SUSTAINABLE SANITARY NAPKIN

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Abstract : **One of the real issue of disposable pads is its non-biodegradability which increases menstrual waste produced. Our study carried out aims at synthesizing sanitary napkins with conventional three layered design using natural waste. Starch based porous bioplastic was synthesized as top sheet. Core absorbing layer consisted of thin cotton layer impregnated with cellulose based hydrogel synthesized using CMCNa, starch and malic acid. The cross-linking property of malic acid was found to be better than citric acid. A fibrous sheet synthesized from Banana stem fibre, Pineapple leaf fibre and coir acted as additional support layer. Gelatin obtained from fish scale was used as an adhesive. Soil burial test for biodegradability gave a remarkable weight loss by 82% and 77.16% of hydrogel and bioplastic respectively within 60 days. Upon performing absorption capacity test and wet back test, the assembled sanitary napkin proved to be efficient than some of the commercially available products. Methanolic extract of *Psidium guajava* worked best against *E.coli* and *S.aureus* when compared with extracts of *Azadirachtaindica and Justicia adhatoda*by AST to increase shelf-life. Thus, the present study gives improved insight and cost effective method for synthesis of biodegradable sanitary napkins using sustainable resources.**

Key words: **Biodegradable, sanitary napkin, bioplastic, hydrogel, AST**

I. INTRODUCTION

Menstruation is a process in which woman discharge blood and other material from the lining of the uterus at an interval of about 28 to 35 days from puberty until menopause (Barman and Katkar, 2017). This uterine discharge can be absorbed by different absorbing materials which include disposable sanitary pads, tampons, cups etc. One of the major concern of these disposable sanitary pads is its non-biodegradability which in turn increases menstrual waste. India being a developing country, with a population of 1.34 billion, out of which 323.6 million female are between the age group of 15-49 years. Over 88% of women use detrimental alternatives like un-sanitized cloth, ashes and husk sand. Reproductive Tract Infection (RTI) incidents are 70% more common among these women. The biggest impediment to sanitary napkin usage is its affordability. Around 70% of women in India find sanitary napkins unaffordable (Goyal, 2016). Even if 10% of the Indian female population uses disposable sanitary napkins each individual will generate half kg of menstrual waste per month. This for a total population of 10% contributes to approximately 16180 tons of menstrual waste every month (Barman et al., 2017). Generally, the menstrual waste is dumped in the landfills where it can stay for about 800 years. Sanitary napkins are made of plastic chemicals like BPA and BPS that can complicate embryonic development and may cause organ damage (Arugula et al., 2017). The plastic used in these sanitary napkins not only have negative impacts on health but also have major environmental consequences because of its non-biodegradability and chemicals used in production. To reduce this waste government promotes incineration as one of the disposal methods. However, due to lack of standard small scale appliances, lack of information about emission regulations and control on incinerators, poor thermal treatment performance limits the practical application of incinerators (Elledge et al., 2018). Also, it involves potential health hazard as certain components of the menstrual product may become toxic on burning. Some chlorine bleached products release dioxins and other toxins that are carcinogenic when burned at low temperatures (Elledge et al., 2018). Dioxins and furans have a deadly effect even in trace quantities.

Thus, there is a need to design sustainable sanitary napkin using alternative raw materials having less harmful effects from renewable sources without altering the functional characteristics of the sanitary napkin (Barman et al., 2017).

II. MATERIALS AND METHODS:

Collection of raw materials

Coir of coconut (*Cocos nucifera*), Banana pseudostem fibres (*Musa spp.*) and Pineapple (*Ananascomosus*) leaves were bought from the local market, Goregaon. Fish scales of Pomfret (*Pampusargentus*) and Catla (*Catlacatla*) were collected from Malad fish market. Adulsa (*Justicia adhatoda*) leaves were taken from Patkar-Varde college campus, Guava (*Psidium guajava*) leaves were taken from Kandivali east garden, Neem (*Azadirachtaindica*) leaves were taken from Charkop sector 7. Chemicals required for the research were taken from Biotechnology laboratory of Patkar-Varde college.

