Development of Low-Cost Menstrual Hygiene Management Clothing by Improving Moisture Absorption of Cotton Fiber

BY

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ABSTRACT

In many parts of the world, especially in least developed and developing countries, shortages of proper hygiene clothing can lead to stigmatization and hinder women's involvement in education, daily activities, and work. By developing hygienic clothing using highly available and low-cost materials, we can help break these barriers and empower women to participate fully in various aspects of life. The main objective of this research was to develop menstrual hygiene management clothing for women by improving cotton fiber's fluid absorption rate and holding capacity. The cotton fibers were collected and cleaned using a laboratory opening (trash analyzer) machine to remove impurities. The cleaned cotton fibers were scoured to remove natural impurities and mercerized to increase the fluid-holding capacity of the fiber. The scoured and mercerized fiber was opened, lapped, and bonded by stitching. The hygiene management prototype clothing were designed, and the patterns were prepared and cut based on the design. The products were constructed of soft and absorbent fabric at the top, repellent fabric at the bottom, and stitched bonded nonwoven sandwiched between them. Then the properties and performance of produced products were evaluated and explained. The scouring process significantly increased the absorption rate of the cotton fiber, and the mercerization process increased the moisture-holding capacity to 23 g/g. The developed products absorb fluid quickly and hold a high amount of fluid in the core part, which is highly repellent on the outer side. It is leak-proof, and the wash durability of the cloth was good to excellent up to 20 washes.

Keywords: Absorption, Cotton, Fabric, Stich bonding, Mercerization, Hygiene Clothing, Scouring

1. INTRODUCTION

The use of conventional clothing is to protect the body from its surroundings, to cover up people's embarrassment, and to provide psychological comfort. Today, textiles are used in different sectors and for various purposes beyond imagination. An important and emerging part of the textile industry is the hygiene management. The number of applications is huge and diverse. Menstrual health, gender equality, babies hygiene, and general human well-being all depend on having access to reasonably priced, clean, and sustainable sanitary textile goods (Sara 2018, Roeckel 2019).

Among these managing menstrual hygiene is essential to women's health and wellbeing (WHO 2016). Currently, conventional sanitary products for women menstrual management clothing often rely on synthetic materials like plastics and chemical additives. This clothing is good at absorbing liquids, but it has problems with the environment because it doesn't biodegrade and can be harmful if chemicals are exposed to it for a long time (Birkmann et al. 2022).

In response to these concerns, there is an emerging interest in exploring natural and sustainable alternatives for the manufacture of sanitary products. Cotton, a widely used natural fiber, presents a promising option due to its biodegradability, breathability, and hypoallergenic properties. However, conventional cotton fibers used in sanitary products may have limitations in terms of absorption capacity and other performance (USAID 2018).

In recent years, there has been a growing global awareness surrounding women's health and hygiene, emphasizing the importance of access to safe and effective sanitary products. Proper menstrual and child care are crucial not only for personal comfort and well-being but also for the overall health and empowerment of women and children (Goup 2017). However, in many regions, the availability and affordability of quality sanitary products remain a significant challenge, leading to adverse health outcomes and hindering educational and economic opportunities for women and girls (Ancane 2016).

To address these issues and contribute to the improvement of women's and children's hygiene, the researchers have done a research project aimed at enhancing the manufacturing process of sanitary products by innovatively improving cotton fiber properties.

The researcher’s objective was to create an efficient process for manufacturing sanitary goods that are affordable, highly absorbent, and environmentally friendly; by incorporating advancements in cotton fiber technology and exploring innovative manufacturing techniques, the researchers intend to overcome the drawbacks (synthetic polymers) associated with conventional sanitary products. It used to create a positive impact on multiple fronts. Firstly, it seeks to elevate the comfort and convenience of menstrual products for women, ensuring they have access to safe, hygienic, and sustainable options during their menstrual cycles, particularly in regions where resources are limited. Secondly, the research strives to contribute to environmental preservation by emphasizing biodegradability and sustainable sourcing of raw materials.

The research aims to work together with NGOs and community organizations to gain insights into the exact desires and challenges encountered by women and children in various socio-economic contexts.

By developing an available materials and sustainable approach to the manufacture of sanitary clothes, the researchers aspire to make a meaningful difference in the lives of girls, incontinence people and children throughout the world. By conducting this research, the researchers seek to promote public health, education, women's empowerment globally.

2. METHODOLOGY

2.1 Materials

Cotton fiber, cotton fabric, a breathable back sheet, an elastic waistband, fastening tabs, leg cuffs, and others are the materials the researchers have used to do this research.

2.2 Chemicals

Sodium hydroxide (NaOH), sequestering agent, wetting agent, and detergent were used to remove natural and processes impurities. Repellent (Careguard-66 (New)), acetic acid and isopropyl alcohol were used to improve back sheet fabric. These, likely targeting properties such as water repellency, durability, and overall fabric integrity.

