Scientific Research Publishing

Materials Sciences and Applications, 2023, 14, 363-381
https://www.scirp.org/journal/msa
ISSN Online: 2153-1188
ISSN Print: 2153-117X

Development of Ecological Absorbent Core Sanitary Pads in Combination of Kenaf and Chitosan Fibers

Desh Maruthi Jeyakanthan, Jens Schuster, Yousuf Pasha Shaik

Department of Applied Logistics and Polymer Sciences, University of Applied Sciences Kaiserslautern, Institute for Plastics Engineering West Pfalz (IKW), Pirmasens, Germany
Email: deshmaruthi1997@gmail.com

How to cite this paper: Jeyakanthan, D.M., Schuster, J. and Shaik, Y.P. (2023) Development of Ecological Absorbent Core Sanitary Pads in Combination of Kenaf and Chitosan Fibers. *Materials Sciences and Applications*, **14**, 363-381.
https://doi.org/10.4236/msa.2023.147023

Received: May 25, 2023
Accepted: July 10, 2023
Published: July 13, 2023

Abstract

The menstrual cycle is always considered as a big nightmare by many women. This research aims to make this process smooth and safe by developing natural sanitary pads which are used to absorb and retain menstrual blood from the body. Some existing sanitary pads contain 90% plastics made of non-woven polypropylene/polyethylene sheets, super absorbent polymers, and polyethylene back sheets that will take up to 600 - 800 years to decompose. So, biodegradable sanitary pads using natural fibers are the best alternative to eliminate the pads which contain non-biodegradable materials. In this research, nonwoven bamboo will be used as the top layer, nonwoven cotton will be used as the second layer, the absorbent core is to be made by the combination of kenaf and chitosan fibers as the third layer, cotton as the fourth layer, and cornstarch-based bioplastic sheets as the bottom layer. These biodegradable natural materials will change the menstrual process into a healthy one as well as create a robust ecological community.

Keywords

Sanitary Pads, Biodegradable, Kenaf, Chitosan, Bamboo, Cotton, Corn-Based Polylactic Acid

1. Introduction

In the ancient days, napkins were less popular because women used leaves, sandbags, wood pulp, and many unshaped, uncomfortable materials to absorb blood flow during their menstrual cycle. After some stages of evolution, women used rags and piece of cloth during the discharge. Furthermore, they had washed the clothes and kept them safe to use in the next menstrual cycle. There was no awareness about the usage of the right products in their important process since "periods" is a kind of taboo topic in the past. They also could not buy napkins from the outside shops. This created serious health hazards for women [1]. In the present scenario, most of the women got access to buy and use sanitary pads. But replacing clothes with non-biodegradable sanitary pads cannot create better solutions to the environment as well as health issues.

During menstruation, women use 15,000 sanitary pads on average throughout their life. Because it is a natural process, that occurs every month for girls and women. Mayank, *et al.* stated that women should use a single sanitary pad for an average time of 3 to 4 hours. It should be changed after the average time. If the sanitary pads are not changed after 5 hours, then it would lead to itches, rashes, reproductive problems, and serious infections [2].

Sabrina Sareen depicted the fact that the sanitary pads which are made of 90% of plastics cause serious issues due to the long contact with the body. Moreover, it will lead to pelvic and fungal cancer. It will take 600 - 800 years to decompose in landfills and it is also unhealthy for the environment [3]. Women should be more diligent about the manufacturing process and materials of today's commercially available non-biodegradable sanitary napkins. As many available napkins in the market are made of plastics containing polyethylene, polypropylene, and super absorbent polymers (SAP) and they will take ages to decompose.

In many undeveloped and developing countries, there is no proper knowledge for girls and women regarding the menstrual process [4]. Due to the high cost of non-biodegradable sanitary pads, it is difficult to afford for users. So, sanitary pads which are made of biodegradable materials can be manufactured at less cost and it is healthy for both humans and the environment.

Jihyun Bae*, et al.* depicted the problems in the commercial sanitary pads that, it contains a non-woven polyethylene/polypropylene sheet as the top layer which is in contact with the human body and allows the menstrual blood inside the pad. The middle layer is made of super-absorbent polymers which absorb and retain the menstrual blood. The polyethylene/polypropylene sheet is used as the bottom layer which prevents the menstrual blood from leaking out of the pads. Also, adhesives, scents, dioxin, and phthalates are used in sanitary pads to make them comfortable for users. The adhesives are used to seal the sanitary pads. The scents are used to give a pleasant smell to the user. Pads are bleached to increase the absorbing capacity, and the bleach contains dioxin. Dioxins are persistent organic pollutants that take more time to break down in the environment. Phthalates are used to make sanitary pads soft and flexible. These non-biodegradable materials increase menstrual waste and pollute the environment. The plastic layers in the non-biodegradable sanitary pads are not easily broken down by the microorganism. It will take more time to degrade. When the sanitary pads are burnt after usage, the ash from the sanitary pads combines with the soil and groundwater and spoils the food and drinking water. These materials also cause many infections and diseases to the users. The polyethylene/polypropylene sheets cause allergies, itches, and rashes to the users. Super absorbent polymers sometimes cause toxic shock syndrome and cancer. The adhesives used in sanitary pads cause dermatitis. The scent used in sanitary pads causes yeast infection with irritation, itching, redness, and swelling. Phthalates cause reproductive problems and sometimes lead to cancer. Dioxin causes reproductive and developmental problems and sometimes damages the immune system of the users [5].

Srikavi Anbalagan, *et al.* indicated that plant fibers are the best alternative for the non-biodegradable materials which are used in commercial sanitary pads. Plant fibers are lignocellulosic fibers that are composed of cellulose, hemicellulose, lignin, and pectin. Plant fibers are biodegradable, renewable, and abundant in nature. Also, they are chemical-free, non-irritant, and have good absorption properties. Biodegradable sanitary pads are intended to degrade spontaneously over time, reducing their impact on the environment and protecting ecology from its downfall [6].

