

Design and Characterization of Eco-friendly Biodegradable Sanitary Napkins using Flax Carding Waste and Sansevieria Trifasciata Fibers

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1. Abstract

Menstrual hygiene is a critical health concern for women worldwide. Commercially available sanitary pads often contain non-biodegradable materials and harmful chemicals like dioxins and petrochemicals, which pose risks to both human health (skin irritation, reproductive issues) and the environment. This study focuses on the development of an eco-friendly, biodegradable menstrual hygiene product. By utilizing natural absorbent materials such as flax carding waste and Sansevieria trifasciata fibers, the research aims to provide a sustainable alternative that ensures high absorbency and comfort. The proposed biodegradable pad not only addresses the health hazards associated with synthetic materials but also mitigates the environmental impact of non-biodegradable menstrual waste, offering a safer and greener solution for feminine hygiene.

Keywords:

Biodegradable sanitary napkins, Menstrual hygiene, Flax carding waste, Sansevieria trifasciata, Sustainable absorbent materials.

INTRODUCTION

2.1 Menstruation

Menstruation is a process in which women discharge blood and other material from the lining of the uterus at an interval of about 28 to 35 days from puberty until menopause. It causes serious problems for women if not managed properly. This menstrual discharge can be absorbed by some absorbent material. The functional requirement of a feminine hygiene product is to absorb and retain the menstrual fluid so that backtracking of fluid does not happen and at the same time it should be odor free. Commercially available menstrual hygiene pads are made up of material which may seem innocuous but they are laced with dioxins, petrochemicals, artificial fragrances etc. When these chemicals come in contact with sensitive skin tissue, which can lead to skin irritation. Cellulosic chlorine bleached pulp; rayon which is used to increase absorbency of pad contains dioxin leads to cervical cancer irregular growth in reproductive organs. Deodorants and synthetic material used in sanitary pads blocks dampness and heat which encourages yeast and bacterial growth. One of the major concerns of disposable pads is its non-biodegradability which increases generation of menstrual waste which ends up in leaking into nature and polluting rivers. Also it causes occupational hazard as the used pads are to be picked up by waste pickers by their bare hand. This problem can be elevated by developing the biodegradable menstrual pad. [Barman, A, et al., 2017]

2.2. Environmental impact

Sanitary napkins indeed contribute significantly to plastic pollution, yet their environmental impact is often underestimated or overlooked compared to other sources. The issue lies in the materials used in most disposable sanitary products, which include plastics like polyethylene, polypropylene, and superabsorbent polymers. These materials take hundreds of years to decompose and often end up in landfills or water bodies, posing a threat to marine life and ecosystems.

Moreover, the packaging of these products also adds to the plastic waste problem. Despite efforts to promote eco-friendly alternatives such as biodegradable or reusable sanitary products, the usage of conventional disposable sanitary napkins remains widespread due to factors like convenience, affordability, and cultural norms. [Siddiqe, R., 2019]

2.3. Environment Degradation

The expansion of population, demand for commodities increases prompting industrialization and use of technologies dependent upon resources leading to exploitation of resources. Industries in the process of manufacturing emerges harmful toxic gasses like carbon monoxide, hydrogen sulphide, solvents and other wastes as by-product passed to the sink capacity of the environment. Today's era is the "Age of plastic" which is a ubiquitous component in industrial sector. Unfortunately, plastic contributes to the degradation of environment as during manufacturing of plastic various toxic chemicals are released like carcinogenic, neurotoxic, and hormone-disruptive chemicals which find their way in ecology through land, water and air pollution. Many industries use plastic as a raw material in manufacturing of goods, women hygiene products industry is one among them. Sanitary napkins comprise of multi-layered structure made up of non-biodegradable materials like polyethylene, polymeric films, wood pulps degrading environment each day, which is the leading concern of the economy.

2.4. To develop biodegradable pad

The normal composition of sanitary napkins poses environmental challenges due to the slow decomposition of synthetic materials. Even this, the products are indispensable for women's hygiene. In looking for more environmentally friendly solutions, we have focused on the made to develop the biodegradable pad with lotus stem fiber and additives.

The choice of lotus stem as the primary material for this project is guided by its unique physical properties, which render it exceptionally suitable for sanitary napkin production. The lotus stem demonstrates an impressive water absorption rate of $263.52 \pm 1.29\%$, which makes it a perfect choice for effectively managing moisture in sanitary napkins. Moreover, its swelling index of 3.2 guarantees it can securely hold liquids while keeping its structural integrity intact. Additionally, the inclusion of globular proteins in lotus stem fibers minimizes foaming, elevates surface tension, and prevents leaks, thus enhancing the overall effectiveness and trustworthiness of the suggested biodegradable napkins [Kirthy Reddy, et al., 2022]. To ensure that our lotus stem fiber-based sanitary napkins not only excel in terms of performance but also provide added benefits to users, we plan to incorporate certain natural additives. These additives, including neem and aloe vera will enhance the product's antiitching properties, provide a pleasant fragrance, and offer a cooling effect, thus making the napkins more comfortable and soothing for users [Banappagoudar, S. B., et al., 2021]. By harnessing the innate capabilities of lotus stem fibers, we aspire to contribute to the development of sustainable, biodegradable sanitary napkins that minimize the environmental impact of menstrual hygiene products. This project seeks to blend traditional wisdom with modern scientific innovation to offer women a greener, healthier, and more eco-conscious choice for their menstrual needs, addressing both hygiene and environmental concerns. [Khurshid, M. F, et al., 2015]

2.5. Objectives:

- ❖ To produce 100 % environment friendly sanitary pads.
- ❖ Chlorine-free biodegradable sanitary napkins
- ❖ Free from irritations, allergies, itchiness, and infections

- ❖ Packaging with biodegradable materials
- ❖ pH compatible and free from plastics
- ❖ Providing natural fragrance
- ❖ To decrease severe complications in women

MATERIALS

- Lotus stem fibre
- Neem
- Aloe vera
- Cotton

3.1 Lotus stem fibre:



Figure 3.1: Lotus stems

3.1.2. Stem lotus fibre



Figure 3.2: Stem lotus fibre

3.1.3 Properties

This fibre is a unique and luxurious natural fibre that is prized for its exceptional properties. Here are some of the key properties of lotus fibre and their explanations in detail:

Softness

Lotus fibre has an incredibly soft and silky texture that is well-known. This is due to the fine and delicate fibers that make up the lotus stem and seed head. Despite its softness, lotus fibre is also quite durable and can withstand regular wear and tear.

