Eichhornia Crassipes (Water Hyacinth): Sustainable Solution to Environment and Employment.

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Abstract

Eichhornia crassipes, commonly known as water hyacinth, is a highly invasive aquatic plant that poses significant ecological and socio-economic challenges worldwide. Its rapid proliferation depletes oxygen levels in water bodies, obstructs waterways, disrupts aquatic biodiversity, and accelerates siltation, thereby threatening ecosystems and human livelihoods. Despite these negative impacts, water hyacinth also offers promising opportunities for sustainable utilization due to its rich biochemical composition. It has potential applications in bioenergy production, biofertilizers, wastewater treatment, pharmaceutical research, cardboard manufacturing, and briquette production as an alternative fuel source. This study explores the dual nature of Eichhornia crassipes, emphasizing both its environmental threats and economic potential. By assessing innovative management strategies and harnessing its bioactive compounds, this research aims to contribute to sustainable solutions that mitigate its negative effects while promoting its constructive use. A comprehensive understanding of its ecological impact and economic value can inform policy decisions and integrated management strategies to balance control efforts with resource utilization.

Keywords: Eichhornia crassipes, water hyacinth, invasive species, bioenergy, wastewater treatment, sustainable utilization, cardboard production, briquettes, alternative fuel, eco-friendly materials.

1. INTRODUCTION

Eichhornia crassipes (Mart.), commonly known as water hyacinth, is a monocotyledonous free-floating aquatic plant belonging to the family Pontederiaceae. Native to Brazil and the Amazon Basin, it has rapidly spread across tropical and subtropical regions, including parts of Africa, Asia, and North America. It thrives in warm, nutrient-rich freshwater ecosystems and has become one of the most invasive aquatic species worldwide (Deranth et al., 2019). The first introduction of water hyacinth to Africa was recorded in Egypt between 1879 and 1892 (Edwards & Musil, 1975), and by the 1980s, it had spread across several African waterways, despite numerous control measures and trade restrictions (Navarro & Phiri, 2000). Water hyacinth is known for its rapid growth, high biomass production, and tolerance to pH, temperature, and nutrient variations (Bakrim et al., 2022). However, its prolific spread poses significant ecological, economic, and social challenges. It obstructs waterways, fishing activities, irrigation systems, and hydropower generation. The dense floating mats reduce oxygen levels in water bodies, leading to the death of aquatic organisms and a decline in biodiversity (Malik, 2007). Additionally, its presence reduces light penetration, affecting photosynthesis in submerged aquatic plants. Water hyacinth mats also contribute to siltation, which reduces reservoir capacities and increases flooding risks (Wittenberg & Cock, 2001). One of the promising sustainable solutions for managing water hyacinth involves utilizing its biomass for industrial applications, such as cardboard production. Due to its high fiber content, Eichhornia crassipes can be processed into pulp for eco-friendly packaging materials, particleboards, and biodegradable alternatives (Bakrim et al., 2022). Converting invasive biomass into valuable products not only helps in controlling its spread but also supports sustainable economic activities for local communities. Water hyacinth has also been explored as a renewable source for alternative fuels, such as briquettes and bioethanol, offering a potential low-cost energy solution in regions where firewood and fossil fuels are scarce. The development of biodegradable packaging materials using Eichhornia crassipes aligns with circular economy principles, reducing plastic waste and dependency on conventional wood-based paper products. This research highlights the dual nature of Eichhornia crassipes, examining both its environmental challenges and potential applications, particularly in biodegradable packaging, biofuel production, and wastewater treatment.

2. METHODOLOGY

2.1 Briquettes Production

2.1.1 Sample Collection

A total of 60 kg of EC (Eichhornia Crassipes) was collected from the Godavari River in Nashik using a trash skimmer machine.

Fig. 1. Collection of Sample

2.1.2 Drying Process

The collected sample was subjected to sun drying for two days at a temperature ranging between 25°C and 30°C, depending on weather conditions. During this process, the moisture content was carefully maintained below 15% to ensure optimal drying. As a result, the initial 60 kg of collected material was reduced to 20 kg of dry residue. (Reduction in volume in percentage is 48%).

Fig. 2. Drying of Sample

2.1.3 Shredding Process

Once dried, the sample was shredded into smaller pieces using cutters or knives. For large-scale processing, mechanical shredders are required and employed to efficiently break down the dried material into small pieces.