2.3 Equipment’s

Laboratory scouring machine, sewing machine, padding mangle, WIRA (Wireless Infrared Analyzer, mini carding machine, pH meter, oven drier, balance, thermometer and other necessary tools were used.

2.4 Methods

1. 1. Collection of Cotton Fibers

Ginned, opened, carded and drawn cotton fiber was collected. The absorbance properties of collected cotton fiber was tested before treatment (modification) using drop test.

2. 2. Cleaning of cotton fiber

Cleaning and removing impurities was done from the cotton fibers through mechanical processes

(MES DAN trash analyzer), ensuring the final product is pure and free from contaminants.

3. **3. Measurement of fiber fineness**

The fineness of fibers were measured by WIRA (Wireless Infrared Analyzer) instrumentation, MESDAN Lab fiber fineness meter.

4. **Fiber length**

The fiber length was measured by the instrument known as WIRA (Wireless Infrared Analyzer) fibre length machine of ISO 6989-1981 standard.

5. **Improve absorbance of cotton fiber**

A. Scouring

After collecting and conditioning, the cotton fiber samples (each weighting 20 gm) were made. Scouring liquor was prepared with MLR: 1:20 with the sequestering agent (1 %), wetting agent (1%), detergent (3%), and NaOH (5%) on weight of fiber. The scouring process was done at PH 9, temperature 95 ^{o}C, and time = 1h. After scouring, the samples were soured with 1.5% hydrochloric acid to neutralize the alkali. Then rinse with hot water and wash with cold water.

Drying: The scoured and soured cotton fiber samples were opened into a web to make them easily and uniformly dry and placed inside the oven dryer for 15 minutes at 100 ^{o}C to remove the excess water from the fibers. After the fibers had been taken out of the dryer, they were kept in a standard atmosphere for 24 hours for conditioning.

Test of scouring efficiency: The efficiency of scouring was evaluated by weight loss calculation and wettability/absorbency.

Weight loss: The following equation has been used to calculate the weight loss (Wt. %):

$$\text{Wt}\ (\%) = \frac{W1 - W2}{W1} * 100 \qquad (1)$$

Where: W_1 and W_2 are the weights of the fiber before and after treatment, respectively.

Absorbency test: Water drop test was used to measure scoured fiber absorbency using Tegewa Drop Test with little modification (Pruś, Kulpiński, and Matyjas-Zgondek 2021). A drop of water was placed on the sample lap of fiber and the time it takes for the drop to penetrate the fiber was recorded. The faster the wetting time, the more absorbent is the fiber.

B. **Mercerization**

It is a treatment of cotton fiber using sodium hydroxide. This process improves the fiber's ability to absorb and retain more amount of moisture, making it ideal for sanitary clothing. The mercerizing parameters were be optimized using design expert, response surface methodology (RSM), central composite design (CCD). The amount of NaOH (16-27 %) and mercerization time (11-138 second) were independent variables and absorbance rate and moisture holding capacity (g/g) were dependent variables. Column five is filled in in the result part

Table 1: Mercerization Optimization Design Matrix

Std	Run	Factor 1 A:Amount of NaOH %	Factor 2 B:Mercerization time Second	Response 1 Absorption g/g
12	1	22	75	
1	2	18	30	
2	3	26	30	
6	4	27.6569	75	
4	5	26	120	
13	6	22	75	
8	7	22	138.64	
11	8	22	75	
3	9	18	120	
5	10	16.3431	75	
10	11	22	75	
9	12	22	75	
7	13	22	11.3604	

C. Characterization of the mercerized cotton fibers

Liquid holding capacity**:** This test aimed to determine the liquid holding capacity of modified and unmodified fibers. Each 5 gram mercerized samples were immersed in separate beakers filled with distilled water for 10 minutes time intervals within 1 hour at room temperature.

$$\text{Absorption } (g/g) = \frac{\text{Wet weight} - \text{Dry weight}}{\text{weight of dry fiber}} \quad (2)$$

D. Web Formation

The modified cotton fibers were opened and fluffed using machines to create a loose mass and uniformly distributed fibers. The opened cotton fibers are carded to align the fibers in a parallel arrangement and remove any remaining impurities using mini carding machine. It creates a thin and continuous web of cotton fibers, known as a carded web. Several carded webs were layered on top of each other, with each layer oriented perpendicular to the previous one. This process helps improve the strength and uniformity of the final absorbent web.

E. Bonding of Web

By using the stitch bonding technic, the webs were bonded. It involves stitching the prepared web using a sewing machine. The stitch patterns designed were straight stitches in widthwise and lengthwise directions to enhance performance.

