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Research article

Investigation of the effect of different process variables on color and physical properties of viscose and cotton knitted fabrics

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ABSTRACT

The aim of this study was to investigate and compare the effect of process variables on the color and physical characteristics of viscose and cotton knitted fabrics. The effect of dye concentration, salt concentration, soda ash, dyeing time, dyeing temperature, material to liquor ratio, different dye class, fabric GSM, washing time, washing temperature, and enzyme concentration were investigated in terms of color strength (K/S value), color fastness, and pilling resistance. The K/S value of the colored fabric was calculated using UV visible spectrophotometer SF 650 TM and the pilling resistance of the enzyme-treated fabrics was tested by an ICI pilling tester. The results show that dye concentration has the greatest and key effect on the K/S value of viscose and cotton fabric. However, viscose fabric shows a higher K/S value than that of cotton fabric in similar dyeing conditions. Furthermore, the multi-functional dyes demonstrate the upmost K/S value than the vinyl sulphone dyes. Moreover, it was found that enzymatic treatment improved the pilling grade of cotton fabric, whereas no enzymatic effect on viscose fabric was observed.

1. Introduction

The knitted textile materials produced from cellulosic viscose and cotton fiber fabrics are very popular for apparel wear due to their unique properties such as wear comfort, excellent hydrophilicity, biodegradability, air permeability, soft to the skin, superior moisture absorbent, easy-care properties and good capacity to pick up various classes of dyestuffs over woven fabrics, [1, 2, 3, 4, 5, 6, 7]. A linear polymer cellulose encompass the repeating unit D-anhydroglucose joined together by β (1–4) glycosidic linkages. The anhydroglucose unit of cellulose has three free hydroxyl groups that make cellulose fiber more absorbent and facilitates easily swelling during wet processing [6, 8]. A distinctive form of cellulosic fiber is shown in Figure 1.

Globally speaking, the present customers expect diversified and highest quality stylish products at the lowest prices and lower lead time for product manufacturing and distribution. The quality of dyed fabric includes color properties namely color strength, color fastness, color levelness, etc., and physical properties are bursting strength, pilling resistance, dimensional properties, etc. The color strength, color fastness and pilling resistance are the fundamental quality characteristics of the dyed fabrics to the consumers. However, in the textile dyeing industry, color strength/color shade variance and poor color fastness properties in dyed fabrics are some of the most important reasons for fabric refusal [2, 3, 4, 9, 10, 11, 12]. Likewise, the pilling of knitted fabric is an undesirable property that affects the handle and appearance drastically and declines the service life of the products [1]. Many inside and outside parameters affect the color and physical properties of the final products in textile dyeing process as stated in the past research investigation [2, 3, 4, 9, 12]. Hence, it is important to investigate the effect of process variables to find the optimal and significant factors in the dyeing process to achieve the final products as per the customer requirement. A number of studies have been described on the method and qualities of textile materials. Dong et al. [1] examined the effects of 2, 4, 6-trichloropyrimidine on the improvement of cellulose fiber blended knitted fabric anti-pilling efficiency. Hossain et al. studied the effects of dyestuff, salt and alkali on color yield of viscose/lycra blended knitted fabric by fuzzy logic intelligent model [2]. Hossain et al. developed a fuzzy knowledge-based expert model to analyze the effects of dyeing time, dye concentration, and dyeing temperature on the color strength of cotton/lycra blended knitted fabric [3]. Jamshaid et al. introduced an ANFIS technique to examine the effect of yarn tenacity, knitting stitch length and fabric GSM on the bursting strength of plain cotton knitted fabrics [5]. Ashraf et al.

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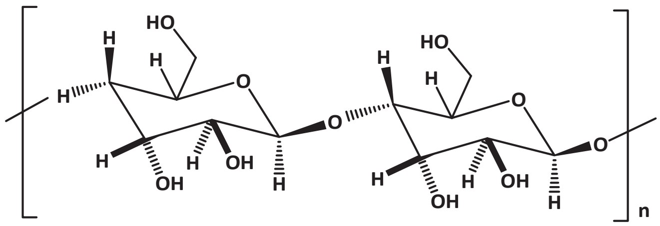

Figure 1. Chemical structure of cellulose.

