Green Solutions: Handmade Paper from the Invasive Weed Artemisia Absinthium

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Abstract: This study explores the potential of Artemisia absinthium, commonly known as wormwood, as a sustainable raw material for paper production. As environmental concerns about deforestation and pollution grow, the search for alternative, eco-friendly resources becomes increasingly important. A. absinthium, known for its fast growth and abundance, offers a promising solution. The research involved the extraction and processing of fibers from wormwood plants, followed by their conversion into pulp suitable for paper manufacturing. The mechanical and chemical properties of the resulting paper were evaluated and compared with conventional wood-based paper. Results indicated that wormwood-derived paper exhibits comparable strength, durability, and printability, while also being more biodegradable. Additionally, the cultivation of the weed requires fewer agricultural inputs, such as water and fertilizers, making it a more sustainable crop. This study also highlights the economic benefits for farmers and industries in regions where wormwood is readily available. By utilizing A. absinthium as a raw material, the paper industry can reduce its ecological footprint and contribute to a more sustainable future. Further research is recommended to optimize the processing techniques and explore the potential of combining wormwood fibres with other natural fibres to enhance paper quality. The findings of this study advocate for the inclusion of A. absinthium in the repertoire of raw materials for eco-friendly paper production, marking a significant step towards sustainable industrial practices.

Keywords: Artemisia absinthium, Invasive weed, Sustainable papermaking, Weed management.

Introduction

Artemisia absinthium, commonly known as wormwood, is a perennial herb renowned for its medicinal properties and distinctive aroma. Traditionally used in the production of absinthe and as a therapeutic herb, A. absinthium has recently garnered attention for its potential in sustainable paper production. This innovative approach aims to address the growing environmental concerns associated with conventional paper manufacturing, which relies heavily on wood pulp and contributes to deforestation and significant carbon emissions (Danielewicz D. et al., 2015).

The exploration of alternative raw materials for paper production is crucial in mitigating the adverse environmental impacts of the traditional paper industry (Ali F. et al., 1993; Pintor et al., 2018). A. absinthium presents a promising solution due to its rapid growth, adaptability to various climates, and high cellulose content. The plant's fibrous structure makes it an excellent candidate for pulp production, potentially reducing the reliance on wood and promoting more sustainable forestry practices (Singh SP. et al., 2003; Vrabic et al., 2022). Studies have indicated that the cellulose fibers derived from A. absinthium are comparable in quality to those obtained from traditional sources, such as trees.

In addition to its environmental benefits, the use of A. absinthium in paper production offers significant economic advantages. The cultivation of this herb requires fewer resources compared to trees, and it can be harvested multiple times a year, providing a continuous supply of raw material (SanajyNaithani et al., 2008; Tamri et al., 2017). This could lead to reduced production costs and increased profitability for paper manufacturers. Furthermore, the utilization of A. absinthiumcan support rural economies by creating new agricultural opportunities and promoting sustainable farming practices (Staresinic M. et al., 2021).

The process of converting A. absinthiuminto paper involves several steps, including harvesting, pulping, and paper formation. The harvested plants are initially processed to extract the cellulose fibers, which are then subjected to chemical or mechanical pulping methods. The resulting pulp is subsequently refined and formed into sheets of paper (Lau et al., 2018; SangeetaPandita et al., 2015; Rishi Raj et al., 2018). Recent advancements in pulping technology have improved the efficiency and quality of paper produced from non-wood sources, making A. absinthiuma viable alternative to traditional raw materials (Benjamin et al., 2019).

Despite the potential benefits, the widespread adoption of A. absinthiumfor paper production faces certain challenges. These include the need for further research to optimize pulping processes, the development of scalable production techniques, and the establishment of supply chains for the consistent availability of raw materials (Kapun et al., 2022). Additionally, there are regulatory and market acceptance barriers that must be addressed to facilitate the integration of this alternative material into mainstream paper production (Islam M.N. et al., 2021).

