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RESEARCH

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Designing pH-responsive SAP-coated menstrual pads and comparing them to marketable products through quality analysis

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Abstract

Background For a specific purpose involving the pH of menstrual blood and the pH of the vagina during menstruation, the current work describes the development of pH-responsive superadsorbent polymer (SAP)-coated menstrual pads. Acrylic acid (AA) and methyl methacrylate (MMA) were used to create a pH-responsive polymer, which was then applied layer by layer to sanitary napkins. Using FTIR, the chemical composition and structure were examined. By examining tests for absorbent capacity, swelling capacity, water retention, sorption under load, strike through, wicking height, and re-wetness under load, the performance studies of coated pads were contrasted with those of menstrual pads that are sold commercially. Additionally, the coated pad's pH response was examined to determine how stable the polymer was against pH variation.

Results The use of SAP in this study resulted in a higher free swelling capacity (102.22 g/g) for tap water and absorption under load in sanitary napkins. The absorption capacity of SAP ranges from 8 to 24 h, with values ranging from 14.84 to 132.41 g/g. Similarly, wet back and striking through analysis indicated superior outcomes in comparison with commercial products. The pH of the prepared SAP helps to maintain the necessary acidity level (pH 3.02) for the vagina during menstruation.

Conclusions Based on comparison results from FTIR, absorbency capacity, rewet, strike-through, and pH, the report recommends using the pH-responsive SAP to coat the top layer of feminine napkins.

Keywords pH-responsive polymer, Superadsorbent polymer, Layer-by-layer, Menstrual pad, Absorbency

Background

Women experience menstruation every 21–28 days, lasting for a total of five days in each menstrual cycle. Menstruation is an essential process in the female reproductive system (Shibly et al. 2021; Woeller & Hochwalt 2015). Menstrual cycles typically span from three to seven days for females aged eleven to fifty. The mean blood loss during a menstrual cycle is 35 ml (ml), with blood losses ranging from 10 to 80 ml (ml) considered within the normal range. The flow rate during the early menstrual day starts off high and gradually decreases from the second day of the cycle until the final few days (Nyoni et al. 2014). Menstrual fluid consists of approximately 50–60% blood, as well as mucous materials, secretions from the uterus, cervix, and vagina (Bae et al. 2018; Chakwana & Nkiwane 2014).

Women across different social strata in developing countries lack sufficient understanding of menstrual hygiene management, resulting in reduced productivity due to frequent school absences, infections, and other health issues that specifically impact women. Additionally, this lack of knowledge leads to feelings of embarrassment and hinders women's ability to engage in work.

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Economically disadvantaged and unconscious women often resort to unsanitary cloths for the purpose of collecting and retaining menstrual fluids. In addition, impoverished women, who are unaccustomed to wearing underwear, are not inclined to use commercial sanitary napkins, which require the use of panties or other types of undergarments. There is a necessity to create a hygienic sanitary napkin that is cost-effective and eco-friendly due to limited knowledge, expensive production, and the current socio-economic framework. Today's health-conscious women utilize a variety of products such as tampons, menstrual cloth pads, sanitary pads, and pantyliners. The menstrual cloth pad consists of three primary layers: the top sheet, which is responsible for direct contact with the body; the absorbing core, composed of materials designed to absorb menstrual flow; and the leaking barrier sheet, which prevents any leakage (Elsherbiny et al. 2022; G et al. 2020; Haider et al. 2023; Yadav et al. 2016).

The work presented focuses on the synthesis of a superabsorbent polymer (SAP) using methyl methacrylate and acrylic acid monomers. This polymer, known as poly(methyl methacrylate-co-acrylic acid) or poly(MMA-co-AA), exhibits pH-responsive properties. The synthesized polymer was applied to the uppermost layer of the sanitary napkin using a layer-by-layer technique. The performance of the coated napkin was evaluated by comparing it to commercially available products.

Methods

Materials

Acrylic acid (AA), methyl methacrylate (MMA), and benzoyl peroxide (BP) were obtained from A. B. Enterprise, Mumbai. Nitrogen gas and liquor ammonia were obtained from Madhu Chemicals (Mumbai), Sunshine Industrial Gas (Ahmedabad), Suvidhi Industry (Vapi), respectively. All the reagents used in the work are of analytical grade, so they are used directly as received without supplementary refinement.

Preparation of pH-responsive polymer

The apparatus comprises a 1000-ml capacity five-necked round-bottom flask with a double-helical parallel impeller agitator, thermometer, additive funnel, nitrogen gas inlet tube, and water condenser attached. Transfer 200 ml of a solvent mixture into the flask and add two small porcelain chips. After gradually heating the solvent mixture to 40 °C, pass nitrogen gas through the flask to remove any remaining air. A constant stream of nitrogen gas is used to add the 50 ml of monomer feed which consists of a solvent mixture, monomers, and cross-linker (Table 1)—dropwise at a rate of 3.0 ml/min into the additive funnel as suggested in Table 2. In order to start the polymerization, 0.01 percent of an initiator is added at the same time, and the temperature is progressively raised to 80 °C. Two hundred milliliters of the remaining monomer feed is added dropwise over the course of 1.5 h after the initial 50 ml of monomer feed has been added. Throughout the entire polymerization process, the temperature is kept between 80 and 90 °C. The polymerization reaction suggested in Fig. 1 is inhibited by adding a 0.01 percent inhibitor at the end of the reaction.

Table 1 Components for polymerization

Monomers	**Monomer–a = Methyl Methacrylate and Monomer-b = Acrylic Acid**
Solvent system	Solvent-I = Toluene and Solvent-II = Ethyl Acetate (solvent mixture of I:II is 60:40)
Cross-linker	Triallylamine, Triallylphosphite in equal proportions
Initiator	Benzoyl peroxide
Inhibitor	Tert-butyl hydroperoxide (TBHP)

Characterization

The chemical structure and composition of pH-responsive microcapsules were examined using the PerkinElmer SpectrumTM 3 FTIR spectrometer, which is capable of performing Fourier transform infrared spectroscopy (FTIR).