investigated the influence of the characteristics of cotton fiber and yarn on color variation in vat-dyed woven fabric [10]. Babu and Selvadas investigated the influence of various wet processing steps on the physical, dimensional and dyeing properties of single jersey cotton knitted fabrics [11]. Shahid et al. examined the effects of dyeing parameters on color fastness & strength properties of lyocell-elastane and cotton-elastane knitted fabrics [13]. Shahid et al. compared the effects of dye, electrolytes, Soda ash, dyeing process time and dyeing temperature, on K/S value of lyocell-elastane and cotton-elastane knitted fabrics [14]. Ibrahim et al. evaluated the impact of cellulase enzyme treatment on the efficiency of color properties of cotton fabrics [15]. Bahar et al. analyzed the effect of various pre-treatment processes on the color performance and fiber morphology of viscose fabrics dyed with reactive dye [16]. Mamun et al. examined the different types of scouring and bleaching processes on the color properties of cotton fabrics dyed with mono-chlorotriazine Reactive dye [17]. Qadir et al. studied the effect of different buffers and salt on the color intensity and color fastness of cotton fabric dyed with Reactive dye 3RF [18]. Shim et al. conducted experiment to study the effect of alkali, salt, temperature, liquor ratio and levelling agent on the dyeing behaviour and fastness of regenerated cellulose fiber [19]. Mule et al. discovered a fuzzy logic controller to study the effects of number of stroke, fabric GSM and viscosity on the color strength of printed fabrics [20]. Kan et al. applied ANN model to observe the impact of input variables such as treatment time, treatment temperature, mechanical agitation, p^H and fabrics yarn twist level on the color propperties of 100% cotton denim fabric [21]. Degirmenci and Topalbekiroglu described the effects on the spirality of single jersey fabrics of dyeing, weight and the twist direction [22]. Tavanai et al. investigated the effects of time, dye concentration, and temperature on the color yield in polyester dyeing with disperses dyes [23]. Zou introduced RSM regression model to assess the effect of process variables namely yarn delivery speed, nozzle pressure and yarn count, on the properties of viscose vortex colored spun yarn [24]. Özgüney et al. examined the impact of various pre-treatment processes on different types and properties of viscose fabrics [25]. Quadir et al. scrutinized the influence of elastane linear density & draft ratio on the mechanical and physical characteristics of staple spun cotton yarns [26]. Moniruzzaman et al. studied the effect of gamma irradiation and chemical treatment on the physico-mechanical properties of the pineapple/epoxy composites [27]. Hossain et al. investigated the effects of knitting stitch length, yarn count, and yarn tenacity on the bursting strength of viscose/lycra knitted fabric through a fuzzy technique [28]. Nasri and Berlic applied an evolutionary fuzzy system model to investigate the effects of dispersed dye concentration, temperature and time on the color yield in polyester high temperature dyeing [29]. Nahar et al. studied the various influence of mordanting agents on the color strength, color co-ordinate and color fastness of jute fabric dyed with extracted eucalyptus solution [30].

It is found from the previous literature survey that no study was performed to examine and compare the impact of various processing parameters on the color and physical properties of viscose and cotton knitted fabrics. Thus, the key purpose of the current work was to study and compare the effects of dye concentration, salt concentration, alkali concentration, dyeing temperature, dyeing time, material to liquor ratio, different dye class, fabric GSM, washing time, washing temperature, and enzyme concentration on color and physical properties of viscose and cotton knitted fabrics.

2. Experimental

2.1. Materials

The cotton and viscose single jersey knitted fabrics having areal density 160 g/m^2, 190 g/m^2 and 220 g/m^2 were used throughout the work. Commercial dyestuffs used were Remazol Blue RR (Dystar, Germany), Sunfix Navy Blue MFD (Ohyoung, Korea). Feloson NOF wetting agent (CHT: Germany); Kappacom E-12 Leveling agent (Kapp-chemie: Germany); Ispon- PSR, soaping agent (Bozzeetto: Italy) and Sodium sulphate (Na_2SO_4), Sodium carbonate (Na_2CO_3), and Acetic acid (CH_3COOH) are all of commercial grade. Commercial grade cellulase enzyme namely Cellusoft CR (Acid enzyme: Novozyme: Netherland) was used in this study.

2.2. Experimental method

2.2.1. Dyeing of viscose and cotton fabric under various dyeing conditions

The dyeing of industry scoured and bleached 100% viscose and cotton knitted fabric samples (every sample 5g) were carried out in Infra-red (IR) laboratory dyeing machine (Ugolini, Italy) using Remazol Blue RR dyes (Figure 2) by exhaust system under the following conditions: Dye (1%, 3%, 5%, 7%, 9% o.w.f.), salt (20 g/l, 30 g/l, 40 g/l, 50 g/l, 60 g/l), soda ash (3 g/l, 7 g/l, 10 g/l, 13 g/l, 16 g/l), dyeing time (30 min, 45 min, 60 min, 75 min, 90 min), dyeing temperature (30 °C, 45 °C, 60 °C, 75 °C, 90 °C) and LR (liquor ratio) (1:4, 1:8, 1:12, 1:16, 1:20). At last, the dyed fabrics were rinsed thoroughly and then soaped using 0.5 g/l Ispon- PSR soaping agent at 90 °C for 10 min rinsed, and dried followed by neutralizing.

2.2.2. Dyeing of viscose and cotton fabric with different classes of dyes

In IR laboratory machine, the dyeing process was performed for two different dyes group such as vinyl sulphone (Figure 2) and multifunctional (Figure 3) dyes according to the set of values for dye (2%, 4% o.w.f), salt (40 g/l, 60 g/l), soda ash (10 g/l, 15 g/l), at 60 °C for 60 min, with LR of 1:10 for viscose and cotton fabrics by exhaust dyeing technique. First of all, the auxiliary & dyes (A), salt (B) and alkali (C) are added to the dye bath at 40 °C. The temperature of the dye bath is then increased from 40 to 60 °C at a heating rate of 2 °C per min, and dyeing continues for 60 min. The dyeing process curve in this experiment is graphically demonstrated in Figure 4. Finally, both dyed fabrics were rinsed thoroughly with cold water and then washed with hot water using 0.5 g/l soaping agent at 90 °C for a time period of 10 min, rinsed, and dried followed by neutralizing.