Preshita Neha Tudu [7] stated that Saathi pads are completely made of banana fibers. Saathi pads are 100% biodegradable and do not contain any plastic or non-organic materials. The absorbency of the banana sanitary pads is 50% more than the commercial sanitary pads. It biodegrades in 6 months which is 1200 times faster than commercial sanitary pads. Other biodegradable sanitary pads which are made from byproducts of sugarcane are less costly and eco-friendly [8].

Another research used bamboo wadding material. Jasmin Foster, *et al.* concluded that the absorbency of bamboo wadding is twice that of commercial sanitary pads, and it is biodegradable, lightweight, and has no dangerous effect on the user and environment [9].

Corn-starch-based PLA bioplastic is one of the best alternatives for non-biodegradable plastics. It is used in pharmaceutical and medical industries and degrades very fast when compared to the existing plastics [10].

Based on prior research findings, commercial sanitary pads which are made of non-biodegradable materials cause danger to both humans and the environment. To overcome this problem, sanitary pads made of biodegradable materials not only maintain a sustainable environment but also leads to good menstrual health.

The purpose of this research is to produce biodegradable and healthy sanitary pads comprised of only eco-friendly materials by making the upper layer with nonwoven bamboo, the middle layer with nonwoven cotton, kenaf fibers, chitosan fibers, and cotton, and the bottom layer with biodegradable corn-based PLA barrier sheets.

Liquid strike through test, wet back strike through test, absorbency test, retention test, and leakage proof test were performed. The result of the tests are compared with the commercial sanitary pads.

2. Experiments

2.1. Materials

Humans, animals, and other living organisms depend on plants for food, air, clothes, medicines, and many other essential products for everyday life. It protects the environment in all ways by regulating the water cycle, absorbing carbon dioxide, preventing soil erosion, reducing pollution, protecting the earth from UV radiation, fighting in climate changes, and many more. It is also known that many life-threatening diseases were treated by the barks, roots, fibers, leaves, and stems from plants in the olden times. As far as women's menstrual health is concerned, they are considered as the abundant source of potential medicines. So, biodegradable materials such as nonwoven bamboo, kenaf fiber, chitosan fiber, cotton, and corn-based polylactic acid sheet are used to manufacture the biodegradable sanitary pads. Figure 1 shows the layer arrangement of the biodegradable sanitary pads.

2.1.1. Bamboo Fibers

Bamboo is one of the self-growing plants as it requires no chemicals, fertilizers or water to grow. Generally, bamboo is highly used in construction, creating musical instruments and utensils. But, as fibers it inherits many properties such as moisture management, anti-bacterial, UV protection, hypoallergic, and eco-friendly [9].

Bamboo plays a vital role in manufacturing sports and intimate clothing. It is more breathable than cotton and it also helps the skin to feel comfortable by absorbing moisture quickly, also evaporating sweat from the human body faster like breathing. Besides that, it contains a unique anti-microbial agent called "bamboo kun" which takes part in arresting odour and fungus [11]. The hypoallergenic property presented in bamboo will not cause any allergic reactions. As bamboo fibers are 100% cellulosic and can be processed through a regenerated or natural process, it is biodegradable in nature.

2.1.2. Kenaf Fibers

Like bamboo, kenaf also can grow with no pesticides or chemical fertilizers. It has an antimicrobial property which can prevent the spread of microorganisms during the menstrual cycle. In addition, antioxidant, and anti-cancer agents help women to escape from diseases and uterus cancer. The outer bast fiber and whole stalk of kenaf can be used in textiles, absorbents, and composites [12]. The fibers also participate in improving the soil structure by fixing soil nutrients in the correct proportion. It can be easily biodegradable.

2.1.3. Chitosan Fibers

The chitosan fibers are prominent and renowned materials in the plethora of fields such as biotechnology, bio-nanotechnology, food technology, and industries. Above all, it is one of the promising agents in curing cancers and it called best cancer therapy agent. It has a bio-compatible property which causes no harm to any living tissue. So, it is irreplaceable in wound dressing, tissue engineering, and sutures. Likewise, the fibers are used to produce clothes for the babies and the elder people who have weak and sensitive skin because it has the ability to keep the skin from drying without any irritation or allergy. It has antimicrobial, antioxidant, anti-inflammatory properties [13]. It is also totally biodegradable.

Figure 1. Layers of biodegradable sanitary pads.

2.1.4. Cotton

The cotton is naturally soft and absorbent. It resists bacterial and fungal growth which are formed due to excessive moisture in sanitary pads. Cotton has good absorption properties and will retain the fluid and separate it from the body [14]. The porosity property of cotton provides a barrier to heat and moisture. So, it is breathable in contact with the body.

2.1.5. Corn-Based Polylactic Acid

Corn starch polylactic acid is a sustainable alternative for petroleum-based plastics. It is used in several hygiene industries. It is anti-bacterial, non-toxic, and biodegradable [15].

2.1.6. Blood Substitute

A blood substitute is an artificial blood fluid that is used as an alternative to biological blood [16]. This artificial blood is supplied in the name of Boland which is used as the blood substitute to carry out all the tests on biodegradable sanitary pads.

2.2. Machinery

2.2.1. Carding Machine

This process is used to convert kenaf and chitosan fiber into a soft, fluffy core. The continuous web of fibers can be attained from the carding process. The impurities and dust in the fibers can be removed by using this process [17].

2.2.2. Hydraulic Hot Pressing Machine

Figure 2 shows the hydraulic hot pressing machine which is used to emboss and seal all the layers of sanitary pads.

2.2.3. Oven

It is used to make the sanitary pads as noncontaminated and also to make sure they are free from bacteria and microbes.

2.2.4. Weighing Scale

It is utilized to measure the weight of every layer of sanitary pads and fibers. While testing it is used to check the weight of dry and wet sanitary pads.

2.3. Methodology

The methods which are used to manufacture the sanitary pads as shown in **Figure 3**

Figure 2. Hydraulic hot pressing machine.

