Simultaneous Dyeing and Rot / Crease Resistance Finishing of Jute Fabric Using Citric Acid and Poly Ethylene Glycol

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Abstract
In this present study, an attempt has been made to combine the two step dyeing and finishing process into a single step process by developing simultaneous dyeing (acid dyeing) and rot/ anti-microbial as well as crease resistant finishing process in one step by pad-dry-cure method. H₂O₂ bleached jute fabric has been dyed with selective acid dye (1%) and chemically finished with different concentrations of Citric Acid(CA) and Polyethylene Glycol (PEG 400) in presence of Sodium hypophosphite monohydrate (SHP). The textile related performances of the said dyed and finished fabric in terms of dry crease recovery angle, rot resistancy, anti-bacterial activity, surface colour strength and other colour interaction parameters and bending length(for stiffness) etc were evaluated and analysed. Jute fabric cross linked with CA alone also showed good crease and rot resistance properties, but, CA/PEG 400 combined treatment imparted somewhat increased functional properties considering enhancement in anti-microbial and crease resistance property and colour strength. Study of FTIR spectroscopy indicated the formation of ester crosslinkage between the jute fibre, citric acid and PEG. This single bath technique thus offers advantages of reduction in processing cost, saving in energy and reduction in time of treatments as well as better colour value and good crease and rot resistance / anti microbial property.

1. Introduction
Jute being abundantly available in India, Bangladesh and to some extent in some other parts of world like China, Thailand, Nigeria, etc. is used mainly for packaging of agro-crops of different countries besides its recent increased use as food grade jute bags, hand bags, decorative hometextiles and also as some protective technical textiles field such as rot resistant and/or fire resistant jute cloth or bags in different end uses. Jute being natural biodegradable fibre, with increasing awareness, on adverse environmental impact of synthetic packaging; jute products are being used more and more in certain areas. Besides its common use as packaging textiles, its uses increasingly preferred in home textiles, geo-textile/ agro-textile. Jute has certain inherent properties, lacking in crease recovery, having susceptibility to rotting, which partially have restricted its further growth as jute diversified products. Govt. of India, has taken a target of increasing its diversified uses up to 25% from presently 10-15%.

Application of rot resistance or anti-microbial finish for packaging substrate like jute bags is gradually gaining interest from all stakeholders due to its potential to provide quality, safety and benefits to extend the shelf life of the food, if packed in rot resistant/anti microbial...
jute package/ bags by either reducing the rate of growth of specific micro-organisms on it or killing the micro organism from the surface of bag touching the foods [1].

It is evident that the anti-microbial treatment so far tried on jute are limited and have been mostly confined to compounds of Copper, Zinc or Cadmium e.g. Sulphate, Naphthenate, Cupramonium etc [2,3]. Majumder et.al. [4] mentioned rot resistance of jute fabrics using quaternary ammonium compounds but the application process is too lengthy. Ghosh and Dutta [5] used a phenol formaldehyde recipe for preventing the microbial attack on jute. Citric acid has been extensively studied as a formaldehyde free durable press agent for cotton and jute fabric [6, 7, and 8]. Cotton and jute textiles modified with citric acid crosslinking have also showed good anti microbial properties [7, 18]. Bagchi et.al [8] also found that for crosslinking of jute with Citric Acid or Butane Tetra Cyclic Acid, Sodium hypophosphite monohydrate (SHP) catalyst is the most effective catalyst. Various research and developments have demonstrated that bound PEG has anti microbial and anti fungal property and is non-toxic [13, 22]. It has been also found that among the PEGs of different mol. wt., PEG 400 also has produced balanced functional property on jute and cotton fabric [14].

Some earlier reports are available in literature [25, 26, 28-29] on single-step dyeing and resin finishing of jute based fabrics, and on simultaneous dyeing and easy care crease resistant finishing for cotton and its blends [27, 30-31] with a view of saving energy, manpower, time, cost and as well as minimizing water pollution. Some studies have been made on simultaneous dyeing and anti-microbial finishing on cotton, wool and acrylic fibre. But a study of the literature revealed no information dealing with simultaneous dyeing and anti-microbial finishing of jute fabric.

Keeping these drawbacks in mind, it is desirable to develop such process formulations which would result in reduction of process steps by way of combining two or three steps together into one step requiring lower energy, water and time consumption for achieving reduced process cost. Therefore, the purpose of present investigation is to study appropriate combination of multi-step processes in a single-step process for both dyeing and anti microbial as well as crease resistant finishing of jute fabric.

