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Sustainable Cationization for Dyeing Cotton Fabric Using Natural Substrates

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Abstract

The simultaneous dyeing and finishing of cotton fabrics using natural agents such as chitosan and anthocyanin have the potential to produce smart textiles that respond to changes in pH, as well as improve the sustainability and environmental performance of textiles. In this study. The pure cotton fabric was treated with an aqueous-based anthocyanin extract as the dye, while chitosan was the finishing agent. The results showed that this treatment resulted in improved dye uptake, as well as enhanced antimicrobial and protective properties of the finished fabrics. The finished cotton fabric exhibited smart textile properties, responding to changes in pH. These findings demonstrate the potential of chitosan and anthocyanin as natural agents for the simultaneous dyeing and finishing of cotton fabrics and highlight the importance of sustainable finishing approaches in the textile industry.
Keywords: Cationization, Chitosan, Anthocyanin, Sustainable Fabric, Colorimetric Sensor.

Introduction

New methods that improve dyeing efficiency have emerged in response to the increased demand to decrease water use and chemical use in the processing of textile substrates. One of these is the chemical modification of cellulose molecules known as cationization, which results in the molecule being strongly cationic. [1-8]

Simultaneous dyeing and multifunctional finishing is a process in which both dyeing and finishing treatments are applied to the fabric at the same time, [9] rather than as separate steps. This approach has the potential to be more efficient and cost-effective, as it reduces the time and resources required for multiple rounds of dyeing and finishing. The simultaneous dyeing and multifunctional finishing of natural fabrics, such as cotton and wool, has received increasing attention in recent years due to the growing demand for environmentally friendly textiles. [10]

Chitosan is a natural polymer that is derived from chitin, which is found in the shells of crustaceans such as shrimp and crabs. It has several beneficial properties that make it a potential candidate for use in green finishing textiles. [9, 11-15] One of the main benefits of chitosan is its ability to improve the dyeability and fastness of fabrics. Chitosan is a cationic polymer with a positive charge, which allows it to interact with the negatively charged fibers of natural fabrics, as well as improve their dye uptake and fastness. This can help to reduce the amount of dye and chemicals needed in the dyeing process and improve the colorfastness of the finished fabric.

In addition to its dyeing properties, chitosan has been shown to have antimicrobial activity against a wide range of microorganisms, making it a potential candidate for use in functional finishes. Chitosan has also been shown to have UV protective properties, which can help to reduce the fading of fabrics caused by exposure to sunlight. Other potential functional properties of chitosan include flame retardancy, wrinkle resistance, and improved tensile strength, However, there are also challenges and limitations to the use of chitosan, such as the cost and availability of chitosan.

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Anthocyanin is a natural pigment found in a variety of plants, including berries and red cabbage. It is a type of flavonoid that is responsible for the vibrant purple, red, and blue colors of these plants. Anthocyanins are known for their antioxidant properties, which can help to protect the fabric from oxidative damage caused by UV radiation and other environmental factors. They have also been shown to have another health-promoting effect, making them a potential candidate for use in functional finishes. [16]

In the present work, the authors are targeting a big section of people especially the "disabled people", by preparing a smart fabric with the capability to sense a certain stimulus, such as heat and pH (2). [16] Chitosan and anthocyanin dye (presented in red cabbage) is used for treating cotton fabric The resulting fabric will fit the disabled people's needs by using natural materials which cause no harm for them and the environment as well. The treated fabric will provide a softer, more comfortable feel to cotton fabrics, making them more pleasant to wear for extended periods which is a necessity for these people, All the required parameters and measurements are investigated and discussed in detail.

Materials And Methods

Materials

El-Mahalla Company for Spinning and Weaving, El-Mahala Egypt, provides cotton fabric (100%). The Red cabbage leaves were obtained from the local Egyptian market. Chitosan (low molecular weight) is obtained from Sigma-Aldrich, Egypt. Ethanol as a solvent and ferrous sulfate are purchased from al-Gomhouria pharmaceutical company.

