Stress-strain properties of Merino, Chokla and Rambouillet x Chokla wet yarns

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Merino, Chokla and Rambouillet x Chokla single ply yarns of 8 Nm tex were dyed (at pH 2.5, 4.5 and 6.5) for 1h and 3h and boiled in distilled water for the same periods. The wet yarns were tested for stress-strain properties and the different parameters were analyzed statistically. The stress at 2, 15 and 30% extension and the hooken slope increased due to the treatments while the breaking stress and extension decreased. pH 2.5 treatment resulted in maximum lowering of stress values in Merino and crossbred yams. pH 4.5 and pH 6.5 treatments resulted in better stress values. In general, Chokla yarn scored higher values.

Keywords: Chokla wool, Dyeing, Merino wool, Rambouillet x Chokla wool, Stress-strain properties, Wool yarn

1 Introduction
The stress-strain properties of yarns are influenced by fibre properties, yarn geometry, processing treatments and conditions of testing. It has been reported earlier that dyeing at different pH influences the yarn properties and that there are differences among the yarns of different origins. The fibres from such dyed yarns also vary in their stress-strain properties, indicating macro and micro molecular structural changes in the fibres. The yarns spun from Merino, Chokla and Rambouillet x Chokla fibres when dyed at different pH and tested at 65 ± 5% RH and 27 ± 2°C for their stress-strain properties indicated the influence of the treatments. In the present work, these yarns have been tested in wet condition at 27 ± 2°C.

2 Materials and Methods
The source of wool, quality of yarn and treatments were same as reported earlier. The yarns were immersed in distilled water over night. Next day, the wet yarns of 20 cm length were tested on Instron machine at 27 ± 2°C, the crosshead and chart speeds being kept at 25 cm/min and 20 cm/min respectively. The average tex of yarn found at 65 ± 5% RH in the earlier experiments was used for calculating the stress-strain properties. The data were analyzed by the standard procedure.

3 Results and Discussion
The statistical analysis of the data is given in Tables 1 and 2. The stress-strain curves of R x C yarn after 3h treatment are shown in Fig. 1.

3.1 Stress at 2% Extension
In general, the curve parameters increase due to treatments. The values differ because of genetic

Fig. 1—Stress-strain curves of Rambouillet x Chokla yarns (3h treatment) [T1—untreated; T2—dyed at pH 2.5; T3—dyed at pH 4.5; T4—dyed at pH 6.5; and T5—treated in boiled-water]
groups and treatments in all the cases. The interaction is significant in 3h treatment. In general, pH 4.5 and pH 6.5 treatments (T$_3$, T$_4$) score higher values. However, in Chokla, pH 2.5 treatment increases $F_2$. Among the wools, Chokla scores higher value. As in Avikalin yarn, dyeing of Merino and R × C yarns at pH 6.5 and pH 4.5 increases the wet strength up to 2% extension whereas dyeing at pH 2.5 weakens the yarns. The present result probably indicates that matrix associated with microfibril prevents plasticising and the inter-fibre cohesion is increased due to wetting.

### 3.2 Stress at 15% Extension

In general, the curve parameters increase. The values differ significantly due to genetic groups. pH 4.5 and pH 6.5 treatments score significantly higher values. In all the 1h treatments, Chokla scores significantly higher values than Merino and R × C. In 3h treatment, all the breeds are at par in control, pH 6.5 and boiling-water treatments. At pH 2.5, Chokla scores a significantly higher value than Merino and at pH 4.5, R × C scores a significantly higher value than the rest.

### 3.3 Stress at 30% Extension

In general, the curve parameters increase. All the effects are significant except genetic group differences in 3h treatment.

In Merino yarns, pH 4.5 treatment results in a significantly higher value than the rest in 1h treatment whereas in 3h treatment, it is at par with the boiling-water (T$_1$) and pH 6.5 (T$_4$) treatments. In 1h treated Chokla yarns, pH 4.5 and pH 6.5 treatments group together and score the highest values whereas in 3h treated Chokla yarns, pH 6.5 treatment results in lower values. This indicates the structural differences in Chokla yarns compared to the other two. In the crossbred yarns also, pH 6.5 and pH 4.5 treatments take the first and second places on the higher side and pH 2.5 treatment results in the least value both in 1h and 3h treatments.

