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# EFFECT OF BIOPOLISHING TREATMENT ON VARIOUS SPUN YARN KNITTED FABRICS

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**ABSTRACT**
In this study, single jersey knitted fabrics manufactured using carded and combed yarns of same count were used. After the enzymatic treatment, it is observed that pilling resistance ratings of the fabric samples of combed yarn were better than the carded ring-spun yarn. Fabrics of combed yarns gave the best bursting strength values for untreated and enzymatic treated, than those of carded yarns. Knitted fabrics using combed yarns show the highest resistance to abrasion before and after enzymatic treatment.The significance colour difference values were also observed in fabric samples of enzyme-treatment after dyeing.

**KEY WORDS:** Bio-polishing, Carded yarn, Combed yarn, Cellulase Enzyme, Knitted Fabric, Pilling.

## INTRODUCTION

Pilling and fuzz, which was not a problem in previous years (especially for cotton fabrics), has become a major problem recently. Fibre type, the yarn spinning system, fabric type, and finishing process plays an important role in the pilling properties of fabrics. Enzymes are mostly used for bio-polishing process of fabrics which removes the pills and fuzz from fabric surface in order to improve the smoothness. Enzymes have been employed in the finishing process of cellulosic textile materials for many years. The advantages of the utilization of specified enzymes for finishing process of cellulosic fabrics are listed as follows; cleaner fabric surface with less fuzz, process simplification, reduced tendency to pill formation, cost reduction, environmentally friendly process, and improved handling properties of fabrics. The cellulase is the enzyme most widely used in finishing process of cellulosic fabric. Cellulase enzymes are nontoxic, environmental friendly biocatalysts which are primarily used to bio-polishing process. Biopolishing, also called bio-finishing, is applied to the fabrics to remove the pills and fuzz from fabric surface, in order to improve the smoothness, drape, flexibility and appearance, especially for knitwear and as a pre-treatment for printing. Fabric pilling is a complex phenomenon comprised of different stages, and it is influenced by several factors. Fiber type and cross-sectional shape, yarn type and construction, fabric type & construction and fabric finishes play an important role in the pilling properties of fabrics [1]. Many researchers have reported that, the spinning system affects the pilling resistance of fabrics. The yarns produced by different spinning systems have structural differences that are expected to impact upon pill resistance. The essential steps of ring spinning are opening, cleaning, carding and drawing of the fibers and spinning them into yarn with twist. So, ring-spun yarn has real twist and good fiber orientation. But in an open-end spinning system, a sliver is fed into the rotating rotor, and the twist is inserted as the yarn is removed from the rotor and formed into the yarn. Rotor spin yarn also has real twist but poor fiber orientation, with fibers wrapped around the yarn core [7, 14]. As a consequence of the difference in the spinning methods, the yarn constructions are different. Open-end yarns have a twisted core and loosely wrapped sheath with trailing loops, while ring-spun yarns are well aligned along the axis. Ring-spun yarns have good fiber orientation. As a result of this, the strength of ring-spun yarns is 15-20% greater than that of open-end spun yarns. But open-end yarns have lower strength and higher elasticity than the corresponding Ring-spun yarn. Due to the differences in spinning methods, Ring-spun yarns have approximately 20-40% higher hairiness than Open-end yarns [2, 3].

Pilling is a very serious problem, especially for knitted fabrics rather than woven fabrics. Although knitted fabrics have many advantages such as higher production rates along with lower production costs, comfortable and softer fabric structures, the pilling problem remains an important objection because of the slack fabric structure [4, 5and 12]. The problem associated with fuzz can also be eliminated in order to improve and maintain quality during the garment's life by removing the fuzz, by using treatments such as singeing or by applying a surface active agent such as silicon softener to soften the surface of the fabric, or by enzymatic bio-polishing. As a general rule, woven fabrics are singed to remove protruding fibers and give the fabric a smooth handle and surface appearance. On the other hand, knitted fabrics are not normally singed or defuzzed. Singeing involves the risk of scorching the fabric, whereas the use of surface-active agents reduces the water absorbency of the fabric. They are also washed out from the fabric, which eventually makes them rough again. However, enzymatic removal of the fuzz is absolutely safe, efficient and permanent as it is carried out under mild chemical and physical conditions with accurate control [8, 9, and 10]. The enzyme most widely used in finishing processes involving cellulosic fiber is cellulase. This enzyme is used extensively in the bio-polishing of cellulosic fabrics. Bio-polishing can be applied to the fabric to remove the pills and fuzz from fabric surface, to reduce the tendency of pilling, to improve the smoothness, drape, flexibility and luster. Bio-polishing consists of a cellulose enzyme treatment to give a partial hydrolysis of cotton; so the short fiber ends are hydrolysed, leaving the surface of the fibers free and providing a more even look. But it should be considered that there is also a loss of strength related to the amount of weight reduction [6, 11and13].

