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DEVELOPMENT OF ALGAL AND RICE STRAW PULP FOR HANDCRAFTED PAPER PRODUCTION

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Abstract

This study assesses the viability of using rice straw and algae pulp in handmade paper production, highlighting their benefits and sustainability as alternative materials. The aim is to analyze the advantages and challenges of integrating these unconventional resources into papermaking processes, considering economic, environmental, and resource factors. By examining bleachingtechniques, paper properties, and raw material compositions, valuable insights are gained.The research indicates that non-chlorine bleaching methods yield higher brightness levels compared to traditional chlorine-based methods, with algae pulp achieving 85% brightness and rice straw pulp reaching 82%. This suggests a more environmentally friendly approach to bleaching. Analysis of paperproperties reveals that algal pulp consists of 35.2% cellulose, 12.4% hemicellulose, and 3.8% lignin, while rice straw contains 40.6%cellulose, 18.9% hemicellulose, and 5.2% lignin. Despite differences in lignin content, both materials demonstrate potential for industrial use, with algae pulp offering scalability and minimal resource requirements, and rice straw aiding in waste diversion and pollution mitigation.Algae paper exhibits a biodegradation rate of 85%, while rice straw paper degrades at a rate of 78%, highlightingtheir eco-friendly characteristics. These findings underscore the importance of utilizing renewable biomass sources for sustainable paper production, while also acknowledging the necessity for further research and investment to enhance processing methods and scale up production.

Keywords: Handmade Paper Production, Environmentally, Rice straw pulp, Algae pulp.

INTRODUCTION

The utilization of sustainable materials in paper production has garnered significant attention due to growing environmental concernsand the need for resource efficiency. Algal pulp and rice straw have emerged as promising alternatives to conventional wood pulp, offering potential advantages in terms of renewability, abundance, and eco-friendliness. As the demand for eco-conscious products continues to rise, evaluating the feasibility and efficacy of incorporating algal pulp and rice straw in handcrafted paper production becomes imperative. This introduction provides an overview of the research landscape surrounding the evaluation of these sustainablematerials and sets the stage for a comprehensive analysis of their applicability in the papermaking industry.

Algal pulp, derived from algae biomass, presents a sustainable solution for paper production, offering scalability and minimal environmental impact compared to traditional wood-based pulping methods (Patil, Patel, and Kumar, 2020). Additionally, algal biomass cultivation does not compete with food crops and can be cultivated in various aquatic environments, further enhancing its sustainability credentials (Bharti, Kumar, and Pant, 2019).

On the other hand, rice straw, an abundant agricultural residue, holds immense potential as a raw material for papermaking, providing an alternative to the burning of straw, which contributes to air pollution (Chen et al., 2020). Utilizing rice straw in paper production not only mitigates environmental pollution but also adds value to agricultural waste streams, promoting a circular economy approach (Wondraczek and Dusold, 2020).

While both algal pulp and rice straw offer promising attributes for sustainable paper production, their integration into handcrafted paper processes requires careful evaluation of their chemical composition, processing techniques, and resulting paper properties.

This necessitates a systematic approach to assess the feasibility and potential challenges associated with utilizing these materials in handmade paper production.

Against this backdrop, this study aims to critically evaluate the suitability of algal pulp and rice straw in handcrafted paper production through a comprehensive analysis of their characteristics, processing methods, and paper properties. By examining the viability of these sustainable materials, this research contributes to advancing the sustainability agenda in the papermaking industry and promotes the adoption of environmentally friendly practices.

METHODOLOGY

SAMPLE COLLECTION AND RAW MATERIAL PREPARATION

The raw material used for this research was algae and rice straw. The algae was collected from an aquaculture pond from nearby village Varapalayam ,Tiruchengode at Namakkal District. The algae was rinsed with tap water to remove grit and deposits before use, then laid flat and sun-dried until the moisture content was less than 10%. The rice straw was collected from a common species (*Oryza sativa*) from nearby village Varapalayam , Tiruchengode at Namakkal District. The rice straw was cut from and chopped in small pieces (2–3 inch) using a clean kitchen knife. Sun dried for about 3/4 days in the open air before being cooked.

