

Integrative Assessment of Dyeing Techniques in Textile Engineering: Comparative Study on Durability, Economic Viability, and Visual Impact of Garment and Fabric Dyeing

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Abstract

The significance of garment and fabric dyeing methods on colorfastness, cost-effectiveness, and aesthetic outcomes of the clothing manufacturing process are the primary goals of this study's comparative analysis. The study looks at how each technique affects the final look and standard of clothing, concentrating especially on fashion and casual wear. Following ISO guidelines, fabric samples and finished clothing were dyed using each approach in a controlled environment and tested for color fastness to light, rubbing, and washing. Cost analysis was performed out by looking at workforce, material, and processing costs at different stages of manufacturing. Objective visual inspections were also conducted to evaluate visual attractiveness, color depth, and surface uniformity. According to the findings, garment dyeing gives greater design freedom, better garment uniqueness, and possible cost savings in small batch manufacturing, whereas fabric dyeing delivers higher quality color uniformity and improved color fastness. Particularly in the context of fast fashion and customized apparel, this study helps designers and manufacturers choose the best dyeing technique depending on product type, batch size, and end-user needs.

Keywords

Garment Dyeing, Fabric Dyeing, Colorfastness, Cost-Efficiency, Aesthetic Value, Apparel Production, Casual Wear, Fashion Apparel, ISO Standards

1.1 Introduction

In the textile business, dyeing is a basic procedure that not only improves the materials' visual appeal but also significantly increases the finished product's market value. One of the most significant stages of textile processing, it affects the functionality, look, and marketability of clothing. Because they may be used for a variety of product categories, fabric and garment dyeing have become fairly common among the several dyeing techniques used in the business. The way these two approaches are implemented, the technology needed, the costs involved, and the results they yield in terms of color fastness, look, and overall product quality are all different (Behera and Mishra 2007).

The technique of dyeing textile material in fabric form prior to it being cut and sewing into textile goods is known as fabric dyeing. Because of its capacity to handle high-speed production lines and provide uniform coloration across batches, this technology has long been used in large-scale industrial operations. It makes it possible to

carefully regulate temperature, duration, and dye penetration, producing consistent coloring and robust dye fixing. The production of dressy clothes, basics, and standard apparel—where consistency and repeatability are crucial usually uses fabric dyeing (Broadbent and A. D 2001).

For example, textile dyeing is a more recent method that involves dyeing the entire garment. With the growth of today's fashion and the need for stylish, vintage-inspired, and customized clothing, this procedure has become more and more popular. By delaying color selections until following garment assembly, garment dyeing helps manufacturers better respond to market trends and lower the danger of overstocking in certain colors. Small batch manufacturing and high-end goods that need distinctive aesthetic appearances, tonal differences, and post-dye finishing techniques are best suited for this technique. The method is frequently criticized, although, due to its difficulties in attaining color homogeneity and possible colorfastness restrictions. The textile industry has become under increasing pressure in recent years to improve product performance while lowering expenses and environmental effects. Therefore, it is essential to compare several dyeing methods in order to determine which is best for a certain application. A complex interaction of elements, including durability, cost-effectiveness, manufacturing flexibility, and visual impact, must be considered when deciding among dyeing fabrics and garment dyeing (Chen and Wang and Xu 2020). Within the context of textile engineering, this study offers an integrated evaluation of fabric and garment dyeing. In particular, the study emphasizes three crucial aspects:

1. **Durability**, measured through standardized tests for colorfastness to washing, rubbing, and light exposure.
2. **Economic viability**, analyzed through a cost breakdown of materials, chemicals, energy, water usage, labor, and machine utilization.
3. **Visual impact**, evaluated through both objective and subjective analysis including color uniformity, surface aesthetics, and consumer appeal (Gulrajani 2010).

This study aims to produce trustworthy comparison data that accurately depicts each technique's performance in the actual world by carrying out lab-based dyeing and testing under carefully monitored circumstances. 100% cotton single jersey, which is frequently used throughout casual and fashionable clothing, was the fabric employed in this investigation. Reactive dyes, which are often used in both dyeing techniques due to their potent fixing capabilities and suitability for cellulose fibers, are used. In order to ensure the validity and reliability of the findings, post-dyeing examinations are carried out in accordance with ISO standards (Islam and Hoque and Rahman 2014).