2. Experimental

2.1. Materials

2.1.1. Jute Fabric

Raw ex-loom, plain weave, fine Hessian 100% jute fabric of decorative variety with 6 ends/cm (count 256 tex), 5 picks/cm (count 256 tex), 275 g/m² (area density) was used in the present work. After conventional desizing and scouring [32,33] followed by conventional 3% (on weight of fabric) H₂O₂ bleaching [34] with usual additives became 255 g/m².

2.1.2. Chemicals and Dyes

Citric acid (CA) as crosslinking agent, Sodium hypophosphite monohydrate (NaH₂PO₃, H₂O) is used as catalyst and Poly ethylene glycol 400 (PEG) is used as additive. All the chemicals are of analytical grade.

A selective acid dye, Acid Yellow GL (CI Acid Yellow 59), supplied by Dye Chem, India was used.

![CI Acid Yellow 59 (Acid Yellow GL).](image)

2.2. Methods

2.2.1. Conventional Two-Step Sequential Dyeing (with Acid Dye) and Rot Resistant Finishing

(i). Dyeing of Jute with Acid Dye by Exhaust Method

For 20 g of fabric sample, 0.25 g of acid dye was used (1% depth of shade) in 400 ml (fabric to liquor ratio i.e. MLR 1:20) aqueous solution of 5% glauber salt and a requisite volume of 5% Alum was added to adjust pH to 4-4.5. The dyeing [35, 36] was carried out for 1 h at 90°C (± 50°C), in Infra Colour Dyeing Machine (Make- RB Electronic Engg Pvt Ltd) after which the dyed sample was squeezed, neutralized with 1% NaOH solution, followed by soaking with 5 gpl non-ionic soap or detergent at 50°C for 15 min (instead of 45 min as in ISO-II method)[37] and finally washed in cold water and dried in air.

(ii). Application of Anti-Microbial Finishing Treatments with Different Formulations

Jute fabrics dyed with Acid dye in exhaust method were padded (100% weight pick-up) with anti-microbial formulations as given in table 1 followed by drying at 100 °C for 10 min and curing at 150 °C for 5 min.

Based on reported literature [13, 14, 19, 22], two optimum formulations developed in this laboratory concentrations of anti-microbial agents were varied in the present work.

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Formulation-A</th>
<th>Formulation-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variations used for simultaneous dyeing and anti microbial finishing</td>
<td>SHP-6% and CA6-14%</td>
<td>SHP-6%, CA10% and PEG-4-12%</td>
</tr>
<tr>
<td>Formulation for sequential dyeing and Anti microbial finishing</td>
<td>SHP-6% and CA10%</td>
<td>SHP-6%, CA10% and PEG 10%</td>
</tr>
</tbody>
</table>

Table 1. Formulation of simultaneous and sequential dyeing and fire retardant finishing.
2.2.2. One Step Simultaneous Acid Dyeing and Anti Microbial Finishing by Pad–Dry-Cure Process

Bleached jute fabric samples were soaked in a solution containing different concentrations (6%, 8%, 10%, 12% and 14%) of CA with SHP of 6% concentrations together with 1% acid dye and non-ionic detergent (Nonidet P-40). The samples were then padded at 100% expression using a laboratory padding mangle (with two-dip and two-nip technique). Finally, the padded fabrics were dried at 100°C for 5 min followed by curing at 150°C for 5 min. After curing, the fabric samples were washed in cold water and soaped with 5 gpl non-ionic soap at 50°C for 15 min, followed by final washing in cold water and drying in air.

The above procedure one step simultaneous acid dyeing (with 1% acid dye Yellow GL) and anti-microbial and crease resistant finishing was repeated using Formulation B.

2.2.3. Testing Method

(i). Soil Burial Test

Rot resistance i.e. resistance to microbial attack of the fabric samples was assessed by determining the % retention of tensile strength after subjecting the fabric to a standard soil burial test for 21-days as per IS:1623:1960 [4, 10].