ALGAE AND RICE STRAW PULP CUISINE CONDITIONS

The dried or cleaned algae (100 g) were cooked with1.5 l detergent at 95ºC. The algal residue that was performing was treated with one H_2O_2 (ground on dry algae weight) and hotted for two hours. The detergents included: 1) NaOH (5, 10, or 20 grounded on dry algae weight) cooked for four hours; 2) Na_2SO_3 (5, 10, or 20 grounded on dry algae weight) cooked for four hours; and 3) NaOH (5, 10, or 20 grounded on dry algae weight) cooked for two hours. Following cooking, the algae were separated, impartially cleaned with distilled water, and dried as algal pulp for eight hours at 50 degrees Celsius. Additionally, in a mixing blender, 8 liters of distilled water (or around 3.57 dry mass base) were combined with 250 grams of dry algal pulp. Three estimates were made for each parameter.

1. After irrigating cooked pulp with distilled water, remove as important water as possible. Retain some NaOH in the pulp.
2. Maintain a pH in the range of9.5 and 11. It was stylish not to wash the pulp too much.

BLEACHING ALGAE AND RICE STRAW PULP WITH BOTH CHLORINE AND NON-CHLORINE BLEACHING

Chlorine bleaching

Preparation of liquid chlorine bleach

About 3.5% solution of chlorine was diluted to 2% solution.

$$\text{Amount} = \frac{2\% \times 500 \text{ ml}}{3.5\%} = 285 \text{ ml}$$

Added 285 ml of chlorine water to 215 ml of water to make up the volume to 500 ml and this liquid chlorine bleach was used for further analysis.

Preparation of Pulp bleaching with Sodium hypochlorite

About 5.25% solution of sodium hypochlorite was diluted to 2%

$$\text{Volume} = \frac{2\% \times 500 \text{ ml}}{5.25\%} = 190 \text{ ml}$$

Added 190 ml of sodium hypochlorite to 310 ml of distilled water to make up the volume to 500 ml .

To ensure that bleach work effectively at least a 12% consistency was prepared and worked this out to be 10 grams of pulp for every 85 milliliters of solution. Placed the mixture in a blender. Blend to pulpy consistency. Blending the pulp with the bleach solution will increase the surface area of the fibres and improve the bleaching efficiency.

The reaction/degradation of lignin with bleach (NaOCl) was improved when the mixture was heated between 35^{o} C and 75^{o}C but not boiled. It takes between 30 and 90 minutes to complete the bleaching reaction. The longer the time, the whiter the pulp. Keep the mixture hot throughout the process. Blend the mixture before rinsing.

Rinse the bleached pulp thoroughly. Most of the bleaching chemicals will be used up in the bleaching process. Rinsing should remove any residual bleach from the pulp.

Non chlorine bleaching

Non-chlorine bleaching using Sodium percarbonate

It was more environmentally friendly approach. Measured out 30g of the crystals to mix 500 ml of solution. Added enough hot water to make up to 500ml. Add crystals then water to make the solution.

Consistency = 12%. This work out to about 10g for every 85 ml of solution.

$$500 \text{ ml} \times (10 \text{ g}/ 85 \text{ ml}) \text{ gives approximately } 60 \text{ g of pulp.}$$

The pulp was mixed with solution and blended in a blender to increase surface area and improve bleaching action. Sodium percarbonate decolorized chromophores. It bleaches in a non-delignifying manner and preserves the pulp yield. Stir mixture periodically and keep it hot (60- 90^{o} C). A pH of 9- 11.5 was ideal. 30-90 minutes was given as a bleaching time. The more time of reaction gives the brighter and whiter pulp.

The solution was blended to a pulp consistency prior to rinsing. Percarbonate produce hydrogen peroxide which is a powerful bleaching agent. It bleaches in a non-delignifying manner and thus preserves the pulp. The removal of chromophores results in a brighter and not necessarily whiter pulp.

Bleaching of algae and Rice straw pulp using Hydrogen peroxide

5% dynamic hydrogen peroxide was utilized by dry weight of the fabric. Temperature, time term , and introductory pH were kept up around 80°C, 1hr, and 12 separately. The pH was controlled by the expansion of sodium hydroxide.

HAND SHEET PREPARATION

The holder was filled around midway with dyed mash. Include more water. The thickness of the paper is decided by the mash to water proportion. Sheets were made with a form and deckle, which are two comparable outlines with a screen connected to one of them. Holding up the shape screen, equally organize the deckle on best. Holding them both at a 45-degree point, the form was plunged, deckled to the foot of the vat, and after that up whereas being held evenly. To adjust the filaments and create a more uniform sheet, it was shaken briefly from cleared out to right and back and forward whereas being evacuated from the slurry. Stop shaking as soon as the sheet starts to drain. Allow the water to slowly come to a halt.

