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Innovative and Biodegradable Sanitary Napkins with Focus on Affordability and Environmental Impact

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ABSTRACT

The awareness people have towards the environment pollution resulting from the use of the normal sanitary napkins has encouraged production of eco-friendly napkins. Modern ones are largely plastic-wired sanitary napkins constructed with superabsorbent polymers as their major components, which take roughly 500 years to degrade. This presents a major environmental concern, seeing that each woman will use about 11,000 pads in their lifetime and these are bound to a landfill. As a remedy the sanitary napkins that are biodegradable has been developed using banana fiber, bamboo, and polylactic acid derived from cornstarch. The current paper seeks to establish the possibility to use these environmentally friendly products with special emphasis on the cost issues and the impact they would have on the environment. Low cost, high biodegradability, high absorbency, high tensile strength, and possibility for banana fiber in the development region are pointed out. The outcome in terms of banana fiber sheets production as well as their incorporation into Sanitary Napkin were encouraging in respect of absorbency, antibacterial activity and biodegradability. The tests proved that the new biodegradable napkins disintegrate much more quickly than current plastic-based products, in a matter of months, contrary to the centuries that it would take for plastic pads to decompose. This is the reason why current biodegradable napkin products cost more than conventional napkin products as production price is still relatively high; however, measures of procuring locally and constantly improving material processing to manage the cost down are in the works. This research adds for the possibility of biodegradable sanitary napkin to reduce environmental degradation, through the alternative provision of safe and affordable, hygienic menstrual solutions where there are few to non-existent. Such products if further developed and marketed on large scale could be made available and sustainable for people all over the world.

Keywords- Banana fiber, Biodegradable, sanitary napkins, Affordability, Environmental impact.

I. INTRODUCTION

Traditional sanitary napkins, commonly used by women during menstruation, are typically composed of a combination of plastic, superabsorbent polymers (SAPs), and nonwoven fabrics. Sanitary napkins have contributed significantly to menstrual hygiene and comfort. The global market for sanitary napkins has dramatically increased in the last several decades. In 2020, the global feminine hygiene products market stood at USD 37.4billion, wherein sanitary napkins held a considerable share of this market[1]. Although sanitary napkins are the most common and crucial of feminine hygiene products, the materials used in conventional sanitary napkins, such as polyethylene, polypropylene, and synthetic adhesives, create substantial environmental concerns since it is nonbiodegradable [2]. Conventional sanitary napkins are major sources of environmental pollution. According to

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research, it is estimated that a single woman uses approximately 11,000 sanitary pads in her lifetime, most of which end up in landfills [3]. As the pads are made primarily out of plastic, they take as long as 500-800 years to decompose and thus add to the ever-growing plastic pollution [4].

Further, synthetic materials have been associated with possible health risks connected to the use of chemicals in the products, which range from skin irritation and infections [5]. There is thus an emerging need for sustainable alternatives. Use of non-biodegradable materials throughout sanitary napkins causes a significant environmental issue. Alternatively, further, such alternatives are affordably available, though a challenge in developing regions where, even for basic menstrual products, affordability is a challenge [6].

There is a greater demand for sanitary napkins that are biodegradable and moderately priced, which shall hopefully ensure reduced damage to the environment, safety, and ease of access for all women irrespective of their socio economic stature. This paper will focus on developing and feasible innovative sanitary napkins which are biodegradable, in consideration of cost with their environmental footprint. Innovations can appropriately be critically highlighted by relationship with existing products such as sanitary napkins, where solutions can be sought that ensure sustainability yet are not very expensive so that these environmentally friendly products can be utilized by everybody.

II. MATERIALS USED IN BIODEGRADABLE SANITARY NAPKINS BIODEGRADABLE ALTERNATIVES TO PLASTICS

In response to the impact of plastic-based sanitary napkins on the environment, researchers have explored various biodegradable alternatives. Materials such as bamboo fiber, banana fiber, Cornstarch-based polymers, cotton, have been examined for their absorbency, biodegradability and performance in period hygiene products in general [7].

These fibers naturally do not only It decomposes faster than any normal plastic, yet it also has hypoallergenic properties and safer for prolonged skin contact.

Banana Fiber

Banana fibers derive from pseudostems of banana plants; it has been the new trend of finding the biodegradable. This material is abundantly available in tropics, and its tensile strength, absorbency, and biodegradability are good [8]. It is a low-cost material; thus, it has become an This is an attractive choice for producing low-cost biodegradable sanitary napkins in developing countries. Environmental Impact of Biodegradable Sanitary Napkins

Biodegradability and Decomposition Time

Biodegradable sanitary napkins constructed from materials such as bamboo, banana fiber, or cornstarch-basedpolymers will degrade within a few months up to years, compared to the centuries it would take the conventional sanitary napkins to decompose [9]. This drastically reduces the waste that menstrual products generate.