(ii). Determination of Antimicrobial Activities of Dyed Fabric

The antibacterial activity of dyed fabrics was estimated by AATCC test method 100-2004. The reduction in number of bacterial colonies formed with respect to the untreated control sample was estimated by using following equation-

\[
R = \frac{100(B - A)}{B}
\]

where,

- \( R \) = % reduction in bacterial count;
- \( A \) = the number of bacterial colonies recovered from the inoculated treated test specimen swatches in the jar incubated for 24 hr contact period;
- \( B \) = the number of bacterial colonies recovered from the inoculated untreated control test specimen swatches in the jar immediately after inoculation (at "0" contact time)

(iii). Measurement of Crease Recovery Performances

Dry Crease recovery angle (warp +weft) of selected fabric samples were measured by the SASMIRA crease recovery tester in accordance with ASTM-D-1295-67 [38].

(iv). Measurement of Tensile Properties

Tensile strength of selected fabric samples were measured by the raveled strip method as per IS-1969-1985 method using an Instron (Model-1445) CRT-Universal tensile tester [37].

(v). Determination of Fabric Stiffness (Bending Length)

Fabric stiffness, as expressed in terms of bending length of the selected fabric samples were measured as per IS-6490-1971 method using Cantilever type SASMIRA fabric stiffness tester [37].

(vi). Measurement of Surface Colour Strength

Surface colour strength of untreated, differently treated and dyed and / or finished jute fabric sample was estimated in terms of \( K/S \) values by measuring the surface reflectance of each fabric sample at the respective \( \lambda_{\text{max}} \) using a Macbeth 2020-plus reflectance spectrophotometer along with associated Colour-Lab plus software for converting the reflectance value to \( K/S \) value using Kubelka Munk’s equation.

(vii). Measurement of Colour Fastness to Washing

Colour fastness to washing was determined using SASMIRA launder-O-meter as per IS: 3361-1984 (ISO-II) method [37].

(viii). Measurement of Colour Fastness to Light

The light fastness of the dyed and / or finished jute fabric samples was evaluated as per BS 1006: BOI: 1978 method using a Shirley (SDL) MBTF-microsal fade-O-meter [37].

(ix). Measurement of Colour Fastness to Crocking Rubbing

Dry Rubbing fastness of the dyed samples was determined using a SDL electronic crockmeter (make: Shirley Development Ltd.) as per IS: 766-1956 method [37].

(x). Fourier Transform Infrared Spectroscopy (FTIR)

Selected jute fibre (finely crushed )samples (3mg) taken out from untreated and treated fabrics were examined in a double beam FTIR spectrophotometer (BOMEM,MB 104)using KBr disc technique [8, 19].

3. Results and Discussions

3.1. Effect of One-Step Simultaneous Dyeing and Crease and Rot Resistant Finishing by Pad–Dry-Cure Process on Physical Properties of Jute Fabric

Relevant results of tensile strength loss and other mechanical properties (crease recovery, bending length etc.) of 3% H₂O₂ bleached jute fabric subjected to two-step conventional sequential process of acid dyeing (using a selective acid dye) and Crease and anti-microbial finishing (using CA and CA-PEG) using different concentrations of finishing agents are shown in Table 2 and Table 3.

Crease recovery: Crease recovery property sharply
increases with increase in CA concentration since the increasing CA concentration will increase the availability of cross linking molecules and consequently increase its accessibility to crosslink jute hydroxyls. DCRA (W+F) value reached to 210 with 10% CA where as untreated fabric DCRA (W+F) value is 140. Further increase in citric acid concentration (12% and 14%) have only marginal improvement on crease recovery property(220 and 232) but fabric suffered higher loss in strength. Citric acid treatment causes loss in tensile strength and an increase in wrinkle recovery of treated fabric, which is a presumptive evidence of cross linking with cellulose. The degree of crease recovery is moderate, and it is thought that moderate level of cross linking is achieved with jute fabric and citric acid forming ester. Citric Acid being an α-hydroxytricarboxylic acid, it is less effective for cross linking cellulose than are tri and tetra carboxylic acids that do not possess hydroxyl groups in their molecular structure [7, 17].

Dry Crease Recovery Angle (DCRA) value (W+F) is found to be slowly increased with increase in PEG 400 concentration up to 10% keeping CA% constant at 10% and with further increase of PEG(12%) DCRA value is slightly decreased (252). Maximum crease recovery value of 256 is obtained with 10% CA and 10% PEG. The glycol react with the cross linking agent CA during curing treatment and become bound to the fabric as part of the finishing agent /fabric matrix, PEG provided more reactive site, increased degree of cross linking having more flexible three dimensional networks than the network produced by CA. Some of the PEG may also react with oxy cellulose (-CHO,-COOH) formed due to bleaching of jute.