Couching

"Couching" is the method of moving the damp sheet from the mold to a surface that's smooth and permeable. Separated from fleece felts, which are culminate, extra choices incorporate fleece covers, smoother towels, thick paper towels, non-fusible meddle or pellon, sham-wows, or bed cloths. Orchestrate the materials for framing on a board that has felt underneath. Extricate the duck from the shape. Position the long edge of the shape onto the felt. Position the shape with its confront down, apply weight, and instantly drag off the primary edge.

Pressing

Put the naturally framed sheet over the paper towel. Apply as small weight as conceivable with a wipe at to begin with, and after that much as you'll.

Drying

Place the wet sheet and gently press it against a non-porous surface or smooth wood planks. The edges should be firmly pressed. Depending on the humidity and the paper's thickness, let the paper dry for 1-3 days. Shed it off.

Sizing and polishing

Sizing and Polishing are the two most critical after wraps up given to the carefully assembled sheets after drying. Sizing may be a that can give paper shifted degrees of dampness resistance. In two stages of the papermaking prepare, estimate can be expanded. The degree of estimate of paper influences how safe it is to dampness penetration. Sizinging prepare makes strides the quality of paper and makes the surface more appropriate for composing. Starch made from rice and sorghum was majorly utilized.There are two types of Sizing

1. Internal/engine/beatersizing
2. Tub sizing.

Estimation of cellulose (Das et al., 2014)

1g of cellulose was splashed in a 5% NaOH (w/v) arrangement after being oven-dried for 4 hours at 105 °C and at that point refrigerated for 5 hours in a nonhygroscopic desiccator (fiber to arrangement w/w proportion: 1:30). The fabric was neutralized with 10% H2SO after cooling. After a exhaustive cleaning, the leftover biomass was treated with a 2% H2O2 arrangement arranged in a pH-9 NaHCO3-Na2CO3 buffer framework for five hours at room temperature. To accomplish a steady weight, the biomass was over and over cleaned and dried at 105 °C. The weight differential was utilized to calculate the cellulose substance. Three free estimations were made on each test.

Estimation of hemicellulose (L. Boopathi et al., 2012)

One gram of the extractive-free test was bubbled for four hours in 0.5 M NaOH. To get a uniform weight, the substance was neutralized after numerous washes with refined water and at that point dried at 105 °C. Utilizing the weight differential, the hemicellulose substance was calculated. Each test experienced three distinctive measurements.

Estimation of lignin (Augustine et al., 2015)

1g of the extractive-free paper test was treated with 72% H2SO4 (test to destructive extent 1:12.5 w/v) taking after cautious shaking for two hours. The beat fabric was released taking after numerous weakenings and washings. The collection was filtered and dried at 105 °C in an endeavor to drive a consistent weight. The weight differential was utilized to decide the lignin substance. There were three isolated estimations for each exam. Augustine and Ayeni (2015), among others.

COMPARISON OF HAND SHEET PROPERTIES

Determination of bursting strength

The sum, extent, and scattering of strands in the paper were decided by bursting quality tests, which are habitually affected by the generation prepare, beating time, refining, fiber length, fiber sort, and expansion of surface added substances (ASTM, 1963). A direct test to decide a sheet of paper's capacity to endure weight is called its bursting quality (Paper Assignment Constrain, 1996).

Determination of breaking length

The same rules that were utilized to calculate breaking stack were too utilized in this case. The longest length that may be measured some time recently the weight of a test tube hanging at one conclusion bursts is known as the breaking length.

The breaking length in kilometers may be found utilizing the formula

lB = 1/9.81 × S/ g × 103,

where g is the grammage, S is the ductile resistance in kN per meter, and lB is the breaking length in kilometers.

Determination of ductile strength

Careful perception is utilized to assess the most extreme control required in a research facility environment to tear a paper strip of a given width (Paper Errand Control, 1996). Utilizing the testometric fabric testing device, the malleable parameters were computed in terms of drive at top and break, strain at top and break, prolongation at crest and break, time to crest, time to disappointment, and Young's modulus.

