International Journal of Bioresource Science
Citation: IJBS: **10**(01): 89-98, June 2023
DOI: 10.30954/2347-9655.01.2023.9

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

Review Paper

Potential of Natural Fibres in Sanitary Napkin

Kartick K. Samanta[1], S.N. Chattopadhyay[1*], D.B. Shakyawar[1], Tripur Baran Debnath[2], S. Bhowmick[1] and S. Bhattacharya[3]

[1]Chemical and Biochemical Processing Division, ICAR-National Institute of Natural Fibre Engineering and Technology, 12 Regent Park, Kolkata, India
[2]Amity Institute of Biotechnology, Amity University, New Town, Kolkata, India
[3]Washonomics Fulcrum Pvt. Ltd., Boral Main Road, Kolkata, India

*Corresponding author: sambhu_in@yahoo.com (**ORCID ID:** 0000-0002-3649-3375)

Received: 10-03-2023 **Revised:** 28-05-2023 **Accepted:** 05-06-2023

ABSTRACT

Menstrual hygiene is one of the important points of national as well as global health consideration that needs more attention for appropriate products development at affordable price. In India, the policy makers have included this issue as an important agenda, as far as public health programmes are concerned. Till date fibre-based cloth material is mostly used a significant figure in place of sanitary napkin that sometimes causes many infections. In the resent past, several companies, self-help-groups, entrepreneurs, etc. have been actively engaged in manufacturing the suitable sanitary napkin at affordable price by utilizing the locally and/or nationally available fibrous raw materials or wood pulp in mixing with requisite super-absorbent-polymer (SAP)/ materials. The wood pulp used in the sanitary napkin manufacturing is commonly imported, and thus becomes expensive. Attempts have been made to explore the alternative raw materials, particularly plant-based natural-fibres for their application in place of wood-pulp. Plant fibres like cotton, jute, flax, ramie, sisal, hemp, pineapple, sisal and nettle are mostly used in apparel, home and technical textiles. Some of these fibres and a few more viz., cotton fluff, organic cotton, water hyacinth, jute, banana, flax, kenaf, hemp, soya fabric, bamboo fabric, lyocell fibre, milkweed fibre, woollen fabrics and cellulose-acetate nano-fibres have been attempted in producing sanitary napkin (medical textile). Likewise, several attempts have also been directed to use/develop different polymers, as a replacement of super-absorbent-polymer (SAP), which is non-biodegradable in nature. Functional value of such sanitary napkins was further enhanced with aromatic and medicinal plant extracts and summarized in this paper.

HIGHLIGHTS

- Development of sanitary napkin.
- Natural fibre based sanitary napkin.
- Development of biodegradable napkin.
- Role of plant fibre as an absorbent layer.

Keywords: Natural fibre, Plant fibre, Sanitary napkin, Absorbent pulp, Medical textile

Feminine hygiene is one of the important health subjects of consideration both at national and international levels. In India, the policy makers have included this agenda under the public health awareness programmes. In the context of feminine hygiene products, sanitary napkin holds an important role as far as menstrual hygiene is concerned. According to the survey conducted

How to cite this article: Samanta, K.K., Chattopadhyay, S.N., Shakyawar, D.B., Debnath, T.B., Bhowmick, S. and Bhattacharya, S. (2023). Potential of Natural Fibres in Sanitary Napkin. *Int. J. Bioresource Sci.*, **10**(01): 89-98.