Among untreated (T$_1$) and pH 2.5 treated yarns, all the genetic groups differ significantly from one another with Chokla on higher side after 1h treatment whereas the breeds are at par in control and Chokla scores a significantly higher value than R × C in 3h, pH 2.5 treatment. At pH 4.5, Chokla scores a higher value. Dyeing for 1h at pH 6.5 results in grouping Chokla and crossbred yarns on the higher side whereas dyeing for 3h results in grouping Merino and R × C on the higher side. The boiling-water treatment for 1h keeps all the yarns at par, whereas

### Table 1—Effect of genetic group, treatment and their interaction on curve parameters of yarns treated for 1h

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degree of freedom</th>
<th>$F_2$</th>
<th>$F_{15}$</th>
<th>$F_{50}$</th>
<th>$H$</th>
<th>$Y$</th>
<th>$PY$</th>
<th>BS</th>
<th>BE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic group</td>
<td>2</td>
<td>0.1143*</td>
<td>0.2753*</td>
<td>0.1958*</td>
<td>342.8660*</td>
<td>0.0622</td>
<td>0.6750</td>
<td>0.3352*</td>
<td>112.28*</td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>0.0116*</td>
<td>0.1294*</td>
<td>0.1650*</td>
<td>3.0278</td>
<td>1.1107*</td>
<td>7.8216*</td>
<td>0.1238</td>
<td>53.2687*</td>
</tr>
<tr>
<td>Interaction</td>
<td>8</td>
<td>0.0024</td>
<td>0.0339</td>
<td>0.0440*</td>
<td>11.2291</td>
<td>0.2216</td>
<td>1.6202*</td>
<td>0.0976</td>
<td>15.7566</td>
</tr>
<tr>
<td>Error</td>
<td>135</td>
<td>0.0024</td>
<td>0.0197</td>
<td>0.0031</td>
<td>9.5942</td>
<td>0.3423</td>
<td>0.8259</td>
<td>0.0740</td>
<td>13.1292</td>
</tr>
</tbody>
</table>

Results of Duncan's multiple range test:

- $G_1$—Merino; $G_2$—Chokla; $G_3$—Rambouillet × Chokla; $T_1$—Untreated yarn; $T_2$—Dyed at pH 2.5; $T_3$—Dyed at pH 4.5; $T_4$—Dyed at pH 6.5; and $T_5$—Treated in boiled water.
- The values of $F_2$, $F_{15}$, $F_{50}$, $H$, $Y$, $PY$ and BS are in g/tex.
- Any two means in same parantheses do not differ significantly.
- *Significant at 1% level; "Significant at 5% level."
### Table 2—Effect of genetic group, treatment and their interaction on curve parameters of yarns treated for 3h

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>$F_2$</th>
<th>$F_{15}$</th>
<th>$F_{30}$</th>
<th>$H$</th>
<th>$Y$</th>
<th>$PY$</th>
<th>$BS$</th>
<th>$BE$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic group</td>
<td>2</td>
<td>0.1568</td>
<td>0.0287</td>
<td>0.0743</td>
<td>444.5036</td>
<td>1.7066</td>
<td>4.5068</td>
<td>0.3690</td>
<td>336.0200</td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>0.0593</td>
<td>0.4678</td>
<td>0.2423</td>
<td>90.0273</td>
<td>2.5816</td>
<td>22.6409</td>
<td>1.0440</td>
<td>122.7650</td>
</tr>
<tr>
<td>Interaction</td>
<td>8</td>
<td>0.0126</td>
<td>0.1292</td>
<td>0.0953</td>
<td>29.0459</td>
<td>2.3238</td>
<td>14.4253</td>
<td>0.0693</td>
<td>113.0475</td>
</tr>
<tr>
<td>Error</td>
<td>135</td>
<td>0.0032</td>
<td>0.0318</td>
<td>0.0443</td>
<td>10.0662</td>
<td>0.4106</td>
<td>0.2783</td>
<td>0.0744</td>
<td>7.1373</td>
</tr>
</tbody>
</table>

Results of Duncan's multiple range test

- $G_1$: Merino; $G_2$: Chokla; $G_3$: Rambouillet × Chokla; $T_1$: Untreated yarn; $T_2$: Dyed at pH 2.5; $T_3$: Dyed at pH 4.5; $T_4$: Dyed at pH 6.5; and $T_5$: Treated in boiled water.

The values of $F_2$, $F_{15}$, $F_{30}$, $H$, $Y$, $PY$ and $BS$ are in g/tex.