F. Measurement of wicking height

Wicking is an absolutely fundamental quality of sanitary pads as they allow the blood and baby fluid to be distributed to whole direction while allowing the accumulated menstrual blood and baby fluid to be retained distributed in the pad, thereby reducing leakage. This was tested using the capillary action test method accompanied by the AATCC TM 197-2011 standard to assess the ability of vertically aligned pad specimens to transport liquid through them.

G. Finishing of back sheet fabric

The fabrics were finished with 50g/l Careguard-66 (New) +5g/l Iso propyl alcohol (IPA) +2g/l acetic acid. Fabric substrate was padded with in the solution with the pick-up of 100%. After padding, the fabric was dried at 120°C followed by curing at 170°C for 2 min.

H. Product Design and Prototyping

Design and develop sanitary products for women, considering their specific needs and requirements. Create prototypes to test the effectiveness, and durability of the new products.

Size of menstrual pad: The size of menstrual pad was 11’ length (L) X 4’ width (W) X 0.3’ thickness (T). Based on this preparing a pattern similar to the one shown in the Fig. 3. This pattern includes extended wings for fastening. Cut two pieces of fabric using the prepared pattern, add a standard seam allowance of 0.5 inches each edges. Then, cut an inner layer, absorbent pad, and repellent (outer) layer by tracing the pattern paper. Place the two fabric pieces and absorbent pad together and sew around the edges. Then add the snaps as fastening mechanisms as marked in the pattern. Finally, overlock stich around the entire pad to secure the layers and provide durability. This method ensures a well-constructed menstrual pad.

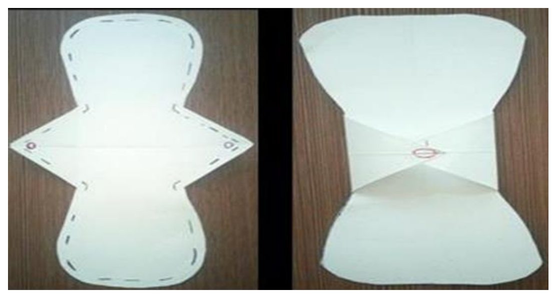

Figure 3: Patterns of menstrual pad

I. Characterization of produced prototype

Absorbency and Leak-Proof Testing: Conduct rigorous testing to measure the absorbency and leak-proof capabilities of the produced sanitary products. Saline (0.9%) and synthetic menstrual fluid were used to test the absorbance. The menstrual fluid simulants was development to mimic real menstrual fluid characteristics like viscosity, stringiness, and particulate matter concentration. It was synthesized following (Owen and Katz 1999) method with little modification. The recipe was prepared with 9% distilled water, 1.5 grams/l carboxyl methyl cellulose (adjust to achieve desired thickness), red food dye (A few drops (adjust to achieve the correct color).

Softness: The interior cotton fabric need to be soft and gentle on the skin to avoid irritation and discomfort. Characterization can involve testing the fabrics softness through tactile analysis to ensure it maintains a soft and comfortable texture.

Wash durability: Sanitary clothing should withstand frequent washing and drying without significant degradation. The wash durability testing for sanitary clothing is crucial to ensuring clothes longevity and effectiveness in protecting users. The pads were washed 15% standard detergent at 60 ^{0}C for 40 minutes.

Breathability: Cotton fibers with good breathability allow air circulation, reducing the risk of bacterial growth and maintaining freshness. Testing the fibers' air permeability

Biodegradability: Hygiene apparel that is kind to the environment and users is growing in popularity. To evaluate the environmental impact of developed hygiene products after disposal, it is essential to characterize their biodegradability. The soil degradation test was conducted through the method described by (Mondal and Saha 2019) with slight modification. Treated and untreated samples were kept under soil five inches deep in the pot filled with approximately 750 g soil and 250 g cow dung each. Sparkling 100 ml water was added to the pots at regular time intervals. The degradation of the samples was determined by weight loss after 30 days. The samples were carefully removed from the soil and washed with water gently, then dried in the sunlight. The weight loss was determined in the following question;

$$\text{Weight loss } (\%) = \frac{W1-W2}{W1} * 100 \quad \text{EQ 2}$$

Where W_1 is the initial weight and W_2 is the after-burial weight.

3. RESULT AND DISCUSSION

3.1 Fiber fineness

The micronaire value of fiber was 4.10. A micronaire value of 4.10 would suggest that the tested samples were relatively fine and mature. This means that the fibers have a smaller diameter (fine) and are well-developed (mature). The fiber fineness, can significantly affect the absorption properties of materials. As fiber fineness increases, the surface area per unit mass increases (a larger surface area-to-volume ratio). Finer fibers are able to absorb more liquids quickly and dry faster due to their larger surface area (Kaewprasit et al. 1999).

