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Impact of Different Modern Chemical Finishing on Cotton Knitted Fabrics Dyed with Anthraquinone Vat Dye

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ABSTRACT

The coloration of cotton using vat dyes is a crucial process in the textile chemical processing industry, especially when high fastness properties are required. However, vat dyes are insoluble in water, necessitating the vatting process to reduce and solubilize the dye. Sodium hydrosulfite is commonly used as a reducing agent, while sodium hydroxide serves as a solubilizing agent for vat dye dissolution. Vat dyes used in dyeing applications today typically consist of anthraquinone derivatives and higher condensed aromatic ring systems with a closed conjugated double bond system. This study investigates the impact of cationic softener, silicone softener, easy care finish, and antimicrobial finish on cotton knitted fabrics dyed with vat dyes. The study measures the various effects using wash fastness, rubbing test, and burst test, following the experimental procedures outlined.

Keywords : Modern Chemical Finishing Techniques, Anthraquinone Vat Dye, Vat-Dyed Cotton Knitted Fabrics

Introduction

Vat dyes are widely used in the dyeing industry due to their excellent wash and light fastness properties, making them an ideal choice for coloring cotton yarns used in the manufacturing of various woven goods such as uniforms, shirts, handkerchiefs, and towels [1]. However, vat dyes require reduction to convert them into soluble compounds that can diffuse into cotton fibers and must be re-oxidized to be trapped within the fiber. This unique characteristics makes achieving level dyeing and target shades more challenging in vat dyeing [2].

The use of vat dyes in textiles dates back to ancient times, with indigo being known in India for centuries and Tyrian purple being exported from Tyre to Mediterranean countries almost 4,000 years ago [3]. While some vat dyes are of animal origin, such as Tyrian purple. Woad and indigo are derived from plants and require modification with reducing agents to become soluble in water [4,5]. They then become substantive towards cellulose and re-oxidize to the insoluble colored pigment within the fiber upon exposure to air. Vat dyes are named after the wooden vats in which they were fermented and solubilized. Textile finishing techniques can be used to correct deficiencies or introduce specific properties to the substrate [6,7].

Chemical finishes involve the application of chemical reagents or polymeric materials to textile structures using various methods, such as padding, spraying, printing, foam application, or vapor techniques [6]. The padding method is the most commonly used one. Many finished fabrics must be dried and cured before the chemical finishing process is completed [8,9]. Achieving thorough wetting of the fiber by the finish solution and spreading the finish evenly over the fiber surface is critical in most cases to achieve the desired effect, and the location of the finish on the surface or within the fiber is important depending on the finish and its function [10-12].

Materials & Methods

Materials

Fabric used: Single jersey cotton knitted fabrics.

Chemical Used: Caustic Soda (NaOH), Hydrogen peroxide (H_2O_2), sequestering agent, wetting agent, levelling agent, salt, detergent, peroxide stabilizer, acetic acid, cellulase enzyme, anthraquinone vat dye, dispersing agent, cationic softener, silicone softener, antimicrobial finishing agent, resin, magnesium chlorite, and peroxide killer.

Machine used: Bursting tester, washing machine, and crock meter.

Methods

1. **Pre-treatment:**

1.1 Combined Scouring-bleaching process

Ingredients	**Amounts**
Caustic Soda (NaOH)	5 g/l
Wetting agent	1 g/l
Detergent	5 g/l
Hydrogen peroxide $_{(35\%)}$ (H_2O_2)	2 g/l
Peroxide stabilizer	1 g/l
pH	11.5-12
Temperature	95-100˚C
Time	40-60 mins
M:L	1:50

Table 1 - Recipe for combined scouring-bleaching process

At first, water was added to the dye bath, then all auxiliaries are added, and stirred till dissolution. Then fabric was immersed in dye bath at 95-100˚C with pH at 11.5-12. The process was continued until desired effect was achieved (40-60 min), then the liquor was drained out of the dye bath.

