

UNDERGRADUATE FINAL YEAR PROJECT REPORT



**Faculty of Engineering
Department of Textile Engineering**

**Development of Distinct Denim Shades Through
Controlled Washing Process**

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**This Report Presented in Partial Fulfillment of the Requirements for
The Degree of Bachelor of Science in Textile Engineering**

Advance in Apparel Manufacturing Technology

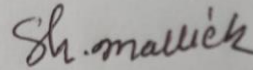
Spring--2025

Author's Declaration

We declare that we are the sole authors of this project. It is the actual copy of the project that was accepted by our advisor(s) including any necessary revisions. We also grant Daffodil International University permission to reproduce and distribute electronic or paper copies of this project.



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LETTER OF APPROVAL

The document “Development of Distinct Denim Shades through Controlled Washing Processes” submitted by Shankar Mallick (ID: 213-23-1031]) and Md.Mahfuj Uddin (ID:213-23-1030) in partial fulfillment of the requirements for the degree of Bachelor of Science in Textile Engineering (Apparel Major), has been examined and approved by the undersigned.

It is hereby recommended for acceptance and approval as a thesis paper for the said degree.

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Statement of contribution

The experiment was carried out by Mahfuj Uddin and Shankar Mallick. Mahfuj Uddin produced all of the samples in addition to designing the clothing. To make the design better, Mahfuj Uddin talks with the target audience and solicits their input. Mahfuj Uddin also computed clothing consumption and CM. Mahfuj Uddin and Shankar Mallick conducted the fabric testing in addition to taking all of the clothing measurements.

Both the beginning and the ends of the order sheet were created by Mahfuj Uddin. The work was primarily written by Mahfuj Uddin and Shankar Mallick. Each author offered insightful criticism and contributed to the development of the study, analysis, and manuscript. The initial idea was devised by Mahfuj Uddin and Shankar Mallick

Project supervision was provided by Abdullah Al Mamun.

Executive Summary

In order to meet the increasing demand for a variety of aesthetic finishes in the textile sector while maximizing production efficiency and reducing environmental effect, this thesis explores the creation of distinct denim hues through a carefully regulated washing procedure. Conventional denim washing frequently entails subjective control, which can result in uneven outcomes and wasteful resource usage. The impact of several factors, such as enzyme concentration, bleaching agent type and dose, washing time, temperature, and mechanical action, on the final shade and physical characteristics of denim fabric is methodically investigated in this study.

To guarantee comparability across experiments, a standardized denim fabric was used in a thorough experimental design. Shade differences were objectively measured using quantitative colorimetric analysis (Lab* values), in addition to evaluations of fabric strength, hand feel, and effluent properties. The results show that a wide range of different blue and grey denim shades, from deep indigo to light vintage looks, can be produced consistently by carefully adjusting the washing parameters, especially the sequential application and concentration of cellulase enzymes and oxidizing agents. Additionally, the study determines the best processing parameters that produce the intended aesthetic results while using less water and chemicals, improving the sustainability of denim finishing. In addition to providing a scientific basis for creating creative and reliable denim treatments and encouraging more environmentally friendly production methods, this study offers insightful information for industrial use.

Keywords:

- a) Denim shades
- b) regulated washing procedure
- c) textile sector
- d) production effectiveness
- e) environmental impact
- f) enzyme concentration
- g) bleaching agent
- h) washing duration
- i) temperature
- j) mechanical action

- k) fabric characteristics
- l) colorimetric analysis (Lab* values)
- m) Fabric durability
- n) Hand feel
- o) Effluent properties
- p) Cellulase enzymes
- q) Oxidizing agents
- r) Eco-friendly production
- s) Denim finishing

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"In the name of the Most Benevolent and Merciful Allah."

First and foremost, we are grateful to Allah Ta'ala for enabling us to finish the report. Additionally, we would like to express our sincere gratitude to everyone who has offered support and assistance. The entire report with success. Daffodil International University gave us a lot of help and direction so that I could finish my internship program effectively. Working on a comparison report allows us to collect real-world experience for the first time. Additionally, we would like to sincerely thank Abdullah Al Mamun, supervision professor and associate professor in the Department of Textile Engineering, for his unwavering support, encouragement, and direction in creating the project report. Finally, we would like to express our gratitude to our beloved family for their unwavering support and inspiration throughout our lives. We come to the realization that we would not be who we are now without their unwavering support.