The paper explores the production of handmade paper from A. absinthium, incorporating aloe vera and washing soda in the process. This involves a series of steps, starting with the collection of suitable weed materials, considering factors such as availability, fiber content, and desired paper characteristics. Weeds commonly utilized include nettles, grasses, thistles, and other fibrous plants, chosen for their potential in creating unique and environmentally sustainable paper products (Paula et al., 2023). By blending traditional craftsmanship with modern techniques, the process aims to leverage abundant and often overlooked resources, thereby reducing dependence on conventional wood pulp. Through ongoing experimentation and innovation, artisans are enhancing this method, broadening possibilities for creative expression and promoting eco-friendly practices in handmade paper production (Roxo CA., et al., 1998, Emmclan, L. S. H., et al., 2018).

The utilization of weeds as raw materials not only facilitates resource efficiency but also aligns with sustainable principles by minimizing environmental impact. This approach encourages a shift towards eco-conscious papermaking practices, emphasizing the value of exploring diverse botanical sources for their inherent fibers (Sonia Rani et al., 2018; Bhodiwal et al., 2024). As artisans refine techniques and explore new combinations of materials like aloe vera and washing soda, they contribute to a growing movement in sustainable craftsmanship. This thesis underscores the potential of weeds in supporting creative and environmentally responsible paper production, offering a pathway towards diversified and sustainable materials in the handmade paper industry (Karlovits I. et al., 2022).

In conclusion, A. absinthiumrepresents a promising and sustainable alternative for paper production, offering environmental, economic, and social benefits. Continued research and innovation are essential to overcoming the current challenges and unlocking the full potential of this versatile herb. By exploring and investing in alternative raw materials like A. absinthium, the paper industry can move towards a more sustainable and eco-friendly future (Nelson GM., et al., 1996).

Materials

In this study, A. absinthium was sourced from Sakthi Nagar near EASA College in Coimbatore, Tamil Nadu, India, as shown in Fig. 1. The weighing balance used was manufactured by EAGLE. Chemicals such as washing soda and caustic soda were obtained from the environmental laboratory at EASA College. An induction stove and utensils were sourced from household supplies, while aloe vera was collected from local fields. Mould and deckle, as well as mesh and cotton cloth, were procured from local suppliers. The hot air oven utilized in the experiment was provided by the environmental laboratory.

Collection of weed

The collection process involved meticulous selection and harvesting of these plants, typically when they were at their peak growth stage, to ensure optimal fiber quality. Before harvesting, careful inspection was conducted to exclude diseased or contaminated plants, ensuring the final paper's integrity. Post-harvest, the weeds were cleaned thoroughly to eliminate dirt, debris, and unwanted substances. Depending on the weed type and its fiber characteristics, additional methods such as boiling, soaking, or mechanical extraction were used to effectively extract fibers. This systematic approach to collecting and preparing weed materials formed the basis for sustainable and environmentally friendly handmade paper production, leveraging easily accessible resources while minimizing ecological footprint.

Fig. 1. Collection ofArtemisia absinthium

Preparationofpulp

Preparing pulp from weeds involved initial steps such as cutting and weighing the plant material, followed by breaking down the fiber content through boiling. This process aimed to extract fibers effectively, preparing them for subsequent stages in handmade paper production.

Making the sheet

The torn leaves were first immersed in water to soften and disintegrate the fibers, with soaking durations adjusted based on paper type and desired pulp consistency (Singh, S. P., et al. 2003). Once sufficiently softened, the soaked paper was transferred to a blending container, where it underwent further breakdown using a blender or pulping machine to achieve a uniform pulp texture. Additional water was introduced during blending to reach the desired pulp consistency, ensuring a smooth and even mixture devoid of large clumps. For added texture or colour variation, supplementary materials like plant fibers or dyes could be integrated into the pulp blend. With the pulp prepared, attention shifted to assembling the mould and deckle,

comprising a frame with a fine mesh screen and a removable edge-framing frame, which were shown in Fig. 2. and Fig. 3. These components were closely fitted to prevent leakage during sheet formation. To initiate paper sheet formation, the mould and deckle were submerged in a water-filled vat, where the pulp mixture was gently agitated for even dispersion. Once evenly spread, the mould and deckle were lifted vertically from the water, allowing excess water to drain through the mesh screen while leaving a thin layer of pulp on the surface. The remaining pulp began to bond together as the water drained, forming the foundational layer of the paper sheet. To further consolidate the fibers and remove excess water, the mould and deckle were gently agitated to create a smooth, consistent surface on the emerging sheet.