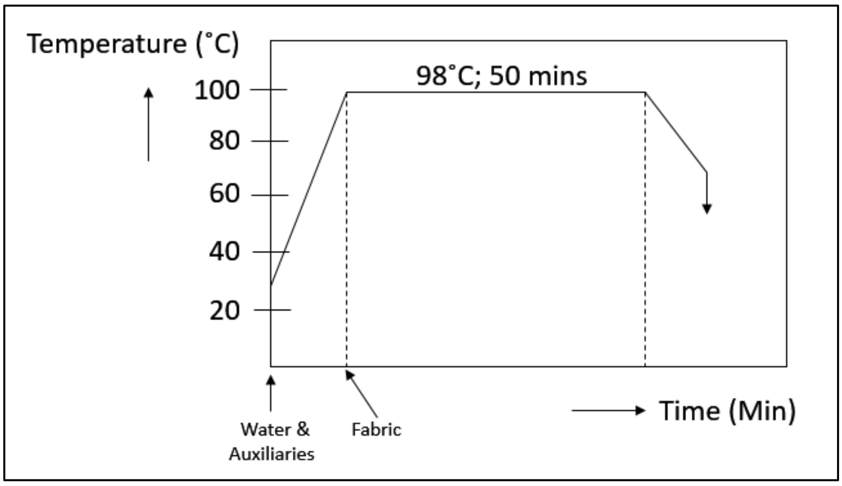

Figure 1 - Time- Temperature profile of combined Scouring-bleaching process

Then a hot wash and a cold wash was done.

1.2 Peroxide killing:

Ingredients	**Amounts**
Peroxide killer enzyme (Catalase)	4 g/l
Acetic acid	1 g/l
pH	4-5
Temperature	60-70˚C
Time	15 mins

Table 2 - Recipe of peroxide killing

The fabrics were immersed in a bath containing all the above ingredients and the process is carried out at 60-70°C for approximately 15 minutes.

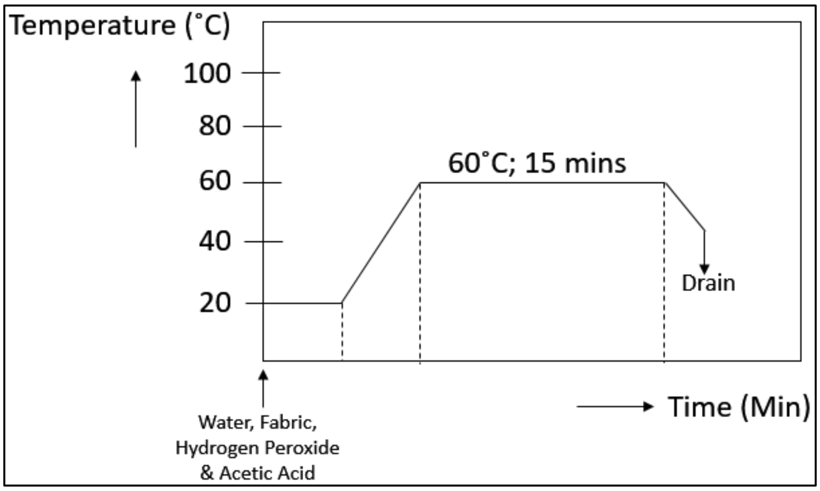

Figure 2 - Process curve of peroxide killing

1.3 Bio-polishing

Ingredients	**Amounts**
Acetic acid	2 g/l
Enzyme	2 g/l
Temperature	60-70˚C
Time	15 mins
pH	4-5
M:L	1:50

Table 3 - Recipe of Bio-polishing

The samples were weighed and the necessary chemicals were measured and added to a bath. The fabrics were then immersed in the mixture and the temperature was gradually raised to 60-70˚C while monitoring the pH value. The process lasted for 10-15 minutes, after which the liquor was drained out and the fabrics were subjected to a hot and cold wash.

