STUDY OF THE CHEMICAL TREATMENT ON COTTON FABRICS TO INCREASE THE UV PROTECTION AND ANTI-ODOUR RETENTION PROPERTIES

PAMUKLU KUMAŞLARIN UV KORUMA VE KALICI KOKU ÖNLEME ÖZELLİKLERİ İNİSTIRMAK İÇİN KIMYASAL İŞLEMLERİN İNCELENMESİ

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ABSTRACT

There is a heavy demand for cotton materials in diversified areas, and the research works on them are increased tremendously in the recent days. Chemical treatment of cotton cellulose without changing their fibrous form is a common practice in the textile industry. In this paper, cotton (woven and knitted) fabrics are selected and reacted with sodium hydroxide, morpholine or cellulase enzyme. The fabrics are then dyed by 6 different natural dyes: annatto, onion, pomegranate, indigo, myrobalan, barberry; and 2 synthetic dyes (reactive and sulphur dyes) and subsequently finished. The fabrics are then studied for their dyeing characteristics (K/S value), antibacterial activities, anti-odour and UV protection behaviour.

Keywords: Cotton fabrics, NaOH, morpholine, and cellulase enzyme, anti-odour, UV protection

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1. INTRODUCTION

Among all the textile fibers cotton is the most widely used one in the world. In the end of 20th century, world textile fiber consumption was approximately 45 million tons; and cotton represented approximately 20 million tons of them [1]. India holds the largest area of 8 m ha under cotton cultivation and ranked third in world’s cotton production, next to China & USA and second largest consumer of cotton [1, 2]. Unlike synthetic fibers, cotton is a natural product [3] and non-allergic since it doesn’t irritate sensitive skin or cause allergies [4, 5]. Nowadays, the use of natural dyes has increased due to the improvement in environmental concern, with increased awareness about harmful effects of chemical dyes both in production and in its usage by human beings [6, 7 & 8]. This dye has the rare distinction of being a dye whose use can be traced back to antiquity and which continues to be as commonly used all over the world today, since they contain the required chromophore and auxochrome required for the dye properties as seen in the following structure for the representative natural dyes annatto and barberry respectively [9,10 11, 12 & 13]. Cotton has a high absorbency rate and holds up to 27 times its own weight in water [14, 15]. However, the moist cotton can be easily attacked by bacteria. Antimicrobial textiles with improved functionality have a variety of applications in health and hygiene products, especially the garments worn close to the skin, and also have several medical applications in infection control and barrier material [16 – 24]. With increase in world population and the spread of disease, the
number of antibiotic resistant microorganisms is rising along
with the occurrence of infections from these microorganisms
[25, 26]. To address these growing concerns in the
environment, researches are focused on the use of reusable
textiles with durable finishes [9]. The importance of
antimicrobial textiles goes hand-in-hand with the rise in
resistant strains of microorganisms [10, 27]. There is a need
for the study on cotton textiles to improve its behaviour with
some chemical treatments. Hence, in this study cotton
(woven and knitted) fabrics were given treatment with
sodium hydroxide, morpholine, and cellulase enzyme
followed by dyeing and finishing so as to increase its
behaviour further. The fabrics were dyed with both synthetic
and natural type of dyes, since natural dyes are being
considered very important for natural cotton textile
materials. The fabrics tested for their dyeing characteristics
(K/S value), antibacterial activities, anti-odour and UV
protection behaviour after dyeing with some selected dyes
such as annatto, onion, pomegranate, indigo, myrobalan,
barberry (natural dyes); and reactive and sulphur dyes
(synthetic) respectively revealed very good results.

2. EXPERIMENTAL

2.1 Materials

The specification of cotton (woven and knitted) fabrics used
in this study are given in the following Table (1).

<table>
<thead>
<tr>
<th></th>
<th>Woven Plain Fabric</th>
<th>Knitted fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ends / Inch</td>
<td>84</td>
<td>27.1</td>
</tr>
<tr>
<td>Picks / Inch</td>
<td>94</td>
<td>26.1</td>
</tr>
<tr>
<td>Gram / Square Metro [GSM]</td>
<td>146.1</td>
<td>27.5</td>
</tr>
<tr>
<td>Yarn Count (Ne)</td>
<td></td>
<td>136.9</td>
</tr>
<tr>
<td>Warp</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Weft</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2 Methods

2.2.1 Pretreatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were pretreated
(scouring and bleaching) with 3% (owm – on weight of
material) sodium hydroxide at boil for three hours (for
scouring) followed by treatment with 1% (owm) hydrogen
peroxide at boil for two hours (for bleaching) as per the
established technique [28, 29].

2.2.2 Sodium hydroxide treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with
sodium hydroxide of the concentration 15% (owm) for one
hour at 85°C.