Source of Support: IUCEA; **Conflict of Interest:** None

by A.C. Nielson, only 12% of the Indian women has access to sanitary napkins (Nielsen 2010). Otherwise, they mostly use cloth which sometimes leads to variety of infections. The possible reasons for low usage of sanitary napkins are higher price of the products that makes them beyond the affordable range of many peoples along with lack of ease of availability in the remote areas. In the recent past, several companies, self-help-groups and entrepreneurs are actively engaged in manufacturing the sanitary napkin at affordable price by utilizing the locally and/or nationally available fibrous raw materials or wood pulp in mixing with appropriate super-absorbent-polymer (SAP)/ materials. According to feminine hygiene products market data the global feminine hygiene products market was valued at $38.9 billion in 2020, and is projected to reach $68.7 billion by 2030, registering a CAGR of 6.1% from 2021 to 2030 (Feminine Hygiene Products Market Size, Share & Forecast, 2030 (alliedmarketresearch.com)). The Indian sanitary napkin market size reached US$ 688.9 Million in 2022 and it is expected to reach US$ 1,227.1 Million by 2028, exhibiting a growth rate (CAGR) of 9.5% during 2023-2028 (https://www.imarcgroup.com/indian-sanitary-napkin-market). The increasing in awareness among the consumers in terms of menstrual hygiene along with the growing number of working women and enhancing the income levels along with purchase capacity are some of the major key factors stimulating the growth of the feminine hygiene products across the country. Furthermore, the increasing female literacy rate both in the rural and urban areas has also played an important role. Menstruation becomes an additional point of consideration in a women's life due to rising and falling of hormone that triggers mental stress in several ways in addition with loss of blood. According to National Family health survey 2022, a data on women age group of 15-24 indicates the 64% use of sanitary napkins, 50% use of cloth and 15% use of locally prepared napkins (https://swachhindia.ndtv.com/in-india-about-50-of-the-women-aged-15-24-years-use-cloth-during-periods-national-family-health-survey-68515/).

A sanitary napkin is mostly three-layers structure consisting, top sheet meant for absorption and transfer the body fluid, middle layer for absorption and holding the fluid, and bottom layer to perform as a barrier sheet. The middle absorbent layer contained the wood pulp and mostly mixed with super-absorbent-polymer (SAP) plays a vital role in order to absorb and hold the body fluid. The wood pulp in admixture with SAP, when comes in contact of liquid (menstrual blood) takes a gel form and that is the reason why it is called 'wood gel'. The wood-pulp used in sanitary napkin is imported, and thus becomes expensive. Cotton is found to be a promising fibre poised to replace the wood-pulp, especially in the feminine hygiene products, where light weight thinner products are desirable. However, the higher cost of cotton along with the high demand in apparel and home textile end-uses, it is one of the reasons, why it has not been considered to replace wood-pulp. There have been several attempts to explore the alternative raw materials particularly plant based natural-fibres, that are available locally/nationally for application as an alternate of wood-gel. Potential plant-based cellulosic to ligno-cellulosic fibres like cotton, jute, flax, ramie, hemp, pineapple, sisal and nettle are mostly used in apparel, home and technical textiles (Samanta *et al.* 2023; Chattopadhyay *et al.* 2020; Gupta, Patra and Samanta, 2021; Basak *et al.* 2018; Basak *et al.* 2014; Teli *et al.* 2014; Samanta, Basak and Chattopadhyay, 2015). As far as their applications in technical textiles are concerned, some of these fibres have also been explored in 'medical textile'. Under the aegis of medical textile, several technological advancements have been documented in the area of exploration of plant, animal and manmade fibres as an absorbent material in sanitary napkin in place of wood-pulp viz., cotton fluff, organic cotton, water hyacinth, jute, banana, flax, kenaf, hemp, soya fabric, bamboo fabric, lyocell fibre, milkweed fibre, woollen fabrics and cellulose-acetate nano-fibres. Efforts were also directed to use/ develop/ synthesis different polymers and bio-polymer as a replacement of super-absorbent-polymer (SAP), which is non-biodegradable have also been summarized in this paper and mentioned below in details. Functionality of sanitary napkins was further improved with aromatic and medicinal plant extract.

Construction of sanitary napkin

Sanitary napkin is a commonly three-layers structure consisting of top sheet, the most important

middle layer i.e., absorbent layer and bottom layer or barrier sheet. Top sheet absorbs the body fluid and transfers it to the absorbent layer and contains polypropylene fibres. The middle absorbent layer contains wood pulp and super absorbent polymer (SAP) so as to absorbs more amount of fluid after converted into a jelly state. Bottom barrier layer/ sheet consists of polyethylene film, which prevents the fluid from leaking out. The schematic diagram of sanitary napkin is depicted in Fig. 1. The following materials are required in manufacturing of sanitary napkin (i) nonwoven, (ii) pulp, (iii) super absorbent, (iv) plastic film, (v) elastic materials, (vi) fastening devices and (vii) packaging.

