OPTIMIZING THE DYEABILITY OF POLYESTER FABRICS WITH DISPERSE DYES USING AN ORTHOGONAL DESIGN

LUU, THI THO[1] AND NGUYEN, TUAN ANH[2*]

[1] Faculty of Garment Technology and Fashion Design, Hanoi University of Industry, 289D, Cau Dien St., Bac Tu Liem Dist., Hanoi City, Vietnam
[2] Faculty of Fashion and Tourism, Ho Chi Minh City University of Technology and Education, 01, Vo Van Ngan St., Thu Duc City., Ho Chi Minh City, Vietnam

ABSTRACT

This study explores the combined effects of dye concentration, dyeing time, and acid concentration on the color strength (K/S value) of polyester fabrics dyed with Disperse Scarlet GS200 (DSG). The Taguchi L25 orthogonal array design was employed to optimize the dyeing process while reducing experimental effort and material usage. Color strength and fastness properties were evaluated through spectrophotometric measurements and analyzed using Minitab statistical software. Among the three variables, dyeing time was found to have the most significant influence on the K/S values, followed by dye concentration, whereas acid concentration had a relatively minor effect. These results highlight the importance of controlling processing time to achieve optimal coloration. In addition to color strength analysis, FTIR spectroscopy was used to examine the interaction mechanisms between DSG dyes and polyester fibers. The results suggested the presence of physical bonding, such as Van der Waals forces or hydrogen bonding. Vapor permeability tests further supported the dye–fiber interaction and fabric surface changes after dyeing. Overall, the findings contribute to improving dyeing efficiency and fabric quality while supporting environmentally conscious practices in textile manufacturing by identifying optimal dyeing conditions with reduced chemical input and energy usage.

KEYWORDS

Polyester Fabric; Disperse Dyes (DSG); Taguchi Method; Orthogonal Design; Color Strength (K/S).

INTRODUCTION

The textile dyeing industry has long been recognized as a major contributor to water pollution, having significant negative impacts on both freshwater ecosystems and human health. One of the primary environmental concerns is the discharge of toxic wastewater, which often contains hazardous substances such as heavy metals, synthetic dyes, bleaching agents, and other chemical auxiliaries [1] [2]. These pollutants, when released untreated or insufficiently treated into the environment, can cause serious ecological damage. The presence of these chemicals in water bodies disrupts aquatic ecosystems by altering pH levels, reducing oxygen content, and interfering with sunlight penetration, which collectively impact biodiversity and disturb aquatic food chains. Furthermore, exposure to such contaminated water can lead to various health risks for humans, particularly for communities relying on nearby water sources for daily use.

In addition to its toxicity, the dyeing process in the textile sector is extremely water-intensive. Large volumes of freshwater are consumed throughout different stages of dyeing—from fiber pre-treatment to dye fixation and washing—resulting in significant water depletion, particularly in regions already experiencing water stress [3]. Alarmingly, it is estimated that the textile industry is responsible for nearly 20% of global industrial wastewater, making it one of the leading industrial polluters of freshwater resources [4]. The widespread discharge of untreated dye effluent into rivers and oceans not only pollutes natural water systems but also leads to long-term degradation of aquatic habitats [5].

The environmental strain caused by textile dyeing has been further intensified by the rapid expansion of the global fashion industry, especially the rise of fast fashion. This trend emphasizes short production cycles, frequent collection updates, and low-cost garments, leading to higher textile output and, consequently, increased water usage and pollution [6]. As a result, the demand for dyeing processes has grown substantially, exacerbating water contamination problems and placing immense pressure on freshwater sources. This situation is

* **Corresponding author:** Nguyen, T.A., e-mail: *nta@hcmute.edu.vn*
Received April 7, 2025; accepted May 6, 2025

particularly problematic in low- and middle-income countries, where a majority of textile manufacturing takes place and where water treatment infrastructure is often inadequate or lacking [7].

Among synthetic fibers, polyester has become one of the most widely used materials in the global textile market due to its outstanding physical properties. These include high tensile strength, excellent durability, low moisture absorbency, and resistance to shrinkage, stretching, and abrasion [8] [9]. These characteristics make polyester ideal for a wide range of applications, from fashion and sportswear to home textiles. However, dyeing polyester fabrics is more complex compared to natural fibers. Polyester's hydrophobic and tightly packed molecular structure presents challenges in achieving desirable color depth and consistent washing fastness [10-12]. As a result, the optimization of dyeing conditions is crucial for achieving both aesthetic quality and long-lasting performance.