Moisture-wicking

This fibre is excellent at wicking away moisture from the skin, making it a popular choice for clothing and accessories. The fibers can absorb up to 30% of their weight in moisture, which helps to keep the wearer dry and comfortable even in hot and humid conditions.

Antibacterial

Lotus fibre has natural antibacterial properties that help to prevent the growth of bacteria and fungi. This makes it an ideal choice for clothing and textiles that come into contact with the skin, as it can help to prevent odors and infections.

UV-resistant

Lotus fibre is naturally resistant to UV radiation, making it an excellent choice for outdoor clothing and accessories. The fibers are able to block up to 98% of the sun's harmful UV rays, helping to protect the wearer's skin from damage and premature aging.

Sustainable

Lotus fibre is a sustainable and eco-friendly alternative to synthetic and conventional natural fibres. The lot The plant grows with minimal water and fertilizer, and the fith fibers are extracted by hand using traditional methods, which reduces the carbon footprint of the industry.

Versatile

Lotus fibre offers a high degree of versatility and finds application in various fields such as clothing, accessories, home textiles, and art. Handcrafted production methods extract the fibres from the lotus plant. Which can then be spun into a variety of yarns. These yarns can be knitted or woven into different fabrics with vVarious textures.

3.2 Neem:



Figure 3.4: Neem

3.2.1. Properties

Anti-microbial

Neem has antimicrobial properties, which means it can kill or inhibit the growth of pathogens that are harmful to us.

Anti-fungal

Neem's antifungal properties make it highly effective against ringworm, athlete's foot, and nail infections.

Antifertility

Neem possesses antifertility properties, affecting both male and female reproductive systems, making it a potential contraceptive agent. These properties are attributed to compounds found in neem leaves, seeds, and other parts of the plant.

Anti-inflammatory & Analgesic

Neem's anti-inflammatory properties may help reduce swelling and pain.

Antipyretic

Neem can help manage fever symptoms and prevent extreme temperature spikes, its antipyretic properties.

Antioxidant

Neem is a rich source of antioxidants, protecting the body from the adverse effects of free radicals.

Nematicidal

Neem has nematicidal properties, making it effective against various nematodes (roundworms) that cause plant diseases.

Anti-diabetic

Neem is known to possess anti-diabetic properties, helping manage blood sugar levels and may encourage insulin production.

Anti-dermatic

Neem leaves, flowers, and fruits can help treat a myriad of skin conditions.[Subapriya R,et al.,2005]

3.3. Aloe Vera



Figure 3.5: Aloe vera

3.3.1. Properties

Moisturizing

Aloe vera is highly hydrating and helps to moisturize the skin, making it useful in skincare products such as lotions and creams.

Wound healing

The wound healing process involves the restoration of damaged tissues to maintain their integrity. Aloe vera contains essential amino acids crucial for this process, along with various inorganic electrolytes like iron, potassium, magnesium, chromium, copper, sodium, calcium, and zinc. Additionally, it aids in preventing scar formation by stimulating cell synthesis and promoting regeneration in the deepest layers of the skin after skin injuries.

Anti-inflammatory

Aloe vera gel is more effective against inflammation caused by prostaglandin synthesis as well as infiltration of leukocytes and is less effective against inflammation caused by allergenic agents.

Anti-Cancer activity

The glycoproteins and polysaccharides found in aloe vera contribute to its effectiveness as a powerful chemo-preventive agent, offering benefits against diverse cancer types. These constituents actively boost the immune system, enhancing its ability to combat cancer cells.

AntiOxidant effects

Aloe vera contains various antioxidants including α -tocopherol, carotenoids, ascorbic acid, flavonoids, tannins, and vitamins C and E. Its antioxidant effect is influenced by dosage, making it beneficial in treating a range of illnesses

Skin-soothing

Aloe vera has a cooling and soothing effect on the skin, which can help alleviate discomfort and irritation. [Abid Aslam, et al., 2018]

3.4. Cotton



Figure 3.6: Cotton

3.4.1. Properties

Comfortable

Cotton is incredibly comfortable to wear

Soft

The cotton plant is naturally soft and fluffy and cotton fabric retains that soft feel

Natural fibre

Cotton is made from cotton fibres, a natural plant based material

Absorbent

The space between cotton fibres means cotton is absorbent and can wick moisture from the skin

Breathable

The gaps in the fibre also makes cotton fabric breathable.

Drapes well

Cotton hangs from the body in a naturally fitting shape

Durable

Cotton is strong, and actually gets stronger when wet. The secret to any sustainable wardrobe is helping your clothes last longer, which makes cotton perfect for fashion

No static

Cotton does not conduct electricity, therefore you won't get a static shock like some synthetic fabrics. [Elmogahzy, et al.,2018]

METHODOLOGY

4.1. Method 1:

Treated - Lotus stem fibre

Lotus stems, cut into 7-centimeter pieces, were cleaned using deionized water to remove surface dirt. Afterward, the cleaned lotus stems were allowed to dry naturally at room temperature. Next, they were treated with an alkaline solution, sodium hydroxide, by immersing 2 grams of the stems in a solution containing 20 grams of sodium hydroxide per liter of water, in a 100-milliliter liquid volume. This mixture was heated to 80°C for 60 minutes. Following this treatment, Sample 1 (S1) was obtained, which involved rinsing to remove soluble impurities and then air-drying for 30 minutes [Cheng, et al.,2017]. After the initial treatment, a 2-gram portion of the sample was treated with hydrogen peroxide in a 50-milliliter volume, undergoing heating for varying durations. The resulting samples were compressed and rinsed to remove debris and impurities from the surface. Lastly, the lotus fibers were rinsed until reaching a neutral pH and then air-dried for an additional 30 minutes, completing the process and yielding Sample 2. [Cheng, et al.,2017]



(a) Lotus stems was cut into 7 cm



(b) Lotus stems were pretreated with alkaline solution



(c) Lotus stems were squeezed and rinsed



(d) after, Sample 1 has obtained



(e) Sample 1 has purification with H₂O₂



(f) Finally, Sample 2 has obtained

Figure 4.1: Treated with Lotus stem fibre

4.2. Method 2:

Non-Treated Lotus Stem Fibre

To begin the process, head to a nearby lotus pond and properly gather raw lotus stems. Once you've collected them, it's time to extract the fibers. This is typically done using a method known as sheeving, which involves separating the fibers from the stems. It's a meticulous process that requires patience and precision. The fibers obtained through sheeving are often strong and durable, making them ideal for various applications such as weaving or crafting. Finally, the raw lotus stem fibers have been manufactured by one of them for sanitary pads.