Tensile property: It is established that cross linking treatment of cellulosic materials causes damages to its several physical properties e.g. tensile strength and stiffness. The fabric suffered 34% loss in strength with 10% CA treatment in case of two step dyeing and finishing and 35% in case of simultaneous dyeing and finishing with formulation A3 due to cross linking. Further increase in CA concentration percentage loss in strength is higher (42 & 45%). This may be due to the acidic degradation of CA during curing.

From Table 3, it is found that incorporation of PEG 400 in citric acid bath also enhanced tensile strength of jute fabric improved than without it.

Stiffness: The bending length of citric acid treated jute fabrics are found to be increased with the increase in concentration of citric acid causing the fabric handle stiffer. Fabric handle is slightly deteriorated on CA treatment at 6% and above as indicated by increased bending length. The stiffness so imparted is due to the effect of cross linking reaction. Stiffness is decreased as indicated by decreased bending length and the treated fabric reached the original bending length. PEG is a good plasticizer which improved the flexibility, reduced brittleness and made a film forming property on jute fabric and hence strength and stiffness improved [15]. The jute fabric dyed and finished in concurrent process with formulation A3 and B4 shows at par results in compare to sequential dyeing and finishing method with 10% CA and combination of 10% CA- 10% PEG formulations respectively.

Table 2. Effect of Citric Acid treatment on physical properties of jute fabric.

<table>
<thead>
<tr>
<th>Expt. No.</th>
<th>Treatment</th>
<th>% Loss in Strength due to treatment</th>
<th>% Retention of Tensile Strength after soil burial for 21 days</th>
<th>Bending Length</th>
<th>Dry Crease Recovery Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nil controlled jute fabric</td>
<td>-</td>
<td>8</td>
<td>4</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>Jute fabric dyed with 1% Acid Dye</td>
<td>10</td>
<td>8</td>
<td>4.1</td>
<td>138</td>
</tr>
<tr>
<td>3</td>
<td>Single step simultaneous dyeing (1% acid dye followed by CA 10%-SHP 6 % (Formulation-A))</td>
<td>34</td>
<td>50</td>
<td>4.5</td>
<td>212</td>
</tr>
<tr>
<td></td>
<td>Formulation A1</td>
<td>CA 6%</td>
<td>22</td>
<td>32</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Formulation A2</td>
<td>CA 8%</td>
<td>30</td>
<td>37</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>Formulation A3</td>
<td>Acid dye 1% SHP 6%</td>
<td>CA 10%</td>
<td>35</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Formulation A4</td>
<td>CA 12%</td>
<td>42</td>
<td>49.5</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Formulation A5</td>
<td>CA 14%</td>
<td>45</td>
<td>50</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Anti-microbial property: The anti-microbial property of dyed and finished jute fabric was measured by soil burial test where the extent of fabric damage by micro organism is indicated by loss in strength. The results are in table 2 shows the fabric performed well in soil burial test with increase in citric acid. The retention % of tensile strength after 21 days soil burial test is 50% with two step sequential dyeing and finishing with 10% Citric Acid, where as untreated fabric is almost completely deteriorated in the soil burial test and retained only 8% tensile strength. The same trend (49% strength retention) can also be finding in concurrent dyeing and finishing method with same formulation. Further increase in CA concentration, anti-microbial property remains to be unchanged, anti-microbial property imparted is attributed to chemical modification which makes the cellulose polymer detrimental to micro-organism. Cross linking protect from...
Relevant data from Table 3 indicates that with the application of 4-12% PEG with 10% Citric Acid, rot resistance performance is significantly increased with increase in PEG concentration up to 10% as indicated by tensile strength% after soil burial test and at 12% PEG 400 concentration, only marginal improvement in % strength retention is achieved. From Table 2, it is evident that the strength retention% after 21 days soil burial test is 85% with two step sequential dyeing and finishing with 10% Citric Acid and 10% PEG, which is higher than the fabric treated with only CA. The same result (85% strength retention) can also be find in concurrent dyeing and finishing method with same formulation. Although CA is the main cross linking agent but PEG played an important role in reducing microbial activities. Different theories have been put forward to explain PEG’s antimicrobial mode of action. The thermal adaptability of the modified fabric is unique because of the latent heat provided by the bound polyols, and hence many other properties are also improved [22]. Highly hydrophilic properties inherent in PEG desiccate microbes by depriving them of moisture.PEG treated fabric also impart a surfactant effect preventing the bacteria or fungi from becoming permanently attached. Their ability to buffer temperature changes and retard changes in surface temperature occurs in the range where most of the microbes have optimum growth. The modified fabric never reaches the temperature conductive to optimum microbial growth and the microbial growth in fabric surface is inhibited [22].