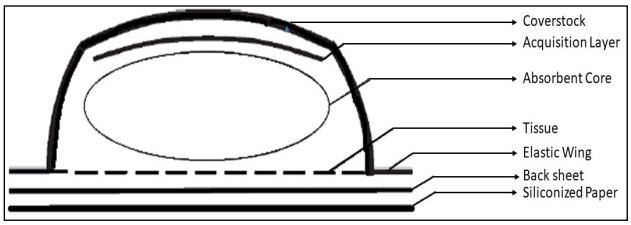

Fig. 1: Schematic of different layers in a sanitary napkin (https://textilelearner.net/sanitary-napkin-types-manufacturing/)

(i) Coverstock and Acquisition layer: The top layer or coverstock is an integral part of sanitary napkin, which comes in direct contact with the skin and keep it dry and comfortable feel. The coverstock is designed in such a way to allow the entry of menstrual fluid and also prevents for its backflow. The below materials may be used for this purpose.

(a) Non-woven fabric: Spunbonded or thermobonded fabrics are commonly used made by bonding of fibres together using heat, chemicals, or mechanical processes. Advantages of non-woven structure are softness, breathability, and ability to allow fluid to pass through, while keeping the surface relatively dry.

(b) Perforated plastic film: A thin perforated plastic film, made of polyethylene or polypropylene is also sometimes used as coverstock to provide a smooth, non-textured feel. Such film is perforated with tiny holes for the passage of fluid, while ensuring top dry surface.

(c) Cotton or cotton-blends: In some case coverstock are made of cotton or a blend of cotton with other fibres by utilization the advantages of cotton like breathable, soft and hypoallergenic, and comfortable and gentle feel to skin.

(d) Organic or sustainable materials: In the recent time with market awareness on eco-friendly products, coverstock made of organic cotton, bamboo fibre, corn husk fibre or other sustainable fibres are also introduced by some companies due to the eco-positive attribute of biodegradability, agro-renewable, reduced environmental impact and potential benefits to sensitive skin.

Acquisition layer: This particular layer also known as acquisition distribution layer or acquisition and distribution layer, is placed below the coverstock of the napkin. The main objective of this layer is to evenly distribute the fluid absorbed by the core, preventing it from accumulating in one zone along with maximizing the overall absorbency of the pad. Non-woven or perforated plastic films, tissue paper or other specially designed materials are suitable in this layer.

(ii) Absorbent layer/ core: It comprises of absorbent material for absorbing and retaining the menstrual fluid during its actual usage. It is located between the acquisition layer and the backing sheet of the sanitary napkin. The layer is made up of a combination of materials (pulp and SAP) to ensure optimal absorbency. Wood pulp is the most common material used as an absorbent core of napkins, derives from the plant fibres after suitable chemical intervention. Air laid structure, mostly formed from the cellulose fluff pulp, is commonly used as an absorbent material. The fluff pulp is hammer milled into individualized fibres that are subsequently air conveyed to a moving belt or forming wire to be formed into a fabric. Short cut or staple synthetic fibres viz., polyester, polypropylene, nylon, regenerated rayon, etc. can also be fed into forming area. The super-absorbent-polymers (SAP), the synthetic material, could retain large amount of fluid compared to its own weight. The majority of super absorbent polymers are made of sodium polyacrylate and available in granular form or fibre. In SAP, millions of polymers are chained together in the form of a chained fence structure, which are linked together to form a three-dimensional network of polymers. In dry state, the polymers remain in coiled shape, but in contact with liquid, the polymers uncoil, thus the polymeric network expanded, facilitating capacity to absorb large quantum of liquid. The key performance of SAP expected to satisfy the end use are high liquid absorbency,