Preparations of various layers for synthesis of sustainable sanitary napkin

Sanitary napkins are made up of various layers such as top sheet, absorbent core and barrier sheet (Barman et al., 2017). Hydrogel embedded within two absorbent cotton layers acts as the absorbent core. Bioplastic is used as top sheet whereas coir bioplastic and fibre sheet as barrier sheet

1. Hydrogel

Hydrogel was synthesized by using sodium salt of carboxymethyl cellulose and starch as described by (Demitri et al., 2008) with modifications in temperature conditions. Malic acid was used as crosslinking agent instead of citric acid as it had better result.

2. Bioplastic

Bioplastic was synthesized by using starch as described by (Ogunrinola and Akpan, 2018) with addition of 60% acetic acid.

3. Fibre Sheet

Fibre sheet was synthesized by using banana pseudostem fibres, pineapple leaf fibres and coconut coir as described by (Ramdhonee and Jeetah, 2017).

4. Coir Bioplastic

Coir bioplastic was synthesized by using starch as described by (Ogunrinola and Akpan, 2018) with addition of coconut coir fibres and 60% acetic acid.

5. Gelatin

Gelatin extraction was carried out using Acid-alkaline treatment on fish scales (devi, P and .K, 2016).

Characterization of different layers of the sanitary napkin

1. Hydrogel

The evaluation of hydrogel was carried out for its swelling ratio, water absorption, desorption and moisture absorption (Islam and Dafader, 2016).

Determination of swelling ratio

The swelling ratio of the hydrogel was determined in water, different concentrations of NaCl solution (0.1% , 0.5%, 1%) and phosphate buffer solution of different pH (pH 6,7,8).The swelling ratio was calculated by the formula:

$$\text{Swelling ratio} = W_1 / W_o \qquad (3.1)$$

Where: W_1= Weight of solution absorbed by the gel

W_o= Weight of dry gel

Determination of water absorption, water desorption and moisture absorption

Determination of water absorption, desorption and moisture absorption was carried out by the procedure described by (Islam and Dafader, 2016).The percentage of water absorption was calculated by the formula:

$$\%\ \text{Water absorption} = (W_a / W_o) \times 100 \qquad (3.2)$$

Where: W_a= Weight of water absorbed by the gel sample at different time interval

W_o= Weight of the dried gel

The percentage of water desorption was calculated by the formula:

$$\%\ \text{Water desorption} = (W_d / W_i) \times 100 \qquad (3.3)$$

Where: W_d= Weight loss of gel sample at different time interval

W_i = Weight of saturated gel sample

The percentage of moisture absorption was calculated by the formula:

$$\%\ \text{Moisture absorption} = (W_{ma} / W_{io}) \times 100 \qquad (3.4)$$

Where: W_{ma}= Weight of gel sample at different time interval

W_{io}= Weight of the dried gel

2. Bioplastic

Strength test

The test was carried out to determine the tensile strength of the bioplastic, coir bioplastic and fibrous sheet using a method described by (Venditt and Hubbe, 2001). A plastic container was attached to the sample and different weights were added to determine the breaking length of the sample. The breaking length can be calculated by the formula:

$$\text{Breaking length} = mb/(W \times \text{Basis Weight}) \qquad (3.5)$$

Where: mb= Mass to break the strip (container + weights)

W= Width at break Basis weight = Sheet mass/Sheet area

Antimicrobial Susceptibility Testing (AST)

Antimicrobial susceptibility testing was evaluated using disc diffusion method (Hudzicki, 2019) for the bioplastic. The media used was Mueller Hinton agar to detect the antibacterial activity of the methanolic extract of *Psidium guajava*, *Azadirachtaindica* and*Justicia adhatoda*against test organisms*Escherichia coli* and *Staphylococcus aureus*. The plates were incubated overnight at 37°C and the zone of inhibition was determined in mm.

