(REFEREED RESEARCH)

EFFECTS OF ENZYMATIC TREATMENT ON THE PERFORMANCE OF KNITTED FABRICS MADE FROM DIFFERENT YARN TYPES

ENZİMATİK İŞLEMİN FARKLI İPLİK TİPLERİNDEN ÜRETİLEN ÖRME KUMAŞLARIN PERFORMANSINA ETKİLERİ

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ABSTRACT

Enzymes are mostly used for bio-polishing process of fabrics which remove the pills and fuzz from fabric surface in order to improve the smoothness. Fabric properties mainly depend on the yarn properties and the yarn arrangements in the fabric construction. In this study, the effects of bio-polishing process on the performance of viscose knitted fabrics made from different yarn types are investigated. After enzymatic treatment, the relatively higher weight loss is observed from fabrics knitted from ring spun (RS) and siro spun (SS) yarns, than those knitted from oe-rotor spun (OERS) and vortex spun (VS) yarns. The decreasing trend of bursting strength of fabrics after enzymatic treatment shows difference for different yarn types. Fabrics knitted from SS yarns show the highest resistance to abrasion before and after enzymatic treatment.

Key Words: Ring yarn, Open-end rotor yarn, Vortex yarn, Siro yarn, Enzyme, Bio-polishing.

ÖZET

Biyo-parlatma işlemlerinde kumaş yüzeyindeki boncuk ve havları yok ederek düzgünlüğü artırmak amacıyla enzimler kullanılmaktadır. Kumaş özellikleri temelde, iplik özellikleri ve ipliğin kumaş yapısındaki yerleşimine bağlıdır. Bu çalışmada, havların azaltılması amaçlı enzimatik işlemin, farklı iplik tiplerinden örülen viskon kumaşların performansına etkileri araştırılmıştır. Enzimatik işlem sonrasında, ring (RS) ve siro (SS) ipliklerden örülen kumaşlarda, oe-rotor (OERS) ve vorteks (VS) ipliklerden örülen kumaşlardan daha yüksek ağırlık kaybı gözlemlenmiştir. Enzimatik işlem sonrası kumaşların patlama mukavemetindeki azalma, farklı iplik tipleri için farklılık göstermiştir. SS ipliklerinden örülen kumaşlar enzimatik işlem öncesinde ve sonrasında, aşınmaya karşı en yüksek dayanımı göstermiştir.

Anahtar Kelimeler: Ring iplik, Açık-uç rotor iplik, Vorteks iplik, Siro iplik, Enzim, Biyo-parlatma.

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1. INTRODUCTION

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 (1). Cellulase enzymes are nontoxic, environmentally-friendly biocatalysts which are primarily used to bio-polishing process (2). Bio-polishing, 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.

There are several studies related to enzymatic treatment of cellulosic fabrics. Most of this work has focused on understanding the impact of the treatments on fabric preparation, dyeing and finishing process.

Fabric properties mainly depend on yarn properties and yarn arrangements in fabric construction. Similarly yarn properties depend on fiber properties and fiber arrangements in yarn structure. The knowledge of fiber arrangements in yarn structure is based on yarn production technique. Ring spinning technology is the most widely accepted yarn production method; it is capable of spinning nearly all sorts of natural and synthetic fiber types within very wide count range (3). Despite the ring spinning technology dominates the market, different or modified spinning technologies such as oe-rotor, air jet, vortex, compact and siro spinning have been introduced into the textile market, which offer improved properties, quality and/or reduced costs for yarn production.

The studies about the influences of yarn types on the performance of enzymes are very limited. Özdil et al. (1) studied the effects of enzymatic process for fuzz reduction on the properties of the fabrics knitted from oe-rotor, and ring-spun cotton (carded, combed) yarns. They showed that bio-polishing improved pilling properties and the fabric from carded yarn had the highest value while that from open-end yarn had the lowest when the weight loss was compared according to the yarn spinning system.

In another study, Özdil et al. (3) compared the basic characteristic properties of fabrics made from ring and compact spun yarns. They reported that fabric samples out of compact yarns displayed better pilling behaviors after enzymatic treatment.

Radhakrishnaiah et al. (4) measured the changes in the hand-related mechanical behaviour of enzyme treated cotton and cotton/polyester yarns corresponding to ring, rotor, air-jet, and friction spinning systems. They concluded that tactile quality improvements occurred after cellulase treatment for the yarns spun by ring, rotor and air-jet spinning systems. The weight loss of friction yarns was highest and enzyme treatment reduced the mechanical properties of yarns.

