Research Article

Development And Preliminary Evaluation Of Eco-Friendly Herbal Sanitary Napkins Fabricated From Flax Stem Fiber And Organic Cotton

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Abstract

Menstrual hygiene management remains a critical public health and environmental concern, as commercial sanitary napkins predominantly rely on non-biodegradable synthetic materials that contribute to microplastic pollution and pose potential dermal health risks. This study aimed to develop and preliminarily evaluate an eco-friendly herbal sanitary napkin fabricated from flax stem fiber and organic cotton, incorporating a standardized polyherbal blend (neem, pomegranate rind, calendula, chamomile, aloe vera, vetiver, lavender, rose petals, cyperus, and mugwort) combined with chitosan at two concentrations (2% and F1; 4%, F2) to impart antimicrobial functionality. The fabricated napkins were assessed for absorbency, rewet behavior, fluid retention capacity, surface pH, antimicrobial efficacy against Staphylococcus aureus, Escherichia coli, and Candida albicans, mechanical properties, biodegradability (soil burial and composting), and phytochemical composition via GC–MS. Both formulations exhibited satisfactory absorbency (16.8–17.5 g/g), low rewet values (0.22–0.28 g), and favorable fluid retention (86.5–89.4%), with physiological pH compatibility (4.48–4.62). F2 (4% chitosan) demonstrated superior antimicrobial activity, achieving up to 3.1 log reduction against E. coli, along with significantly higher dry and wet tensile strength than F1. Soil burial and composting studies confirmed substantial biodegradation (>80% weight loss at 90 days; >60% compost biodegradation). GC–MS analysis identified 20 phytochemical compounds, dominated by oleic acid (27.22%) and linoleic acid (20.40%), supporting the observed anti-inflammatory, antimicrobial, and skin-conditioning properties of the formulation. These findings indicate that the flax stem fiber–organic cotton–herbal–chitosan system is a promising, sustainable, and biocompatible alternative to conventional synthetic sanitary napkins, warranting further large-scale performance and clinical evaluation.

Keywords: Flax stem fiber; Organic cotton; Herbal sanitary napkin; Chitosan; Biodegradability; Antimicrobial activity; Menstrual hygiene; GC–MS phytochemical profiling.

1. Introduction

Menstrual hygiene management (MHM) is a fundamental component of women's reproductive health, dignity, education, and social well-being. Globally, billions of menstruating individuals require safe, accessible, and hygienic menstrual products every month. Inadequate menstrual hygiene has been associated with reproductive tract infections, skin irritation, psychosocial stress, absenteeism from school and work, and reduced quality of life (Hennegan et al., 2019; Kaur et al., 2018). In developing countries, including India, the challenge is compounded by limited access to affordable sanitary products and inadequate disposal infrastructure, resulting in substantial environmental and public health concerns.

Commercial sanitary napkins are predominantly manufactured from synthetic superabsorbent polymers (SAPs), rayon, polyethylene, polypropylene, chlorine-bleached wood pulp, adhesives, and fragrance chemicals (Carwile et al., 2020; Vedantam et al., 2019). Although these materials provide excellent absorbency and structural integrity, they are largely non-biodegradable and may persist in the environment for several decades. The increasing generation of menstrual waste has become a significant contributor to municipal solid waste accumulation and microplastic pollution (Pinto da Costa et al., 2023). Environmental assessments have highlighted that discarded sanitary products can fragment into secondary microplastics, which may enter terrestrial and aquatic ecosystems and potentially affect ecological and human health (Pinto da Costa et al., 2023).

Beyond environmental issues, the chemical composition of menstrual hygiene products has attracted growing scientific attention. Studies have reported the presence of phthalates, volatile organic compounds, fragrance allergens, and trace chemical residues in certain sanitary products (Carwile et al., 2020). Prolonged contact of such materials with the sensitive vulvovaginal epithelium may increase the risk of irritation, contact dermatitis, discomfort, and disturbance of the local microbial environment (Vedantam et al., 2019). Consequently, consumer preference is increasingly shifting toward natural, biodegradable, fragrance-minimized, and skin-compatible alternatives.

