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# Study on Moisture Behavior Properties of Milkweed and Milkweed/Cotton Blended Sanitary Napkins

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**ABSTRACT**
Menstrual hygiene is one of the most important health-related aspects which must be given higher priority to overcome the menstrual cycle period of women. Currently, there are many types of sanitary napkins are available in the market to absorb the menstrual fluid but most of them are constructed by using petroleum bi-product called SAP and it is used to absorb and hold more menstrual fluid. The present work focuses on to produce and study the moisture behavior properties of a sanitary napkin by using 100% natural fibers as core absorbent. Milkweed fibers are the natural organic fibers which have been taken as core absorbent material in different blend ratios as 100% milkweed, 80/20 milkweed/cotton, 60/40 milkweed/cotton, 50/50 milkweed/cotton, 40/60 milkweed/cotton, and 20/80 milkweed/cotton to develop a sanitary napkin by using polyethylene and polypropylene as bottom and top layer respectively. The produced samples were tested and evaluated by Liquid spreading rate test, Liquid Retention test, Liquid holding capacity under pressure test, and quantity of liquid absorbed in order to evaluate the moisture behavior properties of developed sanitary napkin. The outcome of the results demonstrates that sanitary napkins shows enhanced moisture properties when increasing the milkweed fiber blend percentage.

摘要
月经卫生是妇女克服月经周期的重要卫生问题之一, 必须给予高度重视. 目前, 市面上有很多种类的卫生巾可以吸收经期的液体, 但大多数都是用叫做SAP的石油双产品制成的, 用来吸收和保存更多的经期液体. 以100%天然纤维为芯材, 制备并研究了卫生巾的吸湿性能. 马利筋纤维是以100%马利筋、80/20马利筋/棉、60/40马利筋/棉、50/50马利筋/棉、40/60马利筋/棉、40/60马利筋/棉等不同混纺比的天然有机纤维, 以20/80马利筋/棉为原料, 分别以聚乙烯和聚丙烯为底层和顶层, 研制出一种卫生巾. 为了评价研制的卫生巾的吸湿性能, 对制备的样品进行了液体铺展率试验、留液试验、承压持液量和吸液量的测试和评价. 结果表明, 提高了牛奶草纤维混纺产品的含水量.

**KEYWORDS**
Blend; cotton; milkweed; moisture behavior; sanitary Napkin; natural fiber

关键词
混合; 棉花; 马利筋; 水分特性; 卫生巾; 天然纤维

## Introduction

Management of hygiene during women's menstrual period is an essential factor to overcome many menstrual-related ailments and problems. Majority of commercially available sanitary napkins which are used during the menstrual period by women are manufactured by using the materials that may seem harmless but are made from the bi-product of petrochemicals, artificial fragrances, deodorants, synthetic materials, etc. Continuous usage of these type of sanitary napkins leads to

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many serious health problems like irritations, discomfort, mental depression, dampness, and cervical cancer (Barman, Katkar, and Asagekar 2017). Currently, the world is facing a problem of the carbon footprint from many products including used feminine hygiene products during its disposal. As there is a huge amount of nonbiodegradable material dumped in the landfill, which releases harmful gasses into the atmosphere. Female between the age group 15–49 will generate at least half a kilo of used sanitary napkin waste per month. To deal with this problem, we need to identify the more sustainable product by choosing raw material having low carbon footprints (Barman, Katkar, and Asagekar 2018). One of the alternative solution to overcome these problems is to use natural fibers and the fibers which are biodegradable as the core component to manufacture the sanitary napkin since the core component playing a major role in absorbing and retaining the menstrual fluid.Primary requirements of sanitary napkins are that it must absorb the menstrual fluid, it should keep the top layer dry by transferring fluid into bottom core materials and it must hold the absorbed liquid in its core when applying any external pressure. We can able to obtain above moisture management propertiesby using natural fiber as core materials based on its maximum moisture behavior performance properties.Alternative methods and natural fibers may be used to enhance these moisture properties of sanitary napkins.

Milkweed fiber is one of the naturally available fibers which is having many properties that directly linked with moisture management (Shakyawar, Dagur and Gupta, 1999). Previous studies show that milkweed fibers give better moisture management properties in the form of yarn when compared to cotton fibers because of its hollow structure and low density in its structure (Drean et al. 1993; Karthik, Senthilkumar, and Murugan 2018a, 2018b; Bakhtiari et al. 2015; Hassanzadeh and Hasani 2017; Karthik and Murugan 2013; Karthik, Senthilkumar, and Murugan 2018; Jamalirad, Aminian and Hedjazi 2019). In this study, an attempt has been made to develop the sanitary napkin by using milkweed natural fiber as the core material in various blend ratios with cotton.

