PECTIN-ENHANCED RECYCLED TISSUE PAPER: A SUSTAINABLE GREEN TECHNOLOGY AS AN ALTERNATIVE TO VIRGIN PULP FOR THE MODERN PAPER INDUSTRY

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Keywords

Pectin, Recycled paper, Citrus peel waste, Biodegradable tissue, Water absorption, Glycerol, Circular economy, Sustainable materials

Introduction

The global demand for tissue paper has been rapidly increasing, reaching approximately 44 million tons in 2023 and projected to grow further. However, conventional tissue production relies heavily on virgin wood pulp and chemical-intensive processes, leading to deforestation, environmental degradation, and high energy consumption. Recycling paper offers a sustainable alternative, but recycled fibers often suffer from reduced strength, softness, and absorbency due to structural degradation during processing.

To address these limitations, natural bio-based additives such as pectin have gained attention. Pectin, a biodegradable polysaccharide extracted from citrus waste like pomelo peels, exhibits excellent water-binding and gel-forming properties. Incorporating pectin into recycled pulp can enhance fiber bonding, improve moisture retention, and restore softness.

Additionally, softening agents such as glycerol, gelatin, and polyvinyl alcohol (PVA) can further improve flexibility and texture. This study explores a green and cost-effective approach to produce high-quality tissue paper from recycled pulp reinforced with pectin.

By utilizing both fruit waste and paper waste, the project aligns with circular economy principles, reducing environmental impact while creating value-added biodegradable products. This approach presents a sustainable alternative to conventional tissue manufacturing.

Objectives

1. To extract pectin from pomelo peels using an eco-friendly method
2. To incorporate pectin into recycled paper pulp
3. To evaluate the effect of varying pectin concentrations on tissue properties
4. To enhance flexibility using softening agents (glycerol, gelatin, PVA)
5. To analyse water absorption capacity and mechanical properties
6. To identify the optimal formulation for strength and softness
7. To develop a sustainable alternative to virgin pulp-based tissue paper

Methodology

Diagrammatic Representation of Methodology:

Pomelo peel

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Gel extraction from pomelo peel

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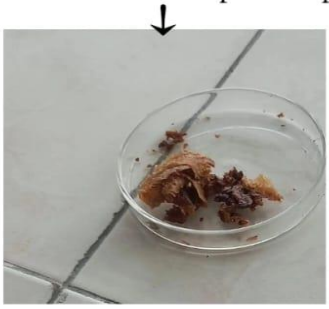

Pectin extract+ scrap papers + additionals

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Paper making
(Recycled paper)

Pectin was extracted from pomelo peels using citric acid-assisted hot aqueous extraction followed by ethanol precipitation. The extracted gel was dried and powdered. Recycled paper was deinked and converted into pulp using a high-speed blender.

Different concentrations of pectin (1.96–7.41 wt.%) were added to the pulp to prepare multiple formulations. A control sample without pectin was also prepared. For optimization, softening agents such as glycerol, gelatin, and PVA were added individually at 5% and 10% concentrations relative to pectin content.

The pulp mixtures were cast into sheets using a mesh frame and dried under controlled conditions. The prepared sheets were conditioned at room temperature for 48 hours to stabilize moisture content.

Water absorption capacity was evaluated by immersing pre-weighed samples in water for specific time intervals and calculating percentage absorption. Flexibility and brittleness were assessed using fold endurance tests and qualitative ratings.

Comparative analysis was performed between control and treated samples to determine improvements in strength, softness, and absorbency. The optimal formulation was identified based on performance metrics.

Figure.1 Pectin extraction from the Pomelo peels and precipitation.

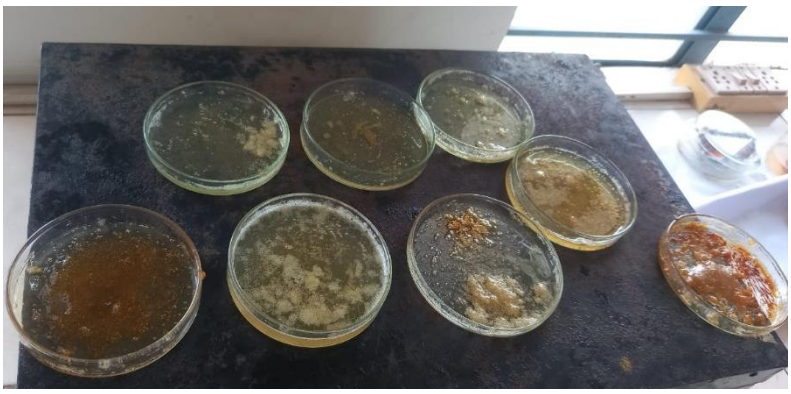

Figure 2. Collected gel was dried using hot plate, to get pectin pellet.

Figure 3. Pectin pellet

Figure 4. Displays the conditioning of pectin added sheets post drying.

