Summary and Conclusion
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Clothing is an important interface between the human and the environment. With technology moving at warp speed, today’s garments must work harder than ever before. This refers to protective clothing for both industrial and consumer use. Protective clothing refers to garments and other fabric related items designed to protect the wearer from hazardous environment. The most prevalent hazard encountered in everyday life is the threat from the natural environment. The hazards include heat, cold, rain snow, wind, dust, microorganisms and ultraviolet rays. These can cause problems during occupational, recreational and routine activities. Hence protective clothing is now a major part of textiles and classified as technical or industrial textiles.

The risk posed by ultraviolet radiation has become more dangerous in recent years as the whole world is suffering from all kinds of pollution. Consequently the damage in earth protective ozone layer has increased, there is considerable evidence that over exposure to ultraviolet radiation can cause sunburn, skin damage, premature skin ageing, eye disorders, suppress immune system and skin cancer. Thus it is important to protect the skin from excessive exposure to UV radiation.

For many years people around the world have relied on sunscreen alone as a primary source of sun protection. But the disadvantage is that it has to be reapplied after every three hours and wears off with sweating. In recent years increase interest is shown in the protective properties of clothing against harmful effects of UV radiation. Designing and modifying fabrics in such a way to offer high protection against UV radiation is a relatively new application. Sun protective clothing provides a better shield than sunscreen, since it never rubs off or requires reapplying. Thus clothing acts as a physical barrier that blocks radiation.
The latest trends aim at improving the quality and technical aspects of the products to such an extent that they not only provide UV protection function, but also meet aesthetic requirements and guarantee adequate wear comfort for the respective end use. Bamboo and Tencel are new age cellulosic fibres that can be made into garments which make people feel extremely cool and comfortable in hot summer.

Knitted fabrics have useful properties and they are porous and provide breathing comfort which are best suited for body fit garments. The distinctive property of a knitted fabric is its high extensibility in both length and width, which gives it the ability to take up the shape of the wearer and allows it to fit. The movement of these knitted yarn loops also helps in pumping air through close-fitting garments, thus removing body heat. The aesthetically pleasing appearance, loose elastic structure, comfort and softness of knits when compared to rigid wovens, make them ideal to be used in sportswear, innerwear, sweaters, casual wear and fashion apparel.

Novel textile materials with particular functions that can provide healthy benefits to people have attracted much attention from researchers in recent years. Only few studies have been carried out to find the ultraviolet protection factor of natural fabrics using UV absorber finish. Hence the investigator desired to study the “Effect of dye and UV absorber finish on Bamboo Cotton and Tencel Cotton knitted fabrics” with the following objectives,

- To elicit information among adolescents regarding awareness of UV protection
- To blend Bamboo and Tencel with Cotton fibres
- To produce single jersey knitted fabric using the blended yarns
- To wet process the produced knitted fabric with reactive dye and UV absorber finish
• To subject the finished fabrics to wear study
• Evaluate the fabrics for visual, mechanical, geometrical, comfort and colour fastness properties
• Analyse the ultraviolet protection factor.

The methodology of the study involved the following:

Survey

Survey was conducted among 200 adolescent (100 boys and 100 girls) involved in sports activity to elicit information regarding sportswear and sun protection practices adopted by them.

➢ Selection of raw material

Bamboo and Tencel are new age cellulosic fibres. Bamboo fibre apparel can absorb and evaporate sweat in a split second. Tencel fabric results in outstanding wear comfort and are breathable and moisture absorbent. Cotton most popular among natural fibre is admired by the consumers for its fascinating feel and comfort. Hence, apparels made from these fibres make people feel cool and comfortable in hot summer. Due to their excellent properties these three fibres were selected.

➢ Evaluation of fibre properties

The physical properties of fibres measured were length, fineness, strength and elongation.

➢ Physical Properties of Bamboo, Tencel and Cotton fibres

The physical properties of fibres measured were Length, Fineness, Strength and Elongation.
Conversion of Fibre into Yarn by Ring Spinning

Bamboo and Tencel fibres were spun into yarn with cotton to get the respective blended yarns. The spinning process consisted of opening, blending the Bamboo and Tencel fibres with cotton, preparation of fibre lap, carding, drawing, speed frame, ring spinning and cone winding. Two types of yarns were prepared namely Bamboo Cotton – 70/30 and Tencel Cotton - 70/30.