In this study, an attempt has been made to study the effect of enzymes on single jersey fabrics knitted using carded and combed yarn. An enzymatic process for fuzz reduction will be carried out at different stages, and the effect of this on pilling, strength, weight loss and the colour differences of the fabric are studied. Earlier cited literature does not show any results of such study, and therefore do not reflect the facts exactly. For this reason, all the phases of this study will be specifically carried out under common working conditions like those prevailing in the industry.

## EXPERIMENTAL

### Materials

Carded and combed ring-spun 24Ne cotton yarns were used for the study. The physical properties of the yarns are tabulated briefly in Table 1. By using these yarns, single jersey fabric samples were knitted on the sample- knitting machine in the laboratory conditions.

### Enzymatic treatment

Bio-polishing process was applied to the samples along with different finishing steps:

Process 1: - Enzymatic treatment after pre-treatment.
Process 2: - Enzymatic treatment after dyeing.

The cellulase enzyme G-ZYME VGB ST LIQ from Rossari Biotech Ltd. was used for enzyme treatments. Enzyme treatments were carried out at different temp, time & conc. as mentioned in Table 2. The fabric samples were dyed with Reactive Red HE7B. All tests will carried out in mill conditions. Enzymatic treatments were carried out in Mathis machine.

**TABLE 1.** Physical properties of yarns

| Parameter | Unit | Carded | Combed |
|---|---|---|---|
| Expected count | | $24^s$ | $24^s$ |
| Actual Count | | 23.4 | 23.6 |
| Twist | TPI | 16.7 | 16.58 |
| TM | | 3.4 | 3.38 |
| Twist Direction | | Z | Z |
| Tenacity | gf/tex | 2.2 | 2.29 |
| CV% | | 9.59 | 11.22 |
| Elongation | % | 16.35 | 16.4 |
| CV% | | 8.9 | 10.22 |
| Unevenness | % U | 12.28 | 10.02 |
| CV% | | 2.44 | 1.71 |
| Thin places (-50%) | - | 6 | 0 |
| CV% | | 110.82 | - |
| Thick places (+50%) | - | 254 | 49 |
| CV% | | 12.31 | 24.99 |
| Neps (+200%) | - | 332 | 59 |
| CV% | | 17.27 | 21.76 |
| Hairiness | - | 912.2 | 677.4 |
| CV% | | 3.29 | 11.16 |

**TABLE 2.** Variables

| Chemical | Acid Cellulase Enzyme | | |
|---|---|---|---|
| Time(mins) | Temperature(ºC) | Concentration (gpl) | Shade (%) |
| 30 | 30 | 3 | 0.5 |
| 60 | 45 | 6 | 1.5 |
| 90 | 60 | 9 | 3 |

### Testing

The properties of treated fabric were tested using standard test method. The GSM, Thickness, Bursting Strength, Pilling Resistance, Abrasion Resistance of the fabrics is measured according to ASTM D – 3776, ASTM D – 1777, ASTM D – 3786, ASTM D – 3512, ASTM D – 3884 test method.

### K/S value

The colour intensity values of the dyed fabrics were measured by using the Macbeth Coloureye®3000 Spectrophotometer Colorlab software.

Bursting Strength, Pilling Resistance, Abrasion Resistance results were analyzed for significance in differences using two- way replicated ANOVA, and the means were compared at 0.05 level using Minitab V. 15.0 software package.

## RESULTS AND DISCUSSION

### Effect of enzymatic treatment on GSM

From the Table 1 and Figure 1, it is clear that there is significant change in GSM values. In carded yarn knitted fabric enzymatic treatment after pretreatment shows higher GSM values in comparision to enzymatic treatment after dyeing and same results are observed in combed yarn knitted fabric samples. But in case of carded yarn the treatment at $30^0$ C for 60 min at 6 gpl concentration of enzyme, at 45°C for 30 & 90 min for 6 & 3 gpl concentration of enzyme and at 60°C for 60 min for 3 gpl concentration of enzyme, the value of GSM for process 1 is less than process 2 and the same result is shown in case of combed yarn at $60^0$C for 30 min for 9 gpl concentration of enzyme. But the GSM values of combed yarn knitted fabric is higher than the carded yarn knitted fabic samples. This may be because as there are more protruding fibres on the surface of carded yarn fabric as comapre to combed yarn fabric and because of this there will more surface eatching of fibres which results in loss in weight of the fabric.

**Effect of enzymatic treatment on thickness**

From the Table 2 and Figure 2, it is clear that there is significant change in thickness values. In carded yarn knitted fabric, enzymatic treatment after dyeing shows higher thickness values in comparision to enzymatic treatment after pretreatment and same results shows in combed yarn knitted fabric samples. But in case of carded yarn, at $30^0$ C for 30 min for 3 gpl the value of GSM of process 2 is less than process 1. But the thickness values of combed yarn knitted fabric is higher than the carded yarn knitted fabic samples. The reason for this is the high amount of mechanical forces and the long process period, which causes the removal of the fuzzes from the yarn surface.