enhanced leakage protection, achieving thin and discrete design, and long-lasting performance. The main components of SAP are acrylic acid, sodium hydroxide (or a similar neutralizing agent), water and a cross linker, that forms the bridge to one polymer chain to another. These components are mixed and undergoes a polymerisation reaction to form the three-dimensional polymeric networks and forms an aqueous gel. Finally, the gel is converted into the granules and sieved to the desired particle size. Also, superabsorbent material can be further cross linked to give the material specific absorbency characteristics. As far as ability to withstand pressure after liquid absorption is concerned, sanitary napkin shall absorb 30 ml of coloured distilled water and it shall not show leakage at the bottom or sides of the sanitary napkin. In-spite of several essential requirement of SAP, some of disadvantages of it are nonbiodegradable, some cases cause skin irritation, bulkiness and discomfort (https://textilelearner.net/sanitary-napkin-types-manufacturing/).

(iii) Bottom layer/ barrier sheet: The back sheet is a fluid impermeable sheet that prevents leakage, generally made up of polyethylene.

A typical composition of a sanitary napkin consists of 48% fluff pulp, 36% polyethylene/ polypropylene/ polyethylene terephthalate, 7% adhesives, 6% superabsorbent and 3% release paper with tentative below specifications (Ajmeri and Ajmeri 2010; https://textilelearner.net/sanitary-napkin-types-manufacturing/).

Pulp: Fluff pulp, thickness of 1-2 mm, width of 280-410 mm (tentative 500 g/m^2)

Tissue: 18 GSM (g/m^2) & width 180 mm

Polyethylene film: Very thin and width of 85-105 mm

Non-woven fabric: Thermo-bonding 16-18 GSM and width of 175-180 mm

Hot melt gum: Pressure sensitive and endurance, good stickiness, white solid adhesive.

Release paper: With acceptable release and width of 19-50 mm

Evolution of sanitary napkin

In the ancient time women used to use rags, clothes and tampons during periods. Likewise, Greeks used homemade rags and tampons that was made of lightweight wood. Romans made homemade pads by woven cotton and cotton is a good absorbent. They also made pads by sheep's wool, but wool has not good absorbency like cotton. Homemade pads were pinned to their garments during periods. Egyptians used papyrus; a water plant whose stem was utilized to produce tampons by softening the papyrus to make it absorbent to blood. Egyptians were the first to use papyrus to make mats, sanitary pads, and above all, paper. Africans used to make a roll of grass or grass mats that could absorbs the body fluid (https://www.mymed.com/health-wellness/interesting-health-info/the-evolution-of-menstrual-products).

The call for sanitation regarding woman's period began in 19th century and then the first pad was made called Hoosier Sanitary Belt. It is a belt pinned to washable cloth pads. While it was believed that sea sponges were used for centuries as a means of sanitary napkins. The first disposable sanitary pads were made during the World War I and it was made of wood pulp bandages (cellucotton), found by French nurses in the hospital. In 1896, Johnson and Johnson made their own sanitary pads named 'Lister's towel' along with Lister's belt to which pinned cloth pads were attached. But their imperfect advertisements and high cost made the women use their regular homemade cloth pads. In India, sanitary napkins came with belts, implying that they would be suited to women wearing petticoats and *salwars*. The introduction of adhesives in napkins in 1990s indicated changes in the use of underwear. In fact, the adhesive napkins had a 60% growth rate in 1990.

Specification of the raw material and sanitary napkins

According to Bureau of Indian standards (IS 5405: 2019) sanitary napkins are classified as follows: Type: thin/ thick; Shapes/design: wings/ no-wings, tab/ tab-less and the recommended sizes mentioned in Table 2.

Table 3 describes the chemical composition of the different fibres for their application in sanitary napkin by the various brands. Likewise, Table 4 mentioned the different polymers that are used as a super-absorbent-polymer (SAP) along with their

Table 1: Menstrual hygiene status in India (https://feminisminindia.com/2017/05/19/journey-menstrual-hygiene-management-india)

