DEVELOPMENT OF SMART COMPOSITE COATED PAPER USING AGRICULTURAL WASTE AS SUBSTITUTE FOR PETROLEUM DERIVED MULCHES

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Introduction

Modern agriculture faces growing challenges to produce higher yields while minimizing its environmental footprint. Traditional farming practices, particularly the use of plastic mulching films, have contributed to soil quality deterioration, pollution, and excessive reliance on synthetic chemicals. As concerns about sustainability and ecological health continue to rise, innovative alternatives are being sought to replace these environmentally harmful materials. One such solution lies in the development of biodegradable, multifunctional mulching paper films made using agricultural waste and natural plant extracts. These eco-friendly films possess dual advantage: they reduce agricultural waste by repurposing byproducts like corn husk, areca fiber, wheat husk coconut husk etc., and they enrich the soil with organic matter as they decompose. This closed-loop approach not only supports soil health but also addresses waste disposal issues effectively.

The integration of plant-based extracts into the films adds a layer of natural pest resistance, decreasing dependence on chemical pesticides and supporting healthier crops and ecosystems. Moreover, these films can be engineered with advanced

features such as UV protection, water retention, and sunlight reflection characteristics that enhance crop resilience in varying climatic conditions.

Smart versions of the film may also include irrigation sensors, allowing precise water management, which is crucial in regions facing water scarcity. UV shielding helps to protect delicate plants from harmful radiation, while reflective surfaces regulate soil temperature, maintaining optimal growing conditions.

By combining biodegradability, pest control, water efficiency, and environmental safety, these innovative paper films represent a comprehensive tool for sustainable agriculture. Their development and potential commercialization mark a significant step toward eco-conscious farming practices, promising a more sustainable and productive agricultural future.

Objectives

The objective of this project is to develop biodegradable, multifunctional mulching paper using agricultural waste and plant extracts as a sustainable alternative to plastic mulch. Materials like corn husk, wheat husk, areca fibre, and coconut husk help reduce waste and enrich soil as they naturally degrade. Infusing plant extracts into the paper provides natural pest resistance, minimizing the need for chemical pesticides and promoting crop and soil health. The mulching paper can also incorporate smart features such as irrigation sensors for precise water management. This conserves water and supports optimal plant growth by maintaining proper soil moisture levels. UV shielding protects sensitive crops from harmful solar radiation, while sunlight-reflective surfaces help regulate soil temperature. These features are especially beneficial in regions with intense heat, preventing crop stress and moisture loss. The biodegradable nature of the paper supports soil health and eco-friendly farming. Combining pest control, water conservation, and environmental protection, this innovation enhances sustainable agricultural practices. Its research and commercialization contribute meaningfully to the global move toward greener farming solutions.

Materials

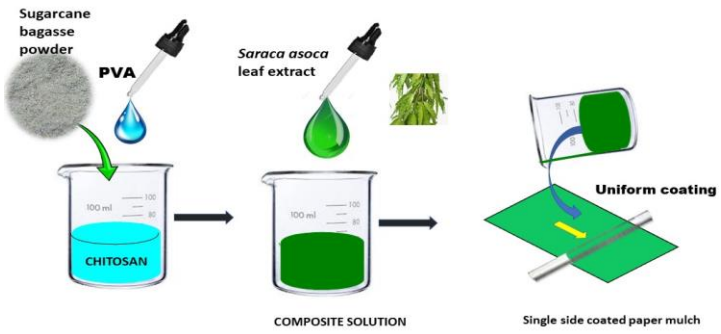
Chitosan, and Poly (vinyl alcohol) (PVA) with a degree of hydrolysis of 99% were purchased from Molychem Laboratories Mumbai, The sugarcane bagasse was collected from the local market of Mangalore. *Saraca asoca* plant leaves were collected from Mangalore University campus. Filter paper was used as base material during coating which was procured from Durga laboratory, Mangalore.

Methodology

Preparation of *Saraca asoca* leaf extract

About 60g of *Saraca asoca* leaves were collected, and they were cleaned to get rid of any dirt. The leaves were converted to powder form by grinding for 3 min using a domestic mixer. The resulting powder was transferred to about 50.0 mL of distilled water and allowed to stand for 15 min. The suspended matter was then filtered and the extract was collected which is used to make the composite.