While some preliminary attempts have been made to understand the influence of yarn type on the efficiency of enzymatic treatments, there is a need for more research in this area. The aim of the study was to provide the understanding of the effects of enzymatic treatment for fuzz reduction on the performance of viscose knitted fabrics made from different yarn types. For this purpose, we measured the changes in pilling, strength and abrasion behaviors of enzyme treated viscose fabrics knitted from different yarn types.

2. MATERIAL AND METHOD

For this study, ring spun (RS), oe-rotor spun (OERS), vortex spun (VS), sirospun (SS) yarns were considered as yarn types. Yarns were manufactured from viscose fibers, which have a staple length of 38 mm and fineness of 1.3 dtex. Fibers were processed on the traditional short staple system using standard mill procedures, adjustments and practices. RS and SS yarns were spun on a Rieter G 30 ring frame. While OERS yarns were spun on the Schlafhorst SE-7 type spinning machine, MVS 861 spinning frame was used for the production of VS yarns. Data describing the spinning settings and conditions for yarns are listed in Table 1.

The physical properties of the yarns

Table 1. Manufacturing data related to the spinning conditions of yarns.

	RS	OERS	VS	SS
Delivery speed (m/min)	18.10	105	350	12.86
Total draft	30.60	238.50	180	36.5
Rotor speed (rpm)	-	96000	-	-
Spindle speed (rpm)	16500	-	-	11750
Rotor diameter (mm)	-	33.00	-	-
Ring diameter (mm)	40	-	-	40
Nozzle type	-	-	70-4J	-
Needle holder	-	-	2P130dL8-8.8	-
Spindle inner diameter (mm)	-	-	1.20	-
Air pressure (MPa)	-	-	0.50	-
FR-SP distance (mm)	-	-	19.5	-
Strand space (mm)	-	-	-	8

Table 2. Physical properties of yarns

	RS	OERS	VS	SS
Yarn count, Ne_c	29.9	29.8	29.9	30.1
(CV of Yarn count, %)	*1.27*	*1*	*0.94*	*1.22*
Um (%)	9.18	10.92	8.93	8.63
Thin places (−50 %) per km	0	11	0	0
Thick places (+50 %) per km	7	26	7	12
Neps (+200 %) per km	17	44	8	26
Neps (+280 %) per km		2		
Rupture of kilometer, Rkm	22.29	15.49	18.52	22.62
(CV of Rkm %)	*9.21*	*9.94*	*8.68*	*8.65*
Elongation at break (%)	14.48	11.6	10.36	14.33
(CV of elon. at break, %)	*9.38*	*12.04*	*12.91*	*11.69*
Hairiness index (Uster)	4.48	4.03	3.8	3.87

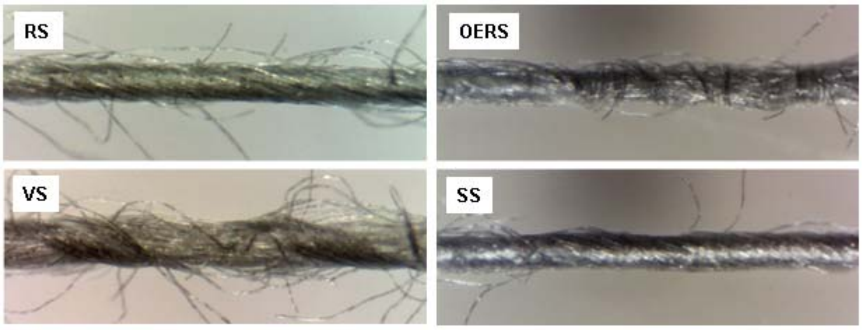

Figure 1. Longitudinal views of RS, OERS, VS and RS yarns at the magnification of 45×.

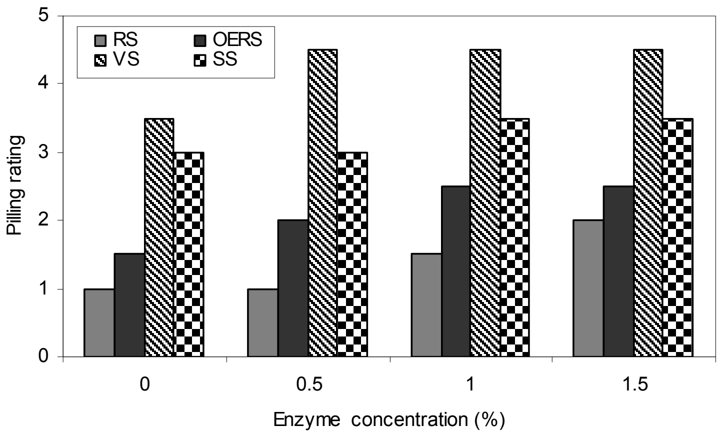

Figure 2. Pilling ratings of samples.

are tabulated briefly in Table 2. Visual comparison of yarn types was examined with Olympus SZ61 stereo microscope and given in Figure 1.