Timings	Menstrual hygiene status in India
Late 80's to 2000	◆ Cloth like rags were used during the periods. In Rajasthan a rectangular pocket (cloth) filled with sand was used as an absorbent. In Uttarakhand ash was used. ◆ Disposable menstrual products were not common. Only the rich can afford to buy these. ◆ There weren't any isolated spaces to change the menstrual cloth, women used to change behind bushes or at dark corners.
2000-2005	◆ Laxmi Murthy designed a pad for rural women in the year 2000 which was called '*lace wallah kapda*'. Over 1000 adolescents were taught to make such pads by cloth and laces (straps) ◆ Goonj, an NGO started a campaign '*not just another piece of cloth*', provided poor women clean menstrual clothes. ◆ Thoughtshop foundation, Kolkata and Vikalpdesign, Udaipur were design studios for designing new and efficient tools and continued to work on menstruation.
2005-2010	◆ Government started health programmes through the National Rural Health Mission and included ASHA workers spreading awareness of menstruation. ◆ In southern Rajasthan and Gujarat, a cheap fabric called Time Piece or Falanel arrived in the market. Made of poly-acrylate, washed easily and could dry within 2 hours. ◆ Proper design and development of underwear was made available, no need to use those lace strapped clothes. ◆ Arunachalam Murganathan patented a low-cost sanitary napkin making machine, many SHGs manufactured napkins using the machines. ◆ Disposable sanitary napkins from branded company appeared, advertisements on television started. ◆ Menstrual cup, the She cup was available, but used by a small section of women.
2010-present	◆ The growing waste-menstrual debris from disposed sanitary napkins and tampons is a concerned. ◆ Negative health problems caused by polymer and gel-based products on female. ◆ Reusable sanitary napkins ◆ SHGs manufactured napkins and NGOs planted many installing units for the Murunganathan's machine. ◆ 2012, government started a sanitation programme under the '*Nirmal Bharat Yatra*' including menstruation management.

Table 2: Different sizes of napkin as per IS standard and other specification

Size	Pad length as per IS 5405: 2019 (mm)	Pad length (L in mm), width (W in mm), and absorbency capacity (V in ml) as per other specification
Regular	< = 210	L = 180 to 220 W = 60- 100 (excluding wings) V = 15-20 Absorbent capacity should be suitable for normal flow.
Large	211 to 240	L = 220 to 260 W = 60- 100 (excluding wings) V = 20 -30 Absorbent capacity should be suitable for moderate flow.
Extra-Large	241 to 280	L = 260 to 300 W = 60- 100 (excluding wings) V = 30- 40 Absorbent capacity should be suitable for heavy flow.
XXL	> = 280	—

Table 3: Applications of different plant fibres in sanitary napkin and their products

Plant fibre used	Chemical composition	Sanitary napkin makes
Bamboo	47.2% cellulose, 23.9% hemicelluloses, 23.8% Klason lignin, 1.5% acid-soluble lignin (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3856011/)	Sparkle
Banana	71.08% cellulose, 12.61% hemicellulose, 7.67% lignin (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8588415/)	Sparkle, SHE-NGO, Saathi
Corn material	Cellulose (~ 35%), lignin (~ 12%), hemicellulose (~ 12%) (https://www.researchgate.net/publication/222676538)	Sparkle, Carmesi
Flax	65-75% cellulose, 15-25% hemicellulose, 1-5% pectin, 5-15% lignin (https://textileengineering.net/flax-fibre-types-properties-and-uses/)	—
Hemp	Bast fibres(20-40%): 57-77% cellulose, 9-14% hemicellulose, 5-9% lignin Hurds (60-80%): 40-48% cellulose, 18-24% hemicellulose, 21-24% lignin (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5456447/)	Himalayan hemp sanitary pads
Jute	58-64% cellulose, 18-24% hemicellulose, 12%-26% lignin (https://www.researchgate.net/publication/345763219)	Magnas, IIT Kharagpur; ICAR-NINFET product
Kenaf	Cellulose (bast fiber 52-59%, core 44-46%), lignin (bast fiber 9.3-13.2%, core 18.3-23.2%) (https://jwoodscience.springeropen.com/counter/pdf/10.1007/s10086-002-0469-7.pdf)	Bliss
Pine wood fibre	These sanitary pads consist of pine wood paper, silicon paper, butter paper, non-woven paper and cotton. (*'Sakhi'* The Biodegradable Sanitary Pads - InnoHEALTH magazine)	Sakhi
Water hyacinth	25% cellulose, 33% hemicellulose, 10% lignin (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9778230)	Jani

