Faculty of Engineering

Department of Textile Engineering

Thesis Report on:

Extraction of Glucose from Dates and Applied it on Textile Wet Processing as a Substitute of Reducing Agent

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Advance in Wet Processing Technology

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LETTER OF APPROVAL

This thesis report on "Extraction of Glucose from Dates and Applied it on Textile Wet Processing as a Substitute of Reducing Agent." is prepared by Nazifa Tasnim (ID:201-23-866), Jannat Ara Richi (ID: 201-23-868) & Md. Reajul Islam (ID: 201-23-918). This report is being presented to partially fulfill the requirements for the Degree of BACHELOR OF SCIENCE IN TEXTILE ENGINEERING. Under my direction, the thesis report was finished in its entirety. They have been sincere, diligent, reliable, and eager throughout the research period.

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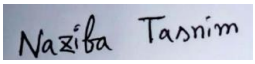
DECLARATION

We hereby announce that this project has been done under the supervision of Md. Kamrul Islam, Lecturer of the Textile Department and co-supervision of Daffodil International University. Based on our own experiment, the entire report is written in our own language. We further declare that neither this project nor any portion of this project has been submitted elsewhere for award of any Bachelor's degree in Textile Engineering degree.

Submitted by:



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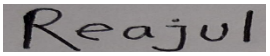

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This is to confirm that the candidates' declaration is accurate to the best of our knowledge.

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ACKNOWLEDGMENT

Initially, we are grateful to Allah for his blessings in allowing us to complete this project successfully.

Special thanks to our honorable **Mr. Tanvir Ahmed Chowdhury, Assistant Professor & Head In Charge, Textile Engineering Department, Daffodil International University**, and We are also grateful to **Md. Kamrul Islam, Lecturer, Department of Textile Engineering** for giving his continuous guidelines, profound Knowledge, and unmistakable fascination of our supervisor who encourages us to do this project. Without his support and direction, it would never be possible for us to make this report. We are also thankful to the lab assistant of DIU TWP for providing us with the essential information to complete the report on time.

We have great pleasure in expressing our profound gratitude **to Md. Hasibur Rahman, Manager (Testing Lab), Laundry Industries Ltd. Envoy Group**, and **Ehsaas Mohammad Rifat, Technical Officer, Central technical team, Ha-Meem Group** for granting us access to the lab and for providing crucial information regarding our project. We would like to sincerely thank the entire staff of **Laundry Industries Ltd. Envoy Group and Creative Washing Plant, Ha-Meem Group** for their helpful support, pleasant demeanor, and friendly cooperation.

And finally, we would like to thank our dear parents and friends for their support and help with the project report, as well as their mental fortitude and aid.

DEDICATION

THIS REPORT IS DEDICATED

TO

OUR BELOVED AND RESPECTED PARENTS

ABSTRACT

The primary emphasis of this study is the comparison between the commercially reducing agent, and glucose as a natural reducing agent, in the processes of reduction cleaning on polyester and dyeing on cotton fabric using disperse, vat, and sulphur dyes respectively. This thesis experiment involves extracting glucose from date fruit in place of hydrose, which is used as a reducing agent in textile dyeing. We employ three different kinds of dyes: sulfur dye, vat dye, and disperse dye which is purchased from Hatkhola chemical stores. Additionally, we use 100% cotton knit single jersey and 100% polyester knit single jersey fabrics that have been thoroughly well-scoured and bleached. From an environmental perspective, the range and complexity of chemicals used in the textile dyeing process in particular make it a significant source of pollution. In this experiment, we avoid commercial reducing agents used in the majority of industrial disperse, vat, and sulfur dyeing processes. This research presents a natural reducing agent derived from a plant, which has been tested in relation to sodium dithionite on disperse, vat, and sulphur dyeing processes with different percentages of shade variation. Through this study, we find out the shade variation of the use of glucose as a reducing agent. After this process statistically analyze the k/s value, color coordinators, reflectance%, and also color fastness properties of rubbing, wash, and perspiration. The obtained results showed that glucose can offer some scientific results similar to those done with commercial reducing agents.

Keywords: Glucose, Hydrose, disperse dye, vat dye, sulphur dye, shade variation, k/s value, color coordinators, color fastness.

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Chapter 1: Introduction

1.1 Introduction:

In textiles, the dyeing process is the interaction between a dye and a fiber, as well as the movement of dye into the internal part of the fiber. Generally, a dyeing process involves adsorption (transfer of dyes from the aqueous solution onto the fiber surface) and diffusion (dyes diffused into the fiber). Cellulosic substrates especially cotton require hydrophilic soluble dyes for their coloration from a dye bath. But there are some water-insoluble dyes such as vat dye, sulphur dye, and disperse dye. Among these dyes, disperse dye is only suitable for polyester. Non-ionic dyes, such as disperse dyes, are utilized because they are unaffected by the surface charge of hydrophobic fibers, such as polyester, rayon, nylon, and other synthetic fibers, whose negative charge cannot be decreased under any circumstances. Reduction cleaning is used to remove unfixed dyes and auxiliaries from the surface of the fabric following polyester portion dyeing, which is necessary for quality. For the reduction cleaning process, hydrose or Sodium hydrosulphite ($Na_2S_2O_4$) and caustic are widely used.

The original vat dye is indigo, once obtained only from plants but now often produced synthetically. The vat dyes are insoluble cannot be used directly and require Vatting. Water-insoluble dyes are converted to soluble forms during the vatting process by the use of reducing agents such as Sodium hydrosulphite ($Na_2S_2O_4$). Sodium hydrosulfite/sodium dithionite ($Na_2S_2O_4$) is also known as hydrose, is a toxic chemical and has harmful effects on living systems. Sodium dithionite (Hydrose) is a popular reducing agent for vat dyeing which is not eco-friendly and sustainable to nature because it produces sulfite, sulphate, thiosulphate, and toxic sulfur in residue.[1-3]

Sulphur dyes are widely used to produce economical black, blue, brown, and green shades on cellulosic fibers in medium to heavy depth.[4] However, sulphur dyes require a complicated application procedure (reduction and oxidation mechanism) because they are practically insoluble in water and have no affinity for cellulosic fibers in such a state. Thus, these dyes have to be reduced before dyeing to be converted into the water-soluble form which has substantivity towards fibers. The most used reducing agent in industrial scale has been sodium sulphide (Na_2S) and sodium hydrogen sulphide (NaHS) due to their efficiency and their weak cost.

The dithionite is not industrially used for sulphur dye due to its difficulty to control. Sodium dithionite destroys some number of sulfur dyes by over-reduction [5]. Moreover, it is very easily oxidized by atmospheric oxygen [6]. The generation of sulfate, sulfite, and thiosulfate ions have harmful effect on the environment due to their toxicity as well as their corrosive effect on wastewater treatment. In addition, sodium dithionite affects the microorganism processes in wastewater treatment, and toxic hydrogen sulfide can be generated from the sulfate present in the wastewater [7].

However, Natural reducing agents are often preferred, typically derived from plant-based materials, for their reducing properties as well as being biodegradable, eco-friendly, and not harmful by-products. Some of the recent research evinced that plant-based products are relatively useful for textile applications with biocompatibility and low toxic properties.

1.2 Objectives of the Thesis Work:

The purpose of the Report is to identify the effect of using glucose as a reducing agent instead of commercial reducing agent. Another objective of this report was to know about the use of natural source like dates can be a possible way of dyeing method. This Report also includes the difference between biodegradable dyeing process and the commercial dyeing process. The specific objectives of the study are describing as follows

1. **An Eco-Friendly Strategy:** Natural reducing agents come from biodegradable sources such as bacteria, plants, and biological extracts. They promote sustainable behaviors since they use fewer synthetic chemicals and have a smaller negative environmental impact.
2. **Removal of Toxic Substances:** Natural reducing agents can effectively transform metal ions into nanoparticles.
3. **Energy Conserving:** Certain conventional chemical reducing agents require a great deal of pressure and energy, whereas natural reducing agents work better in less disruptive conditions.
4. **Expense-effectiveness:** Their accessibility and ease of extraction make them cost-effective for large-scale manufacturing.

Chapter 2: Literature Review

2.1 Review of Related Research Works:

Vat dye is most popular for dyeing cellulosic fiber. Specially, for denim dyeing vat dyes are widely used in industry level. The original vat which is called indigo mainly comes from the plant. But now it produced synthetically.

The author ER Trotman et. Al. [1] discussed that vat dye is non water-soluble dye. And for converting it to soluble form it is mandatory to use a reducing agent. They also worked on the mechanism of reducing agent with vat dyes. They found commercial reducing agent such as hydrose or sodium dithionite is a toxic chemical and it is harmful for the environment.

Heid et.al.[5] discussed about dithionite is not industrially used for sulphur dye due to its difficulty to control. Sodium dithionite destroys some number of sulfur dyes by over-reduction.

The author Camacho et al.[6] said that sulphur dye is very easily oxidized by atmospheric oxygen.

Bozic & Kokol [7] discussed about the generation of sulfate, sulfite, and thiosulfate ions have harmful effect on the environment due to their toxicity as well as their corrosive effect on wastewater treatment. In addition, sodium dithionite affects the microorganism processes in wastewater treatment, and toxic hydrogen sulfide can be generated from the sulfate present in the wastewater

2.2 Disperse Dye:

Disperse dyes are very small, polar molecules without any charged cationic or anionic groups in their structure. Typically, they contain anthraquinone or azo groups. That's why it is non-polar dye. So that disperse dye is insoluble in water. The negative charge on the surface of hydrophobic fibers like polyester cannot be reduced by any means, so non-ionic dyes like disperse dyes are used which are not influenced by that surface charge.