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CHAPTER 1: INTRODUCTION

1.1 Background Information

Denim, a fabric known for its strength, adaptability, and classic design, has evolved from its beginnings as workwear to become a mainstay of international fashion. Its timeless appeal stems from both its innate strength and the wide range of beautiful finishes that can be produced using different post-treatment procedures, especially washing. The textile sector is still driven by consumer demand for a wide variety of creative denim styles, from faded antique looks to traditional deep indigos. However, there are many obstacles in the way of producing denim hues that are reliable and consistent while also addressing the growing environmental sustainability issues. This thesis explores the complex science and art of denim finishing and suggests a carefully regulated washing procedure to create unique and repeatable denim hues, supporting both sustainable textile manufacturing methods and creative aesthetics. Denim's path from raw fabric to its finished, consumer-ready state is frequently characterized by its washing and finishing procedures. In the past, manual abrasion, stone washing, and simple chemical treatments were among the crude and frequently time-consuming techniques used in denim finishing. The intricacy and scope of these finishing processes increased along with the denim industry's growth.

Although they are good at producing a variety of looks, traditional denim washing techniques have long been beset by a number of intrinsic drawbacks. First of all, variations in shade, hand feel, and general appearance among various production batches are commonly caused by the subjective nature of control, which frequently depends on visual evaluation and operator expertise. This unpredictability affects supply chain dependability and profitability by increasing waste, reprocessing, and production costs. Second, a lot of traditional cleaning methods need a lot of resources. They usually use a lot of water, which is a vital and becoming more and more limited resource worldwide. Because of the high chemical oxygen demand (COD), biological oxygen demand (BOD), and presence of toxic substances, the use of a variety of chemical agents, such as strong alkalis, acids, and bleaching compounds, produces large volumes of effluent that, if improperly treated, can pose serious environmental hazards.

The textile industry has looked for more accurate, eco-friendly, and efficient denim finishing techniques in response to these difficulties. Enzyme technology advancements, especially the application of cellulases, have transformed denim washing by providing a more environmentally friendly substitute for conventional stone washing that produces a soft, faded

look. In a similar vein, new opportunities for shade development have been made possible by the development of more environmentally friendly bleaching agents and sophisticated equipment. Despite these developments, obtaining accurate and repeatable shade development still requires a thorough grasp of the synergistic effects of different washing parameters, including enzyme concentration, bleaching agent type and dosage, washing time, temperature, and mechanical action.

The current state of denim finishing is defined by a notable discrepancy between the industry's capacity to reliably and sustainably manufacture different and distinctive denim hues and the expanding market demand for them. Current denim washing procedures frequently lack accurate control, which results in a number of serious problems:

1. **Inconsistent Shade Development:** Traditional washing techniques, which depend on subjective assessment and empirical approaches, frequently lead to batch-to-batch differences in denim color, hand feel, and overall appearance. Because off-shade clothing must be reprocessed or disposed of, this inconsistency reduces product quality, raises rejection rates, and results in substantial material and energy waste. Customer satisfaction and brand identity are hampered by the difficulty to reliably replicate particular hues.
2. **Inefficient Use of Resources:**
Traditional denim washing is infamously water-intensive, requiring large amounts of fresh water for numerous processing and rinsing stages. Additionally, the widespread use of chemical agents leads to excessive chemical consumption and the production of enormous amounts of contaminated effluent, even though it is required to achieve desired effects. In addition to increasing operating expenses, this inefficiency also strains environmental resources, especially in areas with limited water supplies.
3. **Environmental Impact:** There is a major risk to the environment from denim washing plants' release of untreated or insufficiently treated wastewater. High concentrations of organic waste, chemicals (such as strong alkalis, acids, and hypochlorite), and leftover dyes all contribute to water pollution, which affects aquatic ecosystems and public health. Processes that reduce chemical use and water discharge are desperately needed

in order to comply with international sustainability regulations and corporate social responsibility objectives.