Application on sanitary napkin

The top layer of the sanitary napkin was immersed in 20 g of pH-responsive dispersion and then padded through a two-bowl padding mangle as shown in Fig. 2. Again, the padded layer was passed through the SAP dispersion and padded. The process is repeated three times to generate a layer of SAP on top of the sanitary napkin. The samples for all prepared SAPs were coated by the layer-by-layer technique. Finally, all layered samples were baked at 82 °C for 3 min.

Free swell capacity (FSC)

This test outcome indicates how much distilled water the sample absorbs when it is fully swollen. The tea-bag method is the most expedient and convenient choice for samples with low quantities (W_0). The sample was prepared, placed into a teabag, and submerged in water or a saline solution for an hour. The tea bag was weighed again (W_1), and its swelling capacity was computed after it had fully swelled (EDANA 2019c; Qin 2016).

$$\mathrm{FSC} = \frac{(W_1 - W_0)}{W_0} \tag{1}$$

Absorption under load (AUL)

AUL measures the fluid absorption capacity of SAP samples under specific pressure conditions. An SAP

Table 2 Components and amounts are set forth for polymers

Experiment	Monomer (g)		Cross-linker (g)	Solvent (ml)		Temperature (°C)
	a	b		I	II	
SAP1	80	20	0.01	240	160	80 – 90
SAP2	70	30	0.01	240	160	80 – 90
SAP3	60	40	0.01	240	160	80 – 90
SAP4	50	50	0.01	240	160	80 – 90
SAP5	40	60	0.01	240	160	80 – 90