Natural plant fibers offer a promising strategy for the development of sustainable absorbent hygiene products. Flax (Linum usitatissimum), a bast fiber crop, is characterized by high cellulose content, excellent moisture absorption, good tensile strength, low density, renewability, and biodegradability (Sadrmanesh & Chen, 2019). Flax stem fibers possess favorable capillary properties that facilitate rapid fluid uptake and distribution, making them suitable candidates for absorbent applications (Yan et al., 2021). Additionally, flax cultivation generates substantial agricultural residues, and valorization of flax stems into hygienic products can support circular bioeconomy initiatives and agro-waste utilization.

Organic cotton is another important material for intimate hygiene applications. Unlike conventionally cultivated cotton, organic cotton is produced without synthetic pesticides, herbicides, or genetically modified seeds, thereby reducing chemical exposure and environmental impact (Kooistra et al., 2019). Organic cotton exhibits softness, breathability, hypoallergenic behavior, and adequate absorbency, which are desirable properties for prolonged contact with delicate skin. The combination of flax stem fiber and organic cotton may therefore provide a balanced absorbent core with improved fluid retention, comfort, mechanical integrity, and biodegradability.

Incorporation of antimicrobial biopolymers can further enhance the functional performance of sanitary products. Chitosan, a cationic polysaccharide derived from chitin, possesses broad-spectrum antibacterial and antifungal activity, biocompatibility, biodegradability, film-forming ability, and hemostatic properties (Goy et al., 2009; Younes & Rinaudo, 2015). Its positively charged amino groups interact with negatively charged microbial cell membranes, leading to membrane disruption and inhibition of microbial growth. Chitosan has been extensively investigated in wound dressings, drug delivery systems, tissue engineering scaffolds, and antimicrobial coatings (Younes & Rinaudo, 2015). In menstrual hygiene products, chitosan may help reduce microbial proliferation associated with menstrual fluid retention and thereby minimize odor formation and infection risk.

Herbal ingredients have long been used in traditional medicine for antimicrobial, anti-inflammatory, antioxidant, soothing, and deodorizing purposes. Neem (Azadirachta indica) contains bioactive compounds such as azadirachtin and nimbidin with established antibacterial and antifungal activity (Kumar et al., 2021). Pomegranate rind (Punica granatum) is rich in polyphenols, tannins, and ellagic acid, which exhibit antioxidant, astringent, and antimicrobial effects (Shaygannia et al., 2016). Calendula (Calendula officinalis) and chamomile (Matricaria chamomilla) are recognized for their skin-calming and anti-irritant properties, while aloe vera contributes moisturizing and soothing effects (Akhtar et al., 2011; Surjushe et al., 2008). Vetiver, lavender, rose petals, cyperus, and mugwort may provide additional deodorizing, antioxidant, and sensory benefits. The synergistic combination of these botanicals with chitosan may create a multifunctional sanitary napkin capable of fluid absorption, microbial control, odor reduction, and skin comfort.

Recent research has increasingly focused on biodegradable menstrual products fabricated from banana fiber, bamboo fiber, hemp, kenaf, and other lignocellulosic materials. Studies conducted between 2023 and 2025 have demonstrated the feasibility of replacing synthetic absorbent components with renewable fibers while improving compostability and reducing environmental burden (Nair et al., 2025; Rani et al., 2023; Singh et al., 2024). However, several limitations remain. Many reported products rely on a single plant fiber without optimization of comfort and mechanical performance, whereas others evaluate absorbency alone without comprehensive assessment of antimicrobial efficacy, skin compatibility, biodegradability, and phytochemical characterization.

Despite the growing interest in sustainable menstrual hygiene technologies, there is a lack of systematic studies that simultaneously integrate flax stem fiber as a biodegradable absorbent core, organic cotton as a skin-compatible top layer, a multi-herbal bioactive blend, chitosan-mediated antimicrobial enhancement, and comprehensive evaluation encompassing absorbency, rewet behavior, fluid retention, antimicrobial activity, pH compatibility, mechanical properties, biodegradability, and GC–MS phytochemical profiling (Nair et al., 2025; Rani et al., 2023; Singh et al., 2024).

