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The Effect of alkaline pretreatment on the performance of digital inkjet printing and sublimation printing on polyester and cotton-polyester blend fabrics

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Nowadays, digital inkjet printing and sublimation printing have become the center of attention in the clothing and fashion industry due to their outstanding features, such as quick and stable printing, ease of implementation, and high-resolution printing. This study studies the effect of alkaline hydrolysis on digital inkjet printing and sublimation printing on polyester and cotton-polyester blend fabrics. The effects of three main factors, including alkaline hydrolysis, color, and color depth, were investigated using a full factorial design on the response variables, namely color strength (K/S), lightness (L*), and chroma (C*) of the printed fabrics. The results indicated that the three independent factors significantly impacted color strength in inkjet printing on polyester, as well as on cotton-polyester fabrics and sublimation printing on cotton-polyester fabrics. Additionally, it was observed that the three independent factors had a significant impact on the lightness variable in inkjet printing on both fabric types. All three independent factors significantly affected the chroma for both printing methods on cotton-polyester fabrics. Generally, the findings indicate a direct relationship between alkaline hydrolysis pretreatment and enhanced printing quality.

Keywords: Alkaline pretreatment, Cotton-polyester blend, Digital inkjet printing, Polyester, Sublimation printing

1 Introduction

In the textile industry, fabric printing is defined as a specialized activity involving localized dyeing. In fact, printing involves transferring information such as text, letters, images, and more onto a background. Fabric printing combines the use of chemicals and mechanical devices, which can be performed manually or digitally, where precision and quality are of high importance[1,2].

Recently, the demand for higher-quality designs and lower production costs has led to significant attention toward inkjet printing, also known as digital printing. The benefits of inkjet fabric printing include high precision, a wide color range, waste reduction, decreased environmental pollution, minimal time required to progress from idea to prototype, time savings, high repeatability, the ability to print diverse and complex designs, and the capability to print on both finished products and raw fabrics[3-6].

Sublimation printing is a type of digital printing. Today, it is very popular in the clothing and fashion industries, continuously creating new opportunities for fabric and textile products. In this method, the colored design is first printed on a special paper known as transfer or sublimation paper. Then, the design is transferred to the fabric (usually polyester or polyester blend) using a heat press. This printing method offers high flexibility, allowing for printing on any part of the garment or chosen item. The advantages of the sublimation printing method include fast and stable printing, an easy and cost-effective process, minimal sampling costs, no limitations on design and color, high precision, and lower investment costs[7-9]. Some studies conducted on digital inkjet printing and sublimation printing are as follows:

El-Halwagy *et al.* evaluated the sublimation printing on cotton and wool fabrics. They examined the produced prints for color strength, fastness properties, and mechanical properties[10]. Bemska and Szkudlarek evaluated the use of polymers to cotton fibers to improve dye uptake from sublimation inks and, consequently, to facilitate the printing process on cotton[11]. Hajipour and Shams-Nateri evaluated the effect of fabric density on the quality of digital printing on polyester. In this research, the effect of weft density on the inkjet printing of polyester was examined[12]. In another study, researchers investigated the effect of time and temperature variables on printing quality in sublimation transfer printing on

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nylon and polyester fabrics. Results indicated that application differences, depending on both temperature and time, cause changes in color values[7]. Stojanović *et al.* examined the impact of sublimation transfer printing on the structural and physical characteristic of knitted fabrics. Results showed that changes in the structural and physical properties of polyester knitted fabrics were small, while major changes in structure were observed in knitted fabrics containing cotton fibers[13].Alihoseini *et al.* studied direct sublimation inkjet printing on polyester textiles as a novel, eco-friendly method. This approach addresses natural resource limitations and environmental problems by eliminating the need for transfer paper and chemical surface treatments[14]. Adel *et al.* evaluated the effectiveness of modified printable papers for application in heat sublimation transfer printing on polyester fabric. The study also investigated the printability of the transfer and the ease of dye release from the paper to the fabric during this heat transfer process, using silk-screen printing under various transfer parameters[9]. Farzana and Neelakandan investigated pre-treatments to enhance inkjet printing on polyester. For instance, a novel two-step process using lipase enzyme followed by cyclodextrin and citric acid was developed, which significantly improved color yield and outline sharpness by effectively modifying the fabric surface for better ink adhesion[15]. Gao *et al.* investigated direct inkjet printing on polyester fabrics. They developed a thixotropic adjustable disperse dye ink on polyester fabrics without pretreatment[16].

One of the key features of sublimation and inkjet printing is their suitability for various fabrics, including cotton, silk, wool, nylon, and polyester, with recent work continuously improving their efficacy on these materials[15-22]. In the meantime, polyester textiles are widely used in the apparel industry and receive more attention due to their special properties, such as high resistance to chemicals, wrinkling, and abrasion, a dominance that continues to grow, especially in performance applications. However, the lack of hydrophilic functional groups in polyester textiles and their hydrophobic nature lead to undesirable characteristics, such as low moisture absorption, static electricity buildup, poor wettability, and poor dyeability, issues which are now being quantified with advanced surface characterization techniques. So far, various methods have been proposed to modify the surface of different fibers and fabrics, and recent reviews have comprehensively compared these modern strategies[23-32]. The most common method for modifying polyester fiber and fabric surfaces to enhance their properties and dyeability is alkaline hydrolysis using sodium hydroxide (NaOH). This process is still being actively refined and optimized for specific applications, such as blended fabrics[33-34].

This study aims to investigate the impact of alkaline hydrolysis on digital inkjet printing and sublimation printing on polyester and cotton-polyester blend fabrics. For this purpose, a full factorial design and analysis of variance (ANOVA) were employed to evaluate the impact of three important independent factors, including alkaline hydrolysis, color, and color depth, on the response variables, including color strength (K/S), lightness (L*), and chroma (C*). The two printing methods discussed were also analyzed in terms of various factors, including color parameters and washing fastness.

2 Materials and methods

2.1 Fabric Preparation and Printing

The fabrics used in this study include 100% polyester fabric with a simple weave, weighing 114 g/m^2, and cotton-polyester fabric made up of 40% cotton and 60% polyester, also with a simple weave, weighing 144 g/m^2.Both fabrics were produced by Afyouni Fabric Factory, in Isfahan, Iran.Inkjet printing on fabric was conducted by New Chap Co. (Iran) using an Epson SureColor F9200 inkjet printer made in Turkey. Four colors, including yellow, blue, green, and red, were used in two color depths: low and high. Sublimation printing on fabric was performed with an X2-i3200 ECO Solvent Printer featuring an Epson i3200 printhead.

2.2 Alkaline Treatment of Fabrics

Alkaline treatment of fabrics was carried out with 166 g/L of sodium hydroxide for 105,140, and 180 mins at a temperature close to the boiling point. Table 1 shows the weight loss percentage of polyester and cotton-polyester fabrics after alkaline hydrolysis.

