

Physical, Bio-logical and Mechanical properties of Cotton – Viscose Blended with Orange Peel Powder

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Abstract - Orange peel, a major agro-industrial by-product of juice and food processing, represents nearly 40–50% of the fruit's mass and is typically discarded. Rich in cellulose, pectin, hemicellulose, and essential oils, this biomass holds great potential for sustainable fibre and functional material production. This unique composition positions orange peel as an underutilized, renewable resource with immense potential for sustainable fibre and functional material production. This project aims to develop a sustainable, fully biodegradable wipe utilizing these discarded orange peels. The methodology focuses on extracting and processing the orange peel fiber to form the wipe's substrate. This natural substrate will be subsequently infused with the peel's inherent citrus essential oil, leveraging its proven antimicrobial and cleansing characteristics. This research contributes to a circular economy model by converting agricultural waste into a high-value product, offering an effective, plant-based alternative to conventional, synthetic non-biodegradable wipes, thereby mitigating plastic pollution and reducing landfill volume.

Key Words: Orange Peel, Agro-industrial By-product, Biodegradable Wipes, Orange Peel Fiber, Cellulose, Essential Oil, Citrus Oil, Sustainable Material, Antimicrobial Properties, Circular Economy, Waste Valorization, Plastic-free.

1. INTRODUCTION

The rapid growth in the use of disposable wipes composed of synthetic polymers such as polyester and polypropylene has intensified environmental concerns due to their non-biodegradable nature, leading to persistent microplastic pollution and landfill accumulation. Despite their functional advantages, including durability and high absorbency, these materials pose significant challenges to sustainable waste management. Concurrently, the citrus-processing industry

generates substantial quantities of orange peel waste, accounting for nearly half of the fruit's total mass. This by-product is rich in cellulose, hemicellulose, pectin, and essential oils, yet remains largely underutilised.

Recent advancements have highlighted the potential of *Citrus sinensis* peel as a renewable raw material for fibre extraction and biopolymer development. However, most existing studies focus on textile or composite applications, with limited exploration in biodegradable hygiene products. In this context, the present study proposes the extraction of cellulose fibres from orange peel waste and their utilisation in the production of biodegradable wipes. The incorporation of naturally derived citrus compounds enhances antimicrobial and cleansing properties, reducing dependence on synthetic chemical agents.

By converting agro-industrial waste into a value-added functional product, this research aligns with circular economy principles and promotes sustainable material innovation. The study aims to provide an eco-friendly alternative to conventional wipes while addressing both waste valorisation and environmental sustainability challenges.

2. MATERIALS AND METHODS

2.1 Materials

Orange peel (*Citrus sinensis*) waste was collected from local juice processing units and used as the primary raw material for fibre extraction and essential oil recovery. The peels were thoroughly washed to remove impurities and dried under sunlight before further processing.

Cotton and viscose fibres were selected as base materials for wipe development due to their biodegradability, absorbency, and skin compatibility. Cotton provides softness and breathability, while viscose enhances moisture absorption and uniform fibre distribution. The chemicals and reagents used in the study included sodium hydroxide (NaOH) for cellulose

extraction, ethanol as a solvent for formulation preparation, glycerine as a humectant, and sodium alginate as a natural binder. Distilled water and filter paper were also used during processing and filtration stages.

2.2 Extraction of Citrus Essential Oil

Citrus essential oil was extracted from fresh orange peel using a solvent-based extraction method. The peel material was processed to release oil-containing sacs, and ethanol was used as the extraction medium. The extracted oil was separated, filtered, and stored under controlled conditions for further application. The obtained oil, rich in bioactive compounds such as limonene, was utilized to impart antimicrobial and cleansing properties to the wipes.

2.3 Fabrication of Biodegradable Wipes

The wipe substrate was developed using a nonwoven fabrication process. Cotton and viscose fibres were blended with the prepared orange peel powder in suitable proportions.

Carding and Web Formation: The fibres were opened, cleaned, and aligned using a carding process to form a uniform web structure.

Needle Punching: The web was mechanically bonded using needle punching, where fibres were entangled to improve cohesion and strength without the use of chemical binders.

Thermal Bonding: Sodium alginate was applied as a natural binding agent, followed by controlled heat treatment to enhance structural integrity and durability of the fabric.

3. TESTING METHODS

3.1 Physical Properties

- pH (AATCC81)
The sample was soaked in distilled water and the extract solution was tested using a pH meter to determine its acidity or alkalinity.
- Moisture Content (ASTM D2654)
The sample was initially weighed, then dried in an oven and reweighed. The percentage of moisture content was calculated from the weight difference.
- GSM – Mass per Unit Area (ASTD3776)
A known area of the fabric sample was cut and weighed to determine the fabric weight per square meter.

