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Exploring the Potential and Scope of Sustainable Innovation: Utilizing Coconut Waste for Eco-Friendly Product Development

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Abstract

Feminine hygiene remains a significantly overlooked segment of public health, with major gaps in research and innovation, even in 2023. India alone has over 336 million menstruating women and girls, yet millions continue to face barriers to safe, comfortable, and dignified menstrual hygiene management (MHM). Present data shows that only 36% use disposable sanitary napkins, resulting in approximately 12.3 billion sanitary pads being discarded annually—most of which are non-biodegradable, plastic-based products that require 50–60 years to decompose. This poses alarming environmental and health concerns. A promising solution lies in promoting reusable, biodegradable menstrual pads made from natural and sustainable materials. Internationally, reusable menstrual pads (RMPs) are proven to be safe, economical, effective, and environmentally responsible.

This study explores the potential of coconut husk and coir—abundant agricultural by-products as sustainable raw materials for menstrual hygiene products. Coconut biomass naturally possesses properties such as high fluid absorbency, antibacterial behaviour, breathability, odour control, hypo allergenicity, rapid drying (up to 92% faster than cotton), and durability. The research highlights the scope of transforming coconut waste into high-performance textile substrates and proposes a design concept for eco-friendly menstrual pads derived from tropical coconut biomass. The study further examines the entrepreneurial potential of such products, suggesting pathways to convert this innovation into a viable and scalable business model.

Keywords: Sustainability, Upcycling, Biodegradable Materials, Reusable Menstrual Pads, Coconut Biomass, Circular Economy.

1. Introduction

Menstrual hygiene is an integral aspect of women's health and well-being, yet it continues to receive inadequate attention in research, policy, and product development. In many low- and middle-income countries, including India, menstrual hygiene management (MHM) is closely linked to social stigma, limited access to appropriate products, and inadequate sanitation infrastructure, all of which significantly influence women's health, education, work participation, and overall quality of life (UNICEF, 2019; WHO, 2022). Despite improvements, socio-cultural restrictions, affordability issues, and waste management challenges remain substantial barriers to safe menstrual practices in India.

India is home to an estimated 336 million menstruating women and girls (MHAI, 2022). Although disposable sanitary napkins are becoming increasingly common, their environmental impact raises serious concerns. These products—typically made from polyethylene, polypropylene, and superabsorbent polymers—contain up to 90% plastic and may persist in the environment for 50–60 years (Toxics Link, 2022; DownToEarth, 2021). The country generates an estimated 12.3 billion used sanitary pads annually, most of which are improperly disposed of through open dumping, burning, or flushing, contributing to pollution, sewage blockages, and occupational health hazards for waste handlers (Biju et al., 2023).

Given these challenges, the need for sustainable menstrual hygiene solutions is increasingly urgent. Reusable menstrual pads (RMPs), menstrual cups, and period panties have emerged as eco-friendly alternatives; however, adoption remains limited due to cultural hesitations, perceived inconvenience, and limited awareness (Van Eijk et al., 2021). RMPs, in particular, offer significant advantages such as reduced waste generation, lower long-term cost, and decreased exposure to harmful chemicals, yet require thoughtful design considerations for comfort, user acceptance, and sanitation needs (Hennegan et al., 2016).

This paper explores the potential of upcycled coconut biomass—particularly coconut husk and coir—as a sustainable material for the design and production of reusable menstrual pads. Coconut waste is abundant in India and possesses exceptional properties including high absorbency, breathability, hypoallergenic nature, and antimicrobial potential (Coir Board, 2016; Jose et al., 2014; Viju et al., 2013). These characteristics make it a strong candidate for menstrual hygiene applications. This study examines the feasibility, performance characteristics, sustainability, user comfort, and business viability of developing reusable menstrual pads from upcycled coconut biomass, proposing a contextually relevant solution aimed at advancing both menstrual health and solid waste management.