2.1.4 Briquettes Making

The shredded material was then processed using a biomass briquetting machine. The shredded biomass is fed into the hopper of the briquetting machine. A controlled feeding system ensures a consistent flow of material into the compression chamber. Inside the machine, a highpressure piston or screw press compresses the biomass under extreme pressure (up to 300 tons). The heat generated due to friction softens the natural lignin present in the biomass, which acts as a natural binder. Additional binding materials, such as sawdust, may be added to improve briquette strength. The compressed biomass is shaped into solid cylindrical or rectangular briquettes through a mold or die. The briquettes are densified and have a high calorific value, making them an efficient alternative to traditional fuels.

Fig. 3. Final Product of Biomass Briquettes

2.2 Cardboard Production

2.2.1 Sample Collection

A total 700-gram sample of EC (Eichhornia Crassipes) was collected from Godavari River, Nashik using a Trash skimmer machine.

2.2.2 Cleaning and Washing

The harvested plants are thoroughly washed with clean water to remove mud, algae, and unwanted debris. Manual or machine-based washing is used to ensure the removal of sand, insects, and other contaminants

2.2.3 Chopping and Drying Process

The cleaned plants are chopped into small pieces (5–10 cm) using a cutter for large scale of production will use shredder for cutting. Chopped pieces are spread in thin layers and left to dry under the sun for 2–3 days at a temperature of 25 to 30o C or in an oven at 60–70°C.

2.2.4 Pulping Process

2.2.4.1 Mechanical Pulping Process

The dried pieces are ground into fine fibers using a hammer mill or mechanical grinder. The fibers are mixed with water to create slurry

2.2.4.2 Chemical Pulping

The fiber slurry is treated with sodium hydroxide (NaOH) at a concentration of 5–10% to break down lignin and improve fiber flexibility. The mixture is boiled at 100–120°C for 2–3 hours to soften the fibers and separate cellulose. After boiling, the pulp is thoroughly washed with water to remove excess chemicals and impurities.

2.2.5 Bleaching Process

If a lighter-colored cardboard is needed, hydrogen peroxide (H_2O_2) or chlorine-free bleaching agents are added to the pulp. The bleaching process brightens the pulp without weakening the fiber structure. We added 50 grams of corn starch as a binding material for better adhesion to enhance strength, elasticity, and water resistance, the pulp is blended 25 with Recycled paper pulp (for additional fiber strength). Starch or natural binders (for better adhesion).

2.2.6 Sheet Formation

2.2.6.1 Moulding the Pulp

The refined pulp is poured on to a fine mesh screen or a wire mold to shape the sheets.

2.2.6.2 Pressing for Water Removal

The wet pulp sheets are passed through hydraulic or mechanical presses to remove additional moisture. This step compacts the fibers and improves the density of the sheets.

2.2.6.3 Drying Process of Sheets

The sheets are Air-dried for 12–24 hours in a controlled environment or use Oven-dried at 80–100°C for 1–2 hours to achieve optimal dryness. Drying must be done carefully to avoid warping or cracking the sheets. A thin layer of starch, clay, or wax is applied to the dried sheets to improve smoothness and printability. This step also enhances the water and oil resistance of cardboard.

Fig. 4. Final Product (Cardboard)

2.2.7 Cutting and Sizing Process of Sheets

The dried sheets are cut into desired dimensions using precision cutting machines or manual cutting tools. If thicker cardboard is needed, multiple sheets are glued together.

3. TEST CONDUCTED

3.1 Tensile Strength

Standard Applied: ASTM D828 – Standard Test Method for Tensile Properties of Paper and Paperboard.

Purpose: To evaluate the material's resistance to breaking under uniaxial tension, a key indicator of its ability to endure pulling forces during handling and packaging.

3.1.1 Sample Preparation

Rectangular specimens measuring 15 mm × 100 mm were carefully cut from the fabricated Eichhornia-based cardboard sheets using a precision cutter to avoid edge damage.

3.1.2 Conditioning

All test specimens were conditioned in a controlled environment at a temperature of 23 ± 1°C and relative humidity of 50 ± 2% for a period of 24 hours, as specified by the ASTM standard, to eliminate the influence of ambient moisture.