Improving dyeing efficiency requires careful control over several key parameters, including dye concentration, temperature, time, pH level, and the use of dispersing or leveling agents. Adjusting these variables can lead to better dye penetration, increased color strength, and more efficient dye fixation on the fiber surface. Such optimization not only enhances fabric quality but also contributes to reducing water, energy, and chemical usage during production, which is vital for addressing environmental concerns [13] [14]. Typically, the dyeing process for polyester with disperse dyes is carried out in closed dyeing systems at temperatures around 130°C to promote dye diffusion into the fiber matrix [15] [16]. However, the effectiveness of this process can vary depending on multiple factors, such as the concentration of the dye, the dyeing duration, and the pH of the dye bath [17].

To systematically evaluate the influence of these parameters, the Taguchi method was applied in this study using an L25 orthogonal array. This approach allowed for the simultaneous analysis of three critical variables—dye concentration, dyeing time, and acid concentration—and their effects on two key outcomes: color strength (measured in K/S values) and washing fastness [18] [19]. The Taguchi method is a robust statistical optimization tool that minimizes the number of experimental trials while maximizing the amount of information gathered. By varying multiple factors simultaneously and analyzing their interactions, it helps researchers identify the most significant parameters affecting a process and determine optimal conditions with fewer resources [20] [21]. The goal of this study is to optimize the dyeing process for polyester fabrics using Disperse Scarlet GS200 (DSG) dye to achieve maximum color strength and improved fastness properties under efficient dyeing conditions. Through the Taguchi method, the study aims to reduce unnecessary chemical usage, minimize energy and water consumption, and lower the volume of harmful effluents released into the environment. By identifying the optimal combinations of dyeing parameters, manufacturers can achieve better dye fixation and improved fabric performance with minimal ecological footprint. In addition to experimental results on color strength and fastness, the study also integrates FTIR spectral analysis and vapor permeability testing to better understand the interaction mechanisms between DSG dye and polyester fibers. These techniques provide insight into how the dye physically associates with the fabric—likely through Van der Waals forces or hydrogen bonding—rather than through covalent chemical bonding. This contributes to the overall understanding of dye–fiber interactions and supports the optimization process.

Ultimately, the research contributes to the broader objective of sustainable textile manufacturing by combining scientific experimentation with statistical analysis. The findings can be applied not only to DSG dyes but also serve as a model for optimizing disperse dyeing processes more generally. By refining operational parameters and reducing chemical waste, this study supports more environmentally responsible practices in the dyeing industry, balancing production efficiency with ecological sustainability.

EXPERIMENTS

Materials

The work used 100% polyester plain woven fabric with a specific weight of 183.5 g/m^2, which was provided by Truong Thinh Ltd. Co (Vietnam). The fabrics were pretreated by desizing and scouring to remove any impurities, ensuring the consistency of dyeing results. Disperse Scarlet GS200 (DSG) dyes were purchased from Qingdao Sanhuan Colorchem (China), a widely used disperse dye for polyester fabrics, was chosen due to its strong color properties. DSG is a type of disperse dye commonly used for dyeing synthetic fibers, particularly polyester. It is known for its good color fastness properties, vibrant shades of red, high compatibility, and safety. DSG dyes are designed to be insoluble in water and are typically applied using heat, which allows the dye to penetrate the fibers. It is primarily used in dyeing processes such as pad dyeing, batch dyeing, and continuous dyeing. The dye is usually applied in a dispersion, which is then heated to fix the color to the fabric.

Various dye concentrations were prepared in distilled water. The dyeing solution was acidified using acetic acid (CH_3COOH) to adjust pH, which plays a critical role to optimize dye penetration and fixation. Different concentrations of CH_3COOH were tested to determine its effect on dyeing performance. Levelling agent (namely, Albenol - dra) was used to assist in dyeing and fixation.

Experimental design

Polyester fabric was dyed using exhaust method. Samples were dyed at varying DSG concentrations with the optimized process parameters including time, temperature, and pH value. Six different dye concentrations were tested. Dyeing times were varied to investigate the time effect on color strength and washing fastness. A constant temperature of 130°C was maintained for all dyeing experiments to ensure adequate dye penetration into hydrophobic polyester fibers.

Taguchi Orthogonal Array Design (L25) was selected to assess the effect of the three key factors (dye concentration, dyeing time, and pH value) at five levels each. This statistical design reduced the total number of experimental trials while allowing for interaction effects to be observed, including 1) Factor A (dye concentration), 2) Factor B (acid concentration), 3) Factor C (dyeing time). The combination of these variables was systematically varied based on the orthogonal array design (Taguchi method) to optimize the dyeing process through color strength as well as color intensity. Minitab 2010 was used as a powerful statistical software in fields such as manufacturing, engineering, and research for data analysis and process optimization. To optimize the product quality, Minitab supports the Taguchi method.