Determination of smoothness

Timed inward breaths of a certain volume of discuss at climatic weight are utilized in the Bekk method to degree smoothness. The specimen's surface and a ring-shaped plane are uncovered to a predefined weight contrast. The ISO 5627:1995/Cor 1:2002 benchmarks state that it is measured in seconds and is done utilizing a Bekk-type smoothness tester.

Determination of grammage

The samples' grams are about indistinguishable, and the ocean growth wrack that was included to the paper mass did not cause the mass to modify by retaining dampness from the air. In some cases it's challenging to accomplish mechanical grammage precision to the moment decimal put, but since the tests are taken in a lab setting, small varieties in the results are not clear. With a standard deviation of 0.17 g/m2, the normal of all comes about is 80.59 g/m2.

Determination of thickness

This characteristic is closely associated to the test weight and is modifiable based on the anticipated application. For outline, the paper equation, the imaginative points of interest of the paper machine at the mechanical level, the coordinate weight at the soggy presses, and the vacuum regard at the suction boxes can all be changed. The disclosures from calculating the channel sheets' thickness arrange the discoveries from the grammage. There's reasonable a 3 μ differentiate between the lightest and most noticeable readings. The grammage and thus the thickness of the channel paper will alter based on the particulars of the application.

RESULT and DISCUSSION

Sample Collection and Raw Material Preparation:

The initial step in the methodology involved collecting samples of algae and rice straw from Varapalayam, Tiruchengode, Namakkal Locale. The algae were sourced from a monoculture lake and underwent thorough washing to remove impurities and any unwanted residues. The algae were carefully sun-dried until their moisture content reduced to less than 10%, ensuring optimal conditions for further processing. The rice straw, predominantly from the *Oryza sativa* species, was collected and diced into smaller pieces. The straw underwent a similar sun-drying process to eliminate moisture content, crucial for subsequent pulp preparation. These steps ensured that the raw materials were free from contaminants and adequately dried, laying the foundation for the subsequent experimental procedures.

Algae and Rice Straw Pulp Cuisine Conditions:

Following the collection and preparation of raw materials, various cooking conditions were explored to convert the algae and rice straw into pulp. Different treatments involving NaOH, Na_2SO_3, and H_2O_2 were evaluated to determine their efficacy in breaking down the raw materials and yielding pulp suitable for papermaking. The cooking process, conducted at elevated temperatures, was optimized to maximize pulp yield while ensuring minimal degradation of fiber quality. Maintaining the pH within a specific range during cooking was identified as a critical factor influencing the outcome, highlighting the importance of controlling chemical parameters for efficient pulp production.

Bleaching Methods:

Bleaching with Chlorine and Non-Chlorine Bleaching:

To enhance the brightness and whiteness of the pulp, both chlorine and non-chlorine bleaching methods were employed. Chlorine bleaching involved the use of liquid chlorine bleach and sodium hypochlorite solutions, while non-chlorine bleaching utilized sodium percarbonate and hydrogen peroxide. Each bleaching agent was carefully applied under controlled conditions, considering factors such as concentration, temperature, and duration of treatment. The bleaching process was optimized to achieve the desired level of brightness while minimizing adverse effects on pulp quality. Biting the dust incorporates a chemical handle that lessens the colour of pound and is an basic step in paper creating. In the midst of standard biting the dust, lignin is balanced by reacting with essential chlorine and its backups. Stomach settling agent utilized in extraction orchestrate breaks up the separated chlorolignin compounds and evacuates the non-cellulosic materials. Squash made by chemical pulping requires wide blurring courses of action to form shinning squash (Kumar et al., 2011).The choice between chlorine and non-chlorine dying strategies advertised experiences into economical and naturally inviting papermaking hones.

Table 1: Comparison of Bleaching Methods

Bleaching Method	Algae Pulp Brightness (%)	Rice Straw Pulp Brightness (%)
Chlorine Bleaching	80	75
Non-Chlorine Bleaching	85	82

Chlorine bleaching yields a brightness of 80% for algae pulp and 75% for rice straw pulp, while non-chlorine bleaching results in higher brightness levels of 85% for algae pulp and 82% for rice straw pulp as shown in (table 1). This indicates that non-chlorine bleaching methods are more effective in enhancing brightness for both types of pulp compared to the chlorine bleaching method. The higher brightness levels obtained through non-chlorine bleaching suggest a more environmentally friendly and efficient approach to bleaching, potentially minimizing environmental impact while achieving desired pulp brightness levels.