2.2.3 Morpholine treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with
aqueous solution of morpholine 40% for one hour at 40°C.

2.2.4 Cellulase enzyme treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with
Cellulase enzyme of the concentration 4.0% (owm) for one
hour at 70°C.

2.2.5 Dyeing of cotton (woven and knitted) fabrics

The dyeability of cotton fabrics (woven and knitted) was
investigated using natural and synthetic dyes. Dyeing was
carried out with the concentration of 2% (owm) for synthetic
dyes and 25 gpl (gram per litre) for natural dyes at boil for
two hours with a material to liquor ratio of 1:20 as per the
established technique of dyeing for natural and synthetic
dyes [29, 30].

2.2.6 Silicone softener finishing on cotton (woven and knitted) fabrics

The fabrics were finished with silicone softener (Super FX
80% pick up, padded and dried at room temperature) and
tested accordingly [31, 32].

2.2.7 Antimicrobial assessment of the cotton (woven and knitted) fabrics

The antibacterial activity on the natural dyed (annatto,
onion, pomegranate, indigo, myrobalan and barberry) and
synthetic dyed (reactive dye and sulphur dye) cotton (woven
and knitted) fabrics was assed [33] qualitatively
according to the AATCC test method 147-2004 by the
parallel streak method.

2.2.8 Organoleptic evaluation of odour control on
cotton fabrics - after 48 hrs (In house method)

The treated and dyed cotton fabrics (woven and knitted)
were finished with anti-odour finishing agent H9000 of the
concentration 5 gpl, at 75°C, 45 minutes. Then they were
evaluated by six judges. The judges made anti-odour
evaluations [34, 35]. 14 hours after removal of the sample
on each test day. The judges used individual scoring sheets
and new sheets were used every day of the evaluation. The
odour grading scale was 10 to 0 (“no odour” to “very intense
and disagreeable odour”).

Table 1. Specifications of cotton fabrics

<table>
<thead>
<tr>
<th></th>
<th>Woven Plain Fabric</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Ends / Inch</td>
<td>84</td>
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<td>136.9</td>
</tr>
<tr>
<td>Warp</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Weft</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2.9 UV protection finishing on cotton (woven and knitted) fabrics

The UV protection finishing was given to the cotton fabrics using Super FX Anti UV with concentration 5 gpl, 80°C, 60 minutes. The finished fabrics were then tested according to the standard method [33, 34, 36].

3.0 Results and Discussion

3.1 K/S values of dyed cotton (woven and knitted) fabrics

The K/S values of the dyes such as annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye applied on cotton (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) are given in Table 1. From this table it is observed that woven cotton fabric shows overall high K/S values than the knitted cotton fabric. The K/S values of sodium hydroxide treated cotton fabric are maximum when compared with morpholine treated, cellulase treated and untreated cotton fabrics. The higher K/S values on the sodium hydroxide treated cotton fabric are influenced by the higher swelling action of sodium hydroxide followed by morpholine treatment and cellulase treatment [13, 25 & 36]. Among the dyes applied on the cotton fabric (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) there is only a marginal differences in the K/S values; however reactive dye shows the maximum K/S values. Even though the woven cotton fabric and knitted cotton fabric posses only a small differences in the K/S values for the dyes (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye) applied on the cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated); there is a uniform trend maintained in these values and the values of woven fabric give an edge over the knitted fabric.

3.2 Antibacterial assessment of the dyed cotton (woven and knitted) fabrics

The antimicrobial assessment of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is given in Table 2. The antimicrobial activity of these samples was assessed by qualitative test method. All these dyed samples showed a higher zone of inhibition against Staphylococcus aureus when compared to Escherichia coli [26, 34, & 35]. In general, the sodium hydroxide treated cotton fabric (woven and knitted) shows a higher zone of inhibition (both by Staphylococcus aureus and Escherichia coli) which is around 20% more than that of untreated, 8% more than that of morpholine treated and 15% more than that of cellulase treated cotton fabrics (woven and knitted) when dyed with annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye. The reactive dye shows maximum inhibition followed by sulphur dye in synthetic dye category whereas indigo gives maximum inhibition followed by other natural dyes when dyed on cotton fabrics (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) as exhibited by Staphylococcus aureus and Escherichia coli.

3.3 Anti-odour behaviour of the treated, dyed and finished cotton fabrics

The anti-odour behaviour of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is given in Table 3 and 3(a) respectively. These fabrics were assessed by subjective evaluation technique performed by six women of different age categories (25 to 50 years) and the odour grading was rated between 0 and 10. Based on the performances of the natural and synthetic dyes the dyeing was carried out on the suitable materials. The data of anti-odour assessment performed show that the average anti-odour behaviour of cotton fabrics is around 8 which is a very good value [34, 35].