2.2.3. Dyeing of viscose and cotton fabric with various fabric GSM

The samples of cotton and viscose bleached fabrics with an areal density of 160 g/m^2, 190 g/m^2 and 220 g/m^2 were dyed in an infrared laboratory dyeing system using 3% dye, 40 g/l salt, 10 g/l soda ash at 60

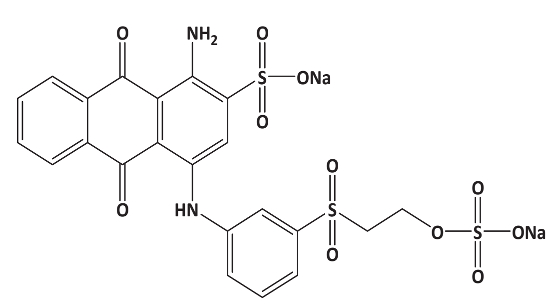

Figure 2. Chemical structure of vinyl sulphone Reactive dye (Remazol Blue RR).

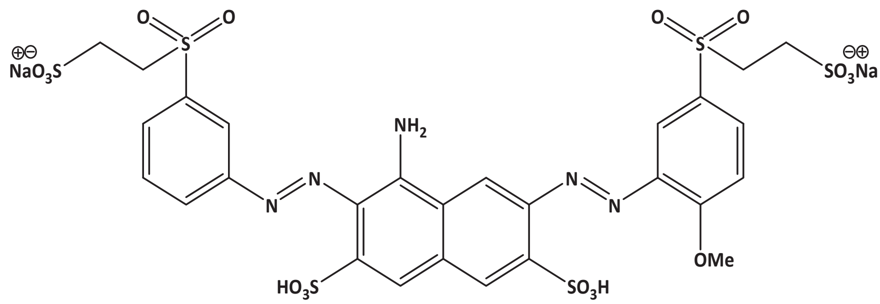

Figure 3. Chemical structure of multifunctional Reactive dye (Sunfix Navy Blue MFD).

°C for 60 min and LR of 1:10. At the end, entire samples were rinsed thoroughly, and then hot washed at 90 °C for 10 min, rinsed, and dried.

2.2.4. Experimental work for color fastness to washing and rubbing

The sample of cotton and viscose bleached fabrics with GSM 190 is dyed in an IR dyeing system using 4 % dye (Remazol Blue RR), 60 g/l G/salt, and 15 g/l soda at 60 °C for 60 min using LR 1:10. Subsequently, the whole dyed samples were rinsed thoroughly with cold water and then washed with hot water using 0.5 percent soaping agent at 90 °C for 10 min and dried, accompanied by thoroughly washing and neutralizing. At the end, the dyed samples were washed under the following washing conditions: Soaping agent (0.5 g/l), washing time (10 min, 20 min, 40 min), and wash temperature (75 °C, 95 °C, 105 °C).

2.2.5. Enzymatic treatment of viscose and cotton fabric

The enzyme treatment of pre-treated cotton and viscose fabrics were done by exhaust method in an Infra-red IR laboratory dyeing machine taking enzyme concentration (0 g/l, 0.5 g/l, 1 g/l), non-ionic detergent 1 g/l, acetic acid 0.5 g/l (pH 5.5), and LR 1:10 at 55 °C for 40 min as presented in Table 1. To deactivate enzyme, pH ($p^H \geq 9$) and temperature of the treatment bath are raised and washed at 80 °C for 10 min, rinsed, and dried.

2.3. Color and physical properties testing

Prior to testing of the color and physical properties, all the colored samples were conditioned for 2 h at 65 ± 2% RH and 20 ± 2 °C temperatures in a standard atmospheric laboratory condition.

2.3.1. Measurement of color strength (K/S value)

Reflectance values (R) of all colored samples were determined by a Data color Spectrophotometer using illuminant D_{65} with 10^o standard observer on SF 650 (Data color, USA), at wavelengths from 400-700 nm. The average value of four readings has been taken for the reflectance of each sample. At the end, using the Kubelka-Munk Eq. (1), the K/S value of each sample was determined [2].

A= Auxiliaries & Dyes; B= Salt and C= Alkali

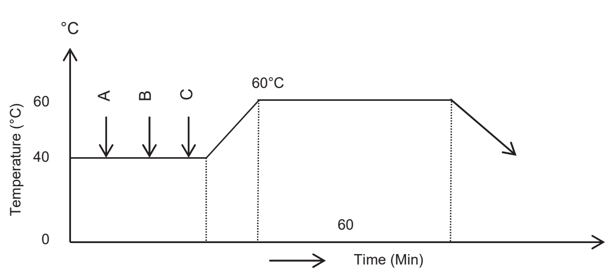

Figure 4. Dyeing process curve with different classes of dyes.

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \tag{1}$$

where, K = Absorption coefficient, S = Scattering coefficient and R = Reflectance of the dyed fabric.

2.3.2. Color fastness testing

Following the conditioning, the color fastness of the dyed fabric was determined according to International Standard and assessed by a color change and staining gray scales as per rating 1–5. Gray scale value 1 implies poor and 5 implies excellent fastness. The ISO 105-C03: 2010 method was employed for testing of color fastness to washing applying a Rota Wash (SDL Atlas: UK), and the ISO 105 × 12: 2002 method was applied for analyzing color fastness to dry and wet rubbing using a crock meter (SDL Atlas: UK). The samples were washed for 30 min in standard soap solution at 60 °C, keeping the ratio of material to liquor as 1:50.