Properties of Disperse Dye:

- Disperse dyes are applied to color man-made cellulose ester and synthetic fibers, particularly acetate and polyester fibers, as well as nylon and acrylic fibers.
- When using disperse dyes for dyeing, carrier or dispersion agents are needed.
- These dyes have a 3–4 grade for wash fastness, which is good to moderate.
- Disperse dyes are non-polar so that no chemical changes occur during the dyeing process.

2.3 Indigo or Vat Dye:

Indigo dye comes primarily from the leaves of the '*Indigofera tinctoria'* plant. The only natural blue derived from plants is indigo. But now it is produced synthetically. The wooden jar that was initially used for the reduction and application of vat dyes is where the word "vat" originates. Vat dyeing is extensively used to color cellulose materials such as cotton. Vat dyes cannot be directly applied to the fabric because it is water insoluble dyes. To convert water-insoluble to water-soluble leuco form, a reducing agent is highly required. After impregnation, it oxidizes back to its original insoluble state.

Stereochemistry of vat dyes:

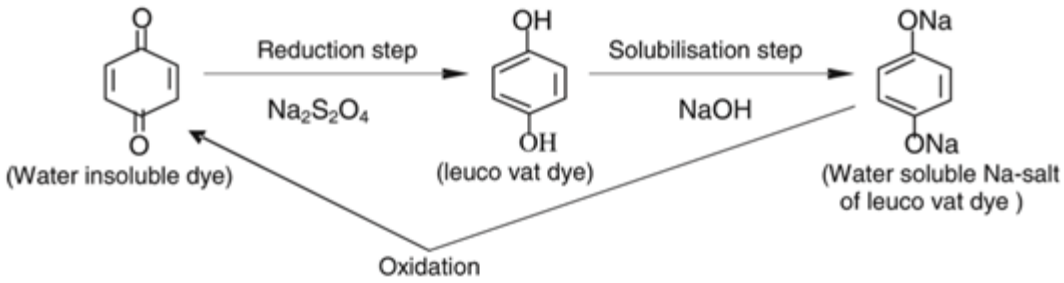

Fig-1: Stereochemistry of Vat Dyes

Properties of vat dyes:

- Vat dye cannot be applied directly to textile materials since it is water-insoluble.
- Vatting process is required to convert insoluble to soluble leuco form.
- Vat dyeing is done on an alkaline medium.
- Vat dyes are commonly used to color cellulosic fibers.
- Vat dye has excellent washing fastness, receiving a grade of 4-5.

2.4 Sulphur Dye:

Sulphur dye is not soluble in water. This dye contains sulphur linkage in its structure so it is called sulphur dye. Sulphur dyes are suitable for dyeing dark shades of color to cellulosic material such as cotton. The black shade of cotton dyeing with sulphur dyes are most popular and also widely used at the industrial level. Sulphur dyes are quite cheap compared to other dyes. For dyeing with sulphur dye, it should be required to be solubilized with a reducing agent in alkaline condition. Through this process, water-insoluble sulphur dyes transfer to the water-soluble leuco form.

Solubilizing Formula:

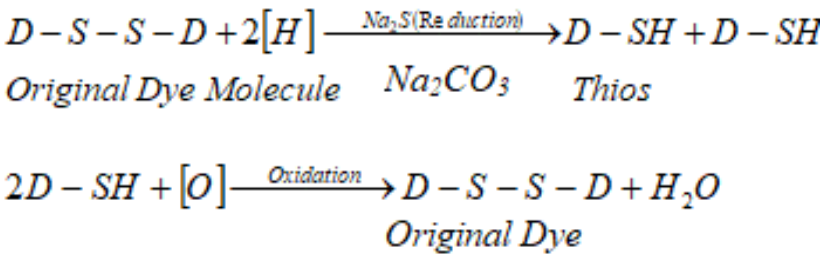

Fig-2: solubilizing formula of sulphur dye

2.5 Commercial Reducing Agent:

Sodium hydrosulfite $Na_2S_2O_4$ is the most common reducing chemical that is used widely at the factory. It is also called hydrose. It is the universally accepted reducing agent in vat dyeing, and reduction clearing of disperse dye. This process converts insoluble vat dye to partially soluble leuco dye and counteracts the effect of dissolved oxygen in water. It is stable in the anhydrous form. Sodium thiosulfate and bisulphite are easily formed when water comes into contact with them.

$$Na_2S_2O_4 + H_2O = Na_2S_2O_3 + 2NaHSO_3$$

When NaOH is present, the reduced form is fairly stable for room-temperature dyeing. It decomposes in water, thermally, and oxidatively, among other methods.

2.6 Caustic Soda:

It is a powerful alkali that neutralizes acidic substances while maintaining the pH of the solution. Additionally, it functions as a solubilizing agent in vat dyeing. Their hydroxide is neutralized to generate salt, which is a water-soluble byproduct. Maintain the reduced dye in its water-soluble form.

2.7 Bio-technology:

In the textile sector, biotechnology plays a vital role. It is dependable, cost-effective, and eco-friendly. Environmentally friendly processing of traditional textile manufacture is being achieved through the application of biotechnology. There are numerous opportunities for biotechnology system development in the textile sector.

2.8 Natural Reducing Agent:

Commercial reducing agents have negative environmental impacts, including toxicity from hydrogen sulphide and corrosion of effluent drainage systems. To safeguard the environment and ensure water purity, sulfide-containing reducing agents are avoided. From an environmental perspective, using glucose and other sugars as reducing agents in this situation seemed like a very promising solution. This investigation introduces a new reducing agent that is natural and comes from a plant. Generally, reducing agents tend to give away electrons. The reducing agent after losing electrons gets oxidized and also causes the other reactant to get reduced by providing electrons. In this experiment, we used dates as a reducing agent. Date contains both glucose and fructose.

Chapter 3: Materials and Methods

3.1 Materials:

In this experiment, we used two types of fabrics. Following fabrics:

1. 100% polyester knit fabric (single jersey)
2. 100% cotton knit fabric (single jersey)

3.1.1 Dyes & chemicals:

Table-01: List of Dyes & Chemicals with their Functions:

Serial No.	Name of dyes & chemicals	Function
1	Disperse dye (Taicron blue SE-UNT)	Suitable for dyeing synthetic fibers
2	Vat dye (indigo blue)	Suitable for dyeing cellulosic fibers
3	Sulphur dye	Suitable for dyeing cellulosic fibers
4	Dispersing Agent	Helps to disperse dyestuff evenly in the bath
5	Levelling Agent	Helps to mix the dye particles uniformly in bath
6	Wetting Agent	Used to reduce the surface tension of water and help the water-based solutions to spread.
7	Sequestering Agent	Used to reduce the surface tension of water and thus help the water-based solutions to spread.
8	Glauber salt	Increase dye affinity toward fabric
9	Caustic soda (NaOH)	To maintain an alkaline pH level
10	Soda Ash (Na_2CO_3)	To maintain an alkaline pH in the dye bath and work as the dye-fixing agent
11	Acetic Acid	To maintain an acetic pH level

12	Sodium hydrosulphite /hydrose ($Na_2S_2O_4$).	Used as reducing agent for the reduction of vat dyes, disperse dyes
13	Sodium sulphide (Na_2S)	Used as reducing agent for dissolving sulphur dyes

3.1.2 Dyeing machine:

In this experiment, every sample was dyed using an IR sample dyeing machine in our wet processing laboratory.

Fig-3: IR Sample Dyeing Machine

3.1.3 Glucose Extraction Process:

Natural reducing agents (Date fruit) were obtained from a local fruit market. Then separate the date seed from the date. After that, chop the dates into small bits. Then freeze it for 2-1 days. The small pieces of dates were boiled for 30 min to obtain extracts. All of the water was dried by boiling. Then it turns to paste form. Preserve date pulp in a suitable jar at room temperature. We use the pulp of date as a natural reducing agent.

Process flow chart:

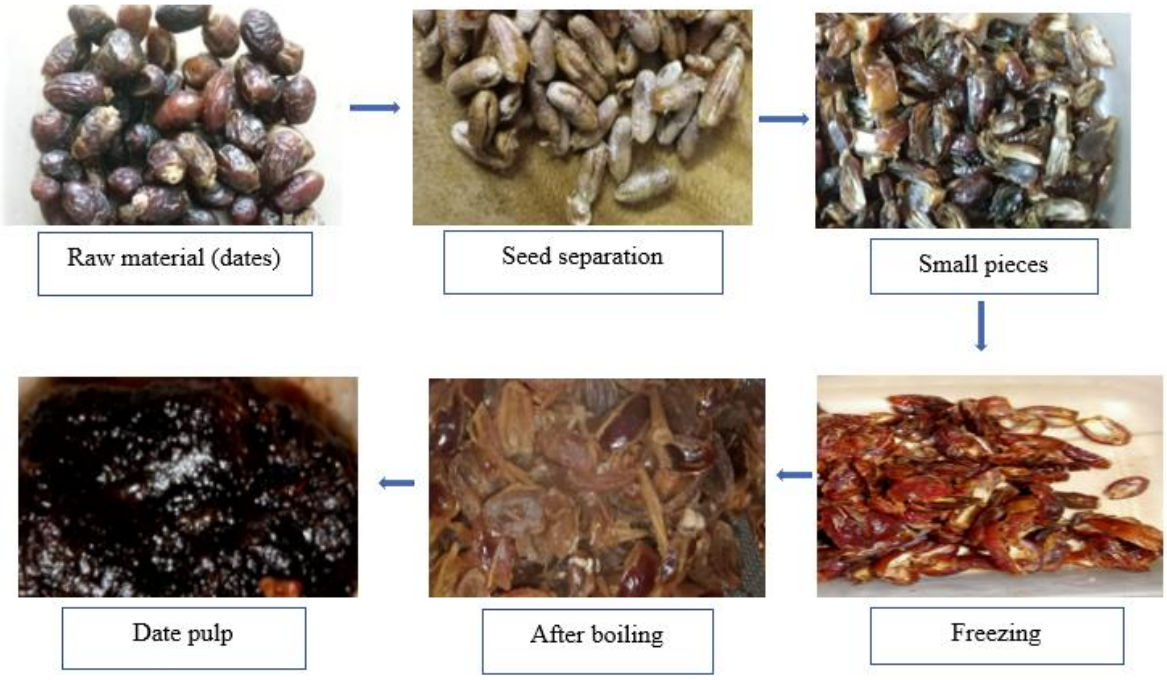

Fig-4: Extraction of glucose from date working flow chart.