3.2 Fiber length

The mean short fiber content and mean fiber length for the 2.5% were 33.4% and 24.6 mm, respectively. This indicates that a large percentage of the fibers are relatively short. As the fiber length decreases, the surface area of mass per unit volume increases, and absorption increases. The length of 50% span length (SL) was 9.7%, which indicates that half of the fibers have a length of approximately 9.7mm. This implies that a significant percentage of the fibers have a shorter length than the mean fiber length of 24.6mm. The mean uniformity ratio was 39.4%, which indicates the degree of uniformity in fiber length distribution. The coefficient of variation was 39.6%. A higher coefficient of variation suggests greater variability in fiber length, which can affect the consistency of absorption properties across different parts of the material if they aren't uniformly distributed in the web. A higher coefficient of variation suggested that the fiber contains short and long fiber; the shorter fiber increases surface area, it increases absorption, and the longer fiber increases cohesiveness and web strength.

3.3 Effect of scouring

Natural fibers such as cotton contain oily substances, fatty substances, waxes, mineral matters, leafy matter and motes as scums that interfere with absorbance properties of the fiber. One well-known technique used to clean fiber surfaces and eliminate undesirable elements is chemical treatment (Williams et al. 2011). The special type of treatment that used to remove these impurities is known as scouring (Morshed 2014). In this research the cotton fiber was scoured by using alkaline scouring method (Ibanescu, Schimper, and Bechtold 2006).

Scouring was accomplished by saturating the cotton fiber with a 5% caustic soda (sodium hydroxide) solution. This alkali solution was allowed to remain on the fiber at elevated temperatures of (95 ^{O}C) to speed up chemical reactions. During this time, the natural oils and waxes are saponified (converted into soaps) (Ogoshi and Miyawaki 1985), the plant matter is softened, and pectin's and other non-cellulosic materials are suspended so that they can be washed away. After one hour, the alkali, saponified waxes, and suspended materials were rinsed away with water

3.4 Effect of scouring on absorption rate

Weight loss: After scouring processes, the weight of cotton fiber decreased. The average weight of the sample after scouring was 19 grams. The percentage weight reduction calculated by the formulas presented in the methodology part was 5%. It is a reasonable weight reduction because the cellulose content of cotton is 88%–96%; the other 12%–4% are impurities that can be removed by scouring and bleaching.

Absorbency test: In fig. 2, to unscored fiber the drop of water remained on the fiber surface in the form of a ball and rolled and fell down as the slope increased.

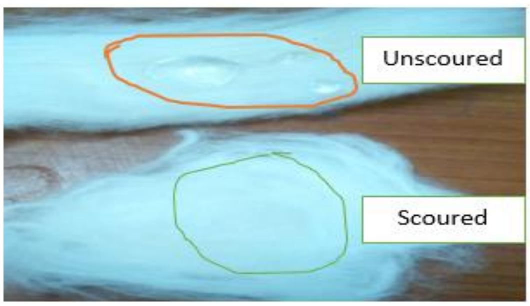

Figure 2: Absorbency of fiber before scouring

The absorption rate is increased by scouring the removal of natural impurities to change from hydrophobic to hydrophilic properties. And the moisture-holding capacity is increased by mercerization. The absorbency was tested by drop test. The wettability of the cotton fiber sample before scouring was very poor. The dropped water doesn't absorb within 3-5 seconds, even up to 5 minutes. The drop of water makes a ball and easily drops rather than being absorbed into the fiber. The fibers scoured using the scouring method described in the methodology absorb dropped water within a microsecond.

3.5 Effect of Mercerization on absorption

Mercerization is the treatment of cotton with concentrated solutions of caustic soda (18–26%) at room temperature. It is widely used on cotton to increase luster and softness, give greater strength, softness, comfort, and improve affinity for dyes and wettability. Under optimum condition each cotton fiber may be contract early 9% in length and swells nearly 150% (Hebeish et al. 1981). Due to swelling of cellulose in caustic soda solution of mercerizing strength, many hydrogen bonds are broken, the plane of molecular chains have been moved apart, molecular structure tend to become decrystallised, the chains or spaces within the cellulose structure become more, uniform and the chains of glucose residues have been given on slight twist (Williams et al. 2011). Because of distortion of polymer network and changes in crystalline structure irreversibly (Cao et al. 2022).

Table 2: Effect of mercerization on absorption capacity

Std	Run	Factor 1 A:Amount of NaOH %	Factor 2 B:Mercerization time Second	Response 1 Absorption g/g
12	1	22	75	25
1	2	18	30	16
2	3	26	30	19
6	4	27.6569	75	26
4	5	26	120	26
13	6	22	75	25.4
8	7	22	138.64	24
11	8	22	75	25.7
3	9	18	120	25
5	10	16.3431	75	22
10	11	22	75	25
9	12	22	75	25.3
7	13	22	11.3604	14.5

The above Table 2 shows the effect of sodium hydroxide concentration and mercerization time on the liquid absorption of modified cotton fiber. The minimum absorption was 14.5 g/g at run number thirteen and maximum absorption was 26 g/g at run number 4 and 5 and the mean of the 13 observations were 23.