Fig. 2.Mixed wellthe pulp intowater

Fig. 3.Makingthesheet

Depending on the desired thickness, additional pulp layers were added, ensuring each layer was evenly distributed and adhered to the previous one. After achieving the desired thickness, the mould and deckle were placed on a flat surface, covered with absorbent material such as fabric or felt to aid water removal. Pressure was applied with a press or weighted object to compress the sheet, expelling excess water and enhancing fiber bonding. Following pressing, the mould and deckle were separated carefully, leaving the formed paper sheet on the screen. The wet paper sheet was transferred to a drying surface, allowing air circulation for gradual moisture evaporation. Drying durations varied based on environmental conditions, necessitating periodic flipping or repositioning to prevent curling or warping. As the paper dried, fiber bonding intensified, resulting in a sturdy and resilient sheet. Once fully dry, the paper sheet was carefully removed from the drying surface and any irregularities were trimmed using scissors or a blade. The completed paper sheet was now ready for use in various artistic or practical applications.

Procedure

The process began with selecting A. absinthium as the raw material, followed by harvesting and weighing the weed scraps and soaking them overnight to soften the fibers. The next step involved boiling the chopped weeds in an electric oven at 300°C

for 2 hours. Then, caustic soda (NaOH) of 6% was added to break down the fiber content. After draining and beating the boiled weed until smooth, additives like 250 ml of aloe vera were blended in for additional binding. A mould, consisting of a fine mesh screen stretched over a frame, along with a deckle to define sheet edges, was used to form the paper pulp mixture in a vat of water. The mixture was gently stirred and evenly dispersed before lifting the mould vertically to drain excess water through the screen. To remove further water and compress the pulp fibers, pressure was applied using absorbent material and a weighted object. The wet paper sheets were then transferred to a hot air oven at 120 °C for 30 minutes and air-dried completely, periodically flipping for even drying. Once dry, the paper sheets were carefully peeled from the surface, trimmed for neatness, and used for printing, crafting, or other purposes. Various pulp mixtures, additives, and techniques were experimented with to achieve desired textures, colours, and effects, and the handmade paper was stored flat in a dry place to prevent curling.

Results and Discussion

The pulping of the invasive weed A. absinthium using different concentrations of NaOH demonstrates a clear relationship between the chemical concentration and the yield of pulp produced, which is shown in Table 1. At a lower NaOH concentration of 4%, the yield is relatively high at 68.3%, indicating that a significant amount of the original material remains intact during the pulping process. As the NaOH concentration increases to 6%, the yield decreases to 64.1%, showing a slight reduction in the amount of pulp retained. This trend continues with 8% NaOH, resulting in a further reduced yield of 57.4%, and at 10% NaOH, the yield drops to 53.2%. This inverse relationship suggests that higher NaOH concentrations are more effective at breaking down the weed's fibrous structure, resulting in a greater removal of non-cellulosic components and a lower yield of the final pulp.

Table 1.Pulping of weed (A. absinthium) at different NaOH

S.NO	Parameters	
	NaOH (%)	Yield (%)
1	4	68.3
2	6	64.1
3	8	57.4
4	10	53.2

The decreasing yield with increasing NaOH concentration can be attributed to the enhanced chemical action of NaOH in breaking down the lignin and hemicellulose present in A. absinthium. Lignin, which acts as a binding agent in plant cell walls, is

more effectively dissolved at higher alkali concentrations, leading to a more thorough separation of the cellulose fibers and a reduction in overall yield (SharminSuraiya et al., 2023). Additionally, the more aggressive pulping conditions likely degrade some of the cellulose, contributing to the observed decrease in pulp yield. This data underscores the need to balance the concentration of NaOH to optimize the pulping process, ensuring sufficient breakdown of the weed while maintaining a desirable yield for sustainable and eco-friendly papermaking.