## Materials and methods

### Materials

The sanitary napkin is constructed by using a three-layer design concept with the top layer, core absorbent layer and bottom layer. Polypropylene spun-bonded nonwoven fabric with 18 gsm is used as a top layer to transfer the fluid from the top layer to the core layer. Polypropylene sheet contains thermoplastic fibers to prevent the capillary collapse of this layer, and the small amount of hydrophilic absorbent fiber allow fluid to absorb (Barman, Katkar, and Asagekar 2018). 100% Milkweed and Milkweed/Cotton blended fibers are used in various ratios as core absorbent layer to absorb and to retain the fluids in its structure under various pressures. The milkweedfibres were treated in hot water with 60°C temperature for 20 minutes and then dried in room temperature. Cotton fiber is having the cellulose constituent of 88–96% and 0.41–1% of wax in is structure and when comparing it with milkweed fiber, it is having the cellulose constituent of 60% and 0.33–0.4% of extractable wax in is structure. Breathable polyethylene sheet with 23 gsm is used barrier sheet to seals the fluid from leakage and staining. The water-soluble adhesive is used to bond the polyethylene barrier sheet and polypropylene top layer.

### Methods

The length of the milkweed fiber was shortened using specially developed shredding device with modified blades as stated in Figure 1. Milkweed and Cotton fibers were mixed uniformly by using the fiber blending machine. The samples were developed by sandwiching the milkweed and milkweed/cotton fiber between the top polypropylene layer and bottom polyethylene barrier sheet by using water-soluble adhesive in the manual compression sanitary napkin machine. Properties of materials used for making the sanitary napkins are given in Table 1 and Table 3.

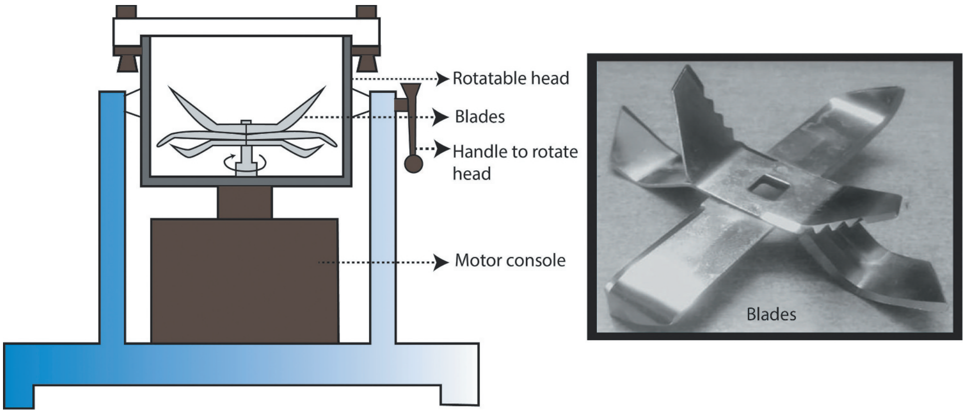


**Figure 1.** Fiber shredding machine.

Sanitary napkin samples were developed in 4 gms and 7 gms with its core absorbent weight in seven different categories as per the particulars given in Table 2.

Liquid spreading rate, Liquid retention capacity, Liquid holding capacity under pressure, and Quantity of liquid absorbed tests were conducted for ten samples in each experiment for different categories of samples as mentioned in Table 2 and the average values were taken to assess and analyze its moisture management properties. Liquid to test the samples is prepared by mixing 200 mg of reactive blue dye with 100 ml of distilled water. Following tests were carried out on developed samples:

### *A. Liquid spreading rate*

Liquid spreading rate of the sanitary napkin evaluated by using an embedded image analysis method (EIAS) using a digital signal processor (Figure 2) as per the principle derived by Raja et al. (2014). In this method, the sanitary napkin samples are marked for the radius of 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, and 60 mm from its center. The total areas of 10 mm, 20 mm, 30 mm, 40 mm, 50 mm, and 60 mm are calculated using $\pi r^2$ where r = radius. Then the sanitary napkin sample is placed on the transparent glass and the liquid flow rate is adjusted to 15 drops/minute, 30 drops/minute, and 60 drops/minute and the time taken to reach the above-mentioned radius are recorded through cameras 1 and 2. Then the recorded videos were analyzed to calculate the spreading rate of sanitary napkin using the following formula

$$\text{Liquid spreading rate (unit is mm}^2\text{/min)} = \frac{\text{Area covered by liquid}}{\text{Reach time of liquid}}$$

### *B. Liquid retention capacity test*

As per the ASTM D2402-02 standard test method, the liquid retention of sanitary napkin sample was tested. It involves immersing the sanitary napkin in liquid, running it through a centrifuge for 5 minutes and comparing the weight before and after as per the formula given below

$$\text{Liquid retention test} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \times 100 \text{ (unit is \%)}$$