3.2.1 Shade %:

Table-02: Shade%

0.5% dye	For lighter shade
1.5% dye	For moderate shade
3% dye	For darker shade

3.2.2 Recipe for Disperse Dye:

Table-03: Dyeing Recipe of 100% Polyester Fabric (knit) with Disperse Dye (high temp. method):

Serial No.	Chemicals	Amount
1	Sequestering Agent	2.5 g/l
2	Levelling Agent	2 g/l
3	Dispersing Agent	2 g/l
4	Disperse Dye (Taicron blue SE-UNT)	0.5%, 1.5%, 3%
5	Acetic Acid	2 g/l
6	M: L	1:20
7	Sample Weight	10 gm

3.2.3 Condition of Solution Bath:

For disperse dyeing process, solution bath should be in acetic media.

Parameters: pH= 4.5

Temp.= 130℃

Time = 40 min

3.2.4 Dyeing Mechanism:

Process path:

Collect fabric (scoured & bleached)
⬇
Cut the sample of 10 gm
⬇
Take beaker (250mL)
⬇
Prepare liquor
⬇
Add acetic acid
⬇
Check pH
⬇
Add sequestering agent
⬇
Add levelling agent
⬇
Add dispersing agent
⬇
Add disperse dye
⬇
Add sample
⬇
Run IR sample dyeing machine (130℃, 40 min)
⬇
Bath drain
⬇
Cold wash
⬇
Drying

Fabric collection:

In this experiment, we use 100% polyester knit fabric that has been well-scoured and bleached. For each of the three shade percentages, 10 grams of fabric are cut.

Prepare liquor:

At first, take three 250 ml beakers for each of the three shade percentages. There is a 1:20 liquor ratio overall. The dyebaths for the disperse dyeing process were prepared with the required amount of disperse dyes (0.5%,1.5%, and 3% owf) with dispersing agent (2 g/l), levelling agent (2 g/l), sequestering agent (2.5 g/l). pH is controlled by adding acetic acid (2 g/l).

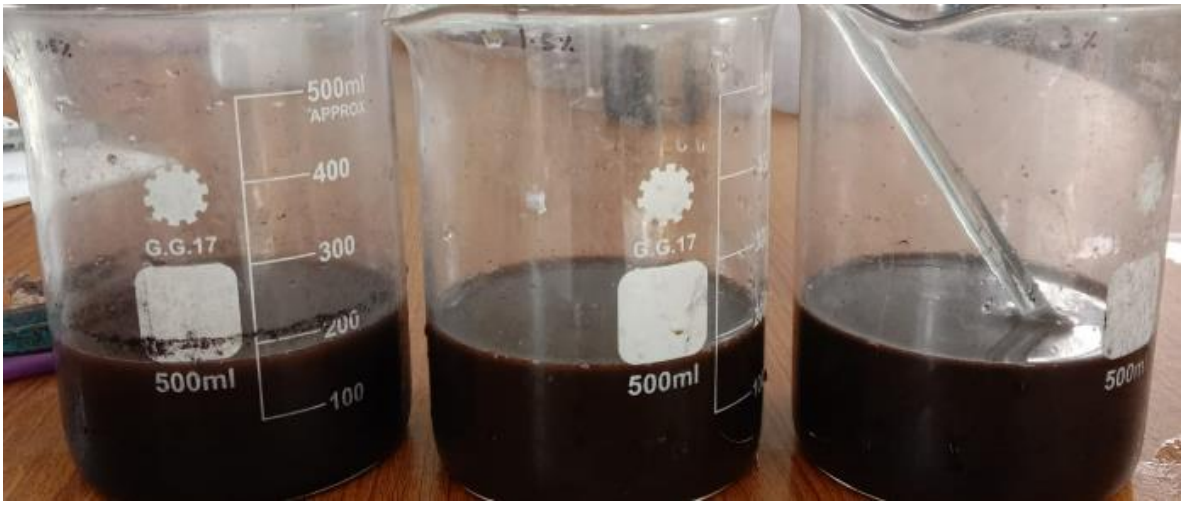

Fig-5: Liquor of Disperse Dye

After checking pH (4.5) with Hanna pH meter, then added the samples. The process was carried out at temperature 130℃ for 40 min.

Fig-6: Running Dyeing Process

Washing and Drying Processes:

After the dyeing process, each of the fabric samples was washed with normal room-temperature water. Then all the dyed samples were put in to the sample dryer machine at 120℃ for 2 min.

3.2.5 Reduction Cleaning with Hydrose:

Reduction cleaning is done to remove unfixed dye molecules from the fabric surface which is necessary for quality. For the reduction cleaning process, hydrose or Sodium hydrosulphite ($Na_2S_2O_4$) and caustic are widely used. In this experiment, we used the ratio of hydrose and caustic is 2:1.

Fabric sample was divided into two parts and they were treated in two methods of reduction cleaning process as follows: the first method of RC used hydrose and the other was date pulp (glucose) as a reducing agent.

Recipe of RC with hydrose:

Caustic (NaOH) = 2 g/l

Hydrose ($Na_2S_2O_4$) = 4 g/l

Time = 20 min

Temp. = 70℃

Fig-7: Liquor of Reduction Cleaning with Hydrose

3.2.6 Reduction Cleaning with Glucose:

In this trial, we take the date pulp that was processed before. Date pulp contains glucose that is mainly used as reducing agent in this experiment. The ratio of glucose and caustic is 2:1 (similar as commercial process).

Recipe of RC with Glucose:

Caustic (NaOH) = 2 g/l

Glucose ($C_6H_{12}O_6$) = 4 g/l

Time = 20 min

Temp.= 70°C

Fig-8: Liquor of Reduction Cleaning with Glucose

3.3.1 Vatting with Hydrose:

Vat dyes are insoluble, and cannot be applied directly to the textile materials. That's the reason it requires vatting process. Vatting is the process of reducing vat dye molecules and converting them to the water-soluble leuco form. In this case, the reducing agent is essential to the vat dye reduction and availability for the dyeing process.

Hydrose or Sodium hydrosulphite ($Na_2S_2O_4$) and caustic are widely used for the reduction cleaning process. Sodium hydrosulphite works as a reducing agent and sodium hydroxide works as a solubilizing agent.

3.3.2 Recipe for Vat Dye Vatting Process with Hydrose:

Table-04: Dyeing of 100% Cotton (knit) Fabric with Vat Dye with Hydrose:

Serial No.	Chemicals	Amount
1	Wetting Agent	1 g/l
2	Sequestering Agent	2 g/l
3	Levelling Agent	2 g/l
4	Caustic soda (NaOH)	2 g/l
5	Hydrose ($Na_2S_2O_4$)	4 g/l
6	Vat Dye (Indigo Blue)	0.5%, 1.5%, 3%
7	M: L	1:20
8	Sample Weight	10 gm

3.3.3 Condition of Solution Bath:

For vatting process, solution bath should be in alkaline media.

Parameters: pH= 11.5

Vatting Temp.= 80℃

Vatting Time = 10 min

Dyeing temp. = 50℃

3.3.4 Dyeing Mechanism:

Process path:

Collect fabric (scoured & bleached)

⬇

Cut the sample of 10 gm

⬇

Take beaker (250mL)

⬇

Add wetting agent

⬇

Add sequestering agent

⬇

Add levelling agent

⬇

Add caustic soda

⬇

Add hydrose

⬇

Add vat dye

⬇

Add sample

⬇

Run IR sample dyeing machine (50℃, 30 min)

⬇

Bath drain

⬇

Oxidation by air

⬇

Cold wash

⬇

Drying

Fabric collection:

In this experiment, we use 100% cotton knit fabric that has been well-scoured and bleached. For each of the three shade percentages, 10 grams of fabric are cut. Ensure the weight of each fabric by digital balance.

Vatting/ Reduction Process:

At first, take three 250 ml beakers for each of the three shade percentages. There is a 1:20 liquor ratio overall. Then prepare the liquor based on this ratio. The dyebaths for the vatting process were prepared with the required amount of vat dyes (0.5%,1.5%, and 3% owf) with sodium hydrosulphite (4 g/l), sodium hydroxide (2 g/l), wetting agent (1 g/l), levelling agent (2 g/l), sequestering agent (2 g/l).

Then check the liquor pH (11.5) with Hanna pH meter. The process was carried out at temperature of 80℃ in open bath. Cotton fabric is added to the solution after ten minutes.

Fig-9: Liquor of Vatting with Hydrose

Dyeing Process:

Whenever vatting is done, then added cotton sample to the solution bath for dyeing with soluble leuco form of vat dye. The dye molecules penetrate the fibers. The vat dyeing process takes place at about 50°C for 30 min.