**Effect of enzymatic treatment on bursting strength**

The Table 3 and Figure 3, shows the effect of enzymatic treatment on bursting strength of fabric. It is observed that there is decrease in bursting strenght of fabric manufactured using carded is more as compare to combed yarn fabric. This may be because of loss in thickness as well as loss in GSM of fabric which results in partly hydrolyses the cotton, which has a negative effect on fabric strength level. Fabrics from combed yarns gave the best strength values for untreated and enzymatic treated in two different stages, rather than fabrics from carded yarns. After the biopolishing process, there is significant change in strength values. In carded yarn knitted fabric, enzymatic treatment after dyeing shows higher bursting strength values in comparision to enzymatic treatment after pretreatment and same results shows in combed yarn knitted fabric samples. The fabric samples strength loss caused by enzymatic treatment after pretreatment or dyeing processes is nearly the same in all type of fabrics.

**Effects of enzymatic treatment on pilling**

The Table 4 shows the effect of enzymatic treatment on pilling of fabrics knitted using carded & combed yarn. Untreated fabrics knitted manufactured using carded & combed yarns were tested for pilling. After the evaluation of these results, it was observed that pilling resistance ratings of the fabric samples from combed yarn were better than the carded ring-spun yarn based knitted fabrics. It was observed that, when the number of turns of the Martindale instrument was increased, both combed & carded yarns demonstrated higher pilling values.

When the fabric samples were tested after enzymatic treatment for pilling, it was established that the best pilling ratings came from the combed yarn in comparison to carded ring spun yarn. However, we found that if enzymatic treatment was applied 2-times, the pilling ratings for all fabric samples were similar. But consequence of applying the enzymatic treatment twice, namely loss of weight, strength & possible deviation in colour shade. This may be because as carded yarn has more protruding fibres on the surface of fabric which results in more pilling as compare to combed yarn knitted fabric.

**Effects of enzymatic treatment on Abrasion**

Table 5 and Figure 4 show the effect on abrasion resistance of fabric. For abrasion resistance of fabric samples the % mass loss values & % thickness loss values are recorded at the end of abrasion cycles. The average % mass loss & % thickness loss values after abrasion of enzymatic treatment and dyeing were given in fig 4. According to statistical analysis, yarn type, enzyme conc. & interaction of these two factors are all significant factor on the abrasion resistance of fabric samples.

The % mass loss values & % thickness values after abrasion for all yarn types decreased with the increase in enzyme concentration. In both cases carded yarn & combed yarn knitted fabric % mass loss values for enzymatic treatment after pretreatment is higher than enzymatic treatment after dyeing and it is vice-versa in case of % loss thickness. But in case of carded yarn, at $45^0$ C for 60 & 90 min for 9 & 3 gpl the fabric % mass loss values for enzymatic treatment after pretreatment is less than enzymatic treatment after dyeing and the same result is shown in case of combed yarn at $30^0$C for 30 & 60 min for 3 & 6 gpl and at $60^0$C for 30 min for 9 gpl.

The abrasion resistance of combed yarn knitted fabric is better than carded yarn knitted fabric.

**Effect of enzymatic treatment on colour change**

The colour differences of fabrics after enzymatic processes at different steps and untreated fabrics were measured. As Table 6 and Figure 5 shows, the greatest colour difference values were observed in fabric samples that had been enzyme-treatment after dyeing. In carded yarn knitted fabric enzymatic treatment after dyeing shows higher K/S values in comparision to enzymatic treatment after pretreatment and same results shows in combed yarn knitted fabric samples. But in case of combed yarn at $60^0$C,0.50% for 90mins for 6gpl and 1.5% for 30 mins for 9gpl the value of K/S of enzymatic treatment after dyeing is less than enzymatic treatment after pretreatment.

**Analysis of Results**

In accordance with the results of this study, after bio-polishing which enables the fuzz to be removed to the maximum extent, substantially reducing the tendency to pilling. It has been observed that the worst pilling properties occurred on the carded yarn-based knitted cotton fabrics which had been treated with ordinary chemicals without enzymes. The lower pilling ratings of samples from carded yarn can be attributed to the hairy structure of the carded yarns with fibers that partly protrude from the yarn. This yarn structure causes fiber fuzz, as the protruding fibers accumulate the abrasion forces. On the contrary, open-end yarns display less hairiness, and combed yarns have a well-aligned long fibre structure. Consequently, the pilling tendency of the fabrics knitted from those yarn types is significantly lower.

