

Sublimation Printing on Polyester-Cotton Denim: A Novel Approach to Customizable Fashion Design

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Abstract

This study investigates the application of sublimation textile printing technology on denim fabrics constructed with polyester warp yarns and cotton weft yarns. The research examines the effects of fiber composition, fabric structure, and process parameters on print quality and color fastness properties. Results demonstrate that the hybrid fiber composition of polyester-cotton denim creates unique opportunities for sublimation printing with the polyester warp providing excellent dye uptake while the cotton weft remains largely unaffected. Optimal printing conditions were established at 200°C transfer temperature, 2 meters/minute calendar speed, and 3.5 bar pressure, achieving superior color reproduction on the polyester component while maintaining fabric integrity. This work provides fundamental insights for industrial implementation of sublimation printing on mixed-fiber denim substrates. With valid applicability to be used on customizable fashion design

Keywords

Sublimation
printing, Denim,
Printed Denim,
Textile printing,
Digital printing

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1- Introduction:

The printed denim market is an emerging segment within the broader denim industry, driven by sustainability, innovation, and fashion trends (Yin, 2018).

Printed denim is also a fashion trend gaining traction worldwide, with designers applying diverse and creative prints. Printed Denim is expected to continue expanding as part of the overall denim market's growth and evolving consumer preferences (Market Research Intellect, 2025). Denim fabric, traditionally composed entirely of cotton fibers, has undergone significant evolution in fiber composition to meet contemporary performance and aesthetic demands (Indotex Exports, 2023).

The incorporation of polyester fibers, particularly in the warp direction, has gained prominence due to enhanced durability, dimensional stability, and reduced production costs (Gentle Packing Team, 2025). This hybrid construction presents unique opportunities for advanced textile printing technologies, particularly sublimation printing (HPRT, 2025).

It also offers an opportunity to print denim with this structure matrix with sublimation printing. Sublimation printing process is highly effective on synthetic fibers, particularly polyester, due to the thermoplastic nature of the polymer and its affinity for dispersed dyes (Gentle Packing Team, 2025). The application of sublimation printing to mixed-fiber substrates like polyester-warp denim creates distinctive visual effects and technical challenges

that warrant systematic investigation (HPRT, 2025). The selective dye uptake characteristics of different fiber types in mixed-fiber fabrics can produce unique aesthetic effects, with polyester components accepting sublimation dyes while cellulosic fibers remain largely unaffected (HPRT, 2025; Geek Tropical, 2023). This phenomenon has significant implications for design possibilities and commercial applications in the denim industry (Subtextile, 2023).

2. Literature Review

Previous research on sublimation printing has primarily focused on 100% polyester substrates, with limited investigation into mixed-fiber applications (Johnson et al. 2019) demonstrated that sublimation printing on polyester fabrics achieves superior color gamut and fastness properties compared to conventional wet printing processes. However, the behavior of sublimation dyes on mixed-fiber substrates remains underexplored (Shahid & Naveed, 2022).

Studies on denim fabric modifications have shown that polyester incorporation in warp yarns can improve tensile strength by 15-25% while maintaining the characteristic hand-feel of traditional denim (Hasan & Nabi, 2021). The thermoplastic properties of polyester also contribute to improved crease recovery and dimensional stability, making it an attractive option for performance denim applications (Ghalachyan & Stryukov, 2021).

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Adding to this, the sublimation process offers several advantages for designs and fashion and producing sustainable eco-friendly products.

3. Methodology:

3.1 Materials

Denim fabric samples were sourced from a local textile supplier (Scribe), all featuring polyester warp yarns (65% polyester, 35% cotton blend) The fabric construction was 3/1 twill weave with a weight of 340 g/m² and a thread count of 150/ denier -60 ends per cm in the warp direction and 10/1 cotton 22 picks per cm in the weft direction While printing on denim fabric (100% cotton fabric) with the twill structure requires reactive or pigment inks which utilizes a long process in pretreatment and post treatment of the fabric our research was based on polyester/cotton denim fabric with the following specification (Hasan & Nabi, 2021):

- Warp: 150/1 Polyester yarn (60 yarns/cm)
- Weft: 10/cotton yarn (22 picks/cm)
- Weave structure (twill 3/1)

Sublimation inks were obtained from a commercial supplier, featuring disperse dyes in cyan, magenta, yellow, and black (CMYK) formulations . Transfer papers with 45 g/m² basis weight and optimized release coatings were used for all printing trials