### *C. Liquid holding capacity under pressure*

Liquid holding capacity under pressure test to evaluate the ability of sanitary napkin to resist the transport back of liquid onto the skin which has already absorbed by the sanitary napkin. In this test method, the blotter paper is weighed and placed on the flat glass surface. Sanitary napkin is placed on the blotter paper and then the load of 3.4 kg weight is applied to the sanitary napkin for 3 minutes

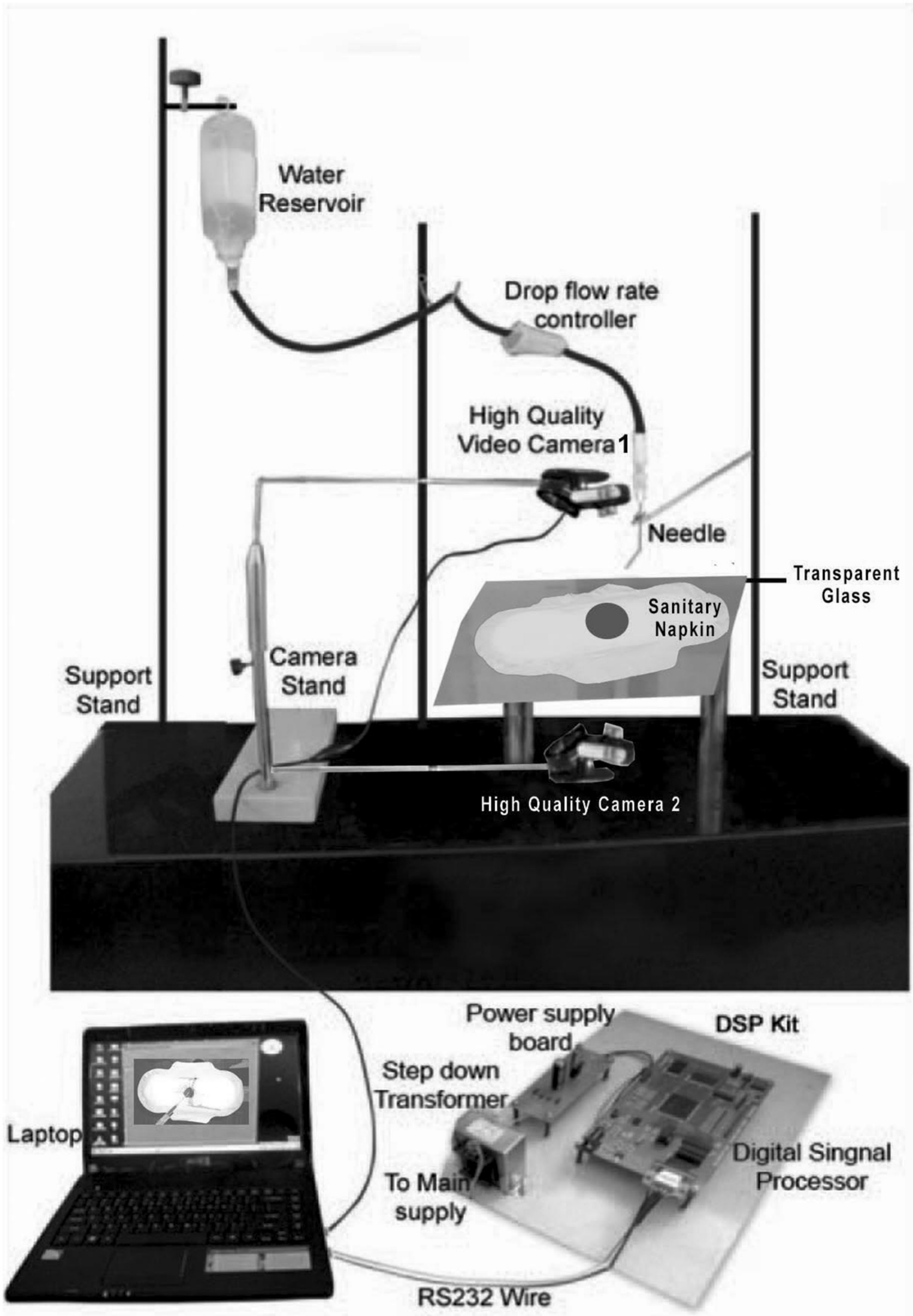


Figure 2. Experimental setup of embedded image processing method using digital image processor.

(Barman, Katkar, and Asagekar 2017). Then the blotter paperweight is noted. Based on the difference in the before and after the weight of blotter paper, the result is expressed in percentage.

### *D. Total quantity of liquid absorbed*

Quantity of liquid absorbed by the sanitary napkin is calculated by applying the known volume of liquid from the reservoir on the sanitary napkin until the sanitary napkin absorption reaches to its saturation. Then the total quantity of liquid absorbed by sanitary napkin is calculated based on the difference between the quantity of liquid absorbed and the volume of liquid remains in the reservoir. The result is expressed in ml.

