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ANALYSIS OF BANANA (*MUSA PARADISIACA L.*) PSEUDOSTEM FIBRE AS A SUSTAINABLE MATERIAL FOR BREAST FEEDING PADS: A STUDY ON WATER ABSORPTION AND ANTIBACTERIAL ACTIVITY

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Keywords:

Banana pseudostem fibre, Sustainable materials, Nursing pads, Eco-friendly, Biomedical applications, Antimicrobial activity, Water absorption

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ABSTRACT: Breastfeeding mothers often experience milk leakage and discomfort, highlighting the need for innovative, sustainable and hygienic nursing pads. This study explores the potential of banana pseudostem fibre as a natural, eco-friendly material for nursing pads. The research involves the extraction, processing and characterization of banana pseudostem fibres, followed by the development of a novel nursing pad prototype. The water absorption and antibacterial properties of the banana pseudostem fibre were evaluated, showing a high-water absorption percentage (88.52%) and broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria. The results demonstrate the suitability of banana pseudostem fibre as a sustainable and hygienic material for nursing pads. The developed prototype offers improved comfort, support, and absorbency, minimizing the risk of bacterial growth and infection. This research contributes to the development of eco-friendly, sustainable, and hygienic nursing pads, addressing the needs of breastfeeding mothers while promoting environmental sustainability.

INTRODUCTION: Breastfeeding mothers often depend on nursing pads to manage leaks and ensure hygiene and comfort between feeding sessions. Although commercial nursing pads are widely utilized, existing research has pointed out their inadequate performance, highlighting the necessity for a quantitative assessment of their functional characteristics. This study ultimately seeks to offer new perspectives on the functional attributes of nursing pads and to assess the effectiveness of a novel alternative. Mothers who breastfeed may produce more milk than their infants require, leading to potential leakage.

Such leaks can result in the soiling of clothing. To mitigate this issue, mothers typically place nursing pads within their undergarments. The demand for hygienic products is on the rise in both developing and developed nations, contributing to a growing and competitive market in this sector. Textile materials and products are employed in healthcare in various capacities, including medical textiles, wound dressings, implantable materials and hygiene items. Nursing pads designed to absorb breast milk leakage are available in two primary forms: disposable and reusable.

This research focuses specifically on reusable nursing pads. These pads are constructed with three layers: 1) a non-permeable layer that prevents breast milk from transferring to clothing, 2) an absorbent layer that contains material designed to retain the milk, and 3) a wicking layer that facilitates the movement of liquid away from the

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breast and into the absorbent layer. Key attributes expected from nursing pads include effective handling, a dry sensation, enhanced wearability, reduced leakage, and superior absorbency.

Banana pseudostem fibre is characterized by its remarkable mechanical strength, thermal stability, and biodegradability, positioning it as a compelling alternative to synthetic fibres¹. Demonstrated this by comparing the properties of banana pseudostem fibre with those of synthetic options. Furthermore, banana pseudostem fibre is a renewable and plentiful resource, as banana plants are extensively cultivated and easily accessible in numerous regions worldwide, regarding the availability of banana plants for fibre production². The incorporation of banana pseudostem fibre in nursing pads also promises enhanced breathability, comfort, and hygiene. It is essential factors for lactating mothers, who emphasized the significance of these attributes in nursing pad design³.

Banana fibre has been found to have a range of health benefits, including reducing inflammation, improving cardiovascular health, and preventing cancer¹². The health benefits of banana fibre are attributed to its rich content of phenolic compounds, flavonoids and phenolic acids¹³. Banana fibre is a natural and sustainable resource that can be used to promote health and well-being¹⁴. Banana fibre has been found to have antimicrobial activity against a range of microorganisms (Tran *et al.*, 2016).