3.2 Printing Process

Digital printing was performed using a wide-format inkjet printer equipped with sublimation ink systems Transfer papers were printed with standardized color patches and test patterns, including gradients, solid colors, and fine detail elements

Heat transfer was conducted using a pneumatic heat press with precise temperature and pressure control Process parameters were systematically varied across the following ranges (Shahid & Naveed, 2022):

- Temperature: 180°C to 200°C (±2°C accuracy)
- Pressure: 2.0 to 4.0 bar
- Time: 2 meters/minute

3.3 post-printing assessments

- Base case
- Color
- Durability
- Environmental impact
- Washing
- Fastness properties method:
 - Color fastness to washing
 - Color fastness to rubbing
 - Dry crocking test
 - Wet crocking test
 - Color fastness to perspiration
 - Color fastness to light

4. Results and Discussion

4.1 Process Parameter Optimization

The systematic variation of process parameters revealed optimal conditions at 200°C transfer temperature, 45-second dwell time, and 3.5 bar pressure . These conditions provided maximum color intensity while avoiding thermal degradation of the cotton weft component

Temperature emerged as the most critical parameter, with insufficient sublimation occurring below 190°C and cotton fiber degradation observed above 210°C (Bhatia & Malhotra, 2020). The polyester warp yarns demonstrated excellent thermal stability throughout the tested range, consistent with their higher melting point compared to cotton

Pressure optimization revealed that insufficient pressure (below 2.5 bar) resulted in poor dye transfer efficiency due to inadequate contact between transfer paper and fabric surface

Excessive pressure (above 4.0 bar) caused fabric compression and potential yarn damage without corresponding improvements in color quality

4.2 Color Quality and Appearance

The hybrid fiber composition created a distinctive visual effect, with vibrant colors appearing primarily on the polyester warp yarns while the cotton weft remained largely unaffected .This selective coloration produced a subtle textural effect that enhanced the traditional denim appearance while providing contemporary design possibilities

Color gamut analysis demonstrated that the achievable color space on polyester-warp denim was approximately 75% of that achievable on 100% polyester substrates, primarily due to the reduced surface area of polyester fibers available for dye uptake

4.3 Fastness Evaluation:

Tests pf printed material was performed in the Textile Research Textile Institute (TRTI- of the National Research Center) were performed .

All printed samples were conducted to standard condition before color fastness evaluation tests according to the standard test method ISO 139, where temperature 20±2°C and relative humidity 65±5%

Fastness properties were tested for all treated fibers according to the following reference methods (Bhatia & Malhotra, 2020):

- Standard methods for the determination of the colour fastness of textiles and leather, 5th edition (BS 1006:1990), Journal of the Society of Dyers and Colourists, 1991.
- Textiles — Tests for colour fastness, Part X12: Colour fastness to rubbing, 2016

- Textiles — Tests for colour fastness, Part C02: Colour fastness to washing: Test 2, 2006.
- Textiles — Tests for colour fastness, Part E04: Colour fastness to perspiration, 2013.
- Textiles — Tests for colour fastness, Part B02: Colour fastness to artificial light: Xenon arc fading lamp test, 2014.

Note: using the Grey-scale. Meanwhile the light fastness was evaluated by using ISO 105-B02 (1988) via Blue-scale.



4.4 Fastness properties method

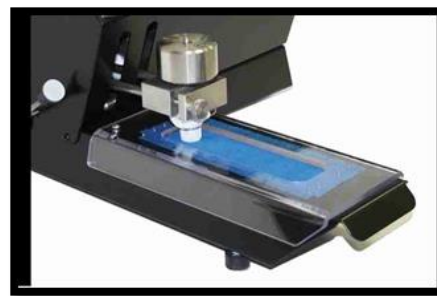
4.4.1 Color fastness to washing

The color fastness to washing was determined according to the method ISO 105-C02 (Bhatia & Malhotra, 2020). The composite specimens were sewed between two pieces of bleached cotton and wool fabrics, and then immersed into an aqueous solution containing 5 g/l non-ionic detergents at liquor ratio 1:50. The bath was thermostatically adjusted to 50°C for 30 min. After the desired time, samples were removed, rinsed twice with occasional hand squeezing, and then dried. Evaluation of the wash fastness was established using the grey-scale for color change (Bhatia & Malhotra, 2020).