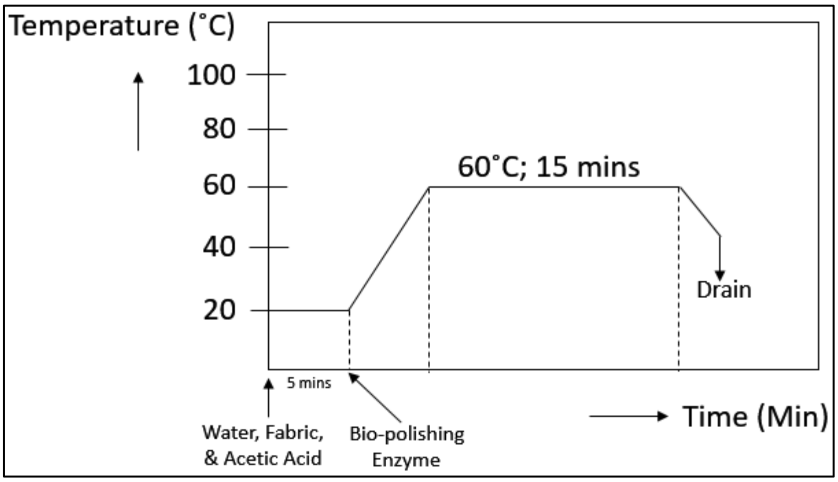

Figure 3 - Process Curve of Bio-polishing

2. Dyeing process:

2.1 Vatting:

Ingredients	**Amounts**
Wetting agent	1 g/l
Sequestering agent	1 g/l
Dispersing agent	2 g/l
Vat dyes	5% o.w.f
Caustic soda	5 g/l

Hydrose	10 g/l
Salt	25 g/l
Temperature	70°C
Time	40 mins
pH	11-12
M:L	1:50

Table 4 - Recipe is used for vatting

For vatting, the required amount of water is placed into the dye bath and heated to the appropriate temperature (between 50-60°C). Next, the vat dye solution was added to the dye bath, which contained the recommended amount of caustic soda, sodium hydrosulphite, at 70°C.

Once the dye bath was prepared, the well-scoured wet fabric was immersed in the dye liquor and turned several times to ensure even color distribution. The fabric remains completely submerged in the dye liquor and the dyeing process continues for one hour, with occasional turning of the fabric. It is crucial to maintain the dye bath at the required temperature and to keep the fabric fully immersed under the liquor.

During the entire dyeing process, exhaustion agents were added to the dye. To ensure the dye remains in a soluble form, excess amounts of both sodium hydroxide (NaOH) and sodium hydrosulphite ($Na_2S_2O_4$) were added to the dye bath.

At the end of the dyeing process, dye bath was kept in a reduced condition to prevent oxidation of the residual vat dye and the appearance of turbidity. This was achieved by adding sufficient sodium hydrosulphite. The dyed goods were then removed from the dye bath, and excess liquor that contains the unexhausted vat dye, sodium hydroxide, and sodium hydrosulphite was removed as thoroughly as possible.

