Effect of chitosan treatment on the properties of turmeric dyed cotton yarn

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Cotton yarn has been coated with different concentrations of chitosan solution and then dyed with turmeric to study their effects on yarn properties. It is observed that the tensile strength, flexural rigidity and shear strength increase with the increase in chitosan concentration. However, the coefficient of friction decreases with the increase in chitosan concentration. Cotton yarn coated with chitosan is found to be darker compared to uncoated yarn while dyeing for the same shade percentage. The dyed yarn coated with chitosan exhibits excellent activity against bacteria, such as E. coli and S. aureus.

Keywords: Chitosan, Colour strength, Cotton, Dyeing, Turmeric, Yarn properties

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1 Introduction

Clothing normally used is prone to microbial attack because of higher amount of surface area and presence of moisture. Textile materials used in medical field are expected to be resistant from microbes apart from offering their conventional properties. These textile materials, used in medical field such as wound dressings, sutures, surgical gowns and other bio-polymers, are now becoming an attractive domain for textile researchers.

Chitosan has been an excellent biomaterial which is used in various types of applications, such as antimicrobial agents, sutures, dye fixing agents and as a finishing chemical. This is because of its ecofriendliness, excellent biomedical properties and abundant availability. Even though several attempts have been made to use this polymer as a dye fixing agent, its use along with natural dyes has been limited. Some of the natural dyes extracted from turmeric and henna exhibit excellent antimicrobial activities apart from having the wound healing properties.

The present study is aimed at evaluating turmeric dyed chitosan coated cotton yarns for their properties, colour strength and antimicrobial activity against E. coli and S. aureus. Studies in this direction are the first step towards the usage of these yarn for biomedical applications.

2 Materials and Methods

2.1 Materials

Bleached cotton yarn (14.8 tex × 2) was used as starting materials for the study. Chitosan having degree of de-acetylation of 0.82 (η=300 cps), obtained from Central Institute of Fisheries Technology, was used as such for coating of the yarn. Commercially available turmeric was used as such for dyeing.

2.2 Methods

2.2.1 Treatment with Chitosan

Bleached cotton yarn was used for coating with chitosan. Chitosan solutions of the concentrations 0.1, 0.5, 1.0 and 2.5 % were prepared in 2.0% (v/v) aqueous acetic acid by stirring the dispersion for 1h at 60°C. Bleached cotton yarn was then immersed in the above solution with constant stirring for 2 h at 60°C. The samples were then taken out, washed with distilled water several times and dried at 60°C for 25 min.

2.2.2 Dyeing with Turmeric

The colouring matter was extracted from turmeric by using ethanol. The extract was dried in vacuum at 45°C and then used for dyeing of cotton in water – ethanol mixture (90:10 v/v) for 60 min at 80°C with

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material-to-liquor ratio of 1:20. All the dyeings were carried out for a constant shade of 12%. The samples were finally washed and dried.

2.2.3 Measurement of Tensile Strength and Elongation
Tensile strength and elongation behaviour of the uncoated and chitosan-coated samples were measured on an Instron tensile tester (Model 4301) using a specimen size of 50mm. The traverse speed was kept at 100mm/min. Average of 20 readings was taken to express the tensile behaviour.

2.2.4 Measurement of Flexural rigidity, Shear Strength and Friction Properties
The flexural rigidity (mgcm\(^2\)) of the yarn was measured using ring loop method.\(^\text{12}\) The shear strength (gf/tex) of the yarn was evaluated using the in-house built shear strength tester.\(^\text{13}\) The frictional properties (yarn-to-metal friction) of the untreated and chitosan-coated yarns were measured on Instron (Model 4301) by making suitable modifications as suggested earlier.\(^\text{14-16}\) The friction values were calculated based on the following relationship:

\[ \frac{T_2}{T_1} = e^{\mu \theta} \]

where \(T_2\) is the output tension; \(T_1\), the input tension; \(\mu\), the coefficient of friction between yarn-to-metal; and \(\theta\), the angle of wrap (in radians).

2.2.5 Determination of Surface Depth of Colour, Colour Strength and Related Parameters
The \(K/S\) value of the dyed samples was determined on a UV-Vis spectrophotometer (U-3210, Hitachi, Japan) using the following formula:\(^\text{17}\)

\[ \frac{K}{S} = \frac{(1 - R)^2}{2R} \]

where \(K\) is the coefficient of absorption; \(S\), the coefficient of scattering; and \(R\), the reflectance value of the fabric at \(\lambda_{\text{max}}\). The colour difference\(^\text{17}\) \((\Delta E)\) and relative colour strength between chitosan-coated and uncoated dyed samples were also obtained using the following relationships:

Relative colour strength (%) = \(\frac{\text{\(K/S\) value of chitosan-coated samples}}{\text{\(K/S\) value of untreated samples}} \times 100\)

\[ \Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \]

where

\[ \Delta L = L_{\text{coated}} - L_{\text{uncoated}} \]

\[ \Delta a = a_{\text{coated}} - a_{\text{uncoated}} \]

\[ \Delta b = b_{\text{coated}} - b_{\text{uncoated}} \]

\(L\) is the lighter/darker; \(a\), the redder/greener; and \(b\), the yellower/bluer.