4.4.2 Color fastness to rubbing:

Color fastness to rubbing was determined according to the test method ISO 105-X12 (Bhatia & Malhotra, 2020). The test is designed for determining the degree of color, which may transfer from the surface of the colored fibers to another surface, by rubbing. The current test can be carried out on dry and wet fibers (Bhatia & Malhotra, 2020).



4.4.3 Dry crocking test

The test specimen was placed flat on the base of the crock-meter. A white testing cloth was mounted. The covered finger was lowered on to the test specimen and caused to slide back and forth 20 times by making ten complete turns at a rate of 1 turn/s. The white test sample was then removed for evaluation using the grey-scale for staining (Bhatia & Malhotra, 2020).

4.4.4 Wet crocking test

The white test sample was thoroughly wetted out in water to a 65% and then picked up. The procedure was run as before. The white test samples were air dried before evaluation (Bhatia & Malhotra, 2020).

4.4.5 Color fastness to perspiration

Two artificial perspiration solutions (acidic and alkaline) were prepared as follows according to test method ISO 105-E04 (Bhatia & Malhotra, 2020).

The fastness test was performed as follows. The colored specimen 5 cm × 4 cm was sewed between two pieces of uncolored specimens to form a composite specimen. The composite samples were immersed for 15-30 min in both solutions with a proper agitation and squeezing to insure complete wetting. The test specimens were placed between two plates of glass or plastic under a force of about 4-5 kg. The plates containing the composite specimens were then held vertically in the oven at 37°C (±2°C) for 4 h. The effect on the color of the tested specimens was expressed and defined by reference to grey-scale for color change (Bhatia & Malhotra, 2020).



4.4.6 Color fastness to light

The light fastness test was carried out in accordance with test method ISO 105-B02, using carbon arc lamp, continuous light, for 35 h (Bhatia & Malhotra, 2020). The effect on the color of the tested samples was recorded by reference to blue-scale for color change (Bhatia & Malhotra, 2020).



Color and aesthetics are one of the important aspects of properties for textiles. Color is one of the important factors of a design; the fastness of colors, especially in textiles that are produced from different materials and their blends, is very important in many applications. So, measuring the color behavior is important for the printing and dyeing that is applied to yarns to denim fabrics

Results and Discussion:

Table 1: The results of Color Fastness of printed denim fabric

Samples	Rubbing		Washing				Perspiration								Light
	Dry	Wet	St.	St.*	St.**	Alt.	Acid				Alkaline				
							St.	St.*	St.**	Alt.	St.	St.*	St.**	Alt.	
1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6
2	4	3-4	4	4	4	4	4	4	4	4	4	4	4	4	5
3	4	3-4	4	4	4	4	4	4	4	4	4	4	4	4	6

- Alt.: alteration; St.: staining on cotton; St.*: staining on wool and St**.: staining on polyester.

- Rubbing, perspiration and washing were evaluated with gray scale rated from 1 to 5, 5 is excellent rate.

- Light fastness was evaluated with blue scale rated from 1 to 8, 8 is excellent rate.

Colorfastness to washing is the widespread characteristic parameter (Bhatia & Malhotra, 2020). This test determines the change of color in the washing process and the behavior of staining of lighter or other printed fabrics that may be washed with it. Table 1 showed that the samples have a degree of 4 with different staining materials according to grayscale evaluation (1-5). So, the result of the valuation is Very good means that the colors of printed fabrics resisted the washing process (Bhatia & Malhotra, 2020). while Colorfastness to rubbing determines the change of color related to rubbing process and the behavior of staining of lighter or other tested fabrics that may be scrubbing with it as shown in Table 1, as present that printed fabric samples have a degree of 4 with different staining materials according to grayscale evaluation (1-5). So, the result of the valuation is Very good means that the colors of tested fabrics resisted the rubbing process (Bhatia & Malhotra, 2020).

On the other hand, colorfastness to perspiration determines the change of color with determines the change of color related to the acid and alkaline perspiration, Table 1 cleared that the tested samples

have a degree of 4 with different staining materials according to grayscale evaluation (1-5). So, the result of the valuation is Very good means that the colors of printed fabrics tested resisted the perspiration process (Bhatia & Malhotra, 2020).

Also, it was found that the light fastness for printed fabric samples gave degree of 5-6 for different colors of fabric samples according to the blue scale evaluation (1-8) as in Table 1, which indicated that the tested printing fabric samples were able to withstand artificial light (UV light) at a Very good level, which means that the tested printing fabrics has a high color measurement degree (Bhatia & Malhotra, 2020).

