Faculty of Engineering
Department of Textile Engineering

Thesis Report on:

Dyeing of 100% Knitted Polyester with Disperse Dyes Using Natural Acid-Buffer and Compared with Conventional Dyeing Method.

Course Code: TE 4214 Course Title: Project (Thesis)

Submitted By:

Name	ID
Avijit Suter	191-23-575
Md. Hasinuzzaman Rifat	191-23-595

Supervised by:

Md. Kamrul Islam
Lecturer, Department of Textile EngineeringDaffodil International University

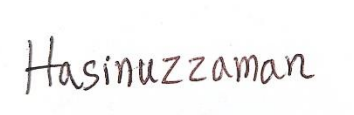
A Thesis submitted in partial fulfilled of the requirements for the degree of
Bachelor of science in Textile Engineering

Fall: 2022

DECLARATION

We therefore announce that, this project has been done by us under the supervision of **Md. Kamrul Islam,** Lecturer of the Textile Department and co-supervision of Daffodil International University. The total report is written on the basis of our own experiment. We also pronounce that neither this project nor any part of this undertaking has been submitted near differently for entitlement of any degree & certification in Textile Engineering degree.

Submitted By:



……..

Md. Hasinuzzaman Rifat

ID: 191-23-595

Department of TE

Daffodil International University

……...

Avijit Suter

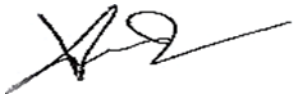
ID: 191-23-575

Department of TE

Daffodil International University

Letter of Approval

This Thesis report has been prepared by **Avijit Suter & Md. Hasinuzzaman Rifat**, whose **ID: 191-23-575 & 191-23-595** has been partially approved to meet the requirements for the degree of Bachelor of Science in Textile Engineering. The mentioned students have completed their thesis work under my supervision. During the research period I found them sincere, hardworking and enthusiastic.



.....

Md Kamrul Islam
Lecturer
Department Of TE
Faculty of Engineering.
Daffodil International University

Acknowledgement

Firstly, we express our heartiest thanks and appreciativeness to almighty Allah for his godly blessings which makes possible to complete this project successfully.

We are thankful and feel debt to our supervisor **Md. Kamrul Islam**, Lecturer, Department of Textile Engineering, Faculty of Engineering, Daffodil International University. Deep Knowledge and keen interest of our supervisor in the field of textile dyeing and finishing impacted us to carry out this project easily. His endless patience, scholar guidance, continual motivation, constant and vital supervision, formative review, precious advice, reading numerous inferior drafts and correcting them at all stages have made it possible to complete this project eventually.

We also wish to express our gratitude to **Md Mominur Rahman**, Head, Department of Textile Engineering, Daffodil International University for his continuous guidance to prepare this project report.

We are highly delighted to express our sincere gratitude to **Md. Arifur Rahman**, General Manager of **AMA Syntex Ltd**. & Admin and Compliance for giving us permission to work in Lab and provide important data about our project. We would like to express our heartiest thanks to the entire staffs of **AMA syntax Ltd**. for their friendly co-operation, helpful support and cordial behavior.

Last but not the least hearty gratitude to our all the teachers of the Department of Textile Engineering for their enormous support.

We dedicated this project work to our beloved parents. who nourishing our soul with their words & never giving up on us. Thank you for all the words of encouragement. For being the absolute rock that you are.

Table of content

ABSTRACT

Disperse dye is famous & most common element to dyeing polyester fabric in the textile world. It is the only dye which can capable to dyeing polyester fabric.

In this studies, focused on maintaining same pH value of dye bath 4.0-4.2, which is extremely required for polyester dyeing with disperse dye. Here also maintain same dye concentration, dyeing temperature and cooling method just bring change in chemical. For dyeing the polyester fabric with disperse dyes, need to use acetic acid for the maintain pH of dye bath and dispersing agent/levelling to proper dispersion of dye. In this experiment, trying to used citric acid which extracted from lemon and sodium citrate make from citric acid & baking soda. Here acid-buffer act as both dispersing agent & acetic acid & helps to dye adsorption on the fabric.

After completing dyeing, observe wash fastness and rubbing fastness difference, color strength difference in spectrophotometer and shade difference after changing chemical & check the all quality parameter of both dyed sample and compare them. The result is natural acid-buffer dyed sample slightly lighter in shade but the other quality parameters are satisfactory.

CHAPTER- 01
INTRODUCTION

1.1 Introduction

Dyeing of textile fabrics is an important process in the textile sector. Most of the dyeing processes of proteinic and synthetic fibers are carried out in acidic dye-bath. Acetic acid is one of the most widely used acids for adjusting the pH of the dye-baths in the range of 4 to 6. Upon economic basis, citric acid was thought to be used as an alternative product for adjusting the pH of the different dyeing baths [1].

Textile industry involves processing or converting raw material into finished textile materials via several processes which consume large amount of water and generate polluting waste effluents containing nonbiodegradable and dissolved toxic substances [2]. Acetic acid, toxic in high concentration, is generally used for adjusting the dyebath pH value in dyeing process [3].