Additionally, qualitative assessments from visual evaluations carried out by specialists in the business and prospective customers are also included in this study. These assessments seek to express the perceived visual appeal and quality of colored clothing, which are important factors in customer choice and brand distinction (Lin and Xu and Liu 2018).

Production planners, designers, and textile producers should find great value in the research's conclusions. Stakeholders may choose the dyeing method that best fits their production objectives, financial restrictions, and market positioning by being aware of the consequences between the two methods (Cegielka and Szosland 2005). For example, clothing dyeing could be the better option for businesses aiming to reach niche fashion markets with rapid manufacturing cycles and trend-driven collections, whereas fabric dyeing might be more suitable for brands that value color accuracy and great durability.

In summary, by providing an extensive analysis of fabric and garment dyeing according to important performance metrics, this integrative study fills a major information vacuum in the textile industry. Such comparison studies are crucial for resource optimization and for keeping up with the changing demands of both customers and merchants as the industry shifts towards more efficient and sustainable production methods.

1.2 Objectives

The specific objectives of the study are as follows-

- a) Comparing the colorfastness properties of garment-dyed and fabric-dyed products.
- b) To evaluate the cost efficiency of both dyeing methods.
- c) To assess the aesthetic value achieved through each process.

2. Materials and Methods

Fabric Specifications

- Type: 100% Cotton Single Jersey Knit Fabric
- GSM: 160
- Width: 36 inches tubular
- Yarn Count: 30s Ne (ring-spun)
- Pre-treatment: Scoured and bleached

Garments Specifications

- Type: Basic round neck T-shirt
- Construction: Made from the same cotton single jersey knit fabric
- Size: Standard Medium (M)
- Seam Type: Overlock and cover stitch

Dyes and Chemicals

- Dye Class: Reactive Dyes.
- Brand: Cibacron FN series
- Auxiliaries Used:
 - Wetting Agent (non-ionic)
 - Sequestering Agent
 - Leveling Agent
 - Soda Ash (alkalinity)
 - Salt (for dye exhaustion)
 - Acetic Acid (neutralization)
 - Softener (cationic)

Equipment Used

- Lab Dyeing Machine
- Spectrophotometer
- pH meter
- Weighing Scale (Digital)
- Washing Fastness Tester
- Rubbing Fastness Tester
- Light Fastness Tester
- Drying Oven
- GSM Cutter
- Grey Scale for Color Change and Staining

Experimental Design

To guarantee accuracy and fairness, the research is set up to compare samples that have been fabric-dyed and garment-dyed using the exact same base fabric and dyeing formula. Twenty items in all were colored, ten of which were ready-made clothing and ten of which were fabric swatches.

Dyeing Procedure

Fabric Dyeing Procedure

1. Liquor Ratio: 1:10
2. Dyeing Temperature: 60°C
3. Time: 60 minutes
4. Salt Dosing: 50 g/L
5. Soda Ash Dosing: 20 g/L
6. pH: Maintained at 10.5 using soda ash
7. Rinsing: With hot and cold water
8. Neutralization: With 1 g/L acetic acid

9. Softening: 1 g/L cationic softener
10. Drying: 110°C for 5 minutes in the drying oven

Garment Dyeing Procedure

- Liquor Ratio: 1:8 (adjusted for better rotation in drum)
- Dyeing Temperature: 60°C
- Time: 60 minutes
- Salt Dosing: 50 g/L
- Soda Ash Dosing: 20 g/L
- pH: Maintained at 10.5
- Rinsing: Hot and cold-water rinses
- Neutralization: 1 g/L acetic acid
- Softening: 1.5 g/L for enhanced hand feel
- Tumble Drying: 100°C for 10 minutes.