The antibacterial activity of only bleached jute sample, conventional dyed and finished jute samples with formulation A and B as well as that of simultaneously dyed and finished samples are also measured with AATCC Test method 100 and tabulated in Table 4. The only bleached sample showed least extent of antibacterial activity among the five categories of the samples. Both the antimicrobial formulation showed excellent antimicrobial property than that of nil controlled bleached jute sample. However, the sample treated with both CA & PEG showed slightly higher antibacterial property. In both the cases simultaneous dyed and finished jute fabrics gave more or less similar extent of overall antibacterial activity compare to two step sequential dyed and finished jute fabric.

**Reaction Mechanism:** Citric acid reacts with jute cellulose to form ester via citric anhydride formation [10, 20 and 21] as
Citric acid also reacts with Poly ethylene glycol and form ester.

During \( \text{H}_2\text{O}_2 \) bleaching of jute, some of the \( \text{CH}_2\text{OH} \) of Cellulose may convert to \( -\text{CHO} \) group and may react with PEG to form acetal\textsuperscript{14,15}.

PEG or \((\text{EG})_n\) also reacts with Acid dye and with Jute Hemicellulose and form a complex.
3.2. Effect of One Step Simultaneous Dyeing and Crease and Rot Resistant Finishing on Surface Appearance and Colour Values of Jute Fabric

Corresponding surface colour strength ($K/S$ value) brightness index (BI), metamerism index (MI), total colour difference ($\Delta E$), lightness-darkness ($\Delta L$), redness-greenness ($\Delta a$), yellowness-blueness ($\Delta b$), chroma ($\Delta C$) and hue ($\Delta H$) values [39,40, 41, 42] etc for 3% $H_2O_2$ bleached control jute fabric dyed with selective acid dye, jute fabric subjected to conventional two step process of acid dyeing and crease/rot resistant finishing and jute fabric subjected to one step simultaneous acid dyeing and crease/rot resistant finishing using different concentrations of CA, and CA-PEG are shown in table 5 and 6. There is an increase in the colour strength ($K/S$) value at $\lambda_{max}$ from 0.712 (for 3% $H_2O_2$ bleached control fabric) to 1.25 (for dyed fabric) after dyeing of the bleached jute fabric with a selective acid dye (Acid-Yellow GL) for 1% (on weight of fabric) depth of shade.