2.3.3. Pilling resistance testing

After conditioning, the pilling resistance of the treated fabric samples are tested according to ISO 12945-1 test method using an ICI pilling tester (Rota Pill, SDL Atlas, UK) for 2000 revolutions and assessed by color staining gray scale as per rating 1–5. The gray scale value 5 implies no pilling; 4 implies partially pilling; 3 implies moderate pilling; 2 implies distinct pilling; 1 implies severe pilling.

3. Results and discussion

The effects of the various process parameters on viscose and cotton knitted fabrics have been experimentally tested and findings are also discussed and compared as bellows:

3.1. Effect of dyeing process parameters on color properties

3.1.1. Effect of dye concentration

To investigate the effect of dye concentration, viscose, and cotton fabric samples were dyed with 1%, 3%, 5%, 7%, 9% dye (o.w.f.), keeping other dyeing parameters constant, namely with Glauber salt 50 g/l, soda ash 13 g/l, at 60 °C for 60 min and liquor ratio 1:8. After dyeing, the K/S value of dyed fabric samples is drawn and depicted graphically in Figure 5 against dye concentrations. It is clear from the Figure that the K/S value increases with the increase in dye concentration results in

Table 1. Treatment conditions.

Process parameters	Unit	Levels		
Cellusoft CR	g/l	0	0.5	1.0
Detergent	g/l		1	
Acetic acid	g/l		0.5	
Time	min		40	
Temperature	°C		55	
Material to liquor ratio			1:10	

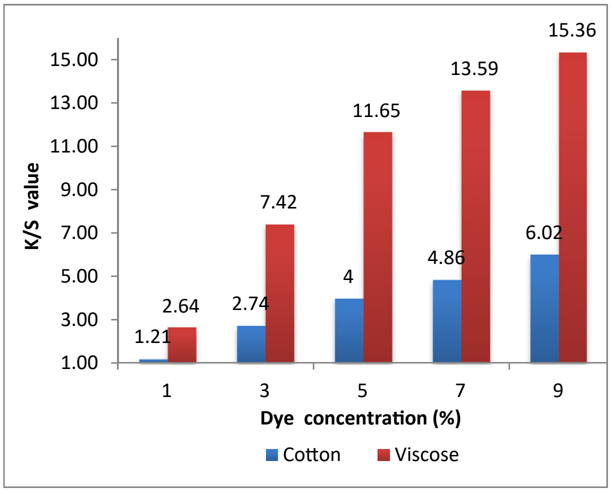

Figure 5. Effects of dye concentration on K/S value.

increases dye bath concentration which leading to higher dye absorption because dye concentration is directly proportional to dye absorption. Approximately, K/S value rises 36.30% and 31.5% for viscose and cotton fabrics respectively, with an increase in 40% of dye concentration due to higher exhaustion and fixation of the dye. It is further observed that the K/S value increases quickly for viscose knitted fabric samples, whereas it increases slightly for cotton knitted fabric. It is because viscose fiber is more absorbent and reactive than cotton [2, 4, 31, 33].

3.1.2. Effect of dyeing time

The effects of dyeing time on the K/S value of viscose and cotton knitted fabrics has been graphically represented in Figure 6. In this experimental study, dyeing time has been varied from 30 to 90 min keeping other parameters fixed. As can be seen from Figure 6 that the K/S value rises with the time increases until dye exhaustion achieves equilibrium state and there is a decline trend in K/S value after further increases in dyeing time over 75 min for both fabrics. From Figure 6, it can be comprehended that K/S value rises from 9.57 to 12.13 for viscose and K/S value rises from 3.67 to 4.18 for cotton fiber fabrics with increases in dyeing time from 30 to 75 min respectively, because of more dye exhaustion until attaining equilibrium; however, it declines with the increase of time over 75 min due to the shifting in the equilibrium of coloring component from fabric to dye bath for a prolonged time. The results exhibited that the increment of K/S value for viscose fiber is higher than cotton in similar dyeing time as viscose fiber is more absorbent than cotton [3, 4, 31, 32, 33].

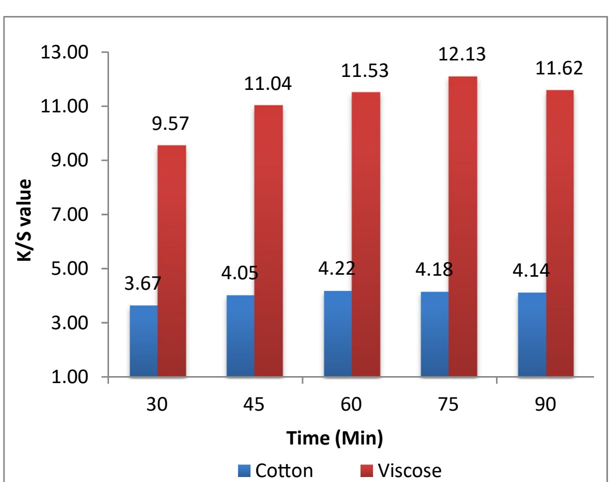

Figure 6. Effects of dyeing time on K/S value.