Testing the Yarns

The Bamboo Cotton and Tencel Cotton blended yarns were tested for their Yarn Count, Breaking Strength, Twist per Inch, Evenness, Imperfections and Hairiness.

Fabric Preparation

The Bamboo Cotton and Tencel Cotton blended yarns were knitted in a circular machine using single jersey structure.

Processing the Fabric

The original fabrics were then subjected to scouring, bleaching, dyeing and application of UV absorber finish. The fabrics were dyed in reactive dyes of three colours namely Brown, Mustard and Navy blue. Each colour was dyed in medium and dark shade. To enhance the effectiveness of UV absorber, dyeing and finishing done simultaneously.

Testing the Fabric – Laboratory Tests

The original and treated Bamboo Cotton and Tencel Cotton fabrics were subjected to visual evaluation and laboratory tests using standard procedures.
• **Visual Evaluation**

All the twenty six fabric samples were displayed for evaluation. The judges were asked to evaluate the samples in terms of general appearance, brilliancy of colour, evenness of dyeing, texture and lustre.

• **Laboratory Tests**

Laboratory tests carried out included Fabric Weight, Fabric Thickness, Angle of Spirality, Bursting Strength, Drapability, Pilling, Absorbency Tests, Air Permeability, Dimensional Stability, Flammability, Colour Fastness, Print Durability and UV Analyzer Tests.

• **Analysis of Results**

The results were analyzed statistically using analysis of variance test.

➢ **Wear Study**

The treated fabrics were constructed into T-shirts. Adolescent sports person were asked to wear the T-shirt. After wear T-shirts were subjected to washing. After 1, 5, 10, 15 and 20 washes ultraviolet protection factor of the fabric was tested. Subjective evaluation of T-Shirt was done in terms of comfort, absorbency and cooling effect.

**FINDINGS OF THE STUDY**

**Survey**

• Majority of the respondents were interested in cricket (27 per cent), Athletics (22 per cent), Volleyball (16 per cent) and Football (23 per cent).

• Regarding the type of garments, it was noted that boys (58 per cent) wore T-Shirt and shorts and 32 per cent preferred tracksuit whereas 82 per cent girls preferred full pants and top.
Regarding make of garments, 54 per cent of adolescents preferred tailor made and 45 per cent preferred readymade sports clothing.

Majority of the adolescents (94 per cent) adopted home wash only.

Majority of adolescents (74 per cent) preferred drying in sunlight rather than in shade.

Majority of adolescents (38 per cent) reported tanning as a major problem and 20 per cent of adolescents felt headache, 16 per cent experienced skin burning and 11 per cent felt burning of eyes and rashes as problem while playing in the sun.

While analyzing the awareness of harmful effects of ultraviolet radiation only 36 per cent of the boys and 34 per cent of girls were aware of the harmful effects of ultraviolet radiation.

Considering the awareness of the adolescents about the effects caused by ultraviolet rays. Skin tanning and ageing was considered as a major harmful effects by 31 per cent of adolescents. Twenty nine per cent of adolescents stated skin cancer as a harmful effect of UV radiation.

Regarding familiarity with protection factors only thirty two per cent of boys and twenty per cent of girls were aware of SPF whereas 28 per cent of boys and 26 per cent of girls were aware of UPF factor.

With regard to the knowledge about UV block fabrics majority of adolescents (boys – 70 per cent and girls – 94 per cent) were not aware of the existence of UV block fabrics.