By using these yarns, single jersey fabric samples were knitted on the sample-knitting machine in the laboratory conditions. After knitting, fabrics were pre-treated with 1 g/L Setalan BNH-Setash GmbH (non-ionic washing agent) at 60ºC and 100:1 liquor ratio for 20 min and dried under laboratory conditions.

The cellulase enzyme Bactosol CA liquid from Clariant GmbH was used for enzyme treatments. Enzyme treatments were carried out in a beaker which was on a hotplate at 60°C and pH 5.5 for 50 minutes in an enzymatic bath containing 0.5 %, 1 % and 1.5 % acidic cellulase. The enzymatic bath was stirred permanently during treatment. Liquor to fabric ratio of 20:1 was used. The enzymatic bath was heated to temperature of 60ºC before the addition of fabric samples. After enzymatic treatment, fabric samples were rinsed with cold tap water and dried under laboratory conditions.

The pilling resistances of the fabric samples were also determined using Nu-Martindale Abrasion Tester according to TS EN ISO 12945-2 at 2000 revolutions. The pilling standards used to rate the knitted fabric had the following scale: 5 = no pills, 4 = slight pilling, 3 = moderate pilling, 2 = severe pilling, 1 = very severe pilling. The statistical analysis of the pilling rate of the fabrics was not evaluated due to the subjective evaluation of this property.

The weight loss of fabric samples, treated by different concentrations of enzyme solutions, was determined. Weight measurements were performed using a digital balance (Shimadzu, Librar AEU–210, Japan). The error in the measurement of weight was ± 0.1 mg.

Fabrics which were conditioned in standard atmosphere of 20ºC and 65% relative humidity for 24 hours, weighted 1 g and then put into enzymatic baths. After rinsing, fabric samples were dried in an oven at 105ºC for 1 hour. Then kept for 24 h under condition of 20ºC and 65% relative humidity, after that the fabric samples were weighted again. The weight loss measurements were performed three times for each of the fabric samples and the weight loss of fabrics was calculated by equation (1).

$$Weight\,loss\,(\%) = \frac{w_a - w_b}{w_a} \times 100 \qquad (1)$$

where, w_a is the weight of untreated fabric sample and w_b is the weight of enzyme-treated fabric sample.

The strength values of fabric samples were tested with a TruBurst instrument by using the bursting strength diaphragm method in compliance with ISO Standard 13938-2. The abrasion tests were performed on a Nu-Martindale Abrasion Tester (James H. Heal, UK) according to TS EN ISO 12947-3. The standard wool fabric, was used for abrading and the fabric samples were abraded under the pressure of 9 kPa. Weight loss, abrasion and bursting strength results were also 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.

3. RESULTS AND DISCUSSION

One important quality aspect of knitted fabrics is their pilling strength. Pilling is defined as the entangling of fibers during washing, dry cleaning, testing, or wear to form pills that stand proud of the surface of a fabric (5). Pilling is not only affects the handle and the appearance of fabrics, but it also has an accelerating effect on the rate of fiber removal from the yarn structure, and hence reduces the service life (6). Since the bio-polishing process is mainly applied to the fabrics to remove the pills and fuzz from fabric surface, fabric samples were tested for pilling firstly.

The pilling rate results of untreated and enzyme treated fabrics showed that fabrics from VS yarn perform the best pilling properties as seen in Figure 2. The pilling rate of fabrics is in the order as follows: VS > SS > OERS > RS.