Methods

Extraction of Anthyocyanin Dye

The 600 g of fresh red cabbage plant leaves were divided into smaller pieces before being crushed. The leaves of cabbage are extracted in a 50:50 solution of ethanol and water at 80^0 C, then the solution is filtered to give a purple color. The aqueous-based anthocyanin extract is preserved at room temperature. [16]

simultaneous Dyeing and Finishing

The dyeing and finishing process was performed in an infra-color device, The simultaneous dyeing and finishing process was carried out on 100% cotton fabric. The fabric was first scoured and bleached to remove impurities and prepared for dyeing and finishing. The dyeing and finishing process was performed using a single dye bath containing anthocyanin dye, and ferrous sulfate and using chitosan at a concentration of 5 % of the fabric weight at temperature 80^0 C, at a liquor ratio of 1:80 for 90 min. The treated fabric was then dried afterward and measured.

Cotton Fabric	1 gm
Chitosan	0.05 gm
Ferrous Sulphate	X (0.01, 0.025, 0.05 gm)
Anthocyanin Dye	80 ml

Measurements

All the measurements are applied to the optimum conditions of the treated cotton sample using 0.1 gm of ferrous sulfate.

Microbiological Test

The disc agar diffusion technique was used to examine the treated sample's antibacterial activity. Staphylococcus aureus atcc 6538-p (g+ve), Escherichia coli atcc 25933 (g-ve), Candida albicans atcc 10231 (yeast), and Aspergillus niger nrrl-a326 were the four typical test microorganisms employed (fungus). Plates of nutrient agar were frequently intensively infected with 0.1 ml. The inoculation plates were covered with 15mm-diameter textile-treated discs. To allow for maximal diffusion, plates were then maintained at a low temperature (4°C) for 2-4 hours. The plates were then incubated for the bacteria at 37°C for 24 hours and for the organisms to develop as much as possible at 30°C for 48 hours in an upright posture. The diameter of the inhibition zone, stated in millimeters, was used to measure the test agent's antimicrobial activity (mm). The experiment was run many times, and the average reading was recorded.

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Using Quanta FEG250, field-emission scanning electron microscopy (FE-SEM) was used to examine the morphological characteristics of the pre-and post-treated textiles (Thermo Fisher Scientific, Brno, Czech Republic). By using various work distances and an acceleration voltage of 20 kV, this was outfitted with energy-dispersive X-ray spectroscopy (TEAM-EDX Model) to investigate the chemical composition of the pre and post-treated textiles.)

color measurement scales

Using UltraScanPro, a product of Hunter Lab, USA, the colorimetric characteristics of the cotton

samples were investigated, including CIE Lab (L*, a*, and b*), and colorimetric strength (K/S).

Results and Discussion

Antimicrobial activity

The antimicrobial activity of cotton samples treated with chitosan and anthocyanin was measured, the obtained data are demonstrated in the following table

The Antimicrobial Activity Against Various Test Microbes Representing G+Ve Bacteria (S. Aureus), G-Ve Bacterium (E. Coli), Yeast (C. Albicans), and Fungi is Shown in the Table (A. Niger)

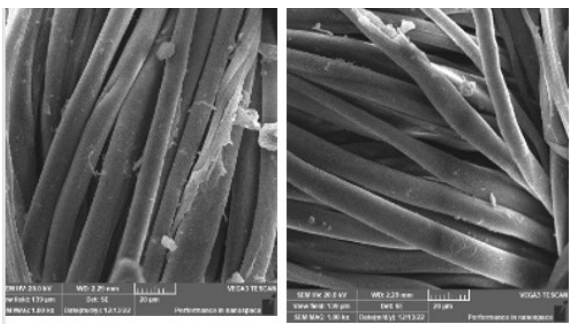
Table 1. Antimicrobial Activity

Clear Zone (ϕMm)			
Staphylococcus Aureus	**Escheichia Coli**	**Candida Albicans**	**Aspergillus niger**
12	**0**	**19**	**0**