Citric acid is a weak organic acid that is found in many fruits and vegetables especially citrus. The compound is produced by fermentation and used primarily in the foods, beverages, pharmaceutical, chemical, textile and electroplating industries. This acid is widely used in food industry, but it also finds applications as a function of additive detergents, pharmaceuticals, cosmetics and toiletries [4].
It is biodegradable, ecofriendly, economical, safe and a versatile chemical for sequestering, buffering, wetting, cleaning and dispersing [5].

Citric acid is known to have many applications in the textile sector and commonly used as a curing co-catalyst or as a crosslinker for durable press finishing. Citric acid, either alone or in a mixture with other poly carboxylic acids, has been reported as an auxiliary in the hydrogen peroxide bleaching of wool in acid medium. Many industrial trials are currently carried out in many textile mills to replace acetic acid by citric acid for disperse dyeing of polyester and acid dyeing of nylon. However, up to our knowledge, no comparative systematic study was carried out to investigate the difference in the dyeing properties [1].

Use of chemical in dyeing sector discharged lot of amount waste water on the environment. Which affected environment, rivers, agricultural land. That’s why if we found any alternative of toxic chemical which is collected from natural source and less harmful for environment. It’s very essential for textile sector.

In this study we can found, the source of citric acid can be lemon and the source of sodium citrate can be buffer of citric acid. Here both of this chemical collected from natural source, which reduced the environment pollution.

In this work, we used a single jersey 100% polyester fabric GSM of 101 dyed in 4 different shades (1%, 2%, 3%, 4%) with disperse dye (EVERSHINE DISPERSE RED FB). Maintaining same pH 4.0-4.2 and same temperature 135c. Just bring change in chemical instead of conventional dyeing chemical (Acetic acid & Disperse dye).

Finally, Compare the natural source & chemical source dyed-sample, and check the shade difference & other all parameters.

1.2 Objective

The key objective of this project are:

- To dyeing 100% of polyester fabric with disperse dye by using natural acid-buffer & conventional dyeing chemical.
- To fine the shade variation between them.
- To find the alternative of acetic acid & dispersing agent from natural source.
- To comparison of washing & rubbing fastness, color strength test between both dyed fabric.
- To reduce environmental pollution.

CHAPTER- 02

LITERATURE REVIEW

2.1 Types of fabric

Fabric is the process of interlocking or interlacing of yarn according to design.

There are many types of fabric:

- Synthetic fabric (Polyester, Nylon, Spandex etc.)
- Natural fabric (Jute, Hemp, Cotton, Wool, Silk etc.)

2.2 Polyester

Polyesters are one of the most used poly-condensation polymers belonging the class containing ester functional group on polymeric main chain. They are derived from dicarboxylic acids and diols and are usually denoted as PET (polyethylene terephthalate). Polyesters are used in various forms, fibers, filament, fabric, composites, resins, and membranes in different fields, such as textile, automotive, medical, electronic, and construction applications, etc.
It is the most important synthetic fiber worldwide in terms of production volume and applications.The main reason for its extensity is being the cheap and easily available raw material along with desirable properties. High tenacity, low creep, good resistance to strain and deformation, high glass transition temperature, and good resistance to acids and oxidizing agents are the desirable properties. All these physical, mechanical and chemical properties make it appropriate not only for apparel and textile products but also for industrial and composite applications [6].

2.3 Dye

Dyes are generally colored organic chemical compound, which are responsible for the coloration of dyed & printed textile material.
There are many types of dyes which responsible to color different types of fabric.

- Natural dyes (Turmeric, Indigo, Henna etc.)
- Synthetic dyes (Direct, Vat, Disperse, Reactive etc.)

2.4 Disperse dye

Disperse dyes are generally non-ionic synthetics with saving dissolvability in water that can hold similarly and better substantively for hydrophobic fibers, for example, nylon and polyester.

To acquire adequate dyeability, the dyeing of polyester fabrics must be performed at high temperature and high pressure or by utilizing a carrier, which suggests huge energy utilization and ecological tainting.

The carrier is an organic compound that quickens dyeing by separating or dissolving dye aggregates and carrying them to the fiber–water interface in little amounts that are enough to be absorbed by the material [7].