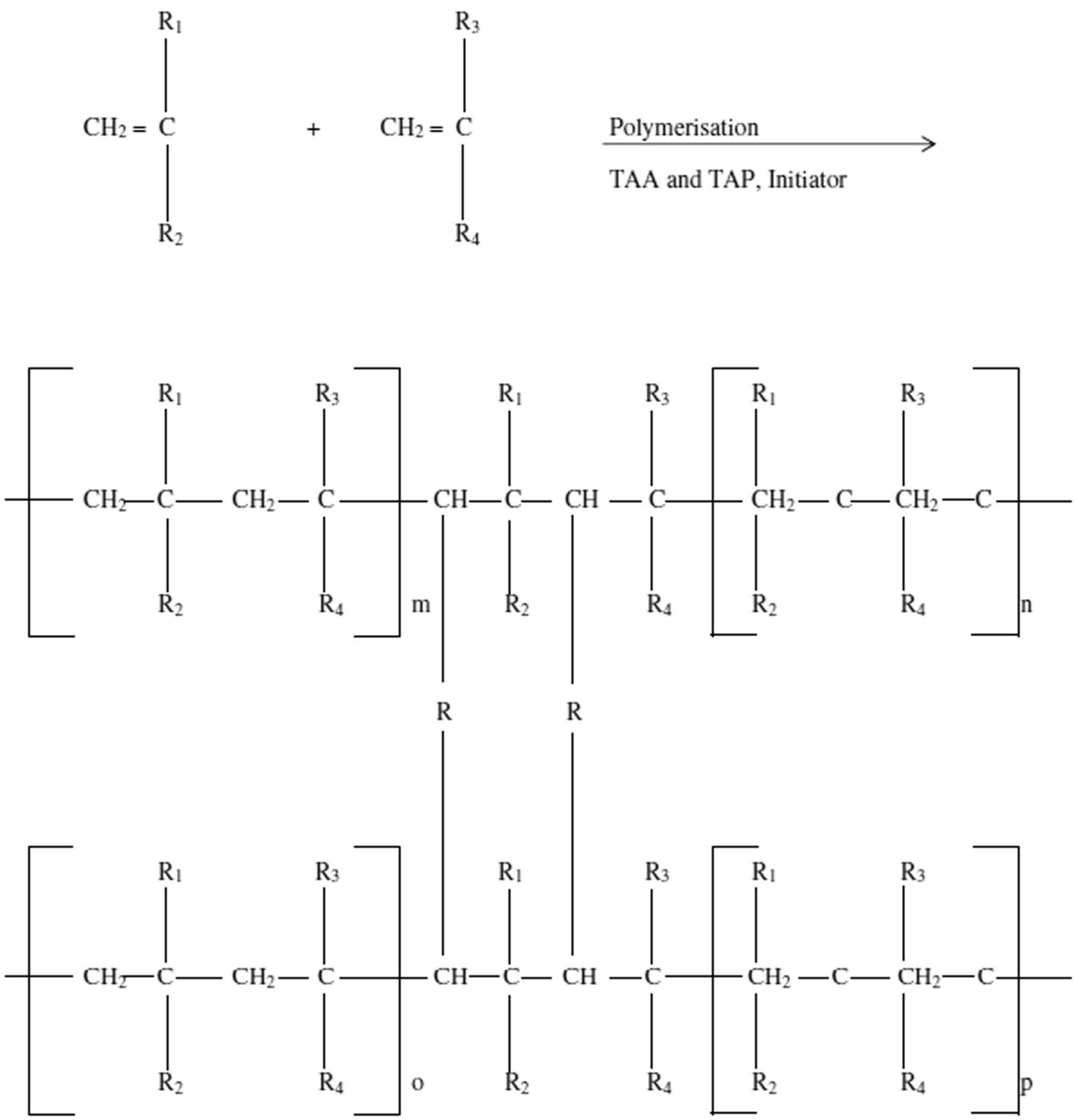


Fig. 1 General reaction scheme for SAP

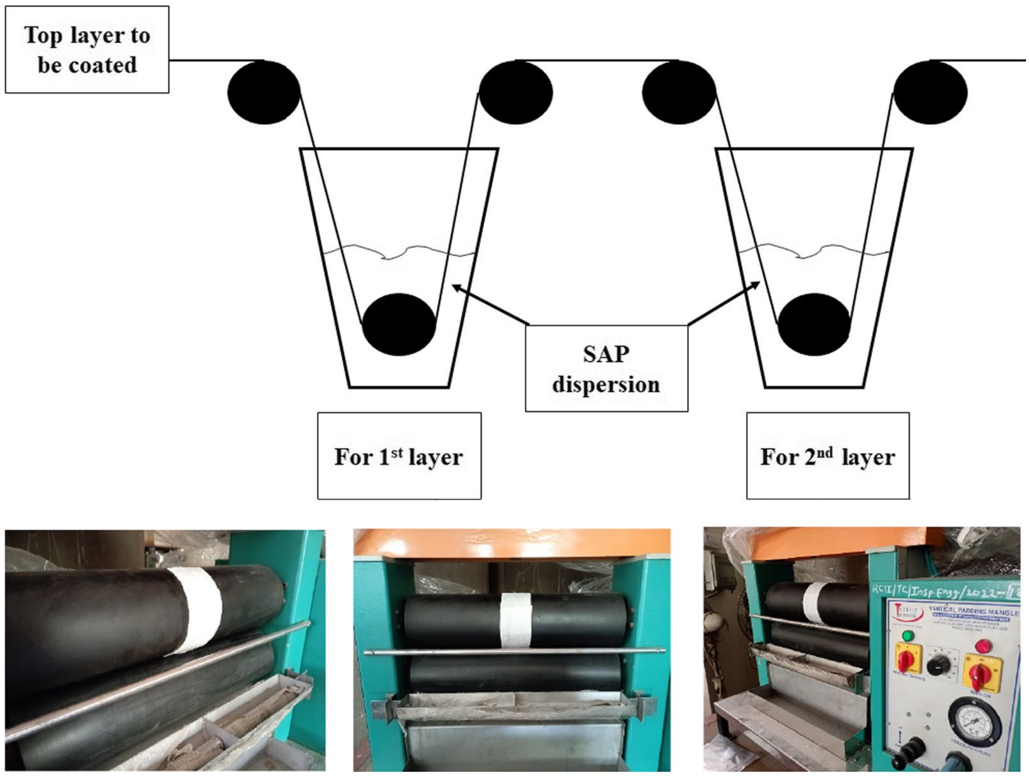


Fig. 2 Layer-by-layer application of SAP on top layer of sanitary napkin

sample weighing 0.9 g was used to completely fill the filter screen, ensuring a uniform bed. An aluminum piston was placed on the bed. The complete assembly had a weight of W_1. Following the placement of a porous disk in a tray, tap water and saline solution were introduced. The entire assembly was positioned on the filter paper under a load of 0.3 psi, as described by Bachra et al. 2020, and EDANA 2019a. The assembly was allowed to remain unchanged for one hour. Following the designated time frame, the assembly was raised, the load was removed, and the cylinder was re-measured as W_2. The AUL was computed using the following equation:

$$\text{AUL}\left(\frac{g}{g}\right) = \frac{(W_2 - W_1)}{W_1} \quad (2)$$

Absorbent capacity

The absorbent capacity of a superabsorbent polymer (SAP) was assessed by measuring its absorbency and absorption speed according to the EAS 96:2008-Annex C standard test procedure. Prior to adding 0.9% saline solution until saturation, the dry weight of the SAP-coated pad was recorded. Once saturation was reached, a weight of 3.4 kg was placed on the pad, as shown in Fig. 3. We used filter paper to absorb any excess fluid, and then we recorded the weight of the pad. In this study, a saline solution was used as a substitute for blood (Mukhila and Amrutha 2023; Yadav et al. 2016). The formula presented in Eq. 3 was utilized for measurement purposes.

$$\text{Absorption Capactiy}(A) = (W - X)g \quad (3)$$

where X = dry weight of the pad in gram.

W = weight of the pad underweights in gram after saturation.

Rewet back

In this test, the resistance of the SAP-coated sanitary napkin to transferring liquid that floods the coverstock to the skin is measured. Five milliliters of 0.9% saline solution was placed in the middle of a SAP-coated sanitary napkin for this test, and the solution was allowed to settle for one minute. Then, after weighing roughly 3 g in the center for 15 s, dry filter paper designated as the first was placed there. The same procedure was then carried out for the second filter paper. The study conducted tests on all the prepared samples and measured the changes between the first and second filter papers (EDANA 2018).

Strike through

A 5 ml drop of 0.9% saline solution is used to conduct the test, and the penetration time is recorded. On the