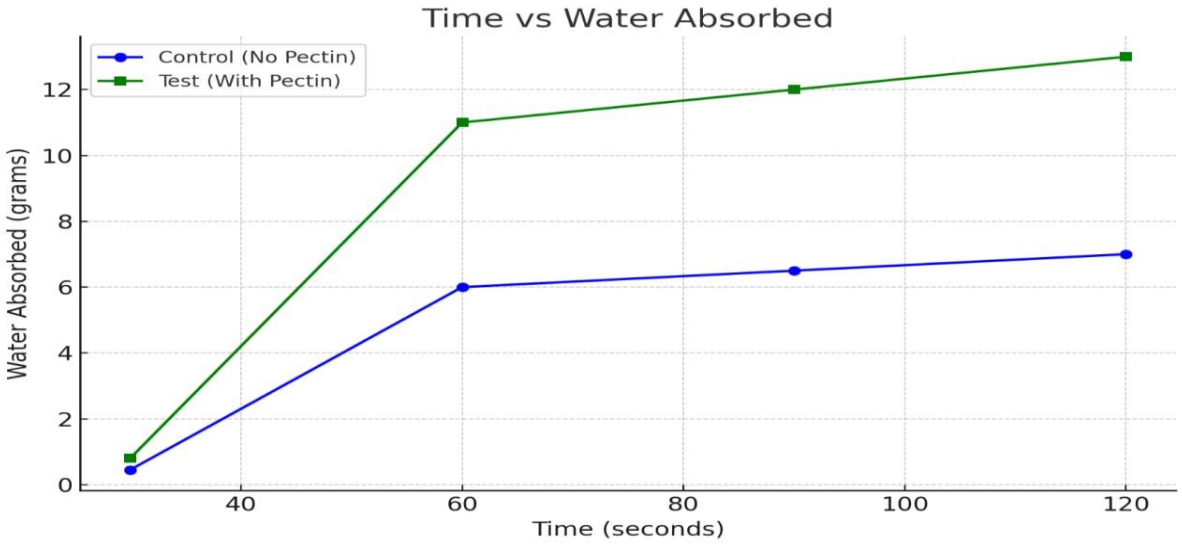

Figure 5. Represents the graph of Time Vs Absorption (shows the difference between normal recycled paper and Pectin-added recycled paper)

Results & Conclusions

1. The extraction process yielded approximately 20% pectin from pomelo peels, demonstrating efficiency using a simple and eco-friendly method. Incorporation of pectin significantly improved the physical properties of recycled paper.
2. Among the tested formulations, 4.76 wt.% pectin (P3) showed the best balance between strength, softness, and flexibility. Lower concentrations resulted in weaker sheets, while higher concentrations caused increased stiffness.

3. Water absorption capacity increased notably in pectin-treated samples compared to control, confirming enhanced hydrophilicity. The addition of softening agents further improved flexibility.
4. Glycerol at 10% concentration exhibited the best performance, producing highly flexible and soft sheets. Gelatin provided moderate improvement, while PVA enhanced structural stability but was less effective in softness.
5. Overall, the study confirms that pectin significantly enhances recycled tissue quality and, when combined with glycerol, produces an optimal biodegradable product.

Project Outcome & Industry Relevance

1. This project demonstrates a sustainable method for producing high-quality tissue paper using recycled materials and agricultural waste. It offers an eco-friendly alternative to conventional tissue manufacturing, reducing dependence on virgin pulp.
2. The process is cost-effective, scalable, and suitable for small- and medium-scale industries. It supports waste valorisation by converting citrus peel waste into valuable bio-additives.
3. Industrially, this approach can reduce environmental pollution, lower production costs, and promote green manufacturing practices. It aligns with global sustainability goals and circular economy models.
4. The developed product has potential applications in hygiene products, packaging, and biodegradable materials industries.

Working Model vs. Simulation/Study

This project is a working experimental model involving laboratory-scale extraction, pulp processing, and sheet fabrication rather than a simulation.

Project Outcomes and Learnings

1. Gained hands-on experience in biomaterial extraction and paper fabrication
2. Understood the role of natural polymers in material enhancement
3. Learned about sustainable material development and circular economy concepts
4. Developed skills in experimental design and analysis
5. Identified optimal formulation for biodegradable tissue production
6. Enhanced knowledge in eco-friendly industrial applications

Future Scope

1. Future work can focus on scaling up the process using mechanized paper-making techniques for industrial applications. Further research can explore the use of other agricultural wastes such as banana peels or apple pomace for pectin extraction.
2. Advanced characterization techniques can be used to study fiber bonding and microstructure in detail. Durability and performance testing under real-life conditions can help validate commercial viability.
3. Blending pectin with other natural polymers or nanocellulose could further improve mechanical strength and softness. Optimization of drying and sheet formation processes can enhance production efficiency.
4. Additionally, exploring biodegradable coatings and antimicrobial additives can expand applications in medical and hygiene sectors.
5. Collaboration with industries can facilitate pilot-scale production and commercialization. Overall, this research opens pathways for sustainable material innovation and eco-friendly product development.