4. **Resource Inefficiency:** Traditional denim washing uses a lot of fresh water for numerous rinse and processing stages, making it infamously resource-intensive. Additionally, the widespread use of chemical agents leads to excessive chemical consumption and the production of enormous amounts of contaminated effluent, even though it is required to achieve desired effects. In addition to increasing operating expenses, this inefficiency also strains environmental resources, especially in areas with limited water supplies.
5. **Environmental Impact:** There is a major environmental risk associated with the release of untreated or insufficiently treated wastewater from denim washing plants. High concentrations of organic waste, chemicals (such as strong alkalis, acids, and hypochlorite), and leftover dyes all contribute to water pollution, which affects aquatic ecosystems and public health. Processes that reduce chemical use and water discharge are desperately needed in order to comply with international sustainability regulations and corporate social responsibility objectives.
6. **Limited Scientific Framework for Shade Control:** Although different washing methods are used, there is frequently a lack of a thorough, methodical, and scientifically validated framework for accurately regulating and forecasting the development of distinct denim shades based on particular process parameters. This lack restricts the potential to generate innovative finishes, hinders innovation in finish creation, and makes process optimization for sustainability and quality difficult. To comprehend the complex interactions between chemical, mechanical, and thermal components in producing desirable colorimetric outputs, the industry needs a more scientific approach.

In order to create a regulated denim washing method that can consistently produce a broad range of unique hues while also increasing resource efficiency and reducing environmental impact, a research-driven strategy is obviously required.

By creating a carefully regulated denim fabric washing method, this thesis seeks to solve the aforementioned issues and make it possible to produce unique hues in a repeatable manner while improving sustainability.

1.2 Significance and Motivation

The denim's feel, quality, and general attractiveness are all impacted by the washing procedure in addition to how it looks. The business is currently highly motivated to create distinctive denim hues while reducing fabric and environmental harm. Controlled washing procedures are crucial for sustainable denim production as people become more conscious of water usage and the effects of chemicals. This study examines how regulated washing parameters, like as duration, chemical dose, and temperature, might produce unique and appealing denim hues, driven by the need to strike a compromise between aesthetic demands and ethical production practices.

1.3 Aims and Objectives

- I. To methodically examine how important washing parameters affect the final coloration and physical characteristics of denim fabric, both individually and in combination. Among these parameters are:
 - a. The concentration of enzymes, particularly cellulase enzymes.
 - b. Bleach agent kind and dosage.
 - c. Time spent washing.
 - d. Temperature of washing.
 - e. Mechanical activity, such as load and agitation speed.
- II. To move beyond subjective visual evaluation by developing a quantitative system for objective shade measuring and analysis utilizing colorimetric techniques (Lab* values) to precisely evaluate and distinguish the various denim tones generated.

- III. To determine the best processing parameters that allow for the consistent production of a broad range of unique blue and grey denim tones, from light vintage to deep indigo, across batches.
- IV. To assess how the controlled washing procedure affects the denim fabric's physical characteristics, such as its tensile strength and hand feel, in order to make sure that visual enhancements don't jeopardize the comfort or durability of the fabric.

1.4 Methodology

This work uses controlled washing procedures to create unique denim hues in a practical and experimental manner. Sample preparation, use of different washing processes, shade assessment, and physical and chemical property evaluation are all part of the methodology. Accurate analysis and results are ensured by combining quantitative testing with qualitative observation. The study was intended to be a laboratory-based experimental investigation that examined the effects of several controlled variables on denim hues during the washing process. The study investigated several methods to create different visual impacts on denim fabric, including enzyme wash, bleach wash, stone wash, and acid wash.

To visually represent each stage in the project's flowchart, the following model was created. Refer to Figure 1.