(a) Gather, a Raw lotus stems



(b) washing through remove any dirt or debris



(c) separating the fibers from the stems



(d) Finally, pure lotus fibre has obtained

Figure 4.2: Non-Treated lotus stem fibre

To yield around 100 grams of lotus stem, one typically requires approximately 10 grams of fiber. This ratio signifies the efficiency of fiber extraction from lotus stems. Through meticulous processing methods, such as sheeving, the fibers are separated from the stems, resulting in a higher quantity of usable material.

4.3. Additives preparation:

4.3.1. Neem Leaves

To collect neem leaves, locate a neem tree in a garden. After harvesting, let the leaves dry for two days. Extend the drying process for a week until they become crunchy. Finally, grind the dried neem leaves into a powder, suitable for a variety of uses including provide a pleasant fragrance, comfortable and anti-itching properties.



(a) Gather, a neem leaves



(b) the Dried neem leaves



(c) neem powder

Figure 4.3: preparation of neem powder

4.3.2. Aloe vera

To collect aloe vera, locate a nearby plant. After harvesting, allow the aloe vera to dry for two days. Then, cut it into small pieces and let it dry for a week. Once dried, grind the aloe vera into a powder form. This powder can be stored for various uses, such as comfortable, cooling effect and soothing for users.



(a) Aloe vera cut into small pieces



(b) Aloe vera powder

Figure 4.4: preparation of Aloe vera powder

4.4. Assessment of physio-chemical properties of lotus stem fibres

After the analysis of composition of lotus stem fibres, their physical and chemical properties were evaluated using standard test methods.

4.4.1. Fibre fineness

Lotus stem fiber fineness refers to the diameter or thickness of individual fibers found in lotus stem fibers. Fineness is a crucial characteristic because it influences various properties of the fiber, such as its softness, strength, and ability to be spun into yarn or woven into fabric. [Dong Sheng, et al., 1954]

4.4.2 Bundle strength and elongation at break

Bundle strength is an important parameter to judge the quality and strength of the resultant yarn. A bunch of fibres is tested together for strength and elongation at break using a Stelometer. It is an instrument that tests a flat sample of fibres for tenacity and elongation. The instrument breaks a flat bundle of fibres and indicates the force required to break the fibres on a graduated scale. The elongation is determined on another graduated scale at the breaking point of the fibre sample. A simple calculation is used to determine the tenacity of the sample. The calculation uses the breaking point number (which is indicated on the graduated scale) and the known weight of the sample to determine tenacity.

A precision balance is needed in conjunction with the Stelometer to get the weight of the sample. It gives tenacity in grams per tex which was converted to grams per denier by standard formula. [Ananthi, P., et al.,2023]

4.4.3 Moisture regain

It was determined according to IS-199 standards. [Archana Jain,et al., 2022]

4.5. Development of sanitary napkins according to BIS 5405-1980 specification

Sanitary napkins were manufactured using lotus stem fibres mixed with additives like neem and aloe vera in the absorbent layer in treated and non-treated proportion.

All the napkins were tested for various physical and hygiene characteristics, which are discussed below.



Figure 4.5: Front side of sanitary napkin by using Lotus stem fibre



Figure 4.5: Front and back side napkin by using Lotus stem fibre

4.6. Evaluation of the branded and lotus stem fibre napkins

Two branded napkins and two unbranded napkins were evaluated for various physical and hygiene properties. Both the branded and unbranded napkins were of regular variety.

4.7. Comparative evaluation of Physical parameters

The manufactured napkins were assessed for following physical parameters:

4.7.1. pH of the sanitary napkins: The pH of sanitary napkins was tested as per the method given in IS: 1390-1961, using the aqueous extracts of the samples. 2g of absorbent layer from the test napkins was taken and put into 100 mL of distilled water (pH-7) at room temperature. The sample was shaken in a mechanical shaker for 30 minutes, and the aqueous extract was checked for its pH. Three samples of each type were tested, and the mean of their readings was calculated.

4.7.2. Absorbency and ability to withstand pressure: One of the main requirements of sanitary napkins is to absorb body fluid and then retain it for long periods of time and also avoid its backflow under pressure .

Good absorbency prevents any leakage from taking place. The napkins were observed for any leakages from the sides or back after placing weight over them. This test was conducted in accordance with IS: 5405-1980. The napkins were laid on a level flat transparent surface, so that the underside of the sanitary napkin can be observed. Then 20 mL test fluid, prepared by the method mentioned in the standard, was poured at the rate of 10 mL per minute on to the centre of the sanitary napkin from a height of approximately 1–2 mm. After the napkin had absorbed the full amount of fluid, a standard weight of 1 kg was kept for 1 minute on the portion where fluid was poured. After removing the weight, back and sides of the sanitary napkin were observed for any fluid showing up.

4.7.3. Water Retention: The water retention of sanitary napkins was measured in quantitative terms using the centrifuge method, ASTM: D 2402-2001. This test is intended to give a measure of the amount of water which cannot be removed from thoroughly wetted fibre solely by mechanical means as applied by the centrifugal force. In this method, water retained by the fibre mass includes water absorbed from the prevailing atmosphere, water imbibed during immersion and water adhering to the fibre surfaces after being centrifuged.

Three samples weighing around various grams were cut out from different sections of each sanitary napkin. The extreme ends were not included where the absorbent core is the thinnest.. Each prepared specimen was immersed in 250 mL distilled water at room temperature for 5 minutes to completely wet it out. The wetted-out specimens were put into centrifuge at an acceleration of 6000 rpm and allowed to spin for 20 min. The average of three readings was calculated as below

$$R = \frac{(M-D)100}{(D-T)}$$

where

R = water retention %

M = mass of moist specimen with its tare mass in grams

D = mass of dried specimen with its tare mass in grams

T = mass of the tare

4.7.4. Disposability: The disposability of the napkins was tested in accordance to IS: 5405-1980. Three samples were drawn from each packet, and each napkin with the top and bottom coverings removed was immersed in 1L of water at room temperature and stirred. Time taken for the absorbent layer to disintegrate in water was noted in terms of more or

less than 5 minutes. The standard requires the fibre mass to disintegrate in water in 5 minutes to fulfil the standards of disposability.

4.7.5. Hygiene parameters: These were tested as per the requirements mentioned in IS-5405-1980 using standard tests prescribed for them. To evaluate the hygiene parameters of sanitary napkins and extracted Lotus stem fibre in terms of the level of micro-organisms in the product as well as the presence of common skin and uterine pathogens.

