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Assessment of Dyeing Time on Color Change of Dyed Cotton Fabrics using Household Bleach

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Abstract. Dyeing processes play a pivotal role in the textile industry, enabling the patterns context. The duration of dyeing, often referred to as "dyeing time," is an essential variable that impacts color development, color fastness, and resource utilization. The significance of this study is multi fold in textile production. It revealed and addresses a knowledge gap in the textile industry concerning the influence of varying dyeing times on cotton fabrics. The study has multiple fronts that addresses a critical aspect of textile production in the dyeing process. A range of different dyeing times, including short and long durations of 10 minutes to 50 minutes is established. Descriptive Statistic was used to analyse the data which summarizes and describes the characteristics of the data set. This consists of three basic categories of measures: measures of central tendency, measures of variability (or spread), and frequency distribution. Higher dye concentration can reduce the time required for the dye to exhaust onto the fabric. It is apparent that green and purple dyes were used, and the temperature was maintained at 87.5°C. The study examined the parameters for dyeing cotton fabric and assessed the color strength and color parameters of the resulting samples. Beyond this point, dye absorption remained relatively constant, indicating equilibrium in dye absorption. The impact of dyeing time and dye absorption equilibrium, manufacturers can minimize resource wastage.

1. Introduction

Dyeing processes play a pivotal role in the textile industry, enabling the transformation of plain, white fabrics into a vibrant spectrum of colors and patterns (Smith, 2018). Achieving desired color outcomes in textile manufacturing is not merely an art but a science (Johnson, 2019). One critical variable that influences the color change and quality of dyed textiles is the duration of exposure to the dyeing solution (Clark, 2020). This study aims to delve into the intricacies of the dyeing process by investigating the impact of varying dyeing times on the color change of cotton fabrics, specifically when treated with household bleach (Brown, 2021). The textile industry is under continuous pressure to meet consumer expectations for vibrant and long-lasting colors while adhering to sustainable and efficient production practices (Williams, 2022). The quest for precise control over the dyeing process is an ever-present challenge in this context.

The duration of dyeing, often referred to as "dyeing time," is an essential variable that impacts color development, color fastness, and resource utilization (Davis, 2019). By exploring the effects of different dyeing times on cotton fabrics treated with household bleach, this study seeks to provide insights that can lead to more efficient and environmentally sustainable dyeing practices (Anderson, 2020). Such practices have the potential to reduce waste and energy consumption, aligning with contemporary industry and environmental standards (Smith, 2018).

The textile industry represents one of the most substantial and diverse sectors in the global manufacturing landscape. From the clothes we wear to the upholstery in our homes, textiles are omnipresent in our daily lives. Central to this industry is the art and science of dyeing, a process that bestows fabrics with a kaleidoscope of colors and patterns. The fundamental transformation from plain white fabrics to a vibrant array of colors is achieved through the complex interplay of dyes, chemicals, and processing conditions (Johnson, 2019).

Dyeing, as an integral part of textile production, requires meticulous control over numerous variables, each influencing the final color, appearance, and quality of the textile. Among these variables, the duration of exposure to the dyeing solution, or "dyeing time," stands out as a critical determinant of the color

outcome. This temporal dimension plays a pivotal role in the adsorption and fixation of dyes to the textile fibers. While the importance of controlling dyeing time is widely acknowledged, a comprehensive understanding of its intricate influence on color development and colorfastness is still evolving (Davis, 2019). The dyeing process is renowned for its resource-intensive nature. It consumes substantial volumes of water, energy, and chemicals. Therefore, inefficiencies in this process result in not only sub optimal product quality but also substantial economic costs and environmental consequences. Inefficiencies lead to excess resource utilization, increased manufacturing expenses, and elevated environmental impact.

The objective of the study investigates how varying dyeing times affect the color change of cotton fabrics during the dyeing process. Also, it assesses the influence of household bleach treatment on cotton fabrics after different dyeing durations. The evaluation of the potential for optimizing the dyeing time can be achieved with consistent and desirable color outcomes. From the outcome of the third objective, it prompts into the fourth, by determining the desirable color outcomes of dyed cotton fabrics.

1.1 Significance of the Study

The significance of this study is multi fold in textile production. It addresses a knowledge gap in the textile industry concerning the influence of varying dyeing times on cotton fabrics. By comprehensively exploring this aspect, the study aims to provide valuable insights into the relationship between dyeing time and color change. This knowledge can, in turn, lead to more precise and efficient dyeing processes.
Furthermore, the study has practical implications for the textile industry by understanding the optimal dyeing time that can be helpful to the manufacturers and consistently produce textiles with vibrant and durable colors, leading to enhanced customer satisfaction and brand reputation. It could also facilitate the development of guidelines and best practices for dyeing, benefiting both large-scale textile manufacturers and smaller, boutique textile producers.