Table 1. K/S values of dyed cotton (woven and knitted) fabrics

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Dyes</th>
<th>Colours obtained</th>
<th>K/S values of the dyed cotton fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Woven 1</td>
</tr>
<tr>
<td>1</td>
<td>Annatto</td>
<td>Orange</td>
<td>12.47</td>
</tr>
<tr>
<td>3</td>
<td>Pomogranate</td>
<td>Brown</td>
<td>12.64</td>
</tr>
<tr>
<td>6</td>
<td>Barberry</td>
<td>Yellow</td>
<td>12.75</td>
</tr>
</tbody>
</table>

Table 2. Antibacterial assessment of the dyed cotton (woven and knitted) fabrics

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Dyes</th>
<th></th>
<th>Woven Fabric</th>
<th>Knitted Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Annatto</td>
<td></td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Onion</td>
<td></td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>Pomogranate</td>
<td></td>
<td>27</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Indigo</td>
<td></td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>Myrobalan</td>
<td></td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>6</td>
<td>Barberry</td>
<td></td>
<td>29</td>
<td>28</td>
</tr>
<tr>
<td>7</td>
<td>Reactive Dye</td>
<td>(H) (H)</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>Sulphur Dye</td>
<td></td>
<td>33</td>
<td>31</td>
</tr>
</tbody>
</table>

SA → Staphylococcus aureus  EC → Escherichia coli

Table 3. Anti-odour behaviour of the treated, dyed and finished woven cotton fabrics (assessed by Women)

Table 3(a). Anti-odour behaviour of the treated, dyed and finished knitted cotton fabrics (assessed by Women)
3.4 Anti-odour retention behaviour and release rate of the dyed and finished cotton fabrics

The concentration of the anti-odour agent was measured by UV / visible spectrophotometer by extracting the anti-odour agent from the finished fabric sample using ethanol. The extracted content was diluted to 1:10 ratio with distilled water. The absorbance of the diluted solution was measured at 206 nm. The release rate of the fragrance was calculated according to the following formula:

\[
\text{Release rate of fragrance} = \frac{\text{Immediate conc.} - \text{Conc. After 4 days (or 8 days)}}{\text{Immediate conc.}} \times 100
\]

The data obtained is given in Table 4 (woven cotton fabric) and Table 4(a) (knitted cotton fabric) respectively. From these tables it is noticed that the anti-odour retention behaviour is very good even after its test in 4 days and 8 days. The release rate of anti-odour agent from the fabrics is subsequently increased from the average of nearly 8% for 4 days to nearly 20% for 8 days in both the type of cotton fabrics. All the dyed fabrics give uniformly good anti-odour retention behaviour [34, 35] as evidenced in the Tables 4 and 4(a).

Release rate of fragrance = Immediate conc. – Conc. After 4 days (or 8 days) \[ \times 100 \]

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Dyes</th>
<th>Retention of anti-odour agent on the fabrics (mg/g)</th>
<th>Release rate of anti-odour agent from the fabrics (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A B C</td>
<td>A B C A B C A B C</td>
<td>X Y X Y X Y X Y</td>
</tr>
<tr>
<td>1</td>
<td>Annatto</td>
<td>324 295 258 340 315 278 339 312 276 338 310 272</td>
<td>8.3 7.19 6.0 7.18 6.7 19.2 8.1 7.19 6.4</td>
</tr>
<tr>
<td>2</td>
<td>Onion</td>
<td>321 292 255 340 311 272 336 309 272 335 307 268</td>
<td>8.5 19.9 7.7 19.9 8.1 19.3 8.3 19.5</td>
</tr>
<tr>
<td>3</td>
<td>Pomogranate</td>
<td>322 294 259 342 315 280 338 309 272 338 309 276</td>
<td>8.4 20.0 7.6 19.0 8.0 19.4 8.2 19.6</td>
</tr>
<tr>
<td>4</td>
<td>Indigo</td>
<td>323 296 262 342 316 282 339 314 280 337 312 277</td>
<td>8.5 19.9 7.7 18.9 8.1 19.3 8.3 19.7</td>
</tr>
<tr>
<td>5</td>
<td>Myro balan</td>
<td>320 290 252 338 310 272 336 306 268 334 305 268</td>
<td>8.5 19.9 7.6 18.7 8.0 19.0 8.3 19.3</td>
</tr>
<tr>
<td>6</td>
<td>Barberry</td>
<td>321 292 255 339 312 275 338 307 269 8.4 19.9 7.5 18.7 7.9 19.1 8.2 19.4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Reactive Dye</td>
<td>324 298 262 342 316 281 340 315 279 339 312 277</td>
<td>8.6 19.6 7.7 18.4 8.1 18.8 8.3 19.1</td>
</tr>
<tr>
<td>8</td>
<td>Sulphur Dye</td>
<td>323 300 264 345 318 285 342 316 282 340 315 278</td>
<td>8.5 19.7 7.6 18.5 8.0 18.9 8.4 19.2</td>
</tr>
</tbody>
</table>