**TABLE 1.** Effect of enzymatic treatment on GSM of fabrics knitted from carded & combed yarn

| | GSM (gm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | **CARDED YARN** | | | | | | | | | **COMBED YARN** | | | | | | | | |
| **Temperature (˚C)** | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | | |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** | 209.6 | 202.8 | 209.6 | 201.2 | 198.4 | 204.4 | 200.8 | 205.2 | 196.8 | 210 | 205.2 | 209.6 | 207.6 | 208 | 206.4 | 200.4 | 206 | 204.4 |
| **Process-2** | 198.4 | 206.4 | 207.6 | 205.2 | 196.8 | 206 | 198.4 | 208.4 | 196.8 | 200.8 | 198.8 | 202.4 | 200.8 | 203.2 | 205.2 | 204.4 | 204.8 | 204 |

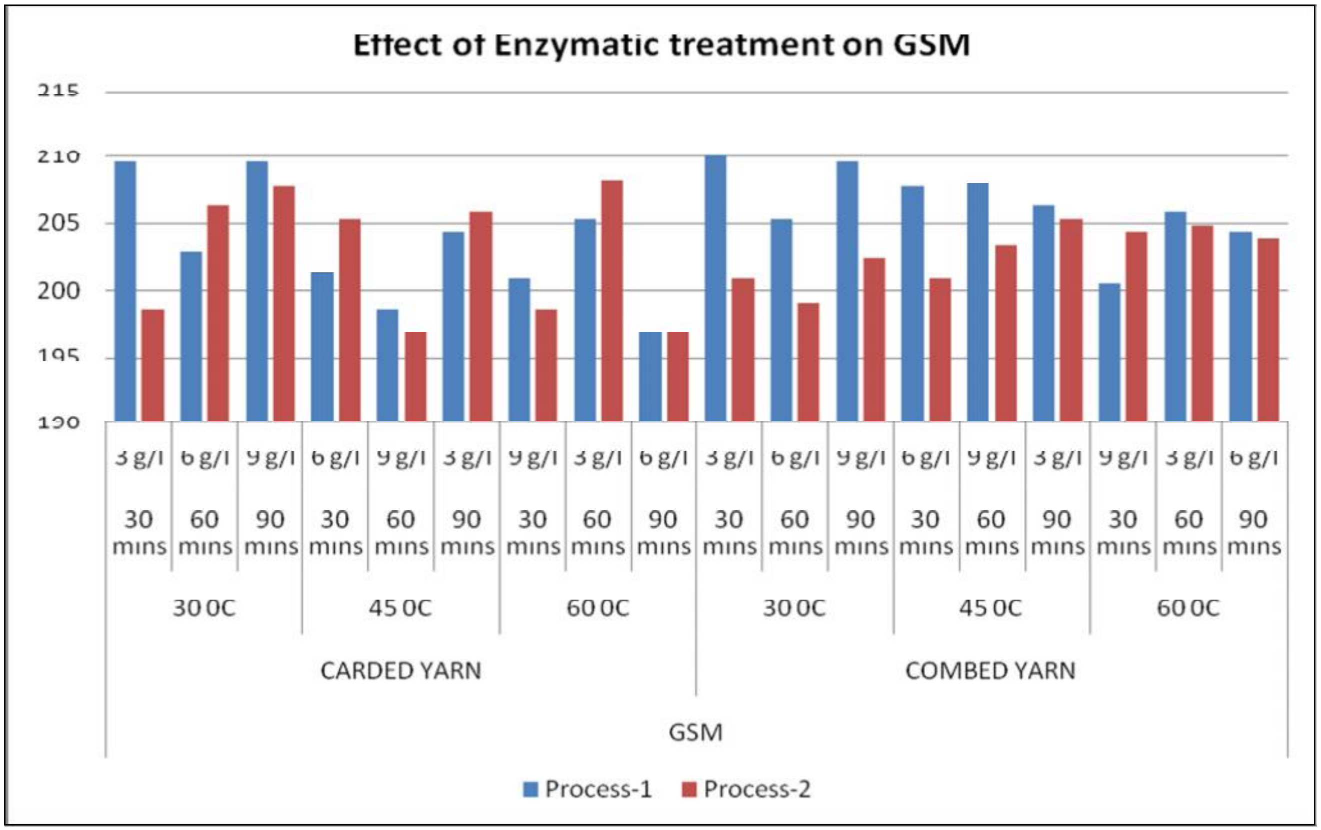


**FIGURE 1.** Effect of enzymatic treatment on GSM of fabrics knitted from carded & combed yarn

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**TABLE 2.** Effect of enzymatic treatment on Thickness of fabrics knitted from carded & combed yarn

| | THICKNESS (mm) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | **CARDED YARN** | | | | | | | | | **COMBED YARN** | | | | | | | | |
| **Temperature (˚C)** | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | | |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** | 0.568 | 0.56 | 0.544 | 0.555 | 0.536 | 0.549 | 0.543 | 0.539 | 0.513 | 0.576 | 0.551 | 0.549 | 0.551 | 0.544 | 0.539 | 0.545 | 0.547 | 0.541 |
| **Process-2** | 0.557 | 0.575 | 0.569 | 0.577 | 0.54 | 0.561 | 0.565 | 0.571 | 0.569 | 0.583 | 0.576 | 0.576 | 0.575 | 0.559 | 0.583 | 0.585 | 0.583 | 0.571 |