III. REDUCTION OF CARBON FOOTPRINT

In contrast, the manufacturing of and eventual disposal of traditional sanitary napkins have high carbon footprints because the processes involved are very power-intensive in plastic manufacturing and waste management. From this point to disposal costs biodegradable sanitary napkins a considerably lower carbon footprint [10].

IV. AFFORDABILITY AND ACCESSIBILITY

Cost of Biodegradable Sanitary Napkins

One of the major barriers to the widespread adoption of biodegradable sanitary napkins is their cost. As of 2023, eco-friendly sanitary napkins are generally more expensive than conventional products due to the higher cost of raw materials and production processes [11]. However, innovations in the production process and the scaling of biodegradable materials are gradually reducing costs, making these products more accessible to the general population.

Strategies for Making Biodegradable Napkins Affordable

Efforts to lower the cost of biodegradable sanitary napkins include sourcing locally available materials like banana fibers, promoting community-based production units, and encouraging governmental subsidies and policies aimed at menstrual health and sustainability [12]. Non-governmental organizations (NGOs) have also played a significant role in providing affordable biodegradable sanitary napkins to women in rural and low-income regions [13].

V Material and method's

Preparation of banana fiber sheet Procedure:

The banana stem was rinsed with water. Subsequently, it was dried with a cloth. The fibers from each banana stem were carefully separated. Separated fibers were collected and desiccated at ambient temperature for two days. Subsequently, dried banana fibers were obtained, and 50 grams were measured and chopped into little pieces [14]. We placed a beaker on the heat source, poured 400 ml of water, and introduced a 12% NaOH solution before boiling it. Subsequently, we incorporated 50 grams of chopped banana fibers into the mixture. It was boiled for a duration of 4 to 5 hours

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without interruption. Subsequent to boiling, the cooked banana fiber was rinsed with cold water to eliminate the NaOH until the pH reached neutrality. Obtained a beaker and filled it with chlorine water. The cooked and washed banana fibers were immersed in chlorine water for two hours [15]. Bleached banana fibers are rinsed with cold water to eliminate all chlorine content. The chlorine-free banana fibers were ground using a mixer grinder and transformed into a pulp [16]. During grinding, we incorporated starch or tragacanth (either one) at a ratio of 2 grams per 50 grams as a binding agent. The combined pulp was transferred into the mold. The pulp was evenly distributed within the mold for sheet production [17]. The banana fiber sheet was desiccated for 2 to 3 days using sunlight or a hot air oven. Upon drying, the sheet is prepared for use in sanitary pads [18].

Fig no.1. Preparation of banana pad from banana dense fibre

VI Materials and methods

Antibacterial tests `

To confer antibacterial qualities to the sanitary napkins, the fabric was treated with boiled water infused with turmeric and neem powder extracts. This procedure has already been approved by numerous researchers. This investigation was assessed with ASTM E2149. For each Neam and Tulshi extract-treated sample, as well as one untreated sample, a 250 ml flask is created containing 50 mL of the working bacterial dilution (1.5−3 x 10^5 CFU/mL) and non-woven fabric samples cut into 1 cm × 1 cm pieces. All flasks were loosely capped, positioned on a shaking incubator, and agitated at 37 °C and 120 rpm for 1 hour. A sequence of dilutions was prepared utilizing the buffer solution, and each 0.1 ml of the dilution was inoculated onto a nutrient agar plate. The inoculation plates were incubated at 37 °C for 18–24 hours, after which the surviving cells were enumerated. A safety cabinet was utilized for the production of bacterial cultures and their transfer to agar plates. The comparison was made between the amount of bacterial cells surviving following contact with the control, utilizing equation-1[19].

%Reduction = [B-A / R]100

A and B represent the viable cell counts (CFU/ml) for the flasks containing test samples and control (blank samples), respectively, after a contact time of 1 hour. Proposed formulation for sanitary napkins.

Fig 2. Antimicrobial test

Table No. 1: Proposed composition for sanitary napkins.