- Thickness (ASTMD1777)
The thickness of the sample was measured using a thickness gauge under standard pressure conditions.

3.2 Mechanical Properties

- Tensile Strength – Dry (ASTM D5035)
The fabric sample was clamped in a tensile testing machine and stretched until it broke. The maximum force applied was recorded.
- Wet Strength (ASTM D5035 – Modified)
The sample was first soaked in water and then tested in a tensile testing machine. The force required to break the wet sample was recorded.
- Tear Strength (ASTM D1424)
A pre-cut sample was subjected to tearing force, and the resistance to tear propagation was measured.
- Abrasion Resistance (ASTM D4966 – Martindale Method)
The sample was subjected to repeated rubbing cycles under controlled conditions to evaluate its resistance to surface wear.

3.3 Biological Properties

- Antibacterial Activity (AATCC 147)
The sample was placed on agar plates inoculated with bacteria such as *E. coli* and *Staphylococcus aureus*. The zone of inhibition was measured after incubation.
- Antifungal Activity (AATCC 147)
The same procedure was followed using fungal strain (*Candida*) to evaluate antifungal performance.
- Skin Irritation Test (ISO 10993-10)
The sample extract was applied on the skin and observed for any signs of redness, irritation, or allergic reaction.
- The higher antifungal performance of the cotton blend can be linked to improved absorption and retention of the active finishing agents. The consistent performance in both samples confirms the effectiveness of the natural antimicrobial treatment.

4. TESTING DEVELOPED WIPES

4.1 Antimicrobial Activity

The antimicrobial activity of cotton and viscose blend wipes was evaluated against *Escherichia coli* and *Staphylococcus aureus*. The cotton blend showed inhibition zones of 24 mm and 23 mm, while the viscose blend showed slightly lower values of 23 mm and 21 mm, respectively. This indicates that the cotton blend has marginally better antibacterial performance, possibly due to its natural fibre structure, which enhances retention of antimicrobial agents and improves microbial interaction.

4.2 Antifungal Activity

The cotton blend exhibited a zone of inhibition of 24 mm against *Candida*, whereas the viscose blend showed 22 mm. This indicates better antifungal performance of the cotton blend, which may be due to its fibre characteristics and ability to support functional finishes, making it suitable for humid and hygiene applications.

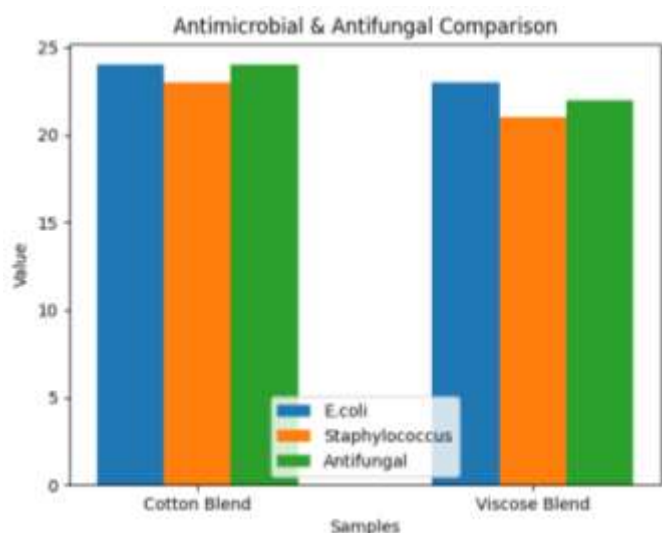


Fig 1: Antimicrobial & Antifungal comparison representation

4.3 pH Analysis

The pH values of cotton (5.2) and viscose (5.5) are within the skin-friendly range. Cotton is slightly closer to natural skin pH, indicating reduced risk of irritation and better suitability for sensitive skin.

4.4 Moisture Content

The viscose blend showed higher moisture content (70%) compared to cotton (68%), indicating better absorbency due to its regenerated cellulose structure. This makes viscose more suitable for applications requiring higher moisture retention.

4.5 Dry Weight

The cotton blend (1.48 g) is slightly heavier than the viscose blend (1.35 g), indicating a denser structure and better durability. In contrast, viscose is lighter and provides improved softness and comfort.