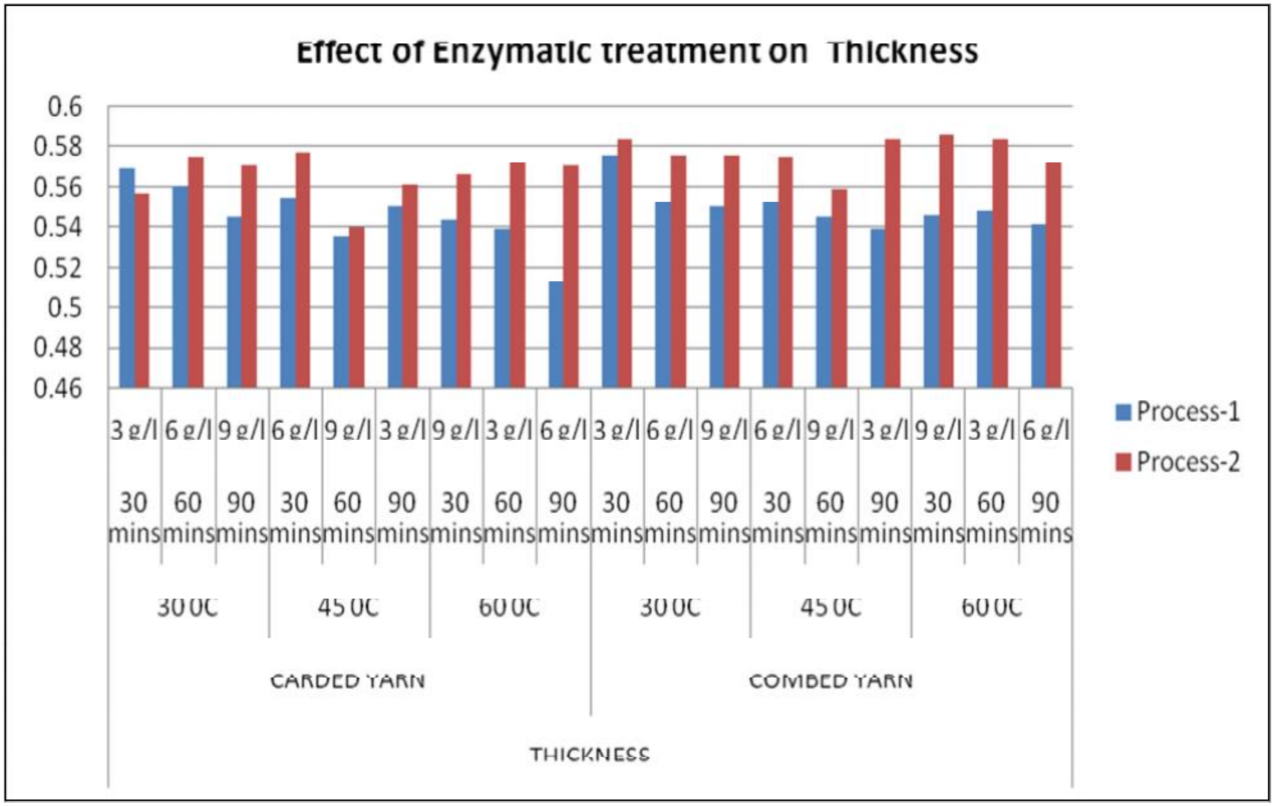


**FIGURE 2.** Effect of enzymatic treatment on thickness of fabrics knitted from carded & combed yarn

**TABLE 3.** Effect of enzymatic treatment on bursting of fabrics knitted from carded & combed yarn

| | BURSTING STRENGTH | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | | | | | **CARDED YARN** | | | | | | | | | | **COMBED YARN** | | | |
| **Temperature (˚C)** | | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** | 7.482 | 6.677 | 6.198 | 6.037 | 5.894 | 6.229 | 6.324 | 6.001 | 5.417 | 6.774 | 6.67 | 6.631 | 6.456 | 6.04 | 6.357 | 6.702 | 6.25 | 5.949 |
| **Process-2** | 7.674 | 7.447 | 6.889 | 6.774 | 6.291 | 6.756 | 6.742 | 6.835 | 6.897 | 7.674 | 7.468 | 6.962 | 7.014 | 7.441 | 7.045 | 7.208 | 7.277 | 7.2 |