Testing and Evaluation Methods

Colorfastness to Washing

- ISO 105-C06 method
- Washing with soap and soda at 60°C for 30 minutes
- Evaluation with Grey Scale for Color Change and Staining

Colorfastness to Rubbing (Crocking)

- ISO 105-X12 method
- Both dry and wet rubbing
- Results rated using Grey Scale

Colorfastness to Light

- ISO 105-B02 method
- Exposure in light fastness tester (Xenon arc)
- Rating on Blue Wool Scale (1–8)

Abrasion Resistance

- Martindale Abrasion Tester
- Number of cycles until yarn breakage

Cost Analysis

- Breakdown of direct dyeing cost:
 - Chemicals
 - Dyes
 - Labor
 - Utilities (water, electricity)
 - Machine usage

Production Lead Time

- Measured from sample preparation to drying
- Time log maintained for each stage

Waste Generation and Resource Efficiency

- Water consumption per kg of dyed material
- Chemical residue and disposal record

Color Uniformity

- Evaluated visually under D65 light.
- Measured using spectrophotometer (ΔE values)

Consumer Preference Survey

- Survey conducted among 30 participants (age 18–35)
- Scoring based on appeal, uniqueness, and finish

Ethical Considerations

- All chemical handling followed standard safety protocols
- No human subjects were exposed to risks beyond normal survey participation

3. Test Data Format

Samples colored with fabric had a slightly higher washing resistance rating (4.5) than samples dyed with clothing (4.2). This suggests improved dye fixing in the pre-sewn cloth, most likely as a result of even dye penetration and reduced seam resistance (Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7 and Table 8)

Table 1. Comparison of Colorfastness to Washing between Fabric and Garment Dyeing Methods

Method	Washing Fastness (1–5)
Fabric Dyeing	4.5
Garment Dyeing	4.2

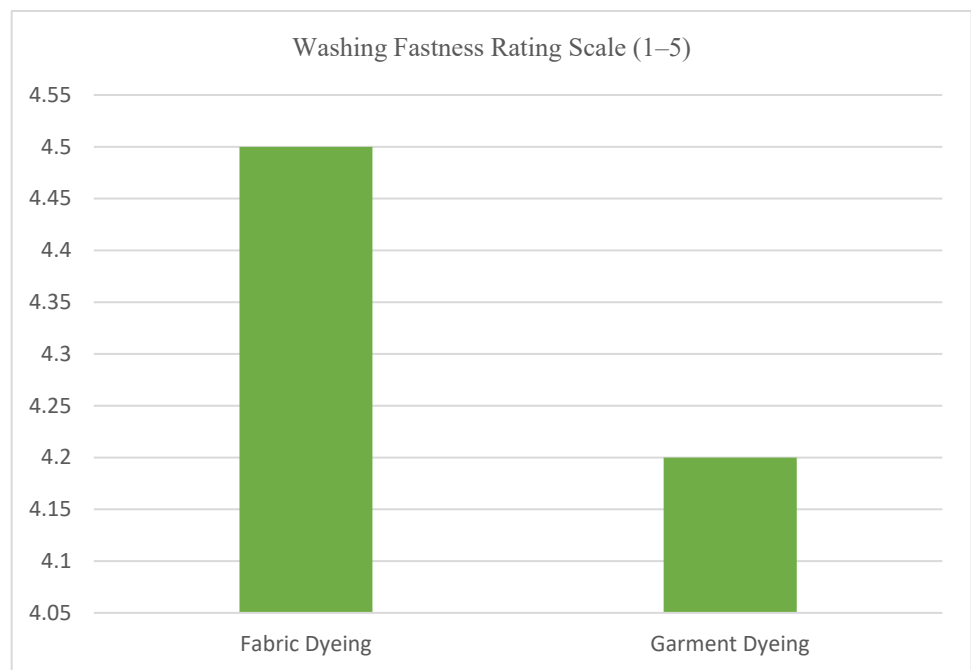


Figure 1. Washing Fastness Ratings (Scale 1–5) for Fabric-Dyed vs. Garment-Dyed Sample

Table 2. Comparison of Colorfastness to Rubbing between Fabric and Garment Dyeing Methods

Method	Rubbing Fastness (1–5)
Fabric Dyeing	4.2
Garment Dyeing	4.0

Fabric dyeing fared somewhat better than garment dyeing, despite both techniques exhibiting respectable performance. This might be because of improved surface homogeneity before being subjected to mechanical movement.