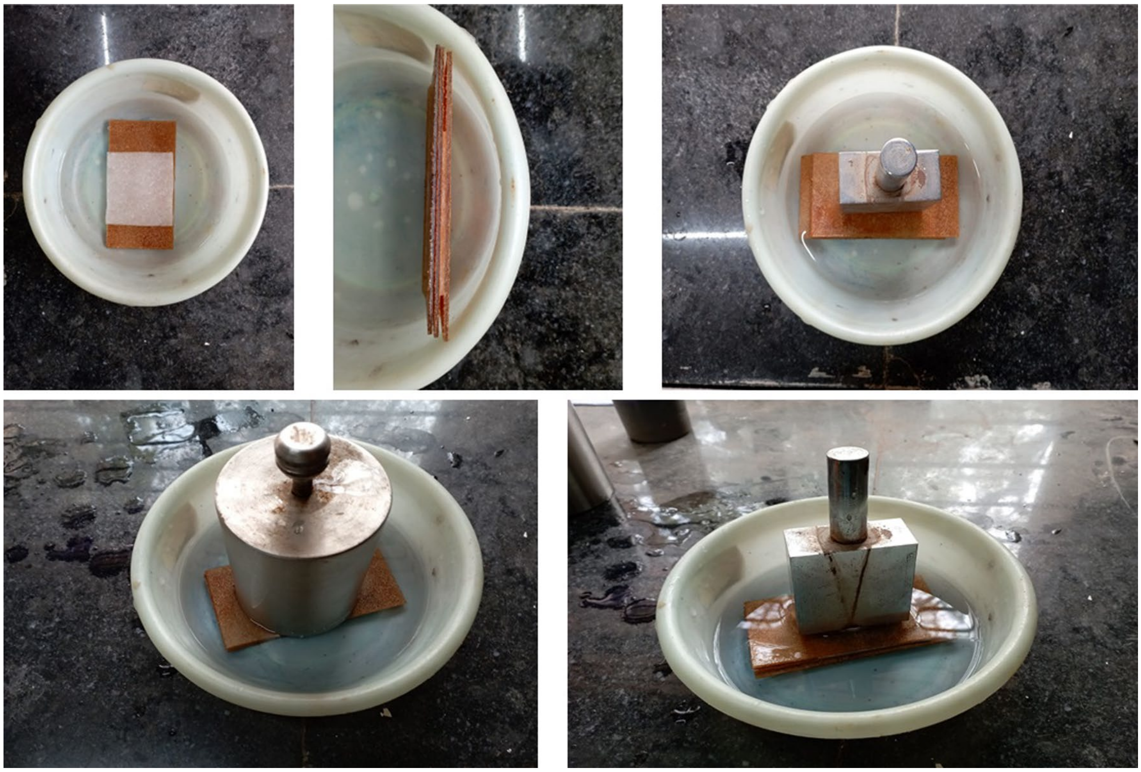


Fig. 3 Setup for measuring absorption capacity

SAP-coated napkin, a drop of test solution is allowed to fall freely, and the amount of time it takes for the solution to absorb from the top layer to the inner layer is recorded (EDANA 2018).

Determination of pH

The pH of the saline solution was determined using a pH meter. 0.5 g of the sample was slowly introduced into a 100-ml saline solution while continuously stirring. Following the solution's settling, the pH was measured (EDANA 2019b).

Antimicrobial activity

Polymer-coated samples were analyzed for antimicrobial activity against *E.coli* (gram negative) by spreading on a nutrient agar plate and incubated at 37°C for 24 to 48 h. The diameter of the inhibiting zone was measured for studying the activity against bacteria (Hassan Shibly et al. 2019). After organisms contacted the prepared samples, a % reduction was calculated for antimicrobial analysis using Eq. 4.

$$\% \text{ Reduction} = \frac{(X - Y)}{X} \times 100 \quad (4)$$

where X and Y are the cells which survived surviving cells in CFU/ml unit for the contained with prepared samples and the control one which was not coated with SAP.

Thickness of SAP-coated samples

IS 7702 test was used for analyzing the thickness of various menstrual pads (SAP-coated SAP 1–5 and commercially available CA 1–4) with the MAG-C1001 thickness tester possessing a range of 0.010–10.00 mm (Shibly et al. 2021).

Results

Characterization

Figure 4 displays the FTIR spectra of poly (MMA-co-AA). Furthermore, the figure clearly illustrates that specific selections of pH-responsive microcapsules are bolstering the selections that facilitate the coexistence of poly(MMA-co-AA). Table 3 provides the specifics of the FTIR analysis.

Absorption capacity

Table 4 shows how much superabsorbent polymer (SAP) can swell freely (FSC) and how much it can absorb under load (AUL) in tap water and saline solution. The sample with the highest FSC value, measuring 102.22 g/g, is attributed to SAP3, whereas SAP1 exhibits the lowest