Oxidation Process:

After dyeing process, the bath solution was drained out. Then the samples were oxidized by exposure to atmospheric oxygen. This process is called Air Oxidation or Airing. The oxidation process helps to fix the dye molecules of vat dye. This process mainly converts the water-soluble dye to the water-insoluble dye.

Washing and Drying Process:

After oxidation, each fabric sample was washed with normal room-temperature water. And then dried the samples again.

3.3.5 Vatting with Glucose:

We use the previously treated date pulp in this experiment. Glucose, which is mostly utilized as a reducing agent in this experiment, is found in date pulp. Caustic and glucose have a 2:1 ratio (similar to the commercial vatting method). Glucose ($C_6H_{12}O_6$) works as a reducing agent and sodium hydroxide works as a solubilizing agent.

3.3.6 Recipe for Vat dye with Glucose:

Table-05: Dyeing of 100% Cotton (knit) Fabric with Vat Dye:

Serial No.	Chemicals	Amount
1	Wetting Agent	1 g/l
2	Sequestering Agent	2 g/l
3	Levelling Agent	2 g/l
4	Caustic soda (NaOH)	2 g/l
5	Glucose ($C_6H_{12}O_6$)	4 g/l
6	Vat Dye (Indigo Blue)	0.5%, 1.5%, 3%
7	M: L	1:20
8	Sample Weight	10 gm

3.3.7 Condition of Solution Bath:

For vatting process, the solution bath should be in alkaline media.

Parameters: pH= 10.5

Vatting Temp.= 80℃

Vatting Time = 10 min

Dyeing temp. = 50℃

Dyeing Time = 30 min

3.3.8 Dyeing Mechanism:

Process path:

Collect fabric (scoured & bleached)
⬇
Cut the sample of 10 gm
⬇
Take beaker (250mL)
⬇
Add wetting agent
⬇
Add sequestering agent
⬇
Add levelling agent
⬇
Add caustic soda
⬇
Add glucose
⬇
Add vat dye
⬇
Add sample
⬇
Run IR sample dyeing machine (50℃, 30 min)
⬇
Bath drain
⬇
Oxidation by air
⬇
Cold wash
⬇
Drying

Fabric collection:

In this experiment, we use 100% cotton knit fabric that has been well-scoured and bleached. For each of the three shade percentages, 10 grams of fabric are cut. Ensure the weight of each fabric by digital balance. (same as previous process)

Vatting/ Reduction Process:

Firstly, take three 250 ml beakers for each of the three shade percentages. There is a 1:20 liquor ratio overall. Then prepare the liquor based on this ratio. The dyebaths for the vatting process were prepared with the required amount of vat dyes (0.5%,1.5%, and 3% owf) with date pulp/glucose (4 g/l), sodium hydroxide (2 g/l), wetting agent (1 g/l), levelling agent (2 g/l), sequestering agent (2 g/l).

Then check the liquor pH (10.5) with Hanna pH meter. The process was carried out at temperature of 80℃ in open bath. Cotton fabric is added to the solution after ten minutes.

Fig-10: Liquor of Vatting with Glucose

Dyeing Process:

Whenever vatting is done, then added cotton sample to the solution bath for dyeing with soluble leuco form of vat dye. The dye molecules penetrate the fibers. The vat dyeing process takes place at about 50°C for 30 min. (same as commercial process)

Oxidation Process:

After dyeing process, the bath solution was drained out. Then the samples were oxidized by exposure to atmospheric oxygen. This process is called Air Oxidation or Airing. The oxidation process helps to fix the dye molecules of vat dye. This process mainly converts the water-soluble dye to the water-insoluble dye.

Washing and Drying Process:

After oxidation, each fabric sample was washed with normal room-temperature water. And then dried the samples again.

3.4.1 Solubilizing with Sodium Sulphide:

Sulphur dyes are insoluble like vat dyes. In this form, the sulphur dyes have no affinity for cellulosic material since they are not soluble in water. With sulphur dyes, the solubilizing groups are not available. Therefore, before dyeing at the required temperature, these insoluble sulphur dyes must first be transformed into the sodium salt of soluble leuco form using an alkaline reducing agent, such as sodium sulphide (Na_2S).

Sodium sulphide (Na_2S) or sodium hydrogen sulphide (NaHS) is the most used reducing agent in industrial scale.

3.4.2 Recipe for Sulphur Dye (commercial):

Table-06: Dyeing of 100% Cotton (Knit) Fabric with Sulphur Dye:

Serial No.	Chemicals	Amount
1	Wetting Agent	1 g/l
2	Sequestering Agent	2 g/l
3	Levelling Agent	2 g/l
4	Soda Ash (Na_2CO_3)	5 g/l
5	Glauber Salt ($Na_2SO_4.10H_2O$)	16 g/l
6	Sodium sulphide (Na_2S)	4 g/l
7	Sulphur Dye (Green)	0.5%, 1.5%, 3%
8	M: L	1:20
9	Sample Weight	10 gm

3.4.3 Condition of Solution Bath:

For solubilizing process, the solution bath should be in alkaline media.

Parameters: pH= 11

Dyeing temp. = 98℃

Dyeing Time = 40 min

3.4.4 Dyeing Mechanism:

Process path:

Collect fabric (scoured & bleached)
⬇
Cut the sample of 10 gm
⬇
Take beaker (250mL)
⬇
Add wetting agent
⬇
Add sequestering agent
⬇
Add levelling agent
⬇
Add soda ash
⬇
Add Glauber salt
⬇
Add Sodium sulphide
⬇
Add sulphur dye (Green)
⬇
Add sample
⬇
Run IR sample dyeing machine (98℃, 40 min)
⬇
Bath drain
⬇
Oxidation by air
⬇
Cold wash
⬇
Drying

Fabric collection:

In this experiment, we use 100% cotton knit fabric that has been well-scoured and bleached. 10 grams are cut of fabric for each of the three shade percentages. Ensure the weight of each fabric by digital balance.

Solubilizing/ Reduction Process:

Firstly, take three 250 ml beakers for each of the three shade percentages. There is a 1:20 liquor ratio overall. Then prepare the liquor based on this ratio. The dyebaths for the reduction process were prepared with the required amount of sulphur dyes (0.5%,1.5%, and 3% owf) with sodium sulphide (Na_2S) (4 g/l), sodium carbonate (Na_2CO_3) (5 g/l), glauber salt (16 g/l), wetting agent (1 g/l), levelling agent (2 g/l), sequestering agent (2 g/l).

Then check the liquor pH (11) with Hanna pH meter. Pieces of fabric sample were added into the liquor. The process was carried out at temperature of 98℃ for 40 min in the IR sample dyeing machine.

Oxidation Process:

After dyeing process, the bath solution was drained out. Then the samples were oxidized by exposure to atmospheric oxygen. This process is called Air Oxidation or Airing. The oxidation process helps to fix the dye molecules of sulphur dye. This process mainly converts the water-soluble dye to the water-insoluble dye.

Washing and Drying Process:

After oxidation, each fabric sample was washed with normal room-temperature water. And then dry them in the open air again.

3.4.5 Solubilizing with Glucose:

For this experiment, the date pulp that was previously treated is used. Glucose, which is mostly utilized as a reducing agent in this experiment, is found in date pulp. Glucose ($C_6H_{12}O_6$) was used as the same amount of sodium sulphide.

3.4.6 Recipe for Sulphur Dye (experiment):

Table-07: Dyeing of 100% Cotton (Knit) Fabric with Sulphur Dye:

Serial No.	Chemicals	Amount
1	Wetting Agent	1 g/l
2	Sequestering Agent	2 g/l
3	Levelling Agent	2 g/l
4	Soda Ash (Na_2CO_3)	5 g/l
5	Glauber Salt ($Na_2SO_4.10H_2O$)	16 g/l
6	Glucose ($C_6H_{12}O_6$)	4 g/l
7	Sulphur Dye (Green)	0.5%, 1.5%, 3%
8	M: L	1:20
9	Sample Weight	10 gm

3.4.7 Condition of Solution Bath:

For solubilizing process, the solution bath should be in alkaline media.

Parameters: pH= 10.5

Dyeing temp. = 98℃

Dyeing Time = 40 min

3.4.8 Dyeing Mechanism:

Process path:

Collect fabric (scoured & bleached)
⬇
Cut the sample of 10 gm
⬇
Take beaker (250mL)
⬇
Add wetting agent
⬇
Add sequestering agent
⬇
Add levelling agent
⬇
Add soda ash
⬇
Add Glauber salt
⬇
Add glucose
⬇
Add sulphur dye (Green)
⬇
Add sample
⬇
Run IR sample dyeing machine (98℃, 40 min)
⬇
Bath drain
⬇
Oxidation by air
⬇
Cold wash
⬇
Drying

Fabric collection:

In this experiment, we use 100% cotton knit fabric that has been well-scoured and bleached. 10 grams are cut of fabric for each of the three shade percentages. Ensure the weight of each fabric by digital balance.

Solubilizing/ Reduction Process:

Firstly, take three 250 ml beakers for each of the three shade percentages. There is a 1:20 liquor ratio overall. Then prepare the liquor based on this ratio. The dyebaths for the reduction process were prepared with the required amount of sulphur dyes (0.5%,1.5%, and 3% owf) with glucose ($C_6H_{12}O_6$) (4 g/l), sodium carbonate (Na_2CO_3) (5 g/l), glauber salt (16 g/l), wetting agent (1 g/l), levelling agent (2 g/l), sequestering agent (2 g/l).