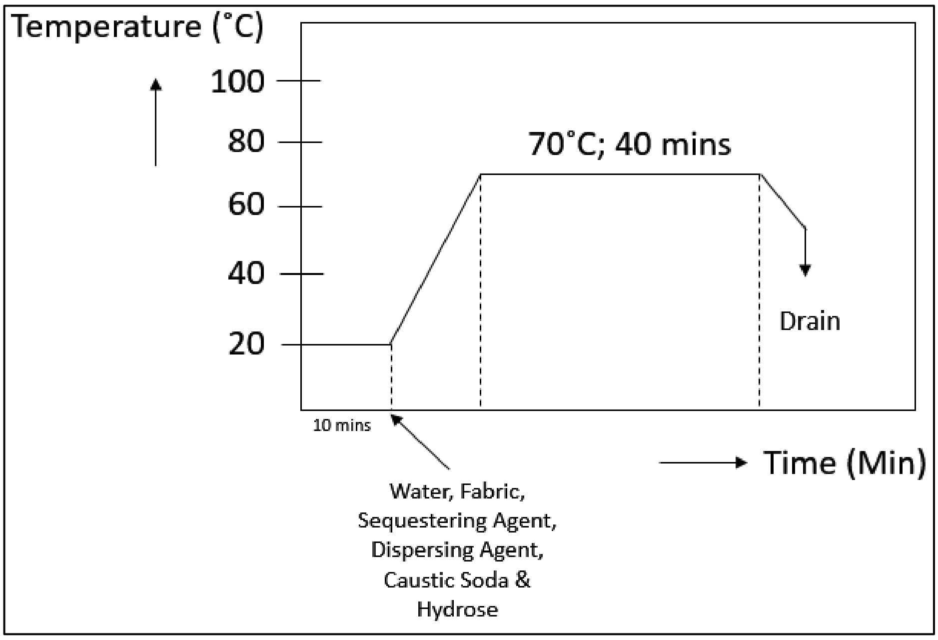

Figure 4 - Process curve of vatting

2.2 Oxidation:

Ingredients	Amounts
Hydrogen peroxide	2 g/l
Temperature	40°C
Time	5 min
M:L	1:30

Table 5 – Recipe for oxidation

During oxidation, the sodium salt of the leuco-vat dye was absorbed by the fiber and transformed into an insoluble dye within the fiber. Additionally, the vatted dye remaining in the residual liquor in the dyed goods was also converted into an insoluble form that was loosely deposited on the fiber surface. To achieve optimal fastness properties, particularly rubbing and washing fastness properties, this loosely deposited dye must be removed.

This was done through a process known as soaping, in which the dyed material was treated with hot soap or synthetic detergent solution for 15-30 minutes. After the soaping treatment, the dyed goods were thoroughly rinsed and dried.

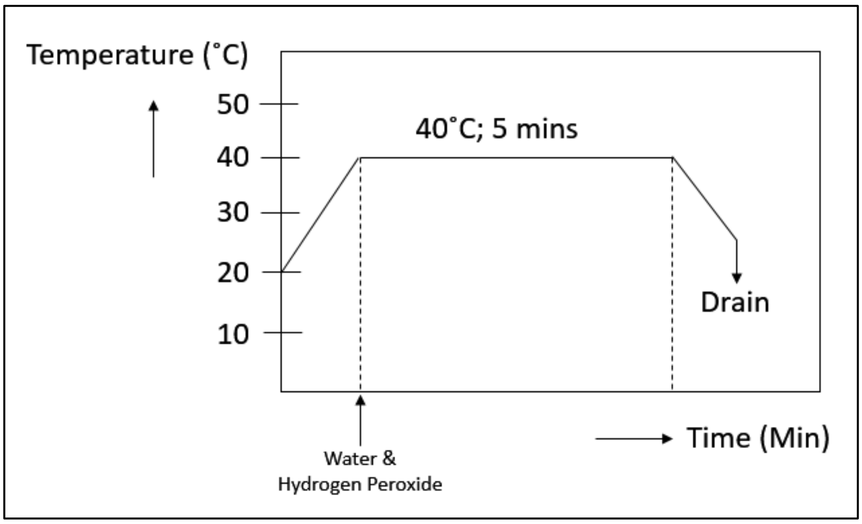

Figure 5 - Process curve of oxidation

3. After-treatment:

Ingredients	**Amounts**
Detergent	2 g/l
Soda ash	1 g/l
Time	10 mins
Temperature	80 °C
M:L	1:20

Table 6 - Recipe for after-treatment

After that a cold wash was done.

4. Finishing:

4.1 Cationic softener:

Ingredients	**Amounts**
Wetting agent	1 g/l
Cationic softener	25 g/l
Acetic acid	2 g/l
pH	4-5
Temperature	70 °C
Time	30 mins

Table 7 - Recipe for Cationic softener

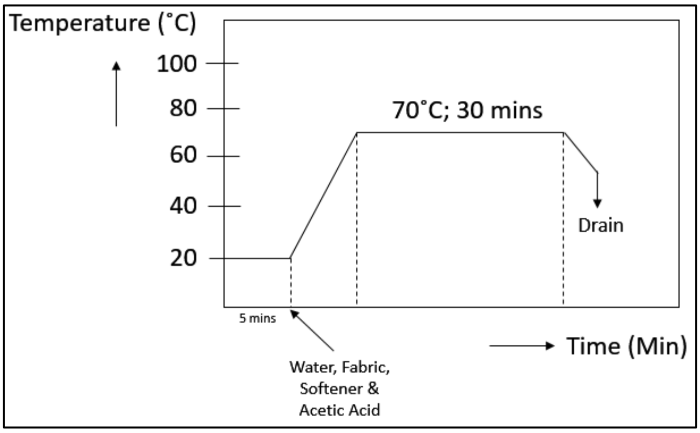

Figure 6 - Process curve of cationic softener

4.2 Silicone softener:

Ingredients	**Amounts**
Wetting agent	1 g/l
Silicone softener	25 g/l
Acetic acid	2 g/l
pH	4-5
Temperature	70 °C
Time	30 mins