4.7.5.1. Bacterial and fungal bio burden: The determination of bacterial and fungal bio burden was carried out by the aerobic plate count method (APC) and the yeast and mould count(YMC) method respectively. Five samples of 5 g each were cut from the centre portion of each napkin and were put into 50 mL of saline solution (0.85% sodium chloride). The sample was shaken vigorously in the solution and the liquid was extracted from the napkin. The extract was serially diluted and plated out on respective medium, that is, plate count agar for bacterial bio burden and Sabouraudramphenicol agar for fungal bioburden. The plates were incubated at 37°C for 48 h for bacterial APC and at 22°C up to 120 h for YMC. All colony forming units (CFUs) were counted.

4.7.5.2. Presence of common skin pathogen (*Staphylococcus aureus*): The sanitary napkins were also tested for the presence of *Staphylococcus aureus* using the standard test method IS:5887. 5 g samples were cut from the centre portion of each napkin and were put into 50 mL of saline solution (0.85% sodium chloride). The sample was shaken vigorously in the solution, and the liquid was extracted from the napkin. The extract was inoculated on medium and the agar plates were incubated for 30 h at 37°C. From the incubated plates, the suspected colonies of the organism, if any, were counted [18].

4.7.5.3. Presence of common uterine pathogen(*Candida albicans*): *Candida albicans* is a common urinary tract pathogen known to cause urinary tract infections. To test for presence of this pathogen, five samples of 5 g each were cut from the centre portion of each napkin and were put into 50 mL of saline solution (0.85% sodium chloride). The sample was shaken vigorously in the solution, and the liquid was extracted from the napkin. The extract was inoculated on potato dextrose agar, and the agar plates were incubated for 48 h at 25°C. From the incubated plates, the suspected colonies of the organism, if any, were counted [Chanana B, et al., 2009].

Results and Discussion

5.1. Extraction and characterization of lotus stem fibres

The fibres extracted from lotus stems using alkali treatment and were bleached and then characterized for their various properties. The Composition of lotus stem was estimated as follows:

| S.NO | Component | Amount in % |
|------|----------------|-------------|
| 1 | Cellulose | 68.04 |
| 2 | Hemicelluloses | 9.36 |
| 3 | Lignin | 8.76 |
| 4 | Pectin | 3.2 |
| 5 | Wax content | 3.1 |
| 6 | Ash content | 2.9 |
| 7 | Hydrotrope | 2.74 |

Table:5.1: characterization of lotus stem fibres

5.2. Micromorphology of lotus fiber in cross section and longitudinal

The scanning microscope photographs of lotus monofilament fiber in cross section, longitudinal and longitudinal revolving are respectively shown in Fig.5.1, Fig. 5.2 and Fig.5.3

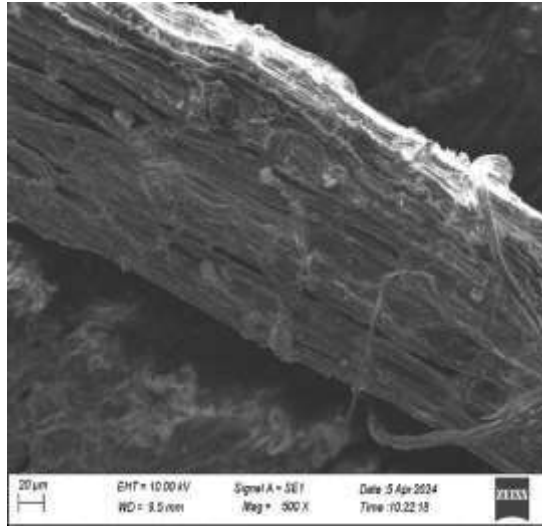
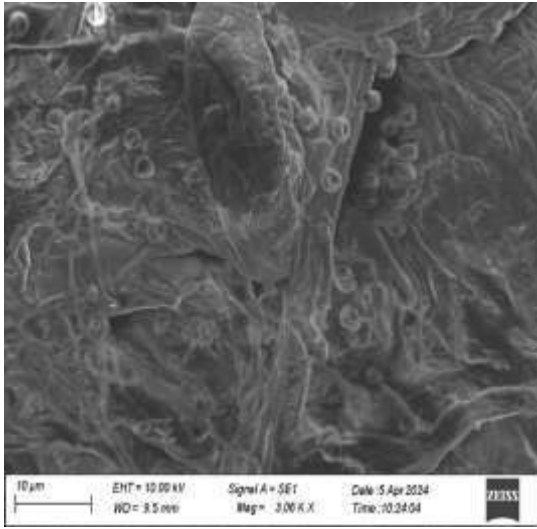


Figure 5.1: Lotus monofilament fiber in longitudinal

Figure 5.2: Lotus monofilament cross section fiber in

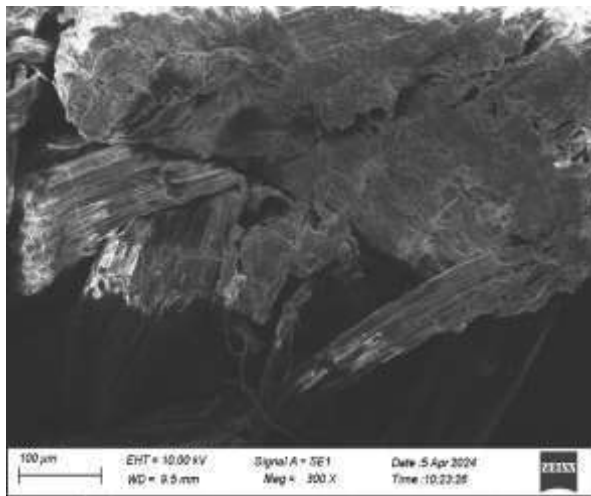


Figure 5.3: Lotus monofilament fiber in longitudinal revolving

5. 3.Physical properties of the extracted lotus stem fibres

The values of various physic-chemical properties of extracted lotus stem fibres:

| S.NO | Parameter | Values for lotus stem fibres |
|------|---------------------|------------------------------|
| 1 | Fineness | 1.55 (dtex) |
| 2 | Bundle strength | 2.23(cN/dtex) |
| 3 | Elongation at break | 4.16 (%) |

| | | |
|---|---|-----------|
| 4 | Moisture regain | 12.32 (%) |
| 5 | Absorbency (drop penetration time in seconds) | <1s |
| 6 | Water retention | 92.69 |
| 7 | pH | 6.43 |

Table 5.2: physico-chemical properties of lotus stem fibre

5.4. Comparative evaluation of Physical parameters of Lotus stem sanitary napkins

The physical parameters of all the branded, locally made and developed lotus stem fibres napkins were evaluated in terms of pH, absorbency, flexibility, water retention and disposability.