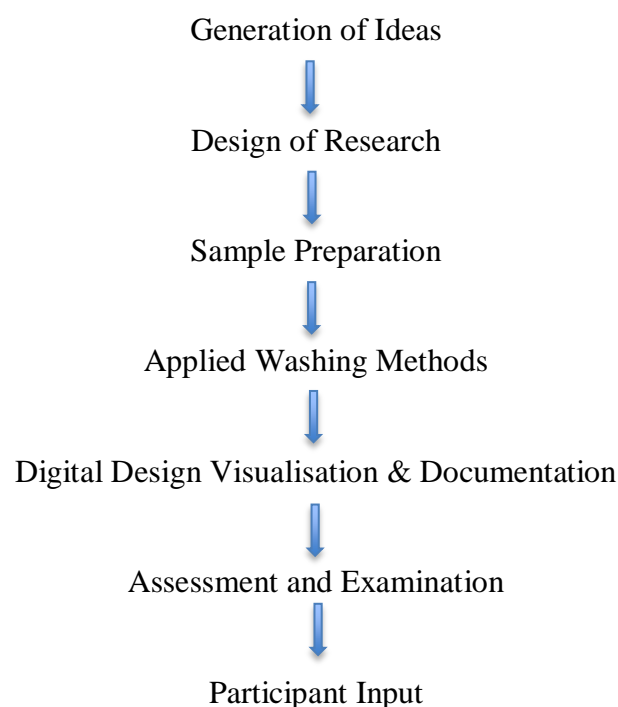


Figure 1: Phase Model flowchart in detail

1.5 Report Outline:

We provided a detailed explanation of our project in this report. We covered the Background Information, Significance and Motivation, Goals, and Objectives in Chapter 1. We looked over a few books, in chapter 2. We spoke about the model description and the process. Implementation and methodology. We discussed the results and discussion in chapter 4. Environmental, sociocultural, health, and safety factors are discussed in Chapter 5: Professional Responsibilities. We wrapped up the report in chapter 6. Finally, we provide citations.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The authors of [1] have talked about how important washing procedures are in determining denim's practical and aesthetic qualities. Conventional washing methods and traditional indigo dyeing have long dominated the business, but they have significant drawbacks in terms of environmental impact, resource inefficiency, and inconsistent results. Promising approaches to getting beyond these restrictions are provided by recent developments, especially the effective incorporation of reactive dyes and improved washing techniques. The intricate relationship between chemical agents, mechanical action, and fabric qualities is shown by the thorough analysis of different washing effects on reactive-dyed denim, including bleach, potassium permanganate, enzyme, and enzyme-stone treatments. Research continuously shows that whereas oxidative treatments, such as bleach and PP washes, produce noticeable color fading, they can also cause more noticeable fabric deterioration (e.g., reduced breaking strength, increased weight loss). On the other hand, enzyme-based washes provide a gentler and more regulated method that maintains fabric integrity while yet producing excellent color fastness and desired aesthetic effects. To achieve accurate and repeatable distinct denim hues, careful research into the synergistic effects of different washing parameters is still necessary despite recent developments. Although the literature suggests a solid basis for comprehending the effects of specific washings, more research is necessary to develop a comprehensive framework that maximizes these parameters for improved sustainability and aesthetic consistency, especially for reactive-dyed denim. By offering a more regulated and quantitative approach to denim shade development, this thesis seeks to expand on the body of information already in existence and support the industry's quest for creative, reliable, and ecologically friendly finishing techniques.

The study's authors [2] shown how to generate different denim hues by optimizing enzymatic washing parameters, including cellulase concentration, temperature, and time. The ideal conditions for color fading while preserving fabric integrity were 2% enzyme concentration at 55°C for 40 minutes. There is a growing need for new fashion designs with a sustainability focus, emphasizing the use of recycled or biodegradable materials, ethical production methods, and creative design strategies that promote longevity, circularity, and environmental responsibility. However, there is a dearth of research on denim washing process optimization, particularly in developing eco-friendly techniques that reduce water consumption, chemical use, and energy demands while maintaining fabric quality and production efficiency. With an

emphasis on minimizing environmental effect through cutting-edge technologies including enzyme treatments, ozone washing, and laser finishing, this project attempts to explore sustainable, eco-friendly denim washing techniques while preserving fabric quality and commercial viability. In order to better understand customer demand and encourage the development of ecologically conscious fashion practices, this study aims to investigate consumer behavior toward eco-fashion and denim by examining attitudes, awareness, and purchase decisions linked to sustainable apparel.