The color strength (*K/S*) of each dyed sample was measured using a UV-visible spectrophotometer (X-rite) to evaluate the reflectance. Higher *K/S* values indicate greater color depth and intensity.

The results in this research were also clarified which the analysis of Fourier-transform infrared spectroscopy (FTIR) and air permeability test were used to determine the bonding mechanism and the structural change in treated samples compared to untreated samples. The washing fastness of dyed polyester fabrics was examined according to ISO 105-C06 standard. Each dyed sample was subjected to a washing test, and the color changes were quantified by measuring the color difference (*ΔE*) between the original and post-wash samples.

RESULTS AND DISCUSSION

Maximum light absorption of dyed polyester fabric at various dye concentrations

The CIELab diagram visualizes color characteristics of polyester fabrics dyed with different dye concentrations (red dye) (Figure 1). Black dots suggests that all dye concentrations place color firmly in the red quadrant. Obviously, the red intensity increases with higher dye concentrations, resulting in color consistency and strong red hue dominance across samples.

The *K/S* values, indicating color strength, were plotted across the visible spectrum (400–700 nm) for polyester fabrics dyed with DSG dyes at different concentrations (1% to 6%) as shown in Figure 2. Each curve reveals a distinct absorption peak, with the highest absorption observed around 550–600 nm, corresponding to the red region of the visible spectrum. This suggests that DSG dyes mainly absorb red light, producing complementary colors on the fabric. As dye concentration increases from 1% to 5%, *K/S* values also rise significantly, showing enhanced dye uptake and stronger coloration. This trend highlights the role of concentration in improving color depth. However, beyond 3%, the rate of increase in *K/S* values slows, suggesting that dye absorption becomes less efficient. The fabric surface may approach saturation, meaning additional dye molecules no longer contribute proportionally to color

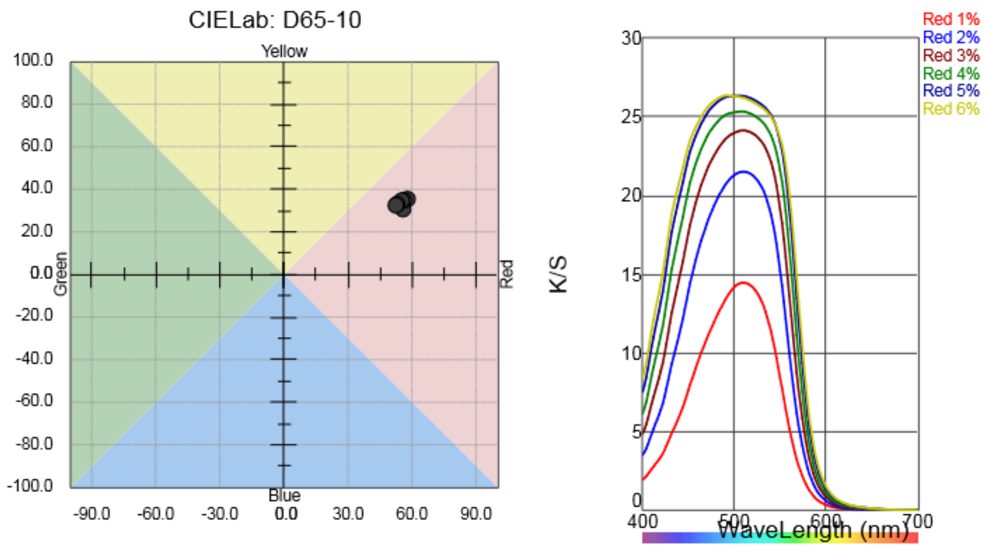

Figure 1. Maximum light absorption and CIELab diagram of polyester samples dyed with 1%, 2%, 3%, 4%, 5%, and 6% DSG dyes in the wavelength range of 400 to 700 nm.