Table 4: Details of different polymers as super-absorbent-polymers (SAP) and their liquid absorption capacity (Sharm a and Harit 2022)

Biodegradable polymer	Source and its derivative	Absorption capacity (g/g)	Biodegradability
Chia flour	Chia seeds	2.0	1-3 months for 100% biodegradability by soil burial test
Chitosan-heparin PEC	Shellfish waste	15	–
Crosslinked starch-graft-poly(acrylic acid)	Starch and acrylic acid (AA)	1077 of distilled water 61 of 0.9% of NaCl	—
Heat-treated dry CMC and cross-linked with polyvalent metal salts and chitosan salts	—	50	—
Heat-treated high molecular-weight CMC sodium salt	—	27	—
Mimosa pudica hydrogel	Mimosa pudica L.	5.2	1-3 months for 100% biodegradability by soil burial test
Nano-hybrid composite (HEC-g-g PAA/diatomite)	Graft polymerization of acrylic acid and HEC in presence of N, N′ methylene bisacrylamide (MBA)	1175 distilled water 99.5 in 0.9% NaCl	—
Polyelectrolyte hydrogels	CMCNa and HEC using (DVS)	—	—

liquid absorption capacity. Different test parameters of sanitary napkin as per the Indian Standard is mentioned in Table 5.

Recent developments in sanitary napkin from natural fibres/materials

Shibly *et al.* have made a comparison of different aspects like absorbency, wickability, etc. for biodegradable materials, viz., soya fabric, poly fabric and bamboo fabric blended with natural fibres (Shibly *et al.* 2021). Interestingly, carboxy methyl cellulose (CMC) had been experimented for layering purpose within these blended napkins. The results indicate that absorbency gets greatly enhanced with such composition, where sodium alginate and CMC are used in combination in the sanitary napkins (SN). Further, coating the SN with neem extract help in developing SAP-free environment-friendly napkins. The development of biodegradable, quality sanitary pads at affordable prices for school girls and women from the loom-waste i.e., cotton fluff and cotton web, with a high absorption capacity of 470% (Sathishkumar *et al.* 2019). Furthermore, neem and orange peel based nano colorants were coated on the sanitary pads to enhance the anti-bacterial efficacy and found to be ideal substitute for synthetic sanitary pads, considering its 100% biodegradability. Here cotton fluff from loom waste was collected, cleaned and hydro-entangled to form an absorbent sheet that shows water absorbency capacity of more than 470%. Microporous polylactic acid biodegradable sheet was used to pack the absorbent layer. Such products can provide a long-term worthwhile alternative to the current practices. Chandra, Yadav and Illa from the IIT Hyderabad developed cellulose acetate biopolymer-based nano-fibres as core of SN, where enhanced absorption was mainly due to greater surface area (Chandra, Yadav and Illa 2016 https://core.ac.uk/download/pdf/80948137.pdf). Cellulose acetate (CA) nano-fibers demonstrate as a better alternative in achieving requisite absorption, without even adding SAP in the sanitary napkins produced, which further exhibits the safe disposal, as reported by Yadav *et al.* (Yadav *et al.* 2016). It has been also suggested the use of the organic cotton

Table 5: Test parameters of sanitary napkin as per the Indian Standard (IS 5405:2019)

Tests to be performed	**Test equipment/chemical requirements**
Sizes	Using suitable measuring object
pH value	◆ Distilled or deionized water ◆ Potassium chloride sol. (0.1 ml/l) ◆ Buffer solutions (having pH around 4, 7, 9)
Ability to withstand pressure after absorption	◆ Coloured distilled water ◆ Bromocresol purple (AR grade) ◆ Distilled water
Hygiene testing requirement	◆ As per Clause 7.3 of IS 5405:2019
Bacterial and fungal bioburden	◆ Plate count agar (PCA) ◆ Sabouraud chloramphenicol agar (SCA) ◆ Sodium chloride (0.85%)
Test to common skin pathogen – Staphylococcus aureus	◆ Cooked salt medium ◆ Baird parker medium ◆ Blood agar ◆ Citrated rabbit plasma ◆ Nutrient agar ◆ Normal saline water ◆ Gram's stain kit
Biocompatibility evaluation- cytotoxicity, irritation and skin sensitization	Cytotoxicity test
Biodegradability and compostability (Optional)	As per Clause 7.5 of IS 5405:2019 / (IS/ISO 17088)