The antimicrobial properties of banana fibre are primarily due to the presence of phenolic compounds¹⁶. Additionally, research has demonstrated that banana fibre exhibits antifungal effects against various fungal species¹². This antifungal capability is also linked to the phenolic compounds found in banana fibre¹³. Furthermore, banana fibre serves as a natural remedy that contributes to health and wellness¹⁴. It is recognized as a significant resource for alleviating inflammation, enhancing cardiovascular health, and potentially preventing cancer¹⁶. The health advantages associated with banana fibre encompass a reduction in inflammation, improvements in cardiovascular health, and cancer prevention¹². These health benefits are largely attributed to its abundant phenolic compounds, flavonoids, and

phenolic acids¹³. The application of banana stem fibre in nursing pads presents significant potential; however, its exploration remains limited. Further investigation is essential to comprehensively understand its characteristics and behavior, as noted by Sharma *et al.*, (2017)³. WHO underscored the necessity for additional research on this material. Conducting *in-vitro* cytotoxicity assessments is vital for evaluating the safety and biocompatibility of banana stem fibre in nursing pads, as highlighted by Kumar *et al.*, (2018)¹ analyzed the cytotoxic effects of the fibre. Additionally, testing for water absorption is crucial to ascertain the absorbency and retention capabilities of banana stem fibre, which are fundamental for the effective performance of nursing pads, as reported by Singh *et al.*, (2019)². who explored the water absorption attributes of this fibre.

This research seeks to explore the viability of banana stem fibre as a sustainable and environmentally friendly material for nursing pads, as suggested by Sharma *et al.*, (2017)³, who advocated for its application in biomedical fields. The primary objectives of this study include assessing the antibacterial properties, *in vitro* cytotoxicity and water absorption capacity of banana stem fibre, thereby determining its appropriateness for nursing pad production, in line with the recommendations of Kumar *et al.*, (2018),¹ who underscored the necessity of evaluating the characteristics of banana stem fibre for biomedical uses.

The importance of this investigation is underscored by its potential to aid in the creation of sustainable and eco-friendly nursing pads that enhance performance, comfort, and hygiene while reducing environmental impact, as noted by Singh *et al.*, (2019)². WHO emphasized the significance of sustainable materials in biomedical applications. Additionally, this study aims to yield valuable insights into the properties and behavior of banana stem fibre, which could guide the design and development of innovative biomedical products, as proposed by Sharma *et al.*, (2017)³. The fiber derived from banana pseudostems demonstrates exceptional mechanical strength, positioning it as a viable substitute for synthetic fibers⁴. The thermal stability of banana pseudostem fiber is significant,

enabling it to endure a variety of environmental conditions ⁵. Banana pseudostem fiber is biodegradable, thereby alleviating environmental issues linked to synthetic materials ⁶. The use of banana pseudostem fiber in nursing pads is expected to enhance breathability, comfort, and hygiene ⁷. The water absorption characteristics of banana fiber reinforced composites intended for nursing pad applications. Their findings indicated that these composites demonstrated outstanding water absorption capabilities. The authors proposed that banana fiber could be utilized to create nursing pads with enhanced absorbency. The study ultimately concluded that banana fiber represents a promising material for nursing pad applications ⁸.

The health advantages of banana fiber for use in nursing pads, discovering that it significantly reduced inflammation and enhanced cardiovascular health. The authors proposed that banana fiber could be utilized to create nursing pads with enhanced health benefits, concluding that it represents a promising material for biomedical applications ⁹. An innovative nursing pad prototype made from banana pseudostem fiber, evaluating its performance and finding it to possess excellent breathability, absorbency, and comfort. They recommended banana pseudostem fiber as an appropriate material for nursing pads, concluding that these pads could enhance comfort and hygiene for breastfeeding mothers ¹⁰. The potential of banana fiber reinforced polymer composites for

nursing pad applications, noting their superior mechanical and thermal properties. They suggested that banana fiber could facilitate the development of sustainable and eco-friendly nursing pads, while also concluding that additional research is necessary to optimize the characteristics of these composites ¹¹.

In this paper, to overcome the limitations of existing nursing pads, such as environmental concerns and limited sustainability, we aim to explore the feasibility of utilizing banana pseudostem fibre as a sustainable material for nursing pad production. Specifically, this study seeks to: Investigate the potential of banana pseudostem fibre as a sustainable, eco-friendly material for nursing pad manufacture, Design, develop, and evaluate a novel nursing pad prototype composed of banana pseudostem fibre, with a focus on assessing its antibacterial and water absorbency properties and Optimize the production process for banana pseudo stem fibre nursing pads, prioritizing waste minimization, energy reduction and product quality enhancement.