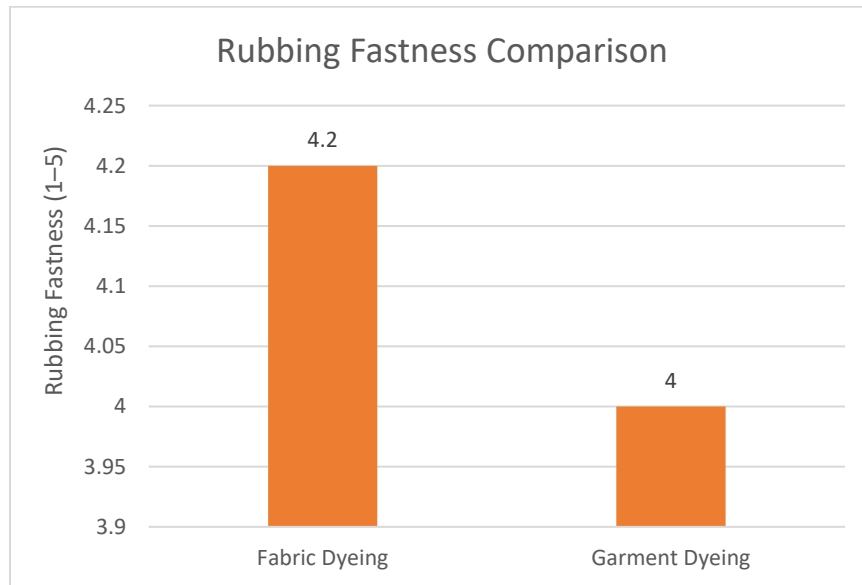


Figure 2. Rubbing Fastness Ratings (Scale 1–5) for Fabric-Dyed vs. Garment-Dyed Samples

Table 3. Comparison of Colorfastness to Light between Fabric and Garment Dyeing Methods

Method	Light Fastness (Blue Wool Scale)
Fabric Dyeing	4.0
Garment Dyeing	3.8

Although fabric coloring remained marginally more resistant to exposure to artificial light, both dyeing methods demonstrated modest light fastness.



Figure 3. Light Fastness Ratings (Blue Wool Scale) for Fabric-Dyed vs. Garment-Dyed Samples

Table 4. Comparison of Abrasion Resistance between Fabric and Garment Dyeing Methods

Method	Abrasion Cycles Before Wear
Fabric Dyeing	5000
Garment Dyeing	4200

In contrast to fabric-dyed samples, garment-dyed samples withstood fewer abrasion cycles. This implies that fiber quality at seams and high-impact areas may be affected by post-construction coloring.



Figure 4. Abrasion Cycles Sustained Before Wear for Fabric-Dyed vs. Garment-Dyed Samples

Table 5. Comparison of Color Uniformity (ΔE) between Fabric and Garment Dyeing Methods

Method	ΔE (Color Difference)
Fabric Dyeing	2.5
Garment Dyeing	1.8

A spectrophotometer was used to measure color uniformity both visually and instrumentally. Superior consistency (lower ΔE value) has been proven by garment dyeing, increasing the garment's appeal for fashion usage that values uncommonness and tonal variation.