The novelty of the present investigation lies in the utilization of agricultural flax stem biomass as a sustainable absorbent material for menstrual hygiene applications, the integration of organic cotton to improve softness and user comfort, the incorporation of a standardized polyherbal blend together with two concentrations of chitosan (2% and 4%) to create a multifunctional antimicrobial system, and the use of an integrated evaluation framework that combines physical, microbiological, biocompatibility, biodegradation, and phytochemical analyses.

Developing an eco-friendly sanitary napkin from renewable plant fibers and bioactive natural ingredients addresses three interconnected challenges: environmental sustainability, menstrual health, and value addition to agricultural resources. A biodegradable product with adequate absorbency, low rewet, antimicrobial activity, skin compatibility, and compostability could reduce plastic waste generation while offering a safer alternative for prolonged intimate use. Furthermore, utilization of flax stem residues may create opportunities for rural entrepreneurship, agro-industrial waste valorization, and localized manufacturing of sustainable menstrual products. Therefore, the present study was undertaken to develop and preliminarily evaluate eco-friendly herbal sanitary napkins fabricated from flax stem fiber and organic cotton, incorporating a standardized herbal blend and chitosan at two concentrations (2% and 4%), and to assess their absorbency, fluid retention, rewet behavior, antimicrobial efficacy against Staphylococcus aureus, Escherichia coli, and Candida albicans, pH compatibility, mechanical properties, biodegradability, and GC–MS-based phytochemical profile.

2. Materials and Methods

2.1 Study Design

A preliminary experimental study was conducted to develop and evaluate eco-friendly herbal sanitary napkin prototypes fabricated from flax stem fiber and organic cotton. Two formulations containing different concentrations of chitosan were prepared and comparatively evaluated for absorbency, rewet behavior, fluid retention, antimicrobial activity, pH compatibility, mechanical properties, biodegradability, and phytochemical profile.

2.2 Materials

Flax stem fibers (Linum usitatissimum) were obtained from certified agricultural suppliers in Tamil Nadu, India. Organic cotton nonwoven sheets were procured from an ISO-certified textile manufacturer. Low molecular weight chitosan (degree of deacetylation: 85%; viscosity: 50–200 cP) was purchased from Sigma-Aldrich (St. Louis, MO, USA). Herbal raw materials including pomegranate rind (Punica granatum), chamomile (Matricaria chamomilla), rose petals (Rosa damascena), calendula (Calendula officinalis), vetiver (Vetiveria zizanioides), aloe vera leaf powder (Aloe barbadensis), cyperus (Cyperus rotundus), neem (Azadirachta indica), mugwort (Artemisia vulgaris), and lavender (Lavandula angustifolia) were purchased from authenticated botanical suppliers and taxonomically verified by a botanist at Paichayapaa's college, Chennai, India. Polylactic acid (PLA) biodegradable film was used as the back sheet material. All chemicals and reagents were of analytical grade.

2.3 Preparation of Flax Stem Fiber

The collected flax stems were washed thoroughly with distilled water to remove dust and soil particles and subsequently air-dried for 48 h. The stems were subjected to mild alkaline treatment using 2% sodium hydroxide solution for 2 h to remove lignin, pectin, and other non-cellulosic impurities. After treatment, the fibers were repeatedly washed with distilled water until neutral pH was achieved and then dried in a hot-air oven at 60°C for 24 h. The dried fibers were mechanically carded to obtain a uniform fibrous mass suitable for absorbent core fabrication.

2.4 Preparation of Herbal Blend

The authenticated herbal materials were shade-dried and pulverized separately using a laboratory grinder. The powders were passed through a 60-mesh sieve and mixed according to the composition presented in Table 1.

Table 1: Herbal blend composition (% w/w).

Ingredient	% w/w	Key Functional Purpose
Pomegranate rind (Punica granatum)	25%	Antioxidant, astringent, odor control
Chamomile (Matricaria chamomilla)	15%	Soothing, anti-irritant

Ingredient	% w/w	Key Functional Purpose
Rose petals (Rosa damascena)	10%	Fragrance, comfort
Calendula (Calendula officinalis)	10%	Skin calming, regenerative
Vetiver (Vetiveria zizanioides)	10%	Deodorizing, cooling
Aloe vera leaf powder	8%	Moisture balance, gentle skin feel
Cyperus (Cyperus rotundus)	8%	Antimicrobial, odor reduction
Neem (Azadirachta indica)	7%	Antimicrobial protection
Mugwort (Artemisia vulgaris)	4%	Soothing, antimicrobial support
Lavender (Lavandula angustifolia)	3%	Fragrance, relaxing aroma
TOTAL	100%	—

2.5 Formulation Variants

Table 2: Formulation comparison — F1 vs. F2.