Table 1 — The weight loss of polyester and cotton-polyester fabrics using alkali treatment

Temperature, C°	Time, min	Weight loss, %	
		Polyester	Cotton-polyester
90	105	4.17	4.86
	140	10.53	8.33
	180	29.82	22.22

2.3 Measurement of Reflectance Spectra and Color Characteristics

The reflectance spectrum of the printed fabrics was measured using an i1 Pro2 spectrophotometer manufactured by X-Rite, covering the wavelength range of 400 to 700 nanometers. The color characteristics of the samples were computed in the CIELAB color space under the CIE standard illuminant D65 and the 1964 standard observer. The scatter plot of the colorimetric data for polyester and cotton-polyester fabrics printed by inkjet and sublimation methods is shown in Figure 1. In the CIELAB color space, L* denotes lightness, a* denotes redness-greenness, b* represents yellowness-blueness, and C* indicates chroma.

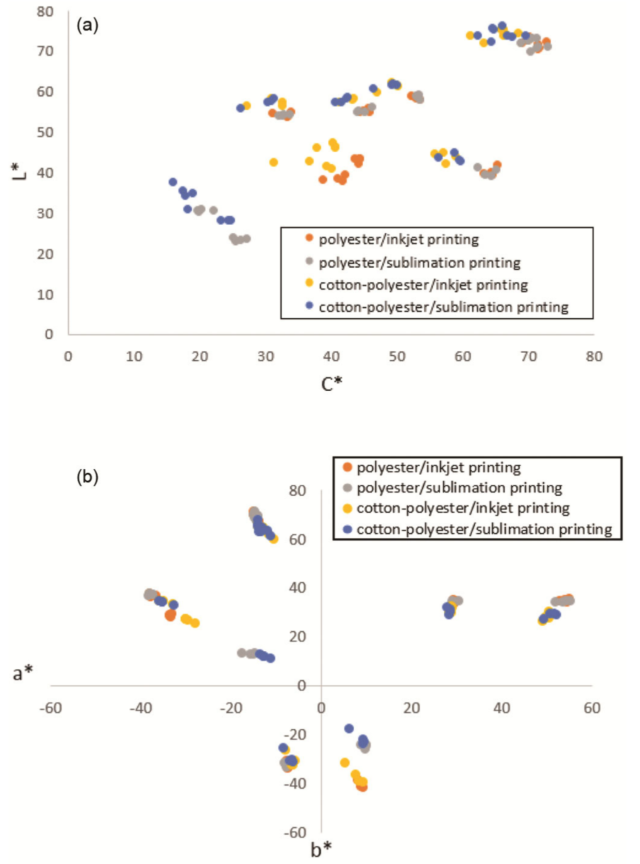

Fig. 1 — The scatter plot of colorimetric data for polyester and cotton-polyester fabrics printed using inkjet and sublimation methods in the CIELAB color space for A (L*, C*) and B (a*, b*)

Furthermore, the color strength of the printed fabrics was calculated using the Kubelka–Munk Equation1[35]:

$$\left(\frac{K}{S}\right)_{\lambda} = \frac{(1-R_{\lambda})^{2}}{2R_{\lambda}} \qquad \dots (1)$$

Where K represents the absorption coefficient, S represents the scattering coefficient, and R represents the reflectance spectra at a specific wavelength.

2.4 Experimental Design Using the Full Factorial Design Method

The full factorial design method is one of the most widely used approaches for experimental design, allowing for the examination of all interactions. The design is conducted based on all possible combinations across the defined levels of the factors and the response variable[36,37]. In this work, the full factorial design method was employed, considering three main factors: alkaline hydrolysisat four levels, color depth at two levels, and sample color at four levels as independent variables, and color strength (K/S), lightness (L*), and chroma (C*) of the printed fabricsas the response variables.

Table 2 presents the factors and the number of levels used. It should also be noted that Minitab version 18 software was used to design the experiment using the full factorial design method and to perform the statistical analysis of the experiment.

2.5 Scanning Electron Microscopy

Morphological analyses of fabric surfaces were carried out using a PHILIPS-XL30 scanning electron microscope (SEM).

2.6 Fourier Transform Infrared Spectroscopy

Fourier Transform Infrared (FTIR) spectroscopy of the fabric samples was recorded using an FTIR spectrometer from JASCO Co. in the range of 350 to 7800 cm^{-1}.

2.7 Measuring the Washing Fastness

AATCC Test method 61-2003 standard was employed for the washing fastness. The color change was evaluated using the AATCC Gray Scale for washing fastness.

Table 2 — Factors and their corresponding levels

Factors	Symbolic coding	level			
Alkaline hydrolysis	A	Untreated	Low	Medium	High
Color	B	Yellow	Blue	Green	Red
Color depth	C	Low		High	

3 Results and Discussion

3.1 Analysis of SEM Results

SEM analysis was used to examine the morphological changes of the fabric surface resulting from the alkaline hydrolysis modification process. Images were captured at four magnification levels i.e., 200x, 500x, 2000x, and 4000x, with an acceleration voltage of 12 to 15 kV.

Figure 2 illustrates the structures of the untreated polyester fabric and hydrolyzed polyester fabric (high level of alkaline treatment) at different magnifications.

Figure 2 (a) to dillustrates the polyester fabric without surface treatment, which appears smooth with very few pores. Figure 2 (e) to h shows the sample with the maximum weight loss, where significantpits are observed on the sample surface after the alkaline hydrolysis treatment.

Figure 3 presents the SEM images of the untreated cotton-polyester fabric and hydrolyzed cotton-polyester fabric(high level of alkaline treatment)at different magnifications.

Figure 3 (a) to d illustrates the cotton-polyester fabric without surface treatment. In Figure 3(e) to (h), the cotton-polyester fabric is treated at a high level of alkaline treatment, and significant pits are observed on the sample surface. A little deterioration is observed in some regions of the cotton fibers.

3.2 FTIR Analysis

FTIR spectroscopy plots were utilized to confirm the presence of hydroxyl groups and carboxylate ions, which contribute to enhancing the hydrophilicity of polyester in the hydrolyzed samples. Figure 4 (a) and (b) illustrate the FTIR spectrum for the untreated and hydrolyzed (high level of alkaline treatment) polyester and cotton-polyester fabrics, respectively. As seen in this figure, a wide peak around 3440 cm^{-1} is due to the OH stretching vibrations, and the absorption at 1720 cm^{-1} corresponds to the C=O stretching vibrations of carboxylic acid.

According to the FTIR plot in Figure 4 (a) and (b), at the beginning of the plot, in the interval between 2900 and 2970 cm^{-1}, a weak peak with low intensity is observed, which corresponds to the stretching of CH bonds. The second interval related to the peak of the C=O carbonyl group in the region between 1710 and 1750 cm^{-1}shows sharp peaks that are observed in the interval between 1500 and 2000 cm^{-1} of part A. The next range corresponds to the aromatic region, showing small peaks in the interval between 1400 and 1500 cm^{-1}, indicated by B.