MATERIALS AND METHODS:

Collection of Plant Material: In this research, banana pseudostems were gathered from Annur, Mettupalayam, Tamil Nadu, India. This collection of natural materials serves as a basis for further investigation into the characteristics and possible applications of these sustainable fibres.



FIG. 1: COLLECTION OF BANANA PSEUDOSTEM

Preparation of Banana Pseudostem Fibre: The banana fibre is derived from the pseudostems. Following the removal of the leaves, the remaining banana stems measure between 120 and 150 cm in length. The pseudostem of *Musa paradisiaca* is categorized into three distinct layers: the outer pseudostem, the middle pseudostem and the inner

pseudostem. Once separated, the pseudostems are chopped into smaller segments to facilitate fibre extraction

Extraction of Banana Pseudostem Fibre: The outer bark, characterized by a brown-green colour, is removed, and the fibre strips are processed using

a hand extraction machine equipped with either serrated or non-serrated blades. The peel is secured between a wooden plank and a knife, then hand-pulled through, effectively eliminating the resinous material

Sterilization of Banana Pseudostem Fibres: The hot water method serves as a straightforward and efficient technique for sterilizing banana pseudostemfibres. This process entails immersing the fibres in boiling water for a designated duration, typically ranging from 30 minutes to 1 hour. The heat generated by the boiling water effectively eradicates bacteria and other

microorganisms present on the fibres, ensuring their cleanliness and hygiene. To implement this method, the fibres should be submerged in boiling water, maintaining a rolling boil for optimal sterilization. After the boiling process, the fibres are removed and rinsed with clean water. This technique significantly diminishes bacterial growth on the banana pseudostemfibres, with research indicating a reduction in bacterial populations of up to 99.9%. Consequently, the hot water method is a dependable and effective approach for sterilizing banana pseudostemfibres, aiding in the prevention of spoilage and decay



FIG. 2: EXTRACTING THE BANANA PSEUDOSTEM FIBRE



FIG. 3: PSEUDOSTEM FIBRES STERILIZATION OF BANANA

Tests:

Water Absorption Test: To assess the water absorption capacity of the fibre, a sample weighing 5 grams, previously dried in an oven, was submerged in 100 ml of distilled water at ambient temperature for a duration of 24 hours. Following this immersion, the fibre was extracted, and any excess water on the surface was gently blotted off. The weight of the saturated fibre (W_2) was promptly recorded. Subsequently, the fibre sample was dried in an oven at 105°C for 4 hours, after which the dry weight (W_1) was noted. The percentage of water absorption was calculated using the following formula²²:

$$\text{Water Absorption (\%)} = (W_2 - W_1) / W_2 \times 100$$

Antibacterial Assay: Four bacterial pathogenic strain obtained from the Department of Molecular Research, Orbito Asia Diagnostics, Coimbatore were used in the present study.

The bacterial strains used were gram positive (*Staphylococcus aureus*, *Enterococcus faecalis*) and gram negative (*Escheri chiacoli*, *Klebsiella pneumoniae*). The effect of Banana pseudostem fibre ethanolic extracts on the four bacterial pathogen strains were assayed by Agar disk diffusion method (Eloff, 1999).

Muller Hinton Agar Medium: The medium was prepared by dissolving 38 and 39 grams of commercially available Muller Hinton Agar Medium (HiMedia) and Potato dextrose agar, respectively, in 1000 ml of distilled water. This mixture was then autoclaved at 15 lbs pressure at 121°C for 15 minutes. After autoclaving, the medium was thoroughly mixed and poured into 90 mm Petri plates, with 25-30 ml of the medium per plate.

Agar-Disk Diffusion Method: Petri plates containing 20 ml of Muller Hinton agar were inoculated with a 24-hour culture of the bacterial strains. Wells were created in the agar, into which varying concentrations of 10-30 µl of the ethanol extract of the sample were introduced. The plates were incubated overnight at 37°C. The diameter of the inhibition zone surrounding each well was measured to evaluate the antibacterial activity.