1. Analysis of variance

The significance of the model was determined by ANOVA analysis Table 3, suggesting the quadratic model fit with experimental data. The model, with a P-value less than 0.0001, indicated the model's relevance. The high correlation coefficiency (R^2) at 0.9918 of the predicted models was obtained, encouraging the significance of the model.

Table 3: Analysis of variance

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	186.04	5	37.21	168.61	< 0.0001	significant
A-Amount of NaOH	11.66	1	11.66	52.82	0.0002	
B-Mercerization time	108.30	1	108.30	490.76	< 0.0001	
AB	1.0000	1	1.0000	4.53	0.0708	
A^2	3.13	1	3.13	14.20	0.0070	
B^2	64.55	1	64.55	292.52	< 0.0001	
Residual	1.54	7	0.2207			
Lack of Fit	1.20	3	0.3989	4.59	0.0877	not significant
Pure Error	0.3480	4	0.0870			
Cor Total	187.59	12				

Furthermore, lack of fit test showed not-significant p-value at 0.0877, which was in good agreement to model p-value and R^2. In case of term models, material to sodium hydroxide (A), and mercerization time (B) were statistically significant (P-value < 0.0001 and 0.002 respectively). The response variable (absorption) and the independent variables (treatment parameters) were related by the following second order polynomial equation in terms of coded factors.

$$\text{Absorption} = +25.28+1.21A+3.68B-0.5000AB-0.6712A^2-3.05B^2 \quad \text{Eq. 1}$$

Equations 1 gives the fitted regression model that described the relationship between absorption and sodium hydroxide concentration (A) and mercerization time (B). The terms that make up the equation each show how a particular constraint or combination of constraints affected the absorption capacity. The terms with coefficients (25.28+1.21A+3.68B-0.5000AB) represent the linear contributions of the individual variables A, and B to the absorption. The terms with coefficients involving two variables (0.5000AB) represent the interaction effects between pairs of variables. The terms with coefficients involving squared variables ($0.6712A^2-3.05B^2$) represent the quadratic effects of the individual variables.

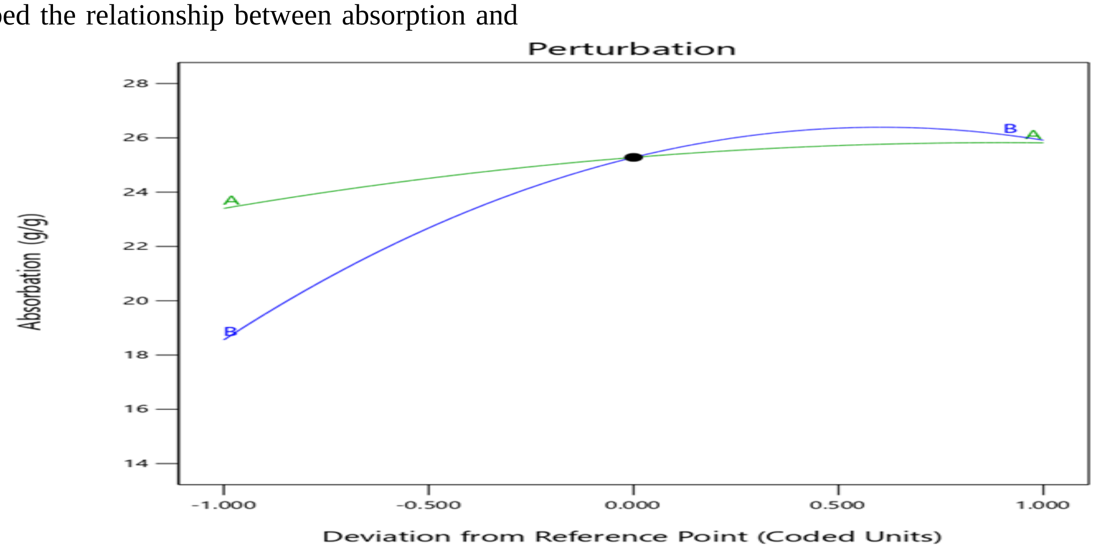

Figure 3: Perturbation graph of treatment parameters

The perturbation graph Fig. 3 of the model exhibits the comparative effect of all the operational parameters at a particular point in the design space. From the graph, it can be observed that factor B (mercerization time) has the steepest curvature. This shows the responses were more affected by mercerization time than sodium hydroxide concentration.

As shown in Fig. 4, in the 3D graph, when the amount of sodium hydroxide and mercerization time increased, the absorption capacity also increased. However, the absorption decreased as the independent factor increased further.