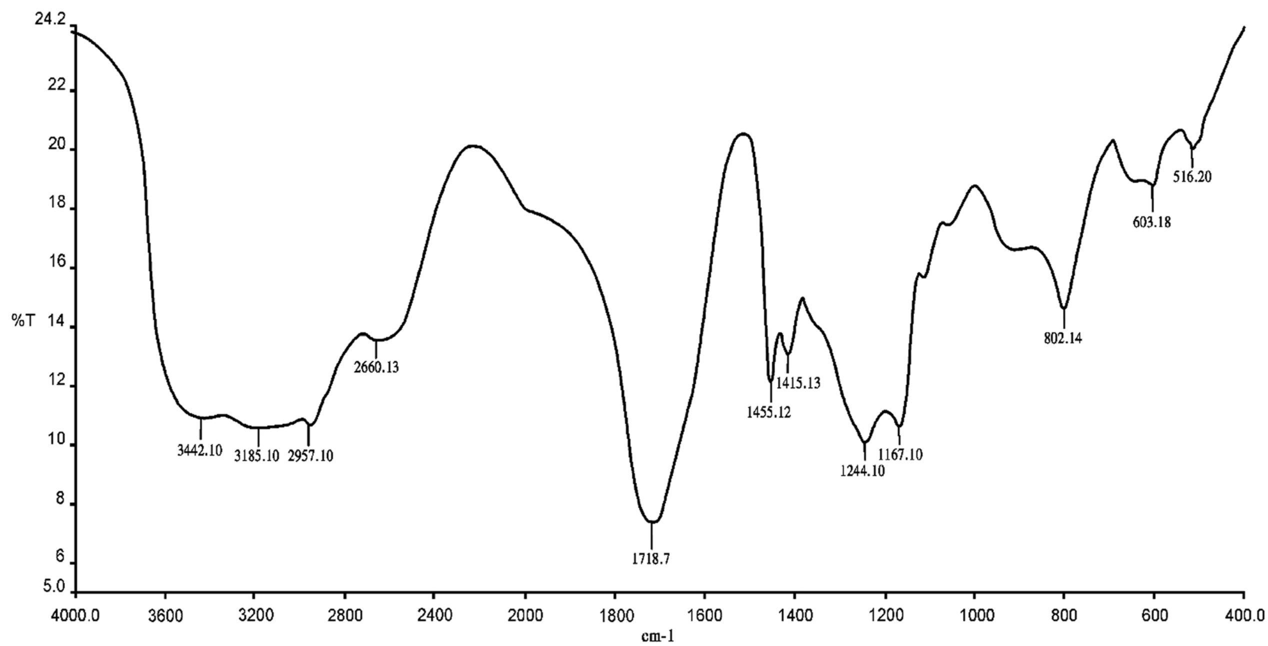


Fig. 4 FTIR of prepared SAP

Table 3 The characteristic IR bands of prepared SAP

IR band/ cm^{-1}	Assignment(s)
3250–3600 (s, b)	Stretching of H-bonded alcoholic –OH group
2984–2960 (m, b)	C-H bond asymmetric stretching vibrations of CH_3 group
1735–1640 (s, b)	Stretching vibration of C = O bond in acrylate carboxyl group and overlapped with bending vibration of alcoholic –OH group (confirms successful polymerization)
1449 (m)	C-H bond bending vibration of CH_3 group
1386 (s) &786 (w)	Stretching vibration of α–CH_3 group (adjacent to carboxylate)
1182 (m)	In-plane-deformation of C–O–C (the polymer is present in normal plane structure which deforms)
851 (m), 959(w) and 1024(m)	Characteristic vibrational absorption bands due to > CH –CH_2 – $COOCH_3$ system
524 and 416 (w)	Vibrations of –CH_3 group coupled with skeletal structure

Table 4 FSC and AUL

	In water (g/g)		In saline solution (g/g)	
Samples	**FSC**	**AUL (0.3 psi)**	**FSC**	**AUL (0.3 psi)**
CA1	70.2	39.28	34.25	22.78
CA2	69.5	38.22	33.81	21.15
CA3	70.8	39.89	35.21	22.12
CA4	68.2	37.25	32.18	20.94
SAP1	76.2	41.25	38.29	23.59
SAP2	83.25	43.28	40.81	24.91
SAP3	102.22	50.82	52.18	26.19
SAP4	82.5	42.79	41.23	25.13
SAP5	81.98	41.92	40.56	23.84

value. The values of SAP2, SAP4, and SAP5 are consistent with one another. The FSC value in saline water is slightly lower compared to that in tap water. The SAP3 account has a value of 52.18 g/g, whereas the remaining samples range from 38.29 to 41.23 g/g.

Additionally, Table 4 shows that the AUL values are all lower than the FSC values for each sample. The range of values for tap water is 41.25 to 50.82, whereas the range for saline solution is 23.59 to 26.19. Moreover, the table presents a comparison with commercially available sanitary napkins identified as CA1, CA2, CA3, and CA4. All commercially available products have FSC values for tap water that are approximately 70 g/g, all of which are lower than the FSC value of the prepared napkin coated with SAP. An analogous phenomenon was observed in the case of AUL. Furthermore, the SAP-coated napkins demonstrated superior value compared to commercial sanitary napkins.

Rewet back

The measurement of the wet back capacity of the sanitary napkins is done because it can prevent fluid from the napkin absorbed on the coverstock from getting to the skin. The performance analysis of samples coated with SAPs and controls is clearly displayed in Fig. 5. When compared to SAP1 and 2-coated sanitary napkins, the control sample exhibits superior wet-back characteristics. SAP3 recommends 0.1 g at the second wet test and 0.19 g at the first wet test, which are the most promising values when compared to sanitary napkins that are sold commercially and used as control samples. Wet back properties in SAP4 and SAP 5 vary slightly, and they exhibit higher values less so than in SAP3 and control. The outstanding wet back property in SAP3 is caused by the 60:40 ratio of MMA to AA, respectively. The results for the first and second wet backs for commercial products CA1, CA2, CA3, and CA4 were also displayed. All of the values are comparable to the results of the SAP3-coated napkin, which range from 0.19 to 0.25 for the first wet back and similar values for the second wet back.

Strike through

The fluid's transit speed from the absorbent surface to the inner pad zone is determined using a strike-through test. The skin feels dry when the strike-through value is higher because it means the pad's top layer is absorbing the fluid more quickly. The fluid moves from the surface to the interior in less time 2.62 s, according to Fig. 6 because the CA3 has a faster rate of transportation. The fluid transportation in the napkin, where SAP3 was applied to the top layer, required slightly fewer seconds (2.46). The times needed to pass the fluid for CA1, CA2, and CA4 are 2.51, 2.48, and 2.46, in that order. Consequently, the amount of time needed to strike through was the same for both SAP3 and CA4. The SAP2-coated layer exhibited the longest duration, resulting in poor strike-through properties. The time for striking is drawing near in the cases of SAP1, 4, and 5.