Sr. No	Component	Raw material	Function
1	Top sheet	1 layer of muslin cloth	Fluid permeable surface cover which allows easy liquid to penetrate and skin friendly
2	Softness core	cotton 3 layers	Provide softness
3	Absorbent core	1 layer of banana fiber sheet	Biodegradable absorbant
4	Back sheet	1 bilayer of parchment paper	Moisture impermeable barrier

Leakage test

As per EAS 96:2008, Annex B, the examination is performed to evaluate the efficacy of the barrier layer. A barrier sheet measuring 6.5 mm in length is cut, weighed, folded into a conical form, and positioned in a

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funnel. Twenty milliliters of the test fluid (water) is poured into it. Following a 24-hour period, the fluid-filled funnel is preserved and examined for leaks by calculating the difference between the final mass and the original dry weight [20].

Absorption rate test

The vertical wicking test entailed submerging a dry pad in a beaker containing 200 ml of a blood substitute (water). One end of the test specimen (25mm × 170mm) is secured vertically, while the opposite end is immersed in the test fluid to a depth of approximately 2mm. The mass gain of the pad was monitored every 30 minutes, while the item was visually inspected and documented. Upon complete saturation of the pad, the absorption rate was determined. The absorption rate can also be ascertained by quantifying the reduction in mass within the beaker [21,22].

Fig 3. Absorption rate test

Degradation study

The samples underwent soil degradation investigations to evaluate their degradability. Test specimens of 2 x 2 cm² were embedded in the soil, and their weight was documented regularly. The weight reduction was computed and is illustrated in Equation [23].

In the environment, the O-H bond at around 3500–3300 cm−1 exhibits a pronounced and wide absorption, indicating the presence of many hydroxyl groups in the fiber. The reduction in strength and intensity can be ascribed to the breakage of hydrogen bonds between the hydroxyl groups of cellulose and hemicellulose molecules. Comparable outcomes were noted by [24]. The band at approximately 1632.65 cm−1 signifies the C=O stretch of the acetyl group in hemicellulose[25]. The peaks at 1000–1200 cm−1 indicate C–O–C asymmetrical stretching (cellulose and hemicellulose) and C–O/C–C stretching vibrations. Nam et al. investigated the O–H stretching of the hydrogen bond network, which diminishes in intensity following alkali treatment[27]. This drop results from the disruption of hydrogen bonds between the O–H groups of cellulose and hemicellulose molecules. Treatment with alkali effectively eliminated the majority of lignin and hemicellulose components. Moreover, the treatment altered the fiber's hydrophilic properties to hydrophobic characteristics. Comparable findings were also documented by [29].

Fig 4. Biodegradable study

Wetback test

A testing approach was utilized to evaluate the pad's capacity to prevent fluid from resurfacing on the skin after penetrating the pad's cover material. In this experiment, 20 cc of a test liquid was applied to the sample. A pre-weighed filter paper was subsequently positioned over the sample, and a 3.4 kg force was exerted for a duration of 3 minutes [30]. Subsequently, the filter paper was reweighed, and the weight differential was documented as "wet back."

V. RESULTS AND DISCUSSION

Characterization of BF Napkins characterization

The physico-chemical characteristics of the proposed materials are detailed in Table 2. The analogous results are substantiated by [31].

Table 2. Banana fibre properties analysis.

Sr. No	Mechanical and Physical Properties	Details
1	Density (g/cm^3)	1.25–1.45
2	Tensile Strength (MPa)	515–795
3	Elongation (mm)	2.2.4
4	Fiber Diameter (m^4)	54–224
5	Chemical properties Cellulose (%)	58–61
6	Hemi cellulose (%)	5–8
7	Lignin (%)	4–7

Leakage test

This is an initial collection of napkins (devoid of SAP) utilized for experimentation. Increments of 2.5 ml, 5 ml, and 7.5 ml of fluid were added to the napkins and maintained for 24 hours. After 24 hours, it yielded sustainability durations ranging from 90 to 50 minutes, as

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illustrated. Furthermore, a second series of leakage testing was performed, concentrating on BF napkins including superabsorbent polymers such as carboxymethyl cellulose (CMC) and sodium polyacrylate (SPA). Water was incrementally added in volumes of 2.5 ml, 5 ml, and 7.5 ml. The sustainability duration for the napkin with SPA as the absorbent polymer ranged from 140 to 65 minutes, whereas for the napkin with CMC, it varied from 75 to 35 minutes, as demonstrated. Consequently, SPA yielded superior results compared to CMC. Comparable findings were documented by [32].