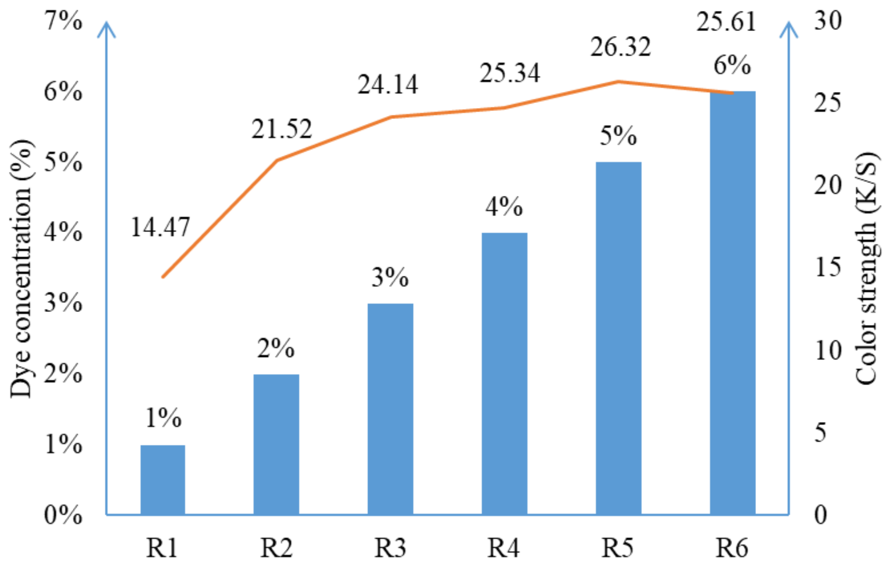

Figure 2. *K/S* values of polyester fabrics dyed with 1, 2, 3, 4, 5 and 6 % of DSG dyes.

Table 1. Levels of three parameters including dye concentration (X_1), acid concentration (X_2) and dyeing time (X_3) on polyester fabrics dyed with disperse dyes.

Level	X_1 dye concentration, %	X_2 acid concentration, %	X_3 dyeing time, min
1	2.0	0.00	20
2	3.0	0.75	35
3	4.0	1.50	50
4	5.0	2.25	65
5	6.0	3.00	80

strength. This behavior indicates a threshold concentration - around 3% - after which higher dye levels result in minimal *K/S* improvement. Recognizing this helps optimize dye usage, avoiding waste while maintaining high color quality in polyester dyeing processes.

Simultaneous effects of dye concentration, dyeing time, and acid concentration

The Taguchi orthogonal array design was essential in analyzing and quantifying the effects of key dyeing parameters on polyester fabric performance using DSG disperse dyes. This method allowed for the evaluation of three main variables—dye concentration (X_1), acid concentration (X_2), and dyeing time (X_3)—as shown in Table 1. It efficiently revealed both individual and interaction effects among these factors, helping to understand their impact on dye uptake and color strength. A major advantage of the Taguchi approach is its ability to minimize the number of required experiments while still delivering meaningful statistical insights. Unlike traditional factorial designs, this method saves time and resources without compromising data quality. Despite fewer trials, it provides strong evidence of how each factor and their combinations influence dyeing results. Furthermore, the study showed that this optimization strategy supports more efficient and reproducible dyeing processes. It enables better control over variables, leading to enhanced dyeability, improved fabric appearance, and more sustainable textile production practices.

The results in Table 2 demonstrate that all parameters contributed to the K/S value of polyester fabrics, with X_3 having the most significant effect at **32.31**%, followed by X_1 at **1.26**%, and X_2 at **0.02**%.

Figure 3 shows a Pareto Chart of Standardized Effects for the *K/S* value (i.e., Y(red)) with a significance level of α = 0.05. The chart illustrates the relative importance of factors A (X_1: dye concentration), B (X_2: acid concentration), and C (X_3: dyeing time), along with their interactions (e.g., AB, AC). The threshold for statistical significance was marked at 2.120. Factors CC and C have the largest effects, extending farthest to the right and indicating that dyeing time (C) has the greatest impact on the K/S value. Factor A (dye concentration) also exceeds

Table 2. Experimental matrix results on the effects of dye concentration, acid concentration, and dyeing time on the K/S value using Taguchi L25 method.

Source	DF	Seq SS	Contrib. (%)	Adj SS	Adj MS	F-Value	P-Value
Model	8	328.400	85.50	328.400	41.050	11.80	0.000
Linear	3	128.998	33.59	101.944	33.981	9.76	0.001
X_1	1	4.836	**1.26**	4.836	4.836	1.39	0.256
X_2	1	0.068	0.02	0.001	0.001	0.00	0.990
X_3	1	124.094	**32.31**	96.164	96.164	27.63	0.000
Square	3	199.016	51.82	159.123	53.041	15.24	0.000
X_1*X_1	1	0.880	0.23	0.880	0.880	0.25	0.622
X_2*X_2	1	1.071	0.28	0.363	0.363	0.10	0.751
X_3*X_3	1	197.064	**51.31**	153.541	153.541	44.12	0.000
2-way interaction	2	0.386	0.10	0.386	0.193	0.06	0.946
X_1*X_2	1	0.040	0.01	0.219	0.219	0.06	0.805
X_1*X_3	1	0.346	0.09	0.346	0.346	0.10	0.757
Error	16	55.681	14.50	55.681	3.480		
Total	**24**	**384.082**	**100.00**				