Need to create awareness programme among adolescents on the harmful effects of ultraviolet radiation has been felt hence an awareness programme was conducted (The details are concised into a booklet and given in Appendix IV.
Fibre Testing

Physical properties of Bamboo, Tencel and Cotton are given below.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Bamboo</th>
<th>Tencel</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>38 mm</td>
<td>38 mm</td>
<td>30 mm</td>
</tr>
<tr>
<td>Fineness</td>
<td>1.2 Denier</td>
<td>1.2 Denier</td>
<td>4.0 Denier</td>
</tr>
<tr>
<td>Strength</td>
<td>18 g/tex</td>
<td>40 g/tex</td>
<td>23 g/tex</td>
</tr>
<tr>
<td>Trash</td>
<td></td>
<td></td>
<td>2.5%</td>
</tr>
<tr>
<td>Uniformity</td>
<td></td>
<td></td>
<td>47 ratio</td>
</tr>
<tr>
<td>Short Fibre Index</td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>Elongation</td>
<td></td>
<td></td>
<td>5.5%</td>
</tr>
</tbody>
</table>

Yarn Testing

- **Yarn Count**

  The Bamboo Cotton and Tencel Cotton blended yarns had similar counts namely 30s.

- **Breaking Strength**

  The breaking strength of Tencel Cotton was higher (85.60 lbs) than Bamboo Cotton yarn (39.63 lbs).

- **Count Strength Product**

  Count strength product was high (2580) for Tencel Cotton yarns and for Bamboo Cotton yarns (1538).

- **Twist Per Inch**

  The twist per inch for Bamboo Cotton and Tencel Cotton was 20.67 and 19.55 respectively.
• **Unevenness**

The unevenness (U%) in case of Bamboo Cotton and Tencel Cotton yarns were 11.20 and 10.28 respectively.

• **Appearance**

The ASTM black board appearance tests done for Bamboo Cotton and Tencel Cotton showed C+ grade and B grade respectively.

• **Imperfection**

Imperfections in yarn for Bamboo Cotton was found to be higher (583) than that of Tencel Cotton (47).

• **Hairiness**

Hairiness of Bamboo Cotton was 5.58 whereas the same for Tencel Cotton was 5.13.

➢ **Fabric Testing**

The original and treated samples were subjected to visual evaluation and laboratory tests. The results are as follows:

• **Visual Evaluation**

All the Bamboo Cotton and Tencel Cotton samples were rated as good in general appearance, bright in colour, even in dyeing, smooth in texture and high in lustre, by majority of the judges. The Bamboo Cotton brown dark dyed and UV finished sample (BCBDDUV) has obtained good rating of 95 per cent. The Tencel Cotton brown dark dyed and UV finished sample (TCBDDUV) was rated as good by 95 per cent of the judges.
Laboratory Tests

**Fabric Weight**

All the Bamboo Cotton samples irrespective of dye, shade and UV finish showed an increase in fabric weight when compared to original. The Bamboo Cotton samples dyed and UV finished irrespective of dye and shade showed further increase in fabric weight when compared to the dyed samples.

All the Tencel Cotton samples irrespective of dye, shade and UV finish showed an increase in fabric weight when compared to their original. The dyed and UV finished samples showed further increase in fabric weight when compared to dyed samples. The increase in fabric weight was due to the dye and UV absorber finish given to the samples.

**Fabric Thickness**

There was reduction in fabric thickness of all the Bamboo Cotton and Tencel Cotton dyed, dyed and UV finished samples when compared to their originals. The reduction in thickness of samples was due to the finishes given to the fabric.

**Angle of Spirality**

The Bamboo Cotton and Tencel Cotton dyed and UV finished samples showed better spirality when compared to dyed samples irrespective of colour and shade.

**Bursting Strength**

The Bamboo Cotton and Tencel Cotton dyed, dyed and UV finished samples irrespective of dye and shade showed decrease in bursting strength when compared to their originals. The dyed and UV finished samples showed further reduction in bursting strength than dyed samples. The decrease in bursting strength was due to the finishing treatment given to the samples.
**Drapability**

All the Bamboo Cotton and Tencel Cotton samples irrespective of dye, shade and UV finish showed reduction in drape values when compared to their originals. This proves that finishing has improved the drapability of the samples. Hence Bamboo Cotton and Tencel Cotton samples exhibit good drapability.