Table 8 - Recipe for silicon softener

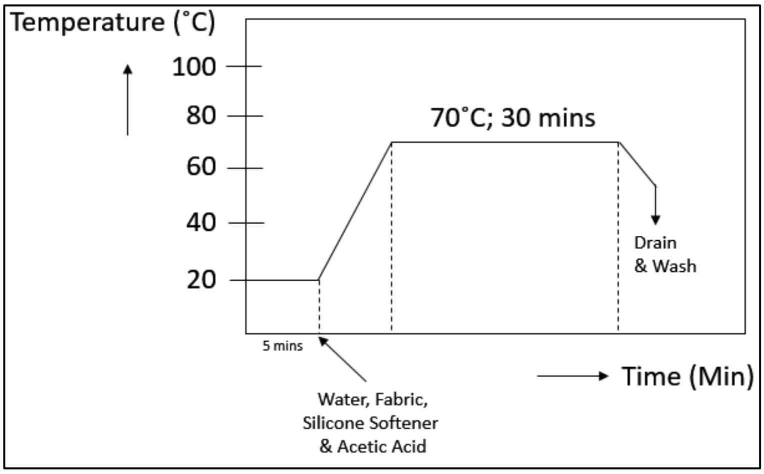

Figure 7 - Process curve of silicon softener

4.3 Easy care finish:

Ingredients	**Amounts**
Resin	20 g/l
Acetic acid	2 g/l
Magnesium Chlorite	1 g/l
Temperature	70˚C
Time	30 mins
M:L	1:30
pH	4-5

Table 9 - Recipe for easy care finish

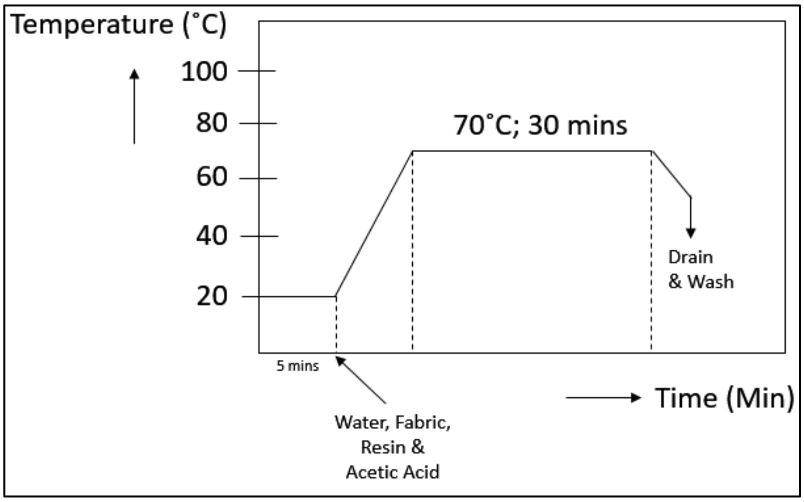

Figure 8 - Process curve for easy care finish

4.4 Anti-microbial finish:

Ingredients	**Amounts**
Anti-microbial finishing agent	20 g/l
Acetic acid	2 g/l
Temperature	70˚C
Time	30 min
M:L	1:30
pH	5-6