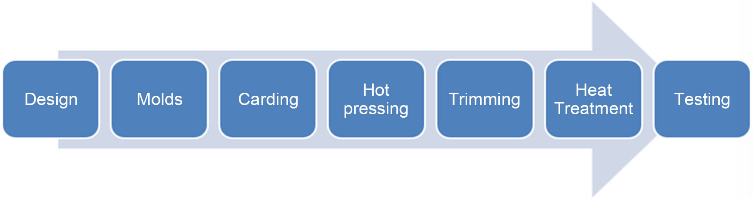


Figure 3. Process flow to manufacture sanitary pads.

2.3.1. Design

Sanitary pads were manufactured in three different sizes like small, medium, and large as shown in Figure 4. Each pad is different in its length but same in its width. The wings length of the sanitary pads is distinct based on the sizes. The lengths of the small, medium, and large sanitary pads are 170 mm, 200 mm, and 230 mm respectively. The width of the small, medium, and large sanitary pads including and excluding wings are 160 mm, and 80 mm respectively. The weights of the small, medium, and large sanitary pads are 6.5 g, 8.5 g, and 10 g respectively.

2.3.2. Molds

The wooden molds are prepared to place the sanitary pads in the hydraulic hot press machine. So that, every layer of the sanitary pads except the absorbent core is completely sealed together into a firm one. All molds have the same measurements in respect to its length, width, and thickness such as 270 mm, 170 mm, and 5 mm respectively as shown in Figure 5.

2.3.3. Carding

The kenaf and chitosan fibers are cut into small pieces. At the initial stage, kenaf fibers were carded and it is followed by the chitosan fibers. Finally, both were combined together and again carded to obtain a continuous web.

2.3.4. Hot Pressing

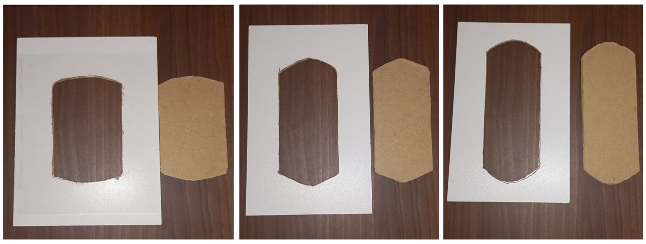
The sanitary pads with wooden molds are kept in the hydraulic hot press machine by arranging the nonwoven bamboo as the top layer, the absorbent core which contains kenaf, chitosan, and cotton as the middle layer, and the biodegradable PLA sheet as the bottom layer as shown in **Figure 6**. The temperature of the upper plate is maintained as 142˚C whereas the temperature of the lower plate is maintained as 60˚C and 40 bar pressure is applied for 1 minute 30 seconds to emboss and seal the sanitary pads.

2.3.5. Trimming

Followed by the previous step, the sanitary pads were trimmed in the exact dimensions based on its respective sizes. So that, the extra portions were removed from the sanitary pads.

(a) Small (b) Medium (c) large

Figure 4. Front and back side of sanitary pad.



(a) Small (b) Medium (c) large

Figure 5. Molds for small, medium and large sanitary pads.

Figure 6. Sanitary pad with wooden mold placed in hot pressing machine.

2.3.6. Heat Treatment

To assure the 100% hygiene of the sanitary pads, they were under heat treatment in the oven at a temperature of 120˚C for 10 minutes.

2.3.7. Testing

After completing all these steps, the sanitary pads were taken through five tests which are liquid strike through test, wet back strike through test, absorbency test, retention test, and leakage proof test [18].

2.4. Tests

2.4.1. Liquid Strike through Test

The test was conducted to measure the time taken by the blood substitute to penetrate inside the dry sanitary pads. The sample was placed on the glass plate to note the changes feasibly. One drop of blood substitute was poured on the sample with the help of a syringe as shown in **Figure 7**. The duration of this process was monitored in seconds by using a stopwatch. It was started when the blood substitute touched the top layer of the sample, and it was stopped when the blood substitute penetrated the sample [19].

2.4.2. Wet Back Strike through Test

The test was conducted to measure the time taken by the blood substitute to penetrate inside the wet sanitary pads. Initially, 10 ml of blood substitute is poured at the center of the sanitary pad to wet the sample. Thereafter, one drop of blood substitute was dropped on the wet sample by using a syringe. The time was noted in seconds before and after the penetration of the blood substitute in the wet sample.

2.4.3. Absorbency Test

This test was done to measure the maximum absorbency rate of sanitary pads until the point of leakage as shown in **Figure 8**. At the first stage the weight of the dry sample was recorded, then the blood substitute was added slowly as drop by drop till the point of leakage by using a syringe. After this process, the final weight of the sample was measured with a weighing scale. The maximum absorbency of the blood substitute in a sanitary pad was calculated in percentage by using the formula [20],

Figure 7. One drop of blood substitute poured on sanitary pad.

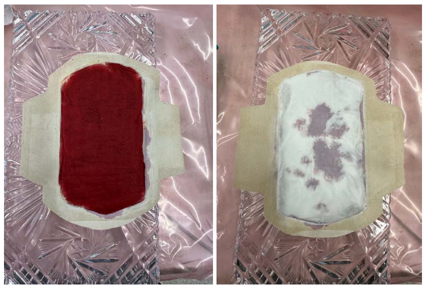


Figure 8. Front and back side of maximum absorbed sanitary pad.

$$\text{Absorption in percentage} = \frac{(FW - IW)}{IW} \times 100 \quad (1)$$

The maximum absorbency of the blood substitute in the sanitary pad was calculated in grams by using the formula [16],

$$\text{Absorption in grams} = (FW - IW) \quad (2)$$

where IW is the initial weight of the actual sanitary pad and FW is the final weight of the maximum absorbed sanitary pad.