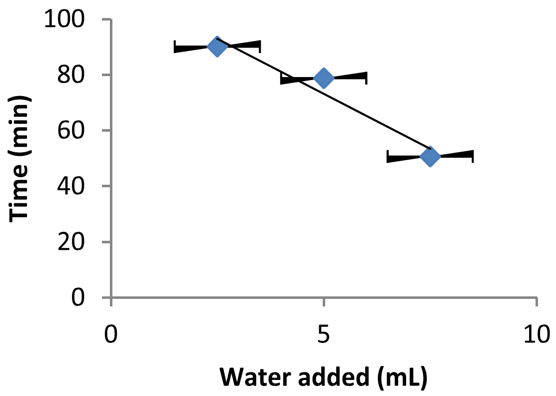

Fig 5. Leakage test without SAP

Absorption rate test

A standard napkin, devoid of SAP, had an absorption capacity of 45–50 g of fluid during a duration of 3 hours. To enable a comparison analysis, we included SAP, in both CMC and SPA forms, into the BF napkin and conducted the absorption test again. The analysis revealed that the napkin with SPA shown an absorption capacity of around 140 g in 3 hours, whereas the napkin with CMC exhibited an absorption capacity of 60 g during the same period. The untreated ordinary napkin absorbed 45–50 g of water over a duration of 3 hours. Results consistent with those reported by [33].The wet back test outcomes for various weights of the BF napkin, excluding SAP. The moisture emitted from the napkin varied between 2.7 and 3.5 grams. For comparative study, the identical test was performed on napkins containing SAP, as illustrated. The moisture emitted from the napkin containing SPA peaked at 2 g, signifying a positive response. The CMC-infused napkin emitted a maximum of 3.1 g of moisture, whereas the standard pad emitted 3.3 g. A lower wetback value indicates superior performance of the sanitary pad. Consequently, the SPA exhibits a reduced wetback value in comparison to the standard and CMC-infused napkin. Comparable results were noted by [34].

Degradation test

Section 2.9 indicates that the weight loss research was conducted at regular intervals. The napkin's initial weight was 2 grams. In vitro degradation, as determined by a standard weight loss research, indicated that the weight of the shredded sanitary pad decreased to 1.88g, 0.79g, and 0.52g after one week, three months, and eight months of degradation, respectively. Remarkably, after a duration of 6–8 months, the synthetic napkin displayed no indications of degradation, with its weight remaining virtually unaltered. In sharp contrast, the napkin made of BF fully dissolved within the same 6-8 month timeframe.

Reshma et al. asserted that the degrading features of the produced membranes distinctly indicated changes in their surface morphology and a weight loss reduction from 24.33 ± 6.94% to 18.67 ± 3.52% [35].

VI. BLOOD ABSORPTION CAPACITY OF PREPARED AND COMMERCIALLY AVAILABLE SANITARY PADS AVAILABLE IN INDIA

Commercially available sanitary napkins are selected for a comparative research with the created napkin. The chosen napkins are Whisper Choice (WC), Stayfree (SF), Fem (FM), Petals (PS), and Carefree (CF). Artificial blood is engineered to substitute natural blood, enabling the delivery of oxygen throughout the body. These compounds are referred to as blood replacements or artificial oxygen carriers.

The blood absorption ability of several sanitary pad models was assessed by quantifying the volume of blood each pad could retain. Whole blood was collected in a 10-mL syringe, maintained in a vertical orientation using a stand, and positioned such that its outlet made contact with the surface of a sanitary pad placed on a level bench top. One milliliter of blood was carefully deposited onto the center of the pad, and the droplet was permitted to be completely absorbed before an additional milliliter was added. The procedure was reiterated until the pad ceased to absorb blood at its center. The syringe was subsequently relocated to a location devoid of blood stains, and blood was introduced until the pad attained its maximum absorption capacity, which is defined as the total volume of blood absorbed before the final droplet remained on the surface for over 10 minutes. Three volumes were documented: Volume-A when the blood spread to at least one lateral edge of the pad, Volume-B when it extended to at least one longitudinal end, and Volume-C when the pad attained its maximal absorption capacity.

The current investigation revealed significant variability in the blood absorption capacity of sanitary pads based on model and brand. The blood absorption capacity of each pad within the same model was quite uniform, as shown by a minimal standard deviation. The results indicate that the current work napkins absorb less blood compared to those commercially available. It is economical due to its hygienic properties and absence of rashes, allowing individuals to utilize it in minimal quantities using a chemically free napkin.