Diagram



Preparation and Coating solution

A known amount of Chitosan was dissolved in 75.0 mL of distilled water containing 1.0 mL acetic acid by stirring for 1h at room temperature. To this solution, a known volume

of PVA solution (prepared by dissolving 2.0 g of PVA in 50.0 mL water) was added. Accurately measured sugarcane bagasse powder was then added to the above mixture and stirred for 8h to ensure uniform dispersion. Subsequently, a known volume of leaf extract was added and solution was stirred for 15 min. The resulting mixture was subjected to ultrasonication to enhance dispersion and was used for coating. The composition of the coating solution were varied to get six combinations as mentioned in Table 1. The solution was referred to as composite coating solution.

Coating

Paper sheets (area: 176 cm^2) were used as base material. A uniform coating was applied using 55.0 mL of the composite coating solution (equivalent to 3.5 mL/m^2) with a brush and a rod. The coated papers were dried at 50 °C for 48h and then stored at 37 °C for further analysis.

Sl.No.	Wt. % of chitosan	Volume of PVA solution (v/v) %	Wt. % Sugarcane bagasse	Volume of plant extract (v/v) %
1	77.0	10.5	23.0	10.5
2	77.0	19.0	23.0	9.5
3	83.0	10.5	17.0	10.5
4	77.0	19.0	23.0	9.5
5	81.0	19.0	19.0	9.5
6	77.0	10.0	23.0	15.0

Results and conclusion

The composite solutions were successfully prepared by incorporating chitosan, PVA, sugarcane bagasse powder, and plant leaf extract. The dispersion appeared homogenous after the 8 h stirring and ultrasonication process. A visible increase in viscosity was noted with increasing sugarcane bagasse content which also affected the ease of application during coating.

The coatings adhered uniformly to the paper surface, forming a smooth and continuous film. Drying at 50 °C for 48 h resulted in well-set films with no visible cracks or peeling. Notably, higher bagasse content (23 wt.%) led to a slightly rougher surface texture due to the increased fiber content, but coating integrity remained intact.

Upon storage at 37 °C, the coated papers maintained structural stability. No delamination or microbial growth was observed, indicating good preservation properties, potentially attributed to chitosan and the bioactive compounds in the leaf extract.

Six single-side coating trials were attempted using the composition mentioned in the Table. Among these, composition mentioned as Sl.No.2 demonstrated superior mechanical properties and a uniform surface finish. Based on its performance, the combination mentioned as Sl.No. 2 has been selected for dual-side coating which is to be achieved in the next phase of the project.

Scope of the future work

The scope of this project lies in developing biodegradable, multifunctional mulching paper using agricultural waste and plant extracts to address key challenges in sustainable agriculture. This innovative material aims to replace conventional plastic mulch, significantly reducing long-term soil pollution and contributing to environmental preservation. By utilizing agro-waste sugarcane bagasse, the project not only promotes waste valorization but also enhances soil fertility through natural biodegradation. Incorporating plant extracts introduces eco-friendly pest resistance, minimizing dependence on harmful chemical pesticides and improving crop health. The scope also extends to integrating smart features such as embedded irrigation sensors for efficient water management, ensuring optimal moisture levels for crops. UV shielding and sunlight-reflective properties further help in protecting plants from solar stress and in maintaining soil temperature, especially in arid and high-heat environments. It opens avenues for scalable and cost-effective production methods suitable for both small-scale and commercial farming. This biodegradable solution supports carbon footprint reduction, enhances yield quality, and preserves long-term soil health. With increasing global emphasis on sustainable practices, this project holds significant potential for

commercialization and policy integration. It encourages circular economy models and promotes a green transition in the agricultural sector. The research can inspire further innovation in bio-based agricultural inputs and packaging materials. Additionally, it offers educational and collaborative opportunities among academic institutions, industries, and farming communities. The project aligns with global sustainability goals, including climate resilience and responsible resource use, contributing to a more sustainable food system.