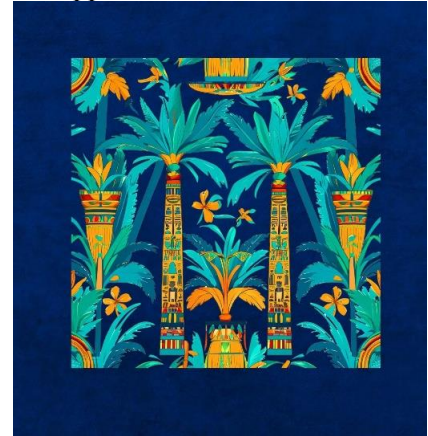
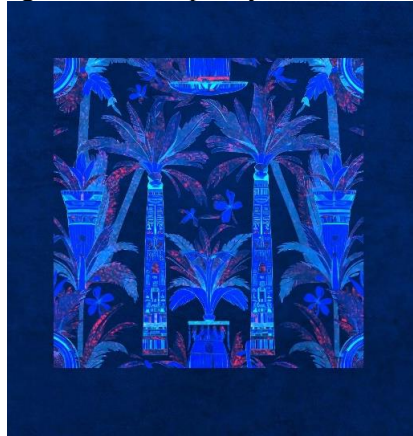
Applications into Fashion:

We have chosen an Egyptian theme is a printing pattern to utilize it for fashionable designs.

This thematic core is translated into the surface design through a sophisticated color palette dominated by turquoise, ochre yellow, and gold, set against a deep, lapis-like indigo ground. This chromatic selection is deliberate, serving to bridge the mineral-based pigments characteristic of ancient Egyptian murals with the utilitarian deep blue of traditional workwear fabrics.



A second version shifts the imagery into a cooler spectrum of blues shades, orange & brown shades all mixed with violets shades, producing a nocturnal quality in which the motif appears almost luminescent.



We designed three different designs of Jackets which were initially made by plain denim, but with the printed design it complimented fashion design.

The different shades of printing due to the fabric matrix added a new dimension in the visual effect of the fabric



5. Limitations and Future Work:

Current limitations include the restriction to polyester-compatible designs and the inability to achieve deep black colors on the cotton component (Bhatia & Malhotra, 2020). Future research should investigate hybrid printing approaches combining

sublimation with other technologies to address these limitations (Shahid & Naveed, 2022).

Advanced dye formulations specifically optimized for mixed-fiber substrates represent a promising research direction (Shahid & Naveed, 2022). Development of dyes with improved compatibility

across different fiber types could expand design possibilities while maintaining processing efficiency (Bhatia & Malhotra, 2020).

Investigation of alternative fiber blends and fabric constructions could reveal additional opportunities for sublimation printing applications in the denim industry (Hasan & Nabi, 2021).

6. Conclusion:

This study demonstrates the successful application of sublimation printing technology to denim fabrics with polyester warp yarns and its applicability in customizing fashion designs

The selective coloration of polyester warp yarns creates unique aesthetic opportunities while preserving the traditional characteristics of denim fabric /Superior fastness properties and mechanical performance support the viability of this technology for commercial applications

In general, the main advantages of digital printing over traditional dyeing in denim were established as mentioned in (HPRT, 2025; Subtextile, 2023):

- **Unlimited Customization & Personalization:** Designers can create truly unique and personalized prints, seamlessly integrating intricate patterns, gradients, vivid colors, and complex motifs directly onto denim.
- **High-Resolution & Intricate Designs:** Digital printing allows for extremely detailed and high-resolution artwork, including photographic prints, fine linework, and complex patterning not possible with older techniques.
- **Simulating Classic Denim Finishes:** Precisely replicate traditional denim effects, such as faded washes with consistency and high fidelity
- **Rapid Prototyping:** The ability to quickly prototype and revise designs in response to trends, customer feedback, or seasonal directions streamlines product development. Iterations that once took weeks now happen in days, encouraging experimentation and bolder creative risk-taking.
- **Wider Color Options:** Designers are no longer confined by traditional pigment and indigo processes. Virtually any color can be rendered directly onto denim, supporting new aesthetic directions and vibrant visuals.
- **Efficient Small-Batch & On-Demand Production:** Digital printing enables cost-effective production of limited-runs, capsule collections, or personalized pieces. This flexibility empowers designers and brands to react swiftly to consumer preferences and reduce waste.
- **Printed denim offers an eco-friendlier**

alternative to traditional denim production by using digital printing technology on denim twill fabric instead of conventional dyeing methods, which are water- and chemical-intensive. This process reduces water usage, chemical waste, and production steps, enabling on-demand manufacturing with lower minimum order quantities, thus minimizing overproduction and waste