Then check the liquor pH (10.5) with Hanna pH meter. Pieces of fabric sample were added into the liquor. The process was carried out at temperature of 98℃ for 40 min in the IR sample dyeing machine.

Fig-11: Liquor of Solubilizing Sulphur Dye with Glucose

Oxidation Process:

After dyeing process, the bath solution was drained out. Then the samples were oxidized by exposure to atmospheric oxygen. This process is called Air Oxidation or Airing. The oxidation process helps to fix the dye molecules of sulphur dye. This process mainly converts the water-soluble dye to the water-insoluble dye. (same as the commercial process)

Washing and Drying Process:

After oxidation, each fabric sample was washed with normal room-temperature water. And then dry them in the open air again.

Chapter-4: Results and Discussions

4.1 Analysis the Shade Variation:

Shade variation or color yield was determined by spectrophotometer (data color m/c). All the dyed sample were folded four times and Following data calibration, the color spectrophotometer was exposed, and sample values were recorded.

4.1.1 Fabric Sample Test Result:

(polyester)

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
l:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
poly light	D65-10	35.23	-1.51	-3.56	3.87	247.07
	TL84-10	34.69	-3.36	-4.47	5.60	233.07

Trial Name	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
Poly med	-12.73 D	0.07 R	-1.17 B	1.07 B	0.46 B	7.28	Failed	0.35
TL84-10	-12.90 D	0.22 R	-1.44 B	1.10 B	0.95 B	7.50		
Poly Dark	-19.23 D	1.49 R	0.36 Y	-0.67 D	1.38 B	10.97	Failed	0.68
TL84-10	-19.19 D	2.15 R	0.47 Y	-1.42 D	1.69 B	11.18		

Table-08: Shade Comparison of Disperse Dyed Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h° indicates hue angle. DL indicates if the shade is lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da* represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.

As we can see in the table-08, we took the lighter shade 0.5% as standard. And for trial DL* came darker for both 1.5% & 3% shade as the value is negative. For Da*, since values are positive so the shade is redder for both 1.5% & 3% shade than the standard. For Db*, values are negative for 1.5% so shade is bluer and for 3% shade is yellower than the standard. For DC*, 1.5% shade is brighter than the standard and 3% shade is duller than the standard. Since the value of DEcmc is more than 1 that's why result showed failed.

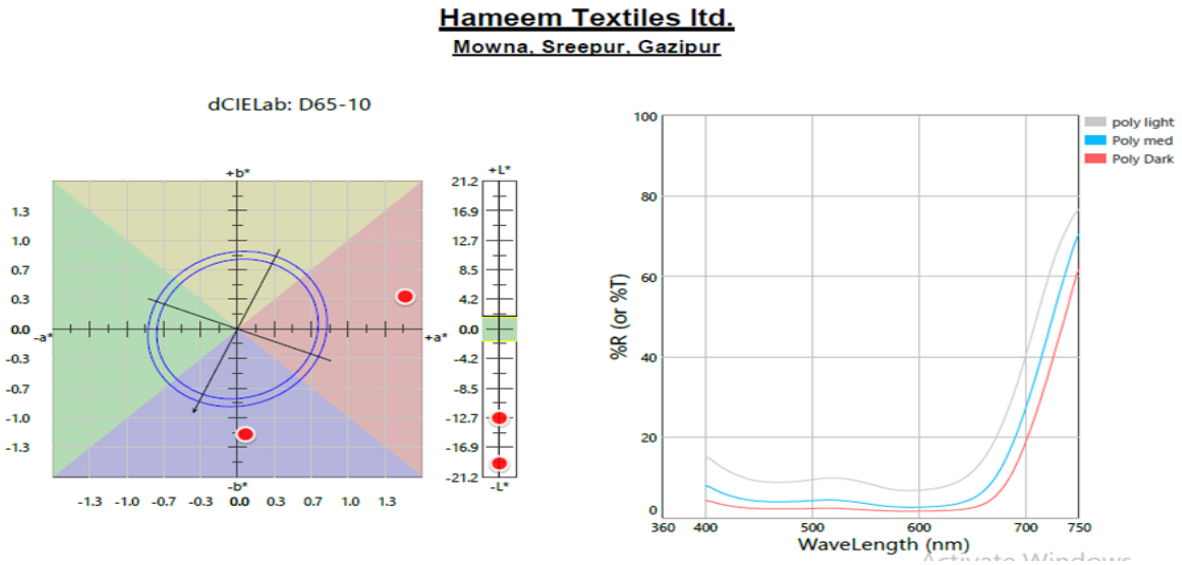

Chart-01: Color coordinates and Reflectance% of Disperse Dyed Sample

Dyed Samples	K/S value
(0.5% shade) 	1.6
(1.5% shade) 	5.53
(3% shade) 	9.02

Cotton Knitted Fabric Sample Test Result (Sulphur dye 0.5% Shade):

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
I:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
0.5%S	D65-10	68.69	-13.22	-3.95	13.80	196.63
	TL84-10	67.46	-11.46	-5.40	12.67	205.26

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
0.5%G	-0.31 D	0.22 R	0.79 Y	-0.42 D	-0.71 Y	0.74	Passed	0.38
TL84-10	-0.19 D	-0.10 G	0.95 Y	-0.28 D	-0.91 G	0.93		

Table-09: Shade Comparison of 0.5% of Sulphur Dyed (Green) Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da*

represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.

As we can see from the table-09, we took 0.5% shade dyed with sodium sulphide as standard and 0.5% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in light source D65-10 shade is redder than the standard and in light source TL84-10 shade is greener. For Db*, in both light sources, the shade is yellower. For DC*, chroma is duller than the standard. Value of DEcmc is less than 1. Hence, result is approved or passed

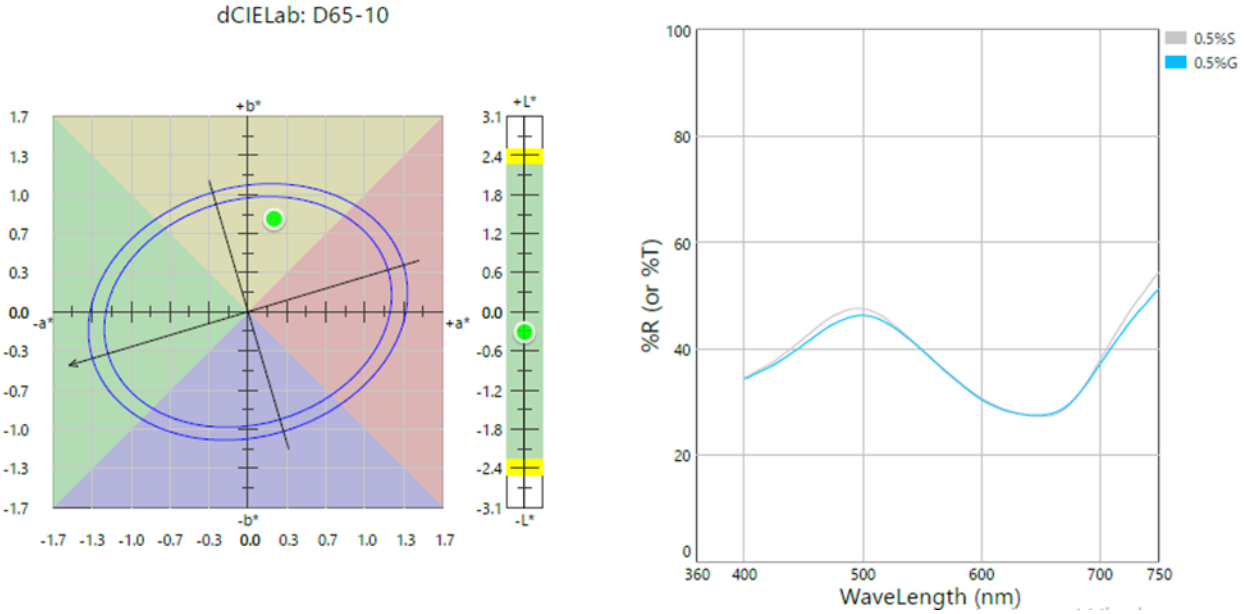

Chart-02: Color coordinates and Reflectance% of Sulphur (0.5%shade) Dyed Sample

Dyed Samples	K/S Value
(0.5% Sodium Sulphide) 	17.51
(0.5% Glucose) 	16.51

Since K/S value of 0.5% glucose shade is less than 0.5% Sodium Sulphide shade, so 0.5% glucose shade is darker.

Sulphur Dye 1.5% Shade:

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
I:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
1.5%S	D65-10	63.16	-14.27	-7.92	16.32	209.05
	TL84-10	61.53	-12.36	-10.12	15.98	219.31

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
1.5%G	-1.58 D	-0.63 G	2.05 Y	-0.31 D	-2.12 G	2.00	Failed	0.43
TL84-10	-1.41 D	-0.86 G	2.38 Y	-0.66 D	-2.44 G	2.34		

Table-10: Shade Comparison of 1.5% of Sulphur Dyed Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da* represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.As we can see from the table-10, we took 1.5% shade dyed with sodium sulphide as standard and 1.5% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in both light sources D65-10 and TL84-10 shade is greener. For Db*, in both light sources, the shade is yellower. For DC*, chroma is duller than the standard. Value of DEcmc is more than 1. Hence, result is failed.