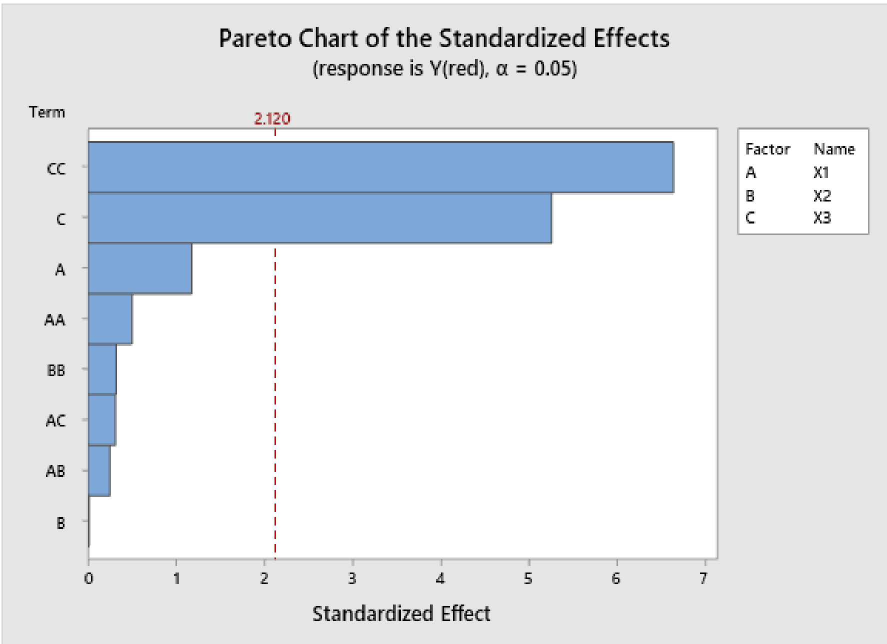

Figure 3. Pareto Chart of Standardized Effects for K/S value (Y(red), α = 0.05).

the significance threshold, showing a notable effect. Other terms (AA, BB, AC, AB, and B) fall below this threshold and are not statistically significant. Overall, dyeing time is the most influential factor on the K/S value, followed by dye concentration (A), while acid concentration (B) has minimal impact. The regression model of the *K/S* value in coded variable form is described by the following equation.

$$\boldsymbol{Y}\ (\mathbf{red}) = \mathbf{5.39} + \mathbf{0.93}\boldsymbol{X_1} - \mathbf{0.30}\ \boldsymbol{X_2} + \mathbf{11.56}\ \boldsymbol{X_3} - \mathbf{0.11}\ (\boldsymbol{X_1})^2 + \mathbf{0.08}\ (\boldsymbol{X_2})^2 - \mathbf{1.71}\ (\boldsymbol{X_3})^2 - \mathbf{0.07}\ \boldsymbol{X_1}\boldsymbol{X_2} + \mathbf{0.08}\ \boldsymbol{X_1}\boldsymbol{X_3} \quad (1)$$

where *R* = 85.5%.

This equation affirms that *Y*(red) is the dependent variable, while X_1, X_2, and X_3 are the independent variables (predictors). It demonstrates that as the independent variables X_1, and X_3 increase, the dependent variable *Y*(red) also tends to increase (i.e., positive coefficients). In contrast, as the independent variable X_2 increases, the dependent variable Y(red) tends to decrease (i.e., negative coefficient)

Figure 4 determined the normal distribution of the simultaneous effects of dye concentration, acid concentration, and dyeing time on the color strength of the fabric. From these results, it is shown that the points close to the diagonal line represent the influence of dye concentration, acid concentration, and time on the *K/S* color strength according to a normal distribution. This variation in color strength is due to random factors, with no abnormalities. The downward curve on the left side of the graph and the upward curve on the right indicate a left-skewed distribution pattern. The density of points on the lower left side near the diagonal suggests that the effects of dye concentration, acid concentration, and dyeing time on fabric color strength follow a right-skewed distribution.

It can be explained that there is an optimal dyeing time after which the *K/S* value stabilizes. Although extended dyeing times can enhance dye penetration, they may not always lead to significantly better results. Increasing dye concentration consistently raised the *K/S* value across all experiments. However, beyond a certain concentration, further increases in *K/S* plateaued, indicating a saturation point where additional dye no longer contributes significantly to deeper colors. Finally, acid concentration is another critical factor, particularly in influencing the dyeing process and colorfastness. While higher acid concentrations improve dye fixation, excessively high acid levels may cause fabric degradation or other undesirable effects. After optimizing the dyeing parameters, the following dyeing and washing recipe was proposed as DSG (5%), CH_3COOH (0.75%), levelling agent (1.0 g/l), and washing agent (1.0 g/l).