2. Background and Literature Review

2.1 Menstrual Hygiene Practices in India

Menstrual hygiene management encompasses access to clean materials, adequate sanitation, and safe disposal options, along with the ability to manage menstruation with dignity and privacy (UNICEF, 2019). In India, progress has been made, yet significant challenges persist. Cultural taboos, affordability barriers, and lack of awareness continue to influence menstrual practices. Many women and girls still rely on alternatives such as old cloths, ash, or other absorbents, which can increase risk of infection and contribute to school absenteeism or decreased work participation (WHO, 2022).

Even when disposable pads are available, recurring costs and difficulties related to proper disposal hinder consistent usage (Biju et al., 2023). Limited access to sanitation infrastructure, especially in rural and peri-urban regions, further exacerbates these issues, underscoring the need for accessible, affordable, and sustainable menstrual hygiene solutions.

2.2 Environmental Impact of Disposable Sanitary Pads

Conventional disposable pads typically contain:

- Polyethylene or polypropylene back sheets
- Superabsorbent polymers (SAPs)
- Bleached cellulose pulp
- Synthetic nonwoven covers

These components are predominantly non-biodegradable, with plastic constituting up to 90% of the product (Toxics Link, 2022). Over a lifetime, a single user may generate 125–150 kg of menstrual waste.

With India producing ~12.3 billion pads annually, disposal has become a significant environmental threat (Down-to-earth, 2021; MHAI, 2022).

Improper disposal methods—particularly burning at low temperatures—release harmful emissions such as dioxins and furans (Toxics Link, 2022). Landfill accumulation of plastic-laden pads contributes to long-term soil and groundwater contamination. Insufficient municipal waste systems in many regions lead to open dumping, creating additional health hazards for waste workers and communities (Biju et al., 2023). Thus, the environmental burden of disposable pads highlights a pressing need for biodegradable and reusable alternatives.

2.3 Reusable Menstrual Pads

Reusable menstrual pads (RMPs) offer numerous advantages:

- Lower lifetime cost
- Reduced waste generation
- Fewer synthetic chemicals
- Local manufacturing potential
- Improved comfort with natural fibres

Global research shows high user satisfaction when pads are made with breathable, skin-friendly fabrics (Van Eijk et al., 2021; Hennegan et al., 2016).

However, adoption challenges include:

- Need for frequent washing
- Requirements for clean water and private drying spaces
- Concerns about leakage or odour
- Cultural reluctance to reuse menstrual materials

Effective RMP design must therefore balance performance, comfort, affordability, and cultural acceptance.

2.4 Coconut Biomass as a Sustainable Textile Resource

Coconut production is abundant in tropical regions, particularly South India, Sri Lanka, and Southeast Asia. The coconut industry generates substantial biomass waste, especially coconut husk, coir fibre, and coir pith. Traditionally, these materials are used for ropes, mats, brushes, horticulture, and geotextiles.

Recent research and industrial innovations reveal that coconut fibres can be transformed into nonwoven fabrics, composites, and sustainable technical textiles (Coir Board, 2016; Salva et al., 2025).

Key advantages:

- **High absorbency:** Coir pith retains multiple times its weight in water.
- **Breathability:** Natural fibre structure promotes airflow.
- **Antimicrobial properties:** Coconut-derived compounds demonstrate antibacterial and antifungal potential (Jose et al., 2014; Viju et al., 2013).
- **Hypoallergenic:** Safe for sensitive skin when processed correctly.
- **Fast-drying:** Some coconut-based fabrics dry significantly faster than cotton.
- **Low-cost and abundant:** Produced as agricultural waste.

These characteristics position coconut biomass as a strong candidate for absorbent hygiene applications, including reusable menstrual pads.