Table 10 - Recipe for anti-microbial finish

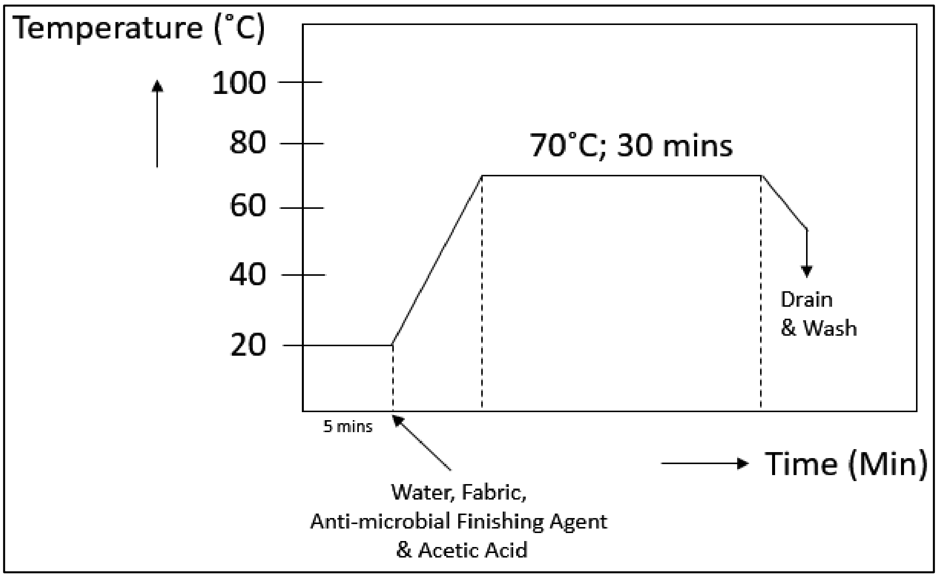

Figure 9 - Process curve of anti-microbial finish

5. Tests & Standards:

The following table depicts the tests done on the specimens and their standards -

Test	**Standard**
Color Fastness to Rub	ISO-105-X12
Color Fastness to Wash	ISO-105-C06 A2S
Bursting Strength Test	ASTMD1776-90

Table 11 - Tests & Standards

Results & Discussion

6.1 Color Fastness to Rub:

No	**Dye/Treatment**	**Dry**	**Wet**
01	Dyed Sample	4/5	4
02	Anti-microbial	5	4
03	Easy Care Finish	4/5	4
04	Cationic Softener	4/5	4
05	Silicone Finish	4/5	4