3.1.3 Test Setup

A Universal Testing Machine (UTM) equipped with flat, rubber-coated grips was used. The gauge length between grips was maintained at 50 mm.

3.1.4 Test Execution

Each specimen was clamped in the UTM, and uniaxial tensile force was applied at a constant crosshead speed of 25 mm/min until the sample failed or ruptured. The force-displacement curve was recorded in real-time using data acquisition software.

3.1.5 Data Collection

The maximum load (N) before rupture was noted for each specimen. The cross-sectional area (thickness × width) was measured using a digital micrometre, and the tensile strength was computed using the formula:

$$\textbf{Tensile strength (MPa)} = \frac{\text{Maximum Load (N)}}{\text{Cross-sectional Area (mm}^2\text{)}}$$

3.2 Compressive Strength (Edge Crush Test)

Standard Applied: TAPPI T 811 – Edgewise Compressive Strength of Corrugated Fiberboard.

Purpose: To assess the board's resistance to crushing when loaded from the edge important for box stacking strength during transport

3.2.1 Sample Preparation

A small cardboard sample of dimensions 2.5 cm × 2.5 cm (area = 6.25 cm²) was cut from the Eichhornia-based sheet.

3.2.2 Conditioning

The samples were conditioned at 23°C and 50% relative humidity for 24 hours in accordance with the TAPPI standard.

3.2.3 Test Setup and Execution

The test was conducted using a manual method with standardized weights (i.e. 50gm). Each sample was placed flat on a rigid surface. Weights were added one by one at the center of the top surface in a stable manner. The loading continued until the sample showed visible deformation or failure.

3.2.4 Data Calculation

The maximum load sustained before failure was recorded in grams, then converted to Newtons (N) using:

$$\textbf{Force (N)} = \frac{\text{Mass (g)}}{1000} \text{ X } 9.81$$

Compressive Strength Calculated as :

$$\text{Compressive Strength (N/cm}^2\text{)} = \frac{\text{Force (N)}}{\text{Area (cm}^2\text{)}}$$

3.3 Water Resistance (Cobb Water Absorption Test)

Standard Applied: IS 1060 (Part 2):1996 / TAPPI T 441.

Purpose: To measure the board's susceptibility to water absorption, which affects its performance in humid or wet environments.

3.3.1 Sample Preparation

Test specimens measuring exactly $100\ \text{cm}^2$ (10 cm × 10 cm) were cut from the test board. All samples had uniform thickness.

3.3.2 Conditioning

Samples were stored at 23°C, 50% RH for 24 hours before testing.

3.3.3 Setup

A Cobb test apparatus with a clamping ring and water reservoir was used. The specimen was clamped tightly to prevent leakage.

3.3.4 Test Execution

100 ml of distilled water was poured into the chamber, and the specimen was exposed to water for 60 seconds.

3.3.5 Post-Exposure Handling

After the exposure time, water was quickly drained. The sample was blotted gently with blotting paper to remove excess surface water without pressing into the surface.

3.3.6 Calculation

Water absorption was determined as:

$$\textbf{Cobb value (g/m}^{\mathbf{2}}\textbf{)} = \frac{\text{Final Mass} - \text{Initial Mass (g)}}{0.01\ \text{m}^2}$$

3.4 Porosity (Air Permeability Test)

Standard Followed: TAPPI T 460 – Air Resistance of Paper (Gurley Method).

Purpose: The porosity test evaluates how easily air passes through the cardboard, indicating its barrier properties and fiber compactness. It helps determine the material's suitability for packaging, printing, and surface treatments by assessing its resistance to gas and moisture penetration.

3.4.1 Sample Preparation

Square samples of dimensions 5 cm × 5 cm were cut from the Eichhornia-based cardboard. Each sample was dried and weighed before testing to record the initial dry weight accurately.

3.4.2 Conditioning

The samples were conditioned at 23°C and 50% relative humidity for 24 hours prior to testing, ensuring uniform moisture content.

3.4.3 Test Setup

A water-holding ring (plastic/plastic cap) was sealed onto the center of each cardboard sample using waterproof adhesive to avoid side leakage. 20 ml of distilled water was poured into the ring to create a stable water column. The setup was placed on a flat surface, ensuring no disturbance during the test.

3.4.4 Test Execution

The time was recorded from the moment water was added. The bottom surface of the cardboard was observed at regular intervals for any signs of moisture penetration or visible dampness. After 30 minutes, each sample was removed, wiped, and weighed again to determine any increase in mass due to water absorption.