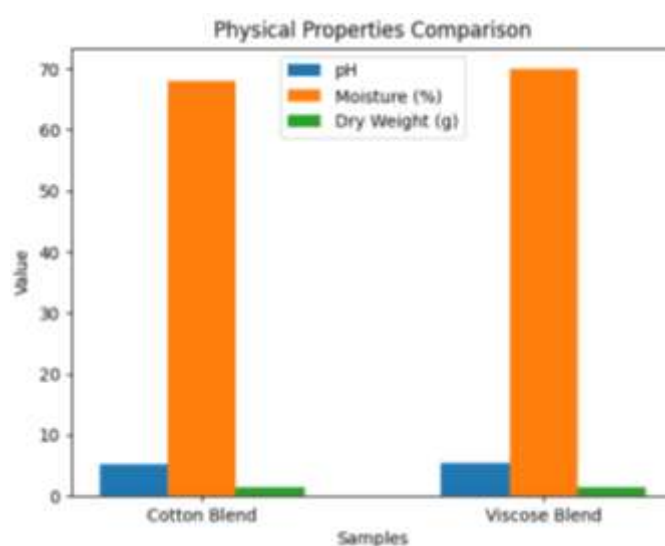


Fig 2: Physical properties comparison

5. RESULTS INTERPRETATION

- Biological testing confirms both samples are skin-friendly, non-irritant, and hygienic, with good antibacterial and antifungal activity.
- High moisture content ensures effective cleaning performance.
- Physical & Mechanical testing shows viscose blend has better strength and durability (tensile, tear, abrasion).
- Cotton blend has higher GSM and thickness, giving better softness and comfort.
- Overall, both samples meet quality requirements; viscose is better for durability, while cotton is better for comfort.

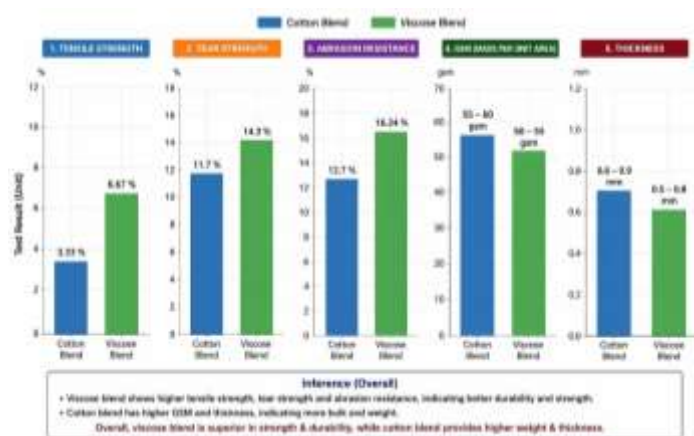


Fig 3: Inference

5.1 Evaluation Parameters

The performance of the wipes was assessed based on the following parameters:

- **Comfort and Skin Feel:** Evaluated based on softness and occurrence of any skin irritation or redness using a rating scale.
- **Absorbency:** Determined by the time taken to absorb liquid and the amount of liquid retained by the wipe.
- **Cleaning Efficiency:** Assessed based on the effectiveness in removing dirt and oil from skin or surfaces.
- **Strength:** Evaluated in terms of tear resistance and wet strength during actual usage.
- **Odor Control:** Assessed based on freshness after use and reduction of unpleasant odour, especially for orange peel incorporated samples.
- **Antimicrobial Effect:** Observed indirectly through improvement in hygiene conditions and reduction in odour or infection signs during usage.

6. CONCLUSIONS

Biodegradable wipes are an emerging alternative to conventional synthetic wipes, designed to address environmental concerns and improve hygiene applications. These wipes aim to provide effective cleansing while ensuring biodegradability, skin compatibility, and functional performance. The design of such wipes focuses on sustainability without compromising essential properties like absorbency, softness, strength, and user comfort.

This project focuses on the development of biodegradable bed bath wipes using orange peel waste as a primary resource, combined with natural and regenerated fibres. The approach emphasizes two key aspects: **sustainable material utilization** and **functional enhancement**. The use of cotton and viscose fibres ensures softness, absorbency, and flexibility, while orange peel-derived cellulose contributes to eco-friendly material development.

In addition to structural development, the project integrates functional finishing through the incorporation of citrus essential oil extracted from orange peel. This natural oil provides antimicrobial and deodorizing properties, improving hygiene and user experience. The formulation and finishing processes are designed to ensure uniform application, moisture balance, and skin-friendly performance.

Overall, the Project aims to convert agro-industrial waste into a value-added hygiene product, promoting a circular economy approach. The final product offers an environmentally responsible alternative to conventional wipes by combining sustainability, functionality, and user comfort in a single solution.

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