2.2.6 Antimicrobial Assessment
All the cotton yarns coated with chitosan and dyed with turmeric were tested for antimicrobial activities against \(E.\text{coli}\) and \(S.\text{aureus}\) by shake flask test method. This standard method was used to measure the reduction rate in the number of colonies formed and provided quantitative data, which could then be converted to the average colony forming units per milliliter (CFU/ml) of buffer solution in the flask.\(^\text{18}\)

The reduction rate in the number of colonies was calculated using the following formula:

Reduction rate (%) = \([\frac{(B - A)}{B}] \times 100\)

where \(A\) is the CFU/ml for the flask containing the treated substrate after 3 h and 6 h contact time; and \(B\), the CFU/ml for the flask at time zero prior to the addition of the treated substrate.

The test tube was shaken at 37°C for 6 h on a rotary shaker and 100 \(\mu\)l of the serially dilute test solution was added to the agar plate and incubated at 37°C for 24 h. The number of colonies in the agar plate was counted.

3 Results and Discussion
3.1 Effect of Chitosan Treatment on Yarn Properties
Physical characteristics, handling characteristics and biological properties determine the performance of textiles used in medical field. Among the handling characteristics, the flexibility, coefficient of friction and shear strength play a vital role apart from tensile properties. In this pursuit of characterisation of these properties, attempts were made and the values are given in Table 1.

Table 1 shows the effect of chitosan concentration on the properties of cotton yarn, such as tensile, elongation, flexural rigidity, shear strength and friction. As the chitosan concentration increases, the breaking strength values of cotton yarns increase and elongation-at-break of the yarn decreases. This is due to the binding of fibres in the yarn by the chitosan, thereby offering better resistance to the axial load.
In case of medical textiles, sutures are subjected to various kinds of forces apart from those exerted in axial direction. The behaviour of the material when it is flexed and sheared, therefore, becomes an important parameter to study. The flexural rigidity and shear strength values of the various chitosan-coated samples are also given in Table 1. It can be seen that the flexural rigidity of the samples increases with the increase in chitosan concentration. This is due to the increased stiffness of the yarn with the increasing concentration of chitosan.

Shear strength values of the yarns also exhibit similar trend to that of tensile strength. This is due to the better binding of fibres in the yarns with the increasing concentration of chitosan.

The frictional values of the yarns, however, show a decreasing trend with the increase in chitosan concentration. This attributed to the uniform film formation of chitosan on the surface of the yarns. This is in agreement with the studies carried out by other researchers.19

The \( K/S \) value of dyed material is directly proportional to the amount of dye present in the material. The \( K/S \) values and the relative colour strength of all the dyed samples are given in Table 2. The \( K/S \) value of chitosan-coated yarns is higher than that of control sample. As the chitosan concentration increases, the dye uptake also increases.

Lower \( L^* \) values indicate that the sample becomes darker to that of control sample. It can be seen from the table that the \( L^* \) value decreases with the increase in chitosan concentration, indicating that the treated sample becomes darker compared to that of the control sample.

### Table 2—Effect of chitosan concentration on colour strength

<table>
<thead>
<tr>
<th>Chitosan Conc., %</th>
<th>( K/S ) value</th>
<th>Relative colour strength</th>
<th>( L^* )</th>
<th>( a^* )</th>
<th>( b^* )</th>
<th>( \Delta E )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (Bleached)</td>
<td>0.0747</td>
<td>100</td>
<td>78.69</td>
<td>0.48</td>
<td>50.12</td>
<td>-</td>
</tr>
<tr>
<td>0.1</td>
<td>0.0793</td>
<td>113</td>
<td>78.28</td>
<td>0.42</td>
<td>50.84</td>
<td>0.83</td>
</tr>
<tr>
<td>0.5</td>
<td>0.1000</td>
<td>142</td>
<td>74.47</td>
<td>2.64</td>
<td>51.74</td>
<td>5.90</td>
</tr>
<tr>
<td>1.0</td>
<td>0.1130</td>
<td>161</td>
<td>73.16</td>
<td>3.52</td>
<td>55.86</td>
<td>8.53</td>
</tr>
<tr>
<td>2.5</td>
<td>0.1355</td>
<td>193</td>
<td>70.59</td>
<td>3.99</td>
<td>56.14</td>
<td>10.68</td>
</tr>
</tbody>
</table>

3.2 Antimicrobial Activity

The bleached cotton thread, samples coated with chitosan and their corresponding turmeric dyed samples were tested for antimicrobial activity against *E.coli* and *S.aureus*. Figure 1 shows that 100% activity is observed in case of cotton yarns coated with highest concentration of chitosan followed by dyeing with turmeric. The presence of these two components in the yarns is likely to offer two layers of defence against bacteria. Even if one layer is exhausted, the second layer can offer resistance, thereby inhibiting the growth of microorganisms and making it a suitable material for biomedical applications. Moreover, chitosan and turmeric are also known for their wound healing properties; antioxidant and anti-inflammatory properties make them potential candidates for wound dressing.

### 4 Conclusions

When cotton yarns are coated with chitosan, the properties of yarns are bound to vary. With the increase in chitosan concentration, the tensile strength, shear strength and flexural rigidity values increase. The yarns coated with chitosan followed by dyeing with turmeric exhibit excellent resistance to bacteria such as *E.coli* and *S.aureus*. Further studies has to be done to characterize the biological properties of the cotton yarns to explore the possibility of their usage in medical application.
References