Antimicrobial activity for the cotton sample treated with chitosan and Anthyocyanin dye shows good results against Escherichia Coli and Aspergillus Niger, This kind of inhibition under the samples always occurs when the antibacterial agent is unable to travel, and as a result, the inhibition is only present in the textile and the areas that are immediately around the antimicrobial textiles. Since the antibacterial agent was chemically bonded to the fabric and dye, therefore it could not leach as much and hence, there was a controlled growth over samples. [20, 21]

Scanning Morphological properties

Both morphological and elemental composition of chitosan on the cotton fabric was performed as represented in the following Fig



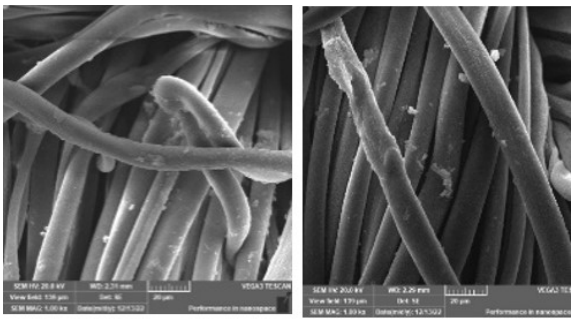


Fig.1. Scanning electron microscopic (SEM) images of cationized cotton fabric dyed with anthocyanin dye

As was evident from the SEM image. SEM Imaging showed that the cationized fabric had a smoother surface compared to the untreated fabric, which may contribute to the improved dyeability and finishing.

Conclusion

This research has proven that anthocyanin holds great potential for fabric industries not only as a dye but for developing “super cloths”. The produced fabric was capable to act as a colorimetric sensor, demonstrating a naked-eye colorimetric shift responding to biochemical variations the change in the pH degree- in perspiration fluids(2). The Extraction And Purification Of The Anthocyanins From The Plant Leaves Were Successful, As Evidenced By The Eye. The Cationization Of The Cotton Fabric Using Chitosan Was Also Successful. This Research Developed A Sustainable Method For Improving The Dyeability And Finishing Of Cotton Fabric Using Cationization And a Natural Pigment. The resulting Smart Fabric Is Capable Of Sensing Stimuli Such As Heat And Ph And Is Suitable For Use By Disabled Individuals And The Environment. The Cationization Of The Cotton Fabric Using Chitosan Resulted In An Antimicrobial finish And Improved Its Dyeability. Further, Research Could Focus On Optimizing The Cationization And Dyeing Conditions And Studying The Performance Of The Treated Fabric.

Conflicts of interest

There is no conflict of interest in the publication of this article.

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الكاتيونية والصباغة الدائمة لأقمشة القطن باستخدام مصادر طبيعية

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الملخص:

إن الصباغة والتشطيب المتزامن للأقمشة القطنية باستخدام عوامل طبيعية مثل الشيتوزان والأنثوسيانين لديها القدرة على إنتاج منسوجات ذكية تستجيب للتغيرات في درجة الحموضة ، فضلا عن تحسين الاستدامة والأداء البيئي للمنسوجات. في هذه الدراسة. تمت معالجة نسيج القطن الخالص بمستخلص الأنثوسيانين المائي كصبغة ، بينما كان الشيتوزان كعامل تشطيب. أظهرت النتائج أن هذا العلاج أدى إلى تحسين امتصاص الصبغة ، فضلا عن تعزيز الخصائص المضادة للميكروبات والوقائية للأقمشة النهائية. أظهر النسيج القطني النهائي خصائص النسيج الذكية ، استجابة للتغيرات في درجة الحموضة. توضح هذه النتائج إمكانات الشيتوزان والأنثوسيانين كعوامل طبيعية للصباغة والتشطيب المتزامن للأقمشة القطنية وتسلط الضوء على أهمية مناهج التشطيب المستدامة في صناعة النسيج.

الكلمات المفتاحية: الكاتيون. الشيتوزان. الانثوسيانين. نسيج مستدام. مستشعر اللون.