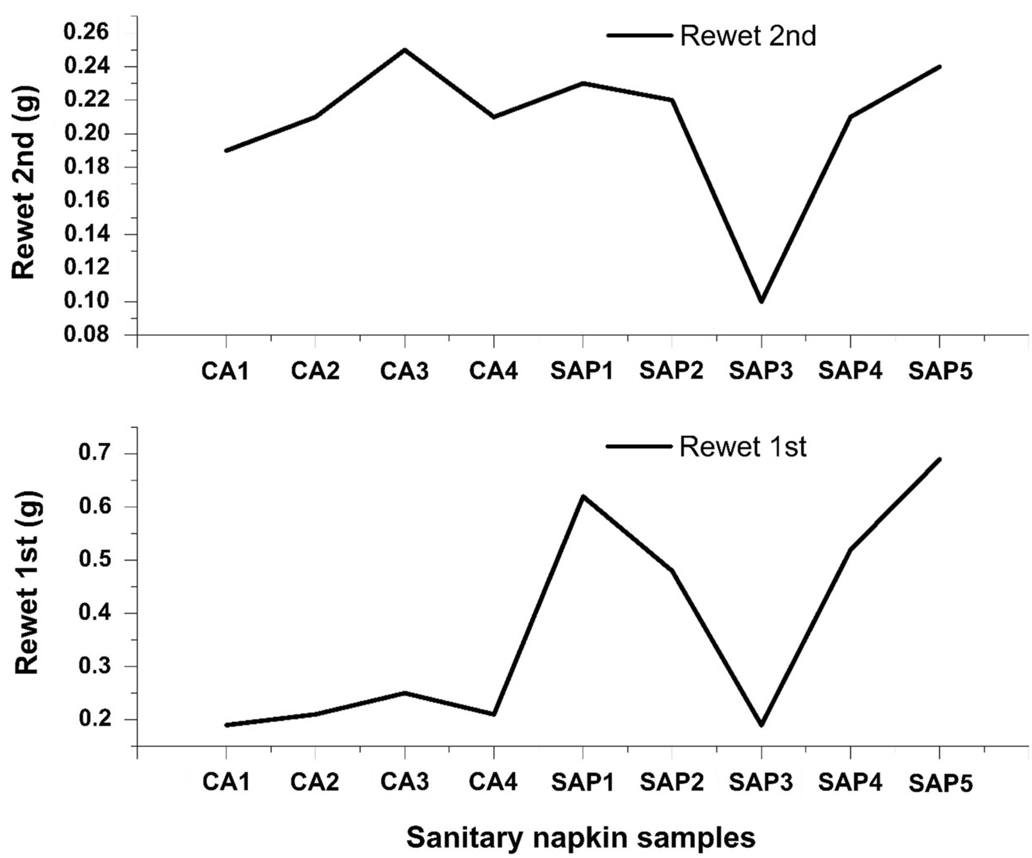
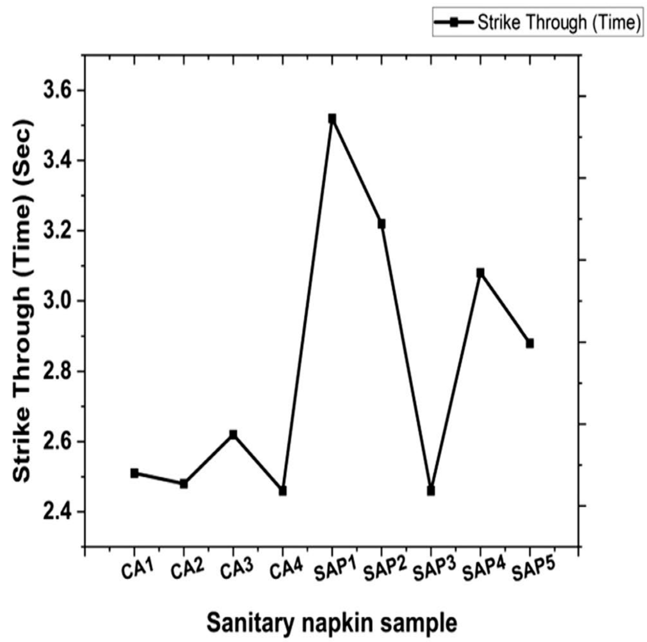


Fig. 5 Rewet (wet back) characteristics of SAP-coated napkins and commercial napkins



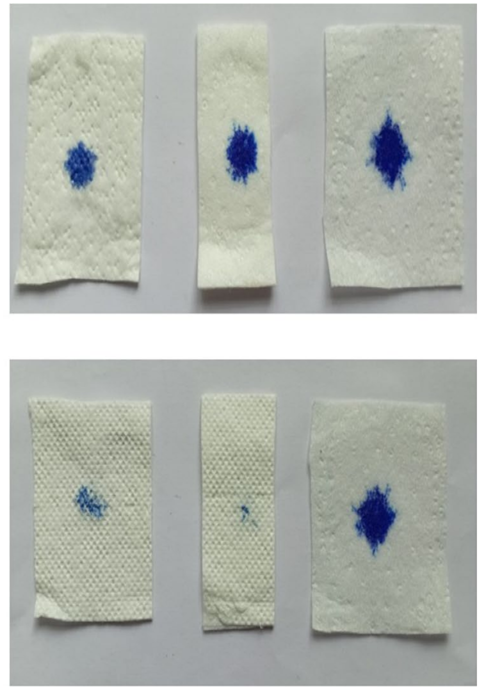


Fig. 6 Strike through of SAP-coated napkins and commercial napkins

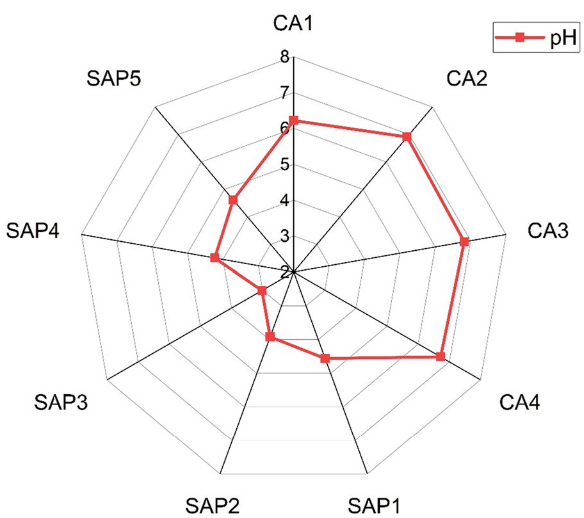


Fig. 7 pH of SAP-coated napkins and commercial napkins

Table 5 Reduction of microorganisms (*E. coli*) in SAP-coated napkin, non-coated and commercially available

Samples	Survived cells against *E.coli* (CFU/ml)	Reduction (%)
Control	2.82 X 10^5 (X)	
CA1	18.0 X 10^3 (Y)	93.61
CA2	16.0 X 10^3 (Y)	94.32
CA3	17.0 X 10^3 (Y)	93.97
CA4	18.0 X 10^3 (Y)	93.61
SAP1	19.0 X 10^3 (Y)	93.26
SAP2	17.0 X 10^3 (Y)	93.97
SAP3	14.0 X 10^3 (Y)	95.03
SAP4	15.0 X 10^3 (Y)	94.68
SAP5	16.0 X 10^3 (Y)	94.32

pH

CA2 recommends a pH of 6.92, which is almost neutral. The prepared pad's pH ranges from 3.02 to 4.62, with all values being acidic (Fig. 7). Since SAP3 has the lowest pH (3.02), which is more acidic, the wearer will feel more comfortable when menstrual blood with a pH of 7.4 comes into contact with the top layer of the prepared pad because of the reaction between the fluid and SAP3. It also lessens the itching. SAP1 has a pH value that is very close to the pH value of SAP3. Since SAP2, 4, and 5 have pH values above 4, they are less comfortable than napkins coated with SAP3.