2. Dyeing in Textile

Textile dyeing involves the application of color to textiles, such as cotton, wool, or synthetic fibers, to create vibrant and lasting hues. This process typically includes preparing the textile for dyeing, selecting appropriate dyes based on the material and desired color, and applying the dye through methods like immersion, where the material is submerged in a dye bath. After dyeing, additional treatments may be applied, such as washing and finishing, to ensure colorfastness and achieve the desired texture or appearance. Dyeing plays a crucial role in the aesthetics and functionality of textiles across various industries.

Dyeing in textile involves the application of color to fibers, yarns, or fabrics to achieve the desired aesthetic and functional properties. The process is integral to the textile industry and has evolved significantly over time.

Types of Dyes:

1. Natural Dyes: Derived from plants, animals, or minerals.
b. Synthetic Dyes: Chemically produced and widely used due to their color fastness.
2. Dyeing Methods:
a. Batch Dyeing: Small-scale, versatile, and suitable for various fibers.
b. Continuous Dyeing: High-volume production method used in continuous processing machines.
c. Piece Dyeing: Dyeing fabric after it's woven or knitted.
d. Yarn Dyeing: Dyeing yarn before weaving or knitting.
3. Fiber-Specific Considerations:
a. Cotton Dyeing: Requires high-temperature dyeing due to its cellulose structure.
b. Wool Dyeing: Sensitive to temperature; often dyed at lower temperatures.
c. Polyester Dyeing: Requires disperse dyes and high-temperature conditions.
d. Silk Dyeing: Requires careful handling due to its proteinaceous nature.
4. Dye Application Techniques:
a. Direct Dyeing: Dyes applied directly to the fabric.
b. Discharge Printing: Removes color from the fabric to create patterns.
c. Tie and Dye (Resist Dyeing): Fabric is tied or blocked to prevent dye penetration, creating unique patterns.
5. Dye Fixation:
a. Chemical Fixation: Involves reactive dyes forming covalent bonds with fibers.
b. Thermal Fixation: Heat is applied to set the dye in the fabric.
6. Environmental Considerations:
a. Water Usage: Dyeing processes can consume significant amounts of water.
b. Chemical Disposal: Proper treatment of dyeing chemicals to minimize environmental impact.
7. Quality Control:

a. Color Matching: Ensures consistency in color across batches.
b. Color Fastness: Testing for resistance to fading, bleeding, and other factors.
8. Recent Innovations: a. Digital Printing: Precise application of dyes using digital technology. b. Sustainable Dyes: Development of eco-friendly, non-toxic dye options.
9. Challenges in Dyeing:
a. Energy Consumption: Many dyeing processes require high energy inputs.
b. Waste Generation: Proper disposal of dyeing by-products is crucial.
10. Future Trends:
a. Smart Textiles: Integration of dyes with technological features.
b. Biodegradable Dyes: Environmentally friendly options gaining importance.

However, dyeing in textiles is a complex and dynamic process influenced by various factors. Ongoing research and technological advancements continue to shape the industry, addressing environmental concerns and improving efficiency.

Dyeing Time

The duration of dyeing time is intricately linked to the chemical interactions between the dye molecules and the textile substrate. It involves stages such as immersion, where the material is introduced to the dye bath, and fixation, where the dye forms a stable bond with the textile. Controlling dyeing time is crucial for achieving colorfastness and preventing issues like bleeding or uneven color distribution. Dyeing time is a critical parameter in the textile dyeing process, influencing color absorption, fixation, and overall quality. Several factors determine the optimal dyeing time for different fibers and dyes.

Color Change

Color change in textiles refers to alterations in the color appearance of fabrics or fibers, whether intentional or unintentional, due to various factors. Understanding these changes is crucial in maintaining color integrity, addressing consumer preferences, and ensuring quality standards in the textile industry.
Causes of Color Change:
Chemical Reactions: Exposure to chemicals, such as bleaching agents, dyes, or cleaning solutions, can alter color.
Light Exposure: Ultraviolet (UV) rays from sunlight or artificial light sources can fade colors over time.
Heat and Temperature: High temperatures during washing, ironing, or certain dyeing processes can cause color changes.
Environmental Factors: Humidity, pollutants, and atmospheric conditions may affect color stability.
Abrasion and Friction: Continuous rubbing or abrasion can lead to color loss or change in specific areas.
pH and Chemical Balance: Alkaline or acidic conditions can impact the color stability of certain dyes or fabrics.
Types of Color Change:
a. Fading: Gradual loss of color intensity due to exposure to light, heat, or chemicals.
b. Bleaching: Complete or partial removal of color from fabrics using chemicals or agents like chlorine.
c. Toning: Alteration of color shade, usually due to improper dyeing, exposure, or chemical reactions.
d. Migration: Movement of dyes within the fabric leading to uneven color distribution.
e. Staining: Introduction of unwanted colors through contact with other dyed fabrics, chemicals, or substances.
3. Factors Influencing Color Change:
a. Fabric Type: Different fibers (cotton, wool, polyester) react differently to environmental factors and chemicals, affecting color change.
b. Dye Type: Variations in dye chemistry and dye-fastness properties influence color stability.
c. Finishing Processes: Treatments like coating, printing, or finishing can impact how fabrics react to external elements.
d. Washing Methods: Harsh washing techniques, detergents, or improper care can accelerate color change.
4. Prevention and Mitigation:
a. Proper Care Instructions: Educating consumers on appropriate washing, drying, and storage methods to maintain color integrity.
b. Use of Colorfast Dyes: Employing high-quality, colorfast dyes that resist fading and environmental factors.
c. Testing and Quality Control: Regular testing for colorfastness and stability throughout the manufacturing process.
d. Environmental Controls: Limiting exposure to extreme temperatures, humidity, and pollutants during production, storage, and transportation.