These findings underscored the critical role of chemical concentration in determining the yield and quality of pulp derived from weeds for paper production. A precise adjustment of NaOH concentration was essential for optimizing fiber breakdown and achieving desirable pulp yields (RanjanaNeelagar et al., 2018). This emphasized the need for careful control and calibration in the papermaking process using weed materials, ensuring efficient utilization of resources and maintaining product quality.

The handmade paper derived from A. absinthium, characterized by its rough texture and subtle variations in dark and pale green hues, represents a sustainable innovation in papermaking. This eco-friendly material offers a distinctive tactile experience; its surface is subtly textured yet gentle to the touch, making it ideal for both drawing and writing purposes. Its foldable nature enhances practicality, allowing for versatile applications in artistic creations and everyday use (Rai AK. et al., 2000). As a biodegradable product, it aligns with environmental goals, ensuring a minimal ecological footprint throughout its lifecycle. Whether used for intricate drawings that benefit from its textured surface or for written compositions that reflect its eco-conscious origins, A. absinthium paper embodies a harmonious blend of aesthetic appeal and environmental responsibility.

Beyond its tactile and aesthetic qualities, the A. absinthium paper underscores a commitment to sustainability. Its production utilizes invasive weed species, repurposing them into a valuable resource that minimizes environmental impact. By transforming these weeds into biodegradable paper, the process not only reduces waste but also contributes to ecosystem management by mitigating the spread of invasive plants (Josep Claramunt M. et al., 2020). This paper's dark and pale green hues symbolize its natural origins, reinforcing its ecological credentials and appeal to environmentally-conscious consumers. Whether folded into intricate origami creations or used as a canvas for expressive artwork, A. absinthium paper stands as a testament to innovation in sustainable materials, offering a blend of functionality and aesthetic beauty. Fig. 4 represents the final output of the handmade paper made from weed.

Fig. 4. Final output of the hand made paper using weed

The A. absinthium handmade paper exhibits unique technical properties that complement its ecological benefits. With a brightness level of 23%, it offers a subdued, natural appearance that enhances its suitability for artistic and writing applications, contributing to a calming visual experience. The paper's burst index of 2.10 kPa·m²/g indicates its resilience and durability, capable of withstanding moderate stress while maintaining its integrity. This characteristic, combined with a tensile strength of 28.90 Nm/g and a tear index of 15.50 mN·m²/g, which were shown in Table 2, underscores its practical utility in various uses, from delicate drawings to sturdy writing surfaces. These properties not only cater to artistic expression but also ensure reliable performance in everyday tasks, making A. absinthium paper a sustainable choice that merges environmental responsibility with functional excellence.

Table 2. Properties of paper derived from the weed (A. absinthium)

S.NO	PARAMETERS	VALUES
1	Brightness (%)	23
2	Burst index (kPa. m²/g)	2.10
3	Tensile strength (Nm/g)	28.90
4	Tear index (mN. m²/g)	11.50

Beyond its technical specifications, A. absinthium paper exemplifies a sustainable approach to material production. Its modest brightness level and robust physical attributes signify a commitment to utilizing natural resources efficiently, offering a biodegradable alternative to conventional paper products. By integrating these technical merits with their eco-friendly origins, this paper supports sustainable practices by repurposing invasive weed species into a resource that meets both artistic

and practical demands. Whether used for detailed illustrations or enduring written documents, A. absinthium paper embodies a harmonious balance of performance and environmental stewardship, appealing to conscientious consumers seeking sustainable solutions without compromising on quality or functionality.

Conclusion

The pulping of A. absinthium using varying concentrations of sodium hydroxide (NaOH) demonstrated that lower NaOH concentrations resulted in a higher pulp yield. This finding is significant as it suggests that effective pulping can be achieved with minimal chemical usage, thereby reducing both cost and environmental impact. The efficiency of the pulping process at lower NaOH concentrations aligns with sustainable practices, making it a preferable choice for large-scale production.

Subsequent analysis of the paper produced from this pulp revealed that its properties are suitable for printing applications. The favourable characteristics of the paper, such as texture and durability, indicate its potential for commercial use.

The process of creating handmade paper from the weed A. absinthium demonstrates a sustainable and eco-friendly approach to paper production. Utilizing this invasive species not only provides an innovative solution to managing its growth but also contributes to waste reduction and resource conservation.

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