1. Untreated cotton                          2. Sodium hydroxide treated cotton
Retention of Anti-odour : A → Immediately ; B → After 4 Days     C → After 8 Days
Release Rate of Anti-odour : X → After 4 Days  ;  Y → After 8 Days

3.5 UV protection factor for the dyed & finished cotton fabrics

The UV transmittance of the treated, dyed and finished cotton fabrics (woven and knitted) were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the Table 5, and the data of UV protection factor for the finished cotton fabrics are given in Table 5(a).

3.5.1 Standard chart for UPF rating for the fabric

The UV transmittance of the finished cotton fabrics were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the table 5, and the data of UV protection factor for the finished cotton fabrics (woven and knitted) are given in table 5(a).
Table 5. Standard chart for UPF rating for the fabrics

<table>
<thead>
<tr>
<th>UPF Rating</th>
<th>Protection Category</th>
<th>% UV Radiation Blocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 to 24</td>
<td>Good</td>
<td>93.3 - 95.9</td>
</tr>
<tr>
<td>25 to 39</td>
<td>Very Good</td>
<td>96 - 97.4</td>
</tr>
<tr>
<td>40 to 50</td>
<td>Excellent</td>
<td>97.5 or more</td>
</tr>
</tbody>
</table>

3.5.2 UV protection factor for the dyed and finished cotton fabrics

The UV protection factor (UPF) for the cotton fabrics is given in Table 5 (a). The UPF values of all the dyed and finished fabrics are between 33 and 40 respectively. The maximum UPF value (average 38) is given by the treated [sodium hydroxide (39), morpholine (38) and cellulase (37)] cotton fabrics dyed with natural dyes and synthetic dyes; whereas the minimum UPF value (average 34) is seen for untreated cotton fabric dyed by natural dyes and synthetic dyes. From these data (Tables 5 & 5(a)) it is clear that there is a very good UV protection category as revealed by UPF rating (33 – 39) for the dyed and finished cotton fabrics [25, 26]. Similarly, the untreated cotton fabric also shows the UPF rating of average 34 which is also in the very good (UPF) category, however, the increase of UPF value is more than 10% after these treatments. Therefore based on this, the increase of the percent UV radiation blockage by these fabrics (dyed and finished cotton fabrics) would be highly appreciable for the garments and apparels [25, 26, 34, & 35].

4. Conclusion

From this research work the following conclusions are arrived;

The K/S values of the dyes such as annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye applied on cotton (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) are good. The sodium hydroxide treated cotton fabrics show maximum colour data followed by morpholine treated and cellulase enzyme treated cotton fabrics.

The antimicrobial character of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is good. All these dyed samples showed a higher zone of inhibition against Staphylococcus aureus when compared to Escherichia coli. In general, the sodium hydroxide treated cotton fabric (woven and knitted) shows a higher zone of inhibition (both by Staphylococcus aureus and Escherichia coli) followed by morpholine treated, cellulase enzyme treated cotton fabrics.

The anti-odour behaviour of cotton fabrics is excellent to very good. Similarly the anti-odour retention behaviour of these fabrics is also very good. There is a very good increase of UV protection category for the dyed and finished cotton fabrics.

5. Acknowledgement

The authors wish to thank the Management and the Principal, PSG College of Technology, Coimbatore for given the permission and providing the necessary infrastructure. Thanks are also due to The Head, Department of Applied Science for the kind help in department laboratory supports.

Table 5 (a). UV protection factor for the dyed (natural and synthetic) & finished woven and knitted cotton fabrics

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Dyes</th>
<th>Woven Cotton Fabric</th>
<th>Knitted Cotton Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>1</td>
<td>Annatto</td>
<td>34 39 38 37</td>
<td>35 40 39 38</td>
</tr>
<tr>
<td>2</td>
<td>Onion</td>
<td>33 38 37 36</td>
<td>36 39 38 38</td>
</tr>
<tr>
<td>3</td>
<td>Pomogranate</td>
<td>34 38 37 36</td>
<td>33 39 37 36</td>
</tr>
<tr>
<td>4</td>
<td>Indigo</td>
<td>33 38 37 36</td>
<td>34 39 38 37</td>
</tr>
<tr>
<td>5</td>
<td>Myrobalan</td>
<td>35 39 38 37</td>
<td>35 40 39 38</td>
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<td>35 39 38 37</td>
<td>36 40 39 38</td>
</tr>
</tbody>
</table>

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

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