Total quanitity of liquid absorbed = Total quantity of liquid taken in the reservoir-Total quantity of liquid remains in the reservoir

## Results and discussion

### *Liquid spreading rate*

Sanitary napkin sample A1 and B1 have been taking more time to spread the liquid with respect the areas of 10 sq.mm, 20 sq.mm, 30 sq.mm, 40 sq.mm, 50 sq.mm, and 60 sq.mm when compared to other sanitary napkin samples A2, A3, A4, A5, A6, A7, B2, B3, B4, B5, B6, B7 in both the liquid flow rate of 30 drops/min and 60 drops/min (Figure 3). It is found that the initial absorption of sample A1 and B1 is significantly low eventhough the wax content of milkweed is lower than cotton, because the milkweed fibers are having low cellulose constituent of 60% in its structure when compared to cotton fiber cellulose constituent of 88–96% and its playing a major role in initial spreading rate of sanitary napkins.It was also analyzed and found that because of high liquid flow rate, the spreading rate is high at 60 drops/minute in all the samples.

### *Liquid retention capacity*

As stated in Figure 4, liquid retention capacity of the 100% milkweed sanitary napkin sample is higher when compared to 100% cotton sanitary napkin and vice versa for all the different milkweed/cotton blended sanitary napkins. Results were analyzed and based on the output, it was assumed that the hollow structure of the milkweed fiber is the main reason and one of the influencing factor for the high liquid retention capacity of the milkweed sanitary napkin and its blends when compared to cotton sanitary napkins and its blends.

### *Liquid holding capacity under pressure*

As stated in Figure 5, liquid holding capacity under the pressure of 100% milkweed sanitary napkin sample is higher when compared to 100% cotton sanitary napkin. Based on this results, an inherent property of milkweed hollow fiber structurewas resisting the liquid flow from inside of the hollow fiber structure to the external surface. Also, the test results shows that liquid holding capacity under the pressure of milkweed and milkweed blended fibers shows better liquid holding capacity when compared to cotton sanitary napkins and its blends (Bahari et al. 2016; Karthik, Senthilkumar, and Murugan 2018).

### *Total quantity of liquid absorbed*

As stated in Figure 6, the quantity of liquid absorbed by the 100% milkweed sanitary napkin sample is higher when compared to 100% cotton sanitary napkin and vice versa for all the different milkweed/cotton blended sanitary napkins. It was found that the quantity of liquid absorbed by the milkweed and milkweed blended sanitary napkin was at the higher side when compared to sanitary napkins which are having higher cotton blend ratio. It was analyzed and found that the cellulose and hollow structure of the milkweed fiber was contributing and allow