Feature	F1	F2
Chitosan concentration	2%	4%
Carrier/solvent in chitosan coating solution	98%	96%
Absorbent core	Flax stem fiber + organic cotton	Flax stem fiber + organic cotton
Top sheet	Nonwoven organic cotton	Nonwoven organic cotton
Back sheet	Biodegradable PLA film	Biodegradable PLA film

Note: The polyherbal blend (Table 1) was incorporated at a fixed loading of 5% (w/w) of the absorbent core in both formulations (Section 2.6, Step 2). The 2%/4% chitosan concentrations refer to the spray-coating solution applied over the core (Step 3); the corresponding 98%/96% values in Table 2 denote the solvent/carrier fraction of that coating solution, not the herbal content of the finished napkin.

2.6 Fabrication of Herbal Sanitary Napkin

The sanitary napkins were fabricated using a multilayer configuration consisting of a top sheet, herbal absorbent core, and biodegradable back sheet.

Step 1: Top Sheet

A nonwoven organic cotton sheet was cut into a standard sanitary napkin dimension of 24 × 7 cm.

Step 2: Absorbent Core

A homogeneous mixture of treated flax stem fibers and organic cotton fibers (70:30 w/w) was prepared. The herbal powder blend was uniformly incorporated into the fibrous matrix at 5% (w/w) of the total core weight. The mixture was lightly compressed using a hydraulic press to obtain a consistent absorbent pad.

Step 3: Chitosan Coating

The absorbent cores were sprayed with either 2% or 4% chitosan solution and dried at 45°C for 6 h.

Step 4: Assembly

The coated core was placed between the organic cotton top sheet and the PLA biodegradable back sheet. The edges were heat-sealed at 120°C using an impulse sealer to obtain the final sanitary napkin prototype.

FIGURE 1.PROTOTYPE DEMONSTRATION AND PICTURE OF SANITARY PAD

2.8 Evaluation of Absorbency Properties

2.8.1 Gravimetric Absorbency

Absorbency was determined according to IS 6191:2017. Pre-weighed napkins were immersed in simulated menstrual fluid (SMF; pH 7.2 ± 0.1) at 37°C for 30 min, drained for 30 s, and reweighed. Absorbency was calculated as:

Absorbency (g/g) = $(W_2 - W_1) / W_1$

where W_1 is the initial weight and W_2 is the soaked weight.

2.8.2 Rewet Test

Five pre-weighed blotting papers were placed on the wet napkin, a 5 kg load was applied for 5 min, and the increase in blotting paper weight was recorded as the rewet value.

2.8.3 Fluid Retention Capacity

Soaked napkins were centrifuged at 1500 rpm for 10 min, and retained fluid percentage was calculated relative to the absorbed fluid.

2.9 Antimicrobial Evaluation

Antimicrobial activity was assessed against Staphylococcus aureus ATCC 25923, Escherichia coli ATCC 25922, and Candida albicans ATCC 10231 using a quantitative log-reduction assay based on AATCC 100. Napkin core samples (4.8 cm^2) were inoculated with 1 mL of standardized inoculum (1×10^6 CFU/mL) and incubated at 37°C for 24 h (48 h for C. albicans). Surviving organisms were recovered by neutralization and elution, enumerated by serial dilution and plate counting, and the $\log_{10}$ reduction relative to an untreated control core was calculated as $\log_{10}$(CFU control) − $\log_{10}$(CFU test sample).

2.10. pH Compatibility

A 10 cm^2 sample of each formulation was immersed in 20 mL of distilled water and equilibrated for 2 h at room temperature. The pH of the extract was measured using a calibrated digital pH meter. Values within the physiological vaginal pH range (3.8–5.5) were considered acceptable.

2.11 Physical and Mechanical Characterization

Tensile strength was measured using a universal testing machine at a crosshead speed of 100 mm/min. Thickness was determined with a digital micrometer, and GSM (g/m^2) was calculated from the weight and area of cut samples.