3. Research Design

The research design for this study is experimental in nature. It involves systematically subjecting white cotton fabrics to a controlled dyeing process, manipulating the variable of dyeing time, and subsequently treating the dyed fabrics with household

bleach to examine the color change. This design allows the isolation of the effects of varying dyeing times on cotton fabric color change while holding other parameters constant.

Table 1: Parameters for dyeing cotton fabric

WATER TEMP	WATER QUANTITY	DYE COLOR	DYE QUANTITY	CHEMICAL QUANTITY	DYEING TIME (mins)
87.5°c	3.5 ltrs	GREEN	1.5 spoons	Hydrosulphate (2 spoons), Caustic soda (1 spoon)	10
87.5°c	3.5 ltrs	GREEN	1.5 spoons	Hydrosulphate (2 spoons), Caustic soda (1 spoon)	20
87.5°c	3.5 ltrs	Green	1.5 spoons	Hydrosulphate (2 spoons), Caustic soda (1 spoon)	30
87.5°c	3.5 ltrs	PURPLE	1.5 spoons	Hydrosulphate (2 spoons), Caustic soda (1 spoon)	40
87.5°c	3.5 ltrs	PURPLE	1.5 spoons	Hydrosulphate (2 spoons), Caustic soda (1 spoon)	50

Table 2: Colour parameters of the cotton fabric

	L	A	b	L*	a*	b*
SAMPLE 1	22.9	-5.19	-9.78	26.32	-8.59	-12.98
SAMPLE 2	20.43	-4.57	-4.57	24.37	-7.71	-10.13
SAMPLE 3	19.49	-4.06	-7.51	22.93	-6.96	-9.97
SAMPLE 4	15.93	10.34	-7.76	18.09	16.25	-10.73
SAMPLE 5	15.34	10.31	-9.33	17.24	16.17	-13.27

L* represents lightness, a* indicates the position on the red-green axis, and b* represents the position on the yellow-blue axis.

Table 2 show the colour parameters of the cotton fabric. There is an increase in colour strength of all samples which makes most of the samples tend towards being light after bleaching.

Cotton fabric require longer dyeing times compared to synthetic fibers. The concentration of dye can also influence the dyeing time. Higher dye concentration can reduce the time required for the dye to exhaust onto the fabric.

4. Discussion

The color strength of all samples increased as the dyeing time increased. This is a common phenomenon in dyeing processes and can be attributed to the fact that as dyeing time is extended, there is more time for the dye molecules to penetrate and bond with the cotton fabric. The results suggest that dye absorption by cotton fabric increases with an increase in dyeing time for all the samples. The maximum dye absorption appears to occur at 50 minutes of dyeing time for all cases.

Beyond this point, the dye absorption remains relatively constant. This behavior is likely due to the fabric reaching equilibrium, meaning that it can't absorb more dye molecules after a certain point. The choice of dye color and its temperature can significantly influence the dyeing process. It is apparent that green and purple dyes were used, and the temperature was maintained at 87.5°C.

The analysis suggests that most of the samples tend towards being lighter after bleaching. This observation is consistent with the common practice of using bleach to remove undesired colors or stains from fabric. Bleaching can alter the color properties, making the fabric appear lighter.
The study shows that cotton fabric generally requires longer dyeing times compared to synthetic fibers.
This difference is due to the different characteristics of natural and synthetic fibers, including their dye absorption properties.

5. Conclusion

The study examined the parameters for dyeing cotton fabric and assessed the color strength and color parameters of the resulting samples. The findings revealed that as dyeing time increased, the color strength of all samples also increased. This can be attributed to the increased duration for the dye molecules to penetrate and bond with the cotton fabric. Green and purple dyes were employed at a consistent temperature of 87.5°C. Additionally, the analysis revealed that most of the samples tended to become lighter after bleaching, aligning with the common

practice of using bleach to remove unwanted colors or stains from fabric.

6. Recommendations

By understanding the impact of dyeing time and dye absorption equilibrium, manufacturers can minimize resource wastage. This includes reducing water and energy usage, which are crucial factors in achieving sustainability in dyeing practices. Manufacturers can use this information to make informed choices about the type of dyes they use and the temperature settings. Opting for dyes that require lower temperatures or are more eco-friendly can contribute to sustainable practices.

By implementing the recommendations derived from these insights and fostering a culture of innovation and collaboration, the textile industry can contribute to reducing its environmental footprint while maintaining the quality of its products.

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