5.4.1. pH

According to IS 5405-1980, a sanitary napkin should have a pH of 6–8.5.

The pH of sanitary napkins was tested as per the method given in IS: 1390-1961. The pH of all the napkins varied from 6.25-6.43. Thus, all the sanitary napkins conformed to the acceptable pH range, that is, 6–8.5. Both the napkins, which were made by using treated and non-treated lotus stems fibres in absorbent layer, also fell in the acceptable range and had almost similar pH, that is, 6.43 and 6.30, respectively. The pH impacts the adhesion of resident skin microflora; an acid skin pH is required to keep the resident bacterial flora attached to the skin, while an alkaline pH (8–9) might result in its dispersal from the skin. In subsequent studies efforts could be made to lower the pH to a more desirable range of 5.5–6.5.



Figure 5.4:pH test

| S.NO | NAPKIN CODE | PH VALUES | | | AVERAGE |
|------|---------------------------|-----------|------|------|---------|
| 1 | A BRAND | 6.26 | 6.34 | 6.68 | 6.32 |
| 2 | | 6.24 | 6.30 | 6.22 | 6.25 |
| 3 | B BRAND | 6.30 | 6.35 | 6.24 | 6.29 |
| 4 | | 6.26 | 6.41 | 6.34 | 6.33 |
| 5 | C LOCAL | 6.26 | 6.41 | 6.34 | 6.43 |
| 6 | | 6.32 | 6.44 | 6.55 | 6.30 |
| | D LOCAL | 6.24 | 6.32 | 6.35 | |
| | | 6.24 | 6.32 | 6.35 | |
| | E TREATED LOTUS FIBRE | | | | |
| | | | | | |
| | F NON-TREATED LOTUS FIBRE | | | | |
| | | | | | |

Table 5.3: pH values of sanitary napkins



Figure 5.5: pH values of sanitary napkins

5.4.2. Absorbency and ability to withstand pressure:

The test is conducted under weight to simulate the real time conditions as the napkin incurs pressure to varying degrees during use, especially while sitting, which is when there are maximum chances of leakage and spotting.

The time taken for absorption of fluid by different sanitary napkins ranged from 02 s to 09s. Locally made napkin brands took a maximum of 09 s while treated lotus stem fibre napkins took the lowest time, that is, 02 s. Both the napkins which were made by using treated and non-treated lotus stem fibres recorded water absorption time of 02 s and 03 s, respectively.

The spread (patch size after placing the weight) of the patch formed by the fluid absorbed varied from 7.87× 2.36 inches square to 9.06 × 2.95 inches square for various napkins. Fluid retention is dependent on density of the absorbent layer. Most of the sanitary napkins available in market these days have super absorbent polymer (SAP) in compressed and uncompressed form which greatly enhances the absorbency and water retention properties of the napkins . All the napkins showed an increase in patch size after placing of weight.

None of the napkins showed any kind of leakage at back or sides. Though, some of the napkins showed a narrow line of liquid flowing lengthwise, through capillary action, apart from the patch formed in centre . Branded A napkins had the smallest patch size before placing the weight, but it was highest after placing the weight. The ability to withstand pressure is not dependent solely on the type of fibres used in absorbent layer rather it gets affected by multiple factors. Density of the absorbent layer also influences the absorption and stability of the product to a large extent. A highly compressed fibre expands on absorption while lightly compressed fibres gets collapsed due to absorption



Fig 5.6: 100 ml coloured distilled water in absorbency test



Fig 5.7: A (Brand)sanitary napkin after absorption of fluid

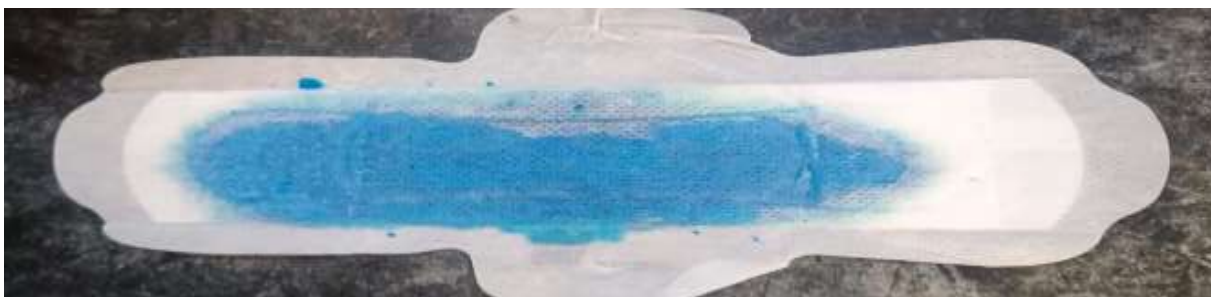


Fig 5.8: B (Brand) sanitary napkin after absorption of fluid



Fig 5.9: C (Local) sanitary napkin after absorption of fluid



Fig 5.10: D (Local) sanitary napkin after absorption of fluid

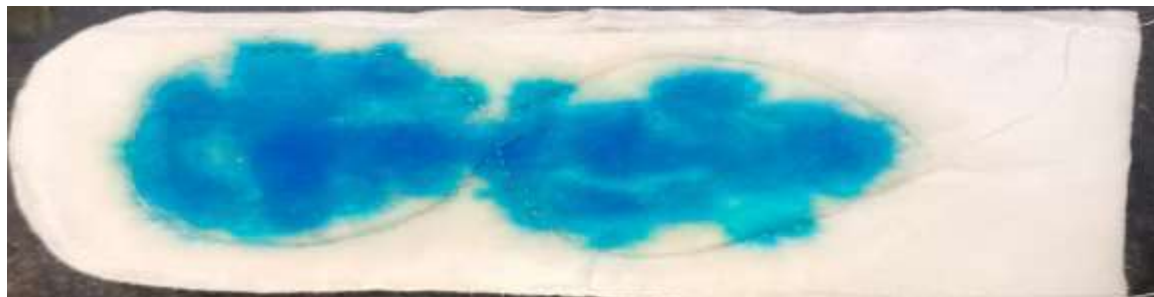


Fig 5.11: E (Treated lotus stem fibre) sanitary napkin after absorption of fluid



Fig 5.12: F (Non-treated lotus stem fibre) sanitary napkin after absorption of fluid