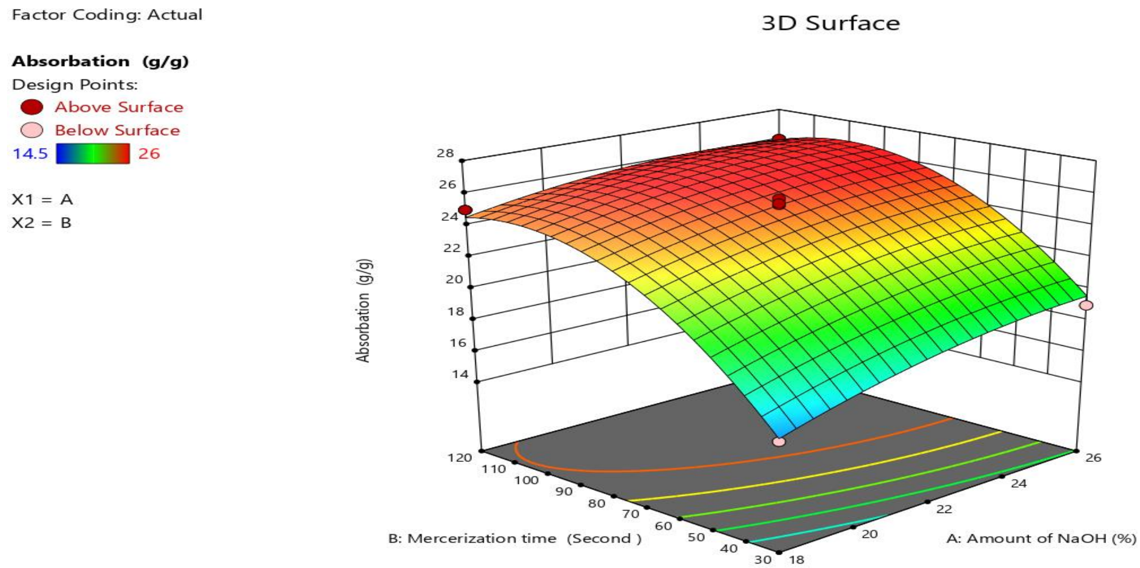

Figure 4: Three D graph

2. Optimized parameter

A higher response in the experimental runs is the goal of the optimization. This can be effectively accomplished by modifying constraints with the aid of a suitable numerical optimization technique.

The optimization parameter (concentration of sodium hydroxide and mercerization time) was set with the goal in the range, and the goal of absorption was high.

Table 4: Optimized parameter

Number	Amount of NaOH	Mercerization time	Absorption	Desirability	
1	22.204	109.667	26.347	1.000	Selected

According to Table 4, the best result, 26. 347 g/g of the absorption, may be produced with a desirability of 1:00 at an amount of NaOH 22.204 %, a mercerization time 109.67 seconds. Generally, the effects of parameter variables (amount of sodium hydroxide and mercerization time) and their interactions on absorption were studied. As shown in Fig. 3 and 4, with increase amount of sodium hydroxide and mercerization time the amount of liquid absorbed increased and reached the maximum value and then decreased. During mercerization with sodium hydroxide solution cotton fibres swell so that the secondary wall thickness is increased. The swelling process increases the accessibility of cotton fibres to liquid, resulting in substantial increase in the liquid uptake.

The fiber surface appearance and the internal structure of the fibre are modified due to alkali cellulose is created by chemical events, and cellulose units can be rearranged by physical reactions. Due to deconvolution, the fiber hair soon starts to untwist from its twisted ribbon-like structure and tends to become a cylindrical rod-like surface. The fiber's diameter gets more rounded as its cross-section decreases. After mercerizing, the almost cylindrical cotton fiber's surface becomes glossier and reflects light more uniformly to all sides than the cotton fiber's kidney-shaped surface.