According to the study's authors [3], it investigates the process of enzyme washing indigo and sulfur-dyed denim, maximizing cellulase concentration, time, and mechanical agitation to produce distinctive fading effects. This lowers color depth considerably while controlling back staining, allowing for the controlled creation of distinctive denim shades. There is a growing demand for creative fashion designs that put sustainability first, incorporating eco-friendly materials, ethical production practices, and circular design principles. However, little research has been done on optimizing the denim washing process, which is essential for lowering water usage, chemical discharge, and environmental impact in denim manufacturing. The purpose of this project is to look into sustainable and environmentally friendly denim washing techniques that preserve fabric quality and consumer appeal while reducing environmental damage. Additionally, it will investigate how consumers behave in relation to eco-fashion and sustainable denim, with an emphasis on awareness, choices, and willingness to pay for eco-friendly goods.

The production of unique denim hues through controlled washing methods has not been extensively addressed by the authors [4]. It focuses on how core-spun yarn and denim fabric characteristics are affected by spandex drafts and deniers both before and after washing. Alternative core materials utilized in denim manufacture will be examined in this study, along with their impacts on overall performance, comfort, durability, and environmental impact. Additionally, it will investigate how different denim washing methods affect important fabric characteristics like colorfastness, tensile strength, texture, and sustainability.

The creation of various denim hues by a controlled washing process has not been demonstrated by the authors [5]. Instead of using conventional yarn dyeing techniques, it emphasizes recycling cellulose fibers that have been indigo-dyed and incorporating coloring into the viscose process. The majority of current study concentrates on certain scientific issues pertaining to cellulose fibers, such as their processing methods, mechanical characteristics, and biodegradability, frequently in isolated contexts.

The behavior of colors during textile recycling, particularly with regard to dye retention, migration, and environmental impact in closed-loop systems, is not well understood, nevertheless.

2.2 Summary

Traditional denim washing techniques are popular, but research indicates that they have problems with uniformity and the environment. Better fabric care and controlled fading are provided by enzyme-based methods. The secret to sustainable shade development is to optimise washing parameters. More study is required to develop consistent and environmentally friendly denim washing methods, even though some studies examine yarn varieties and recycled fibres.

Chapter 3: Experimental Procedures

The project is broken up into thirteen sections, each of which is further subdivided into numerous phases and processes, as was mentioned in the previous section. Every stage and phase of this process was equally important.

3.1 Materials & Methods

We picked 100% cotton indigo-dyed denim fabric for this experimental study since it is a popular textile in the clothing industry because of its strength, longevity, and visual appeal. The chosen fabric had a medium-dark synthetic indigo dye, was woven with a S-right-hand twill construction, and weighed about 340 oz/sq yd). All samples came from the same supplier and were desized prior to treatment in order to guarantee uniform quality. we used three different controlled washing procedures—enzyme wash, bleach wash, and potassium permanganate spray—to look into shade development. The neutral cellulase enzyme, sodium hypochlorite, potassium permanganate, acetic acid, sodium metabisulfite, non-ionic detergent, and silicone softener were among the industrial-grade chemicals we used. An industrial front-loading washing machine, a hydro extractor, a temperature-controlled tumble drier, and a spray booth were the tools We used for all of the washing trials in order to replicate actual textile finishing procedures. For testing and analysis, we also used a colour assessment cabinet, a digital pH meter, and a spectrophotometer.

We used an indigo-dyed denim fabric made entirely of cotton for the experimental investigation, which is frequently used to make jeans and casual clothing. Because the denim came straight from [Insert Mill Name or Supplier], all of the samples utilised in the study were consistent.

3.1.1 Information about the materials used

GSM (grams per square meter): 13.2 oz/yd² (equivalent to 14.5 oz/ yd²)

- Weave structure: S- Right-hand Twill, 3/1
- Color: Medium-dark indigo dyed with synthetic indigo
- Yarn Composition: Warp -10s ring spun, Weft -12s carded
- Pretreatment: Before the trial washing, it was desized and dried.