2.4.4. Retention Test

This test can be used to calculate the ability of the sanitary pads in holding the maximum amount of absorbed blood after the removal of 1 kg of weight for 1 minute. It was followed by the absorbency test. In the beginning, the weight of the blotting paper was measured and it was placed on the glass plate. In the next step, the maximum absorbed sanitary pad sample was kept above the blotting paper. 1 kg of weight was remained on the maximum absorbed pad for 1 minute as shown in **Figure 9**. After a minute, 1 kg of weight was taken away and the weight of the sample was measured.

The maximum retention of the blood substitute in the sanitary pad was calculated in percentage by using the formula,

$$\text{Retention in percentage} = \frac{(FW - IW)}{IW} \times 100 \quad (3)$$

The maximum retention of the blood substitute in the sanitary pad was calculated in grams by using the formula,

$$\text{Retention in grams} = (FW - IW) \quad (4)$$

where IW is the initial weight of the actual sanitary pad and FW is the final weight of the maximum retinted sanitary pad.

2.4.5. Leakage Proof Test

After the retention test, this test was conducted to measure the amount of blood substitute which leaked out of the sanitary pads after placing a 1 kg. As a result of the weight placed, some quantity of blood substitute was leaked outside from the sample and it was collected by the blotting paper. Finally, the final weight of the blotting paper was measured by using a weighing scale. The leakage of blood substitute from the sample was calculated in grams by using the formula,

Figure 9. Sanitary pad kept under 1 kg of weight.

$$\text{Leakage in grams} = (FWB - IWB) \quad (5)$$

where, IWB is the initial weight of blotting paper and FWB is the final weight of the blotting paper.

3. Results

3.1. Liquid Strike through Test

In Table 1 and Figure 10, the three various sized biodegradable pads such as small, medium, large show better results than commercially available small, medium and large pads. Biodegradable pads took less time to penetrate when it was compared to commercial sanitary pads. So, it keeps the skin dry and provides comfort for users.

3.2. Wet Back Strike through Test

As similar as the above test, the wet back strike through test recorded positive results in biodegradable sanitary pads. The blood substitute took a short time to penetrate inside biodegradable pads when it was compared to commercial sanitary pads as shown in Table 2 and Figure 11.

3.3. Absorbency Test

Table 3 represents the maximum absorbency of the sanitary pads in both grams and percentages. Commercial sanitary pads exhibited more absorbency power but very slightly extra than biodegradable sanitary pads. Figure 12 and Figure 13 show the graphical representation of the maximum absorbed sanitary pads.

3.4. Retention Test

Commercial sanitary pads showed high retention capacity but in the small difference than biodegradable sanitary pads as shown in Figure 14 and Figure 15. Because this test was followed by the results of absorbency test. When it is not followed by the absorbency test, biodegradable sanitary pads will show good retention results. The leakage of blood substitute is less when compared to commercial sanitary pads after the removal of 1 kg weight when laid for a minute. Table 4 shows the retention result of sanitary pads in both grams and percentage.

Table 1. Results of liquid strike through test.

Sample	Small [Second]	Medium [Second]	Large [Second]
Commercial	1.95	1.90	2.28
Biodegradable	1.74	1.87	2.19

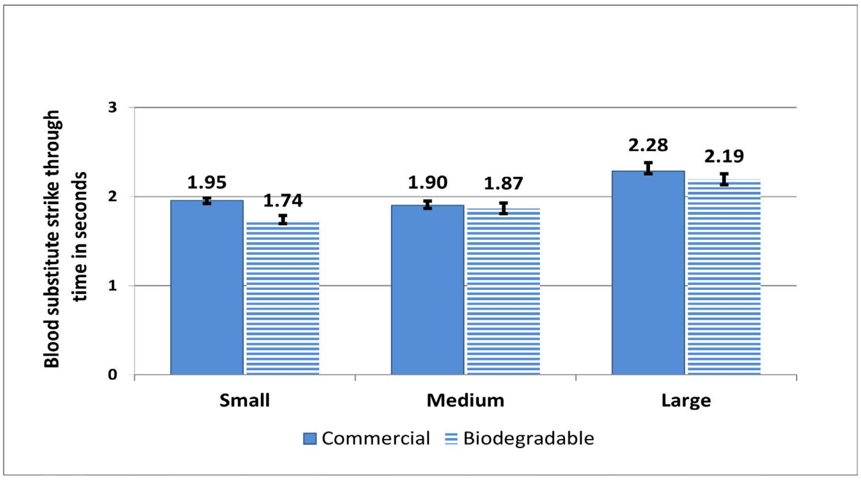


Figure 10. Liquid strike through test in biodegradable vs commercial sanitary pads.

Table 2. Results of wet back strike through test.

Sample	Small [Second]	Medium [Second]	Large [Second]
Commercial	3.63	3.68	3.71
Biodegradable	3.55	3.48	3.47

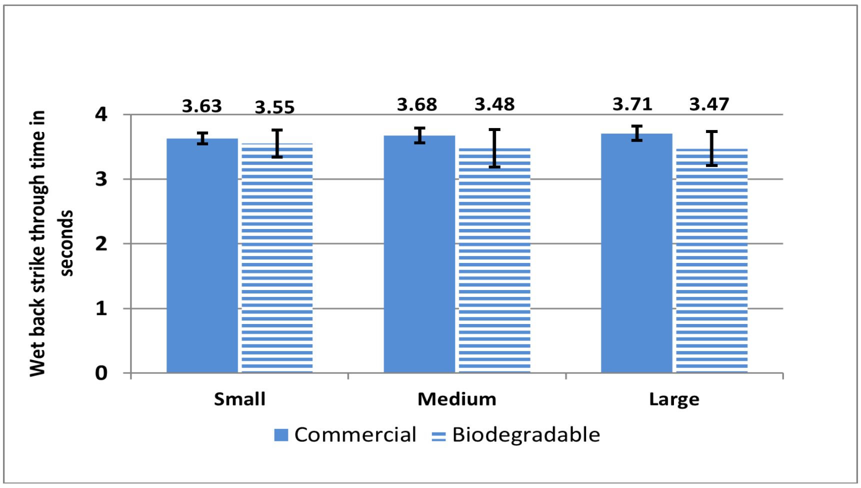


Figure 11. Wet back strike through test in biodegradable vs commercial sanitary pads.

