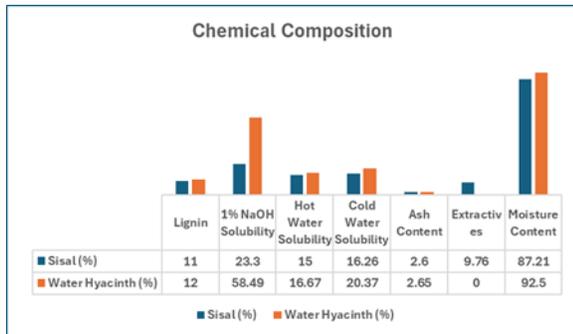
where F is the maximum force and A is the cross-sectional area.

3.5.4 Grammage

$$\text{Grammage (g/m}^2\text{)} = \frac{\text{Mass (g)}}{\text{Area (m}^2\text{)}}$$

IV. RESULTS AND DISCUSSION

4.1 Chemical Composition

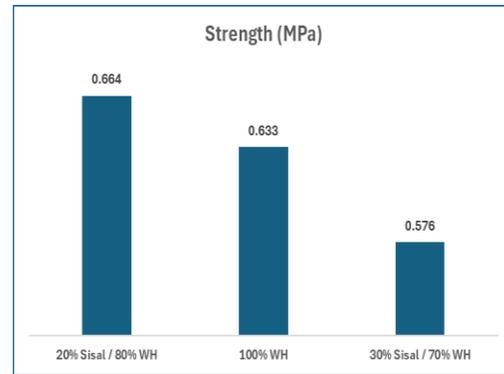


Water hyacinth exhibited higher solubility and moisture content, reflecting its aquatic origin and less rigid structure. Both fibres demonstrated acceptable lignin levels for pulping

4.2 Mechanical Properties

Tensile Strength

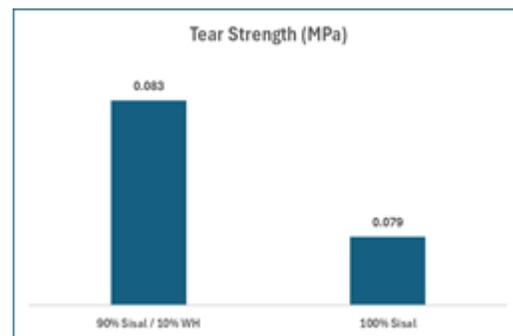
Sample	Strength (MPa)
20% Sisal / 80% WH	0.664
100% WH	0.633
30% Sisal / 70% WH	0.576



Tear Strength

Sample	Tear Strength (MPa)
90% Sisal / 10% WH	0.083
100% Sisal	0.079

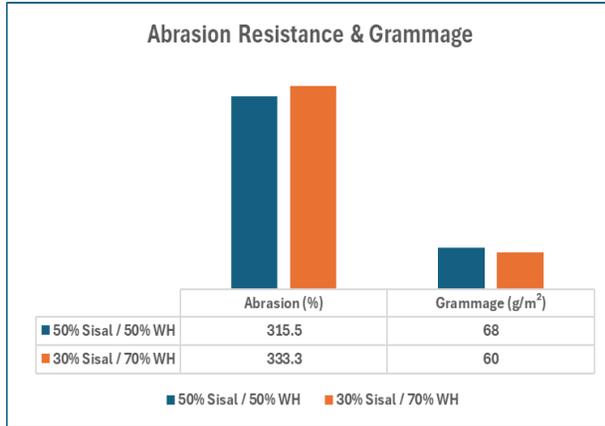
Parameter	Sisal (%)	Water Hyacinth (%)
Lignin	11	12
1% NaOH Solubility	23.3	58.49
Hot Water Solubility	15	16.67
Cold Water Solubility	16.26	20.37
Ash Content	2.6	2.65
Extractives	9.76	0
Moisture Content	87.21	92.5



Abrasion Resistance and Grammage

Sample	Abrasion (%)	Grammage (g/m ²)
50% Sisal /	315.5	68

50% WH		
30% Sisal / 70% WH	333.3	60



Blends containing higher proportions of sisal yielded greater tear strength and abrasion resistance, attributed to sisal's coarse fibre structure. Conversely, water hyacinth contributed to better sheet formation and tensile performance [9].

4.3 Morphological Observation

Scanning Electron Microscopy (SEM) was employed to observe the structural bonding and surface texture of the handmade paper sheets. The blended sheets, particularly those containing both sisal and water hyacinth, exhibited a fibrous network with interwoven structures [10]. Sisal fibres contributed to the rigidity and long-fibre bonding, while the finer, more flexible water hyacinth fibres filled in the voids and enhanced sheet uniformity [10, 11].

Micrographs revealed that at higher sisal content, fibres aligned more distinctly with fewer micro-cracks, resulting in better tear resistance. Conversely, samples with more water hyacinth showed denser fibre packing and smoother surface finishes, which contributed to better tensile strength. The combined microstructural characteristics of these two fibres made the composite sheets comparable to conventional paper derived from hardwood pulp.

These observations affirm the physical compatibility of both fibres when blended, reinforcing the potential

for hybrid fibre optimisation in sustainable papermaking applications.

IV. CONCLUSION

This study validates the application of *Eichhornia crassipes* and *Agave sisalana* in pulp and paper production. Through comprehensive chemical and mechanical testing, both fibres have demonstrated their potential as alternative raw materials. Blended fibre sheets showed a balance of strength and flexibility, with sisal enhancing tear resistance and water hyacinth improving tensile strength and sheet formation.

Moreover, the morphological studies confirmed favourable fibre-to-fibre bonding and compatibility. From an environmental and socio-economic standpoint, the use of these plants offers numerous advantages. It provides a sustainable outlet for managing invasive species like water hyacinth and promotes the agricultural utilisation of underexploited sisal crops. Adoption of these materials in commercial papermaking can reduce reliance on forest-based resources, lower production costs, and foster local economies.

Future research should focus on scaling up processing techniques, optimising pulp extraction parameters for industrial use, and performing durability assessments of finished paper products under real-life usage conditions.

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