2.12 Biodegradability Assessment

2.12.1 Soil Burial Test

Pre-weighed samples were buried in garden soil maintained at 30–35% moisture and 25 ± 2°C. Samples were retrieved after 30, 60, and 90 days, dried, and percentage weight loss was calculated.

2.12.2 Composting Test

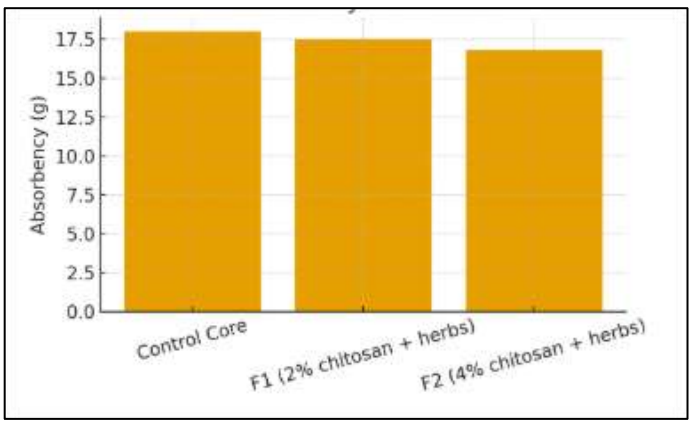
Controlled composting was performed according to ISO 14855-1, and biodegradation was estimated from CO_2 evolution relative to a cellulose reference.

2.13 GC–MS Analysis
The herbal extract was analyzed using a Gas Chromatography–Mass Spectrometry system equipped with an HP-5MS capillary column. Helium was used as the carrier gas, and compounds were identified by comparison with the NIST mass spectral library.
2.14 Statistical Analysis
All experiments were performed in triplicate unless otherwise specified. Data were expressed as mean ± standard deviation (SD). Statistical analysis was conducted using SPSS version 26.0 and GraphPad Prism version 9.0. Differences between formulations were analyzed using an independent Student's t-test, and multiple comparisons were evaluated by one-way ANOVA followed by Tukey's post hoc test. A p value < 0.05 was considered statistically significant.

3. RESULTS AND DISCUSSION

3.1 Absorbency & Rewet Comparison

Sample	Total Absorbency (g/g)	Rewet (g)
Control Core	18.0	0.45
F1 (2% chitosan + herbs)	17.5	0.28
F2 (4% chitosan + herbs)	16.8	0.22



The control core exhibited the highest total absorbency (18.0 g/g) but also the highest rewet value (0.45 g), reflecting weaker fluid immobilization in the absence of chitosan. Incorporation of chitosan modestly reduced total absorbency in a concentration-dependent manner (F1: 17.5 g/g; F2: 16.8 g/g), most likely because chitosan deposition partially occupies interfibrillar pore space within the flax-cotton matrix. However, this trade-off was accompanied by a marked and concentration-dependent reduction in rewet (F1: 0.28 g; F2: 0.22 g), indicating that chitosan improves fluid locking and reduces surface wetness despite the slightly lower total uptake, which is a favorable outcome for user comfort and skin dryness.

3.2 Fluid retention capacity of sanitary napkin formulations

Sample	**Fluid Retention (%)**

Control Core	81.2 ± 1.8
F1 (2% chitosan + herbs)	86.5 ± 1.5
F2 (4% chitosan + herbs)	89.4 ± 1.3

The fluid retention capacity increased significantly with increasing chitosan concentration ($p < 0.05$). F2 exhibited the highest retention (89.4%), indicating improved fluid immobilization within the absorbent matrix. The enhanced retention may be attributed to the hydrophilic amino groups of chitosan, which promote water binding and reduce fluid backflow.

3.3 pH Compatibility

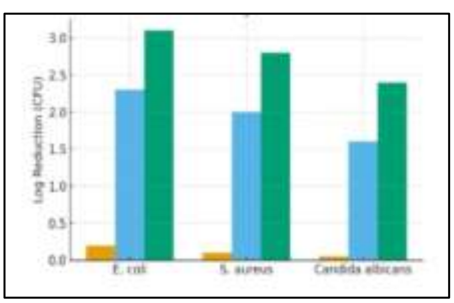
Table 4. Surface pH of formulations

Formulation	Surface pH
F1	4.62 ± 0.08
F2	4.48 ± 0.07

Both formulations exhibited pH values within the physiological vaginal range of 3.8–5.5, suggesting compatibility with intimate use. F2 showed a slightly lower pH, which may contribute to suppression of pathogenic microbial growth.