Physical and chemical properties of dyed fabrics with DSG dyes

To gain a deeper understanding of the chemical bonding interaction mechanism between DSG dyes and polyester fibers under optimized dyeing conditions—as determined using the Taguchi orthogonal array design outlined earlier—an in-depth analysis of the FTIR spectra provides critical insights. The spectral differences between untreated and dyed polyester samples help elucidate several important aspects of how DSG dyes interact with the fiber's chemical structure during the dyeing process (Figure 5). The FTIR baseline spectra, corresponding to the untreated polyester sample (SP0), primarily display characteristic peaks that reflect the inherent chemical composition of polyester. These include strong absorption bands associated with the carbonyl (C=O) stretching vibrations, methyl and methylene (C-H) stretching, and other typical functional groups found in the polymer backbone. In this untreated state, the fiber remains chemically unmodified, with no influence from dye molecules or processing conditions. Although DSG dyes are not capable of forming covalent bonds with the polyester substrate, they can still establish physical interactions, primarily via Van der Waals forces and possibly hydrogen bonding. These non-covalent interactions, though weaker than covalent bonds, can still cause observable modifications in the FTIR spectra. Such modifications may include slight shifts in the position of absorption bands and changes in peak intensities due to alterations in the molecular environment of the functional groups involved.

In the dyed samples, specifically SP4 and SP6, the FTIR spectra exhibit notable differences when compared to the untreated sample. One of the most prominent observations is the increased intensity of peaks in regions corresponding to hydroxyl (O-H) and carbonyl (C=O) stretching vibrations. This suggests a greater degree of dye-fiber interaction, possibly due to enhanced dye uptake, stronger hydrogen bonding, or dye aggregation at the fiber surface. These changes in spectral features support the hypothesis that optimized dyeing conditions facilitate more

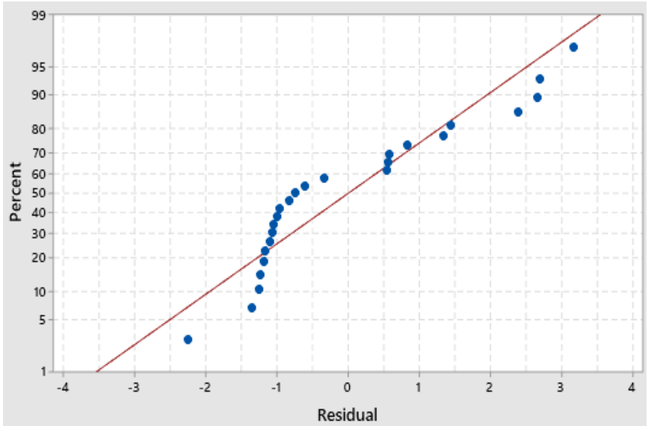

Figure 4. Normal probability of simultaneous effects between dye concentration (A), acid concentration (B) and dyeing time (C) for dyed polyester fabrics on K/S value.

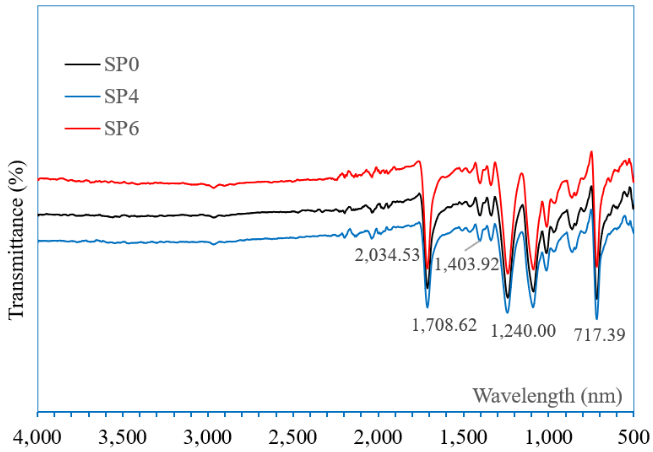

Figure 5. FTIR spectra of polyester fabrics dyed with 0% (SP0), 4% (SP4) and 6% of DSG dyes.