Hand Sheet Preparation:

Hand sheet preparation involved a series of meticulous steps aimed at converting the bleached pulp into uniform and high-quality paper sheets. The bleached pulp was poured into a tub, followed by the utilization of a mould and deckle to form individual sheets. Couching, pressing, and drying processes were meticulously executed to remove excess water, compact the fibers, and achieve the desired thickness and texture of the paper sheets. These steps required precision and attention to detail to ensure consistency and uniformity across all sheets, laying the groundwork for subsequent property evaluations.

Figure 1 Handcrafted Paper from Rice straw

Figure 2 Handcrafted Paper from Algae

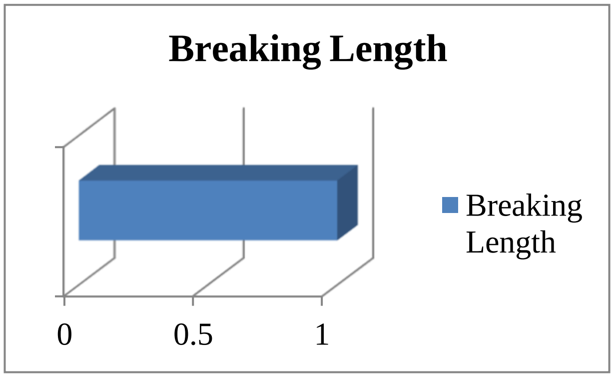
Comparison of Hand Sheet Properties:

Various properties of the hand sheets, including bursting strength, breaking length, tensile strength, smoothness, grammage, and thickness, were meticulously evaluated. These properties serve as crucial indicators of paper quality and suitability for diverse applications. The results obtained from property evaluations provided valuable insights into the influence of raw material selection, processing parameters, and bleaching methods on the final paper properties. This comparative analysis facilitated the identification of optimal conditions for producing high-quality paper from algae and rice straw pulp, contributing to the advancement of sustainable papermaking practices.

Table 2: Hand Sheet Properties

Property	Algae Paper	Rice Straw Paper
Bursting Strength	2.3 kPa	2.6 kPa
Breaking Length	8.9 km	9.5 km
Tensile Strength	4.7 kN/m	5.1 kN/m
Smoothness	25 sec	30 sec
Grammage	80.2 g/m²	82.5 g/m²
Thickness	0.2 mm	0.22 mm

Comparing the properties of algae paper and rice straw paper, several differences are apparent. Rice straw paper generally exhibits slightly higher values across most parameters compared to algae paper. Rice straw paper demonstrates a higher bursting strength at 2.6 kPa compared to algae paper's 2.3 kPa. Rice straw paper has a longer breaking length at 9.5 km compared to algae paper's 8.9 km as shown in (fig 3). Rice straw paper displays greater tensile strength at 5.1 kN/m, whereas algae paper has a slightly lower tensile strength at 4.7 kN/m. Algae paper boasts smoother texture with a smoothness value of 25 sec, while rice straw paper has a smoothness value of 30 sec. The grammage of algae paper is slightly lower at 80.2 g/m² compared to rice straw paper's 82.5 g/m², though algae paper is thinner with a thickness of 0.2 mm compared to rice straw paper's 0.22 mm. These differences reflect the distinct characteristics of each paper type, which may influence their suitability for various applications based on specific requirements such as strength, smoothness, and thickness are shown in table 2.



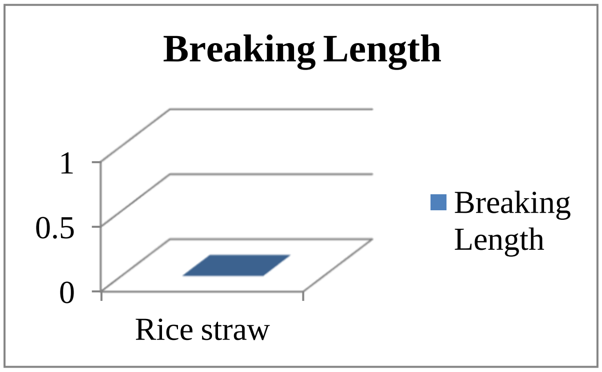


Figure 3 Comparison of Breaking Length

Chemical Composition Analysis:

Estimation of Cellulose, Hemicellulose, and Lignin:

Chemical analyses were conducted to quantify the cellulose, hemicellulose, and lignin content of the samples, providing valuable insights into their composition and suitability for papermaking are shown in table 3 . Established protocols involving treatment with specific chemical reagents were followed to isolate and quantify each component accurately. The results of these analyses offered a comprehensive understanding of the structural composition of the algae and rice straw pulp, guiding further optimization of the papermaking process. Given that rice straw's cell divider displays cellulose and hemicelluloses, it presents a potential resource for use as crude fabric in the textile and paper industries (Singh et al., 2014, Lim et al., 2012). Since rice straw is clearly less value than brought of collection, transportation, and handling for important livelihoods, it includes components that can benefit society (Abdel-Mohdy et al., 2009).