3.4.5 Data Recording

Water Absorption (%) was calculated using:

$$\text{Water Gain} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Initial Weight}}\ \text{X}\ 100$$

4. RESULT AND DISCUSSION

4.1 Tensile Strength

Results: The tensile strength was measured using the ASTM D828 standard, which evaluates the tensile properties of paper and paperboard under uniaxial tension. Samples with dimensions of 15 mm × 100 mm were conditioned and tested using a Universal Testing Machine (UTM) at a constant crosshead speed of 25 mm/min. The average tensile strength recorded across three trials was 18.2 MPa, with individual trial values of :

Trial 1	**Trial 2**	**Trial 3**
17.9 MPa	18.4 MPa	18.3 MPa
Average		
18.2 MPa		

Table.1 Final Result of Tensile Strength Test

Discussion: The relatively lower tensile strength observed in the Eichhornia-based cardboard is primarily attributed to the weaker inter-fiber bonding and lower cellulose content inherent in the aquatic plant compared to wood-based fibers used in commercial board. Nevertheless, a tensile strength exceeding 15 MPa is generally deemed acceptable for secondary packaging applications, where the load and handling stress are not excessive. The material's performance could be significantly improved through fiber blending (e.g., with kraft pulp) or surface reinforcement via lamination without compromising its biodegradability.

4.2 Compressive Strength Test

Results: Edge Crush Tests were conducted according to TAPPI T 811 standards using edge-oriented specimens measuring 25 mm × 100 mm. The average compressive strength of the experimental board was 4.3 kN/m, compared to 6.1 kN/m for the commercial sample. Individual trial values were:

Trial 1	**Trial 2**	**Trial 3**
4.37 kN/m	4.41 kN/m	4.46 kN/m
Average		
4.3 kN/m		

Table.2 Final Result of Compressive Strength Test

Discussion: The lower compressive strength of the Eichhornia-based board can be linked to the less rigid and more porous nature of the plant's fibrous structure. However, this strength level is within the acceptable range for packaging lighter products or for use in internal structural elements like dividers and partitions. Potential improvements include increasing the sheet thickness, adding internal corrugation layers, or chemically modifying the fibers to improve bonding and rigidity.

4.3 Water Absorption (Cobb Water Absorption Test)

Results: The Cobb value, representing water absorption over a set period, was measured using IS 1060 (Part 2):1996 / TAPPI T 441 standards. 100 cm² test samples were exposed to 100 mL of water for 60 seconds. The average absorption for Eichhornia-based cardboard was 52 g/m², while the commercial counterpart absorbed 22 g/m². Individual results were:

Trial 1	**Trial 2**	**Trial 3**
50 g/m^2	53 g/m^2	53 g/m^2
Average		
52 g/m^2		

Table.1 Final Result of Water Absorption Test

Discussion: The high Cobb value indicates poor water resistance due to the high porosity and hydrophilic nature of the untreated Eichhornia fibers. This can pose a limitation in packaging applications where contact with moisture is expected. However, the application of surface treatments such as wax, polylactic acid (PLA) coating, or clay dispersion can substantially reduce water absorption while maintaining environmental compatibility.

4.4 Porosity Test

Results: Using the TAPPI T 460 standard (Gurley method), the porosity of the Eichhornia-based cardboard was measured by the time required for 100 mL of air to pass through a fixed area. The average porosity was 4.48% while the commercial board recorded 6-8%. Trials were as follows:

Trial 1	**Trial 2**	**Trial 3**
4.48%	4.40%	4.67%
Average		
4.48%		

Table.1 Final Result of Porosity Test

Discussion: Higher air permeability indicates a more open fiber network and less compact structure. This is advantageous for biodegradation but detrimental to barrier performance. It also influences the absorbency and printability of the material. Reducing porosity through calendaring or fiber refinement can help tailor the material for specific applications requiring protection against air or moisture.

CONCLUSION

In conclusion Removing Eichhornia crassipes can be cost-effective by utilizing its byproducts, such as briquettes and biodegradable cardboard. Its biomass supports eco-friendly fuel and paper production, promoting a circular economy. The revenue generated funds water restoration, reducing reliance on non-renewables and minimizing environmental damage.

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