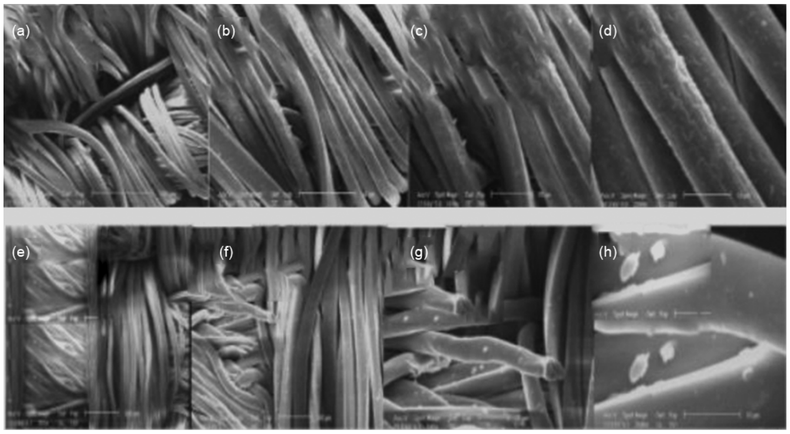

Fig. 2 — SEM images of (a) to (d) the surface of untreated polyester fabric, and (e) to (h) the surface of the hydrolyzed polyester fabric(high level of alkaline treatment), (magnifications of 200x, 500x, 2000x, and 4000x, respectively)

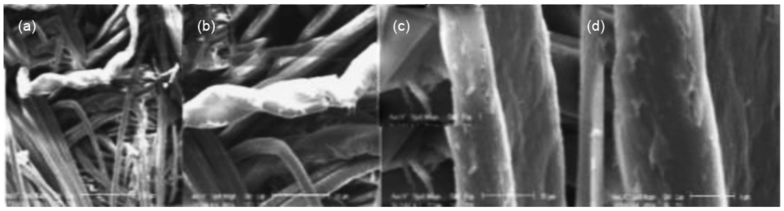

Fig. 3 — SEM images of (a) to (d) the surface of untreated cotton-polyester fabric, and (e) to (h) the surface of the hydrolyzed cotton-polyester fabric with the maximum weight loss (magnifications of 200x, 500x, 2000x, and 4000x, respectively)

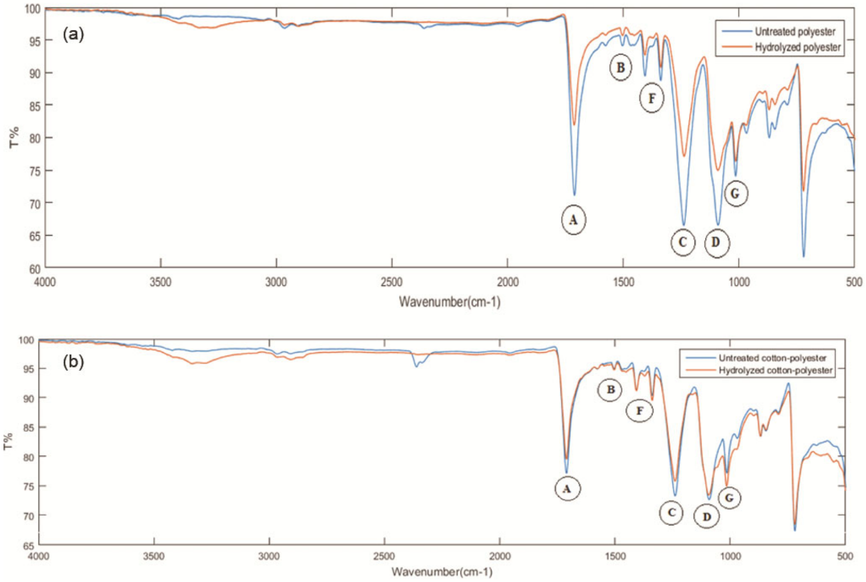

Fig. 4 — FTIR spectrum: (a) untreated and hydrolyzed (high level of alkaline treatment) polyester, and (b) untreated and hydrolyzed (high level of alkaline treatment) cotton-polyester

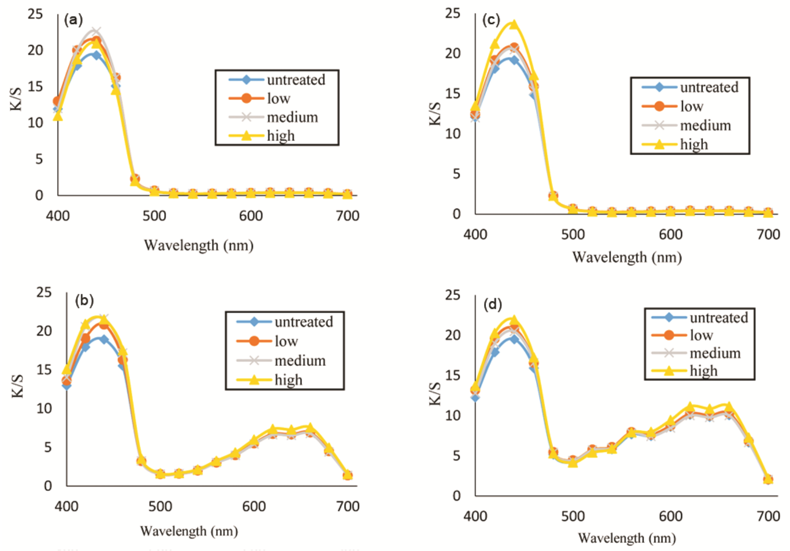

Fig. 5 — Color Strength (K/S) of polyester fabric printed at different levels of alkaline hydrolysis for (a) inkjet printing, yellow; (b) inkjet printing, green; (c) sublimation printing, yellow; and (d) sublimation printing, green

The subsequent range corresponds to the carboxylic acid group C-O, appearing at 1240 cm^{-1}, indicated by C. The D and G regions correspond to the ester group COOR, which appears in the range of approximately 1000 to 1100 cm^{-1}, and region F shows the methyl group, which is asymmetrically situated in the structure and appears around 1450 cm^{-1}.

3.3 Examination of the Color Strength of Printed Fabrics

Figure 5 illustrates the color strength of polyester fabrics printed using inkjet and sublimation printing methods in two colors of yellow and green with high color depth, under different levels of alkaline hydrolysis. As Figure 5 demonstrates, alkaline hydrolysis treatment enhances the color strength of the printed samples, with the highest color strength in sublimation printing achieved at the maximum level of alkaline hydrolysis.

Figure 5 also indicates that in both printing methods, fabrics printed without alkaline hydrolysis exhibit the lowest color strength.

Figure 6 illustrates the color strength of cotton-polyester fabrics printed using inkjet and sublimation

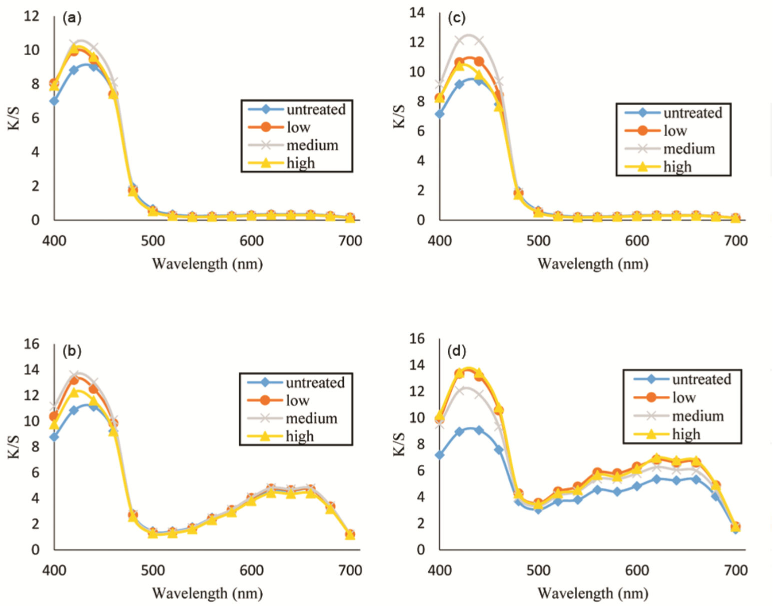

Fig. 6 — Color Strength (K/S) of cotton-polyester fabric printed at different levels of alkaline hydrolysis for (a) inkjet printing, yellow; (b) inkjet printing, green; (c) sublimation printing, yellow; and (d) sublimation printing; green