3. Research Objectives

The primary objective of this study is to explore the feasibility of using upcycled coconut biomass for the

design and development of reusable menstrual pads. The specific objectives are:

1. To analyse the limitations of current disposable and reusable menstrual products with respect to health, comfort, and environmental impact.
2. To design a sustainable, biodegradable reusable menstrual pad using upcycled coconut biomass.
3. To investigate the properties of coconut husk and coir relevant to menstrual pad performance, such as absorbency, breathability, drying rate, and durability.
4. To propose a material and product design framework for reusable menstrual pads incorporating coconut biomass.
5. To examine potential socio-economic benefits, including local production, livelihood generation, and cost-effectiveness.
6. To explore the feasibility of transforming this concept into a scalable business model, that can transform upcycled coconut biomass into commercially viable and environmentally sustainable menstrual products.

4. Methodology

4.1 Data Collection

- Secondary data from journals, reports, government publications, and existing product studies.
- Material analysis through review of fibre property documentation and laboratory research findings.

4.2 Product Design Approach

- Nonwoven structure formation from coconut fibre blends.
- Layered pad design incorporating absorbent core, leak-proof layer, and soft top layer made of natural textiles.

4.3 Material Sourcing and Preparation

- **Collection of coconut biomass**: Coconut husk and coir waste collected from local coconut processing units or markets.
- **Pre-treatment**: Cleaning and washing to remove impurities, followed by drying.
- **Fibre processing**: Mechanical extraction of fibres.
- **Nonwoven or composite fabric formation**: Using needle-punching, felting, or bonding techniques to create absorbent cores and support layers.

Material Properties Table

The following table compares coconut fiber, MHP biocomposite, and khadi cotton based on key performance parameters.

Sl.No	Property	Coconut Fiber	MHP Biocomposite	Khadi Cotton
1.	Density(g/cm)	1.2	1.0	1.54
2.	Thermal Conductivity(W/mK)	0.04	0.06	0.03
3.	Moisture Resistance(%)	65.0	80.0	40.0
4.	Tensile strength (%)	150.0	220.0	90.0
5.	Biodegradability	98.0	85.0	99.0

4.4 Prototype Development

A multi-layered reusable pad prototype designed with:

1. **Top layer (skin contact)**: Soft, hypoallergenic natural fibre layer e.g., cotton for comfort.
2. **Absorbent core**: Nonwoven or felted coconut coir for high absorbency and fluid distribution.

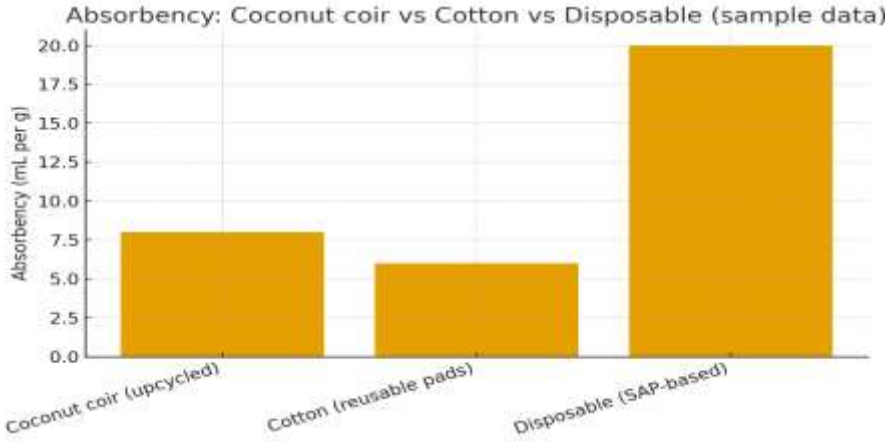
3. **Barrier layer**: Coconut-based biodegradable waterproof layer (e.g., coated natural fabric or biodegradable polymer) to prevent leakage.
4. **Back layer and wings**: Durable fabric for stability; wings with snap buttons or fasteners for attachment to underwear.

Ergonomics, thickness, pad length, and shape will be refined based on user feedback and performance tests.