Table 5. Surface appearance and other colour parameters of CA- treated jute fabrics dyed with acid Yellow GL by both two step sequential and single step simultaneous process.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>$K/S_{\max}$</th>
<th>$\Delta E$</th>
<th>$\Delta L$</th>
<th>$\Delta a$</th>
<th>$\Delta b$</th>
<th>$\Delta C$</th>
<th>$\Delta H$</th>
<th>BI</th>
<th>MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Nil Control Bleached Jute)</td>
<td>0.712</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>49.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid Yellow GL Dyed Jute</td>
<td>1.25</td>
<td>17.70</td>
<td>-5.86</td>
<td>2.17</td>
<td>16.56</td>
<td>16.69</td>
<td>0.81</td>
<td>26.24</td>
<td>14.25</td>
</tr>
<tr>
<td>Two-step sequential application of 1% acid dye followed by CA 10%-SHP 6 % (Formulation-A)</td>
<td>2.21</td>
<td>17.44</td>
<td>-5.32</td>
<td>2.74</td>
<td>18.86</td>
<td>16.58</td>
<td>0.92</td>
<td>12.46</td>
<td>12.26</td>
</tr>
<tr>
<td>Single step simultaneous dyeing (1% acid dye Yellow GL) and Rot and crease finishing (using following variations by pad-dry-cure technique)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulation A1 CA 6% Acid dye 1% SHP 6%</td>
<td>1.14</td>
<td>14.95</td>
<td>-4.42</td>
<td>4.32</td>
<td>17.45</td>
<td>14.24</td>
<td>1.12</td>
<td>12.05</td>
<td>12.16</td>
</tr>
<tr>
<td>Formulation A2 CA 8%</td>
<td>1.65</td>
<td>14.43</td>
<td>-3.35</td>
<td>4.65</td>
<td>18.30</td>
<td>13.98</td>
<td>1.24</td>
<td>12.21</td>
<td>12.34</td>
</tr>
<tr>
<td>Formulation A3 CA 10%</td>
<td>2.32</td>
<td>13.52</td>
<td>-2.54</td>
<td>4.87</td>
<td>18.67</td>
<td>13.22</td>
<td>1.26</td>
<td>12.49</td>
<td>13.27</td>
</tr>
<tr>
<td>Formulation A4 CA 12%</td>
<td>2.67</td>
<td>12.88</td>
<td>-1.16</td>
<td>5.65</td>
<td>19.24</td>
<td>12.76</td>
<td>1.35</td>
<td>10.57</td>
<td>13.56</td>
</tr>
<tr>
<td>Formulation A5 CA 14%</td>
<td>2.75</td>
<td>12.36</td>
<td>-0.74</td>
<td>5.82</td>
<td>19.33</td>
<td>12.26</td>
<td>1.37</td>
<td>10.05</td>
<td>13.74</td>
</tr>
</tbody>
</table>
In two step conventional and sequential dyeing and rot and crease resistant finishing by acid Yellow GL (1%) and CA, corresponding K/S value at $\lambda_{\text{max}}$ is 2.21, whereas the same obtained by single step simultaneous dyeing and rot and crease resistant finishing a slightly higher K/S value is found to be some extent higher with increase in amount of CA in table 5. The same trend is also found with CA-PEG rot and crease resistant formulation for increase in PEG concentration in table 6. The increase in surface colour strength for one step simultaneous dyeing and rot and crease resistant finishing may be due to the combine effect of acidic degradation and structural loosing effect in jute fibre due to this action of CA-PEG.

The colour difference values ($\Delta E$, $\Delta L$, $\Delta a$, $\Delta b$ and CDI) of different variations of CA and CA-PEG is also tabulated in table 5 and 6. Relevant results indicate that Formulation A3 (using CA-10% and SHP 4%) in table 5 and Formulation B4 (CA 10%, PEG 10% and SHP- 4%) in table 6, show higher K/S values than that of same dyeing and finish obtained by two stage conventional process with minimum $\Delta b$ i.e. less tonal change to blue and yellow, with lesser tenacity loss percentage.

The observed reduction in Brightness index for dyeing only and more on dyeing and finishing by two step conventional process and further more by one step simultaneous dyeing and Rot and crease resistant finishing, may be explained by the increase in diffused reflection for dye molecules and finishing chemicals fixed or adhered to jute changing its reflection pattern making it more diffused to reduce the overall brightness. However the best two formulations 3c and 6c shows quite a lower MI, indicating a better closer match possibility in any case.

### 3.3. FTIR-Spectroscopic Study

Fig 2 shows FTIR spectra of Dyed Jute (2a); dyed and CA treated jute fabric (2b); Dyed- CA- PEG treated jute fabric (2c) from wave no. 4000 cm$^{-1}$ - 500 cm$^{-1}$. The spectra of dyed jute (2a) showed characteristics broad peaks at 3344 cm$^{-1}$ (for H bonded H-O Stretching), 1649 cm$^{-1}$, 1030 cm$^{-1}$ (assigned to aromatic C-H in plane deformation & C-O deformation for primary alcohol in lignin), 897 cm$^{-1}$ (for $\beta$-glycosidic linkage). CA treated jute fabric (Fig. 2b) showed additional broad peaks at, 2868 cm$^{-1}$ (for alkyl C-H stretching), 1722 cm$^{-1}$ (showed esterification of jute led to increased peak area -CO-stretching). This can be explained by the formation of ester linkage as a result of reaction between cell-OH group and citric acid [20, 21] and 814 cm$^{-1}$ (for substituted benzene of jute). In case of CA and PEG 400 treatment, addition of PEG with CA (Fig. 2c) has shifted the peak at 3337 cm$^{-1}$ from 3358 cm$^{-1}$, this is due to alcohol group R-OH stretching and it is seen that peak of 1722 cm$^{-1}$ has shifted to 1738 cm$^{-1}$ with broad area which indicate a very strong C-O stretching of saturated aliphatic ester. These suggest that PEG has an effect in increasing the degree of esterification reaction with jute and CA.