in sanitary napkins with the objective to develop sustainable, skin-friendly and highly absorbent raw material (Barman, Katkar and Asagekar 2018). Organic cotton is cultivated in a pesticide-free environment, which further restricts the use of chemicals and paves way towards an environment friendly production process. Cotton being a plant-based natural fibre comes directly from nature, thus get degraded in contact with soil in the presence of microorganism. The work on Lenzing Company's Lyocell fibre, by the same researched group also mentioned its usage as top sheet, being completely biodegradable and hydrophobic in nature with extra softness. Similar to plant-based cellulosic/ ligno-cellulosic fibres, protein fibre e.g., woollen fabric, as a backing material, has been used by women for time immemorial to absorb menstrual waste. It is less waterproof, as compared with fleece, however it may be used as a strong backing option and produced from the natural fibre. It is also mentioned that woollen fabric commonly undergone felting shrinkage, if it is not delt with care and also certain skin types are found to be allergic to the woollen fabrics. It has been reported that sanitary pad was produced from water hyacinth (a kind of weed) and hemp fibre, and a comparison was drawn among them on different aspects (Ghosh *et al.* 2020). The sanitary napkins (SN) thus produced were found to be cost-effective and biodegradable. Kumar *et al.* has utilized the important properties of Milkweed and its blend with cotton in sanitary napkins, as milkweed fibre shows high absorption index (Kumar *et al.* 2022). In such SN, milkweed fibre was used as core layer, and polyethylene and polypropylene as bottom and top layer, respectively. Jute is a natural, eco-friendly, renewable, ligno-cellulosic plant fibre has also explored for use especially in the absorbent core to produce sanitary napkin (Chattopadhyay *et al.* 2016; Samanta *et al.* 2022). In a recent work conducted by IIT- Kharagpur describes the use of jute fibre as a substitute a cotton core in sanitary pad, due to its high 65-70% cellulose percentage as well as high-water affinity (https://www.jute.com/documents/10437/0/FTR+on+the+project+CCJ+%28Cotton+Lap%29.doc/8512805f-b3ab-47ba-b4ad-e4ba84762f48). Furthermore, other advantages of jute as absorbent layer are low cost, available in plenty in the commercial market and bio-fibre (Samanta *et al.* 2022). Jute-fibre based pulp as an absorbent material was developed by ASAM pulping process, where the fibres were treated sodium hydroxide (5%, o.w.f.), sodium sulphite (20 %), Anthraquinone (0.1%) and methanol (15 %) with a fibre to liquor ratio of 1:12 (Chattopadhyay *et al.* 2016). Absorbent pulps were also produced by other pulping techniques. Pulps produced in the ASAM process leads to achievement of very high whiteness index of 88.2 after bleaching along with good pulp yield and product performance. Several napkins were produced from such pulp after addition of 2% SAP from the two manufacturing units (Fig. 2). The products were field tested in two different locations (Purulia and Howrah), West Bengal with the objective of upgrade the quality of the jute, West Bengal pulp further, if required. Following parameters as per specifications of Bureau of Indian Standards (BIS) were tested such as, absorbance, retention of fluid, disposability, pH of the product, sensitivity to skin, etc. and the products were found to better than those available in the market. The performance of the product during field trial clearly shows that the sample prepared from jute pulp is preferred by most of the respondents. Majority of the respondents stated that absorbency power of the developed napkins is superior to the napkins used currently, the percentage is marginally lower in Purulia than in Howrah. Product prepared from virgin jute pulp is economic, hygienic, and sustainable in character.