Table 3. Results of the absorption test.

Sample	Small		Medium		Large	
	grams	%	grams	%	grams	%
Commercial	32.73	498.24	34.18	402.1	39.52	395.1
Biodegradable	31.44	483.0	32.48	382.0	37.07	370.6

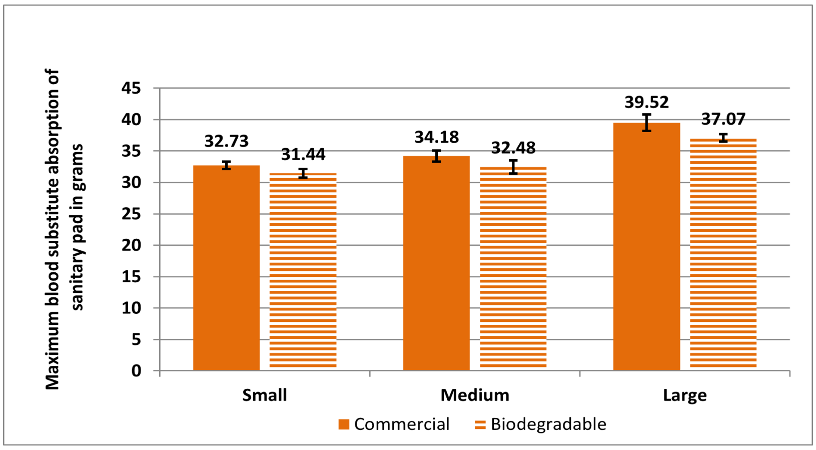


Figure 12. Maximum absorption of blood substitute in grams.

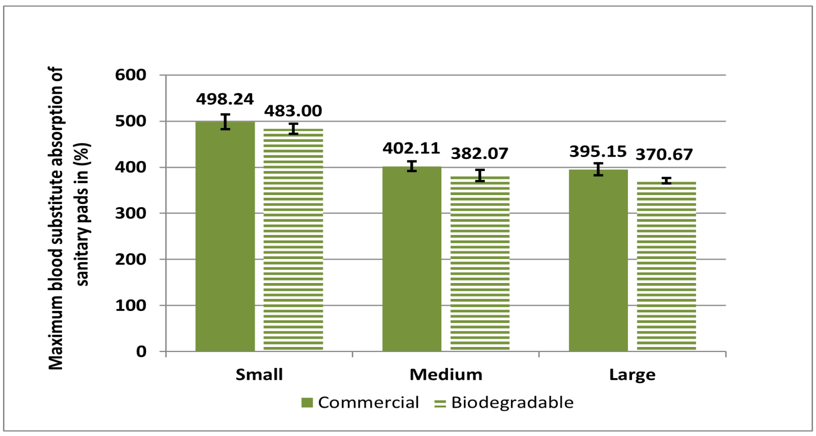


Figure 13. Maximum absorption of blood substitute in percentage.

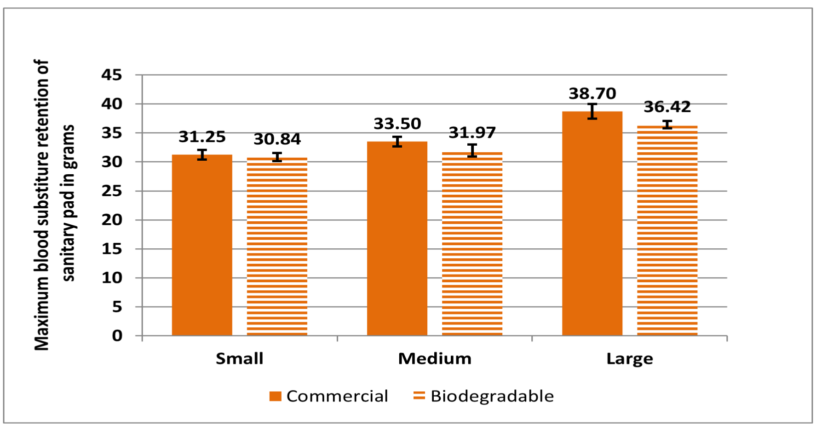


Figure 14. Maximum retention of blood substitute in grams.

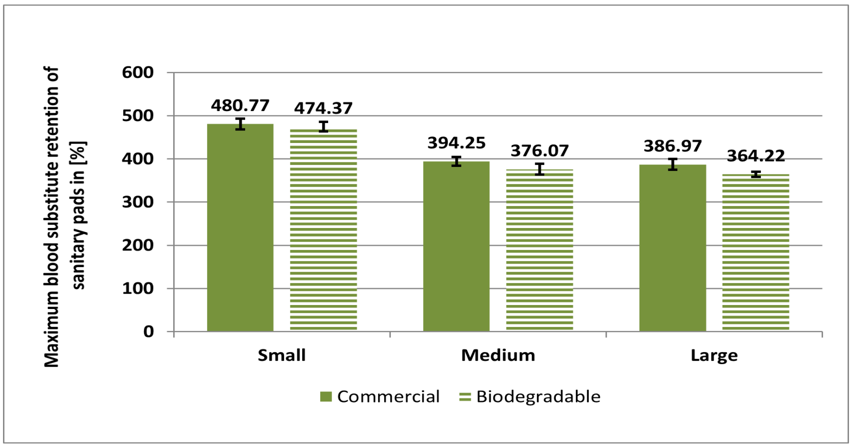


Figure 15. Maximum retention of blood substitute in percentage.

Table 4. Results of the retention test.

Sample	Small		Medium		Large	
	grams	%	grams	%	grams	%
Commercial	31.25	480.7	33.50	394.2	38.70	386.9
Biodegradable	30.84	474.3	31.97	376.0	36.42	364.2

3.5. Leakage Proof Test

Biodegradable sanitary pads displayed good results in leakage proof test as shown in Table 5 and Figure 16. It diffused only less amount of blood substitute in contrast to commercial sanitary pads as mentioned in the retention test.