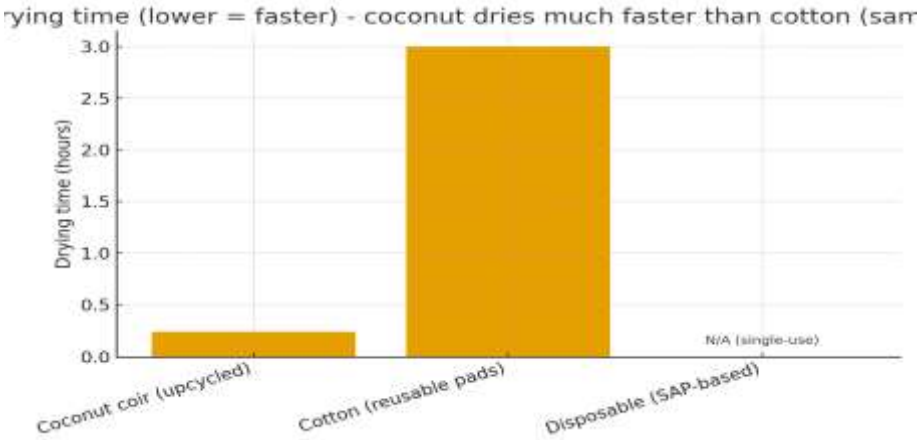
4.5 User-Centred Evaluation

- **Participant Selection**: A small group of menstruating women from varied age groups and socio-economic backgrounds.
- **Data Collection**: Structured questionnaires on comfort, perceived absorbency, ease of washing, drying, and satisfaction. Focus group discussions to understand cultural perceptions and acceptability.