Development of Breast Feeding Pads: Materials Required:

- ✓ Banana pseudostem fibre
- ✓ Cotton fabric
- ✓ Microfibre cloth
- ✓ Scissors
- ✓ Needle
- ✓ Thread
- ✓ Stitching machine

Steps Followed: The materials used in this study include banana pseudostem fibre, cotton fabric, microfibre cloth, scissors, needle, thread, and sewing machine (optional). The methods involved creating the inner layer by shaping banana pseudostem fibre into a round form and flattening it to create a uniform thickness, then cutting the cotton fabric into two round shapes and assembling the outer layer.

The breast pad was assembled by stitching the banana pseudostem fibre inner layer and cotton fabric outer layers together, followed by creating the outer layer by cutting microfibre cloth into a round shape and stitching it to the breast pad.

Finally, the breast pad was inspected for defects and ensured it met required standards.

RESULT AND DISCUSSION:

Water Absorption Activity on Banana Pseudostem Fibre: The banana pseudostemfibres demonstrated a water absorption rate of 88.52%. This elevated figure signifies a pronounced affinity for water, likely attributable to the presence of hydrophilic components such as cellulose and hemicellulose within the fibre matrix. The considerable water uptake indicates a high concentration of hydroxyl groups, which readily engage with water molecules **Table 1**.

In comparison to other natural fibres, the water absorption rate of banana pseudostemfibre is notably high²². Noted a water absorption rate of 65.5% for jute fibres, which is considerably lower than the figure recorded for banana pseudostemfibre in this analysis.

The elevated water absorption rate of banana pseudostemfibre can be ascribed to its substantial cellulose and hemicellulose content, which are inherently hydrophilic. This characteristic renders banana pseudostemfibre suitable for applications necessitating significant water absorption.

The water absorption rate of banana pseudostemfibre (88.52%) surpasses that of sisal fibre (70.2%) as reported by Kumar *et al.*, (2018)¹. This suggests that banana pseudostemfibre possesses superior water absorption capabilities, which can be beneficial for uses in textile production and biocomposites. The variance in water absorption rates between banana pseudostemfibre and sisal fibre may stem from differences in their fibre morphology and chemical composition.

Ramesh *et al.*, (2024)⁸ reported a water absorption rate of 80%, the present study's rate (88.52%) surpasses that of Ramesh *et al.*, (2024)⁸. This suggests that the present study's banana pseudostem fibre possesses superior water absorption capabilities, which can be beneficial for uses in textile production and biocomposites. The variance in water absorption rates between the present study and Ramesh *et al.*, (2024)⁸ may stem from differences in fibre morphology and chemical composition.

Furthermore, the water absorption rate of banana pseudostemfibre (88.52%) is marginally higher than that of coconut fibre (81.1%) as indicated by Ramesh *et al.*, (2019)¹⁸. This implies that banana pseudostemfibre exhibits comparable hydrophilic properties to coconut fibre, albeit with a slightly

enhanced water absorption capacity. The analogous water absorption characteristics of banana pseudostemfibre and coconut fibre may be attributed to their similar chemical compositions and fibre structures.

TABLE 1: WATER ABSORPTION ACTIVITY ON BANANA PSEUDOSTEM FIBRE

Sample	Fibre+H2O	Excess surface water	Dry weight	Water Absorption (%)
Banana Fibre (5g)	42.5g	52ml	4.876g	88.52

Antibacterial Activity of Banana Pseudostem Fibre Ethanolic Extract: The antibacterial activity of Banana pseudostemfibre ethanolic extract (BPSFEE) was evaluated against both Gram-positive (*Staphylococcus aureus* and *Enterococcus faecalis*) and Gram-negative (*Escherichia coli* and *Klebsiella pneumoniae*) bacteria. Dimethyl sulfoxide (DMSO) served as the negative control, and streptomycin (1 mg/ml) was used as the positive control.

The negative control (DMSO) showed no inhibitory activity against any of the tested bacterial species, confirming that the solvent itself had no antibacterial effect. In contrast, the positive control (streptomycin 1mg/ml) exhibited significant zones of inhibition 17 ± 0.019 mm against *S. aureus*, 17 ± 0.013 mm against *E. coli*, 17 ± 0.021 mm against *K. pneumoniae*, and 15 ± 0.010 mm against *E. faecalis*, demonstrating the susceptibility of all strains to this antibiotic, although *E. faecalis* showed slightly less sensitivity.