3.1.2 Table of process parameters

Washing type	Time in minutes	Temp (°C)	Chemical Used
Bleach Wash	Deep Indigo Blue	40.-50°C	NaOCl
Heavy Bleach Wash	Faded Light Blue / Ice Blue	40.-50°C	Acetic Acid, Non-ionic Detergent, NaOCl
Dyeing	Red Sulphur	25°C	Vat dye
Enzyme Wash	Dark Indigo Denim	50-55°C	Acetic Acid, Softener, Non-ionic Detergent, Neutral Cellulase Enzyme

Table No 1: Process parameters

3.1.3 Names and specs of machines

Front Loading Washing Machine



Figure 3.1: Front Loading Washing Machine

Machine Description:

Brand	DANIS
Model	MKM 545
No of Machine	125
Capacity	500 kg
Volume	5000 lt

Table No 2: Washing Machine Machine Description

Steam Dryer Machine



Figure 3.2: Steam Dryer Machine

Machine Description:

Brand	MACHINE TEK
Model	MTK 5430
No of Machine	40

Table No 3: Steam Dryer Machine Description

3.2 Process Description

3.2.1 Idea Generation: A careful idea development process that prioritised market preferences, industry demand, sustainable fashion trends, and technological viability served as the cornerstone of this study. The objective was to use controlled washing procedures to produce visually distinct denim hues that satisfy functional and aesthetic standards while maintaining production sustainability and reproducibility.

Choosing the types of denim shades to be developed and determining the target demographic were two important considerations during the idea creation process in order to accomplish this.

- ✓ **Selecting the Target Market :** Determining and comprehending the target consumer group was the first stage in the idea generation process. The study concentrated on the following factors to identify the most pertinent audience because fashion trends and preferences range greatly among various demographics:

Age range: Young adults (18–35 years old)

Gender: Customers who are male and female

Lifestyle Segment: People that care about fashion and are looking for fashionable yet casual clothing

Market Behaviour: Customers who like denim items with a faded, washed, or vintage appearance

Sustainability Awareness: Customers who care about the environment and encourage eco-friendly cleaning methods

The project's focus on this market segment is in line with current denim trends, particularly in urban and youth-oriented areas where there is a growing desire for distinctive and environmentally friendly denim styles.

- ✓ **Selecting the Shade Type:** Identifying the kinds of denim hues that would be produced by controlled washing was the second step. The choice was made in light of:

Market research: Shades that are in style at fashion and retail stores

Washing Feasibility: Shades that can be obtained by acid, stone, bleach, and enzyme washing

Shades that create visual contrast and a worn-in or vintage appearance are considered to have aesthetic appeal.

Sustainability Factor: Shades that can be produced with less water, less chemicals, and less damage to fabrics

These considerations led to the selection of the following shade types for development:

Light Blue (Bleach Wash): Produced by carefully regulated oxidation

Enzyme-washed mid-blue: gentle fading with little harm to the fabric

Vintage Grey (Stone Wash or Acid): A rugged appearance with contrasting textures

PP Spray or Enzyme-Stone Frosted/White Effect: Strong contrast for streetwear appeal

3.2.2 Design of Research

The goal of the practical, experimental study was to create unique denim hues through a range of carefully regulated washing techniques. Assessments of the denim fabric's physical and visual qualities as well as washing results were conducted using both quantitative and qualitative methods

- ✓ **Type of Research:** This research is applied and experimental in nature. Through the use of several controlled washing processes and an analysis of their effects on fabric shade, quality, and sustainability, it seeks to investigate and create workable solutions for denim finishing.

- ✓ **Methods of Research:** The research methodology includes:

An investigation into current cleaning methods

controlled tests with acid washing, stone, bleach, and enzymes

Seeing and recording the visual results

Testing of washed denim both physically and chemically

Using Illustrator, digitally visualise shade variations

- ✓ **Selection of Samples:**

Fabric Type: Indigo denim made entirely of cotton

Sample Size: 6" x 4" patches for each treatment

Total Samples: Several samples for each method of washing to ensure consistency and comparison Time, temperature, chemical concentration, and mechanical activity are all factors that affect washing.