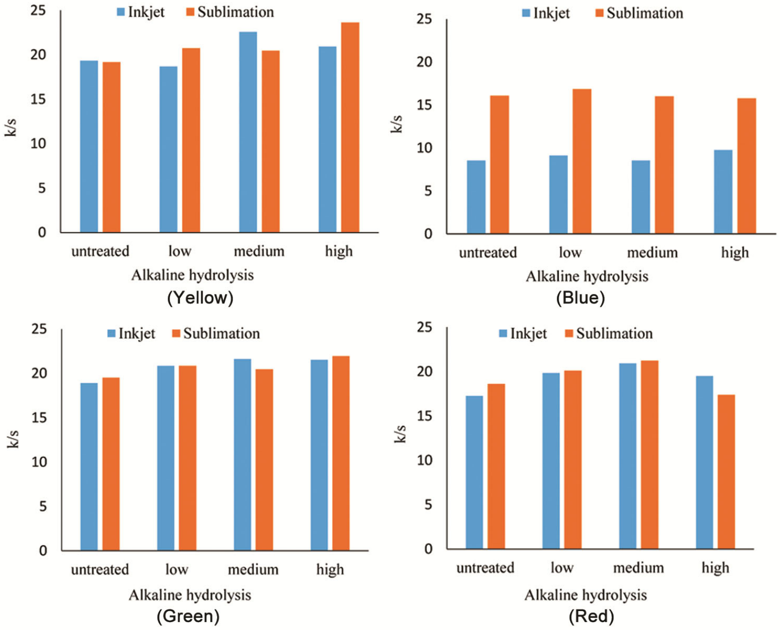

Fig. 7 — The comparison of the color strength (K/S) of the polyester fabrics printed using inkjet and sublimation methods

printing methods in two colors of yellow and green with high color depth, under different levels of alkaline hydrolysis. As Figure 6 shows, the untreated fabrics demonstrated the least color strength for both printing methods. The highest color strength was achieved at a high level of alkaline hydrolysis for green samples printed using the sublimation method. Additionally, the highest color strength was achieved at the medium level of alkaline hydrolysis for the samples printed by the inkjet method.

3.4 Comparison of the Color Strength (K/S) of Printed Fabrics Using Inkjet and Sublimation Methods

A comparison was made between the color strength (K/S) of the printed polyester fabric using inkjet and sublimation methods, in four colors, high color depth, and various levels of alkaline hydrolysis (Figure 7).

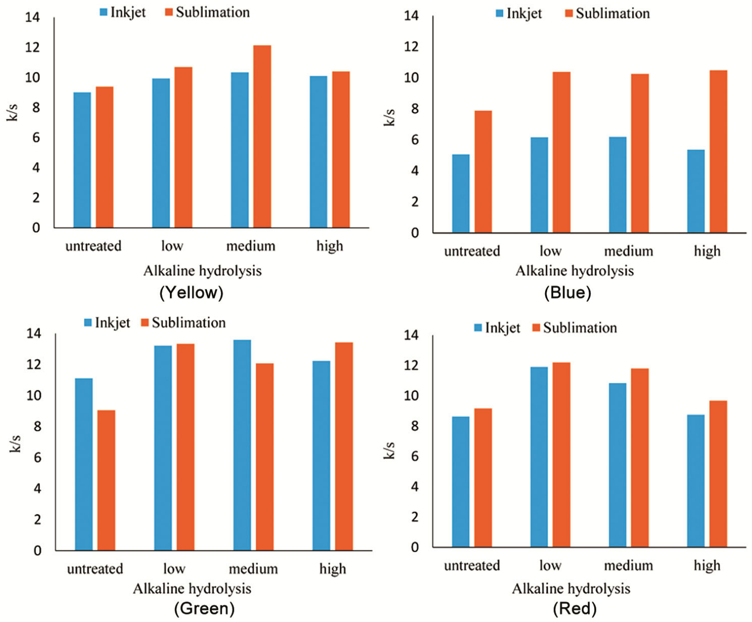

Fig. 8 — The comparison of the color strength (K/S) of the cotton-polyester fabrics printed using inkjet and sublimation methods

Table 3 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the color strength (K/S) of polyester fabrics printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	14.12	4.708	4.24	0.040	8.02	2.672	2.90	0.094
B	3	809.47	269.822	242.74	0.000	445.80	148.599	161.04	0.000
C	1	291.06	291.064	261.85	0.000	527.50	527.502	571.67	0.000
A*B	9	6.64	0.738	0.66	0.724	11.68	1.298	1.41	0.310
A*C	3	5.18	1.728	1.55	0.267	0.74	0.248	0.27	0.846
B*C	3	106.72	35.572	32.00	0.000	132.51	44.170	47.87	0.000
Error	9	10.00	1.112			8.30	0.923		
Total	31	1243.20				1134.56			

As shown in Figure 7, in blue samples, the K/S values of the sublimation method are higher than those of the inkjet method. Additionally, this result is observed to some extent for other colors.

Figure 8 also compares the K/S values of cotton-polyester fabrics using the two mentioned printing methods. As illustrated in this figure, the K/S values for all the samples printed by the sublimation method are higher than those printed with the inkjet method, except for two samples in green color.

3.5 ANOVA Analysis of Color Strength of Printed Fabrics

One of the most useful and common statistical methods for analyzing data is variance analysis, commonly known as ANOVA. Table 3 shows the ANOVA results for assessing the influence of three independent factors: alkaline hydrolysis (A), color (B), and color depth (C), on the response variable, which is the color strength of polyester fabric printed by inkjet and sublimation methods. Table 4 presents the ANOVA results for cotton-polyester fabric printed by inkjet and sublimation methods.

In this study, the P-value was used to assess the significance of the factors on the response variable at a 95% confidence interval.