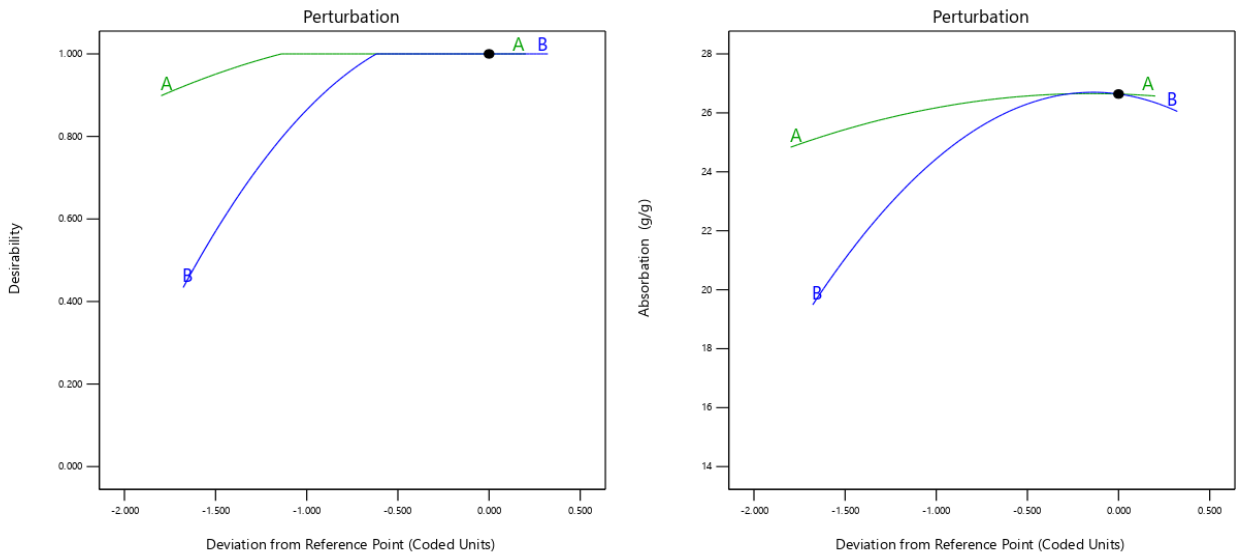

Figure 5: Perturbation plots of desirability and absorption

Perturbation plots of the desirability function at each optimum can be used to explore the function in the factor space. The desirable ranges are from zero to one (least to most desirable, respectively) (Abd Aziz, As, and Noraziman 2018). The numerical optimization finds a point that maximizes the desirability function. The characteristics of a goal may be altered by adjusting the weight or importance. For several responses and factors, all goals get combined into one desirability function.

3.6 Formed webs

The web was made using a mini-carding machine. It was prepared by carding and aligning the modified cotton fibers to create uniform and consistent web materials. This ensures that the final absorbent pad will have a smooth and even texture, thickness, and absorption capacity.

Figure 6: Absorbent webs

3.7 Stich Bonded webs

The prepared web was bonded by the stitching method using sewing machine. This join the fibers of the prepared cotton web together. Fig. 7 shows the layered and stitched absorbent pad of modified cotton fiber. The thickness of the absorbent pad was 0.5cm. It depends on the number of fibers per unit area of the web. As the number of fibers increases, the thickness increases, and the absorption (moisture holding capacity) increases.

Figure 7: Stitch bonded absorbent pad

3.8 Wicking property of the web

The wicking height was recorded 3 inches for the pad produced from the modified cotton fiber as its absorbent core.

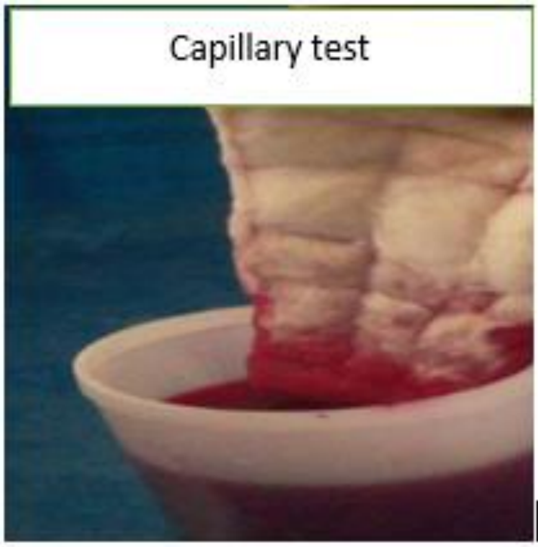

Figure 8: wicking height

The cotton fibers were modified to maximize the absorbency rate by removing the hydrophobic impurities from the fiber.

3.9 Menstrual pad

The menstrual cloth has a bottom, top layer and inner core layer. This cloth use by women during menstruation comprises a fluid absorbent pad having an inner layer of fluid absorbing cotton fabric, an outer layer of a repellent finished fabric which is impermeable to fluid, and one stich bonded absorbent modified cotton layers trapped between inner and outer layers.

Figure 9: Menstrual clothing

3.10 Characterization of prepared product

Absorbance test: These tests help determine the absorption capacity of the prepared pad by dropping a solution containing water, sodium chloride, carboxyl methyl cellulose and colorant to simulate menstrual fluid fig. 10. This test was done to investigate the constructed product's absorbency rate. The rate of absorption and liquid holding capacity was high.

Figure 10: Menstrual fluid absorbance test

Leak proof test: The outer, water repellent fabric treated by the repellent chemical acted as a stopper to the seepage of fluids to the exterior. Fig 11 showed that the repellent ability of outer fabric.