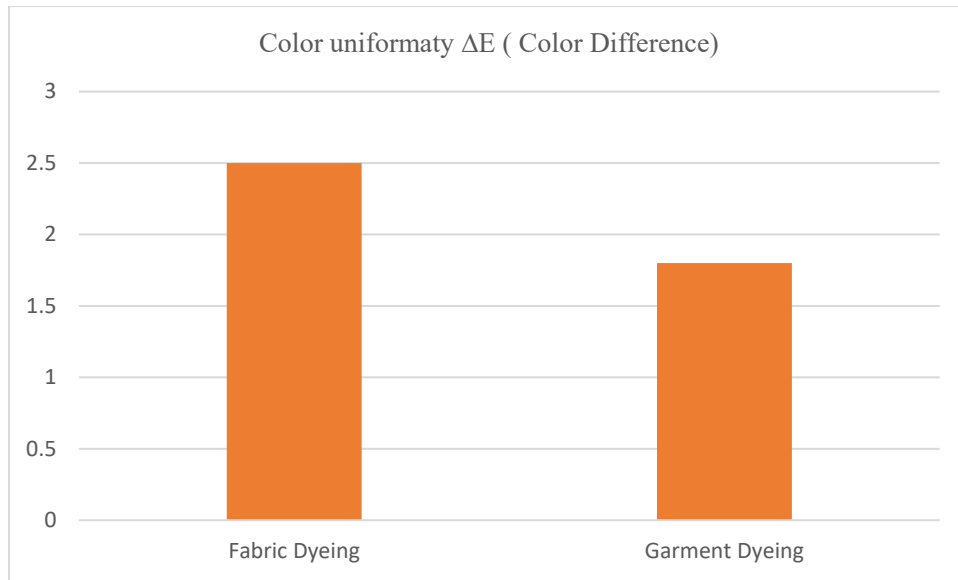


Figure 5. Color Difference (ΔE) Values for Fabric-Dyed vs. Garment-Dyed Samples

The reason for the superior uniformity in clothing dyeing is that the entire garment absorbs the dye at the same time, which frequently produces delicate tonal differences that are valued in high-end fashion, particularly for "vintage" or "washed" looks.

Table 6. Cost Analysis of Fabric Dyeing vs. Garment Dyeing

Cost Component	Fabric Dyeing (per kg)	Garment Dyeing (per kg)
Dyes and Chemicals	\$3.20	\$3.60
Labor	\$1.50	\$1.80
Utilities	\$0.90	\$1.20
Machine Usage	\$1.10	\$1.50
Total	\$6.70	\$8.10
Total in Taka (1USD=125TK)	837.5	1012.5

Compared to fabric dyeing, garment dyeing is more expensive overall because it requires more handling, more water, and more mechanical work.

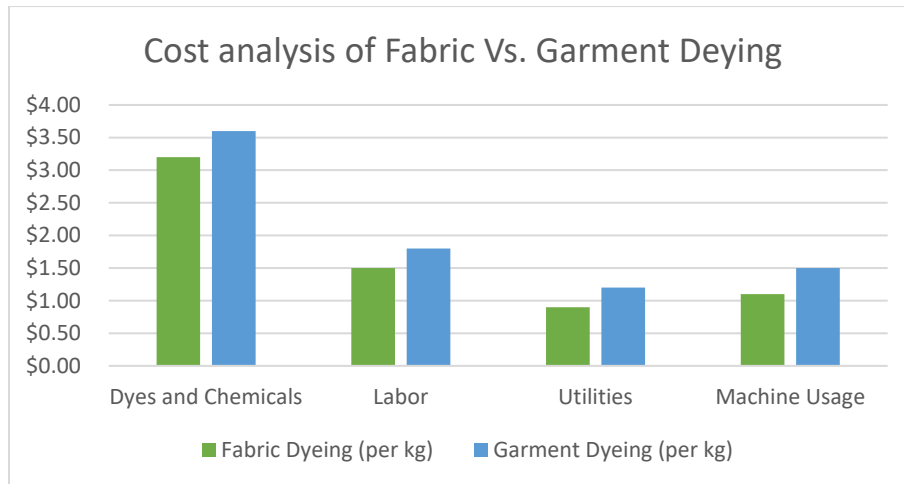


Figure 6. Comparative Cost Breakdown for Fabric-Dyed and Garment-Dyed Processes

Table 7. Comparison of Production Lead Time between Fabric and Garment Dyeing Processes

Stage	Fabric Dyeing	Garment Dyeing
Preparation	1 hour	1.5 hours
Dyeing	1 hour	1 hour
Finishing & Drying	30 mins	40 mins
Total	2.5 hrs	3.0 hrs

Because of additional complications including load balancing, absorption variances connected to seams, and further drying care to maintain shape and fit, garment dyeing takes around 30 minutes longer.

