

Optimizing Eriofast Fix Concentration for enhanced Colorfastness and Sustainability in Nylon/Spandex Fabrics

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ABSTRACT

This study examines the impact of Eriofast Fix mordant concentration on color intensity and colorfastness of Single Jersey knitted fabric composed of Nylon/Spandex (PA/PU) dyed with disperse dyes. Mordant concentrations ranging from 2.0% to 2.8% were evaluated under standardized processing conditions to measure key characteristics, including washing fastness (TCVN 7835-C10:2007), dry and wet rubbing fastness (ISO 105-X12), acid and alkaline perspiration fastness (ISO 105-E04), and color intensity (*K/S* values). The results demonstrated that concentrations between 2.0% and 2.4% improved color intensity and washing fastness, minimizing fading, staining, and environmental impact. For rubbing and perspiration fastness, the optimal concentration range extends to 2.6%. Concentrations exceeding 2.6% result in diminished colorfastness, inefficient chemical utilization, and increased production costs. These findings provide a scientific basis for optimizing the dyeing process of PA/PU fabrics, along with the economic efficiency and sustainable production in the textile industry.

Keywords-mordant concentration; color intensity optimization; colorfastness evaluation; sustainable textile processing; Nylon/Spandex dyeing

I. INTRODUCTION

PA/PU fabric is recognized as a premium material in the textile industry due to its characteristics, including lightweight construction, superior elasticity, and cost-effectiveness. These properties can result in a lightweight, breathable, and highly moisture-wicking featured fabric, making it suitable for activewear, swimwear, and lingerie [1]. Additionally, when integrated with a Single Jersey knit, PA/PU fabric becomes the optimal choice for high-end fashion, such as sportswear, fashion apparel, and advanced garment lines. This kind of fabric not only stretches about five times its original length, but also provides a comfortable and snug fit during use. Besides its quick-dry and wrinkle-free properties, it adds to the mentioned applications [2]. Its versatility and durability contribute to its widespread use in the textile industry, catering to the growing demand for modern fashion trends [3]. Moreover, the cost-effectiveness of PA/PU fabric makes it an attractive option for

manufacturers, aiming to produce high-quality products while maintaining affordability. Its ease of care and long-lasting performance further add to its appeal in the fashion and sportswear markets [4].

Despite these advantages, maintaining colorfastness and color intensity after dyeing remains a critical challenge for PA/PU fabrics, especially when combined with disperse dyes. This kind of dye, known for its nonionic structure and low water solubility, is well-suited for hydrophobic synthetic fibers, like PA/PU, delivering vibrant and durable coloration. However, it is often associated with issues, such as color fading, bleeding, and uneven dyeing, necessitating the optimization of dyeing processes to overcome these limitations [5]. Extensive research worldwide and especially in Vietnam has focused on improving the dyeing quality of polyamide and other synthetic fibers. Authors in [6] tried to optimize dyeing parameters for better colorfastness and color intensity, while authors in [7] indicated that cationic dyes outperformed anionic

dyes in nylon fabric dyeing. In Vietnam, some studies [8, 9] focused on the significance of controlling dye and fixing agent concentrations to refine the dyeing process as well as product quality while mitigating chemical waste and environmental impact.

Eriofast Fix is known for increasing the color fastness of polyamide fabrics without compromising their softness and hydrophilicity. However, its exact usages as a potential mordant for the disperse dyeing of PA/PU blends remain unexplored. Therefore, research deploying a systematic approach is necessary to optimize dyeing procedures and achieve the desired fabric performance [10, 11].

As manufacturers attempt to combine the production of premium products with ecological responsibility, sustainable processing of textiles has now become a priority in this industry [12]. Eco-friendly dyeing, such as optimizing mordant concentrations, contributes to a decrease in chemical waste and the ecological footprint of textile operations [13, 14]. This study investigates the effect of Eriofast Fix concentration on the colorfastness and color intensity of Single Jersey knitted PA/PU fabric. The primary objective is to determine the optimal mordant concentration that ensures high product quality while reducing chemical consumption, in alignment with sustainable development goals. The findings of this research provide a robust scientific foundation for optimizing finishing processes and offering practical solutions to enhance the competitiveness of Vietnam's textile industry in the global market.

