Optimizing Outdoor Textile with Aloe Vera: UV Protection and Antibacterial Properties

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I. INTRODUCTION

The growing demand for multifunctional textiles has led to research on integrating natural compounds like aloe vera into fabrics. Aloe vera, known for its medicinal properties, contains bioactive compounds such as anthraquinones and Acemannan, which offer UV resistance and antibacterial effects. However, traditional methods of applying aloe vera to textiles often result in reduced effectiveness over time.

Despite these efforts, a significant gap remains in exploring how aloe vera's protective properties can be enhanced and effectively combined in a multifunctional textile. Specifically, the need to improve the overall effectiveness and multifunctionality of aloe vera-treated fabrics has not been fully addressed. This study aims to fill this gap by investigating the dual functionality of aloe vera-treated polyester fabrics using microencapsulation techniques. By focusing on the microencapsulation of aloe vera, this research seeks to improve the fabric's UV resistance and antibacterial properties, providing a more effective and multifunctional solution.

II. LITERATURE REVIEW

Recent research has focused on integrating natural compounds into textiles, with aloe vera emerging as a promising candidate. Containing around 75 active constituents, including vitamins, enzymes, minerals, and anthraquinones, aloe vera offers significant UV protection and antibacterial properties [1]. Aloe vera contains bioactive compounds, notably anthraquinones, which exhibit strong UV absorption capabilities. When these extracts are applied to textiles, they can reduce the transmission of harmful UV radiation, offering a layer of protection to the wearer [2]. Further, Aloe vera has several components contributing to its exceptional antibacterial characteristics. Among these chemical components, anthraquinones, polysaccharides, and phenolic compounds have been shown in studies to have significant antibacterial properties [3]. Anthraquinone, a fundamental component of aloe gel, is a strong compound that inhibits the growth of bacteria. Anthraquinones can interfere with or destroy bacterial biofilms, which are protective layers that bacteria form to shield themselves from hostile environments and antibiotics. By disrupting these biofilms, anthraquinones enhance the susceptibility of bacteria to antibiotics. Also, it provides an antibacterial effect by disrupting bacterial biofilms and generating reactive oxygen species to kill bacteria [4]. Additionally, Acemannan has shown effectiveness against both Gram-positive and Gram-negative bacteria [5].

Although Traditional UV-protective finishes and antibacterial agents are effective, it has environmental and health risks. In contrast, natural, eco-friendly agents like aloe vera offer a sustainable alternative.

This study introduces a novel method for enhancing polyester fabrics by incorporating aloe vera microcapsules, with chitosan serving as a binder, applied via electro-spraying techniques. This approach effectively combines the UV-protective and antibacterial properties of aloe vera with the durable adhesion provided by chitosan, resulting in a functional and eco-friendly textile treatment. Electro-spraying offers precise control over the size and distribution of the microcapsules, allowing for uniform application while minimizing material waste [6]. By targeting polyester, a widely used synthetic fabric, this method not only improves fabric performance but also addresses sustainability, representing a significant advancement in textile technology.

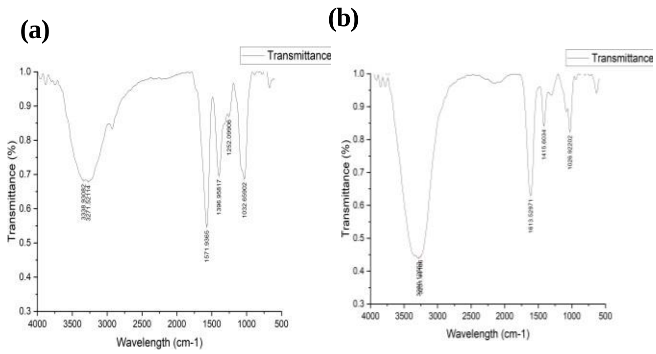

Fig 1: (a) FTIR graph of dehydrated Aloe vera powder (b) FTIR graph of microcapsules

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III. MATERIAL AND METHODS

A. Aloe vera extraction

Aloe vera leaves were collected from the Hambantota district and processed by washing, drying, and slicing.

To prepare aloe vera powder, two drying methods were used: sunlight drying, where 800g of aloe gel was dried over 2-3 days, and dehydration, where 1.2 kg of gel was dried at 65°C for 24 hours.

B. Preparation of Aloe vera Microcapsules.

To prepare microcapsules, 2.554 g of sodium alginate was dissolved in 100 ml of distilled water, while 0.052 g of aloe vera powder was dissolved in 10 ml of methanol. The two solutions were mixed in a 1:2 ratio and then sprayed into a calcium chloride solution using an electrospinning machine, forming microcapsules. These were collected by filtering the solution through filter paper.