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

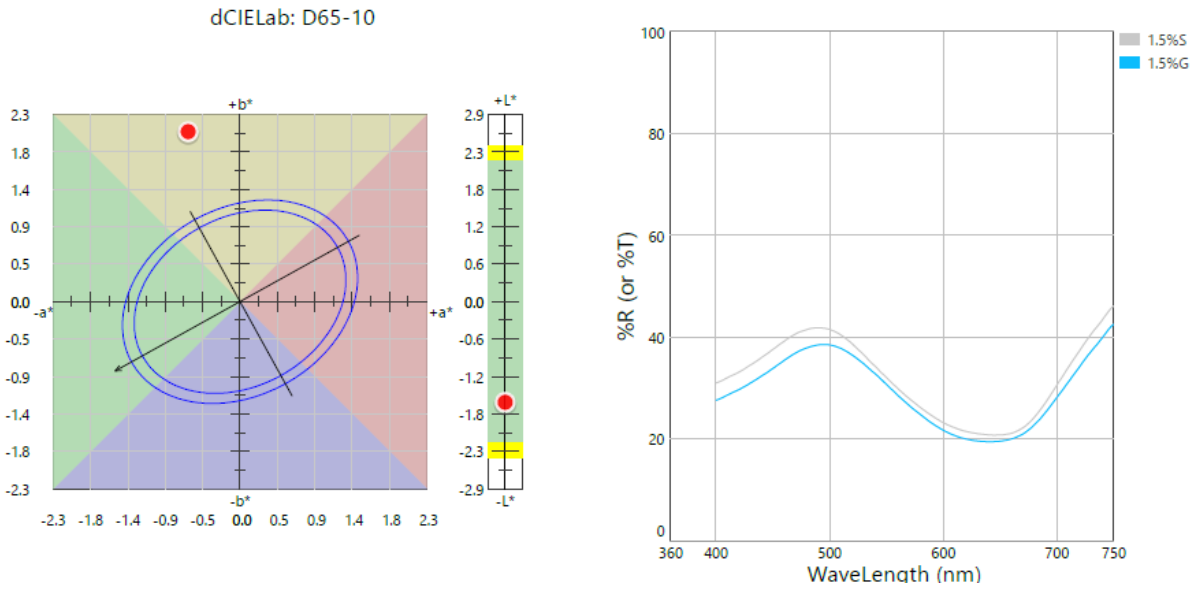

Chart-03: Color coordinates and Reflectance% of Sulphur (1.5%shade) Dyed Sample

Dyed Samples	K/S Value
(1.5% Sodium Sulphide) 	13.01
(1.5% Glucose) 	11.52

Since K/S value of 1.5% glucose shade is less than 1.5% Sodium Sulphide shade, so 1.5% glucose shade is darker.

Sulphur Dye 3% Shade:

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
I:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
3%S	D65-10	51.90	-15.86	-6.09	16.99	201.01
	TL84-10	50.22	-13.35	-8.20	15.67	211.55

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
3%G	-0.77 D	-0.03 G	-0.38 B	0.17 B	0.35 B	0.47	Passed	0.35
TL84-10	-0.72 D	-0.38 G	-0.38 B	0.52 B	0.12 B	0.50		

Table-11: Shade Comparison of 3% of Sulphur Dyed (green) Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is

lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da* represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that. As we can see from the table-11, we took 3% shade dyed with sodium sulphide as standard and 3% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in both light sources D65-10 and TL84-10 shade is greener. For Db*, in both light sources, the shade is bluer. For DC*, chroma is brighter than the standard. Value of DEcmc is less than 1. Hence, result is approved or passed

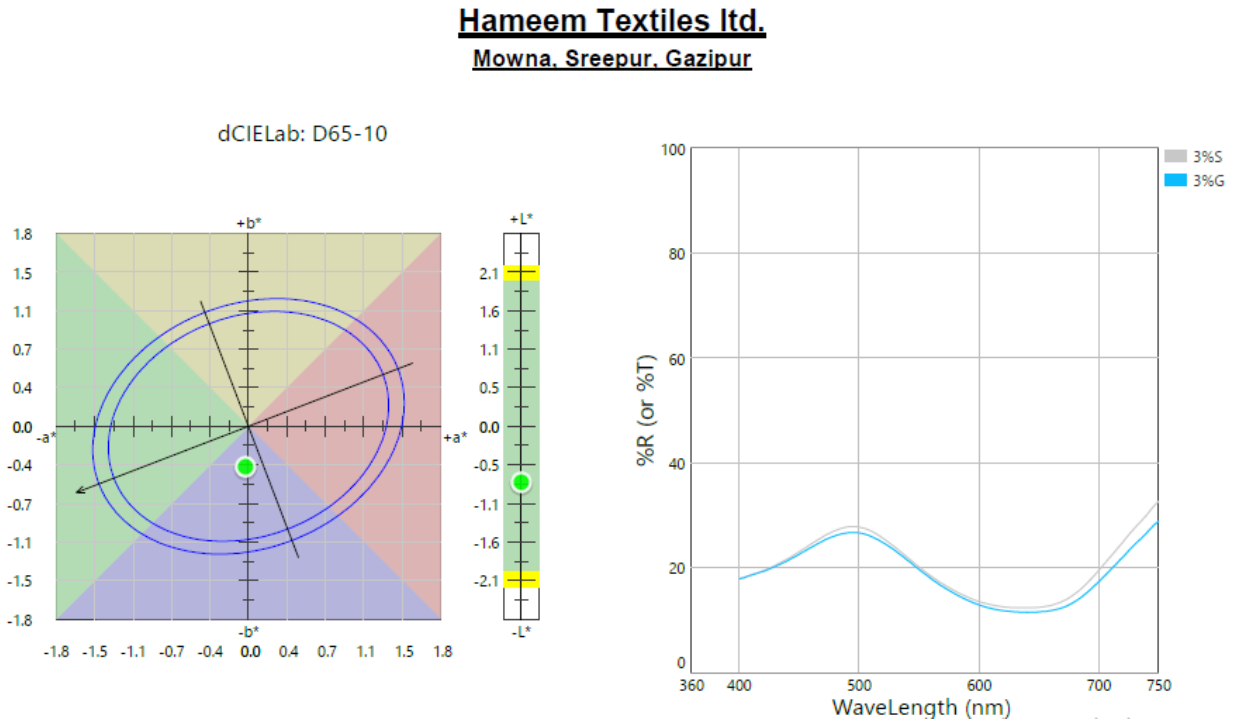

Chart-04: Color coordinates and Reflectance% of Sulphur (3%shade) Dyed Sample

Dyed Samples	K/S Values
(3% Sodium Sulphide) 	8.52
(3% Glucose) 	8.02

Since K/S value of 3% glucose shade is less than 3% Sodium Sulphide shade, so 3% glucose shade is darker.

Cotton Knitted Fabric Sample Test Result (Vat Dye 0.5% Shade):

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
l:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
0.5%H	D65-10	83.34	-2.73	-0.76	2.83	195.62
	TL84-10	83.04	-2.09	-1.21	2.42	210.07

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
0.5%H	-1.85 D	-1.19 G	2.23 Y	1.35 B	-2.14 Y	3.28	**Failed**	0.43
TL84-10	-1.81 D	-1.06 G	2.64 Y	1.04 B	-2.65 G	3.77		
0.5%G	-2.34 D	-0.88 G	2.36 Y	1.11 B	-2.26 Y	3.33	**Failed**	0.44
TL84-10	-2.27 D	-0.76 G	2.78 Y	0.83 B	-2.76 G	3.86		

Table-12: Shade Comparison of 0.5% of Vat Dyed (Blue) Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is

lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da* represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.

As we can see from the table-12, we took 0.5% shade dyed with hydrose as standard and 0.5% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in both light sources D65-10 and TL84-10 shade is greener. For Db*, in both light sources, the shade is yellower. For DC*, chroma is brighter than the standard. Value of DEcmc is more than 1. Hence, result is failed.

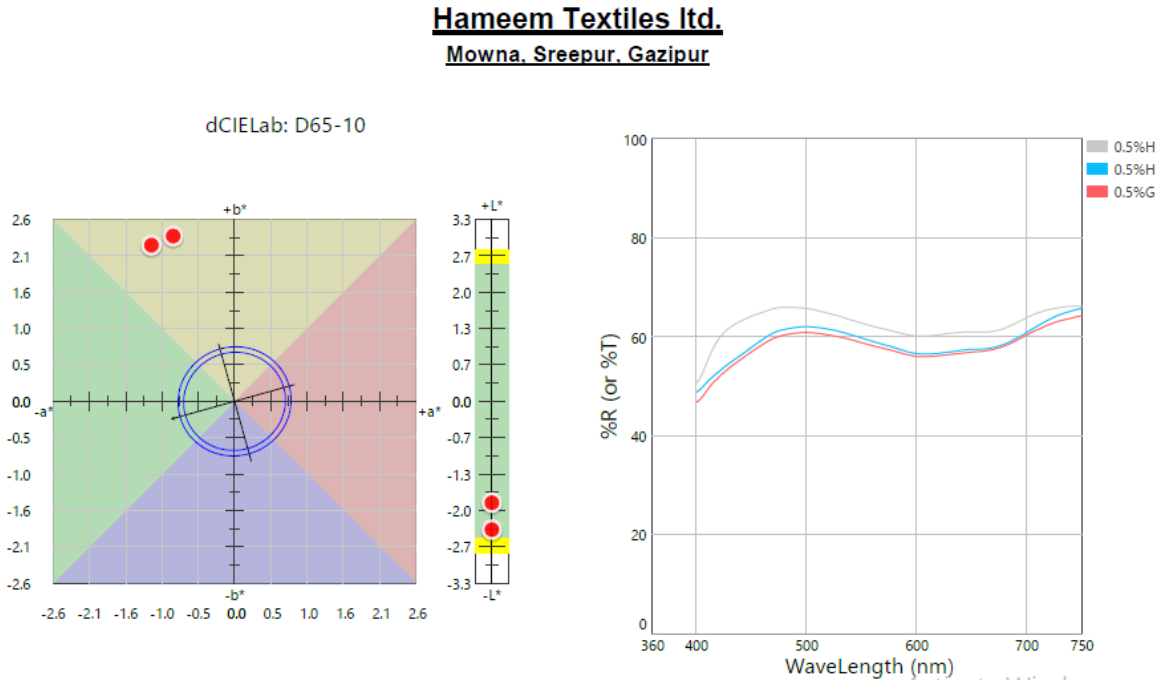

Chart-05: Color coordinates and Reflectance% of Vat (0.5%shade) Dyed Sample

Dyed Samples	K/S values
(0.5% Hydrose) 	24.01
(0.5% Glucose) 	22.51

Since K/S value of 0.5% glucose shade is less than 0.5% hydrose shade, so 0.5% glucose shade is darker.