Table 12 – Data Table for Rubbing Fastness

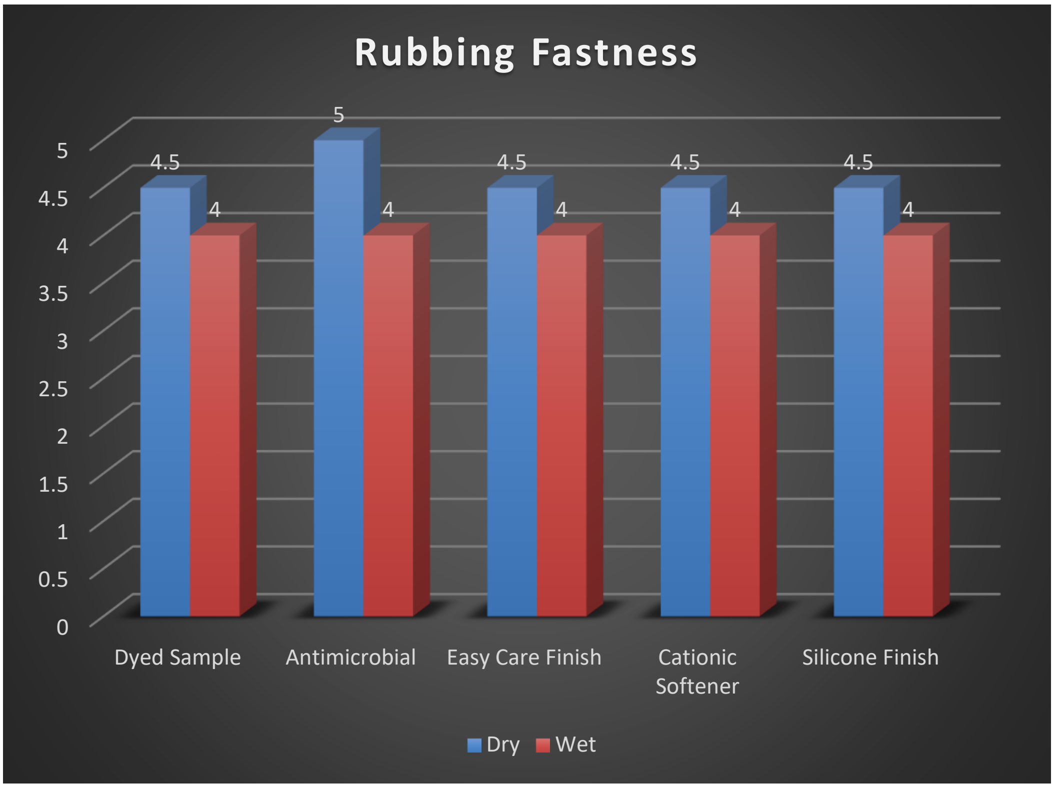

Figure 10 - Bar Diagram of Rubbing Fastness

The above bar diagram displays the results of a rubbing fastness test conducted on vat-dyed cotton knitted fabric in both wet and dry conditions. The fabric was tested before and after undergoing various modern finishing processes, such as cationic softener, silicone-based softener, anti-microbial finish, and easy care finish.

Table-12 and Figure-10 present the rubbing fastness ratings of the fabric, which are divided into two parts: before and after the application of finishing processes. Each part is further divided into dry and wet conditions. The rubbing fastness rating of the fabric in dry condition is 4 (fast) for all samples except for the antimicrobial finished sample, which has a rating of 5. Additionally, the rubbing fastness of all samples in wet conditions is rated as 4 (fast).

It was observed that only the antimicrobial finished sample showed a change in rubbing fastness properties after undergoing the finishing process. However, the rubbing fastness properties of all finished and unfinished samples were deemed to be good based on the results obtained.

6.2 Color Fastness to Wash

No	Treatment	Rating of Shade Change	Rating of Staining
01	Dyed Sample	4/5	4/5
02	Antimicrobial	4/5	4/5
03	Easy Care Finish	4/5	4/5
04	Cationic Softener	4/5	4/5
05	Silicone Finish	4/5	4/5

Table 13 - Data Table for Wash Fastness

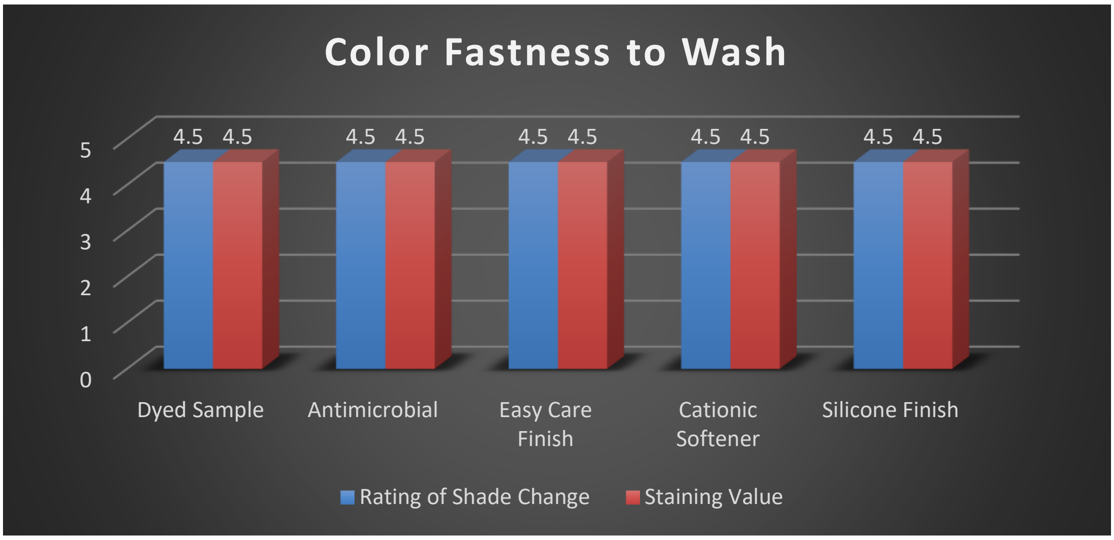

Figure 11 - Bar Diagram of Color Fastness to Wash

The bar chart depicts the results of a wash fastness test conducted on samples of vat-dyed cotton knitted fabric. The study also evaluated the color fastness to wash after applying various modern finishing agents, such as cationic softener, silicon-based softener, antimicrobial finish, and easy care finish.