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Fig 5. Blood absorption capacity

VII. COST OF DEVELOPED PAD SAMPLE

Cost analysis is a systematic procedure for ascertaining the expense associated with each component. This is crucial in the product design process.The market potential for emerging technology is substantial, especially in developing nations with untapped markets. The emergence of the middle class in areas such as Asia and Africa has led to heightened demand for many goods and services, including consumer electronics and healthcare. E-commerce has experienced significant development, with worldwide revenue projected to attain $6.5 trillion by 2023. Although biodegradable sanitary napkins may have a higher upfront cost than traditional alternatives, the long-term societal expenses, encompassing environmental remediation and public health implications, are likely to be significantly reduced [37]. Nonetheless, the elevated initial expense may impede wider adoption [38]. The cost of the designed napkin was one-third that of commercially available napkins, such as WC (Rs. 10/pad), SF (Rs. 12.6/pad), FM (Rs. 13.3/pad), PS (Rs. 15/pad), and CF (Rs. 15/pad). The maximum retail price (MRP) per unit of the developed sample is comparatively lower than that of commercial samples. The newly developed samples are not only cost-effective but also exhibit superior performance compared to other samples.

Table 3. Cost analysis of proposed pad.

Sr. No	Raw material use to develop napkin	Cost
1	1 layer of muslin cloth	0.1
2	cotton 3 layers	1.25
3	1 layer of banana fiber sheet	2.0
4	1 bilayer of parchment paper	0.50
Total cost		3.85 Rs

Social aspect

For an invention to be sustainable, it is insufficient to examine only the financial and ecological ramifications. The social effect is an essential element that must be incorporated for the study to be comprehensive. Unfortunately, the majority of studies undervalue this impact, along with the effects of mining, processing raw materials, and agricultural activities on laborers and local populations. Consequently, the societal concerns pertain to pad manufacture broadly, as well as to the specific materials utilized in pads, such as plastic and cotton [39].

Customer survey

In this portion, we conducted the survey freely after distributing the napkins to a designated group of ladies. To assess consumer experience and satisfaction, to reinforce safe usage in the marketplace, and to be notified of any unforeseen concerns or atypical tendencies. Consumers can comments using a telephone line. Health-related inquiries and remarks are subjected to ongoing analysis. The sanitary pad examined in this study was initially launched in 2021 at no charge. The incidence of health-related remarks, specifically about skin impacts, was two complaints regarding pad roughness per 50 pads provided. Although no commonly used sanitary pad is entirely free from minor irritation or pain complaints, the created product has received an exceptionally low volume of such complaints.

VIII. FUTURE WORK

In future study, additional scholars may do a statistical analysis of all quantitative results to ascertain the significance of differences between the new product and commercial alternatives. Additionally, tests on the comparative analysis of enhancing absorption capacity while preserving biodegradability. Finally, the characterization of TEM and HRTEM images can be conducted for a comprehensive analysis of the structure, morphology, and dimensions of the materials.

IX. DISCUSSION

The manufacture of eco-friendly sanitary pads signifies significant advancement regarding environmental effect and the financial challenges associated with current sanitary products. This study has demonstrated that the creation of natural products, particularly banana fiber as a substitute for plastic napkins, is viable. The expansion of banana fiber extends beyond local contexts, since its use in the production of sanitary pads holds significant worldwide relevance, particularly in developing nations where the lack of affordable hygienic pads is prevalent The biodegradable sanitary napkins designed for usage degrade more rapidly than the majority of conventional sanitary napkins that accumulate in landfills. The study's findings indicate that these napkins can biodegrade within 6 to 8 months, but traditional pads require a century to decompose.

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Furthermore, the utilization of natural fibers in the manufacturing process eliminates the usage of hazardous chemicals, rendering these items safe for prolonged use as they do not induce skin irritation or result in skin infections. The cost analysis reveals that the biodegradability issues of the newly created sanitary napkins are less expensive than those of most commercial alternatives. Ongoing enhancements and expansions in the production processes of the pads allow for a reduction in their price, making them more accessible to a broader audience.

X. CONCLUSION

The manufacture of eco-friendly sanitary pads signifies significant advancement regarding environmental effect and the financial challenges associated with current sanitary products. This study has demonstrated that the creation of natural products, particularly banana fiber as a substitute for plastic napkins, is viable. The cultivation of banana fiber extends beyond local significance, as its use in the production of sanitary pads holds greater relevance on an international scale, particularly in underdeveloped nations where the lack of affordable hygienic pads prevails.The biodegradable sanitary napkins designed for usage degrade more rapidly than the majority of conventional sanitary napkins that accumulate in landfills. The study's findings indicate that these napkins can biodegrade within 6 to 8 months, but traditional pads require a century to decompose. Furthermore, the utilization of natural fibers in the manufacturing process eliminates the usage of hazardous chemicals, rendering these items safe for prolonged use as they do not induce skin irritation or result in skin infections. The cost analysis reveals that the biodegradability issues of the newly created sanitary napkins are less expensive than those of most commercial alternatives. Ongoing enhancements and expansions in the production processes of the pads allow for a reduction in their price, making them more accessible to a broader audience.

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