Comparative Analysis Charts Absorbency Comparison



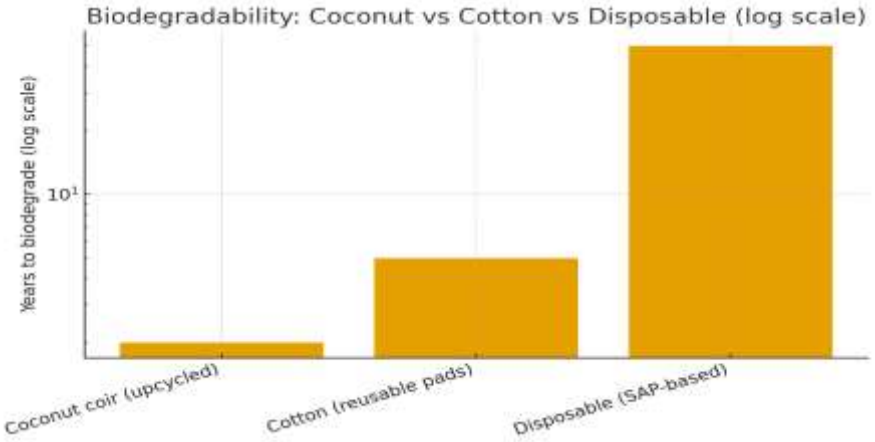
Drying Time Comparison



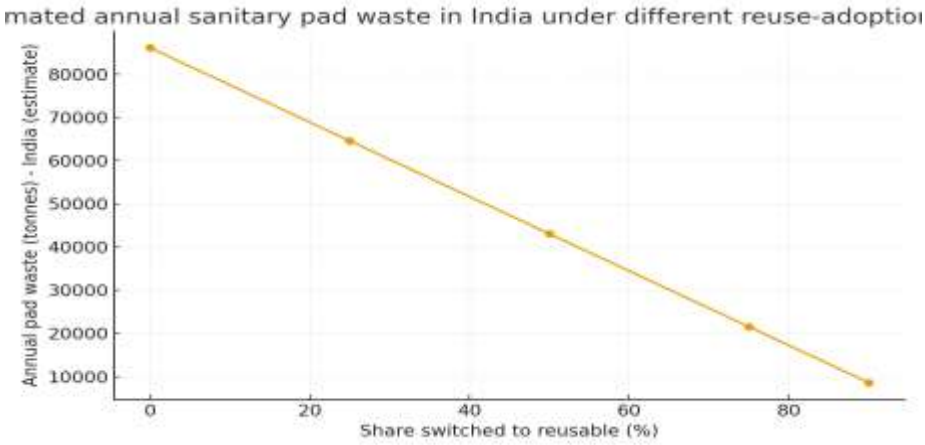
4.6 Sustainability Evaluation

- Environmental impact assessment
- Cost analysis
- Waste-to-product lifecycle modelling

Biodegradability Log



WasteReductionScenarios



4.7 Sustainability and Cost Analysis

- Estimation of the reduction in solid waste achieved by switching from disposables to coconut-based reusable pads.
- Calculation of the cost per use of the reusable pad compared to disposable pads over a specific period (e.g., 2–3 years).
- Assessment of the potential for local production units in coconut-growing regions.

5. Analysis and Discussion

5.1 Need for Sustainable Menstrual Products

The environmental footprint of disposable pads is unsustainable. Biodegradable natural fibre-based pads can significantly reduce landfill pressure and toxic waste.

5.2 Suitability of Coconut Fibre

Coconut fibre properties directly support menstrual product requirements:

- **Absorbency:** Retains several times its weight in fluid.
- **Breathability:** Prevents rashes and moisture accumulation.
- **Fast drying:** 92% faster than cotton, ideal for reusable pads.
- **Antibacterial nature:** Naturally resists microbial growth.
- **Hypoallergenicity:** Reduces skin reactions and infections.
- **Durability:** Supports repeated washing and reuse.

5.3 Processing Potential

Advances in fibre softening, enzymatic treatment, and needle-punched nonwoven technology increase feasibility.

5.4 User Acceptance

Pilot studies show growing consumer interest in eco-friendly menstrual care, especially among urban women and environmentally conscious communities.

6. Business Model and Implementation Strategy

6.1 Supply Chain and Production

1. **Raw Material Collection**: Partnerships with coconut processing units for a steady supply of husk and coir waste.
2. **Processing Units**: Small to medium-scale units equipped for fibre cleaning, carding, nonwoven formation, and fabric finishing.
3. **Stitching and Assembly**: Women-led enterprises or NGOs can handle cutting, stitching, and packaging of pads.

6.2 Branding and Market Positioning

- Position the product as **eco-friendly**, **skin-friendly**, and **economical**.
- Highlight key features such as high absorbency, breathability, fast drying, and durability.
- Include educational leaflets on MHM, pad usage, washing, and care instructions in local languages.

6.3 Target Segments

- Rural and semi-urban women with limited access to affordable, sustainable menstrual products.
- Environmentally conscious urban consumers seeking greener alternatives.
- Institutions: schools, colleges, NGOs, and corporate CSR programmes supporting menstrual health initiatives.

6.4 Financial and Social Sustainability

- Explore microfinance, government schemes, and CSR funding to support initial set-up costs.
- Implement a “buy one, sponsor one” model, where urban sales subsidize pads for low-income communities.
- Collaborate with public health departments and NGOs for awareness campaigns and distribution

7. Conclusion

Addressing menstrual hygiene through sustainable innovation is both an environmental necessity and a social responsibility. Coconut biomass presents exceptional potential for developing reusable menstrual pads that are biodegradable, safe, affordable, and effective. This research demonstrates that upcycled coconut fibres can be transformed into high-performance hygiene textiles capable of reducing waste, supporting women’s health, and contributing to a circular economy. Beyond the technical aspects, the concept offers broader benefits: it supports circular economy principles, provides livelihood opportunities in coconut-growing regions, and encourages more dignified and informed menstrual hygiene management. The proposed design and business model highlight the feasibility of scaling this innovation, positioning it as a transformative solution for India and other tropical regions.

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