Antimicrobial activity

The result shown in Table 5 clearly indicates that SAP-coated napkins suggest outstanding antimicrobial properties against *E.Coli*. The results are very comparable to the napkins available on the market, while non-coated materials are not showing any antimicrobial activity against *E.Coli*.

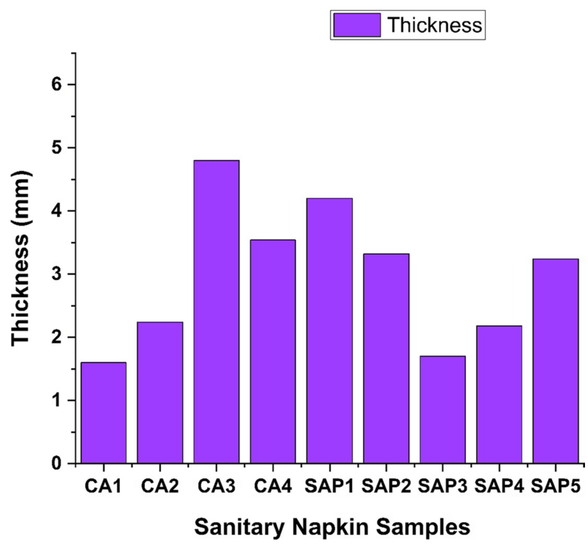


Fig. 8 Thickness of SAP-coated napkins and commercial napkins

Thickness of SAP-coated samples

As the SAP was applied to a non-woven cotton web, the thickness of the SAP-coated napkins improved, as shown in Fig. 8. CA1 shows the lowest thickness among all the samples. CA2 and CA3 have hydrophilic fiber and cotton, so thickness is higher than CA1. SAP-coated napkins (SAP1 to SAP3) were thinner, except CA1, and the thickness of Sap1 to SAP3 was between 1.7 and 4.2 mm due to the presence of adsorbent sheets. SAP3 shows the lowest thickness value of 1.7 mm, which is near CA1.

Results and discussion

Characterization

FTIR analysis clearly supports the preparation of polymer via indicating the bands 851 (m), 959 (w), and 1024 (m). Also, 1735–1640 (s, b) denotes the presence of stretching vibration of the C–O bond in the acrylate carboxyl group and overlaps with bending vibration of the alcoholic OH group, which confirms successful polymerization. 524 and 416 (w) support the vibrations of the -CH_3 group coupled with skeletal structure. So, the polymer containing MMA and AA is confirmed by FTIR analysis, and the formulized copolymer is poly(MMA-co-AA).

Absorption capacity

The ability of each hygiene product to absorb water for both saline solutions and tap water is shown in Tables 6 and 7. Table 6 makes it evident that, after ten minutes, SAP3 has the maximum absorption capacity. Within a 60- to 8-h period, the weight can fluctuate between 14.84 and 132.41 g. According to the SAP3-coated feminine napkin, a 24-h maximum of 131.9 g of water can

Table 6 Water absorbency of SAPs at different time intervals

Time (s)	CA1	CA2	CA3	CA4	SAP1	SAP2	SAP3	SAP4	SAP5
10	11.06	11.6	10.69	11.28	10.3	11.64	14.84	12.7	9.5
20	13.58	14.12	13.21	13.8	12.61	13.36	20.27	18.34	11.63
30	24.19	24.73	23.82	24.41	23.25	25.46	42.04	37.06	25.69
40	47.52	48.06	47.15	47.74	47.74	49.94	71.78	70.01	51.12
50	75.65	76.19	75.28	75.87	75.82	78.85	113.84	109.2	81.1
60	93.51	94.05	93.14	93.73	94.05	97.11	132.41	129.03	102.04
480	93.51	94.05	93.14	93.73	94.05	97.11	132.41	129.03	102.04
1440	93.42	93.96	93.05	93.64	93.82	96.68	131.9	127.58	100.58

Table 7 Saline solution absorbency of SAPs at different time intervals

Time (s)	CA1	CA2	CA3	CA4	SAP1	SAP2	SAP3	SAP4	SAP5
10	14.06	14.6	13.69	14.28	13.3	14.64	17.84	15.7	12.5
20	16.58	17.12	16.21	16.8	15.61	16.36	23.27	21.34	14.63
30	27.19	27.73	26.82	27.41	26.25	28.46	45.04	40.06	28.69
40	50.52	51.06	50.15	50.74	50.74	52.94	74.78	73.01	54.12
50	78.65	79.19	78.28	78.87	78.82	81.85	116.84	112.2	84.1
60	96.51	97.05	96.14	96.73	97.05	100.11	135.41	132.03	105.04
480	96.51	97.05	96.14	96.73	97.05	100.11	135.41	132.03	105.04
1440	96.42	96.96	96.05	96.64	96.82	99.68	134.9	130.58	103.58

be absorbed. On the other hand, at intervals of 10 min, the water absorption capacities of SAP1, SAP2, SAP3, and SAP4 are 10.3, 14.84, 12.7, and 9.5 g, respectively. At the same time interval, the absorption capacities of CA1, CA2, CA3, and CA4 are suggested to be 11.06, 11.6, 10.69, and 11.28, respectively. Moreover, the absorption of all the CAs was between 93.05 and 93.96 g/g for a 24-h period. A feminine napkin coated with polymer may be able to absorb the saline solution, according to Table 7. It further supports the absorption of tap water. Over the course of 60 min to 8 h, the feminine diaper coated with SAP3 demonstrates the most efficient absorption of saline solution, with a weight of 135.41 g. During the control period, 97.05, 100.11, 132.03, and 105.04 g of saline solution were absorbed, according to the control, SAP1, SAP2, SAP3, and SAP4 samples. Likewise, the absorption values for CA1, CA2, CA3, and CA4 were 96.51, 97.05, 96.14, and 96.73 over an 8-h period, respectively.