**Pilling**

The pilling test revealed that the Bamboo Cotton and Tencel Cotton samples irrespective of dye, shade and UV finish showed improvement in pilling when compared to their originals. The dyeing and UV finish has improved the pilling of fabrics.

**Drop Test**

The time taken to absorb water by Bamboo Cotton and Tencel Cotton samples irrespective of dye, shade and UV finish was less when compared to their original. Bamboo fabrics can absorb and evaporate human sweat in split second. Tencel absorbs fifty per cent more moisture than cotton. Hence the Bamboo Cotton and Tencel Cotton fabrics can absorb sweat quickly and transport it to the outer surface of the garment and due to above mentioned reason these fabrics can be used for summer wear and sports wear.

**Wicking Test**

The wickability, of both Bamboo Cotton and Tencel Cotton treated samples, was good when compared to their originals. The dyed and dyed and UV finished samples showed good wickability which is important function other than breathability and protecting skin from UV rays for sport wear. Hence these fabrics can be recommended for sportswear.
Air Permeability

It was observed that there was decrease in air permeability of all the Bamboo Cotton and Tencel Cotton samples when compared to their originals. Dyeing and UV finish have reduced the air permeability of fabrics.

Dimensional Stability

Original samples showed shrinkage in both length and width direction. The Bamboo Cotton and Tencel Cotton dyed, dyed and UV finished samples showed shrinkage in width direction and extension in lengthwise direction.

Flammability

The flammability of Tencel Cotton samples was better than Bamboo Cotton samples.

Colour Fastness Test

All the dyed and UV finished samples showed excellent fastness to dry crocking and very good to wet crocking. The colour fastness to perspiration was found to be good for all Bamboo Cotton and Tencel Cotton samples. The colour fastness to dry cleaning was found to be good. The colour fastness to washing was rated as very good for staining on acetate and wool fabrics whereas on other fabrics it was rated good.

Print Durability

In both Bamboo Cotton and Tencel Cotton T-shirts after one machine wash there was no noticeable colour change observed in the prints. The print durability was found to be satisfactory.

UV Analyzer

The original, dyed, dyed and UV finished Bamboo Cotton and Tencel Cotton samples were subjected to Ultraviolet Protection Factor (UPF) Test. It
was noted that Bamboo Cotton samples possessed Very Good UV protection than Tencel Cotton samples. The highest ultraviolet protection factor (58.1) was found in Bamboo Cotton dyed in dark shade of Navy blue with UV finish (BCNDDUV) which offers Excellent UV protection and the Tencel Cotton sample (38.1) dyed in dark Navy blue shade with UV finish (TCNDDUV) which offers Very Good Protection. The fabrics were tested after 1, 5, 10, 15 and 20 washes.

After one wash all the Bamboo Cotton and Tencel Cotton fabrics irrespective of dye, shade and UV finished showed increase in UPF values when compared to their originals. The increase in UPF values was due to the shrinkage of fabrics after washing. The Bamboo Cotton samples irrespective of dye, shade and UV finish offers better UV protection when compared with Tencel Cotton samples. The maximum UPF value in Bamboo Cotton was seen in BCNDDUV (58.1) which offers excellent protection whereas sample TCNDDUV (38.1) in Tencel Cotton offers very good UV protection.

After 5 washes the UPF values further increased in all Bamboo Cotton and Tencel Cotton samples. The mean UPF values of all Bamboo Cotton were higher when compared to Tencel Cotton samples. There was no change upto 10 and 15 washes. There was a slight decrease in mean UPF values after 20 washes.

After 20 washes the mean UPF of all the Bamboo Cotton dyed samples ranges from 28.6-31.2 which offers Very Good UV Protection whereas mean UPF of all the Bamboo Cotton dyed and UV finished samples ranges from 33.1-34.9 which offers Very Good UV Protection. The maximum UPF value was seen in navy blue dark dyed with UV finish BCNDDUV (57.1) which offers Excellent Protection.

The mean UPF of all Tencel cotton dyed samples ranges from 24.0-31.9 which offers Very Good UV Protection whereas mean UPF of all the tencel cotton dyed and UV finished samples ranges from 28.2-38.2 which offers Very