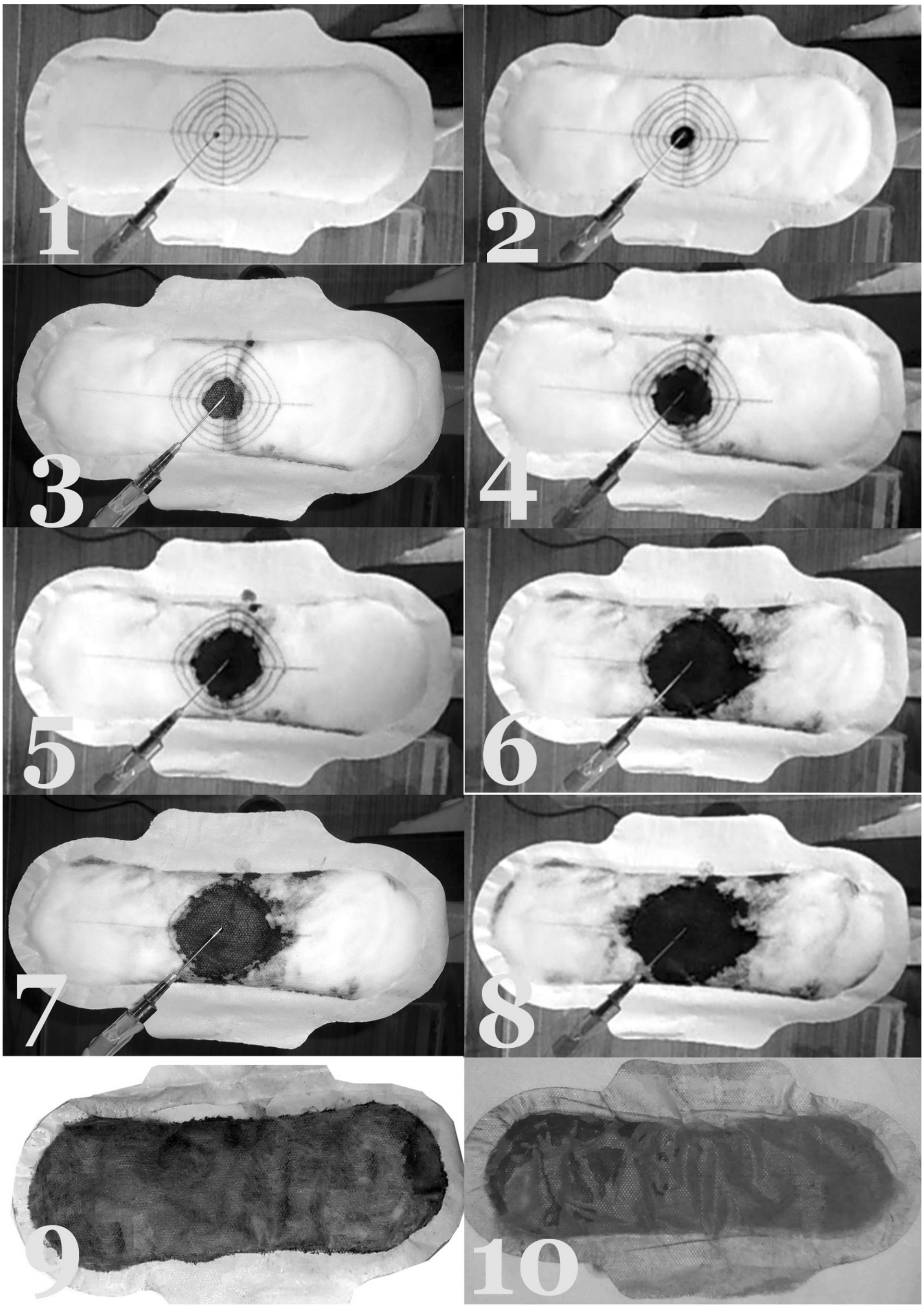


Figure 3. Spreading rate of sanitary napkin (recorded by HD camera).

high liquid absorption from the external surface. It was found that the quantity of liquid absorbed by the 100% milkweed sanitary napkin sample at a liquid flow rate of 60 drops/min is higher when compared to 100% milkweed sanitary napkin at a liquid flow rate of 30 drops/