C. Development of Aloe vera treated fabric.

A 1% (w/v) chitosan binder solution was prepared by dissolving 1 gram of chitosan in 1 ml of acetic acid and 99 ml of distilled water to incorporate the microcapsules into the fabric. Then the solution was stirred at 400 rpm for 15 minutes. One milliliter of this prepared solution was dispensed into a petri dish. Then microcapsules were placed in it. A 4x4 cm^2 piece of 100% polyester fabric was then submerged in the solution. The setup was allowed to sit at room temperature for one hour to ensure proper binding. Afterward, the fabric was dried in an oven at 40°C for 40 minutes to remove any excess water.

D. Assessment of UV protection properties and Antibacterial properties.

A UV absorption test was conducted on the treated fabric. Prepared microcapsules with aloe vera were attached to a 2x2 cm^2 fabric sample using 0.3 ml of chitosan solution. After drying, the fabric was shaken in 5 ml of 1% concentrated NaCl solution, followed by the addition of 10 ml of methanol. The extracted solution was tested for UV absorbance. The antibacterial properties were evaluated using the AATCC 147 method for Gram-positive (Staphylococcus aureus) and Gram-negative (Klebsiella pneumoniae) bacteria, assessing bacterial growth inhibition around the fabric samples.

IV. RESULTS AND DISCUSSION

A. Yield of Aloe vera powder

The Aloe vera powder prepared by the dehydration method produced a yield of 0.68%, higher than that obtained by sunlight drying.

(a)  **(b)** 

Fig. 2. (a) aloe vera powder sample (dehydrated) before testing (b) after testing

B. FTIR Results

Fig. 1 shows FTIR spectra for dehydrated aloe vera powder and microcapsules. The aloe vera powder exhibited peaks at 3209.8 cm-1 and 3271.5 cm-1 for -OH groups, 1548.9 cm-1 and 1571.94 cm-1 for C=O stretching, and 1402.69 cm-1 and 1396.95 cm-1 for COO- groups. The microcapsules showed peaks at 3251.14 cm-1 and 1415.60 cm-1 for -OH and COO- bonds, and a peak at 1613.52 cm-1 for C=O bonds, confirming the presence of both alginate and aloe vera components [7].

C. Borntrager's Test

As in Fig.2, the aloe vera powder sample exhibited a pinkish-red color when conducting the Borntrager's test, which confirms the presence of Anthraquinone [8].

D. Testing for Treated Fabric

1) UV Absorbance Test for the Treated Fabric

The UV-vis spectrum of fabric treated with aloe vera microcapsules showed peaks at 223 nm and 267 nm, indicating effective UV absorption, particularly in the UV-C and UV-B ranges, as shown in Fig. 3. However, the fabric was less effective at absorbing UV-A radiation, providing strong protection against UV-C and UV-B but limited UVA protection.

2) Antibacterial Test for the Treated Fabric

The antibacterial properties of the aloe vera-treated fabric were evaluated using the AATCC 147 method. According to Fig 4, the fabric showed a stronger antibacterial effect against Gram-positive bacteria, with a visible inhibition zone, than the untreated fabric. For Gram-negative bacteria, the effect was less pronounced, though no bacterial growth occurred directly under the treated fabric for either type. This demonstrates the fabric's potential as a protective textile, particularly in environments requiring reliable antibacterial protection.

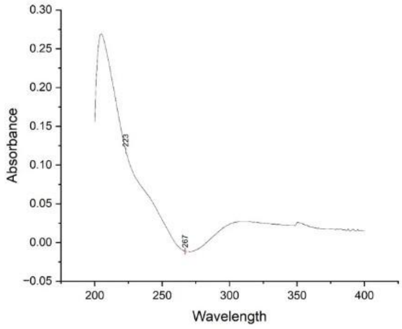

Fig 3. UV-vis spectra of treated fabric

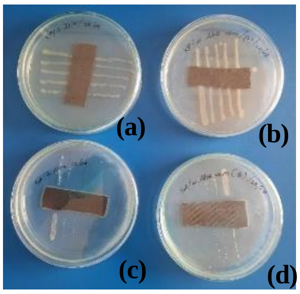

Fig 4. (a, b) Antibacterial effect of sample A and sample B against gram-negative bacteria (c, d) Antibacterial effect of sample A and sample B against gram-negative

V. CONCLUSION

This study demonstrated the potential of aloe vera microcapsules in enhancing the UV resistance and antibacterial properties of polyester fabric, making it ideal for outdoor textiles. Microencapsulation allows for the controlled release of aloe vera's active ingredients, extending the functional lifespan of the treated fabric. Notably, these microcapsules become active upon contact with sweat, as the capsule walls break down, releasing the active compounds. This targeted activation improves the fabric's effectiveness, ensuring its protective properties are enhanced precisely when needed. Future research could focus on optimizing the microencapsulation process to improve the retention and release of bioactive compounds. Additionally, exploring the combination of aloe vera with other natural agents could further enhance the protective properties of the fabric. The environmental benefits of using natural compounds in textile production should also be considered, as they offer a sustainable alternative to synthetic chemicals.

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