Table 5. Results of leakage proof test.

Sample	Small [grams]	Medium [grams]	Large [grams]
Commercial	0.76	0.64	0.72
Biodegradable	0.55	0.48	0.53

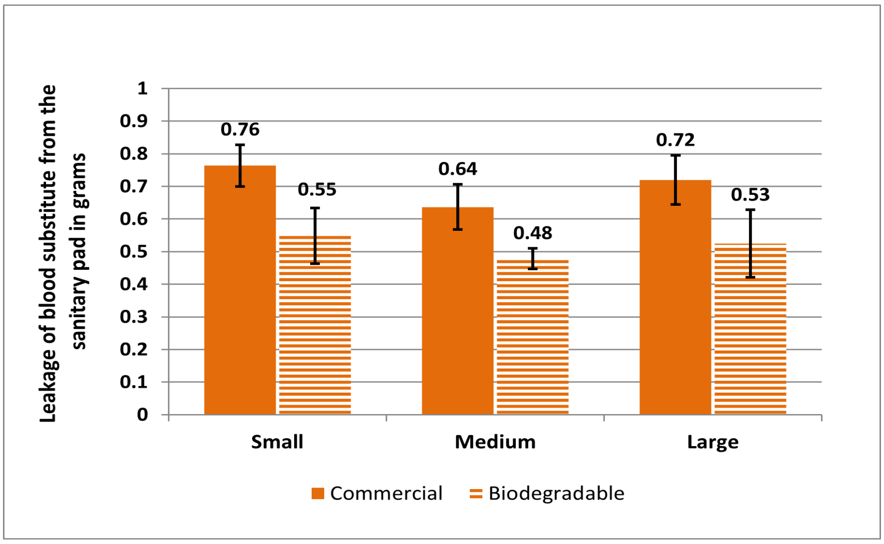


Figure 16. Leakage of blood substitute from biodegradable vs commercial sanitary pads.

4. Discussion

The alternative materials used in biodegradable sanitary pads are shown in Table 6.

The top layer is used as a nonwoven polyethylene/polypropylene sheet in non-biodegradable sanitary pads causing skin irritation, rashes, and produces more heat around the private part due to the long contact. But nonwoven bamboo used in the biodegradable sanitary pad is softer than cotton, breathable, antibacterial, UV protective, and provides coolness when in contact with the body. Scent used in non-biodegradable sanitary pads causes skin irritation and allergies. Yet, bamboo has an antimicrobial bioagent known as bamboo kun. It naturally contains antibacterial, antifungal, and odour resistant properties. Kenaf fiber is a good resistance to mildew and rot. Chitosan fiber has good resistance to malodor. Super absorbent polymer like sodium polyacrylate is used in nonbiodegradable sanitary pads cause skin irritation, toxic shock syndrome, and cancer. But kenaf fiber and chitosan fiber contain anticancer, antioxidant, analgesic, and antibacterial properties. Cotton is good absorbent, breathable, soft, and non-toxic. Polyethylene or polypropylene is used as the barrier sheet for non-biodegradable pads. But biodegradable PLA sheet is used as the barrier sheet for biodegradable pads.

Weight factors are calculated by giving points to each test. By comparing one test with another, the points are given to each test based on their importance. The weight factor is calculated by dividing the total value of each test and the overall value of all the tests as shown in Table 7. The point factor is determined by giving the points for each test based on their results. The product of the weight factor and point factor gives the final value. Table 8 and Table 9 show the point factor and evaluation criteria of the small biodegradable and small commercial sanitary pads. Table 10 and Table 11 show the point factor and evaluation criteria of the medium biodegradable and medium commercial sanitary pads. Table 12 and Table 13 show the point factor and evaluation criteria of the large biodegradable and large commercial sanitary pads.

The evaluation criteria of medium biodegradable sanitary pad show good results compared to the medium commercial sanitary pad.

The evaluation criteria of large biodegradable sanitary pad show good results compared to the large commercial sanitary pad. Table 14 shows the results of the evaluation criteria between biodegradable and commercial sanitary pads in all sizes which are taken from Table 9, Table 11, and Table 13.

Table 6. Comparison of materials between nonbiodegradable and biodegradable sanitary pads.

Non-biodegradable sanitary pads	Biodegradable sanitary pads
Nonwoven polyethylene/polypropylene sheet	Nonwoven bamboo
Scent sheet	Nonwoven cotton
Super absorbent polymers	Kenaf fibers, chitosan fibers, and cotton
Polyethylene or polypropylene back sheet	Corn-based PLA back sheet

Table 7. Weight factor for all tests.

Evaluation criteria 1) Is important. 2) Is same important. 3) Is less important	Liquid strike-through test	Wet back strike-through test	Absorbency test	Retention test	Leakage proof test	
Liquid strike-through test		2	3	1	1	
Wet back strike-through test	2		3	1	2	
Absorbency test	1	1		2	3	
Retention test	3	3	2		1	
Leakage proof test	3	2	1	3		
Total	9	8	9	7	7	40
Weight factor	0.225	0.2	0.225	0.175	0.175	

Table 8. Point factor for the small biodegradable and small commercial sanitary pads.

Points factor	Points for liquid strike-through test	Points for wet back strike-through test	Points for absorbency and retention test in grams	Points for absorbency and retention test in percentage	Points for leakage proof test in grams
5	<1.8	<3.5	>32	>490	<0.5
4	1.8 - 1.9	3.5 - 3.6	31 - 32	480 - 490	0.5 - 0.6
3	1.9 - 2.0	3.6 - 3.7	30 - 31	470 - 480	0.6 - 0.7
2	2.0 - 2.1	3.7 - 3.8	29 - 30	460 - 470	0.7 - 0.8
1	>2.1	>3.8	<29	<460	>0.8

Table 9. Evaluation criteria for small biodegradable and small commercial sanitary pads.