In the past several developments were taken place on all the three components of a sanitary napkin, viz., top, absorbent and barrier layers. Like above i.e., possibility of application of several natural and manmade fibres in absorbent or other layers, work has also been carried out on synthesis of biodegradable superabsorbent hydrogel derived from native and carboxymethylated cassava starch. Native starch isolated from cassava was chemically modified by carboxymethylation and used in the production of superabsorbent hydrogel. Chemical analysis by FTIR confirmed the presence of the carboxymethylated group on the modified cassava starch, while the X-ray diffraction exhibited the loss of crystallinity after carboxymethylation process of the starch. The superabsorbent hydrogel produced from the native and carboxymethylated cassava starch could absorb water and saline more than

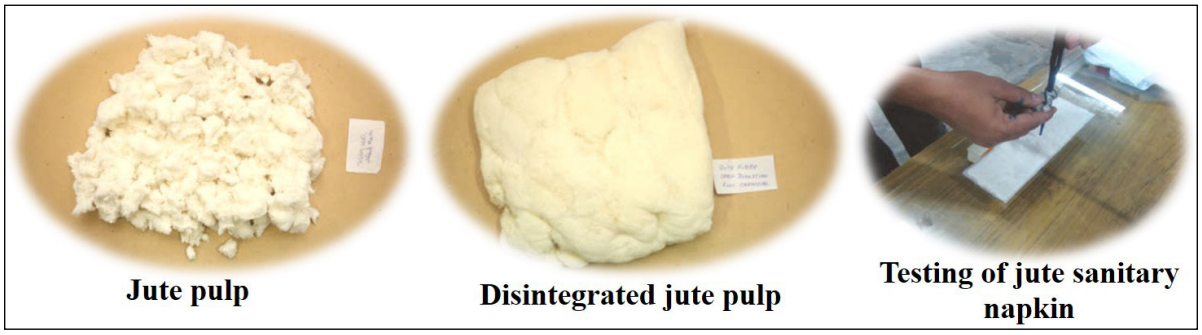

Fig. 2: Development of jute fibre-based sanitary napkin (Chattopadhyay, Ghosh and Bhowmick 2016)

100 times of dry weight. The carboxymethylated starch hydrogel having superior water absorbing capacity and also have good biodegradability, as about 70% biomass was found to degrade within 14 days. Physicochemical properties of the produced hydrogel were at par with the commercial 'synthetic' hydrogel (Afolabi 2019).

CONCLUSION

Feminine hygiene is one of the important health concerns at national and global levels. In the context of feminine hygiene products, sanitary napkin serves an important role as far as menstrual hygiene is concerned. According to a survey conducted by A.C. Nielson, only 12% of the Indian women has access sanitary napkins. Cloth-based napkin till date is used that sometimes lead to variety of infections. In the recent past, several companies, self-help-groups and entrepreneurs actively engaged in the area of production of sanitary napkin at affordable price using locally available natural resources. Sanitary napkin is a mostly three-layers structure consisting of top sheet for absorption & transfer the body fluid, absorbent layer and bottom layer or barrier sheet. The middle absorbent layer consisting of wood pulp and super absorbent polymer (SAP) plays a vital role in order to absorb the body fluid. The wood pulp used in the absorbent layer is mostly imported and thus costly. Several natural as well as manmade fibres were also explored to find out their efficacy as an absorbent layer. Cotton fibre has the potential to replace wood pulp especially in the feminine hygiene products, where properties like light weight and thinner are desirable. However, due to its higher cost along with high demand in apparel and home textiles, it is not a very meaningful choice to use cotton fibre in replace wood-pulp. There have been attempts to explore the other plant fibre in place of wood gel. In this line cotton fluff, organic cotton, water hyacinth, jute, banana, flax, kenaf, hemp, soya fabric, bamboo fabric, lyocell fibre, milkweed fibre, woollen fabrics and cellulose-acetate-based nano-fibres have been used as absorbent layer. Efforts were also directed to use/develop different polymers, as a replacement of super-absorbent-polymer, which is non-biodegradable in nature. In some cases, functionality of sanitary napkins was further improved with neem extract and orange peel formulation to impart anti-bacterial efficacy. From the several findings, it can be stated that natural fibre-based pulp can be used as an absorbent material in place of wood-pulp for their application in feminine hygiene sanitary napkin products.

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