3. Gelatin

Yield

The yield of the extracted gelatin was determined by formula:

$$\% \text{ Yield} = (\text{Mass of dried gelatin}/ \text{Mass of clean scales})\times 100 \qquad (3.6)$$

Biodegradability test

Biodegradability of different layers of sanitary napkin was determined by natural soil burial test described by (Liu, Zhang, and Yao, 2014). The layers of the sanitary napkins were buried in natural soil and the weight of the sample was taken after an interval of 10 days for a period of 60 days. The percentage of weight loss was calculated by the formula:

$$\% \text{ Weight loss} = (W_1 - W_2 / W_1)\times 100 \qquad (3.7)$$

Where: W_1= Weight of the sample before soil burial test

W_2=Weight of the sample at different time interval during soil burial test

Assembly of various synthesized layers

The different layers were assembled into a prototype sanitary napkin. Needle punched top sheet of bioplastic was the first layer followed by the absorbent core of hydrogel embedded within cotton layers. Barrier sheet formed of fibre sheet and coir bioplastic is the last layer.

Characterization of Assembled Sanitary Napkin

Artificial blood absorption capacity test

The assembled sanitary napkin was evaluated for absorbency and wet back value using artificial blood (Barman and Katkar, 2017).The absorption capacity of the sample (6.5cm × 4.5cm) was calculated by the formula:

$$\text{Absorption capacity} = (W - X) \text{ grams} \qquad (3.8)$$

Where: X = Dry weight of the sample expressed in grams

W = Final weight of the sample after saturation expressed in grams

IV. RESULTS AND DISCUSSION

Preparations of various layers for synthesis of sustainable sanitary napkin

1. **Hydrogel**

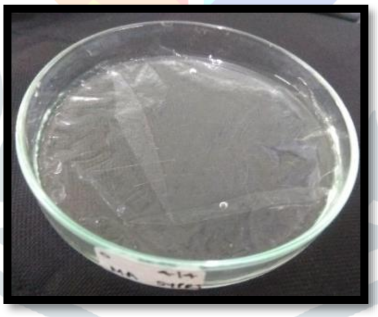
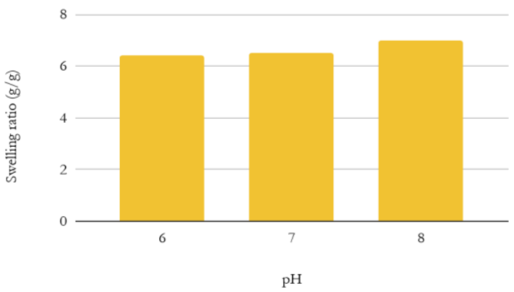
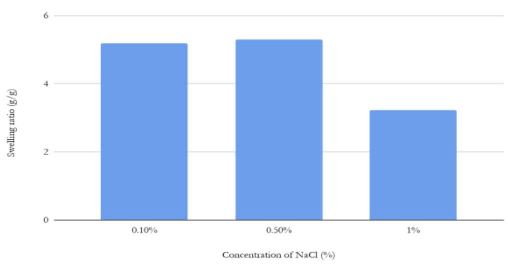


Fig.1. Hydrogel

Swelling ratio of the hydrogel was determined in distilled water, phosphate buffer and NaCl solutions. Swelling ratio of the hydrogel in distilled water was 7.87 and it was similar in different pH values of phosphate buffer. The swelling ratio of the hydrogel in different concentrations of NaCl solution was studied and 1% NaCl solution showed significantly decreased swelling ratio value. Similar findings were reported previously and the phenomenon is attributed to osmotic pressure evolved due to the unbalanced distribution of ions in the medium and the polymer network. The disparity between the concentration of counter ions in the gel phase and solution phase decreases with the increase in the concentration of Na^+ ions in the polymer network. Consequently, the equilibrium water uptake of the hydrogel decreases and the swelling ratio lessens (N. Vishal Gupta, 2019).

