Towards the Development of a Super Absorbent Textile Structure for Enhanced Absorption

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I. INTRODUCTION

Super absorbent textile materials are materials that have been developed to have the ability to absorb and hold large amounts of liquid in comparison to their own weight. The super-absorbent textile structure is a type of textile that incorporates super-absorbent polymers (SAPs) into its fibers or yarns[1]. Superabsorbent textiles can be produced in various ways. The properties of super absorbent textiles can be further enhanced by incorporating other functional materials, such as antimicrobial agents, into the fibers or yarns. The amount of time it takes for the sample to absorb a specific volume of distilled or deionized water involves the determination of the absorption capacity of the material. The hydrophobic or hydrophilic nature of certain materials is mainly influenced by the chemical groups that are present[3]. However, the capillary radius and water viscosity of a textile structure determine its absorbency and wicking ability.

This study addresses the limited exploration of fiber arrangement within textile substrates to optimize moisture absorption. While prior research has examined superabsorbent materials, the study focuses on the interplay between fiber orientations (random, horizontal, and vertical) and a superabsorbent polymer to determine the most effective structure for enhanced moisture uptake. By investigating how material orientation influences absorption efficiency, the research contributes to a nuanced understanding of this critical aspect in superabsorbent textiles. Particularly, this research offers exceptional benefits for the final product that uses absorbent core, in terms of facile manufacturing, sustainability, biodegradability, and user-friendliness.

II. LITERATURE REVIEW

Water absorption is one of the most important properties of textile fibers, which determines comfort, strength, elongation, and many other fabric or end-product properties[5]. This research has been looking for natural replacements for synthetic fibers, which will be easily available, green, renewable, and sustainable resources at the same time. Water absorption leads to swelling of the fiber. Natural fibers are prone to water absorption due to their chemical composition rich in cellulose, and hydrophilic in nature. Water absorption of natural fiber is more likely to increase with the increase in cellulose content of the fiber due to the increase in the number of free hydroxyl groups existing in the fiber.

The key properties of absorbency in an absorbent core are the absorption and diffusion of the liquid[3]. Absorption refers to how quickly the core takes in the liquid and the amount it can hold, while diffusion refers to the movement of the flow from areas of higher concentration to lower concentration within the core. Banana fiber exhibits excellent moisture absorption qualities due to its cellulose content, crystallinity (19-24%), and natural porosity (35-53%)[3], [4]. These findings indicate that banana fibers are suitable for absorption and diffusion in an absorbent core. Its hollow structure contributes to its excellent moisture retention capacity, making it suitable for achieving desired properties in the absorbency layer with a lower weight.

Table 1:Chemical properties of Banana Fibers

Component	**Banana Fibers** [3]–[5]
Cellulose	65.112
Hemi cellulose	17.325
Lignin	08.018
Oil & wax	02.502
Ash	-
Pectin	02.124
Mineral & other matters	04.919

Banana pseudo-stem fibers contain pathogenesis proteins with antimicrobial properties, which can be an additional advantage for using banana fibers as raw materials. Studies indicate that treated banana fibers can enhance durability without compromising fiber strength, although the strength may decrease after storage periods exceeding three months [6].

Table 2: Physical Properties of Banana Fibers

Physical properties	**Banana Fibers**[3],[5]
Density (g/cm^3)	1.35
Tensile Strength (MPa)	54
Flexural Modulus (GPa)	2 - 5
Young's Modulus (GPa)	3.48
Moist Absorption (%)	10 - 11

Sodium polyacrylate is a super-absorbent polymer (SAP) that can absorb 343% of weight than its own mass in water[5]. This makes it ideal for use in an absorbent core, as it can absorb a large amount of liquid and keep the skin dry. Sodium polyacrylate is also non-toxic and biodegradable, making it a safe and environmentally friendly choice for hygiene products[6]. Because of the sodium and polyacrylate chain, it's certainly strong in the environment and less likely to break down when water absorption happens the sodium ions are exchanged with the hydrogen ions this is how they absorb the water molecules and lock themselves into them. Sodium polyacrylate is not skin irritating because it is a large molecule that cannot penetrate the skin barrier. It is a hydrophilic polymer.

III. Materials and Method

1) Identify the raw material requirements and fabrication method for developing a super-absorbent core.
Banana fibers and Sodium polyacrylate were selected as raw materials by considering their absorption behavior.
As a fabrication method to impart superior absorbent properties to a textile structure, the composite manufacturing method was selected.