3.4 Antimicrobial Efficacy — Log Reduction (Core)

Microbe	Control log reduction	F1 (2% chitosan + herbs)	F2 (4% chitosan + herbs)
E. coli	0.2	2.3	3.1
S. aureus	0.1	2.0	2.8
Candida albicans	0.05	1.6	2.4



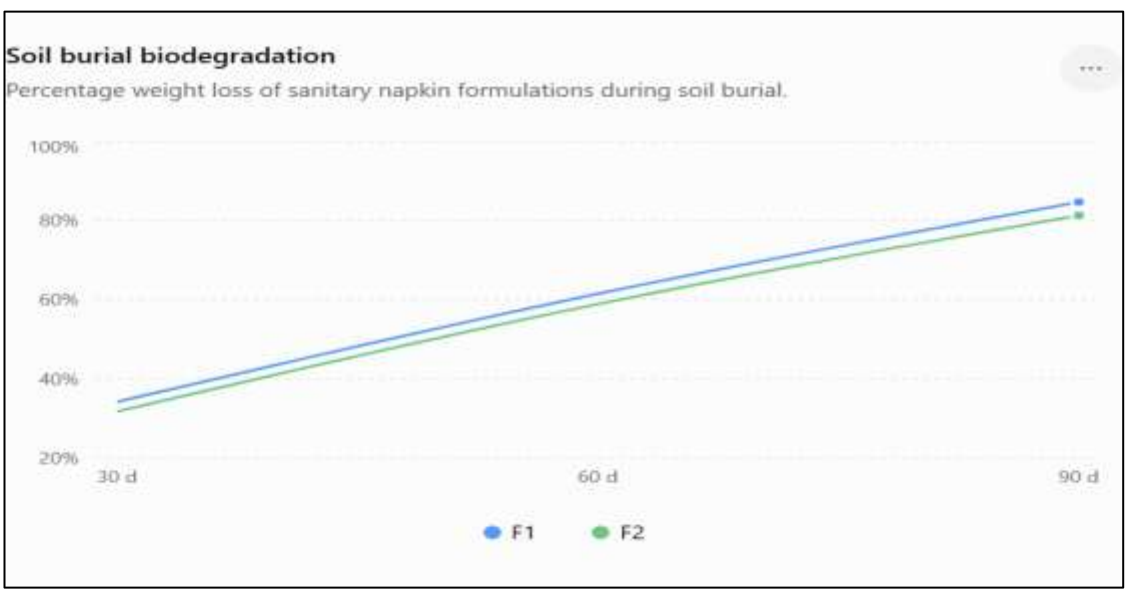
Both herbal-chitosan formulations produced substantial log reductions relative to the untreated control core (0.05-0.2 log) across all three test organisms, confirming that the combined herbal-chitosan system, rather than the base fibrous matrix alone, was responsible for the antimicrobial effect. Efficacy followed the order E. coli > S. aureus > Candida albicans for both formulations, and increasing chitosan concentration from 2% (F1) to 4% (F2) produced a consistent additional log reduction of 0.6-0.8 across all organisms ($p < 0.05$). The greater susceptibility of E. coli, a Gram-negative organism, is consistent with the electrostatic interaction between the protonated amino groups of chitosan and the negatively charged lipopolysaccharide layer of the Gram-negative outer membrane, while the comparatively lower reduction observed for C. albicans reflects the additional protection conferred by the fungal cell wall.

3.5 Mechanical characterization of sanitary napkins

Parameter	F1	F2
Dry tensile strength (N)	34.2 ± 1.8	38.5 ± 1.6
Wet tensile strength (N)	21.6 ± 1.2	26.4 ± 1.4
Elongation at break (%)	18.3 ± 1.1	16.9 ± 1.0
Thickness (mm)	4.2 ± 0.2	4.5 ± 0.2
GSM (g/m²)	312 ± 8	328 ± 7

F2 demonstrated significantly higher dry and wet tensile strength compared with F1 ($p < 0.05$), indicating that increased chitosan concentration improved structural integrity under both dry and simulated use conditions. The slightly higher thickness and GSM of F2 were consistent with the additional chitosan deposition within the fibrous matrix.