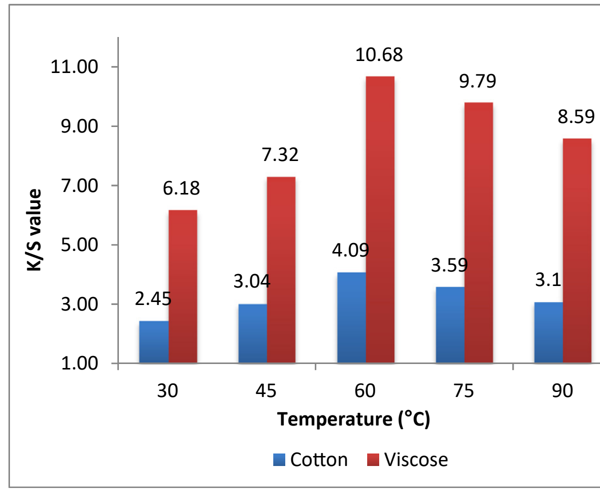

Figure 7. Influence of dyeing temperature on K/S value.

3.1.3. Effect of dyeing temperature

The impact of dyeing temperature on K/S value of viscose and cotton fabrics is demonstrates in Figure 7. In this study, dyeing was started at 30 °C and was steadily increased up to 90 °C. At low temperature (30 °C), less amount of dye is sorbed and mostly sustained at the surface of the fabrics, results in lower K/S value while at higher temperature more dye molecules quickly transfer onto the surface from the dye bath and diffused inside of the fabrics through the open pore in cellulosic fabric, leading to larger K/S value. K/S value increases with rises in temperature and reaches an utmost value at 60 °C for both fabrics and it declines after 60 °C. It can be seen that K/S value rises approximately 31.35% and 25.7% for viscose and cotton fabrics respectively, with an increase of dyeing temperature (25%) from 30 to 60 °C. This is because the dye solubility, dye strike rate and dye absorption increase at a higher temperature, resulting in faster diffusion of dye molecules into inside of the fabrics through the open void in fabric, leading to larger K/S value. On the other hand, K/S value gradually declines nearly 8.3% and 12.2% for viscose and cotton fabrics respectively, with an additional increase of dyeing temperature (20%) from 60 to 90 °C. The reason for a decrease in K/S value after a particular dyeing temperature (60 °C) is probably due to the desorption of dye molecules while reaching its equilibrium state (60 °C) in presence of alkali, leading to lesser dye uptake, resulting in lower

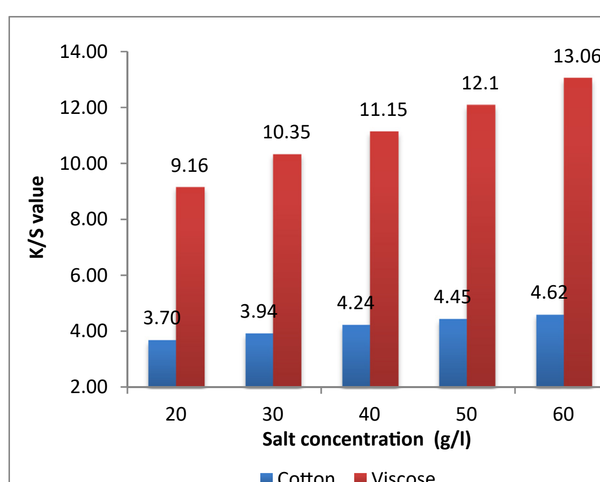

Figure 8. Effects of salt concentration on K/S value.

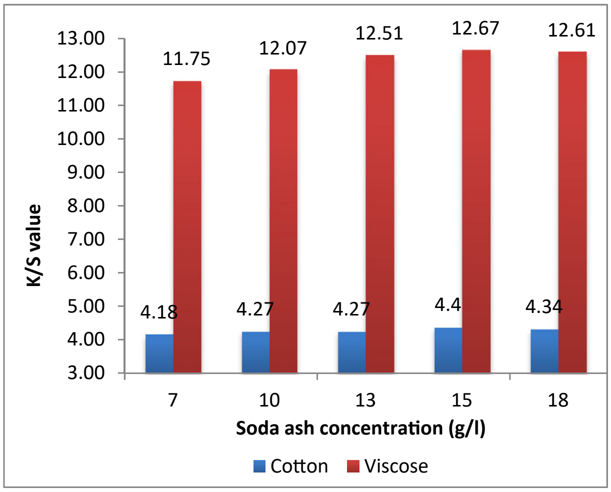

Figure 9. Influence of soda ash on K/S value.

K/S value for both fiber fabrics. From the results, it is noticed that viscose fiber fabrics is more influenced by dyeing temperature than that of cotton [3, 4, 31, 32, 33].

3.1.4. Effect of salt concentration

Subsequent to dyeing, K/S value of dyed viscose and cotton fabric samples is plotted against changing salt concentration from 20 to 60 g/l as shown in Figure 8. Fundamentally, reactive dyes and cellulose fibers such as viscose & cotton fiber exhibit negative charge in an aqueous state and drive back each other decreasing substantivity of dye. Once salt is added in the dye bath to reduce the negative charge by decreasing its zeta potential difference between the fiber phase and dye molecule, resulting

$$\mathrm{D-SO_2-CH=CH_2+HO-Cell \rightarrow D-SO_2-CH-CH_2-O-Cell}$$
(Dyed Fiber)

Scheme 1. Formation of H-bond between cellulose-OH groups of fabrics and dye molecule.

$$\mathrm{D-SO_2-CH=CH_2\ +H_2O \quad \rightarrow D-SO_2-CH-CH_2-OH}$$
(Hydrolyzed dye)

Scheme 2. Reaction of dye molecules with water-OH groups.