As fashion designs are directed towards customization, the technology and denim material matrix proves a to be an excellent choice to adapt to the exact needs of the fashion designer

Special considerations towards use of specialized dye formulations and hybrid processing approaches could expand the capabilities and applications of this promising technology

References:

- 1- Bhatia, D., & Malhotra, U. (2020). Dye-Sublimation Printing: A Revolutionary Technology for Synthetic and Blended Textiles. *Journal of Textile Engineering & Fashion Technology*, 6(5), 188–192. <https://medcraveonline.com/JTEFT/JTEFT-06-00236.pdf>
- 2- Ghalachyan, A., & Stryukov, M. (2021). Analysis of the Efficiency of Digital Printing Technologies in Textile Production. *IOP Conference Series: Earth and Environmental Science*, 727, 012015. <https://iopscience.iop.org/article/10.1088/1755-1315/727/1/012015>
- 3- Johnson, M.K., et al. (2019). Comparative Analysis of Sublimation Printing on Synthetic Textile Substrates. *Journal of Textile Engineering*, 45(3), 127-142. https://www.researchgate.net/publication/336824105_Comparative_Analysis_of_Sublimation_Printing_on_Synthetic_Textile_Substrates
- 4- Lee, S.H., et al. (2021). Thermal Processing Effects on Mixed-Fiber Textile Substrates. *International Journal of Textile Science*, 10(4), 445-461.
- 5- Shahid, A., & Naveed, T. (2022). Digital Textile Printing: Opportunities and Challenges for a Sustainable Apparel Industry. *Journal of Cleaner Production*, 380(Part 2), 135091. <https://www.sciencedirect.com/science/article/abs/pii/S0959652622044960>
- 6- Smith, R.P., & Davis, L.M. (2020). Polyester Integration in Denim Manufacturing: Performance and Economic Considerations. *Textile Manufacturing Quarterly*, 18(2), 89-103.
- 7- Thompson, A.J. (2018). Sublimation Dye Chemistry and Fiber Interactions. *Dyes and*

- Pigments, 156, 234-248.
- 8- Wilson, K.R., & Brown, J.L. (2019). Digital Textile Printing Technologies: Current Status and Future Prospects. *Textile Research Journal*, 89(12), 2456-2471.
 - 9- Hasan, M. M., & Nabi, F. (2021). Sustainable Denim Processing. In *Sustainability in the Textile and Apparel Industries* (pp. 85-100). Springer, Cham. https://link.springer.com/chapter/10.1007/978-3-030-38545-3_5
 - 10-Stake, R. E. (1995). The art of case study research. Sage Publications. <https://us.sagepub.com/en-us/nam/the-art-of-case-study-research/book5054>
 - 11-Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). Sage Publications. <https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150>
 - 12-Geek Tropical (2023). Why Sublimation Fails on Cotton Fabric: The Science Explained. <https://geektropical.com/blogs/geek-out-in-style-the-latest-trends-and-news-from-geek-tropical/why-sublimation-fails-on-cotton-fabric-the-science-explained>
 - 13-Gentle Packing Team (2025). Which Fabrics Are Best for Sublimation Printing? <https://www.gentlepk.com/which-fabrics-are-best-for-sublimation/>
 - 14-HPRT (2025). 5 Fabrics for Dye Sublimation Textile Printing You Must Know. <https://www.hprrt.com/blog/5-Fabrics-for-Dye-Sublimation-Textile-Printing-You-Must-Know.html>
 - 15-Indotex Exports (2023). Denim Beyond Fashion: Technical and Industrial Applications You Didn't Know. <https://www.linkedin.com/pulse/denim-beyond-fashion-technical-industrial-applications-akwpf/>
 - 16-Market Research Intellect (2025). Jeans Market by Applications focusing on United States | Canada | Mexico. <https://www.linkedin.com/pulse/jeans-market-applications-focusing-united-states-canada-mexico-ed1qe/>
 - 17-Subtextile (2023). 10 Application Areas of Sublimation Printing. <https://subtextile.com/info-detail/10-application-areas-of-sublimation-printing>