Vat Dye 1.5% Shade:

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
I:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
1.5%H	D65-10	76.62	-0.92	-2.95	3.09	252.65
	TL84-10	76.24	-0.52	-3.76	3.80	262.14

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
1.5%G	-2.27 D	-3.30 G	-0.06 B	2.09 B	-2.55 G	4.26	**Failed**	0.50
TL84-10	-2.48 D	-2.84 G	-0.04 B	1.27 B	-2.54 G	3.74		

Table-13: Shade Comparison of 1.5% of Vat Dyed Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da*

represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.

As we can see from the table-13, we took 1.5% shade dyed with hydrose as standard and 1.5% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in both light sources D65-10 and TL84-10 shade is greener. For Db*, in both light sources, the shade is bluer. For DC*, chroma is brighter than the standard. Value of DEcmc is more than 1. Hence, result is failed.

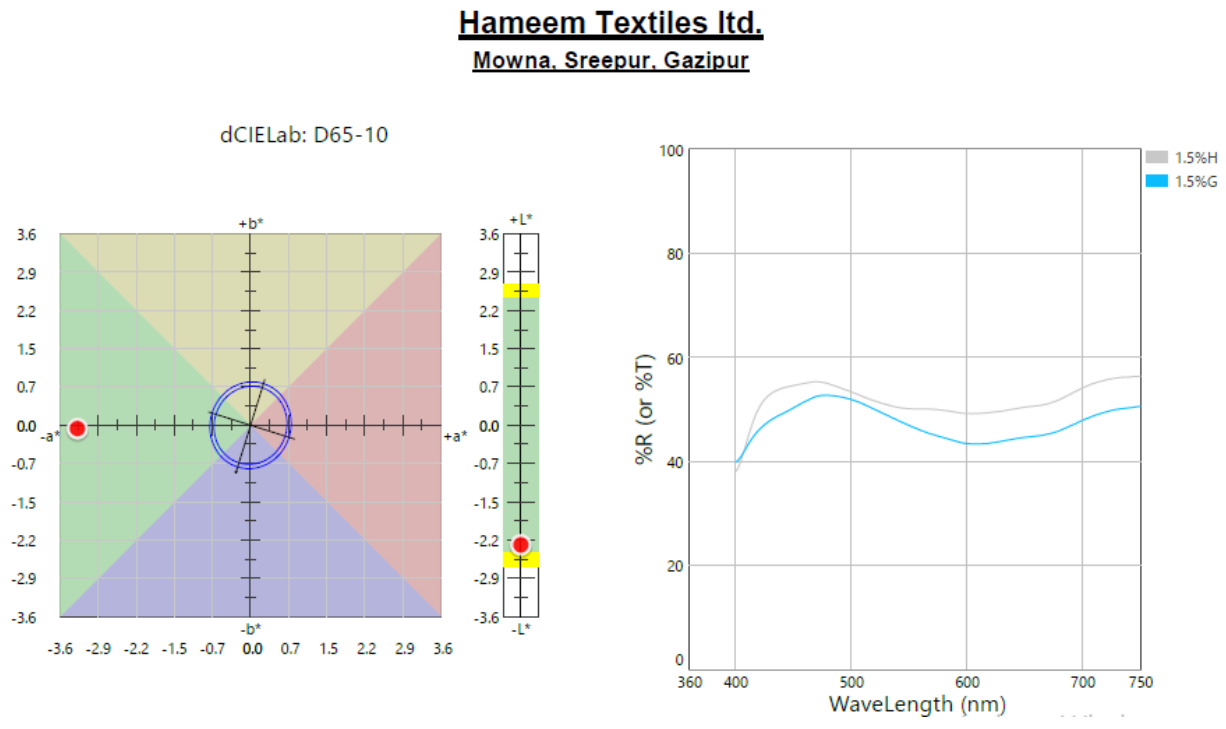

Chart-06: Color coordinates and Reflectance% of Vat (1.5%shade) Dyed Sample

Dye Samples	K/S values
(1.5% Hydrose) 	18.51
(1.5% Glucose) 	19.01

Since K/S value of 1.5% glucose shade is higher than 1.5% hydrose shade, so 1.5% glucose shade is lighter.

Vat Dye 3% Shade:

Hameem Textiles ltd.
Mowna, Sreepur, Gazipur

ILL 1 D65-10
ILL 2 TL84-10
ILL 3 F02-10 (CWF)

P/F Limit 1.00
Margin 10.00
l:c 2.00

Standard Nam	ill-obs	L*	a*	b*	C*	h°
STD.3%H	D65-10	70.16	-5.60	-7.10	9.04	231.75
	TL84-10	69.17	-4.55	-8.54	9.68	241.96

Trial Nam	DL*	Da*	Db*	DC*	DH*	DEcmc	P/F DEcmc	MI-(1,2)
3%G	-0.63 D	1.00 R	2.12 Y	-2.26 D	-0.61 G	2.09	**Failed**	0.48
TL84-10	-0.40 D	0.86 R	2.51 Y	-2.61 D	-0.50 G	2.28		

Table-14: Shade Comparison of 3% of Vat Dyed Sample

Here, L* indicates lightness, a* indicates greenish or reddish tone effect, b* indicates blueish or yellowish tone effect. C* indicates chroma and h◦ indicates hue angle. DL indicates if the shade is lighter or darker. And +DL indicates that shade is lighter & -DL indicates that shade is darker. Da*

represents redness-greenness difference between trial and standard color. If the value is positive then the shade is redder and if the value is negative then the shade is bluer. Db* represents blueness-yellowness difference between trial and standard color and if the value is positive then the shade is yellower and if the value is negative then shade is bluer. DC* indicates delta chroma and if the value is positive then it is brighter and if the value is negative then it is dull. DH* represents delta hue. DEcmc represents Deviation and for approval value should be 1 or less than that.

As we can see from the table-14, we took 3% shade dyed with hydrose as standard and 3% shade dyed with glucose as trial. And the result for trial DL* came darker since the value is negative. For Da*, in both light sources D65-10 and TL84-10 shade is redder. For Db*, in both light sources, the shade is yellower. For DC*, chroma is duller than the standard. Value of DEcmc is more than 1. Hence, result is failed.

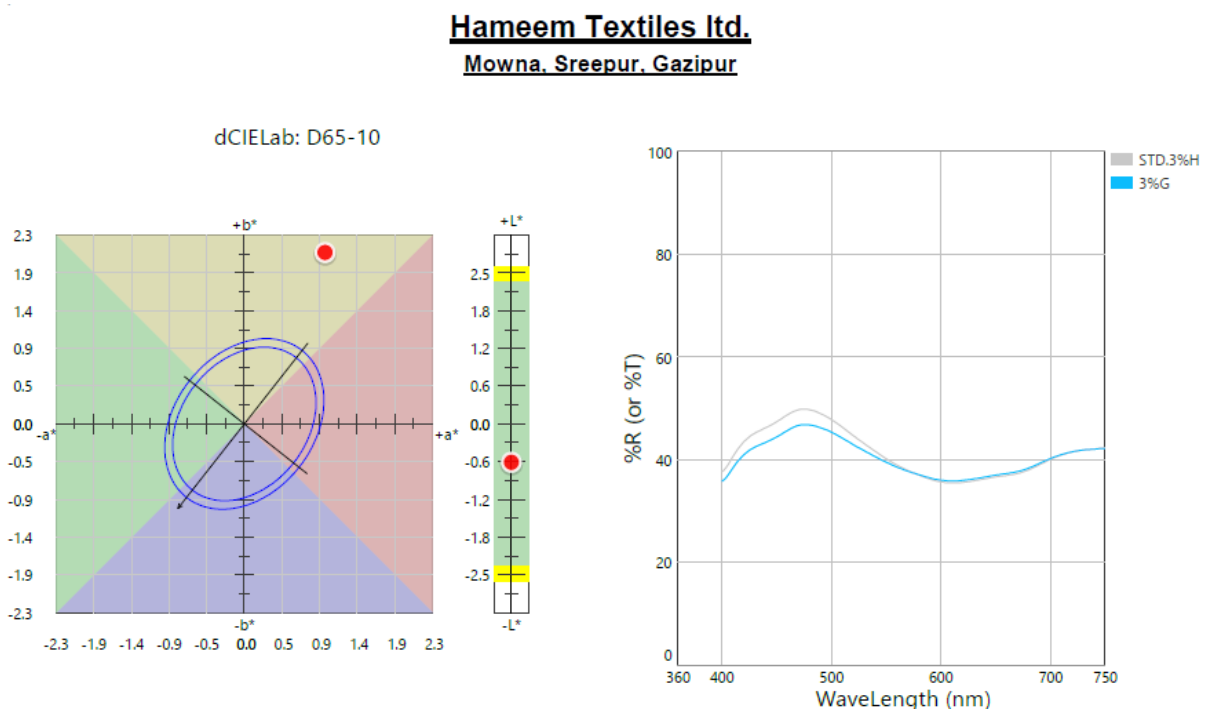

Chart-07: Color coordinates and Reflectance% of Vat (3%shade) Dyed Sample

Dyed Samples	K/S Value
(3% Hydrose) 	18.51
(3% Glucose) 	17.51

Since K/S value of 3% glucose shade is less than 3% hydrose shade, so 3% glucose shade is darker.