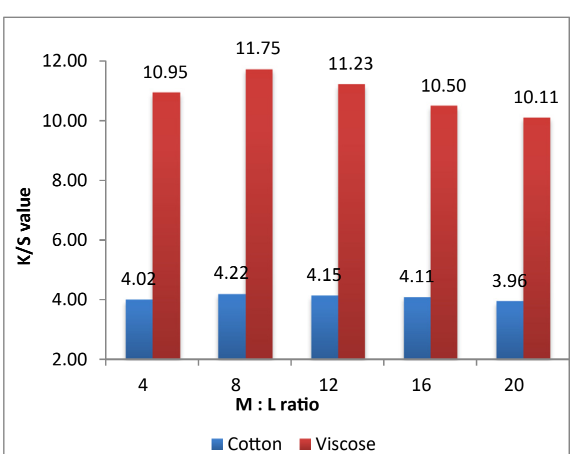

Figure 10. Effect of M: L ratio on K/S value.

VS = Vinyl sunphone and MF = Multifunctional

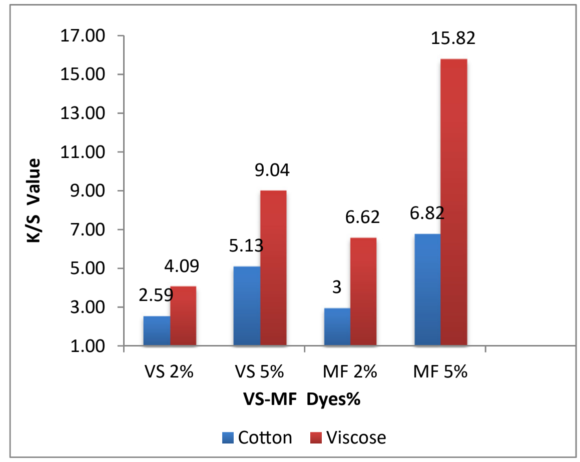

Figure 11. Influence of different dyes class on K/S value.

in absorption of dye molecules from dye bath to inter and intra-fibre pores of viscose and cotton fabric. It is observed from Figure 8 that the K/S value increases from 9.16 to 13.06 for viscose fiber & the K/S value rises from 3.70 to 4.62 for cotton fiber with increases in salt concentration from 20 to 60 g/l, respectively. This is because salt concentration quashes negative charge development at the surface of fabrics and endorses the rate of dye exhaustion, resulting in a greater K/S value. The results showed that the increment of K/S value for viscose fiber is higher than cotton in similar salt concentration as viscose fiber is more absorbent than cotton [2, 4, 31, 32, 33].

3.1.5. Effect of soda ash

The K/S value of dyed viscose and cotton knitted fabrics at various amount of soda ash ranging from 7 to 18 g/l are demonstrated in Figure 9. It is observed from Figure 9 that the K/S value increases slowly from 11.75 to 12.67 for dyed viscose fabrics and K/S value rises from 4.18 to 4.40 for dyed cotton fabrics respectively, with the increase in amount of soda ash from 7 to 15 g/l due to formation of H-bond between cellulose-OH groups of fabrics and dye molecule (Scheme 1). However, K/S value steadily declines from 12.67 to 12.61 and 4.4 to 4.34 for viscose and cotton fabrics, respectively, with an additional increase in soda ash concentration from 15 to 18 g/l. It is because, a higher soda ash concentration over 15 g/l of a specific dye concentration and salt concentration formed the dye bath much more anionic that drive back each

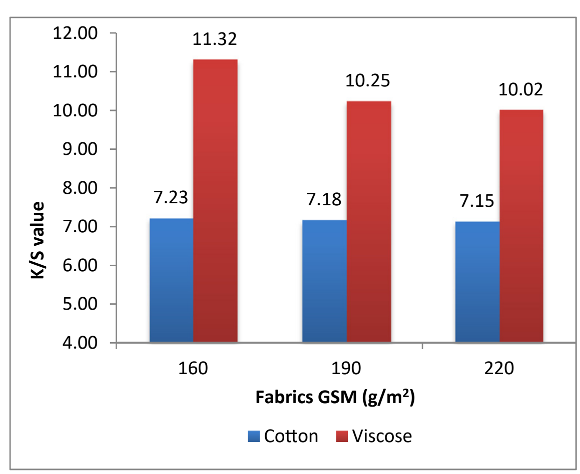

Figure 12. Effects of fabrics GSM on K/S value.

Table 2. Influence of wash time on color fastness to wash and rub.

Exp. No.	Fiber type	Washing Time (Min)	Wash Fastness				Rubbing Fastness	
			Color staining			Color change	Dry	Wet
			Cotton	Nylon	Polyester			
1	Cotton	10	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4
2	Cotton	20	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4
3	Cotton	40	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4

other, results in reaction of dye molecules with water-OH groups (hydrolysis) instead of cellulose-OH groups (Scheme 2), leading to lower K/S value for both fiber fabrics [4, 31, 32].