3.2.3 Sample Preparation

The first step was to carefully prepare fabric samples in order to examine the impact of several controlled washing techniques on the development of denim shade. Throughout the experimental phase, this guaranteed precision and consistency.

✓ **Selection of Fabrics**

Fabric Type: Denim made entirely of cotton

Colour: Raw or unclean deep indigo dyed

Grams per square metre, or GSM: around 12.5 oz/yd²

Type of Weave: Right-hand Twill, 3/1

Yarn Count: Weft: 12s; Warp: 10s

Dyeing Method: Indigo-dyed rope

✓ **Treatment Before Washing**

The samples were subjected to a standardised desizing procedure prior to the washing process in order to eliminate impurities and sizing materials that might have an impact on the wash outcomes.

Recipe for Desizing:

10:1 liquor to water ratio

60°C is the temperature.

Duration: ten minutes

1 g/L of wetting agent

The fabric samples were desized and then allowed to air dry in a shaded area.

3.2.4 Applied Washing Methods

Four separate washing methods—enzyme wash, bleach wash, acid wash, and stone wash—were used under carefully monitored circumstances to create unique denim hues. The ability of each technique to create distinctive fading effects while maintaining fabric integrity and its commercial relevance led to its careful selection.

Under laboratory conditions, a sample industrial washing machine was used to perform the washing procedures. For every procedure, specific controls were made on variables like temperature, time, chemical concentration, and mechanical agitation.

Heavy Bleach wash



Figure 3.3: Heavy Bleached wash Fabric

Dyeing Wash

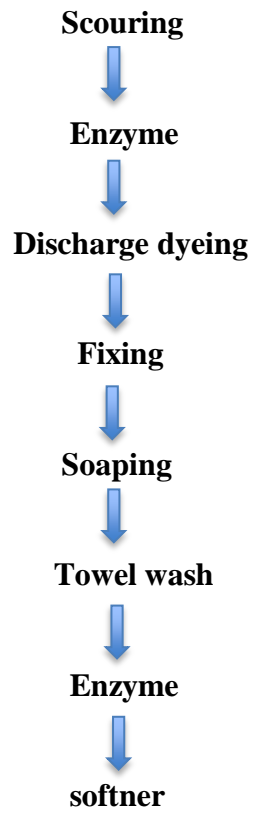


Figure 3.4: Dyeing Washed Fabric

Enzyme Wash

Desize
↓
Enzyme
↓
Bleach
↓
Clean up
↓
Tint
↓
Softner



Figure 3.5: Enzyme Washed Fabric

Bleach Wash

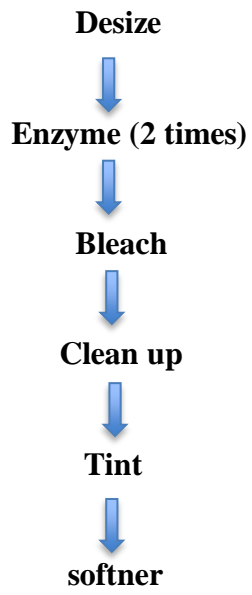


Figure 3.6: Bleach Washed Fabric

3.2.5 Digital Design Visualization & Documentation

Using digital color analysis tools (such as a spectrophotometer or colorimeter), visual shade changes were recorded and all wash results were photographed in controlled conditions. Adobe Illustrator was used to digitally sketch garment illustrations in order to replicate their use in actual design projects.

3.2.6 Visual Assessment and Examination

A thorough evaluation and inspection procedure was conducted to appraise the technical and aesthetic qualities of the final hues following the completion of the controlled washing treatments on the denim samples. Analysing each washing method's efficacy, reproducibility, and fabric integrity was the aim.

The surface look, fading pattern, and shade variation of each cleaned sample were assessed.

The following factors were taken into account:

The degree to which the color faded uniformly throughout the sample

The degree of lightening in comparison to the original blue tint is the intensity of fading.