4.2 Color Fastness to Rubbing:

The capacity of dyed materials to maintain their original color when rubbed with a crock meter is known as rubbing color fastness. We tested color fastness to rubbing for all the samples.

Table-15: Color Fastness to Rubbing Test

Fabric & dyes type	**Shade%**	**Dry**	**Wet**
RC with Hydrose Polyester fabric (Disperse dye)	0.5%	4-5	3-4
	1.5%	4-5	4
	3%	4-5	3-4
RC with Glucose Polyester fabric (Disperse dye)	0.5%	4-5	4
	1.5%	4-5	4-5
	3%	4-5	4-5
Dyeing with hydrose Cotton knitted fabric	0.5%	4-5	3-4
	1.5%	4-5	3-4

(Sulphur dye)	3%	4-5	2-3
Dyeing with Glucose Cotton knitted fabric (Sulphur dye)	0.5%	4-5	3-4
	1.5%	4-5	3
	3%	4-5	3
Vatting with Hydrose Cotton knitted fabric dyeing (Vat dye)	0.5%	4	3
	1.5%	4	2-3
	3%	4	2-3
Vatting with Glucose Cotton knitted fabric dyeing (Vat dye)	0.5%	4	3
	1.5%	4	2-3
	3%	4	3

Discussions of results for rubbing test:

Color fastness to crocking/rubbing is scored on a scale of one to five. The higher the number, the faster the connection. Rubbing fastness "dry" is normally acceptable at grade 4, whereas rubbing fastness "wet" is acceptable at grades 3–4. For polyester fabric, both hydrose and glucose have good rubbing fastness. Both performed similarly across all shades. So, glucose is a safe reduction agent for polyester fabric RC.

For cotton knitted fabric dyed with sulfur dye, rubbing fastness for both hydrose and glucose as reducing agents was tested head to head across all shades. As a result, dyeing with sulfur dye and employing glucose as a reduction agent is satisfactory in terms of fabric rubbing fastness.

Finally, for cotton knitted fabric dying with vat dye, we use both hydrose and glucose as reducing agents for the vatting process, which is also suitable for fabric rubbing fastness for dry rub. However, the wet rub of glucose perfume is a little unexpected. In this case, glucose fails the wet rubbing test.

4.3 Color Fastness to Wash:

The capacity of dyed materials to maintain their original color when wash with a multi fiber strip is known as wash color fastness. We tested color fastness to wash for all the samples.

Table-16: Color Fastness to wash Test

	Shade %	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool	Color change grade
RC with hydrose polyester fabric	0.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	1.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	3%	4-5	4-5	4-5	4-5	4-5	4-5	4
RC with glucose polyester fabric	0.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	1.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	3%	4-5	4-5	4	4	4-5	4-5	4
Dyeing with hydrose cotton knitted fabric	0.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	1.5%	4-5	3-4	4-5	4-5	4-5	4-5	4
	3%	4-5	3-4	4-5	4-5	4-5	4-5	3-4
Dyeing with glucose cotton knitted fabric	0.5%	4-5	4-5	4-5	4-5	4-5	4-5	3-4
	1.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	3%	4-5	3-4	4-5	4-5	4-5	4-5	3-4
Vatting with hydrose cotton knitted fabric	0.5%	4-5	4-5	4-5	4-5	4-5	4-5	4
	1.5%	4-5	3-4	4-5	4-5	4-5	4-5	4
	3%	4-5	3-4	4-5	4-5	4-5	4-5	3
Vatting with glucose cotton knitted fabric	0.5%	4-5	3-4	3-4	4-5	4-5	4-5	4
	1.5%	4-5	3-4	4-5	4-5	4-5	4-5	4
	3%	4-5	3-4	4-5	4-5	4-5	4-5	3-4

Discussions of Results for Wash Fastness Test:

The color fastness test evaluates the color loss and color staining on the adjacent fabric caused by desorption and/or abrasion in a single test that is very close to a commercial or domestic laundry test. The two primary standards for washing detergents is ISO 105 C06. AATCC 61 is also used. The color change rating should be 4 and the color staining rating should be 3 to 5 when washing detergent.

Polyester fabric color stains in multifiber strips are similar for both hydrose and glucosides for all shade colors. The color-changing grade is 4, which is the same as the standard for the wash test. Therefore, the use of glucose as a reducing agent is accepted.

For cotton knitted fabrics dyed with sulfur dye, the color-changing grade in the multifiber strip matches the standard for the washing test. Both hydrose and glucose were successful for all shade colors, and the color changing grade was acceptable for both categories.

Finally dyeing cotton knitted fabric by vat dye and using hydrose and glucose as reducing agent for vatting samples wash fastness is also good. They performed head to head in term of wash fastness result. So, using glucose is acceptable for good wash fastness.

4.4 Color Fastness to Perspiration:

The capacity of dyed materials to maintain their original color relates to a fabric's capacity to resist fading and staining when it perspires. We tested color fastness to perspiration for all the samples.

Table-17: Color Fastness to Perspiration Test

	Shade %	Perspiration type	Acetate	Cotton	Nylon	Polyester	Acrylic	Wool	Color change grade
RC with hydrose Polyester fabric	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	1.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	3%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
RC with glucose polyester fabric	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	1.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	3%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Dyeing with hydrose cotton knitted fabric	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4
	1.5%	Acidic	4-5	4-5	4	4-5	4-5	4-5	4
		Alkaline	4-5	4-5	4	4-5	4-5	4-5	4
	3%	Acidic	4-5	3-4	4	4-5	4-5	4-5	4
		Alkaline	4-5	3-4	4	4-5	4-5	4-5	4
Dyeing with glucose cotton knitted fabric	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	3-4
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	3-4
	1.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4-5
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	3%	Acidic	4-5	3-4	4	4-5	4-5	4-5	3-4
		Alkaline	4-5	3-4	4	4-5	4-5	4-5	3-4
Vatting with glucose cotton	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	3-4
	1.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	3-4
	3%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4

knitted fabric		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4
Vatting with hydrose cotton knitted fabric	0.5%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4
		Alkaline	4-5	3-4	4-5	4-5	4-5	4-5	4
	1.5%	Acidic	4-5	3-4	4-5	4-5	4-5	4-5	3-4
		Alkaline	4-5	4-5	4-5	4-5	4-5	4-5	4
	3%	Acidic	4-5	4-5	4-5	4-5	4-5	4-5	4
		Alkaline	4-5	3-4	4-5	4-5	4-5	4-5	3-4

Discussions of results for perspiration test:

For both acidic and alkaline sweat, a color fastness level of 3–4 is necessary (color change and staining). For polyester fabric both hydrose and glucose samples color changing grade is about 4-5. So, using glucose performed as well as hydrose.

For cotton knitted fabric both Sulphur and Vat dye samples performed well as the requirement to pass the sample. All the shades color change grade is 4 which is good for perspiration test. We can say that using glucose instead of hydrose is good for acceptable perspiration test results.

Chapter 5: Conclusion

5.1 Conclusion:

The purpose of this study was to determine whether glucose could function as a natural reducing agent with the same effectiveness as any commercial reducing agent. During this experiment, we used six recipes for three different shades 0.5%, 1.5%, and 3% by using the commercial reducing agent and the natural reducing agent. We found the shade variation in the result and discussion part. Here we took the sample of commercial reducing agent as standard and the sample of natural reducing agent as trial to see yellowish, bluish, reddish, and which shade is darker in the data color machine in presence of two light sources. In case of 0.5%,1.5%, 3%Sulphur dye shade, shade dyed by glucose was darker than shade dyed by sodium sulphide. In case of 0.5%,1,5% and 3% vat dye shade, the yellowish tone effect was more visible. And 1.5% glucose vat dye shade was lighter than 1,5% hydrose vat dye shade In case of the 0.5% disperse dye shade, yellowish tone effect was more visible. But 1.5% and 3% disperse dye shade provided accurate result.

So, we can say that to dye in an eco-friendly environment, we can use glucose as a reducing agent. It will help to avoid the effects of hazardous effects of hazardous chemicals on the environment.

5.2 Suggestion for Future Work:

While doing this experiment with glucose as reducing agent, we faced some challenges. So, here are some suggestions for future scope:

- **Balancing pH medium**: We have to be very careful about the pH medium since extreme pH conditions can alter the reactivity and selectivity of glucose and can hamper its effectiveness.
- **Temperature:** We have to maintain proper temperature to achieve the optimal result.
- **Side Reactions:** We have to be careful as glucose can react with other functional groups or compounds present in the system, leading to byproducts. These side reactions may reduce the overall yield of the desired product.
- **Reaction Selectivity:** It is important to observe if glucose undergoes multiple reactions due to its complex structure. Ensuring the desired reaction is important.

Glucose is an eco-friendly, non-toxic natural reducing agent. So, it is safe to say that we use it to save our environment from the toxicity of the toxic chemicals.

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