Table-13 and Figure-11 show the wash fastness ratings of the fabric samples before and after the application of finishing agents. The results indicate that the wash fastness of the vat-dyed fabric is good, with a rating of 4/5 before finishing. However, after applying the various finishes, there was no significant increase or decrease in wash fastness properties. The color fastness to wash remained constant, suggesting that vat-dyed fabric has excellent wash fastness properties.

6.3 Bursting Strength Test:

No	**Dye/Treatment**	**Bursting Strength (kg/cm^2)**
01	Dyed Sample	10.8
02	Antimicrobial Finish	10.1
03	Easy Care Finish	10.1
04	Cationic Softener	9.5
05	Silicone Finish	8.5

Table 14 - Data Table for Bursting Strength Test

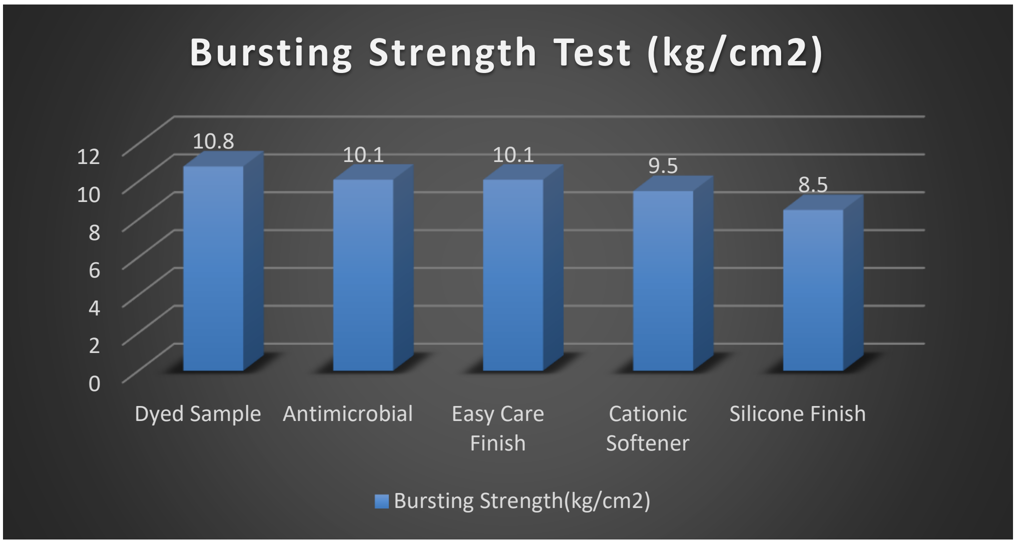

Figure 12 - Bar Diagram for Bursting Strength Test (Kg/cm^2)

The bar diagram presents the results of the bursting strength test performed on vat-dyed cotton knitted fabric samples. The bursting strength was also observed after applying different types of modern finishing agents.

The results are displayed in Table-14 and Figure-12, where the bursting strength rating of the fabric is shown before and after the application of various chemical finishes. The dyed fabric had the highest bursting strength of 10.8 kg/cm^2, while the silicone finished fabric had the lowest bursting strength of 8.5 kg/ cm^2. After antimicrobial and easy-care finishing, the bursting strength slightly decreased to 10.1 kg/ cm^2. However, in case of cationic and silicone finished specimens, the bursting strength considerably dropped to 9.5 kg/cm^2 and 8.5 kg/cm^2 respectively.

The above results indicate that applying any kind of finishing process can cause a slight or significant drop in the bursting strength of the fabric.

Conclusion

Finishing is indeed an important process in the textile industry as it enhances the performance and aesthetics of fabrics. This work has provided practical knowledge about different types of finishing agents and their effects on cotton knitted fabric dyed with anthraquinone vat dyes. By analyzing the properties such as color fastness to rub, wash and bursting strength, it has evaluated the effectiveness of different finishing agents. Such efforts can help in improving the quality of textiles and meeting consumer expectations.

Acknowledgment

None.

Conflict of Interest

No conflict of interest.

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