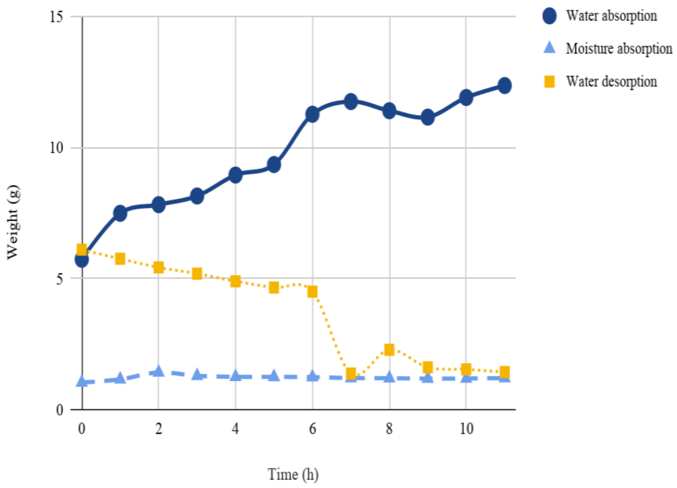


Graph 1: SR of hydrogel in phosphate buffer of pH 6, 7, 8.



Graph 2: SR of hydrogel NaCl solution of concentration 0.10%, 0.50%, 1%

Water absorption, water desorption and moisture absorption of the hydrogel were studied and it was found that as the time period increases, water absorption increases, water desorption decreases and moisture absorption remains constant.



Graph 3: Determination of water absorption, water desorption and moisture absorption.

2. Bioplastic

Fig. 2. Strength test of coir bioplastic

Fig. 3. Bioplastic

Strength test

The strength of the bioplastic and coir bioplastic was determined by calculating its breaking length. A commercially available biodegradable plastic was used as a control.

Table 1: Strength test of bioplastic

Test	Commercially available biodegradable plastic	Bioplastic	Coir bioplastic
Strength test	1737.75 m	1474.63 m	672.9 m

Antimicrobial Susceptibility Testing (AST)

Methanolic extract of *Psidium guajava* worked best against *Escherichia coli* and *Staphylococcus aureus* when compared with extracts of *Azadirachtaindica*, *Justicia adhatoda* for AST to increase shelf-life of the top layer i.e. the bioplastic.

Table 2: Antimicrobial activity (zone of inhibition) of methanolic extract of *Psidium guajava, Azadirachtaindica*, *Justicia adhatoda* against *S. aureus*

Methanolic Extracts	*Psidium guajava*	*Azadirachtaindica*	*Justicia adhatoda*
Test (in mm)	21	18	16

Table 3: Antimicrobial activity (zone of inhibition) of methanolic extract of *Psidium guajava, Azadirachtaindica*, *Justicia adhatoda* against *E.coli*

Methanolic Extracts	*Psidium guajava*	*Azadirachtaindica*	*Justicia adhatoda*
Test (in mm)	22	-	-

3. Fibre pulp sheet

Fig. 4. Fibre pulp sheet

The banana pulp fibre sheet withstood more than 200 g. Thus it can be used as a support layer.

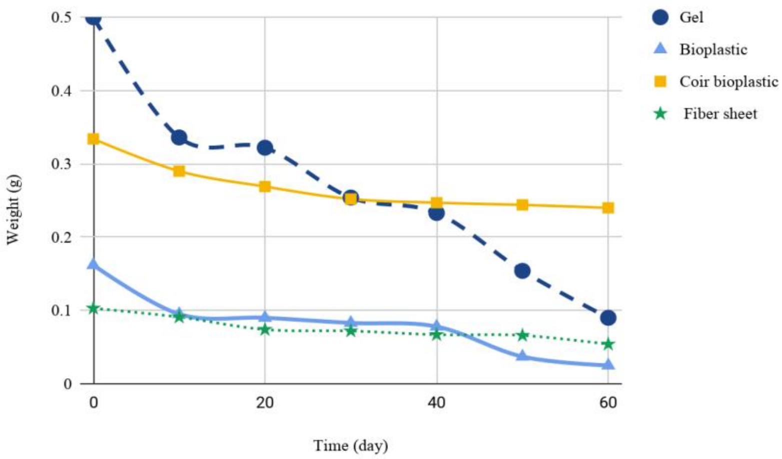
4. Gelatin

Fig. 5. Gelatin

The yield of gelatin was 1 g from 25 g of fish scales after alkaline and acid treatment. Thus the percentage yield of gelatin (%) was 4%. The aqueous solution of gelatin, when applied to the bioplastic, adheres to cloth.