II. MATERIALS AND METHODS

A. Materials

Single Jersey knitted fabric composed of PA/PU with a fiber blend ratio of 75/25 was used in the current study. This fabric was selected due to its light weight, high elasticity, and hydrophobic properties, making it suitable for disperse dyeing. The color-fixing agent, Eriofast Fix, was employed to enhance dye adhesion and improve color fastness, with concentrations ranging from 2.0% to 2.8%. The selection of these materials is common in industrial practices and aims to address challenges in optimizing mordant concentration for improved dyeing performance while minimizing environmental impacts.

B. Experimental Design

The dyeing process was conducted using a jigger dyeing machine (GT-D22B) under controlled conditions. Fabric samples were pre-treated by washing in a 1 g/L nonionic detergent solution at 50 °C for 15 minutes, followed by thorough rinsing and drying. The dye bath composition included disperse dye (2% OWF), acetic acid (0.5 g/L), and a nonionic dispersing agent (1 g/L), with a liquor ratio of 1:12. The procedure was carried out at 90 °C for 20 minutes, with continuous agitation to ensure uniform dye penetration.

After dyeing, the fabrics were rinsed in warm water (40 °C) and subjected to a post-treatment fixation process using Eriofast Fix at varying concentrations (2.0% –2.8%) for 20 minutes at 60 °C, as displayed in Table I. The samples were then air-dried (GT-D10 machine) at room temperature before further evaluation.

TABLE I. EXPERIMENTS WITH VARYING CONCENTRATIONS OF COLOR-FIXING AGENT

| Experiment | Chemicals | Concentration (%) | Dosage (g) |
|------------|--------------|-------------------|------------|
| M1 | Eriofast Fix | 2.0 | 0.20 |
| M2 | | 2.2 | 0.22 |
| M3 | | 2.4 | 0.24 |
| M4 | | 2.6 | 0.26 |
| M5 | | 2.8 | 0.28 |

C. Evaluation Methods

The evaluation of the dyed PA/PU fabric was conducted by several methods to assess color intensity and colorfastness. The procedures are detailed as follows:

1) Color Intensity Measurement

Color intensity was determined using the Kubelka-Munk equation [15]:

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

where R represents the decimal reflectance of fabric.

K/S values were calculated using a Datacolor Spectro 1000 spectrophotometer under D65 illuminant at 10° observer angle. The reflectance measurements were recorded between 400 nm and 700 nm at intervals of 10 nm. The instrument was calibrated using a white standard tile before each measurement to ensure accuracy. Figure 1 illustrates the experimental equipment for each method used.

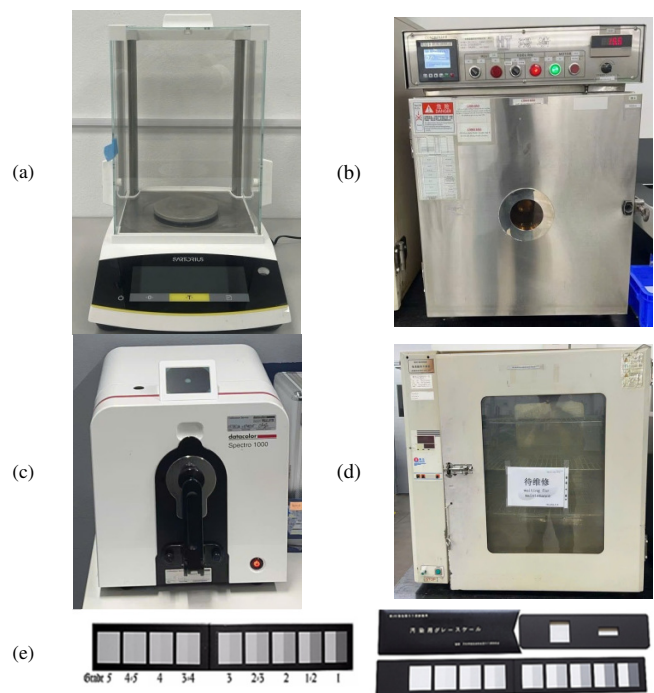


Fig. 1. Experimental equipment: (a) electronic scale, (b) sample dyeing machine GT-D22B, (c) datacolor spectro 1000, (d) fabric drying machine GT-D10, (e) gray scale for assessing staining.