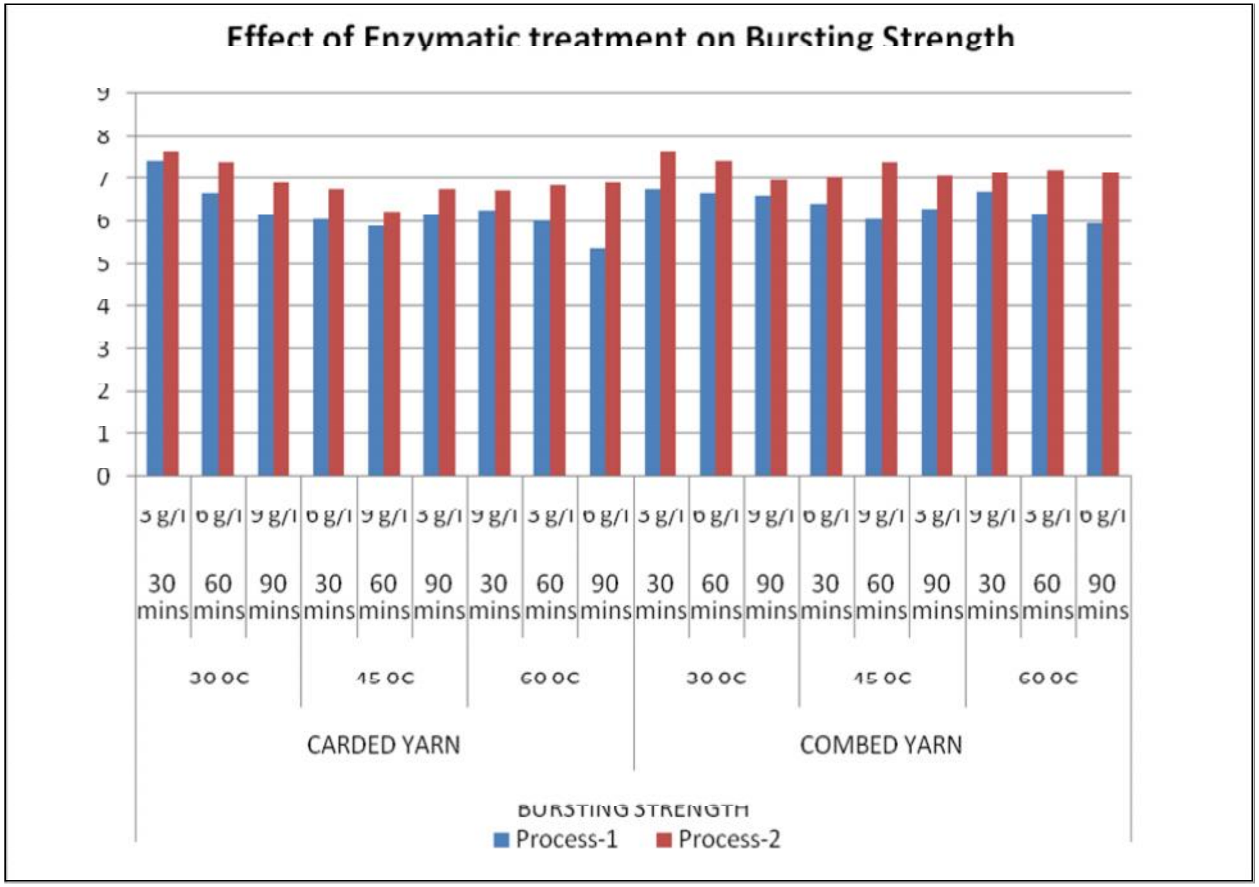


**FIGURE 3.** Effect of enzymatic treatment on bursting of fabrics knitted from carded & combed yarn

**TABLE 4.** Effect of enzymatic treatment on pilling of fabrics knitted from carded & combed yarn

| PILLING | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | **CARDED YARN** | | | | | | | | | **COMBED YARN** | | | | | | | | |
| **Temperature (°C)** | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | | |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** | 3-4 | 3-4 | 4-5 | 4-5 | 3-4 | 2-3 | 3-4 | 3-4 | 4-5 | 3-4 | 4-5 | 4-5 | 3-4 | 4-5 | 4-5 | 4-5 | 4-5 | 4-5 |
| **Process-2** | 2-3 | 3-4 | 3-4 | 3-4 | 3-4 | 4-5 | 4-5 | 3-4 | 2-3 | 2-3 | 4-5 | 4-5 | 3-4 | 4-5 | 3-4 | 3-4 | 2-3 | 3-4 |

**Table 5.** Effect of enzymatic treatment on Abrasion of fabrics knitted from carded & combed yarn

| ABRASION RESISTANCE | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | **CARDED YARN** | | | | | | | | | **COMBED YARN** | | | | | | | | |
| **Temperature (°C)** | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | | |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** %Loss in wt. | 2.134 | 2.297 | 2.652 | 2.799 | 1.671 | 2.026 | 2.416 | 2.159 | 2.426 | 2.204 | 2.052 | 2.07 | 2.881 | 3.524 | 2.223 | 1.746 | 2.398 | 2.421 |
| **Process-2** %Loss in wt. | 2.105 | 2.011 | 2.194 | 1.733 | 2.25 | 2.441 | 2.256 | 1.919 | 2.213 | 2.272 | 2.249 | 2.102 | 1.651 | 1.364 | 1.73 | 1.936 | 2.209 | 2.103 |
| **Process-1** %Loss in thickness | 9.423 | 7.572 | 6.811 | 7.941 | 6.695 | 8.163 | 7.894 | 7.923 | 6.577 | 9.08 | 8.699 | 6.881 | 6.29 | 6.423 | 6.841 | 7.819 | 6.111 | 6.102 |
| **Process-2** %Loss in thickness | 14.123 | 12.881 | 11.057 | 12.493 | 12.41 | 9.774 | 12.354 | 12.248 | 11.436 | 11.855 | 9.72 | 10.137 | 10.748 | 12.029 | 11.013 | 10.671 | 10.736 | 14.256 |