Biodegradability test

Biodegradation of individual layers was studied by natural soil burial test over a period of 60 days. The weight of the individual layer gradually decreased and the percentage weight loss is as follows.



Graph 4 : Biodegradation test of different layers

Table 4: Percentage weight loss after a period of 60 days

Hydrogel	Bioplastic	Coir bioplastic	Fibre pulp sheet
82%	77.16%	28.14%	35.92%

Assembly of various synthesized layers

Fig. 6. Assembled sanitary napkin

Characterization of Assembled Sanitary Napkin

The assembled sanitary napkin was checked for its absorption capacity and wet back test. The prototype showed comparable results with the commercially available non-biodegradable and biodegradable sanitary napkins. Lower the wet back value indicates efficient retention of absorbed fluid.

Table 5: Characterization of Assembled Sanitary Napkin

Test	Brand 1	Brand 2	Brand 3	Brand 4	Brand 5 (Biodegradable)	Prototype
Absorption Capacity (g)	17.605 g	22.71 g	10.971 g	24.281 g	24.361 g	22.33 g
Wet back Test (g)	0.031 g	0.249 g	0.468 g	0.364 g	0.838 g	0.55 g

V. CONCLUSION

Sustainable sanitary napkin was synthesized based on the conventional three layered design. Swelling ratio of the hydrogel was stable over a range of pH values however swelling ratio decreases as the osmolarity of the solution increases. The swelling ratio can be regulated by proficient control of conditions followed for gel preparation (Sasaki and Suzuki, 2015). Bioplastic has good tensile strength making it tear proof under ideal conditions. Methanolic extract of *Psidium guajava*was found to be a potential antimicrobial agent which in turn will increase the shelf life of the product. The aqueous solution of gelatin adheres to cloth thus it can be used as an adhesive. A gradual decrease in the weight of the hydrogel and bioplastic, two major components of the sanitary napkin was observed over a period of two months. The prototype showed good results when compared with different commercially available biodegradable and non-biodegradable brands. The absorption capacity can be increased and the wet back value can be decreased by increasing the concentration of hydrogel present in the sanitary napkin. The sanitary napkin developed not only reduces the generation of non-biodegradable menstrual waste but also utilizes components of biowaste for its synthesis thereby making it a sustainable product. Use of naturally available components makes it environment-friendly. The individual layers of the sanitary napkin can also be used in other areas of science due to its different properties. In a nutshell, the conclusion drawn is, with the help of proper aid and robust approach biodegradable sanitary napkins from organic waste can be mass produced at industrial scale and made available to the masses at reasonable prices thereby having a significant decrease in carbon footprint.

REFERENCES

[1] A, B., PM, K., & SD, A. (2017). Natural and Sustainable Raw Materials for Sanitary Napkin. *Journal Of Textile Science &Engineering*, *07*(04).

[2] Arugula, P., Paramasivam, S., Kanuri, N., Srirangam, A., &Vemuluri, M. (2017). Perception on Use of Sanitary Napkins Among Students in Khammam Locality: A Survey. *Indian Journal Of Pharmacy Practice*, *10*(2), 133-136.

[3] Barman, A., Katkar, P., &Asagekar, S. (2017). Development of Eco-friendly Herbal Finished Sanitary Napkin. International Journal For Innovative Research In Science And Technology, 4(1), 183 – 189.

[4] Biswas, B., Rogers, K., McLaughlin, F., Daniels, D., & Yadav, A. (2013). Antimicrobial Activities of Leaf Extracts of Guava (Psidium guajavaL.) on Two Gram-Negative and Gram-Positive Bacteria. *International Journal Of Microbiology*, *2013*, 1-7.

[5] Biswas, K., Chattopadhyay, I., Banerjee, R., & Bandyopadhyay, U. (2002). Biological Activities and Medicinal Properties of Neem (Azadiractaindica). Current Science, 82(11), 1336 - 1345.

