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Eco-Friendly Sweat Solutions: Advances in Functional Underarm Pads

Sathvika J[1], Dr. R Geetha Devi[2]
[1]*M.Sc. Student,* [2]*Assistant Professor, Department of Costume Design and Fashion, PSG College of Arts and Science, Coimbatore*

Abstract: ***Sweating is a natural bodily function essential for thermoregulation, but excessive moisture can lead to discomfort, skin irritation, and allergic reactions, particularly in individuals with sensitive skin. This review examines recent advancements in sweat-absorbing technologies, focusing on the development of functional, breathable, and eco-friendly underarm pads. Various designs are discussed, including disposable pads composed of nonwoven fabrics and polyethylene films, as well as innovative products incorporating natural materials such as banana fiber, bamboo, and cotton. These materials offer hypoallergenic, biodegradable, and antimicrobial properties, addressing growing consumer demand for sustainable and skin-friendly hygiene solutions. Performance evaluations highlight key attributes such as moisture management, air permeability, and antibacterial efficacy, with certain pads demonstrating superior comfort and sweat absorption. The integration of herbal extracts and metal-oxide nanoparticles (e.g., ZnO) is shown to enhance functionality, providing rapid drying and microbial resistance. This synthesis underscores the potential of engineered textiles to improve sweat management while promoting environmental sustainability and skin compatibility, paving the way for future innovations in personal care products.***
Keywords: Hyperhydrosis, Kenaf, Azadiracta Indica, Nyctanthes Arbor-Tristis, Manihot esculenta, disposable underarm pad.

I. INTRODUCTION

Sweating is a natural bodily function that helps regulate body temperature, but excessive sweating can lead to discomfort, skin irritation, and social embarrassment. Traditional sweat pads often contain synthetic materials and chemicals that can exacerbate skin sensitivity, highlighting the need for alternative solutions. Kenaf (Hibiscus cannabinus L.) is a versatile, annual herbaceous plant capable of thriving in diverse climatic conditions. It can reach heights exceeding 3 meters in just 3 months, with a peak growth rate of up to 10 cm per day[1]. This review explores the development of eco-friendly, hypoallergenic sweat pads using natural fibers like banana, kenaf, and bamboo, which offer superior absorbency, breathability, and antibacterial properties.Kenaf consists of two main components: the bark and the core. Characterized by its brittle texture, kenaf fibre bears a strong resemblance to jute fibre, leading the FAO to classify it as a jute-like fibre[2].

Excessive sweating, or hyperhidrosis, affects millions of people worldwide, impacting their quality of life. Conventional sweat management products often rely on synthetic materials and harsh chemicals, which can cause skin irritation, allergic reactions, and environmental concerns. The effects can vary from mild symptoms like itching and redness (dermatitis) to severe, potentially fatal skin cancers, posing a significant health risk. It exhibits a range of beneficial properties, including anti-inflammatory, antibacterial, analgesic, antiviral, antifungal, immunomodulatory, and antioxidant effects[3]. In contrast, natural fibers like banana, kenaf, and bamboo have been shown to possess inherent properties that make them suitable for sweat management, including high absorbency, breathability, and antimicrobial activity.

The use of natural fibers in sweat pads can provide a sustainable and skin-friendly alternative to traditional products. Banana fibers, in particular, have been found to possess excellent moisture-wicking properties, making them an ideal material for sweat management. Additionally, the incorporation of natural antimicrobial agents, such as neem and nyctanthes arbor-tristis, can enhance the hygiene and freshness of sweat pads. Nyctanthes arbor-tristis flowers contain a range of bioactive compounds, including modified diterpenoid nyctanthin, flavonoids, anthocyanins, and an essential oil with a scent profile similar to jasmine. These flowers are utilized in perfumery and exhibit various therapeutic properties, such as anti-bilious, antifilarial, anti-inflammatory, antioxidant, diuretic, dyspepsia, ophthalmic, and sedative activities.[4][5]

This review aims to provide an overview of the current state of sweat management products, highlighting the benefits and limitations of traditional products and the potential of natural fibers like banana, kenaf, and bamboo as alternative solutions. We will discuss the development of hypoallergenic sweat pads using these natural fibers, exploring their absorbency, breathability, and antimicrobial properties, and examining their potential for widespread adoption.

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II. MATERIALS AND METHODS

The development of eco-friendly sweat pads involved the selection of natural fibers and materials, including cotton, kenaf, and bamboo. The manufacturing process consisted of several stages: fiber preparation, nonwoven fabric production, and sweat pad assembly.