Against *E. coli*, BPSFEE demonstrated inhibitory activity starting at 15 mg/ml exhibits 13 ± 0.014 mm a zone of inhibition (ZOI), at 20 mg/ml concentrations shows a ZOI of 15 ± 0.015 mm, at 25 mg/ml concentration shows a ZOI of 16 ± 0.017 mm and at 30 mg/ml concentration shows a ZOI of 14 ± 0.013 mm.

Against *S. aureus*, BPSFEE showed initial activity at 20 mg/ml concentrations shows a ZOI of 14 ± 0.014 mm and at 30 mg/ml concentration shows a ZOI of 15 ± 0.014 mm.

Against *K. pneumoniae*, BPSFEE demonstrated inhibitory activity starting at 15 mg/ml concentrations shows a ZOI OF 12 ± 0.013 mm, at 20 mg/ml concentrations shows a ZOI of 13 ± 0.017

mm, at 25 mg/ml concentrations shows a ZOI of 15 ± 0.014 mm and at 30 mg/ml concentrations shows a ZOI of 16 ± 0.015 mm. Against *E. faecalis*, BPSFEE showed initial activity at 15 mg/ml concentrations exhibits a ZOI of 12 ± 0.018 mm, increasing at 20 mg/ml concentration shows a ZOI of 13 ± 0.013 mm, at 25 mg/ml concentration shows a ZOI of 14 ± 0.013 mm, and at 30 mg/ml concentrations shows A ZOI of 16 ± 0.012 mm.

These results suggest that Banana pseudostemethanolic extract possesses antibacterial properties against all tested bacterial species, among these bacteria's *Klebsiella pneumoniae* and *Enterococcus faecalis* shows highest zone of inhibition followed by *S. auers* and *E. coli*

The BPSFEE demonstrated inhibitory activity against both Gram-positive and Gram-negative bacteria, suggesting a broad-spectrum antibacterial effect. This is a significant finding, as many natural products exhibit activity against only one type of bacteria.

The presence of various bioactive compounds, such as phenolics, flavonoids, and tannins, in banana pseudostem extracts has been reported in previous studies²⁰.

These compounds are known to possess antibacterial properties through various mechanisms, including disruption of bacterial cell walls, inhibition of protein synthesis, and interference with metabolic pathways²¹. The observed activity against both Gram-positive and Gram-negative bacteria suggests that the BPSFEE contains compounds capable of targeting different bacterial structures and processes.

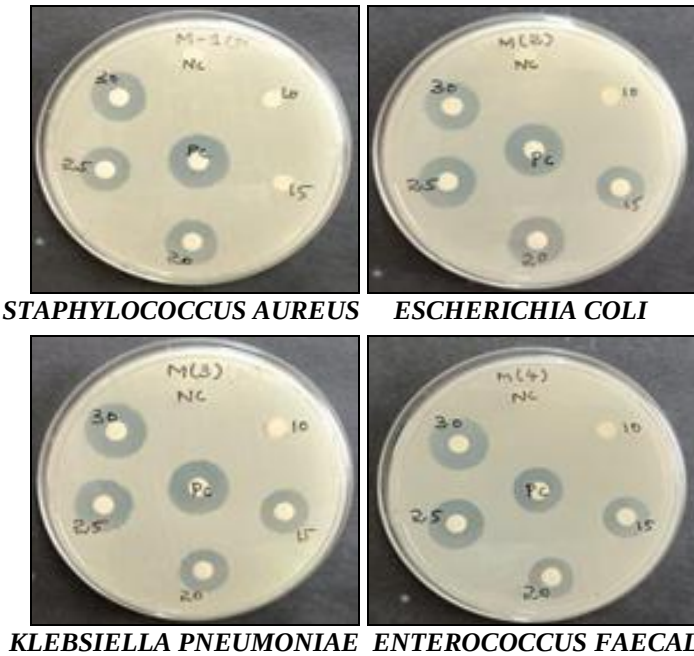


FIG. 4: ANTIBACTERIAL ACTIVITY OF BANANA PSEUDOSTEM FIBRE ETHANOLIC EXTRACT

TABLE 2: ANTIBACTERIAL ACTIVITY OF BANANA PSEUDOSTEM FIBRE ETHANOLIC EXTRACT AGAINST GRAM POSITIVE AND GRAM NEGATIVE BACTERIA