As observed in Table 3, the P-value of factors A, B, and C of the fabrics printed by the inkjet method is less than 0.05. Therefore, these three factors have a significant impact on the color strength of the samples. In the sublimation method, factors B (color) and C (color depth) significantly affect the color strength of the samples, whereas the alkaline

Table 4 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the color strength (K/S) of cotton-polyester fabrics printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	8.121	2.7070	8.21	0.006	13.117	4.372	9.19	0.004
B	3	160.830	53.6098	162.64	0.000	60.683	20.228	42.51	0.000
C	1	89.227	89.2272	270.70	0.000	185.241	185.241	389.27	0.000
A*B	9	2.863	0.3182	0.97	0.521	3.857	0.429	0.90	0.561
A*C	3	2.447	0.8158	2.48	0.128	7.573	2.524	5.30	0.022
B*C	3	18.369	6.1229	18.58	0.000	24.123	8.041	16.90	0.000
Error	9	2.967	0.3296			4.283	0.476		
Total	31	284.824				298.877			

Table 5 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the lightness (L*) of polyester fabrics printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	5.95	1.98	6.02	0.016	2.45	0.82	3.82	0.051
B	3	3462.78	1154.26	3504.83	0.000	5054.58	1684.86	7878.67	0.000
C	1	1097.58	1097.58	3332.72	0.000	2898.34	2898.34	13553.09	0.000
A*B	9	3.32	0.37	1.12	0.434	2.30	0.26	1.19	0.398
A*C	3	2.25	0.75	2.27	0.149	0.87	0.29	1.36	0.316
B*C	3	323.33	107.78	327.26	0.000	1043.76	347.92	1626.93	0.000
Error	9	2.96	0.33			1.92	0.21		
Total	31	4898.17				9004.22			

Table 6 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the lightness (L*) of cotton-polyester fabric printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	6.25	2.08	8.74	0.005	1.13	0.38	0.56	0.652
B	3	3230.04	1076.68	4514.28	0.000	4580.03	1526.68	2284.73	0.000
C	1	1033.28	1033.28	4332.30	0.000	2486.21	2486.21	3720.71	0.000
A*B	9	10.77	1.20	5.02	0.012	9.29	1.03	1.55	0.264
A*C	3	2.06	0.69	2.88	0.096	9.12	3.04	4.55	0.033
B*C	3	258.45	86.15	361.21	0.000	888.30	296.10	443.12	0.000
Error	9	2.15	0.24			6.01	0.67		

hydrolysis factor does not significantly affect the color strength. Additionally, it can be observed that the interaction between the AB and AC factors is not significant for either of the printing methods (P>0.05), while it is significant for the BC factors.

As shown in Table 4, for the samples printed by both printing methods, three independent factors have a significant effect on color strength. Furthermore, the interaction between alkaline hydrolysis (A) and color (B), as well as alkaline hydrolysis (A) and color depth (C), is not significant for printed samples using the inkjet method (P>0.05), while the interaction between color (B) and color depth (C) is significant. Additionally, the interactions between color (B) and color depth (C) and between alkaline hydrolysis (A) and color depth (C) are significant for the samples printed by the sublimation method.

3.6 ANOVA Analysis of Lightness (L*) of Printed Fabrics

Tables 5 and 6 present the results of the analysis of variance for assessing the influence of three independent factors on the lightness response variable of polyester and cotton-polyester fabrics printed using inkjet and sublimation methods, respectively.

Tables 5 and 6 show that the factors alkaline hydrolysis (A), color (B), and color depth (C) have a

Table 7 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the chroma (C*) of polyester fabrics printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	5.35	1.78	1.93	0.195	3.9	1.31	1.82	0.214
B	3	4799.67	1599.89	1734.03	0.000	8258.5	2752.83	3811.99	0.000
C	1	184.87	184.87	200.37	0.000	181.8	181.76	251.70	0.000
A*B	9	9.97	1.11	1.20	0.395	10.4	1.15	1.59	0.249
A*C	3	2.32	0.77	0.84	0.507	2.2	0.73	1.01	0.431
B*C	3	825.13	275.04	298.10	0.000	2771.6	923.87	1279.33	0.000
Error	9	8.30	0.92			6.5	0.72		
Total	31	5835.62				11234.8			

Table 8 — ANOVA evaluating the influence of factors alkaline hydrolysis (A), color (B), and color depth (C) on the chroma (C*) of cotton-polyester fabrics printed using inkjet and sublimation methods

Source	DF	Inkjet printing				Sublimation printing			
		Adj SS	Adj MS	F-Value	P-Value	Adj SS	Adj MS	F-Value	P-Value
A	3	72.49	24.16	44.99	0.000	42.5	14.16	11.61	0.002
B	3	4172.98	1390.99	2589.72	0.000	7562.4	2520.80	2067.87	0.000
C	1	85.88	85.88	159.90	0.000	175.8	175.77	144.19	0.000
A*B	9	41.51	4.61	8.59	0.002	31.1	3.45	2.83	0.068
A*C	3	1.41	0.47	0.87	0.491	0.8	0.28	0.23	0.876
B*C	3	611.28	203.76	379.36	0.000	2444.2	814.74	668.36	0.000
Error	9	4.83	0.54			11.0	1.22		
Total	31	4990.39				10267.7			

significant effect on the lightness (L*) of polyester and cotton-polyester fabrics printed using the inkjet method ($P<0.05$). In contrast, in the samples printed via the sublimation method, the alkaline hydrolysis factor does not have a significant effect on lightness (L*). Additionally, Table 5 indicates that only the interaction between the factors color (B) and color depth (C), is significant in both printing methods. According to Table 6, the interaction between the factors alkaline hydrolysis (A) and color (B), as well as the interaction between color (B) and color depth (C), is significant for the samples printed using the inkjet method. Meanwhile, the interaction between color (B) and color depth (C), along with the interaction between alkaline hydrolysis (A) and color depth (C), is significant for the samples printed using the sublimation method.

The results in Table 7 indicate that the factors color (B) and color depth (C) have a significant impact on the chroma of the samples printed by both printing methods, while the effect of the factor alkaline hydrolysis (A) on the response variable is not significant. Additionally, the results indicate that the interaction between the factors color (B) and color depth (C) is significant for both printing methods.

According to Table 8, in both printing methods, all three independent factors have a significant impact on the chroma (C*) of the samples. The interaction between the factors alkaline hydrolysis (A) and color (B), as well as the interaction between color (B) and color depth (C) in inkjet printing, and the interaction between color (B) and color depth (C) in sublimation printing are significant.

3.7 ANOVA Analysis of Chroma (C*) of Printed Fabrics

Tables 7 and 8 show the results of the analysis of variance for assessing the influence of three independent factors on the chroma (C*) response variable of polyester and cotton-polyester fabrics printed using inkjet printing and sublimation printing methods, respectively.

3.8 Main Effects

A main effect is observed when different factors affect the response differently, and any change in the main variable results in a change in the experimental response. The slope of the line indicates the importance of the main effect.

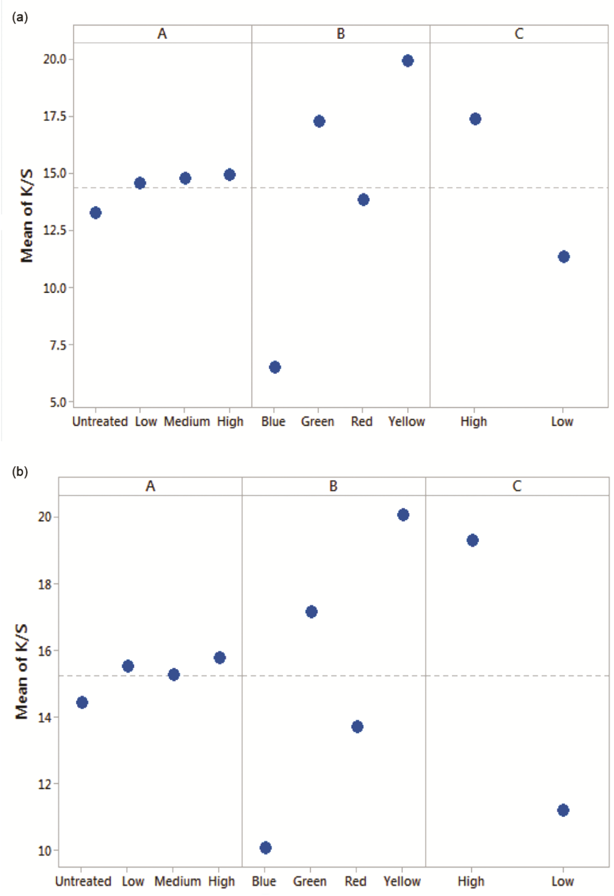

Fig. 9 — The main effect plot for the color strength (K/S) of polyester fabrics printed by (a) inkjet method, and (b) The sublimation method

The main effect plots for the three independent factors: alkaline hydrolysis (A), color (B), and color depth (C) on the color strength (K/S) response variable of polyester fabrics printed using inkjet and sublimation methods are illustrated in Figure 9. In Figure 9 (a), it is observed that all three independent factors impact the color strength of the samples. Figure 9 (b) indicates that two independent factors, color (B) and color depth (C), affect the K/S of the samples, which is supported by the variance analysis results in Table 3.