A. Materials

1) Cotton Spunlace Fabric: A biodegradable nonwoven fabric produced using a wet-laid method.
2) Kenaf Fiber: A natural fiber extracted from the kenaf plant, softened using a sodium hydroxide (NaOH) treatment.
3) Bamboo Fabric: A breathable and moisture-wicking fabric used as the top sheet layer.
4) Azadirachta Indica (Neem) Flower Extract: A natural antimicrobial agent used to finish the core fabric.
5) Nyctanthes Arbor-Tristis Flower Extract: A natural fragrance used to enhance the sweat pad's scent.
6) Biodegradable Cassava Starch Film: A biofilm used as the bottom layer to prevent sweat leakage.
7) Adhesive Tape: A biodegradable and non-toxic adhesive used to attach the sweat pad to clothing.

B. Methods

1) Fiber Preparation
- Kenaf fibers were softened using a NaOH treatment and then ground into a fluffy core material.
- Cotton fibers were used to produce a spunlace fabric.

2) Nonwoven Fabric Production
- The kenaf core material was converted into a nonwoven fabric using a wet-laid method.
- The cotton spunlace fabric was used as the top sheet layer.

3) Sweat PAD Assembly
- The sweat pad consisted of three layers: a top sheet layer, an absorbent core layer, and a bottom biofilm layer.
- The top sheet layer was made from bamboo fabric or cotton spunlace fabric.
- The absorbent core layer was made from kenaf fiber or a combination of kenaf and cotton fibers.
- The bottom biofilm layer was made from biodegradable cassava starch film.

4) Finishing
- The core fabric was finished with Azadirachta Indica (Neem) flower extract using a dip-and-dry method.
- The core fabric was also treated with Nyctanthes Arbor-Tristis flower extract using a spraying method.

5) Testing and Evaluation
- Thickness Test: The thickness of the sweat pad was measured using an ultrasonic thickness gauge.
- Wicking Test: The wicking properties of the sweat pad were evaluated using a wicking test.
- Absorbency Test: The absorbency of the sweat pad was evaluated using an absorbency test.
- Antimicrobial Test: The antimicrobial properties of the sweat pad were evaluated using an antimicrobial test.

III. RESULTS AND DISCUSSION

The investigation focused on developing sustainable underarm sweat-absorbing pads through material analysis and prototype fabrication. The study was divided into material characterization and product design phases to assess performance for hyperhidrosis management.

A. Material Analysis

Material evaluation in-volved testing eight nonwoven fabrics (A–H) for mechanical strength, liquid strike-through time, and absorbency.

- Mechanical Strength: Breaking strength was measured in machine direction (MD) and cross direction (CD). The required strength for top sheets is $\geq 6 \pm 1$ N/cm for 15 g/m² fabrics and $\geq 9 \pm 1$ N/cm for 40 g/m² fabrics. All tested fabrics (A–F) met the strength criteria for underarm pad applications (Table 1). Fabrics A–D are commonly used as top sheets in personal-care products; E–F are garment interlinings.
- Strike-Through Time: The acceptable strike-through time for sweat (smaller fluid volumes) is <4 s, with personal-care standards <3 s. Fabrics A and B showed times of 3.462 s and 3.080 s, respectively, balancing performance with lightweight and cost considerations.

- Absorbency: Fabrics G and H, used as absorbent layers, exhibited high water absorption of 8.67 g/g and 8.75 g/g, respectively, making them suitable for moisture capture.

B. Prototype Development And Performance

Four prototype pads were constructed using top layers (A or B) combined with absorbent layers (G or H) (Table 4). The design emphasized material compatibility and eco-efficiency. Preliminary trials with hyperhidrosis patients assessed comfort and absorption, indicating effective sweat management.

C. Discussion Of Findings

Material selection is pivotal for sweat-pad functionality. Polypropylene nonwovens provide sufficient strength and wicking for top sheets, while absorbent fabrics G and H enhance moisture handling. The choice of lightweight fabrics A and B offers an optimal balance of strength, strike-through, and cost. The study demonstrates that eco-friendly pads can manage sweat effectively while reducing environmental impact.

Future improvements could involve biodegradable fiber blends for enhanced sustainability and antimicrobial treatments for severe hyperhidrosis cases. Optimization of absorbent layer structure may further increase moisture retention and wicking speed.

IV. CONCLUSION

The three-layered functional sweat pad (FSP) developed in this study delivers a high-performance textile with antimicrobial and rapid-drying capabilities. Key achievements include:

1) Multilayer Design: The pad comprises an inner needle-punched Coolmax/polypropylene nonwoven blend treated with ZnO nanoparticles (2, 4, 6 wt %), a middle electrospun polyamide-6 nanofiber layer with super-absorbent polymer (SAP) for optimized moisture absorption, and an outer Coolmax/polypropylene nonwoven sheet for enhanced breathability.