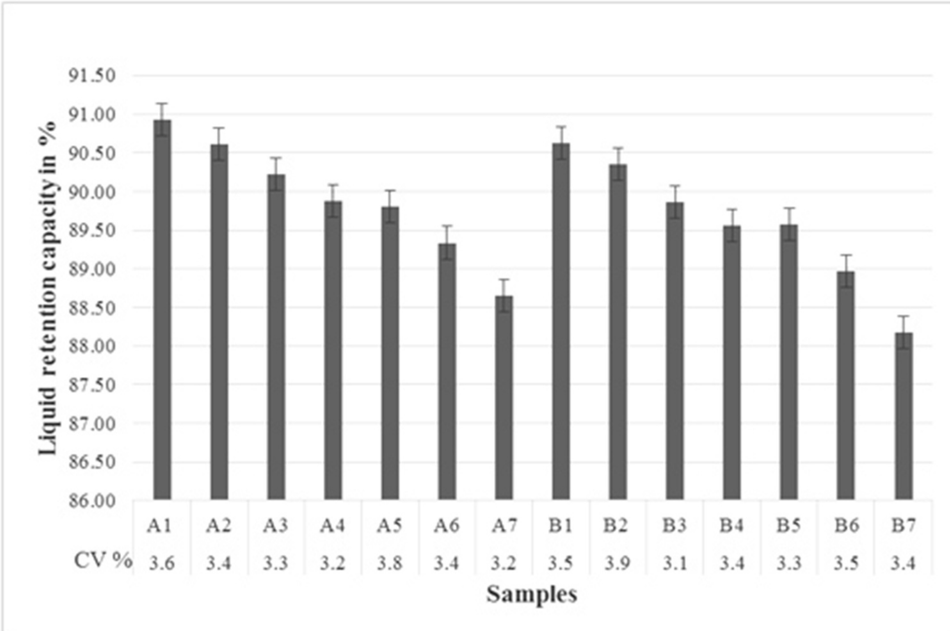


**Figure 4.** Comparison of liquid retention capacity of different samples in %.

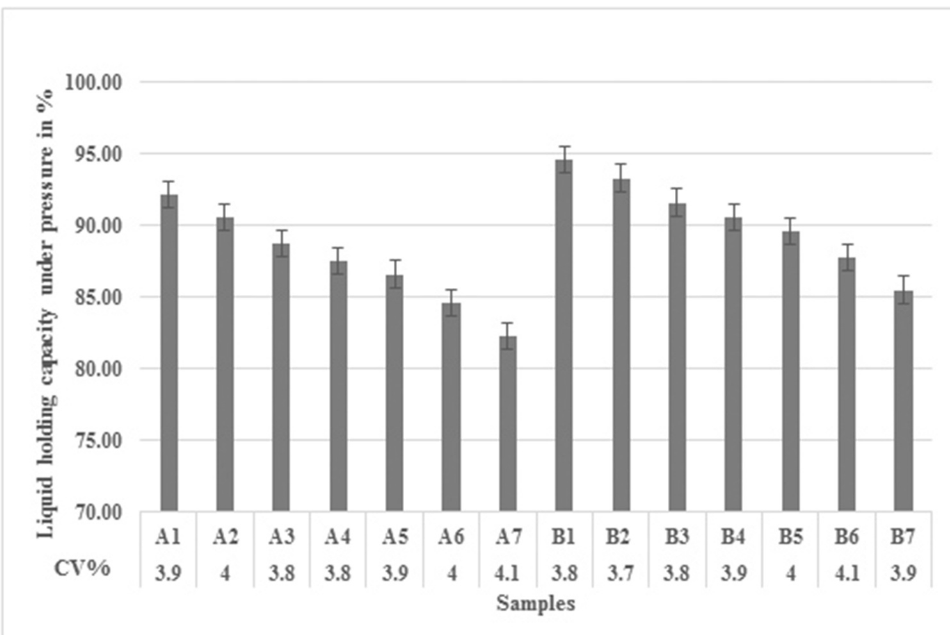


**Figure 5.** Liquid holding capacity under pressure sanitary napkin samples in %.

min for all the milkweed/cotton sanitary. It was also found that quantity of liquid absorbed by the 100% milkweed sanitary napkin sample is higher when compared to 100% cotton sanitary

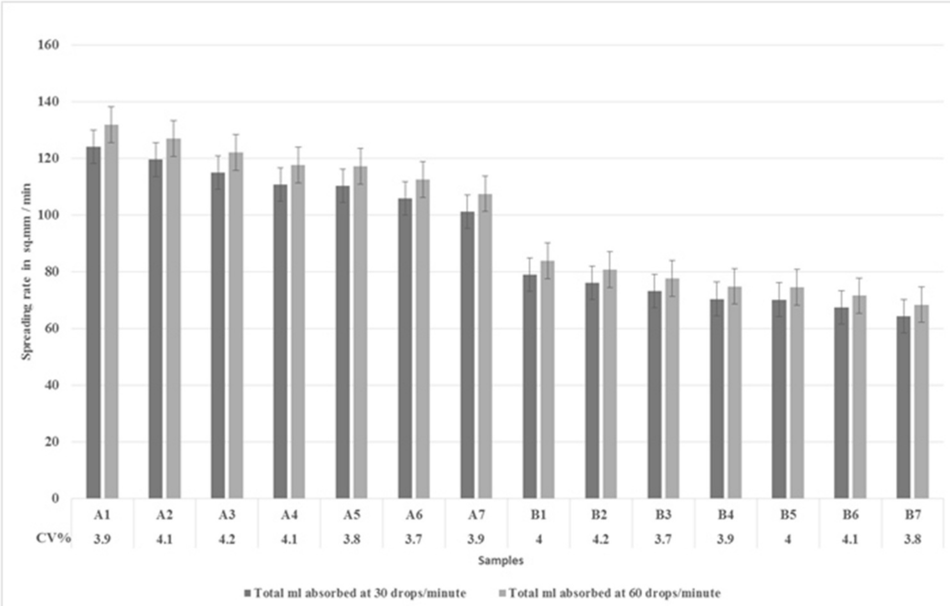


**Figure 6.** Comparison of total quantity of liquid absorbed by different samples at 30 drops/minute and 60 drops/minute.

**Table 1.** Properties of materials used for making sanitary napkin.

| Properties of polyropylene (top layer) | | Properties of polyethylene sheet (barrier) | | |
|---|---|---|---|---|
| Thickness | 1 mm | Thickness | 0.05 ± 0.005 mm | |
| GSM | 18 | GSM | 23 | |
| | | **Properties of core absorbent** | | |
| **Fiber type** | **Fiber length (mm)** | **Fineness (mTex)** | **Diameter (μm)** | **Density (g/cm$^3$)** |
| Milkweed | 3–5 | 94.4 | 27.23 | 0.97 |
| Cotton | 3–5 | 141.7 | 29 | 1.54 |

**Table 2.** Blend ratios of samples and its specifications.

| Sample code | Top layer | Absorbent core (Blend ratio and Weight in gms) | Barrier bottom sheet |
|---|---|---|---|
| A1 | P.P | 100% M – 7 | P.E |
| A2 | P.P | 80/20 M/C – 7 | P.E |
| A3 | P.P | 60/40 M/C – 7 | P.E |
| A4 | P.P | 50/50 M/C – 7 | P.E |
| A5 | P.P | 40/60 M/C – 7 | P.E |
| A6 | P.P | 20/80 M/C – 7 | P.E |
| A7 | P.P | 100% C – 7 | P.E |
| B1 | P.P | 100% M – 4 | P.E |
| B2 | P.P | 80/20 M/C – 4 | P.E |
| B3 | P.P | 60/40 M/C – 4 | P.E |
| B4 | P.P | 50/50 M/C – 4 | P.E |
| B5 | P.P | 40/60 M/C – 4 | P.E |
| B6 | P.P | 20/80 M/C – 4 | P.E |
| B7 | P.P | 100% C – 4 | P.E |