Surface Texture: Any obvious damage, fuzziness, or roughness

Aesthetic Appeal: A subjective evaluation of visual appeal for appropriateness in fashion'

Under normal white light, each sample was contrasted with an untreated control sample.

3.2.7 Participant Input

The aesthetic attractiveness of cleaned samples was assessed by a small group of individuals from the target market, such as fashion students, designers, or customers. Their opinions were gathered in order to determine their preferences with relation to perceived quality, fabric feel, and shade depth.

Chapter 4: Findings and Conversation

4.1 Shade Evaluation

Since the main goal of this study was to create unique denim shades using a variety of controlled washing methods, shade evaluation is one of the most important components. To evaluate the variance, depth, and homogeneity of shades derived from each approach, the evaluation methodology integrated instrumental color measurement with visual inspection.

Sample	Washing Type	Shade	GSM After	GSM Before	Shrinkage (%)	Fastness (1–5)
01	Dyeing	Red Sulphur	15.2	14.2	3.2%	4
02	Enzyme	Dark Indigo Denim	14.3	14.4	3.1%	4
03	Heavy Bleach	Faded Light Blue / Ice Blue	16.3	14.5	3.1%	4
04	Bleach	Deep Indigo Blue	15.4	14.3	3.2%	3

Table No 4: Shade Evaluation

4.2 GSM Physical Test Results (before to and following washing)

The percentage of shrinkage - 3.15%

Fabric strength and tensile strength - 1116 N

Color fastness to washing and rubbing- 4 (Good Slight Fading)

4.3 Talk about / Discussion

Compare the hues and describe why some techniques produced superior outcomes.

Talk about the benefits and drawbacks (for example, enzyme is environmentally friendly but fades more slowly, while bleach fades quickly but ruins cloth).

Refer return to the literature review.

CHAPTER 5: CONCLUSION

This study shown that controlled washing methods such enzyme washing, bleach washing, and potassium permanganate spraying can effectively produce unique denim hues. Enzyme washing stood out among these as the most ecological and well-balanced choice, offering even and moderate fading while maintaining the strength and suppleness of the cloth. On the other hand, bleach washing produced the lightest hues but presented difficulties such as uneven color and possible fabric deterioration. Although potassium permanganate spray created stylish, high-contrast effects, it needed to be carefully controlled and neutralized to prevent long-term harm. I was able to consistently and reliably affect fading results by varying variables including chemical concentration, temperature, pH, and processing time. The research's conclusions provide insightful information about denim finishing techniques as well as useful advice for academics and business experts who are concerned with sustainability, design, and quality.

CHAPTER 6: References

- [1]Bhattacharjee, M., Dhar, A. K., Islam, Md. M., & Rashid, Md. A. (2019). Development of Washing Effects on Reactive Dyed Denim Fabrics: A Value Added Approach of Denim Wash. *International Journal of Textile Science*, 8(2), 41–48.
<http://www.sapub.org/global/showpaperpdf.aspx?doi=10.5923/j.textile.20190802.03>
- [2]Mondal, I. H., & Khan, M. R. (2014). Characterization and process optimization of indigo dyed cotton denim garments by enzymatic wash. *Fashion and Textiles*, 1(1), 19.
<https://doi.org/10.1186/S40691-014-0019-0>
- [3]Patra, A. K., Madhu, A., & Bala, N. (2018). Enzyme washing of indigo and sulphur dyed denim. *Fashion and Textiles*, 5(1), 1–15. <https://doi.org/10.1186/S40691-017-0126-9>
- [4]Hossain, M. A., Hossain, M. A., Emon, J. H., & Islam, M. T. (2024). Effect of core material draft ratio and denier on core spun yarn and denim fabric properties pre and post washing. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2024.e24965>
- [5]Galais, V., Wilson, S., Dugard, P., Ganniccliffe, C., Murphy, B. E. P., Nic Daéid, N., & Ménard, H. (2025). A novel method for assessing the shedding of fibre in forensic science: investigating the effects of washing. *Forensic Science International*, 367, 112369.
<https://doi.org/10.1016/j.forsciint.2025.112369>

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