		Small size biodegradable pad		Small size commercial pad	
	Weight factor	Point factor	Final	Point factor	Final
Liquid strike through time in seconds	0.225	5	1.125	3	0.675
Wet back strike-through time in seconds	0.2	4	0.8	3	0.6
Absorbency test in grams	0.1125	4	0.45	5	0.5625
Absorbency test in percentage	0.1125	4	0.45	5	0.5625
Retention test in grams	0.0875	3	0.2625	4	0.35
Retention test in percentage	0.0875	3	0.2625	4	0.35
Leakage proof test in grams	0.175	4	0.7	2	0.35
Total	1		4.05		3.45

Table 10. Point factor for the medium biodegradable and medium commercial sanitary pads.

Points factor	Points for liquid strike-through test	Points for wet back strike-through test	Points for absorbency and retention test in grams	Points for absorbency and retention test in percentage	Points for leakage proof test in grams
5	<1.8	<3.4	>33	>400	<0.4
4	1.8 - 1.9	3.4 - 3.5	32 - 33	390 - 400	0.4 - 0.5
3	1.9 - 2.0	3.5 - 3.6	31 - 32	380 - 390	0.5 - 0.6
2	2.0 - 2.1	3.6 - 3.7	30 - 31	370 - 380	0.6 - 0.7
1	>2.1	>3.7	<30	<370	>0.7

The small, medium, and large biodegradable sanitary pads show good results in evaluation criteria when comparing to the small, medium, and large commercial sanitary pads as shown in Table 14. The small size biodegradable pad shows

Table 11. Evaluation criteria for medium biodegradable and medium commercial sanitary pads.

		Medium size biodegradable pad		Medium size commercial pad	
	Weight factor	Point factor	Final	Point factor	Final
Liquid strike through time in seconds	0.225	4	0.9	3	0.675
Wet back strike-through time in seconds	0.2	4	0.8	2	0.4
Absorbency test in grams	0.1125	4	0.45	5	0.5625
Absorbency test in percentage	0.1125	3	0.3375	5	0.5625
Retention test in grams	0.0875	3	0.2625	5	0.4375
Retention test in percentage	0.0875	2	0.175	4	0.35
Leakage proof test in grams	0.175	4	0.7	2	0.35
Total	1		3.625		3.337

Table 12. Point factor for the large biodegradable and large commercial sanitary pads.

Points factor	Points for liquid strike-through test	Points for wet back strike-through test	Points for absorbency and retention test in grams	Points for absorbency and retention test in percentage	Points for leakage proof test in grams
5	<2.2	<3.4	>39	>390	<0.5
4	2.2 - 2.3	3.4 - 3.5	38 - 39	380 - 390	0.5 - 0.6
3	2.3 - 2.4	3.5 - 3.6	37 - 38	370 - 380	0.6 - 0.7
2	2.4 - 2.5	3.6 - 3.7	36 - 37	360 - 370	0.7 - 0.8
1	>2.5	>3.7	<36	<360	>0.8

Table 13. Evaluation criteria for large biodegradable and large commercial sanitary pads.

		Large size biodegradable pad		Large size commercial pad	
	Weight factor	Point factor	Final	Point factor	Final
Liquid strike through time in seconds	0.225	5	1.125	4	0.9
Wet back strike-through time in seconds	0.2	4	0.8	2	0,4
Absorbency test in grams	0.1125	3	0.3375	5	0.5625
Absorbency test in percentage	0.1125	3	0.3375	5	0.5625
Retention test in grams	0.0875	2	0.175	4	0.35
Retention test in percentage	0.0875	2	0.175	4	0.35
Leakage proof test in grams	0.175	4	0.7	2	0.35
Total	1		3.65		3.475

Table 14. Results of evaluation criteria between commercial and biodegradable sanitary pads.

	Small	Medium	Large
Commercial	3.45	3.337	3.475
Biodegradable	4.05	3.625	3.65

better results when compared to all the other sanitary pads. The large size biodegradable pad is the second and medium size biodegradable pad is the third largest in evaluation criteria. This is due to the materials which are used and the tests which are performed on biodegradable sanitary pads. The biodegradable sanitary pads showed better results in the liquid strike through test and wet back strike through test. Because the nonwoven bamboo layer has good absorption properties compared to the polyethylene or polypropylene sheet. The kenaf, chitosan fiber, and cotton used as the absorption core in biodegradable sanitary pads have less absorption properties compared to super absorbent polymers. The absorption of super absorbent polymers in non-biodegradable sanitary pads is 100 times more than its volume. So, there is a slight difference in results when compared to the commercial pads. But kenaf, chitosan, and cotton have better retention properties compared to superabsorbent polymers. So, it shows better results in the retention and leakage proof tests. By using all these test results, the evaluation criteria are calculated. From this, the biodegradable sanitary pads show good results when compared to commercial sanitary pads.

5. Conclusions

The usage of sanitary pads is getting increased day by day. So sanitary pads which are completely made from biodegradable materials are good for both humans and nature.

In this research, biodegradable sanitary pads were produced in three different sizes. The materials used in biodegradable sanitary pads have been selected based on their properties which are suitable for the healthy menstrual cycle. Also, these materials degrade faster and will not stay in landfills for a long time. These pads did not contain any fragrance, bleach, or chemicals that are dangerous for humans and the ecosystem.

Various tests were carried out to investigate the ability of the sanitary pads. The results of the biodegradable sanitary pads were also compared with the commercial sanitary pads. These results show that biodegradable sanitary pads are good in liquid strike through test, wet back strike through test, and leakage proof test and show small differences in absorbency test and retention test when compared to commercial sanitary pads. Finally, the evaluation criteria are also calculated. Based on the results of the evaluation criteria, biodegradable sanitary pads are better when compared to commercial sanitary pads. This research has carded fibers as the absorbent core. In future research, the form of the fibers can be changed from carded to shredded fibers.

Acknowledgements

The Institute for Plastic Engineering West Pfalz (IKW) is acknowledged by the authors for its financial assistance. It is a research and testing facility run by the Department of Applied Logistics and Polymer Sciences at Hochschule Kaiserslautern, Pirmasens, Germany.