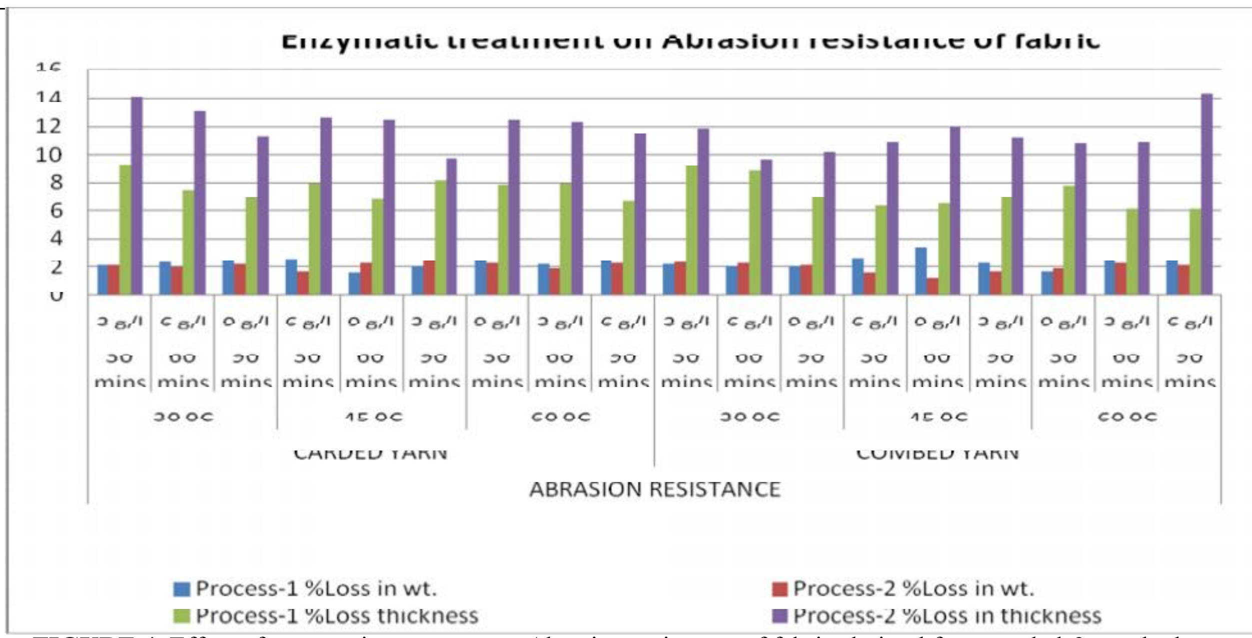


**FIGURE 4.** Effect of enzymatic treatment on Abrasion resistance of fabrics knitted from carded & combed yarn

**TABLE 6.** Effect of enzymatic treatment on K/S of fabrics knitted from carded & combed yarn

| | K/S | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of yarn** | **CARDED YARN** | | | | | | | | | **COMBED YARN** | | | | | | | | |
| **Temperature (˚C)** | | **30** | | | **45** | | | **60** | | | **30** | | | **45** | | | **60** | |
| **% Shade** | **0.5** | **1.5** | **3.0** | **3.0** | **0.5** | **1.5** | **1.5** | **3** | **0.5** | **0.5** | **1.5** | **3.0** | **3.0** | **0.5** | **1.5** | **1.5** | **3** | **0.5** |
| **Time (mins)** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** | **30** | **60** | **90** |
| **Concentration (g/l)** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** | **3** | **6** | **9** | **6** | **9** | **3** | **9** | **3** | **6** |
| **Process-1** | 0.788 | 1.492 | 2.436 | 2.457 | 0.747 | 1.551 | 1.511 | 2.448 | 0.812 | 0.945 | 1.807 | 2.588 | 2.636 | 0.929 | 1.783 | 1.941 | 2.613 | 0.964 |
| **Process-2** | 0.921 | 1.618 | 2.564 | 2.518 | 0.898 | 1.73 | 1.674 | 2.622 | 0.968 | 0.992 | 1.891 | 2.875 | 2.985 | 1.04 | 1.953 | 1.829 | 2.923 | 0.948 |