Any two means in same parantheses do not differ significantly.

*Significant at 1% level; "Significant at 5% level.

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In 3h treatment, Merino scores a significantly higher value than Chokla.

#### 3.4 Hookean Slope

The treatment effect is significant in 1h whereas all the effects are significant in 3h treatment. In all the 1h treatments, all the breeds differ significantly from one another with Chokla scoring the highest value. In 3h treatment, pH 6.5 treated Merino yarn and pH 4.5 treated Chokla and R × C yarns score higher values. In general, Chokla scores higher values due to treatment. Unlike in air test, R × C yarn improves over Merino in wet strength due to treatment.

#### 3.5 Yield Slope

In 1h, only the treatments differ significantly with boiling water followed by control at par with pH 6.5 treatment being on the higher side. In 3h, all the effects are significant. In Merino, pH 6.5 treatment scores a significantly higher value than pH 4.5 treatment. In Chokla, control scores a significantly higher value than pH 2.5 and boiling-water treatments. In R × C, pH 4.5 treatment scores a significantly higher value than the rest.

In control, pH 2.5 and pH 6.5 treatments, all the breeds are at par. In pH 4.5 treatment, R × C scores a significantly higher value than the rest and in boiling-water treatment Merino scores a significantly higher value than Chokla.

#### 3.6 Post Yield Slope

In general, the values decrease due to treatments. The slopes differ significantly due to treatments and the interaction is significant in both 1h and 3h treatments. The genetic groups differ significantly only in 3h treatment.

The pH 4.5 treated Merino yarn ($T_3$) scores the lowest value both in 1h and 3h treatments. In Chokla, control yarn scores the highest value. In the crossbred yarns, pH 2.5 and pH 4.5 treated samples score lower values than the rest.

The genetic groups are at par in all the 1h treatments except pH 6.5 treatment. Chokla scores higher values in control and pH 4.5 treatments whereas Merino scores higher values in pH 2.5 and boiling-water treatments. In pH 6.5 treatment, crossbred differs significantly from Chokla. In pH 2.5, pH 6.5 and boiling-water treatments for 3h, merino scores significantly the highest values.
3.7 Breaking Stress
In 1h treatment, the effects due to genetic group are significant and in 3h treatment, the effects due to breeds and treatments are significant. In 1h, only crossbred scores significantly the lowest value. In 3h, pH 6.5 treatment scores significantly the highest value in all breeds put together and Merino scores the highest in all treatments put together.

3.8 Breaking Extension
The breaking extension generally decreases due to treatment. The values differ significantly due to genetic groups and treatments. Interaction is significant only in 3h treatment. In 1h treatment, the extension in all the genetic groups is significantly higher in pH 2.5 treatment than the rest except control which is at par. The extension in pH 4.5 boiling-water and pH 6.5 treatments are at par and significantly the lowest. In all the treatments, Merino scores a significantly higher extension than the rest. In 3h, boiling-water treated Merino yarn, pH 2.5 and pH 4.5 treated Chokla yarn and pH 4.5 treated R × C yarn score significantly the lowest values. Except in boiling-water treatment, Merino scores higher values.

4 Conclusions
4.1 Both in 1h and 3h treatments, the values of F2, F15, F30 and H increase due to dyeing and boiling-water treatments. This indicates possible extra crosslinking and association of dye molecules in the molecular structure of the wools, improving the cohesion of fibres in the yarn structure.

4.2 The values of Y, PY and BE decrease after 1h treatment. After 3h, Y shows a mixed trend whereas PY and BE decrease. This indicates that the yarn structure is loosened due to the treatments and there is lack of cohesion when extensibilities are considered. However, after 3h, further deposition of dye probably improves cohesion. But the cohesion is not able to bear the loads beyond certain limits and, therefore, the breaking extension decreases due to the treatments.

4.3 The decrease in breaking stress both in 1h and 3h treated samples indicates the weakening of the yarn due to these treatments.

4.4 In the test at 65% RH, Chokla yarn scores higher values, indicating its structural difference from the rest.

4.5 The pH 2.5 treatment results in maximum lowering of the stress values, mostly in Merino and crossbred yarns. However, sometimes it supports the strength in Chokla yarns. The pH 4.5 treatment generally results in better stress values. Sometimes pH 6.5 treatment results in better stress values. These findings are similar to those reported for Avi-kalin yarns.

References
8 Duncan David B, Biometrics, 13 (1957) 165.