2) Treatment for banana fibers with an Alkali solution known as mercerization.

- Alkali concentration: 1% NaOH, 1% H_2O_2
- Temperature: 130ºC
- Time: 30 minutes

3) The fibers were laid manually just after the treatment process to construct the fiber layer and dried under environmental conditions to retain the flexibility of the layers. The fibers were laid according to the lengthwise direction, widthwise direction, and random direction.

4) The SAP gel was poured on top of one fiber layer, and it has been covered with another fiber layer. The whole sample was fused by a low GSM non-woven fabric.

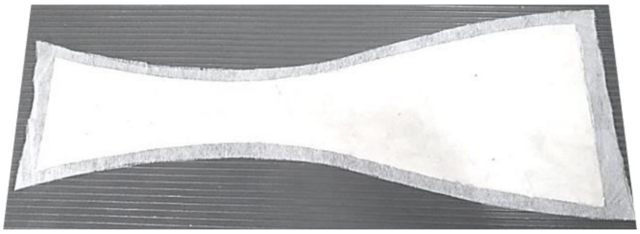

Figure 1: Developed sample of super absorbent textile material

The final sample has a composition of 70% fibers and 30% SAP. The fixed fiber length of 1cm was adopted for further sample development, ensuring consistent and reliable outcomes.

5) Testing and analyzing the absorbent and wicking behavior of the developed textile structure.

a) Test the absorption capacity of the banana fibers and Sodium polyacrylate.

- 5 grams of banana fiber samples immersed in water with a 200ml beaker. Then their weight changes over time were measured. The precisely weighed quantity of 0.35 grams of SAP was immersed in 300 grams of distilled water and left to soak for a duration of 2 hours.
- Following the soaking period, the swollen gel formed by the absorbed water and SAP was separated from the excess water. Once the gel was separated, the filtering paper containing the water-swollen gel was weighed.

b) Diffusion test

The burette dispensed 20 drops per 1 ml, and the prepared sample was positioned beneath the nozzle. Following this setup, the diffusion time for both individual drops and sets of five drops of the solution was recorded, alongside the measurement of the diffused area.
The burette was adjusted as 20 drops per 1 ml.

The developed sample was hung as in the above figure. Then 150ml of water has been from the burette.

Figure 2: Setup arrangement of diffusion test

c) Vertical wicking test AATCC197

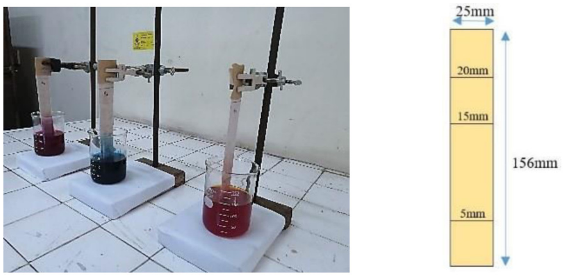

Figure 3: Setup arrangement & specimen of vertical wicking test

IV. RESULTS AND DISCUSSION

1) Moisture content of banana fibers

$$Absorption\ percentage = \frac{Final\ Weight\ - Initial\ Weight}{Initial\ Weight} \times 100\%$$

Banana fibers have a high absorption percentage of 470% after 1 minute and 710% after 5 minutes.

They exhibit rapid absorption properties, making them ideal for quick liquid uptake in products. However, challenges like mechanical strength and durability may affect their performance. Banana fibers can be blended with other materials to enhance absorbency, strength, and overall performance.

2) Absorption capacity of sodium polyacrylate

$$Q = \frac{\text{weight of swollen SAP} \ - \ \text{weight of dry SAP}}{\text{weight of dry SAP}} \times 100\%$$

Sodium polyacrylate is renowned for its impressive fluid absorption capabilities, providing a thin and lightweight solution ideal for specific products, ensuring discretion and user comfort. Its high absorption capacity not only prevents leakage by rapidly drawing moisture away from the skin and containing it within the absorbent core but also promotes even moisture distribution, minimizing discomfort. Additionally, its cost-effectiveness compared to other absorbent materials renders it a practical choice for efficient absorbent products. The absorption capacity of sodium polyacrylate, approximately 343 times its weight in water, makes it a highly suitable option for absorbent cores in various consumer products, enhancing user comfort, performance, and convenience.

3) Absorbency tests

Both test methods were customized according to the requirements of this study.

a) AATCC 79 test method

This test has been done for the 3 types of samples. According to the absorption levels observed, all the 3 samples absorbed about 150 ml of water.

b) ISO 20158 test method

Figure 4: Results of customized absorbency test

According to the results of this test method, all three types of samples showed slightly similar absorption percentages.