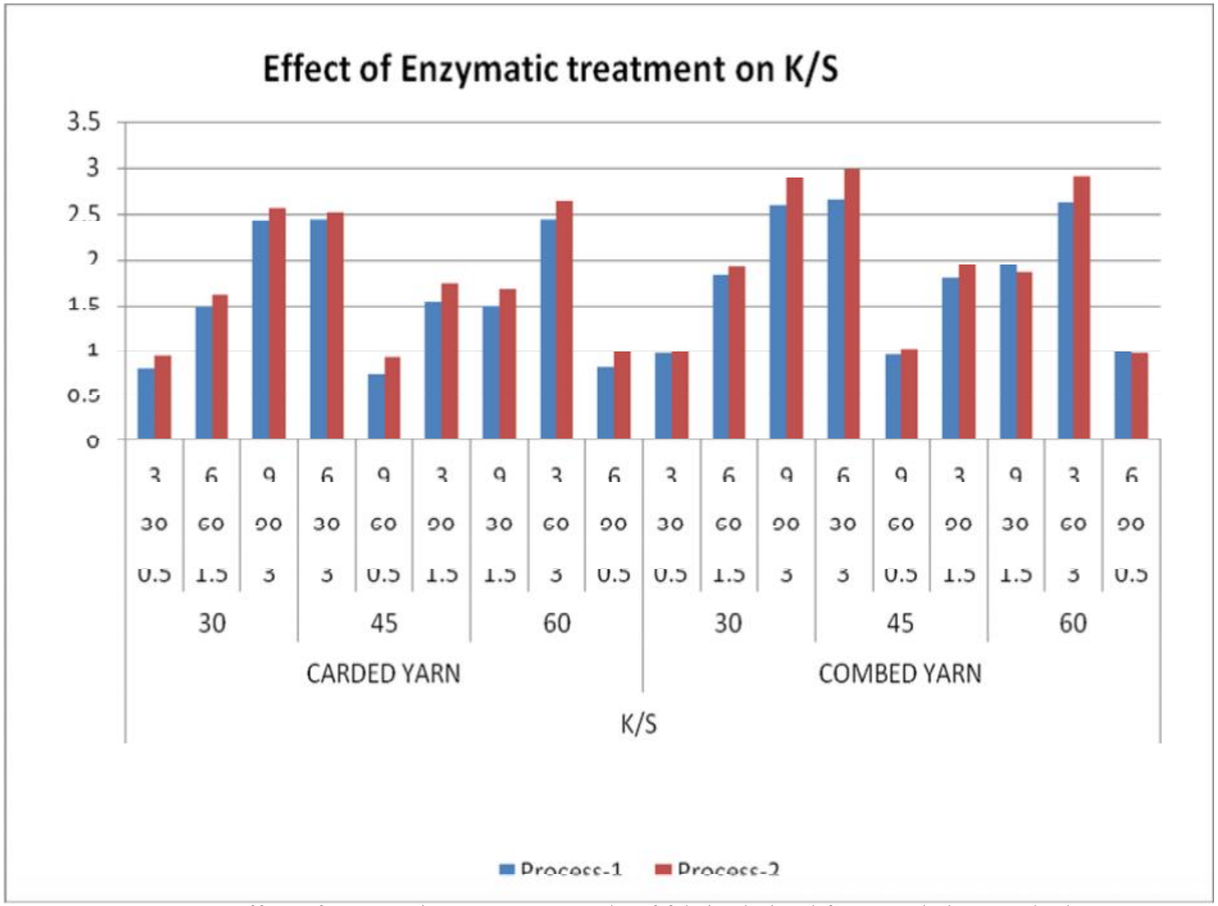


**FIGURE 5.** Effect of enzymatic treatment on K/S of fabrics knitted from carded & combed yarn

It is also observed that there was no significant difference between the pilling behaviors of the fabric samples, irrespective of whether the fabric samples had been pre-treated or dyed before the enzymatic process. Once applied, enzymatic treatment causes a strength loss which falls within acceptable limits. Double enzymatic treatment causes severe strength loss beyond acceptable limits

This may be explained by the mechanism of bio-polishing. Enzymes are surface-active; during the first bio-polishing process, they will most probably act mainly on the protruding excessive fibrilious surfaces, and also on the outer surfaces of the yarn. In second bio-polishing process, enzymes will react on the increased surface area, and they will damage the yarn to the major extent to cause severe strength and weight loss. Although twice bio-polishing improves pilling properties, this will take place at the expense of basic fabric requirements such as strength and weight.

The reasons for the slightly higher weight loss of fabric samples enzymatically treated after pre-treatment than those after dyeing are the more number of process phases, the high amount of mechanical forces and the long process period, which cause the removal of the fuzzes from yarn surface. When the weight loss is compared according to the yarn spinning system, the fabric from carded yarn has the highest value of weight loss while that from combed yarn has the lowest. The amount of weight loss that occurs after the double enzymatic treatment is significantly higher. Because of the higher loss of weight, the double enzymatic treatment is not recommended for normal applications. When the color difference values of dyed fabrics are examined, severe deviations in colour shade on enzyme treatment after dyeing were observed.

## CONCLUSIONS

- When carded and combed yarns are considered, carded yarn-based knitted fabrics treated with enzymes exhibited the worst pilling properties. The pilling behavior of enzymatic treated fabric samples did not display any significant difference whether they were pre-treated or dyed.
- It is evident that single enzymatic treatment reduces pilling tendency, and double enzymatic treatment reduces it more. Double enzymatic treatment affects with the weight and the strength of fabrics severely, even beyond the acceptable limits.
- The results demonstrate that enzymatic treatment causes weight loss in carded yarns to the highest degree.
- Enzyme treatment after dyeing fabric samples display severe colour deviations in comparison to enzyme treatment after pretreatment. This subject merits a detailed investigation.

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