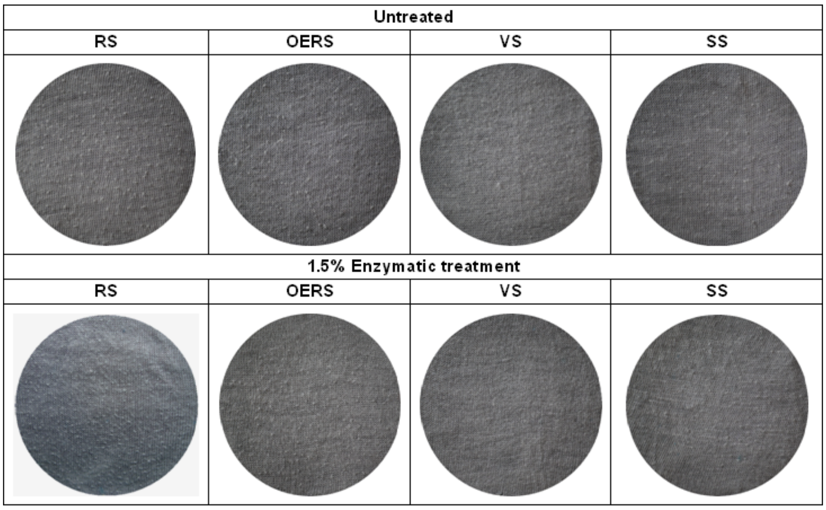

Figure 3. The pilling photographs of fabric samples before and after 1.5% enzymatic treatment.

The pilling resistance of fabrics depends on the structural properties of yarns. Yarn hairiness can be defined by the measurement of fibers length by vertically yarn axis. There is similar order in terms of pilling tendency of fabrics and hairiness index values of yarn types. The higher hairiness of yarns means the lower pilling resistance of fabrics. The VS yarns' wrapped structure inhibits the fibers protruding from the main yarn body and retards pill formation. The experimental results for pilling rate show that when enzymatic treatment at the 0.5 % enzyme concentration is applied to the fabrics knitted from VS yarn, piling rate increases from 3-4 to 4-5 level. As can be seen in Figure 2, the increase of enzyme concentration up to 0.5 % does not affect the pilling rate of fabric knitted from VS yarns.

The hairiness value of SS yarns is found lower than that of OERS and RS counterpart (Table 2). As a result of the lower hairiness properties of SS yarns, the fabrics knitted from SS yarns show higher pilling resistance than the fabrics knitted from OERS and RS yarns. From the results, we observed that even though enzymatic treatment at the 0.5 % enzyme concentration does not affect the pilling properties of fabrics knitted from SS yarn, enzymatic treatment at the 1 % enzyme concentration improves the pilling rate from 3 to 3-4 level. There is no change in the pilling rate of fabrics knitted from SS yarn, when enzyme concentration increases from 1 % to 1.5 %. Sirospun process is a modified ring spinning process. In sirospun process, two rovings per spindle are fed to the drafting system within specially developed condensers separately and drafted simultaneously. Emerging from the nip point of front rollers, the two strands are twisted together, as in the case of normal single ring spun yarn, by the ring and traveler system (7). Sirospun yarn has better evenness, hairiness and tenacity properties compared to ring counterpart as seen in Table 2. The fiber arrangement in the SS yarn structure is more regular and tightly compare to the other yarn types. The visual assessment of yarn samples confirms these findings (Figure 1). This tightly structure affects the penetration of enzyme in the yarn structure.

The fabric samples from RS yarn display the worst pilling rate. Enzymatic treatment at the 0.5 % enzyme concentration does not affect the pilling rate of fabrics knitted from RS yarn. Enzymatic treatment at the 1 % enzyme concentration improves the pilling rate from 1 to 1-2 level. After the enzymatic treatment at the 1.5 % enzyme concentration, the pilling rate of fabrics knitted from RS yarn reaches the pilling rate of 2.

The pilling rate of fabrics knitted from OERS yarns is better than that of fabrics knitted from RS yarns. After the enzymatic treatment at the 0.5 % and 1 % enzyme concentration, the pilling rate is increased up to 2 and 2-3 respectively. Although the enzymatic treatment at the 1.5 % does not affect the pilling rate of fabrics knitted from OERS yarn.

Yarn types used for production of fabric are of profound importance for the efficiency of enzymatic process as they impact the penetration of the enzymes. The photographs of all fabric samples before enzymatic treatment and after 1.5 % enzymatic treatment given in Figure 3 were compatible with the pilling results in Figure 2.

Effect of enzymatic treatment on weight loss of fabrics knitted from different yarns related to enzyme concentration is shown in Figure 4. The results clearly show that, the weight loss of fabric increases with the increase in the enzyme concentration.