A higher absorption has shown here when compared with the test method ISO 20158 and it could be a result due to the specific rate that has been used in putting the droplets onto the material and there is a time duration for the material to wick the solution properly along the material to all directions.

4) Vertical wicking test

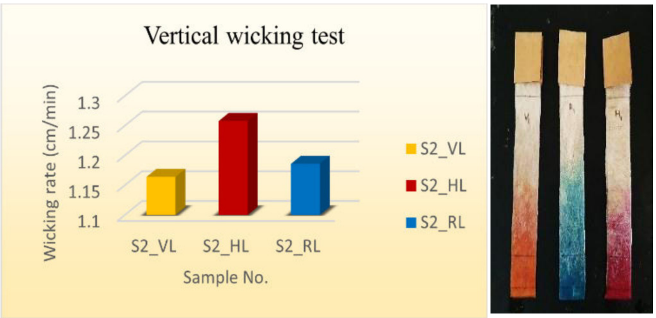

Figure 5:Vertical wicking test results and specimens

Measured in centimeters per minute, these rates indicate wicking efficiency. Vertically Laid samples consistently showed an average wicking rate of around 1.17 cm/min, signifying excellent liquid transport properties. Similarly, Horizontally Laid samples exhibited relatively high wicking rates at approximately 1.28 cm/min, though slightly lower than the Vertically Laid ones. The Horizontally Laid samples performed as well as the Randomly Laid samples in terms of wicking rates, suggesting effective liquid transport in the horizontal orientation. These findings highlight the impact of the fibers laid orientation of samples on wicking behavior, offering insights applicable to applications requiring efficient liquid absorption and distribution.

5) Diffusion test

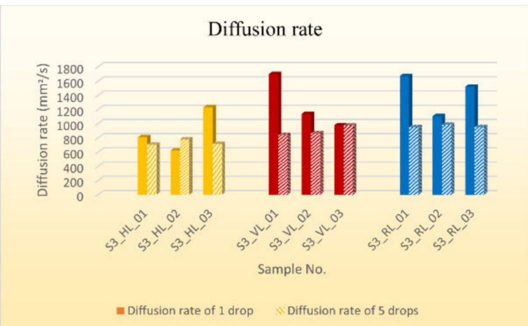

Figure 6: Diffusion test results

The randomly arranged structure showed the highest diffusion rate for both 1 and 5 droplets of the solution. Comparisons with horizontally and vertically laid samples suggest that fiber alignment significantly affects diffusion rates. Horizontally laid samples might experience altered moisture flow due to fiber alignment, while vertically laid samples possess distinctive wicking properties that influence diffusion rates uniquely. The observed prominence of diffusion in the randomly arranged structure revealed its efficacy in absorbing moisture. This intricate relationship between fiber orientation and diffusion behavior ultimately guides the selection of randomly laid samples as the optimal configuration for specific absorption requirements.

6) Average sample thickness

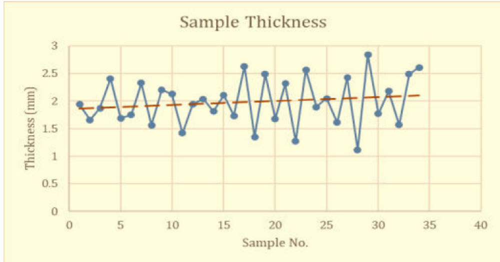

Figure 7: Average sample thickness

Average thickness of the samples prepared was 1 mm – 3 mm.

V. Conclusion

The main objective of this study was to develop a superabsorbent textile substrate for enhanced absorption. The structure having randomly laid fibers showed the highest absorbent rate when tested under ISO 20158 at 102.01ml and in the AATCC 79 test method, all the 3 samples showed 150 ml of absorbency which might be due to the rate of addition of solution onto the sample was done in a constant manner. The highest results were shown by the structure containing vertically laid fibers which is very similar to the randomly arranged structure from the vertical wicking test. The highest diffusion rate was observed in the randomly arranged structure for 1 or 5 droplets of the solution. Accordingly, the structure having randomly arranged banana fibers was concluded as the most suitable textile structure to use as a superabsorbent textile structure for enhanced absorption. Further developments could be done to automate the development process and increase the absorbency of the substrate.

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(VL - Vertically Laid, HL - Horizontally Laid, RL - Randomly Laid)