2) Colorfastness Testing

In addition to color intensity, the colorfastness of treated samples was evaluated through washing, rubbing, and perspiration tests under standardized conditions. Each test was performed on three replicates per sample to ensure reproducibility. Wash fastness was evaluated by washing dyed samples in a 5 g/L soap solution at 50 °C for 30 minutes, followed by color change assessment using the Gray Scale for Color Change, following TCVN 7835-C10:2007. Rubbing fastness was tested under dry and wet conditions following ISO 105-X12, using a Crockmeter, with the results being rated on a 1-5 scale. Finally, the perspiration fastness was tested as per ISO 105-E04 for acidic and alkaline conditions to simulate its effect on colorfastness.

These evaluation methods ensured a comprehensive analysis of the effects of Eriofast Fix concentration on the physical and aesthetic properties of PA/PU fabric.

III. RESULTS AND DISCUSSION

A. Effect of Mordant Concentration on Color Intensity

The impact of Eriofast Fix concentration on the color intensity of PA/PU fabric was analyzed using the Kubelka-Munk equation. Measurements of the color intensity (*K/S* values) were conducted at the maximum wavelength (λ_{max}). The results, as presented in Table II, indicate a significant relationship between mordant concentration and color intensity. *K/S* values decreased with higher concentrations of Eriofast Fix revealing that the increase in concentration can lead to saturation of the fabric surface or side reactions that reduce dye absorption efficiency.

TABLE II. RESULTS OF THE EFFECT OF COLOR-FIXING AGENT CONCENTRATION ON COLOR INTENSITY OF FABRIC

| Test sample | Color-Fixing agent concentration (%) | Color reflectance coefficient (<i>R</i>) | Color intensity (<i>K/S</i>) |
|-------------|--------------------------------------|--|--------------------------------|
| M1 | 2.0 | 18.00 | 8.03 |
| M2 | 2.2 | 17.00 | 7.53 |
| M3 | 2.4 | 16.00 | 7.03 |
| M4 | 2.6 | 14.60 | 6.28 |
| M5 | 2.8 | 13.00 | 5.54 |

The relationship between *K/S* values and mordant concentration is depicted in Figure 2. Maximum color intensity was obtained at a 2.0% concentration followed by a gradual decrease as the concentration was increased. The trend shows that concentrations above 2.4% led to a reduction in dye absorption, thereby increasing light reflection i.e., lower *R* values with decreased *K/S* values since excess mordant leaves behind a chemical residue on the fabric surface, which interferes with the proper binding of the dye.

These results highlight that the optimal mordant concentration range for achieving high color intensity is between 2.0% and 2.4%. Concentrations in this range not only maximize dye absorption, but also reduce chemical waste, aligning with sustainable production practices.

B. Effect of Mordant Concentration on Colorfastness

The influence of Eriofast Fix concentration on the colorfastness of PA/PU fabric was examined through washing, rubbing, and perspiration tests. Each property was tested under standardized conditions, and the results are discussed below.