The highest FSC values for tap water come with the use of SAP3 for coating the top layer, and other SAPs are also near each other in the numerical data. Commercially available products CA1 to CA4 also suggest FSC values close to those of other SAPs, except SAP3. Products with less fluff and more SAP that are thinner are in demand, according to the market situation. The SAP concentration of sanitary materials is limited by AUL. Although it has the potential to be raised to 50 g per gram, the hygiene industry's accepted value is currently between 18 and 30 g per gram. According to the current study, tap water has a higher absorption capacity than saline solutions. The ion content of water affects the absorption properties of SAP, which can be affected by the electrolyte in a saline solution. This is referred to as the "charge screening effect," and it occurs when the osmotic pressure difference between the SAP network and the solution decreases. It is caused by the fact that saline solutions have more NaCl cations than tap water (Fang et al., 2018; Klinpituksa & Kosaiyakanon, 2017; Likhitha et al., 2014). Therefore, electrolytes in saline solutions, which are influenced by the concentration of ions in water, can affect the absorption characteristics of SAP.

As the napkins are utilized for specific time durations, the work also analyzed the absorption capacity for certain intervals of time for each SAP-coated napkin and commercial products. The result supports SAP3, which has shown excellent absorbency (132.41 g) until 8 h, and after 24 h, the absorption decreases to 131.9 g, which is negligible. Both tables support the SAP3 for tap water and saline solution absorbency. It increases steadily for eight hours before stabilizing for twenty-four hours. At the designated interval of time, it became constant, indicating that the napkins coated with SAPs are indeed significantly absorbing the fluid with each passing moment. Since the napkin will no longer absorb fluid after the specified amount of time, it must be changed after 8 h.

Rewet back

Wet back for first and second, due to variation in the ratio of composition of monomers used for preparing polymers, shows the variation in result, but a ratio of 64:40 (MMA:AA) has suggested the best suitability for preparing polymers, which is SAP3. Similarly, because of the cotton's hydrophilicity and SAPs' absorbency capacity, the prepared samples' top layer of needle-punched cotton and cotton also suggests that the commercial product's strike-through property is similar.

Strike through

The times needed to pass the fluid for CA1, CA2, and CA4 are 2.51, 2.48, and 2.46, in that order. Consequently, the amount of time needed to strike through was the same for both SAP3 and CA4. The SAP2-coated layer exhibited the longest duration, resulting in poor strike-through properties. The time for striking is drawing near in the cases of SAP1, 4, and 5.

pH

The pH range of the vagina is between 3.8 and 5.0, whereas the menstrual blood has a pH of almost 7.4. Because the vaginal mucosa is more acidic than blood or interstitial fluids, it can protect against pathogenic organisms (Lin et al. 2021). In order to ensure the wearer's comfort, the sanitary napkin's pH must remain acidic. Since menstrual blood will come into contact with the pad, its pH will also remain close to neutral or 7. Therefore, the pH of the sanitary napkin must be acidic at the time of menstruation, so it can manage the slightly alkaline pH of the menstrual blood and help maintain the pH of the vagina, so the wearer can feel comfort due to the itching characteristics that happen due to pH variation.

Antimicrobial activity

Improvements were found in the case of the SAP3-coated napkin, as compared with the others coated with SAP 1, 2, 4, and 5. As the molecular ratio of monomers suggests the better combination for preparing SAP, which is in the case of SAP3, bacteria decrease. As the monomer ratio changes, the antimicrobial resistance also changes.

Thickness of SAP-coated samples

The absorbance of blood determines the type of fibers in the pad; some may be hydrophilic, while others may be hydrophobic. Thickness does not necessarily exhibit high absorbency. Generally speaking, a thinner sanitary napkin indicates more even liquid distribution, which guarantees good menstrual fluid absorption and comfort during the use of the pad.

Conclusions

To develop a feminine napkin that is both cost-effective and superior to current products, the most efficient approach is to integrate or utilize superabsorbent polymers (SAP). This will fulfil all the mentioned objectives, as there is a significant demand for such a product.

The preparation of poly (MMA-co-AA) was carried out using practical procedures, and it was subsequently applied to the upper layer of a feminine napkin. Additionally, a comparison was made between the coated product and a napkin that is readily available for purchase. Following a series of performance analyses, it was found that the cotton-carded web coated with SAP3 demonstrated the highest FSC values in both tap water and saline solutions. This suggests that the SAP3-coated cotton card is the most suitable option for feminine hygiene. SAP3 is the most suitable choice for serving tap water due to its superior AUL (absorbency under load). In addition, the top layer of feminine hygiene products is coated with SAP3, which is supported by its absorbency, reset capability, and strike-through performance. Wet back, strike-through, and pH analysis are beneficial for supporting the application of SAP 3 in coating the outer layer of sanitary napkins. The antimicrobial properties of SAP-coated napkins are more favorable as compared to commercially available products. Also, the thickness of SAP3-coated napkins is promising as it shows a negligible difference. Therefore, SAP3 is the most suitable polymer product for applying a coating to the top layer of sanitary napkins among the options available in the market.

There is a problem with the biodegradability of the prepared SAP. In order to enhance biodegradability and reduce toxicity, it is possible to produce the same polymer by grafting natural polymers. In addition, SAP can undergo surface modification, lamination, or coating with additional monomers to make it suitable for feminine hygiene applications.

Abbreviations

SAP	Superadsorbent polymer
AA	Acrylic acid
MMA	Methyl methacrylate
FTIR	Fourier transform infrared spectroscopy
BP	Benzoyl peroxide
FSC	Free swelling capacity
AUL	Absorption under load
CA	Commercially available
TBHP	Tert-butyl hydroperoxide
CFU	Colony forming unit
E.coli	Escherichia coli
Ml	Millimeter

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Author contributions

CM has investigated, helped in methodologies, analyzed, and wrote draft. BP supervised, analyzed, reviewed, and rewrote draft. All authors have read and approved the manuscript.

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