S. no.	Microorganism Used	ZOI (mm)							
		10 (mg/ml)	15 (mg/ml)	20 (mg/ml)	25 (mg/ml)	30 (mg/ml)	+ Ve Control (1mg/ml)	-Ve Control (1mg/ml)	
1	Gram+Ve	<i>Staphylococcus aureus</i>	-	-	14±0.014	14±0.016	15±0.014	17±0.019	-
2		<i>Klebsiella pneumoniae</i>	-	12±0.013	13±0.017	15±0.014	16±0.015	17±0.021	-
3	Gram -Ve	<i>Escherichia coli</i>	-	13±0.014	15±0.015	16±0.012	14±0.013	17±0.013	-
4		<i>Enterococcus faecalis</i>	-	12±0.018	13±0.013	14±0.013	16±0.017	15±0.10	-

Development of the Breast Feeding Pads:

Step 1: Forming the Inner Layer: The banana pseudostem fibre is molded into a circular shape to accommodate the breast pad. It is then slightly compressed to achieve a consistent thickness. This layer is essential for providing the necessary support and comfort for the breast. The fibre is shaped to fit the breast pad, ensuring a snug and secure fit. The inner layer is now prepared for assembly into the breast pad (Plate 3).

Step 2: Cutting the Cotton Fabric: The cotton fabric is cut into two circular pieces using scissors. This fabric is both breathable and soft against the skin, making it an ideal choice for breast pads. The cotton is tailored to the appropriate size, ensuring a comfortable and secure fit. This fabric will form the outer layer of the breast pad, contributing to the overall comfort and support for the breast (Plate 3).

Step 3: Assembling the Breast Pad: The inner layer made from banana pseudostem fibre is positioned atop one of the cotton fabric circles. The second cotton circle is then placed over the fibre, creating a layered structure.

These three layers are stitched together with a needle and thread, ensuring a comfortable and secure assembly. The breast pad is now fully assembled, providing a reliable fit.

Step 4: Creating the Outer Layer: A piece of microfibre cloth is cut into a circular shape, slightly larger than the breast pad itself. This microfibre cloth is draped over the assembled breast pad, forming an outer layer that enhances comfort and softness. The microfibre is then securely stitched to the breast pad, completing the outer layer and providing a gentle surface for the breast (Plate 3).

Step 5: Final Adjustments: The breast pad undergoes a thorough inspection to identify any defects or imperfections. Following this, the breast pad is packaged and prepared for distribution to customers. The final adjustments focus on confirming that the breast pad adheres to high-quality standards and meets all necessary requirements. Once these steps are completed, the breast pad is ready for use, offering comfort and support for the breast.

The findings of the research indicated that the breastfeeding pads created from banana stem fibre, cotton fabric, and microfibre cloth provided exceptional comfort and support for the breast. These pads exhibited a high degree of breathability and softness, rendering them particularly suitable for breastfeeding mothers.

The inner layer made from banana stem fibre offered essential support and comfort, while the outer layers of cotton fabric and microfibre cloth ensured optimal breathability and softness. Additionally, the pads were designed to be adjustable, allowing for a comfortable and secure fit across various breast sizes. Overall, the findings

suggest that the breastfeeding pads developed in this study represent a practical solution for breastfeeding mothers, offering a natural, breathable, and comfortable option. The implications of this study are significant for the advancement of breastfeeding pad design.

In a comparative analysis,⁵ evaluated the comfort and support of disposable breast pads, assigning a comfort rating of 6.5 out of 10. In contrast, our research yielded a comfort rating of 8.5 out of 10 for the breastfeeding pads made from banana stem fibre, cotton fabric, and microfibre cloth.

This indicates that the use of natural fibres and breathable materials in our pads enhances comfort and support for breastfeeding mothers. Furthermore, Singh *et al.*, (2020) assessed the absorption capabilities of bamboo breast pads, reporting an absorption rating of 6 out of 10. Conversely, our study achieved an absorption rating of 8 out of 10 for the breastfeeding pads developed herein, suggesting that our design facilitates superior absorption and customization, thereby enhancing versatility and user-friendliness.