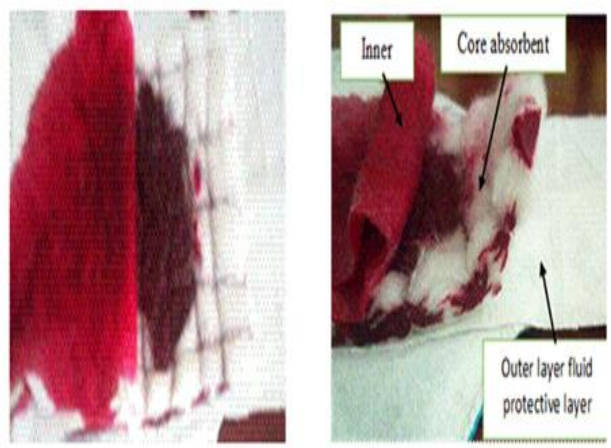

Figure 11: leake proof test

Careguard-66 (New) is an important chemical designed to provide water and stain resistance, ensuring the fabric remains effective under exposure to various liquids. The combined application of these substances likely results in a back sheet fabric with superior protective qualities, making it suitable for demanding applications where fabric resilience and performance are critical.

Softness of the product: Cotton fibers need to be soft and gentle on the skin to avoid irritation and discomfort. Characterization was tested through tactile analysis to ensure it maintains a soft and comfortable texture. The softness of the interior fabric was good with the lower frictional characteristics. The softness properties of cotton fabric for the interior parts of a menstrual management clothes are crucial for ensuring comfort and preventing skin irritation. Research by (Bender, Faergemann, and Sköld 2017) highlights the use of natural fiber fabric, including cotton fiber, in hygiene clothes for its ultra-softness and skin-friendly characteristics.

Durability: Durability testing for hygiene textiles like menstrual pads is crucial to ensure their performance and longevity. Sanitary clothing should withstand frequent washing, dry cleaning, and different loads without significant functional and performance property loss.

Wash durability test: The prototype for menstrual hygiene management products demonstrated excellent wash durability and maintained its performance up to 20 wash cycles. Throughout the testing, the absorbance capacity remained consistent, effectively managing liquid without significant loss of functionality. The materials used in the prototype showed resilience to the mechanical stresses of washing and drying, preserving their structural integrity and ensuring continued comfort and reliability for the user. This indicates that the design and materials of the developed products are robust enough to withstand repeated laundering, which is essential for reusable hygiene products.

In addition, the leak-proof performance of the produced product also remained intact after 20 washes. There were no signs of liquid escaping through the sides or bottom of the pads, which is crucial for user confidence and comfort. The developed product's ability to maintain its absorbance and leak-proof characteristics after multiple washes highlights its potential as a sustainable and cost-effective solution for both baby diaper and menstrual hygiene management. This performance ensures that the product can be reused multiple times, reducing waste and offering an environmentally friendly alternative to disposable options. The successful testing strengthens the viability of the developed product in real-world applications, paving the way for further development and potential market introduction.

Breathability: Testing the outer layer fabric air permeability is a possible aspects of the characterization. Cotton fibers with good breathability allow air circulation, reducing the risk of bacterial growth and maintaining freshness. The air permeability of the outer layer fabric was 12 $m^3/m^2/min$. The menstrual hygiene management pads were designed to provide optimal air permeability, ensuring comfort and skin health for users.

Biodegradability: Hygiene apparel that is kind to the environment and users is growing in popularity. To evaluate the environmental impact of generated hygiene products after disposal, it is essential to characterize their biodegradability. The test result demonstrated that the hygiene products were biodegradable, as evidenced by an average weight loss of 25% within the thirty days. This significant reduction in mass indicates that the product is breaking down and decomposing when buried in soil, mimicking natural environmental conditions.

The 25% weight loss reflects the product's ability to decompose over time, reducing its environmental footprint and contributing to a more sustainable lifecycle for hygiene products. This result supports the conclusion that the product can effectively biodegrade in natural settings, aligning with environmental and sustainability goals.

4. CONCLUSION

Raw cotton is treated by alkali treatment to develop liquid absorbency property, thus increasing its range of applications. Raw cotton contains impurities that are difficult to remove completely, and this restricts their applications, e.g., to the manufacture of high-quality nonwovens which demand high levels of quality and purity. The research provides a scientific for the development of absorbent sanitary products, ensuring their performance meets the required standards. The product design aims to provide a reusable and sustainable alternative to disposable sanitary products, promoting environmental friendliness and cost-effectiveness. Through testing, the washable sanitary clothes demonstrated effective fluid absorption and retention capabilities, meeting the requirements for menstrual hygiene management clothing. The results showed that the sanitary clothes could offer a practical and eco-friendly solution for baby diaper and women's menstrual needs.

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