| NAPKIN CODE | INITIAL PATCH SIZE (INCHES) | PATCH SIZE AFTER PLACING 1KG WEIGHT (INCHES) | TIME TAKEN FOR ABSORPTION(S) | ABSORBENCY CAPACITY (mL) |
|-------------|-----------------------------|--|------------------------------|--------------------------|
| A BRAND | 7.87 × 2.36 | 8.02 × 2.68 | 02 | 50 |

| | | | | |
|----------------------------|-------------|-------------|----|----|
| B BRAND | 8.27 × 2.76 | 8.29 × 2.91 | 03 | 60 |
| C LOCAL | 8.07 × 2.56 | 8.39 × 2.68 | 05 | 40 |
| D LOCAL | 9.45 × 2.95 | 9.65 × 3.03 | 03 | 80 |
| E TREATED FIBRE | 9.06 × 2.95 | 8.80 × 3.07 | 02 | 90 |
| F NON- TREATED FIBRE | 9.06 2.95 | 8.88 3.10 | 02 | 90 |

Table:5.4:Absorbency and ability to withstand pressure

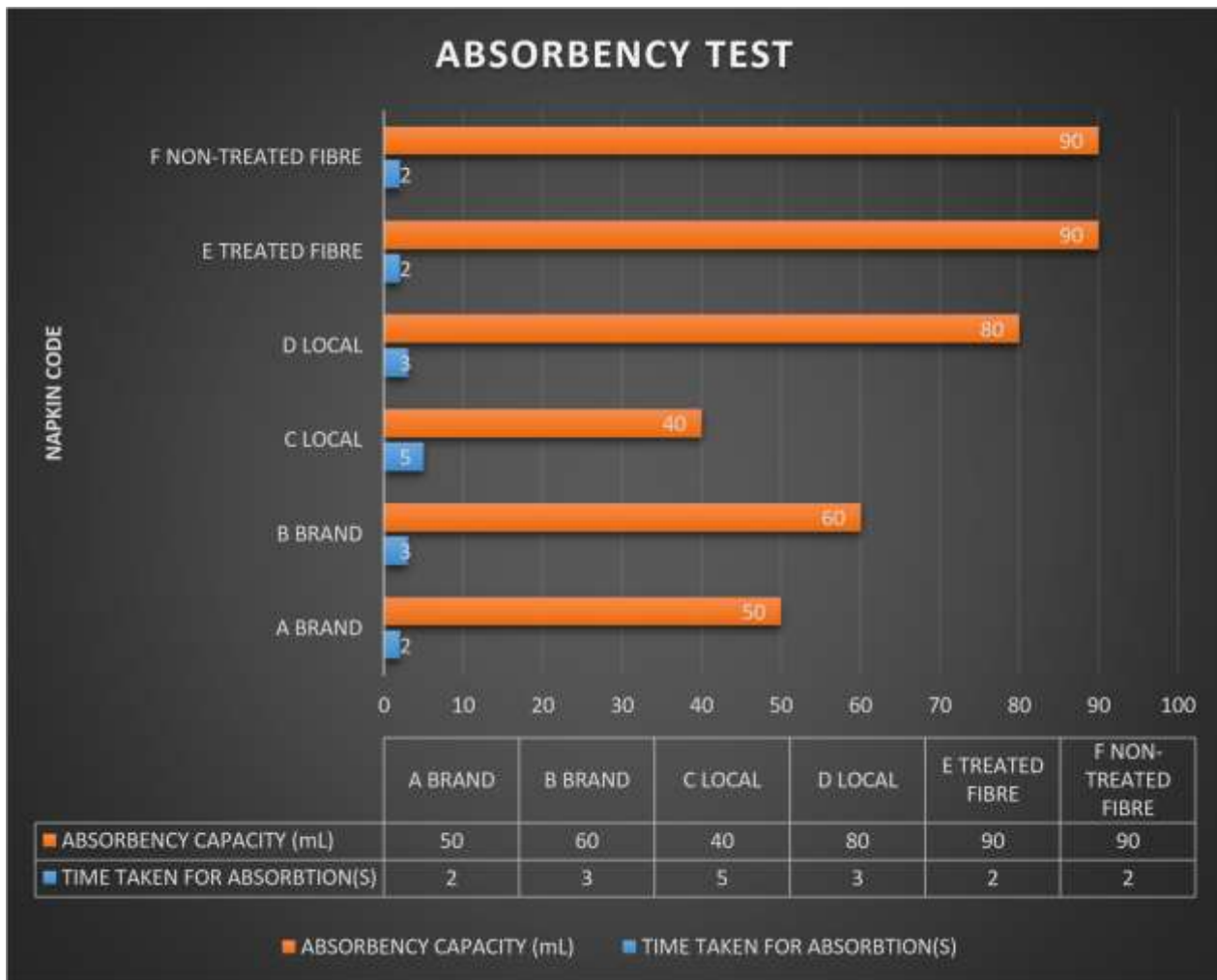


Figure 5.13: Absorbency test in sanitary napkins

5.4.3 Water retention

Table 5.5 shows the water retention capacity of various sanitary napkins. Water retention of all the napkins ranged from 40.83 % to 92.69 %. Treated lotus stem fibre E had the maximum water retention while napkin local C showed the minimum retention of water. Napkin with Treated lotus stem fibres showed better water retention, that is, 92.69 % as compared to napkin with Non-treated fibres.