After enzymatic treatment, fabrics knitted from ring spun (RS) and siro spun (SS) yarns show higher weight loss than those knitted from oe-rotor spun (OERS) and vortex spun (VS) yarns. These obtained results may be explained by the number of protruding longer fiber ends from the yarn body. Enzymes caused a removal of the fuzzes from the surface of fabrics as expected. However, the level of removal is different among the fabric types which were knitted by different yarn types.

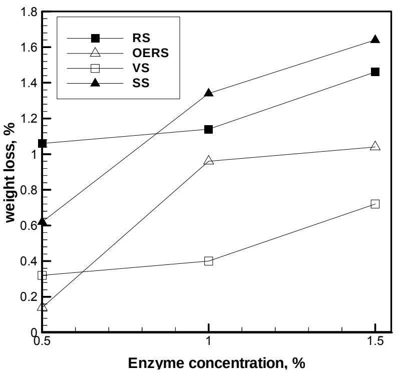

Figure 4. Weight loss (%) of fabric samples versus enzymatic concentration

Untreated and enzyme-treated fabric samples were tested for bursting strength whose mean results were given in Figure 5. Enzyme concentration of '0%' indicates untreated fabric sample. According to statistical analysis, yarn type, enzyme concentration and interaction of these two factors are all significant factor on the bursting strength of fabric samples. The bursting strength of untreated fabrics knitted from SS yarn is quite higher than that of other fabric samples. There is similar order in terms of bursting strength of untreated fabric samples and Rkm values of yarn types: SS>RS>VS>OERS. However this order changes with enzymatic treatment. The well known strength loss effect of enzymatic treatment shows difference for different yarn types as seen in Figure 5.

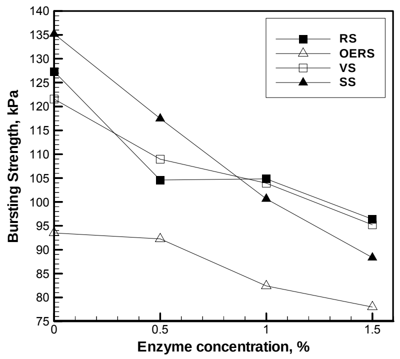

Figure 5. Bursting strengths of fabric samples versus enzyme concentrations.

For abrasion resistance of fabric samples the mass loss values are recorded at the end of 5000 abrasion cycles. The experiment is repeated four times for each of the fabric samples. The average mass loss values after abrasion of untreated and enzyme treated fabrics were given in Figure 6. According to statistical analysis, yarn type, enzyme concentration and interaction of these two factors are all significant factor on the abrasion resistance of fabric samples.

The mass loss values of untreated samples after abrasion in the order as follows: OERS>RS>VS>SS. Mass losses of fabrics after abrasion for all yarn types decreased with the increase in enzyme concentrations. The most dramatically reduce is observed from the fabric knitted from OERS yarns after enzymatic treatment at the 0.5% enzyme concentration.

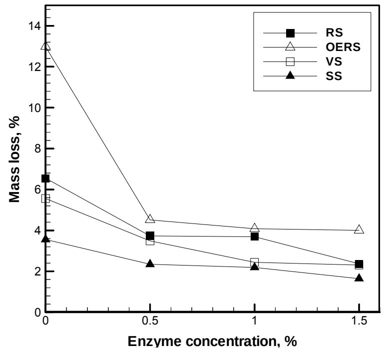

Figure 4. Mass loss values of samples related to enzyme concentrations after abrasion.

4. CONCLUSIONS

Pilling tendency of fabrics is related to the structural properties specially hairiness values of yarns. The test results revealed that fabric samples from VS yarns, which have the lowest hairiness value, demonstrate the best pilling properties in both untreated and enzyme-treated form. Improving effect of enzymatic treatment on the pilling resistance of fabrics show difference for different yarn types since the yarn structure affects the penetration of enzyme.

The weight loss value of fabric which is normally observed after enzymatic treatment mainly depends on the yarn structure. Fabrics knitted from RS and SS yarns show higher weight loss than those of the fabrics knitted from OERS and VS yarns.

Bursting strength values of fabrics are in a relation with the Rkm values of yarns. Fabrics knitted from SS yarns show the best bursting strength before enzymatic treatment. However, strength loss effect of enzymatic treatment shows difference for difference yarn types.

As the abrasion properties are concerned, fabrics knitted from SS yarns show the highest resistance before and after enzymatic treatment. Mass losses of fabrics after abrasion decrease with the enzymatic treatment for all yarn types.

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