[6]Chanda, S. and Kaneria, M. (2011). Science against Microbial Pathogens: Communicating Current Research and Technological Advances. Spain: FORMATEX Research Center, Badajoz, Spain, 1251-1259.

[7] Demitri, C., Del Sole, R., Scalera, F., Sannino, A., Vasapollo, G., &Maffezzoli, A. et al. (2008). Novel superabsorbent cellulose-based hydrogels crosslinked with citric acid. *Journal Of Applied Polymer Science*, *110*(4), 2453-2460.

[8] Devi, A., P, K., & K, L. (2016). Extractiom, Characterization and Application of Gelatin from Carcharhinus amblyrhyncho and Sphyraena barracuda. IOSR Journal Of Biotechnology And Biochemistry, 2(6), 40 - 49.

[9] Elledge, M., Muralidharan, A., Parker, A., Ravndal, K., Siddiqui, M., Toolaram, A., & Woodward, K. (2018). Menstrual Hygiene Management and Waste Disposal in Low and Middle Income Countries—A Review of the Literature. *International Journal Of Environmental Research And Public Health*, *15*(11), 2562.

[10] Goyal, V. (2016). Scope and Opportunities For Menstrual Health and Hygiene Products in India. International Research Journal Of Social Sciences, 5(7), 1 - 5.

[11] Gupta, N., &Shivakumar, H. (2012). Investigation of Swelling Behaviour and Mechanical Properties of a pH-Sensitive Superporous Hydrogel Composite. Iranian Journal Of Pharmaceutical Research, 11(2), 481 - 493.

[12] Hudzicki, J. (2019). ASMscience | Kirby-Bauer Disk Diffusion Susceptibility Test Protocol. Retrieved from http://www.asmscience.org/content/education/protocol/protocol.3189

[13] Islam, M., &Dafader, N. (2016). Studies on Swelling and Absorption Properties of theγ– Irradiated Polyvinyl Alcohol (PVA)/Kappa-Carrageenan Blend Hydrogels. *Journal Of Advanced Chemical Engineering*, *06*(02).

[14]Khan, M., Sarkar, M., Al Imam, F., Khan, M., &Malinen, R. (2014). Paper Making from Banana Pseudo-Stem: Characterization and Comparison. *Journal Of Natural Fibers*, *11*(3), 199-211.

[15] Liu, H., Zhang, Y., & Yao, J. (2014). Preparation and properties of an eco-friendly superabsorbent based on flax yarn waste for sanitary napkin applications. *Fibers And Polymers*, *15*(1), 145-152.

[16] Nnadi, F., & Brave, C. (2011). Environmentally friendly superabsorbent polymers for water conservation in agricultural lands. Journal Of Soil Science And Environment Management, 2(7), 206 - 211.

[17] Ogunrinola, T., & Akpan, U. (2018). Production of Cassava Starch Bioplastic Film Reinforced with Poly-Lactic Acid (PLA). *International Journal Of Engineering Research And Advanced Technology*, *4*(8), 56-61.

[18] Pa, R., & Mathew, L. (2012). Antimicrobial activity of leaf extracts of Justicia adhatoda L. in comparison with vasicine. *Asian Pacific Journal Of Tropical Biomedicine*, *2*(3), S1556-S1560.

[19] Ramdhonee, A., &Jeetah, P. (2017). Production of wrapping paper from banana fibres. *Journal Of Environmental Chemical Engineering*, *5*(5), 4298-4306.

[20] Suzuki, A., & Sasaki, S. (2015). Swelling and mechanical properties of physically crosslinked poly(vinyl alcohol) hydrogels. *Proceedings Of The Institution Of Mechanical Engineers, Part H: Journal Of Engineering In Medicine*, *229*(12), 828-844.

[21] Venditti, R., &Hubbe, M. (2001). Measuring paper strength. Retrieved from https://cnr.ncsu.edu/fb/wp-content/uploads/sites/2/2014/04/testingpaper.pdf