2) Moisture Management: The electrospun nanofiber middle layer enables efficient moisture transfer from the inner to outer surface, outperforming conventional fabrics in moisture-management testing (MMT).

3) Air Permeability: The multichannel Coolmax structure exhibits high air permeability of 882 mm/s, improving wearer comfort and ventilation.

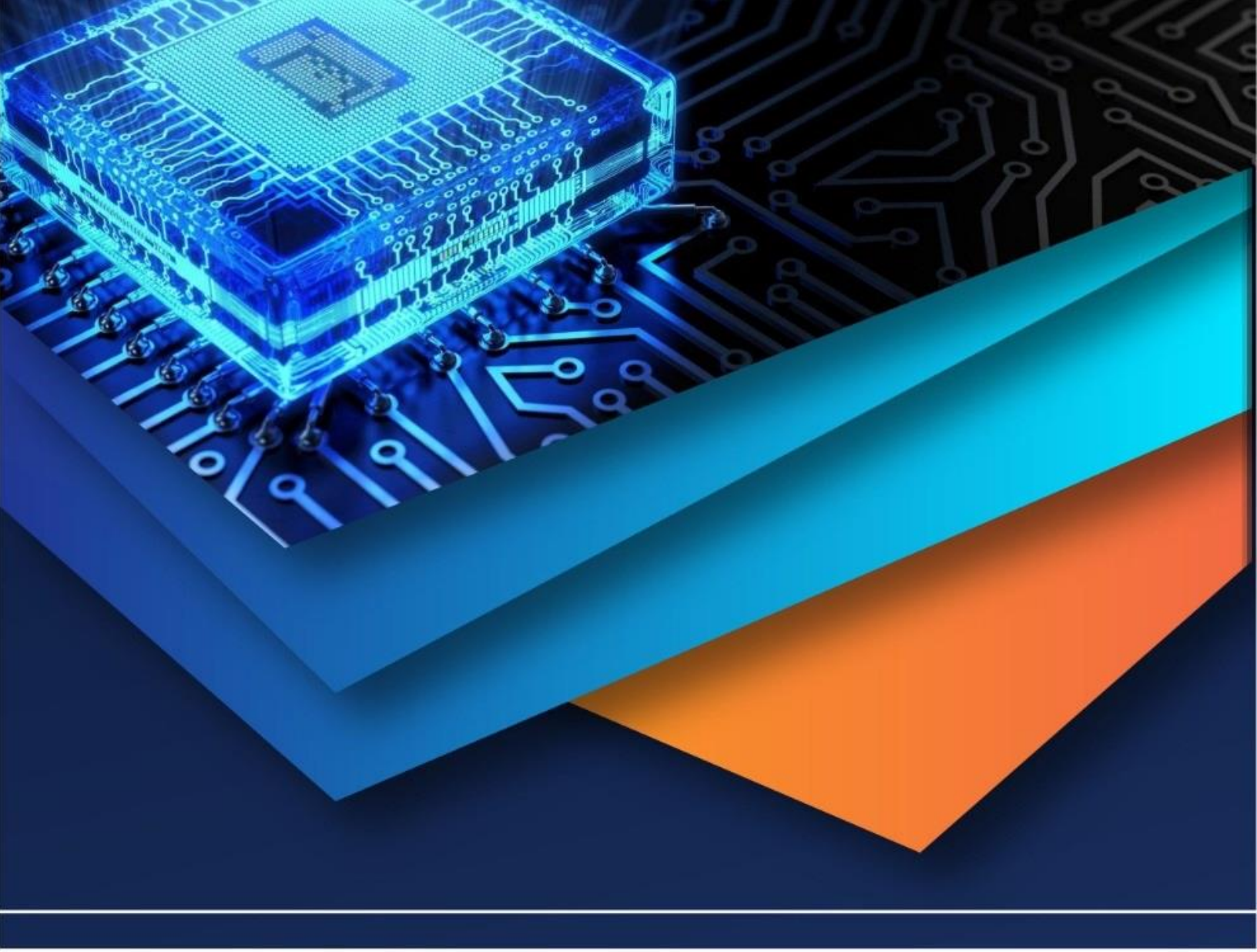
4) Antimicrobial Performance: ZnO nanoparticle infusion grants superior antibacterial activity against Staphylococcus aureus compared with standard samples and untreated fabrics, enhancing the pad's hygienic properties.

5) Material Synergy: The nonwoven blend in the first layer provides advanced moisture handling, while ZnO addition boosts overall antibacterial efficacy, demonstrating the benefit of combining nanomaterials with textile engineering.

6) Future Directions: Further research can optimize other metal-oxide nanoparticles for broader antimicrobial spectra and investigate fabrication of metal-oxide nanowebs in functional garments such as sweatpants, expanding the application scope of the technology.

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