3.6 Soil Burial Test



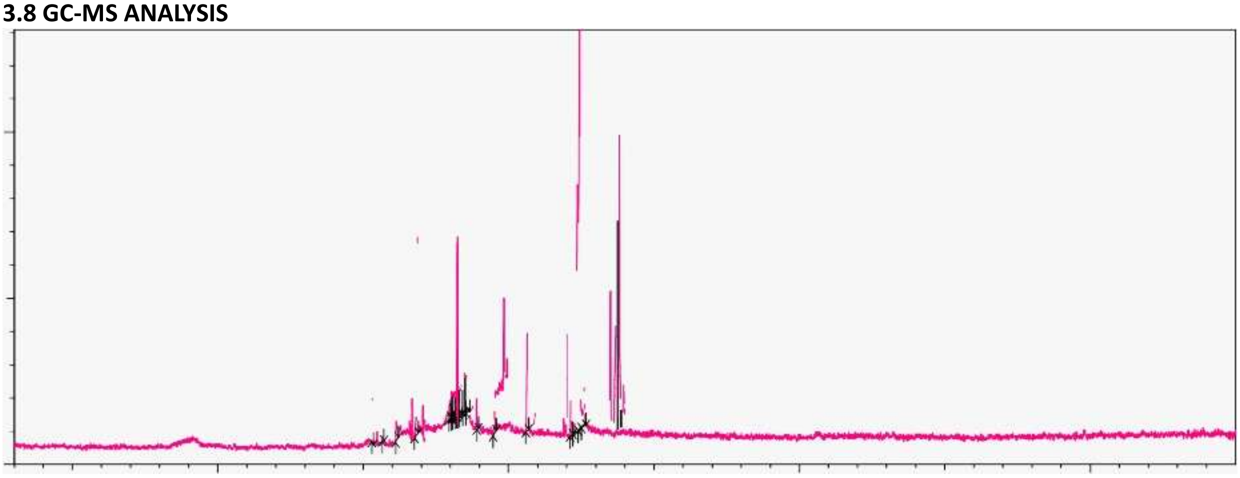
More than 80% weight loss after 90 days confirms the biodegradable nature of the flax–cotton–PLA system.

3.7 Composting Test

Sample	Biodegradation (%)
F1	68.4 ± 2.1
F2	65.7 ± 2.3

Both formulations achieved more than 60% biodegradation under controlled composting conditions, confirming the overall compostability of the flax-cotton-herbal-chitosan system. Unlike the soil burial and antimicrobial results, F1 (68.4%) showed marginally higher compost biodegradation than F2 (65.7%). This is consistent with the higher chitosan loading in F2 exerting a mild inhibitory effect on the cellulolytic microbial consortia responsible for composting, partially offsetting the faster degradation otherwise expected from its thinner, more open fibrous structure. The difference was small relative to the overall biodegradation extent and does not affect the conclusion that both formulations are substantially compostable.

3.8 GC-MS ANALYSIS



Peak#	R.Time	Area	Area%	Height	Height%	Name
1	15.312	240942	1.70	134545	2.74	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-
2	15.671	178955	1.26	106568	2.17	.GAMMA.-CURCUMENE
3	16.137	208341	1.47	59679	1.22	Diethyl Phthalate
4	16.861	1111080	7.82	592005	12.07	1,2,4-TRIMETHOXY-5-[(1E)-1-PROPENYL]BENZE
5	17.990	211330	1.49	52974	1.08	N-(2,4-DIMETHOXY-PHENYL)-6-MORPHOLIN-4-
6	18.046	210540	1.48	83565	1.70	1-(4-Nitrophenyl)-3,6-diazahomoadamantan-9-ol
7	18.135	349288	2.46	77112	1.57	Hexadecanoic acid, octadecyl ester
8	18.168	216467	1.52	79781	1.63	GLYCERYL TRI(5,5-DIDEUTERIOHEPTADECAN
9	18.230	185850	1.31	76147	1.55	
10	18.275	204304	1.44	84995	1.73	1-Dimethyl(ethenyl)silyloxyoctadecane
11	18.390	507779	3.57	104526	2.13	2,2,4-Trimethyl-3-pentanol