3.1.6. Effect of material to liquor ratio

The dyeing processes were conducted for viscose and cotton fabric by exhaust method with dye 5% o.w.f., G/salt 50 g/l, soda ash 13 g/l, dyeing time 60 min, dyeing temperature 60 °C and varying liquor ratio at 1:4, 1:8, 1:12, 1:16, 1:20. The impact of different liquor ratios on the K/S value of both fiber fabrics is illustrated in Figure 10. As can be observed from Figure 10 that the K/S value of dyed fabrics increase with the rise in liquor ratio from 1:4 to 1:8, and optimal K/S value of 11.75 and 4.22 were achieved at a liquor ratio of 1:8 for viscose and cotton fabrics, respectively, due to higher exhaustion of dye molecules. It is evident that K/S values increase 6.8% and 4.7% for viscose and cotton fabrics, respectively, with an increase in liquor ratio from 1:4 to 1:8. However, it declines 4.4% and 1.7% for viscose and cotton fabrics, respectively, with an increase in liquor ratio over 1:8. This is because, at a higher liquor ratio, the concentration of dye baths is low; accordingly, the dye concentration gradient is lower, which tends to lesser dye exhaustion and poor K/S value. Moreover, at a lower liquor ratio of 1:4, it is inadequate in quintiles of liquor to dye the fabrics, leading to uneven dyeing quality. It is concluded from this investigation that the effects of liquor ratio on the K/S value of viscose fiber fabrics are more prominent than cotton fabric [4, 31, 32, 33].

3.1.7. Effect of different dyes class

The dyeing process was executed for viscose and cotton fabrics by exhaust method using two different classes of dyes such as vinyl sulphone (VS) and multifunctional (MF) dyes with dye (2%, 4% o.w.f), salt (40 g/l, 60 g/l), soda ash (10 g/l, 15 g/l), at 60 °C for 60 min and LR of 1:10. The effects of VS and MF dyes on the K/S value of dyed viscose and cotton fabric samples are plotted and graphically depicted in Figure 11. It can be seen that the K/S value of MF dyes is greater than VS dyes and the K/S value increase with the increase in dye concentration for both fiber fabrics. It is observed from Figure 11 that the K/S value of VS dyes for cotton and viscose fabrics is 2.59 and 4.09 respectively, while the K/S value of MF

Table 3. Influence of wash temperature on color fastness to wash and rub.

Exp. No.	Fiber type	Wash Temperature (°C)	Wash Fastness				Rubbing Fastness	
			Color staining			Color change	Dry	Wet
			Cotton	Nylon	Polyester			
1	Cotton	80	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4
2	Cotton	95	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4
3	Cotton	110	4–5	4–5	4–5	4–5	4–5	2–3
	Viscose		4–5	4–5	4–5	4–5	4–5	3–4

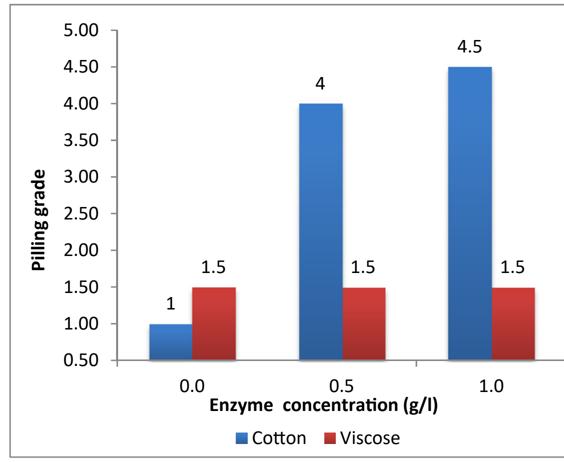

Figure 13. Effects of enzyme on pilling resistance.

dyes for cotton and viscose fabrics is 3 and 6.62 respectively, at 2% shade. Furthermore, in the case of 5% shade, it can be seen from Figure 11 that the K/S value of VS dyes is 5.13 and 9.04 for cotton and viscose fabrics, respectively, while the K/S value of MF dyes is 6.82 and 15.82 for cotton and viscose fabrics, respectively. A possible explanation for this greater K/S value in the case of both fiber fabrics may be due to the higher reactivity and substantivity of MF dyes as compared to VS dyes. Moreover, the K/S value of viscose fabric is superior to cotton in both classes of dyes due to the more absorbent viscose fabrics than cotton [4].

3.2. Effect of knitted fabric GSM

In Figure 12, the K/S value of dyed viscose and cotton fabrics is plotted against varying fabric GSM (Fabric areal density) from 160 to 220. It is fairly logical that the lower linear density of yarn of lower count would result in higher fabric GSM, leads to lower number porosity in the fabric. It is evident that the K/S value decreases slowly from 11.32 to 10.02 for dyed viscose fabrics and K/S value declines gradually from 7.18 to 7.15 for dyed cotton fabrics respectively, with the increase in fabric GSM from 160 to 220. This is because fabric with higher GSM contains lesser number of porosity in the fabric due to coarser yarn linear density, results in lesser dye penetration into the fabrics through open void in cellulosic fabric, leading to lower K/S value for both fiber fabrics. Therefore, it could be concluded that the effect of Fabric GSM on K/S value is inverse [4, 10].