Contribution from the Author

Desh Maruthi Jeyakanthan contributed to the original manuscript draft, data collection, and data synthesis. Jens Schuster assisted with the review of the report and research process. The supervision of Yousuf Pasha Shaik aided in the review of the report. The published version of the manuscript has been read and approved by all authors.

Funding

The APC was sponsored by Hochschule Kaiserslautern, whereas no external funding was provided for this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Kaur, R., Kaur, K. and Kaur, R. (2018) Menstrual Hygiene, Management and Waste Disposal: Practices and Challenges Faced by Girls/Women of Developing Countries. *Journal of Environmental and Public Health*, **2018**, Article ID: 1730964. https://doi.org/10.1155/2018/1730964

[2] Banappagoudar, S., Mayank, B., Ravi, Kripa, N., Kishore Kanna, R. and Noble Kurian, K. (2021) Anti-Bacterial Sanitary Napkin Using Biomaterial Application. *Natural Volatiles & Essential Oils*, **8**, 12254-12263.

[3] Sareen, S. (2021) Sustainable Menstrual Alternatives: The Journey so Far. *International Journal of Home Science*, **7**, 216-219.

[4] Lather, D. and Singh, A. (2021) Marketing of Eco-Friendly and Low Cost Sanitary Napkin: A Literature Review. *Indian Journal of Research*, **10**, 66-69. https://doi.org/10.36106/paripex/7608843

[5] Bae, J., Kwon, H. and Kim, J. (2018) Safety Evaluation of Absorbent Hygiene Pads: A Review on Assessment Framework and Test Methods. *Sustainability*, **10**, Article 4146. https://doi.org/10.3390/su10114146

[6] Anbalagan, S. and Mekala, M. (2021) An Overview of the Plant Fibers in the Development of Ecologically Sustainable Sanitary Napkins for the Green Economy. *Journal of University of Shanghai for Science and Technology*, **23**, 161-172. https://doi.org/10.51201/JUSST/21/08362

[7] Tudu, P.N. (2019) *Saathi sanitary* Pads: Eco-Friendly Pads which Will Make You Go Bananas! *International Journal of Nonprofit and Voluntary Sector Marketing*, **25**, 1-5. https://doi.org/10.1002/nvsm.1667

[8] Greenmatters (2019) How This Ugandan Startup Uses Sugarcane to Help Girls Stay in School. https://www.greenmatters.com/news/2017/08/31/2d101c/sugarcane-sanitary-napkins

[9] Foster, J. and Montgomery, P. (2021) A Study of Environmentally Friendly Menstrual Absorbents in the Context of Social Changes for Adolescent Girls in Low- and Middle-Income Countries. *International Journal of Environment Research and Public health*, **18**, Article 9766. https://doi.org/10.3390/ijerph18189766

[10] Kothekar, S., Shukla, S. and Suneetha, V. (2018) A Brief Study on Starch Based Bio-Plastic Produced From Staple Food Items. *Research Journal of Pharmacy and Technology*, **11**, 4878-4883. https://doi.org/10.5958/0974-360X.2018.00888.0

[11] Ann, M. and Joseph, K. (2013) Development of a Highly Absorbent and Antibacterial Biodegradable Sanitary pad from Bamboo. *Proceedings of National Council for Science and Technology 2nd National Science*, *Technology and Innovation Week*, Nairobi, 13-17 May 2013, 1-6.

[12] Sfiligoj, S.M., Hribernik, S., Stana Kleinschek, K. and Kreza, T. (2013) Plant Fibers for Textile and Technical Applications. *Advances in Agrophysical Research*, 369-398. https://doi.org/10.5772/52372

[13] Aranaz, I., Alcántara, A.R., Civera, M.C., Arias, C., Elorza, B., Heras Caballero, A. and Acosta, N. (2021) Chitosan: An Overview of Its Properties and Applications. *Polymers*, **13**, Article 3256. https://doi.org/10.3390/polym13193256

[14] Imran, M.A., Khan, M.Q., Salam, A. and Ahmad, A. (2020) Cotton in Nonwoven Products. In: Wang, H. and Memon, H., Eds., *Cotton Science and Processing Technology*, *Textile Science and Clothing Technology*, Springer, Singapore, 305-332. https://doi.org/10.1007/978-981-15-9169-3_12

[15] Barman, A., Katkar, P.M. and Asagekar, S.D. (2017) Natural and Sustainable Raw Materials for Sanitary Napkin. *Journal of Textile Science & Engineering*, **7**, Article ID: 1000308. https://doi.org/10.4172/2165-8064.1000308

[16] Nhlapo, M., Mashego, M., Low, M. and Harding, K. (2019) Investigating the Development of Low-Cost Sanitary Pads. *Procedia Manufacturing*, **35**, 589-594. https://doi.org/10.1016/j.promfg.2019.05.083

[17] Mohsin, U., Shariful, I.T. and Sadman, S. (2020) Producing Sanitary Pads from Knitwear Waste in Bangladesh. *Material Circular Economy*, **2**, Article No. 6. https://doi.org/10.1007/s42824-020-00008-w

[18] EDANA (2018) EDANA Guidelines for Testing Feminine Hygiene Products—Version 13th December 2018. Edana Voice of Nonwovens, 1-21. https://www.edana.org/docs/default-source/international-standards/femcare-testing-guidelines-final

[19] Kathirvel, K.P. and Ramachandran, T. (2014) Development of Antimicrobial Feminine Hygienic Products Using Bamboo and Aloe Vera Fibers. *Journal of Natural Fibers,* **11**, 242-255. https://doi.org/10.1080/15440478.2013.879548

[20] Tharakeswari, S., Barshana, S., Indhu, R., Vinu Arthi, M. and Yuva Bharathi, B. (2021) Development of Eco-Friendly Herbal Sanitary Napkins Using Cotton and Kenaf Fibers. *International Journal of Mechanical Engineering,* **6**, 224-229.