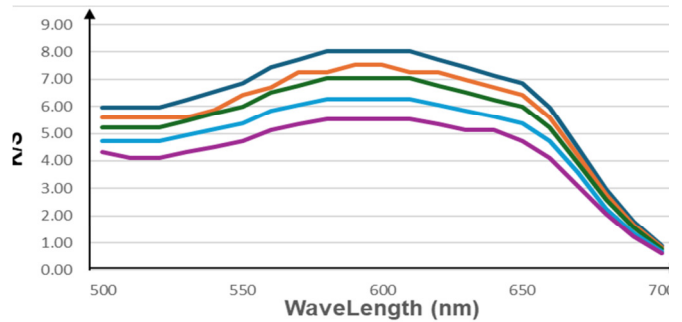


Fig. 2. Color intensity of fabric through the *k/s* value at the λ_{max} wavelength range.

1) Washing Fastness

The washing fastness results, summarized in Table III, demonstrate that mordant concentrations between 2.0% and 2.4% generated the best performance, with grades of 4-5 for both color fading and staining across all tested fibers. However, at concentrations exceeding 2.6%, washing fastness decreased, due to the presence of excess chemical residues. These findings indicate that higher concentrations of Eriofast Fix result in inefficient utilization of the fixing agent, leading to chemical wastage and reduced color retention during washing.

TABLE III. EFFECT OF COLOR-FIXING AGENT CONCENTRATION ON WASH FASTNESS

| Color - Fixing agent concentration (%) | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | |
|--|-----------|-----|-----|-----|-----|-----|
| Wash fastness of sweat | Acetone | 4-5 | 4-5 | 4-5 | 3-4 | 3-4 |
| | Cotton | 4-5 | 4 | 4-5 | 3-4 | 3-4 |
| | Nylon | 4-5 | 4-5 | 4 | 3 | 3 |
| | Polyester | 4-5 | 4 | 4 | 4 | 3 |
| | Acrylic | 4-5 | 4-5 | 4 | 4 | 4 |
| | Wool | 4-5 | 4 | 4-5 | 3 | 3 |
| Color fading | 4-5 | 4-5 | 4-5 | 3-4 | 3 | |

2) Rubbing Fastness

The dry and wet rubbing fastness results are presented in Table IV. Mordant concentrations between 2.0% and 2.6% consistently exhibited high grades (4-5), ensuring good resistance to friction. At 2.8% concentration, the dry rubbing fastness decreased to 3-4, while wet rubbing fastness dropped to grade 3, reflecting weaker dye adhesion under mechanical stress. These results suggest that while moderate mordant concentrations are effective in maintaining rubbing fastness, excessive concentrations lead to over-saturation, diminishing fabric performance.

TABLE IV. EFFECT OF COLOR-FIXING AGENT CONCENTRATION ON RUBBING COLORFASTNESS

| Color-Fixing agent concentration (%) | Dry rubbing | Wet rubbing |
|--------------------------------------|-------------|-------------|
| 2.0 | 4-5 | 4-5 |
| 2.2 | 4-5 | 4-5 |
| 2.4 | 4-5 | 4 |
| 2.6 | 4 | 4 |
| 2.8 | 3-4 | 3 |

3) Perspiration Fastness

The acid and alkaline perspiration fastness results are summarized in Tables V and VI. At concentrations ranging from 2.0% to 2.6%, grades of 4-5 were achieved across most fibers, ensuring excellent resistance to color fading and staining under simulated sweat conditions. However, at 2.8% concentration, the grades declined, particularly for polyester and wool fibers, reaching 3-4 and 3. This trend indicates that excessive mordant concentration leads to residual chemicals that weaken the bond between the dye and fibers under acidic or alkaline conditions.

TABLE V. EFFECT OF COLOR-FIXING AGENT CONCENTRATION ON ACID SWEAT COLORFASTNESS

| Color - Fixing agent concentration (%) | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | |
|--|-----------|-----|-----|-----|-----|-----|
| Acid sweat colorfastness | Acetone | 4-5 | 4-5 | 4-5 | 4-5 | 4-5 |
| | Cotton | 4-5 | 4-5 | 4-5 | 4-5 | 4 |
| | Nylon | 4-5 | 4-5 | 4-5 | 4 | 4 |
| | Polyester | 4-5 | 4-5 | 4-5 | 4-5 | 3 |
| | Acrylic | 4-5 | 4-5 | 4-5 | 4-5 | 4-5 |
| | Wool | 4-5 | 4-5 | 4-5 | 4 | 3 |
| Color fading | 4-5 | 4-5 | 4-5 | 4 | 4 | |