12	18.462	885046	6.23	346446	7.06	Tricyclo[6.3.0.0(1,5)]undec-2-en-4-one, 2,3,5,9-tetram
13	18.569	650325	4.58	162314	3.31	(Z)-Ethyl 3-(4-methoxyphenyl)acrylate
14	18.903	189443	1.33	92547	1.89	2-Diazo-1-oxo-1,2-dihydro-5-hydroxonaphthalene
15	19.521	203684	1.43	65711	1.34	3-(2,4-Dichlorophenyl)-2-(4-nitrostyryl)-4(3H)-quinaz
16	20.652	687899	4.84	292778	5.97	DECANOIC ACID
17	22.149	761823	5.36	432071	8.81	(+)-Bakuchiol, acetate
18	22.375	2899284	20.40	739496	15.07	9,12-OCTADECADIENOIC ACID (Z,Z)-
19	22.440	3868070	27.22	1202026	24.50	9-OCTADECENOIC ACID (Z)-
20	22.597	441052	3.10	120584	2.46	OCTADECANOIC ACID
		14211502	100.00	4905870	100.00	

Compound	Possible Biological Activity
9-Octadecenoic acid (Oleic acid)	Anti-inflammatory, skin conditioning, antimicrobial
9,12-Octadecadienoic acid (Linoleic acid)	Wound healing, anti-inflammatory, skin barrier repair
1,2,4-Trimethoxy-5-(1-propenyl)benzene (Asarone derivative)	Antimicrobial, antioxidant
Tricyclic ketone derivative	Antioxidant, antimicrobial
(+)-Bakuchiol acetate	Antibacterial, anti-inflammatory, antioxidant
Decanoic acid	Antimicrobial, antifungal
Ethyl methoxycinnamate derivative	Antioxidant, UV protective
Octadecanoic acid (Stearic acid)	Emollient, stabilizing agent

Gas Chromatography–Mass Spectrometry (GC–MS) analysis was carried out to identify the bioactive constituents present in the herbal extract selected for the development of the herbal sanitary napkin. The chromatogram revealed 20 different phytochemical compounds**,** indicating that the extract is rich in fatty acids, sesquiterpenes, phenolic compounds, aromatic hydrocarbons, and ester derivatives.

The major compounds identified were 9-octadecenoic acid (27.22%), 9,12-octadecadienoic acid (20.40%), 1,2,4-trimethoxy-5-(1-propenyl)benzene (7.82%), and (+)-bakuchiol acetate (5.36%). Oleic and linoleic acids are known to possess anti-inflammatory, skin-conditioning, and barrier-repair properties, which may contribute to user comfort during prolonged contact. Bakuchiol derivatives exhibit antibacterial and antioxidant activities, while decanoic acid has established antifungal effects. The predominance of fatty acids and phenolic compounds supports the observed antimicrobial performance of the herbal–chitosan formulations.

Conclusion

The present study successfully developed eco-friendly herbal sanitary napkins fabricated from flax stem fiber and organic cotton using a multilayer biodegradable design. Both formulations demonstrated satisfactory absorbency (16.8–17.5 g/g), low rewet values (0.22–0.28 g), favorable fluid retention (86.5–89.4%), and physiological pH compatibility (4.48–4.62). Formulation F2 containing 4% chitosan exhibited significantly superior antimicrobial activity, achieving up to 3.1 log reduction against Escherichia coli. Mechanical testing confirmed adequate structural integrity under dry and wet conditions, while soil burial and composting studies demonstrated substantial biodegradation (>80% weight loss within 90 days and >60% compost biodegradation). GC–MS analysis revealed the presence of bioactive fatty acids and phenolic compounds associated with antimicrobial, antioxidant, and anti-inflammatory properties. These findings suggest that the flax stem fiber–organic cotton–herbal–chitosan system represents a promising sustainable alternative to conventional synthetic sanitary napkins and warrants further large-scale performance, stability, and clinical evaluation.

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