3.3. Effect of washing time and temperature on color fastness properties

The influence of washing time on washing and rubbing fastness is shown in Table 2. It can be seen that the color fastness to wash is 4–5 (good to excellent), under different wash times for viscose and cotton fabrics. This may be due to good dye fixation, resulting in smaller unfixed dyes on the dyed fabrics surface, leading to a greater rating of wash fastness of both fiber fabrics. It can also be comprehended from Table 2 that the results of dry rubbing fastness of viscose and cotton fabrics samples are 4–5 (good to excellent), while wet rubbing fastness of viscose dyed samples is between 3–4 (fair to good) and wet rubbing fastness of cotton dyed samples lie between 2–3 (average to fair). A possible explanation for this may be higher exhaustion and fixation of dye molecules from fiber surface to inside of the fiber because of superior absorbent viscose fiber as compared to the cotton, resulting in a lesser amount of unfixed dye on the fiber surface, leading to a higher rating of wet rubbing of viscose. The results of color fastness of washing and rubbing for viscose and cotton fabrics dyed samples in different wash temperatures are presented in Table 3. It can be seen that color fastness to washing and dry rubbing rating for both fiber fabrics dyed samples in

E	+	S	→	ES	→	E	+	P
Enzyme		Substrate		Enzyme-substrate complex		Enzyme		Product

Scheme 3. Bio-reaction mechanism between enzyme and fabric.

various wash temperatures is similar (4–5) (good to excellent). However, the wet rubbing fastness rating of viscose dyed samples is between 3–4 (fair to good) and the wet rubbing fastness rating of cotton dyed samples lie between 2–3 (average to fair). This can be attributed to that viscose fiber uptakes extra dyes due to more absorbent than cotton, resulting in a smaller amount of unfixed dyes on the surface of dyed fabric, leading to a larger grade of wet rubbing of viscose in various wash temperatures. The wet rubbing fastness of cotton varies between 2–3 (average to fair) that can be enhanced by using of silicone-emulsion treatment through pad-dry-cure method. From Tables 2 and 3, it is concluded that color fastness properties particularly color fastness to washing and rubbing are not influenced by the washing time and temperature rather it depends on the brand of reactive dye and dyeing process. As vinyl sulphone reactive dye and exhaust dyeing method has only been used in this study for both fiber fabrics, hence no comparison has been presented on the color fastness properties of viscose and cotton fabrics. Moreover, the color fastness to wet rubbing of viscose fiber is inherently greater than cotton.

3.4. Analysis of enzyme on pilling performance

The pilling performance of treated viscose and cotton fabrics is plotted against changing enzyme concentration from 0 to 1.0 g/l keeping other parameters constant as schematically depicted in Figure 13. Fundamentally, enzyme (E) is a biocatalyst, and it can't enter inside the cellulosic fabric substrate (S). Moreover, the active site of the enzyme acts on surfaces of the fabric and binds to a specific substrate. The active site of the enzyme catalyst works at first to produce an enzyme-substrate complex (ES), which lastly breaks down into the product (P) and regenerated enzyme (E) through the bio-reaction mechanism as demonstrated in Scheme 3. This bio-reaction increase with the increase in enzyme concentration and the process continues until the enzyme deactivates. It can be seen from Figure 13 that the pilling grade of cotton knitted fabric increase from 4 (good) to 4.5 (good to excellent) with the increase in enzyme concentration from 0.5 to 1 g/l due to the removal of projecting fiber from the surface of the fabric through the bio-reaction. However, it is further observed from Figure 13 that there is no enzymatic effect on the pilling grades of viscose fiber fabric. This may be because cellulosic viscose fiber fabric is regenerated in nature and pilling grades of viscose fabric can be improved by mechanical singeing process. Moreover, the pilling grade of non-enzyme treated viscose and cotton fabrics is found to be 1.5 (poor to average) and 1 (poor), respectively. It is because cotton fiber contains more projecting fiber on the surface than viscose fiber, which increases the pill formation, leads to lower or poor pilling grade. It is concluded that enzyme treatment improves the pilling grades of cotton knitted fabric while no enzymatic influence on the pilling ratings of viscose fiber fabric.

4. Conclusion

In this study, the effects of different process variables on the K/S value, color fastness, and pilling resistance of viscose and cotton knitted fabrics have been analyzed and the results are subsequently compared between both fabrics. The K/S value increases promptly for viscose fabrics whereas increases slowly for cotton fabric with the increase in salt concentration, temperature, dyeing time, and dye concentration. However, for both fabrics, the effects of dyeing time, temperature and liquor ratio on the K/S value were found not to be linear and the extreme K/S value was obtained at 60 °C for 75 min. Besides, dye is the most influential process parameter on K/S value of both viscose and cotton fabrics than other parameters. On the contrary, the K/S value decreases abruptly for viscose knitted fabrics but declines marginally for cotton fiber fabrics with rises in the liquor ratio and the fabric GSM, and optimal K/S value was found to be at LR of 1:8. Moreover, because of high substantivity, the multi-functional dyes exhibit the uppermost K/S value than the vinyl sulphone dyes. Additionally, it is found that the fastness of the dyed fabric is influenced by the various classes of reactive dye and dyeing techniques other than washing parameters and kind of fibers. The results of this analysis demonstrate that the K/S value of viscose fiber is stronger than the cotton under similar process variables and there is no enzymatic effect on viscose fabric.

Declarations

Author contribution statement

Ismail Hossain: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Md. Moniruzzaman, Md. Maniruzzaman: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Mohammad Abdul Jalil: Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

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