TABLE VI. EFFECT OF COLOR-FIXING AGENT CONCENTRATION ON ALKALINE SWEAT COLORFASTNESS

| Color - Fixing agent concentration (%) | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | |
|--|-----------|-----|-----|-----|-----|-----|
| Alkaline sweat colorfastness | Acetone | 4-5 | 4-5 | 4-5 | 4 | 3-4 |
| | Cotton | 4-5 | 4 | 4-5 | 4-5 | 3-4 |
| | Nylon | 4-5 | 4-5 | 4 | 4 | 3 |
| | Polyester | 4-5 | 4 | 4 | 4 | 4 |
| | Acrylic | 4-5 | 4-5 | 4 | 4-5 | 4 |
| | Wool | 4-5 | 4 | 4-5 | 4 | 3 |
| Color fading | 4-5 | 4-5 | 4-5 | 4-5 | 4-5 | |

The overall evaluation of colorfastness highlights that the optimal concentration range for Eriofast Fix lies between 2.0% and 2.6%. Within this range, the fabric exhibited superior washing, rubbing, and perspiration fastness, ensuring stable dye adhesion and minimal color loss. Concentrations exceeding 2.6% negatively impacted performance due to inefficient chemical usage and increased residues.

C. Environmental and Economic Impacts

The optimization of Eriofast Fix concentration not only affects fabric performance, but also has significant environmental and economic implications.

- **Environmental Sustainability:** Excessive use of mordants, as observed at concentrations above 2.6%, poses

environmental risks due to the discharge of unutilized chemicals into wastewater. Such discharge can contribute to water pollution and harm aquatic ecosystems. By maintaining mordant concentration within the optimal range, the dyeing process becomes more eco-friendly, aligning with sustainable production practices.

- **Production Costs:** Higher mordant concentrations not only compromise fabric performance, but also increase production costs. These costs arise from the overuse of mordants, additional washing cycles required to remove residues, and the treatment of wastewater containing unutilized chemicals. In contrast, the optimized range of 2.0% to 2.4% reduces material costs and operational expenses while maintaining high product quality. This balance between cost-efficiency and performance is critical for industrial competitiveness, particularly in global markets demanding sustainable textile solutions.

D. Literature Comparison

Unlike previous works that primarily focused on general mordant applications, this research provides a systematic evaluation of Eriofast Fix and its effect on both color intensity and colorfastness in knitted PA/PU fabrics. When compared to [6], where mordanting effects on polyester-based fabrics were explored, this study extends the analysis to the specific case of PA/PU, which presents different dyeing challenges due to its elasticity and hydrophobic nature. Additionally, these results align with those of [7], where the advantage of cationic mordants over anionic ones was demonstrated for nylon. Furthermore, the improvements in color retention observed contrast with the findings of [8], where the focus was on reactive dyeing rather than disperse dyes.

IV. CONCLUSION

This study investigated the effect of Eriofast Fix concentration on the color intensity and colorfastness of Single Jersey knitted Nylon/Spandex (PA/PU) fabric dyed with disperse dyes. The results revealed that Eriofast Fix concentrations from 2.0% to 2.4% significantly improve colorfastness characteristics, particularly wash, rub, and perspiration fastness, while maintaining high color intensity. Beyond enhancing dye retention, the appropriate application of Eriofast Fix contributes to a more sustainable dyeing process by minimizing excessive chemical usage and reducing environmental impact.

These findings provide a practical reference for textile manufacturers seeking to optimize mordant application in PA/PU fabrics. Future research should explore alternative mordanting agents with lower environmental impact while maintaining similar or better dyeing performance. Additionally, further investigations into the interaction between mordants and fabric structure could offer deeper insights into improving both the functional and ecological aspects of the dyeing process.

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