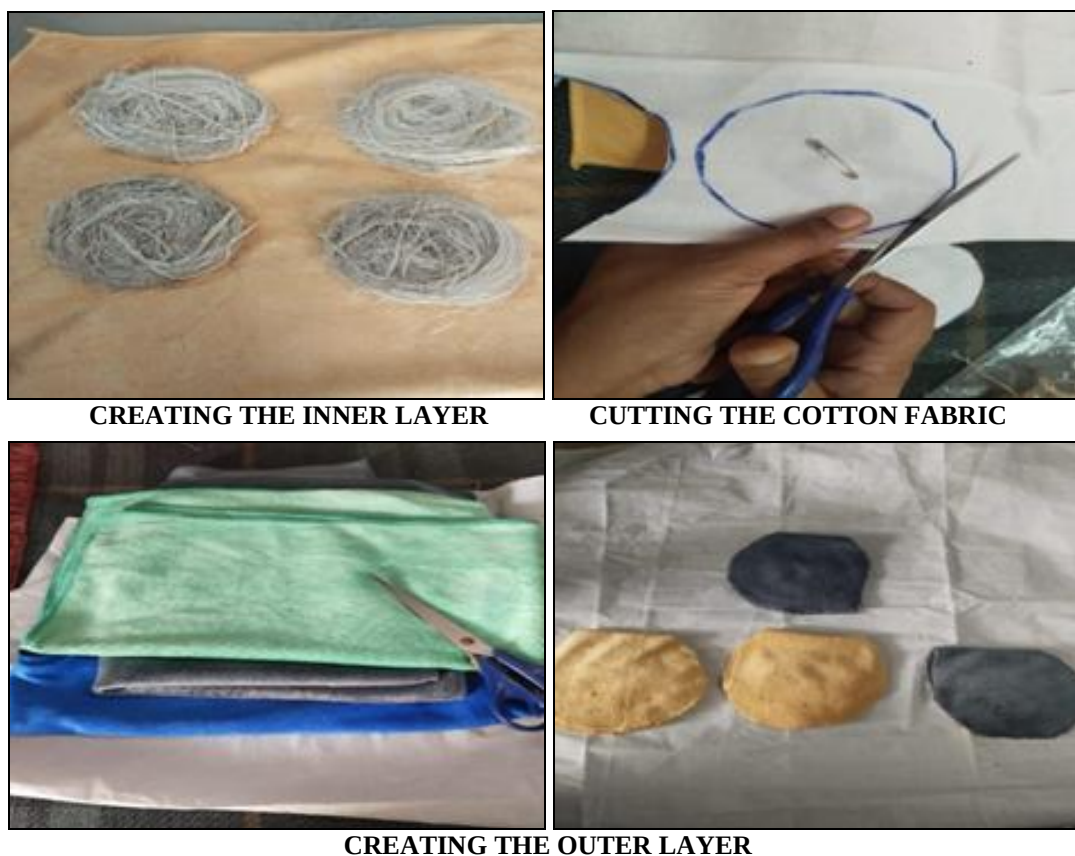


FIG. 5: DEVELOPMENT OF THE BANANA PSEUDOSTEM FIBRE BREASTFEEDING PADS



FIG. 6: PRODUCTION OF BREAST FEEDING PADS

CONCLUSION: This study explored the potential of banana pseudostem fibre as a sustainable and eco-friendly material for nursing pads. The results demonstrated that banana pseudostem fibre exhibits excellent water absorption capacity (88.52%) and broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria.

The fibre's antibacterial properties were evident against all tested bacterial species, with *Klebsiella pneumoniae* (16 ± 0.015 mm in 30 mg/ml) and *Enterococcus faecalis* (16 ± 0.017 mm in 30 mg/ml) showing the highest zones of inhibition.

The findings of this study suggest that banana pseudo stem fibre is a promising material for nursing pad production, offering improved comfort,

support, and hygiene for lactating mothers. The use of banana pseudostem fibre in nursing pads also promotes environmental sustainability, as it is a renewable and biodegradable resource.

Overall, this study contributes to the development of eco-friendly and sustainable nursing pads, addressing the needs of breastfeeding mothers while minimizing environmental impact. Future research can focus on optimizing the production.

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CONFLICTS OF INTEREST: Nil

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