### 3.4. Effect of One Step Simultaneous Dyeing and Finishing on Fastness Properties of Jute Fabric

Table 7 indicate the colour fastness to wash, light and rubbing for acid dyed jute fabric, acid dyed and rot and crease resistant finished jute fabric obtained by conventional two step process of acid dyeing and rot and crease resistant finishing and acid dyed and rot and crease resistant finished jute fabric obtained by one step simultaneous dyeing and rot and crease resistant finishing by pad-dry-cure process.

Bleached jute fabric dyed (by exhaust process) with 1% acid dye using selective acid dye, (Acid-Yellow GL) without any anti-microbial and crease resistant finishing shows colour fastness to wash 2 (change in shade) and 3 (Staining on cotton). Colour Fastness to wash for formulation A improves by 1 grade and for formulations A3, B, B4 it further improve by 1 grade. Rubbing fastness (Dry) for formulation A improves by only half grade and for formulation A3, B, B4 it show 4 where light fastness for all the formulations remain same.

The improvement of rubbing fastness after acid dyed jute fabric with crease resistance and anti-microbial finishing either by sequential or by simultaneous one step process can be viewed as cross linking effect of CA and PEG over the dyed fabric surface [23]. One grade higher improvement of rubbing fastness by single step simultaneous dyeing and finishing may be explained by possibly higher amount of dye-penetration assisted by padding pressure in pad-dry-cure process.

Wash fastness depend on either insolubilisation of dye present/anchored in the fibre on type of anchoring bond/interactional force restricting dye molecules to come out from
the fibre substrate. Addition of PEG irrespective of technique followed shows 1 grade improvement in wash fastness, which can be viewed as an effect of possible cross linking of CA with PEG and acid dye [23, 24].

4. Conclusions

From the present study it is revealed that combination of CA and PEG finished fabric shows adequate wrinkle resistance, high tensile strength retention property and higher colour value of jute fabric and also rendered high anti-microbial property as indicated by soil burial test and antibacterial test AATCC 100 as compared to untreated fabric. The optimum performance were obtained when jute were treated with 10% CA, 10% PEG 400 with 6% Sodium hypo phosphate monohydrate(catalyst) and cured at 150°C for 5 min.

Irrespective of the technique followed, the surface colour strength of simultaneous dyed and anti-microbial and crease resistant finished jute fabric is found to increase with an increase the percentage of application of both the rot and

Fig. 2. FTIR Spectroscopy of Dyed jute fabric (2a), Dyed and CA treated jute fabric (2b) and Dyed and CA &PEG treated jute fabric (2c).
crease resistant finishing chemicals from and beyond which it almost tends to level off. The fastness parameters are also satisfactory.

Table 7. Effect of Application of Selective Acid Dye and CA or CA and PEG by One-Step Simultaneous Pad-Dry-Cure Method on Colour Fastness Properties of Jute Fabric.

<table>
<thead>
<tr>
<th>Treatment and Formulation No.</th>
<th>Fastness to wash (ISO II)</th>
<th>Fastness to Light (BS 1006: BOI: 1978)</th>
<th>Fastness to Rubbing (Dry)IS: 766-1956</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyeing with 1% acid dye(Yellow GL, exhaust process) without any finishing chemicals</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Two-step sequential application of 1% acid dye followed by Formulation-A</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Single step simultaneous dyeing (1% acid dye Yellow GL) and finishing by Formulation-A3</td>
<td>4</td>
<td>3-4</td>
<td>4</td>
</tr>
<tr>
<td>Two-step sequential application of 1% acid dye followed by Formulation-B</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Single step simultaneous dyeing (1% acid dye Yellow GL) and finishing using Formulation-B4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Single step simultaneous dyeing (with acid dye) and crease resistance and anti-microbial finishing (with CA, PEG and SHP) of jute fabric by pad-dry-cure technique offers savings in energy, process time, giving satisfactory colour strength and other physical parameter as compared to the conventional two-step sequential dyeing and crease resistance and anti-microbial finishing process.

References