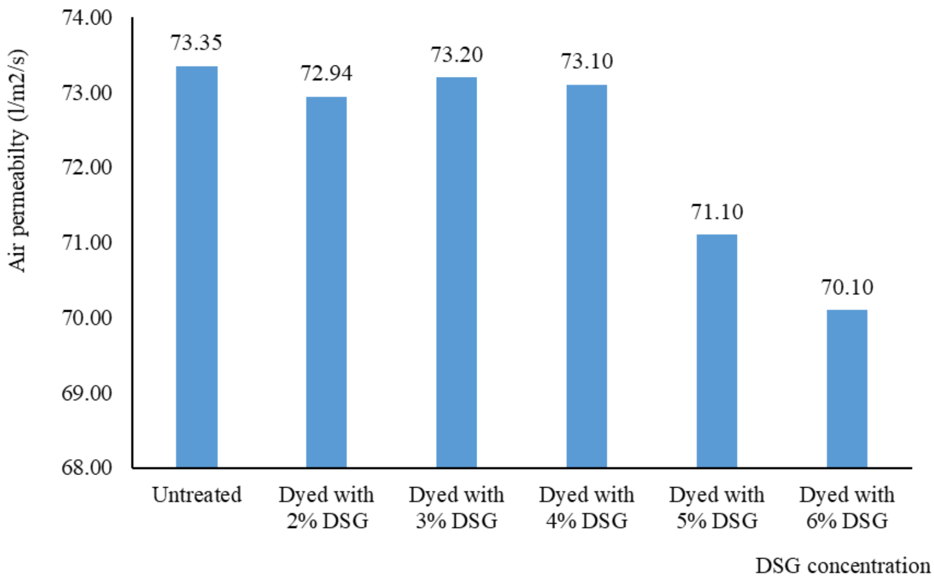

Figure 6. Breathability of polyester fabrics dyed with 0, 2, 3, 4, 5 and 6% of DSG dyes (20 cm2 of test area, and 100 Pa of pressure).

effective dye penetration and binding, even in the absence of chemical bonding. Additionally, subtle shifts in peak positions, especially within the fingerprint region (1,500–700 cm^{-1}), may indicate minor structural rearrangements in the polyester polymer. These could arise from changes in intermolecular forces or variations in polymer crystallinity as a result of the dyeing process. In some cases, new absorption bands may appear, pointing to localized interactions between the dye molecules and specific sites on the fiber. Overall, the FTIR analysis highlights the significance of physical interactions in the dyeing mechanism and provides evidence of how the optimized parameters enhance these effects, leading to improved dyeability of polyester fabrics with DSG disperse dyes.

Figure 6 illustrates the air permeability results of polyester fabrics dyed with varying concentrations (0%, 2%, 3%, 4%, 5%, and 6%) of Disperse Scarlet GS200 (DSG) under standardized dyeing conditions at 130°C for 60 minutes. The data reveal a slight, gradual decline in air permeability as the dye concentration increases, suggesting that the accumulation of DSG dyes on the fabric surface slightly affects the pore structure of the polyester. This subtle reduction in air flow is expected due to the presence of dye molecules that may partially settle into or near the micro-pores of the fabric during high-temperature dyeing. Despite this minor decrease, the overall breathability of the dyed polyester fabrics remained largely unaffected, as the air permeability values did not deviate significantly from those of the undyed control samples. This indicates that the dyeing process with DSG does not substantially hinder the airflow or comfort properties of the fabric. The azo functional groups and hydrophobic aromatic structures present in DSG dyes may slightly interfere with air exchange, but their effect is minimal and not detrimental to end-use applications. Therefore, the maintained air permeability of dyed fabrics reinforces their suitability for commercial textile products, particularly in apparel where breathability is essential for wearer comfort. This finding adds value to the practical applicability of DSG dyes in polyester processing.

CONCLUSION

This study successfully optimized the dyeing process for polyester fabrics using Disperse Scarlet GS200 (DSG) by employing the Taguchi L25 orthogonal array method, which allows for efficient evaluation of multiple parameters with minimal experimental trials. Through systematic analysis, it was determined that among the three investigated factors—dye concentration, dyeing time, and acid concentration—dyeing time had the most significant influence on color strength (K/S values). Dye concentration also contributed notably to the overall dyeing outcome, while acid concentration exhibited only a minor effect. These findings highlight the importance of accurately controlling key variables in order to maximize dye uptake and color depth. The optimized conditions derived from the Taguchi approach led to considerable improvements in dyeing efficiency, enabling stronger coloration with potentially lower resource usage. Furthermore, the presence and interaction of DSG dyes within the polyester fiber matrix were confirmed by Fourier-transform infrared (FTIR) spectral analysis, which revealed specific shifts and changes in absorption bands that support the occurrence of dye-fiber interactions. In addition, vapor permeability (breathability) tests indicated that the dyeing process had minimal impact on the comfort properties of the fabric. Overall, this research offers a scientifically grounded and environmentally conscious strategy for enhancing the polyester dyeing process, paving the way for more sustainable and cost-effective practices in textile manufacturing.