The main effect plots for the three independent factors on the color strength (K/S) response variable of cotton-polyester fabrics printed using inkjet and sublimation methods are illustrated in Figure 10. In Figure 10 (a) and (b), it is observed that all three independent factors impact the color strength of the samples.

Figure11 shows the main effect plots for the three independent factors: alkaline hydrolysis (A), color (B), and color depth (C) on the lightness (L*) response variable of polyester fabrics printed using inkjet and sublimation methods.

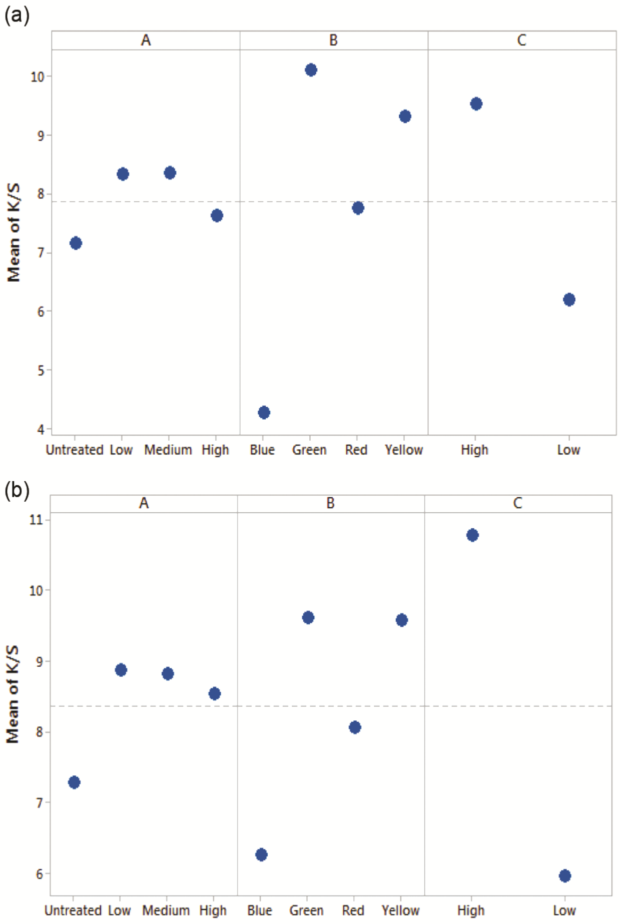

Fig. 10 — The main effect plot for the color strength (K/S) of cotton-polyester fabrics printed using (a) the inkjet method, and (b) the sublimation method

Figure11 (a), like the results of Table 5, confirms that all three independent factors affect the lightness of the samples. In Figure 11(b), the main plot indicates that color (B) and color depth (C) influence the lightness of the samples. Figure12 shows the main effect plots for the three independent factors on the lightness (L*) response variable of cotton-polyester fabrics printed using inkjet and sublimation methods.

According to the results presented in Table 6, Figure 12 (a) indicates that three independent factors, A, B, and C, affect the lightness of the samples. In contrast, Figure 12 (b) shows that only two independent factors, B and C, affect the lightness of the fabrics.

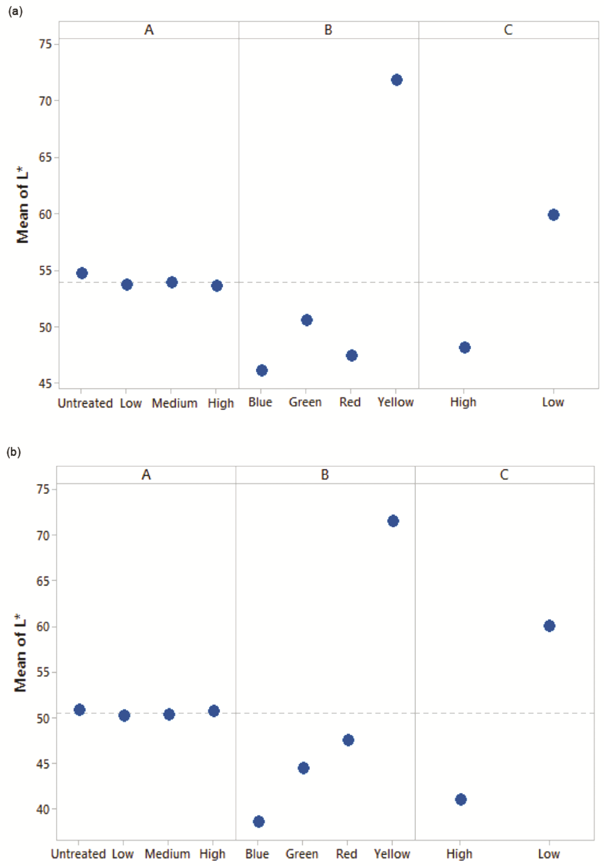

Fig. 11 — The main effect plot for the lightness (L*) of polyester fabrics printed by (a) inkjet method, and (b) sublimation method

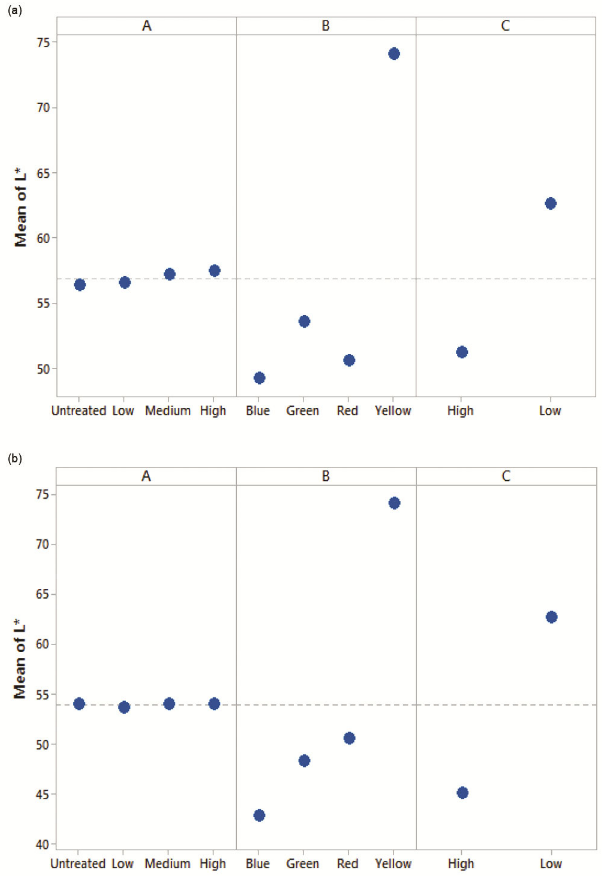

Fig. 12 — The main effect plot for the lightness (L*) of cotton-polyester fabrics printed by (a) inkjet method, and (b) sublimation method

Figure13 illustrates the main effect plots of the three independent factors: alkaline hydrolysis (A), color (B), and color depth (C) on the chroma (C*) response variable of polyester fabrics printed using inkjet and sublimation methods.