M-Milkweed, C-Cotton, P.P-Polypropylene, P.E.S-Polyethylene sheet

Table 3. Sanitary napkin composition.

| Sample code | Measurements dimensions (cms) T | L | W | Top layer (gms) | Absorbent core (gms) | Barrier bottom sheet (gms) | Total weight (gms) |
|---|---|---|---|---|---|---|---|
| A1 | 1.8 | 23.5 | 9.3 | 0.8525 | 7.0 | 0.63 | 8.73 |
| A2 | 1.8 | 23.5 | 9.3 | 0.8012 | 5.6/1.4 | 0.65 | 8.70 |
| A3 | 1.7 | 23.5 | 9.3 | 0.8401 | 4.2/2.8 | 0.62 | 8.71 |
| A4 | 1.7 | 23.6 | 9.4 | 0.7911 | 3.5/3.5 | 0.65 | 8.69 |
| A5 | 1.7 | 23.5 | 9.3 | 0.8317 | 2.8/4.2 | 0.64 | 8.72 |
| A6 | 1.6 | 23.5 | 9.3 | 0.8681 | 1.4/5.6 | 0.64 | 8.75 |
| A7 | 1.6 | 23.5 | 9.3 | 1.0210 | 7.0 | 0.63 | 8.9 |
| B1 | 1.1 | 23.5 | 9.4 | 0.8503 | 4.0 | 0.64 | 5.74 |
| B2 | 1.1 | 23.5 | 9.3 | 0.8112 | 3.2/0.8 | 0.63 | 5.69 |
| B3 | 1.0 | 23.6 | 9.3 | 0.8612 | 2.4/1.6 | 0.64 | 5.75 |
| B4 | 1.0 | 23.5 | 9.4 | 0.8100 | 2/2 | 0.65 | 5.70 |
| B5 | 0.9 | 23.6 | 9.4 | 0.7701 | 1.6/2.4 | 0.65 | 5.67 |
| B6 | 0.9 | 23.6 | 9.3 | 0.8701 | 0.8/3.2 | 0.64 | 5.76 |
| B7 | 0.9 | 23.5 | 9.3 | 1.0100 | 4.0 | 0.64 | 5.9 |

M-Thickness, L-Length, W-Width

napkin in both liquid flow rate of 30 drops/min and 60 drops/min. It was found that high liquid flow rate is facilitating the speed of liquid absorption by the sanitary napkins when compared to lower liquid flow rates.

### *Statistical data analysis*

The sanitary napkins were evaluated with the statistical analysis of variance at the confidence level of 95% with SAS System (version 8 of windows) (Ergun. 1985) for estimating the significance level of the layer weight and blend ratio parameters on the moisture behavior properties of the sanitary napkins. The $p$-values were examined to analyze the significance levels of layer weights and blend ratios. The findings of two-way ANOVA are given in Table 4 and Table 5. It is evident that the Liquid spreading rate, Liquid retention capacity, Liquid holding capacity under pressure and Quantity of liquid absorbed results are significant factors for the layer weights and blent ratios, with the $p > .05$, respectively.

## Conclusion

Liquid spreading rate test, liquid retention capacity, liquid holding capacity, and quantity of liquid absorbed tests were performed to analyze and evaluate the moisture behavior properties of milkweed, cotton, and milkweed/cotton blended sanitary napkins. Based on the result and analysis of this results, it's been concluded that initial spreading rate of the sanitary napkin made by using milkweed and milkweed blended napkins is low and this property of milkweed sanitary napkin facilitate the vertical wicking of sanitary napkin instead of horizontal wicking and this vertical wicking helps the liquid to fill from bottom-most core to all adjacent and the upper core of the sanitary napkin evenly. This vertical wicking property of milkweed sanitary napkin gives lower skin contact with the wet area of the top layer to the users. During the menstrual period of womens, if the contact area of the skin with wet area is lower, ultimately the user will get better comfort level when compare to higher level of skin contact with wet area. Liquid retention capacity, Liquid holding capacity, and Quantity of liquid absorption properties of milkweed and milkweed blended sanitary napkins shows better performance because of its inherent hollow structure and its cellulose content in its structure.