Acknowledgement: *The authors would like to express their thanks for supports from Hanoi University of Industry, Industrial University of Ho Chi Minh City, and Ho Chi Minh City University of Technology and Education.*

REFERENCES

1. Uddin F.: Environmental hazard in textile dyeing wastewater from local textile industry. Cellulose, 28(17), 2021, pp. 10715-10739. https://doi.org/10.1007/s10570-021-04228-4
2. Khan S., Malik A.: Environmental and health effects of textile industry wastewater. Environmental deterioration and human health: Natural and anthropogenic determinants, 2014, pp. 55-71. https://doi.org/10.1007/978-94-007-7890-0_4
3. Khattab T.A., Abdelrahman M.S., Rehan M.: Textile dyeing industry: environmental impacts and remediation. Environmental Science and Pollution Research, 27(4), 2020, pp. 3803-3818. https://doi.org/10.1007/s11356-019-07137-z
4. Tripathi M., et al.: Recent strategies for the remediation of textile dyes from wastewater: a systematic review. Toxics 11: 940, 2023. https://doi.org/10.3390/toxics11110940
5. Gomes K., et al.: Sustainability transformation in the textile industry—The case of wastewater management. Business Strategy & Development, 7(1), 2024, e324 P. https://doi.org/10.1002/bsd2.324
6. Bailey K., Basu A., Sharma S.: The environmental impacts of fast fashion on water quality: a systematic review. Water, 14(7), 2022, 1073 P. https://doi.org/10.3390/w14071073
7. Gita S., Hussan A., Choudhury T.: Impact of textile dyes waste on aquatic environments and its treatment. Environ. Ecol, 35(3C), 2017, pp. 2349-2353.
8. Paul R.: Functional finishes for textiles: an overview. Functional Finishes for Textiles, Improving Comfort, Performance and Protection, 2015, pp. 1-14.
9. Paul R.: Functional finishes for textiles: improving comfort, performance and protection. Elsevier, 2014.
10. Smith D., Hall M.: An empirical examination of a three-component model of professional commitment among public accountants. Behavioral Research in Accounting, 20(1), 2008, pp. 75-92. https://doi.org/10.2308/bria.2008.20.1.75
11. Omar A.Z., et al.: Synthesis, characterization, and application of novel aryldiazenyl disperse dyes on polyester fabrics. Scientific Reports, 13(1), 2023, 21554 P. https://doi.org/10.1038/s41598-023-48368-y
12. Blackburn D., Gallagher V.C.: Disperse dyes for polyester: A new approach to compatibility. Journal of the Society of Dyers and Colourists, 96(5), 1980, pp. 237-245. https://doi.org/10.1111/j.1478-4408.1980.tb03526.x
13. Aspland J.: Disperse dyes and their application to polyester. Textile Chemist and Colorist, 24, 1992, 18 P.
14. Patterson D., Sheldon R.: The dyeing of polyester fibres with disperse dyes. Mechanism and kinetics of the process for purified dyes. Transactions of the Faraday Society, 55, 1959, pp. 1254-1264. https://doi.org/10.1039/TF9595501254
15. Fité F.C.: Dyeing polyester at low temperatures: kinetics of dyeing with disperse dyes. Textile research journal, 65(6), 1995, pp. 362-368. https://doi.org/10.1177/004051759506500607
16. Dawson J.: The structure and properties of disperse dyes in polyester coloration. Journal of the Society of Dyers and Colourists, 99(7-8), 1983, pp. 183-191. https://doi.org/10.1111/j.1478-4408.1983.tb03685.x
17. Epps H.H.: Basic principles of textile coloration. Wiley Online Library, 2003.
18. Hossain I., Hossain A., Choudhury I.A.: Dyeing process parameters optimisation and colour strength prediction for viscose/lycra blended knitted fabrics using Taguchi method. The Journal of The Textile Institute, 107(2), 2016, pp. 154-164. https://doi.org/10.1080/00405000.2015.1018669
19. Kharisma A., et al.: Application of Taguchi method and ANOVA in the optimization of dyeing process on cotton knit fabric to reduce re-dyeing process. in IOP conference series: earth and environmental science. IOP Publishing, 2017. https://doi.org/10.1088/1755-1315/109/1/012023
20. Sriraman V.: A primer on the Taguchi system of quality engineering. The journal of technology studies, 22(2), 1996, pp. 64-66.
21. Freddi A., et al.: Introduction to the Taguchi method. Design principles and methodologies: from conceptualization to first prototyping with examples and case studies, 2019, pp. 159-180. https://doi.org/10.1007/978-3-319-95342-7_7