According to the results obtained from Table 7 and illustrated in Figure13 (a) and (b), it is evident that for the two printing methods, factor A does not affect the chroma of the samples, while the other two factors (color (B) and color depth (C) influence this variable.

Figure 14 illustrates the main effect plots of the three independent factors, A, B, and C, on the chroma (C*) response variable of cotton-polyester fabrics printed using inkjet and sublimation methods. Figure 14 (a) and (b) indicate that the factors of alkaline hydrolysis (A), color (B), and color depth (C) affect the chroma of the samples, a finding supported by the variance analysis results in Table 8.

3.9 The Washing Fastness of Printed Fabrics

The washing fastness of the printed fabrics was assessed using the grayscale. The results of the washing fastness tests of fabrics printed using inkjet and sublimation methods are shown in Table 9. Table 9 indicates that the washing fastness of the polyester fabrics printed by inkjet and sublimation methods is outstanding (rank 5). The washing fastness of cotton-polyester fabrics printed using both methods is rated as good (rank 3/4), very good (rank 4), excellent (rank 4/5), and outstanding. However, the washing fastness of the cotton-polyester fabric printed by inkjet printing (sample 16) was moderate.

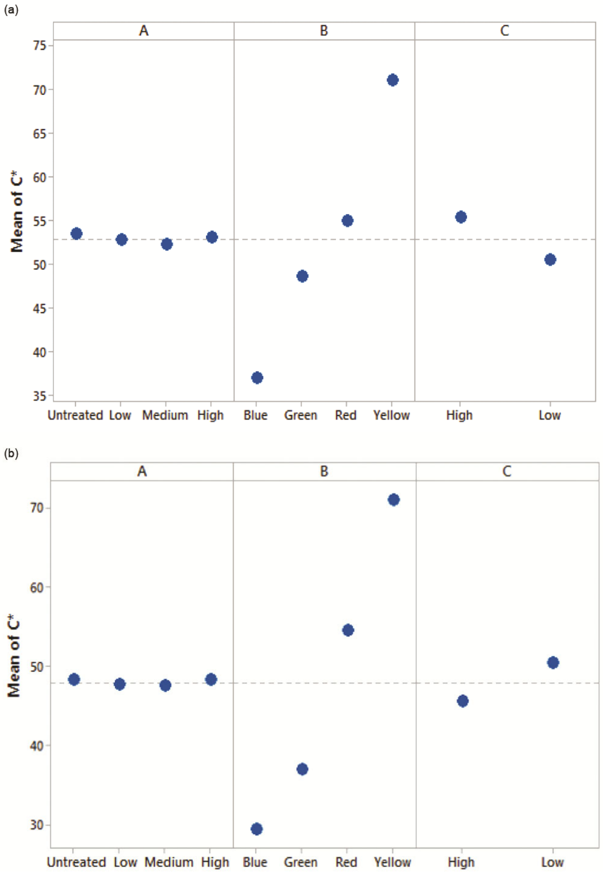

Fig. 13 — The main effect plot for the chroma (C*) of polyester fabrics printed by (a) inkjet method, and (b) sublimation method

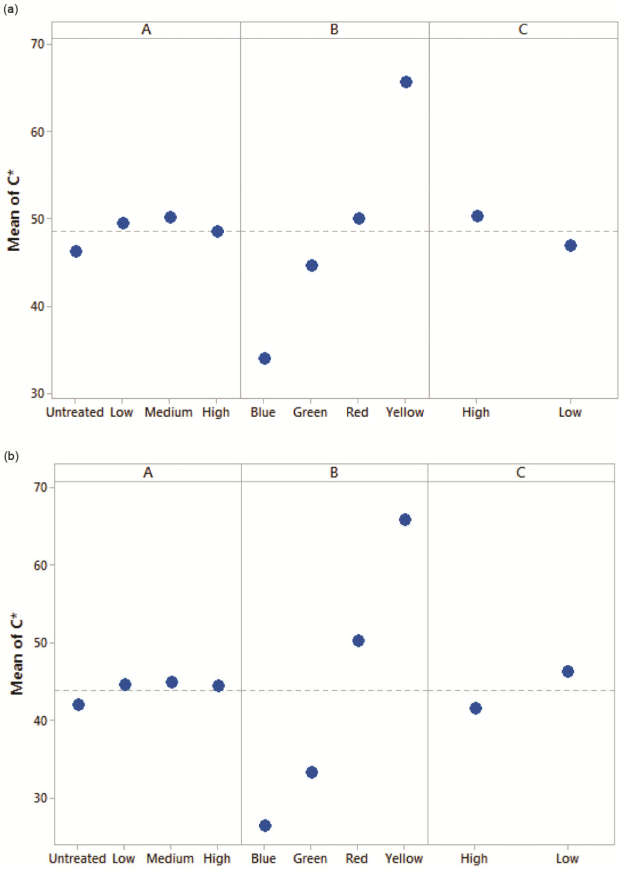

Fig. 14 — The main effect plot for the chroma (C*) of cotton-polyester fabrics printed using (a) the inkjet method, and (b) the sublimation method

Table 9 — Results of the washing fastness test for printed fabrics using inkjet and sublimation methods

No. of sample	Color	Alkaline hydrolysis	Color depth	Washing fastness			
				Inkjet	Sublimation	Inkjet	Sublimation
				polyester	polyester	cotton-polyester	cotton-polyester
1	Yellow	Untreated	Low	5	5	5	5
2		Untreated	High	5	5	5	5
3		Low	Low	5	5	4/5	4/5
4		Low	High	5	5	4/5	4/5
5		Medium	Low	5	5	4/5	4/5
6		Medium	High	5	5	4/5	4/5
7		High	Low	5	5	4	4
8		High	High	5	5	4	4
9	Blue	Untreated	Low	5	5	5	5
10		Untreated	High	5	5	5	5
11		Low	Low	5	5	4	4/5
12		Low	High	5	5	4	4/5
13		Medium	Low	5	5	4	4
14		Medium	High	5	5	4	4
15		High	Low	5	5	3/4	4
16		High	High	5	5	3	3/4

(*Contd.*)

Table 9 — Results of the washing fastness test for printed fabrics using inkjet and sublimation methods (*Contd.*)

No. of sample	Color	Alkaline hydrolysis	Color depth	Washing fastness			
				Inkjet polyester	Sublimation polyester	Inkjet cotton-polyester	Sublimation cotton-polyester
17	Green	Untreated	Low	5	5	5	5
18		Untreated	High	5	5	5	5
19		Low	Low	5	5	4/5	4/5
20		Low	High	5	5	4/5	4/5
21		Medium	Low	5	5	4/5	4/5
22		Medium	High	5	5	4/5	4/5
23		High	Low	5	5	4	4
24		High	High	5	5	4	4
25	Red	Untreated	Low	5	5	5	5
26		Untreated	High	5	5	5	5
27		Low	Low	5	5	4	4
28		Low	High	5	5	4	4
29		Medium	Low	5	5	5	4
30		Medium	High	5	5	5	4
31		High	Low	5	5	4/5	4
32		High	High	5	5	4/5	3/4

4 Conclusion

This study aims to investigate the impact of alkaline hydrolysis pre-processing on the printing quality of inkjet and sublimation printing methods on polyester and cotton-polyester fabrics using the full factorial design method. In the full factorial method, three independent factors, including alkaline hydrolysis, color, and color depth of samples, are considered at various levels, and the response variables are selected as color strength (K/S), lightness (L*), and chroma (C*) of the printed fabrics.