**Table 4.** Comparison of Liquid spreading rate in $mm^2$/min at 30 drops/minute and 60 drops/minute.

| | | Area in square mm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **S. no.** | **Samples** | **10 $mm^2$ at 30 d/m** | **10 $mm^2$ at 60 d/m** | **20 $mm^2$ at 30 d/m** | **20 $mm^2$ at 60 d/m** | **30 $mm^2$ at 30 d/m** | **30 $mm^2$ at 60 d/m** | **40 $mm^2$ at 30 d/m** | **40 $mm^2$ at 60 d/m** | **50 $mm^2$ at 30 d/m** | **50 $mm^2$ at 60 d/m** | **60 $mm^2$ at 30 d/m** | **60 $mm^2$ at 60 d/m** |
| 1 | A1 | 24 | 29 | 9 | 25 | 15 | 39 | 22 | 53 | 29 | 68 | 40 | 92 |
| 2 | A2 | 29 | 35 | 10 | 25 | 16 | 39 | 23 | 55 | 30 | 69 | 42 | 95 |
| 3 | A3 | 31 | 45 | 10 | 27 | 17 | 42 | 24 | 57 | 32 | 71 | 44 | 99 |
| 4 | A4 | 35 | 45 | 11 | 27 | 18 | 43 | 26 | 58 | 32 | 72 | 45 | 101 |
| 5 | A5 | 35 | 52 | 12 | 29 | 19 | 43 | 27 | 58 | 33 | 73 | 46 | 105 |
| 6 | A6 | 39 | 63 | 13 | 30 | 20 | 44 | 28 | 61 | 35 | 79 | 48 | 110 |
| 7 | A7 | 45 | 52 | 14 | 31 | 21 | 46 | 29 | 62 | 37 | 84 | 51 | 117 |
| 8 | B1 | 45 | 63 | 15 | 41 | 25 | 66 | 35 | 93 | 48 | 125 | 68 | 157 |
| 9 | B2 | 45 | 63 | 16 | 45 | 27 | 69 | 37 | 95 | 50 | 129 | 71 | 179 |
| 10 | B3 | 52 | 79 | 17 | 48 | 29 | 72 | 40 | 99 | 53 | 138 | 74 | 188 |
| 11 | B4 | 52 | 79 | 19 | 48 | 31 | 74 | 42 | 103 | 55 | 143 | 77 | 195 |
| 12 | B5 | 63 | 79 | 21 | 52 | 32 | 76 | 43 | 103 | 56 | 145 | 78 | 198 |
| 13 | B6 | 63 | 105 | 22 | 55 | 34 | 81 | 45 | 105 | 59 | 154 | 82 | 206 |
| 14 | B7 | 79 | 105 | 24 | 55 | 35 | 83 | 47 | 112 | 61 | 160 | 86 | 217 |

**Table 5.** ANNOVA multivariable data analysis.

| Source of variation | Sum of square value (SS) | Degree of freedom (df) | Mean square value (MS) | F-value | p-value | F crit |
|---|---|---|---|---|---|---|
| Liquid spreading rate in mm2/min at 30 drops/minute and 60 drops/minute | | | | | | |
| Between Weight | 2123.2143 | 6 | 353.8690 | 6.95 | 0.000602[a] | 2.66 |
| Between Blend Ratio | 83033.2500 | 3 | 27677.7500 | 543.59 | 7.725E-18[a] | 3.16 |
| Error | 916.5000 | 18 | 50.9167 | | | |
| Total | 86072.9643 | 27 | | | | |
| Comparison of liquid retention capacity of different samples in % | | | | | | |
| Between Weight | 7.6150 | 6 | 1.2692 | 372.52 | 1.911E-07[a] | 4.28 |
| Between Blend Ratio | 0.3787 | 1 | 0.3787 | 111.16 | 4.281E-05[a] | 5.99 |
| Error | 0.0204 | 6 | 0.0034 | | | |
| Total | 8.01 | 13 | | | | |
| Liquid holding capacity under pressure in % | | | | | | |
| Between Weight | 128.1345 | 6 | 21.3558 | 568.71 | 5.394E-08[a] | 4.28 |
| Between Blend Ratio | 30.3915 | 1 | 30.3915 | 809.33 | 1.249E-07[a] | 5.99 |
| Error | 0.2253 | 6 | 0.0376 | | | |
| Total | 158.7513 | 13 | | | | |
| Comparision of total quantity of liquid absorbed by different samples at 30 drops per minute and 60 drops per minute | | | | | | |
| Between Weight | 1053.2372 | 6 | 175.5395 | 59.59 | 6.726E-11[a] | 2.66 |
| Between Blend Ratio | 12672.1384 | 3 | 4224.0461 | 1433.86 | 1.333E-21[a] | 3.16 |
| Error | 53.0266 | 18 | 2.9459 | | | |
| Total | 13778.4022 | 27 | | | | |

*Note*: [a] Significant for $\alpha = 0.05$

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