BEFORE CENTRIFUGATION



Figure 5.14: Before centrifugation

AFTER CENTRIFUGATION



Figure 5.15: After centrifugation

| S. NO | NAPKIN CODE | M(mass of moist specimen in grams) | D(mass of dry specimen in grams) | T(mass of tared specimen in grams) | R (retention%) | Average R (%) |
|-------|--------------|------------------------------------|----------------------------------|------------------------------------|----------------|---------------|
| 1 | A BRAND | 1.10 | 3.71 | 2.00 | 34.48 | 45.60 |
| | | 2.20 | 5.94 | 4.06 | 49.73 | |
| | | 3.30 | 7.164 | 5.33 | 52.59 | |
| 2 | B BRAND | 1.10 | 3.30 | 1.81 | 32.27 | 50.45 |
| | | 2.20 | 6.42 | 3.90 | 40.28 | |
| | | 3.30 | 9.24 | 8.79 | 78.79 | |
| 3 | C LOCAL | 1.10 | 3.00 | 1.77 | 35.26 | 40.83 |
| | | 1.17 | 3.00 | 1.91 | 40.44 | |
| | | 3.30 | 8.30 | 5.64 | 46.80 | |
| 4 | D LOCAL | 1.10 | 4.28 | 4.25 | 89.94 | 86.23 |
| | | 2.20 | 7.39 | 7.23 | 86.32 | |
| | | 3.30 | 9.28 | 8.93 | 82.44 | |
| 5 | E TREATED | 1.10 | 3.36 | 3.13 | 89.82 | 92.69 |
| | LOTUS STEM | 2.20 | 5.10 | 4.98 | 95.86 | |
| | FIBRE | 3.30 | 7.77 | 7.43 | 92.39 | |
| 6 | F NONTREATED | 0.28 | 0.83 | 0.77 | 89.09 | 90.76 |
| | LOTUS STEM | 0.42 | 1.13 | 1.09 | 94.37 | |
| | FIBRE | 1.05 | 3.20 | 2.66 | 88.84 | |

Table 5.5 : Water retention of sanitary napkins

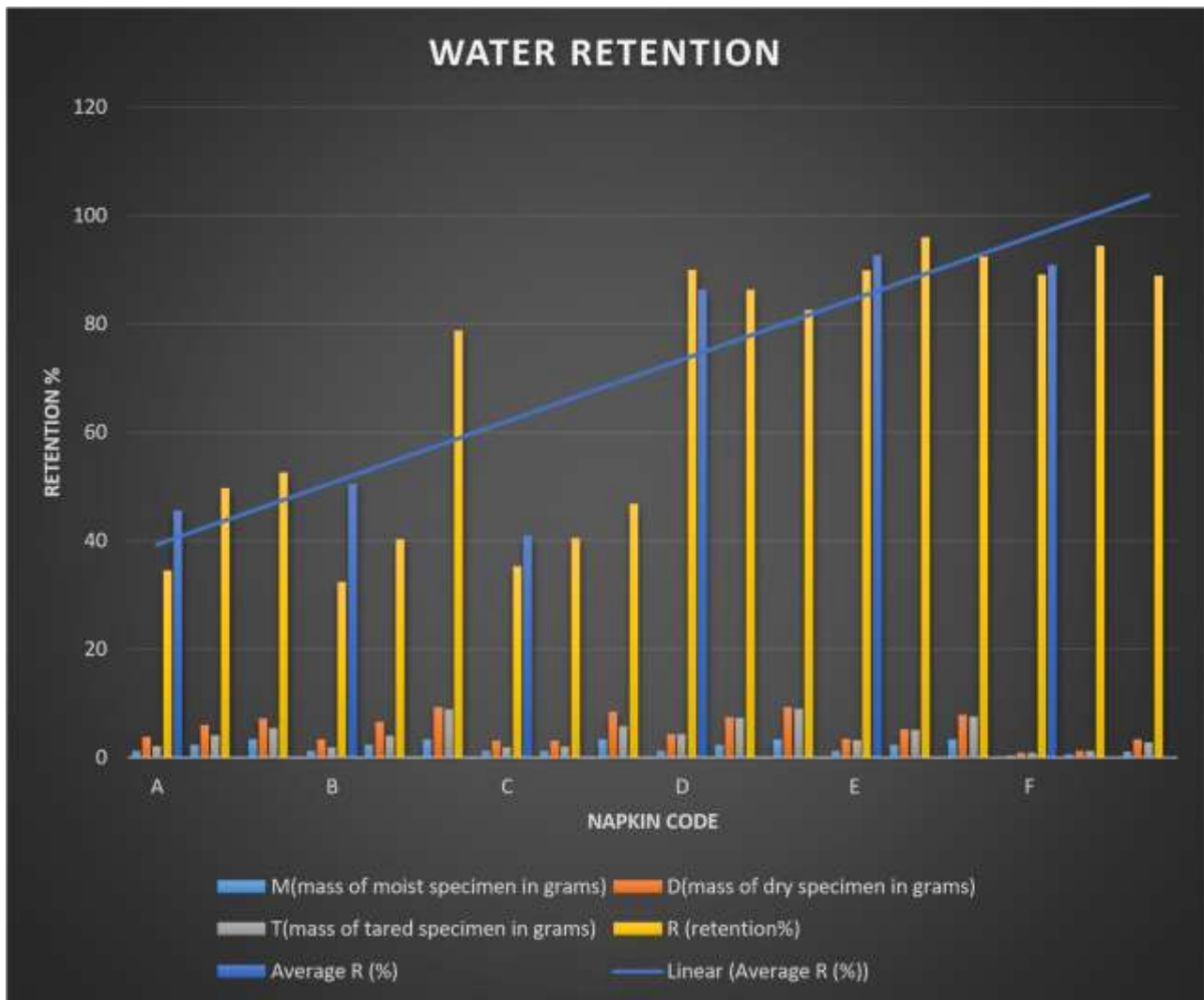


Figure 5.16: Water retention of sanitary napkins

5.4.4. Disposibility

It was observed that all the napkins disintegrated in water in less than 5 min.

5.4.5. Evaluation of Hygiene Parameters of Branded and Lotus stem fibre Sanitary Napkins

Microbial testing of hygiene products like sanitary napkins holds significance because these are worn in close contact to the vagina. At puberty, the normal bacterial flora of the vagina maintains acidic pH by acid from carbohydrates, especially glycogen. This seems to be an important phenomenon for prevention of growth of other, possibly harmful, microorganisms. If the pH gets altered, yeasts or bacteria might increase in numbers and cause irritation and inflammation [18].

5.4.5.1 Bacterial and fungal bio burden

The level of bio-burden of a product gives an idea of the status of hygiene during processing, handling and packaging. The manufacturers of branded sanitary napkins consider a bio-burden of less than 1000 c.f.u/ml as acceptable for their products [Chanana B, et al., 2009]. The bacterial and fungal bio-burden determined for various sanitary napkins is shown in Table: 5.6. Thus, the bacterial and fungal bio-burden of the napkins made with lotus stem fibres was found to be within permissible and acceptable limits.