The statistical analysis of variance indicates that in inkjet printing on polyester and cotton-polyester fabric, as well as sublimation printing on cotton-polyester fabric, the three independent factors—alkaline hydrolysis (A), color (B), and color depth (C)—have a significant effect on color strength.

Additionally, the significant effect of the three independent factors on lightness (L*) was evident in inkjet printing on both types of fabrics, while in sublimation printing, alkaline hydrolysis exhibited no significant impact on lightness (L*) for either fabric. For polyester fabric, alkaline hydrolysis showed no significant effect on chroma (C*) for inkjet and sublimation printing, while all three independent factors exhibited a significant impact on the Chroma (C*) of cotton-polyester fabrics printed by both methods. The results generally showed a direct correlation between alkaline hydrolysis and the printing quality of polyester fabric. Alkaline hydrolysis treatments at medium and high levels led to increased printability and color strength of polyester and cotton-polyester fabrics in both inkjet and sublimation printing methods. However, it was observed that alkaline hydrolysis has a lesser effect on the printability of sublimation-printed polyester fabrics.

Our study's primary contribution is providing quantitative data that links chemical treatment to print performance. The key insight is that alkaline hydrolysis significantly enhances inkjet printing but has a much smaller effect on sublimation printing on pure polyester. This novel finding offers a clear, cost-saving directive for manufacturers, indicating that high-level hydrolysis may not be cost-effective for sublimation on 100% polyester. In essence, our work provides a practical, data-driven framework for optimizing processes and balancing quality with production costs.

References

1 Ragab MM, Othman H & Hassabo A, *Egypt J Chem*, 65(8) (2022) 749.

2 Magdassi S, *The chemistry of inkjet inks* (World scientific, Singapore), (2009) 3.

3 Hudd A, *Inkjet printing technologies* (World Scientific, Singapore), (2010) 3.

4 Shah MA, Lee DG, Lee BY & Hur S, *IEEE Access*, 9 (2021), 140079.

5 Nie L, Xu X, Chen Y, Dong Y, Chang G & Li R, *Langmuir*, 39(17) (2023) 6266.

6 Hajipour A& Shams-Nateri A, *Indian J Fibre Text Res*, 49(1) (2024), 83.

7 Özomay M & Özomay Z, *ejosat*, 23 (2021) 882.

8 Sarkodie B, Tawiah B, Agbo C & Wizi J, *AATCC J Res*, 5(2) (2018) 1.

9 Adel A M, Ahmed N M, Diab M A, El-Shall F N & El-Shinnawy N, *Sci Rep*, 13(1) (2023) 6536.

10 El-Halwagy A A, El-Sayad H S & El-Molla M M, *Macromol Mater Eng*, 286(10) (2001) 618.

11 Bemska J & Szkudlarek J, *Autex Res J*, 13(3) (2013) 67.

12 Hajipour A & Shams-Nateri A, *Fibers Polym*, 18 (2017) 2462.

13 Stojanović S, Geršak J, Trajković D &Ćirković N, *Color Technol*, 137(2) (2021) 108.

14 Alihoseini M R, Khani M R, Jalili M & Shokri B, *Prog Color Colorant Coat*, 14(2) (2021) 129.

15 Farzana A H & Neelakandan R, *Indian J Fibre Text Res*, 49(1) (2024) 50.

16 Gao X, Zhang Q, Jiang C, Yu Y, Li Y, Xing T, Hou X, Li R & Chang G, *Prog Org Coat*, 210 (2026) 109698.

17 Özen İ, Schneider R, Buchmeiser M R & Wang X, *Color Technol*, 138(6) (2022) 581.

18 Wang M, Shi F, Zhao H, Sun F, Fang K, Miao D, Zhao Z, Xie R & Chen W, *J Clean Prod*, 362 (2022) 132333.

19 Silva M C, Petraconi G, Cecci R R R, Passos A A, do Valle W F, Braite B, Lourenço S R & Gasi F, *Polym*, 13(12) (2021) 1969.

20 Zhang C, Guo F, Li H, Wang Y & Zhang Z, *Appl Surf Sci*, 490 (2019) 157.

21 KARİPER İ, *Indian J Fibre Text Res*, 48(3) (2023) 302.

22 Shaker R N, Ashour N S & Abd El Rahman S H, *Int Des J*, 16(2) (2026) 9.

23 Zhang C & Fang K, *Surf Coat Technol*, 203(14) (2009) 2058.

24 Pransilp P, Pruettiphap M, Bhanthumnavin W, Paosawatyanyong B & Kiatkamjornwong S, *Appl Surf Sci*, 364 (2016) 208.

25 Hassabo A G, Khaleed N, Shaker S, El-Salam A, Neaama A, Mohamed N A, Gouda N Z, Abdullah A Y & Othman H, *J Text Color Polym Sci*, 21(1) (2024) 75.

26 Hassabo A G, Gouda N Z, Khaleed N, Shaker S, El-Salam A, Neaama A, Mohamed N A & Othman H, *J Text Color Polym Sci*, 21(1) (2024) 149.

27 Zhao H, Wang M, Zhang K, Fang K, Song Y, Shi F & Chen W, *Prog Org Coat*, 172 (2022) 107127.

28 Wang L, Qin M, Ma J, Wu M, Wang X & Li H, *Colloids Surf A: Physicochem Eng Asp*, 704 (2025) 135447.

29 Nadi A, Boukhriss A, Bentis A, Jabrane E & Gmouh S, *Text Prog*, 50(2) (2018) 67.

30 Mamdouh F, Hassabo A G & Othman H, *J Text Color Polym Sci*, 22(1) (2025) 219.

31 Kodrić M, Đorđević D, Tarbuk A, Islam S, Čorak I, Đorđević S & Motaleb K A, *Fibers Polym*, 26(7) (2025) 2937.

32 Guo D, Li J, Shao Y, Wang L, He G, Wu L & Qi D, *Prog Org Coat*, 203 (2025) 109185.

33 Zeronian S H & Collins M J, *Text Prog*, 20(2) (1989) 1.

34 Musale R M & Shukla S R, *J Text Inst*, 108(4) (2017) 467.

35 Yang H, Zhu S & Pan N, *Text Res J*, 80(3) (2010) 263.

36 Durakovic B, *Period Eng Nat Sci*, 5(3) (2017) 421.

37 Spall J C, *IEEE Contr Syst Mag*, 30(5) (2010) 38.