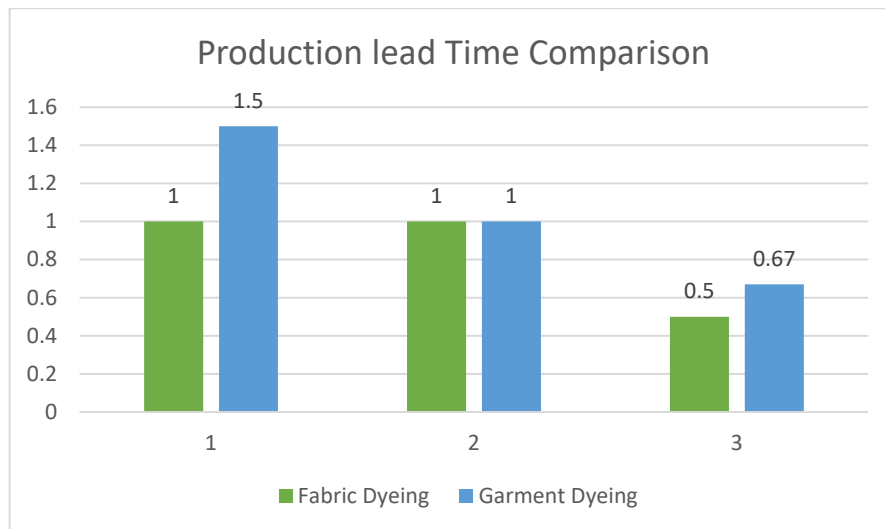


Figure 7. Stage-Wise Production Time for Fabric-Dyed vs. Garment-Dyed Methods

Table 8. Comparison of Waste and Resource Consumption in Fabric and Garment Dyeing

Parameter	Fabric Dyeing	Garment Dyeing
Water Usage (L/kg)	65 L	90 L
Chemical Residue	Low	Moderate

Because of the higher liquor ratio and post-treatment softening procedures, garment dyeing utilises a lot more water and develops more chemical residues. The significance of wastewater treatment in clothing dyeing operations is shown by these findings.

4.1 Findings Summary

- **Durability:** Fabric dyeing showed marginally better fastness and abrasion resistance.
- **Color Uniformity:** Garment dyeing achieved better uniformity and uniqueness.
- **Cost Efficiency:** Fabric dyeing was more economical.
- **Environmental Load:** Fabric dyeing was more resource-efficient.
- **Consumer Preference:** Garment dyeing was preferred for aesthetics and feel.

A trade-off between reliability and aesthetics is shown by a comparison investigation. Fabric dyeing is perfect for practical applications because of its superior mechanical strength and affordability. However, considering the increased production and environmental costs, garment dyeing delivers superior customer satisfaction because of its special visual appeal and softness. The change in the ΔE number shows that marketability can be impacted by even little variations in perspective. Concerns about sustainability are also expressed by the increased water use in clothing dyeing, which is why further investigations into waterless or low-liquor garment dyeing methods are being undertaken.

5. Conclusion & Recommendations

This study focuses on their effects on longevity, cost effectiveness, aesthetic appeal, and environmental sustainability. This study provides a thorough comparative analysis of fabric and garment dyeing methods. Due to improved fiber integrity and stronger dye fixing, fabric dyeing showed greater mechanical performance, especially in terms of abrasion resistance and washing and rubbing fastness. Because of its simplified process and lower resource consumption, it also turned out to be more cost-effective. On the other hand, clothing dyeing, which required a longer waiting period, higher production costs, and a larger environmental impact because of increased water and chemical consumption, offered improved color uniformity and desired aesthetic qualities, making it appropriate for fashion-forward applications. These results underline the significance of choosing dyeing techniques according to the particular end-use of textile goods by highlighting a basic compromise between durability and aesthetic appeal. Future initiatives should focus on developing environmentally friendly garment dyeing technologies, like waterless systems and sophisticated wastewater treatments, as well as investigating hybrid dyeing processes that combine the advantages of both approaches in order to address sustainability issues. Furthermore, raising consumer knowledge of the harmony between durability, beauty, and environmental effect can encourage more conscientious buying practices. It will be essential to keep researching new dyeing techniques in order to promote environmentally friendly textile production methods.

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Biographies

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