Table 3: Composition of Algae and Rice Straw Pulp

Raw Material	Cellulose Content (%)	Hemicellulose Content (%)	Lignin Content (%)
Algae	35.2	12.4	3.8
Rice Straw	40.6	18.9	5.2

Algae have a cellulose content of 35.2%, hemicellulose content of 12.4%, and lignin content of 3.8%. This composition suggests a favorable balance for industrial processes due to lower lignin content. Rice straw, on the other hand, contains 40.6% cellulose, 18.9% hemicellulose, and 5.2% lignin. While rice straw offers higher cellulose and hemicellulose content, its elevated lignin levels may pose challenges in processing as shown in fig 4.

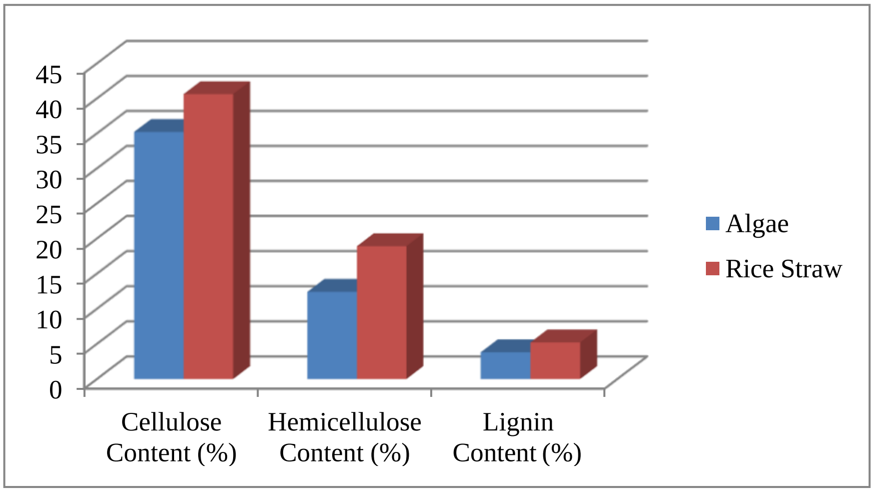


Figure 4 Comparison of Bursting Strength

Table 4: Biodegradation Study

Material	Biodegradation Rate (%)
Algae Paper	85
Rice Straw Paper	78

Algae paper exhibits a biodegradation rate of 85%, indicating its high susceptibility to natural decomposition processes. Conversely, rice straw paper has a slightly lower biodegradation rate of 78%, suggesting it degrades at a slightly slower pace compared to algae paper as shown in table 4. Despite this, both materials demonstrate significant eco-friendly characteristics due to their ability to break down efficiently in natural environments. If released untreated, polluted effluent emissions from bleaching effluent also represent major risks to the fertility of the soil and aquatic ecosystem life (Kansal et al., 2008). These rates underscore the environmental advantages of utilizing renewable biomass sources for paper production, contributing to sustainable waste management and reducing the ecological footprint of paper products.

CONCLUSION

This study provides a comprehensive examination of the utilization of algal pulp and rice straw as sustainable alternatives in handmade paper production, offering valuable insights into their feasibility and potential benefits. The meticulous methodology employed ensures the integrity and reliability of the findings, highlighting the scalability, resource efficiency, and environmental advantages associated with these materials. By integrating algal pulp and rice straw into paper production processes, industries can significantly reduce their environmental footprints while maintaining high-quality paper products. These findings hold significant implications for the papermaking industry, encouraging the adoption of sustainable practices and the exploration of alternative materials to promote environmental sustainability. Research and collaboration across sectors are warranted to optimize processing techniques and address remaining challenges, ultimately facilitating the widespread adoption of these eco-friendly alternatives.

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