5.4.5.2. Presence of common skin pathogen (*Staphylococcus aureus*) and common uterine pathogen (*Candida albicans*):

Many studies have shown earlier that diseases such as toxic shock syndrome and candidiasis might occur due to these [Achuthan K, et al.,2021]. The developed sanitary napkins were also tested for the presence of *Staphylococcus aureus* and *Candida albicans*. Both of these microorganisms were found to be absent in all the samples. *Staphylococcus aureus* is the causative agent for multiple human infections like bacteremia, infective endocarditis, skin and soft tissue infections [Unakal CG,et al.,2020].

| S.NO | NAPKIN CODE | AEROBIC PLATE COUNT(cfu/ml) | Mean yeast & mould count(cfu/ml) |
|------|--------------------------------------|--------------------------------|-------------------------------------|
| 1 | A (BRAND) | 2.1×10^2 | 2.3×10^2 |
| 2 | B (BRAND) | 1.5×10^2 | 2.0×10^2 |
| 3 | C (LOCAL) | 4.8×10^3 | 4.9×10^3 |
| 4 | D (LOCAL) | 9.5×10^2 | 9.7×10^2 |
| 5 | E (Treated lotus stem fibre) | 1.2×10^2 | 1.1×10^2 |
| 6 | F (Non- Treated lotus stem fibre) | 5.1×10^2 | 4.0×10^2 |

Table 5.6: Bacterial and fungal bio- burden of sanitary napkins

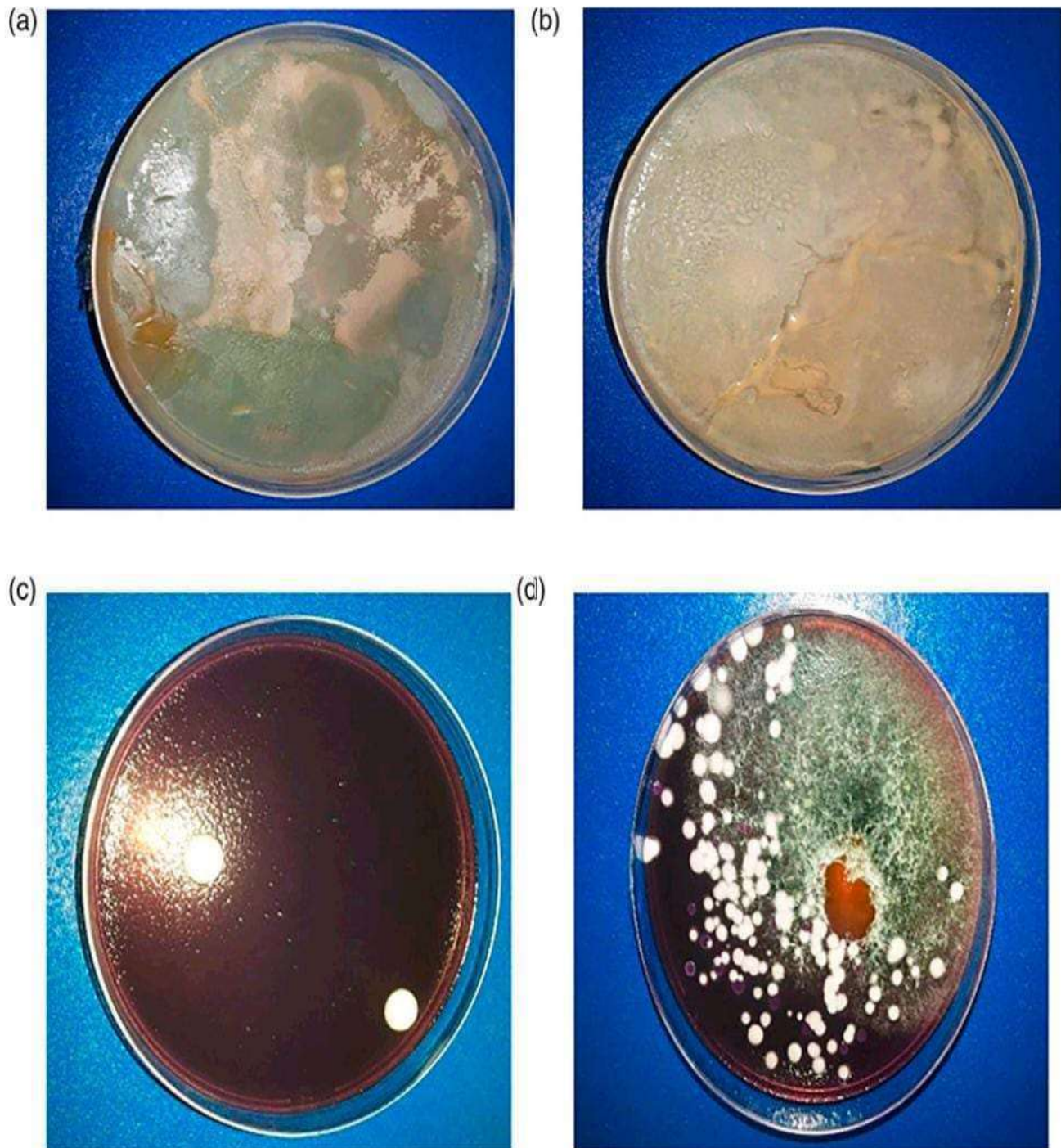


Figure:5.17:Typical colony characteristics of (a) and (b) bacterial bio-burden, (c) and (d) fungal bio-burden.

6.CONCLUSION

Nature has encompassed every solution within itself. With more and more use of Lotus stems fibre in hygiene product will make it eco-friendly. Use of Lotus stems fibre in sanitary pad will reduce the cost of the product will lower accessible to low income group women. As, the product is biodegradable, prevent nonbiodegradable waste generation.

The results of the study clearly indicate that Lotus stem fibre could prove to be a promising alternative in various hygiene products like sanitary napkins, diapers and absorbent sheets. The napkins developed with absorbent layer having Lotus stem fibres were found to be comparable to the napkins already available in the market. Various parameters like pH and bacterial and fungal bio-burden were within the range specified as per BIS standards and common skin and uterine pathogens were found to be absent. Though the absorbency and water retention of Lotus stem fibres are very high, the napkins having Lotus stem fibres in absorbent layer were high absorbent as compared to the branded napkins.

This might have resulted due to combination such as the top sheet and SAP, used in the sanitary napkins. The study aimed to find out the feasibility of using Lotus stems fibres in the absorbent layer of sanitary napkins/hygiene products. As consumption of hygiene products is on a continuous rise, alternative sources are required due to environmental concerns. Thus, an extensive study to standardize all the parameters for construction of sanitary napkins using Lotus stems fibres in absorbent layer shall be carried out so that application of Lotus stems fibres for various hygiene products could be undertaken successfully at the commercial level. As Lotus stems is considered a waste, its utilization as a big leap in conservation of natural resources.

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