2.4.1 Structure of disperse dye

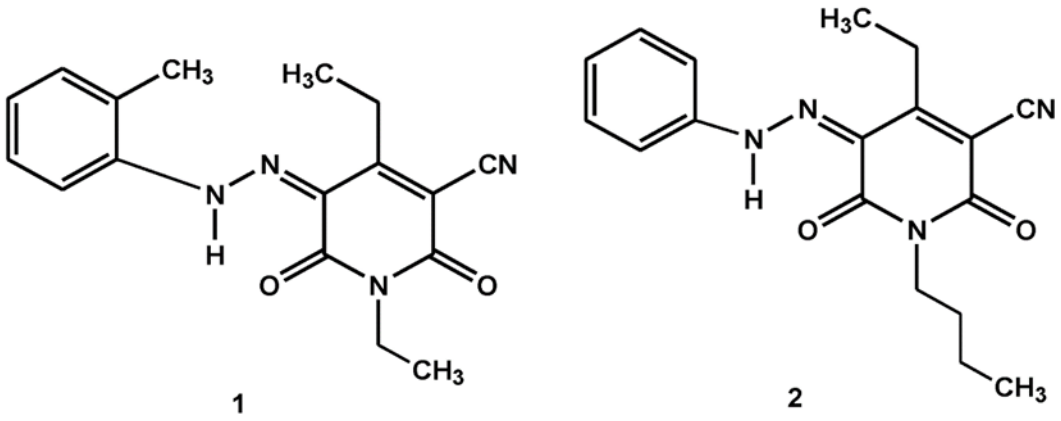


Fig no 01: Structure of disperse dye

2.4.2 Properties of disperse dye

- It's non-ionic dyes.
- Dyes are insoluble in water.
- Molecular size is very small.
- Appropriate for hydrophobic fiber.
- Good light-fastness & water-fastness.
- Required carrier or high temperature.

CHAPTER-3

Materials & Method

3.1 Materials

Dyes, chemical & fabric: In this project, we used polyester dyes such as EVERSHINE DISPERSE RED FB, Acetic acid (StarTex UN-2789), Disperse levelling (Biosphere), which all are collected from color lab of AMA Syntex ltd. We also used citric acid (lemon) & sodium citrate (Buffer of citric acid), which is collected from local market. We take 100% single jersey polyester fabric, which GSM is 101.

Sodium citrate solution:

Name of chemical	Concentration
Citric Acid	8ml
Baking Soda	9.5gm
Water	12.5ml

Table no 01: Sodium citrate solution

3.2 Method

3.2.1 Dyeing process:

At first we are take 8 sample of 100% single jersey polyester fabric, which GSM is 101 & each sample weight is 10gm. For identify the sample fabric is numbering at corner, here M:L= 1:8 ratio is maintained. Following the mentioned recipe, prepare the dye solution on pot. For polyester dyeing with disperse dye solution pH maintained 4.0-4.2. Then the sample are immersed on the solution. Finally the pot is loading in the sample dyeing machine at 40degree c temperature. The temperature is increase rapidly & reached 135degree c temperature run for 45minutes. After completing dyeing samples are washed by cooled water and dried by drier machine.

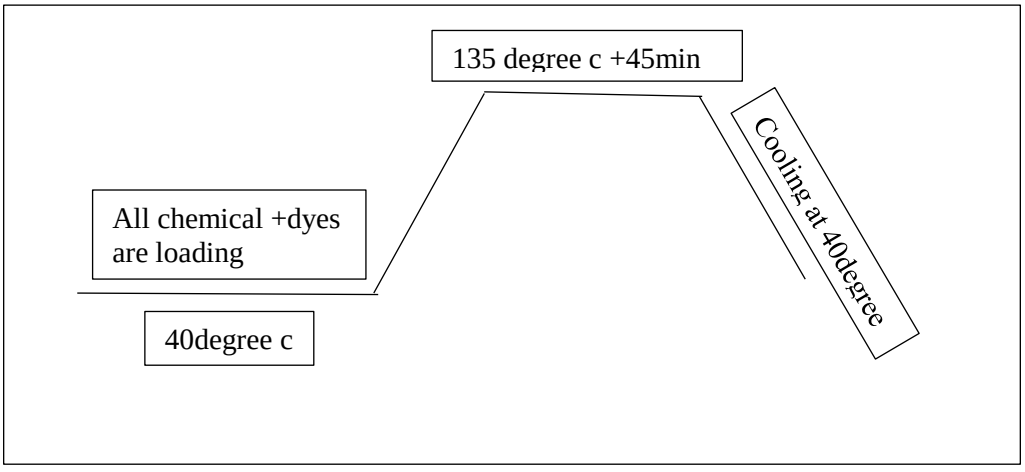


Fig no 02: Process curve of dyeing

3.2.2 Recipe for disperse dyeing with conventional dyeing method

Dyes & chemical	Concentration			
Dye (Evershine disperse red FB)	1%	2%	3%	4%
Acetic acid	0.8 ml/L	0.8 ml/L	0.8 ml/L	0.8 ml/L
Dispersing agent	2 ml/L	2 ml/L	2 ml/L	2 ml/L
M:L	1:8	1:8	1:8	1:8

Table no 02: conventional dyeing with acetic acid & dispersing agent

3.2.3 Recipe for disperse dyeing with natural acid-buffer

Dyes & chemical	Concentration			
Dye (Evershine disperse red FB)	1%	2%	3%	4%
Citric acid (Lemon)	15 ml/L	15 ml/L	15 ml/L	15 ml/L
Sodium citrate	2 ml/L	2 ml/L	2 ml/L	2 ml/L
M:L	1:8	1:8	1:8	1:8

Table no 03: Disperse dyeing with citric acid & Sodium citrate

3.3 Testing of Color Fastness

Colorfastness refers the resistance to fading the property of a dye to retain it's color. When the dyed textile material is exposed to condition or agent such as light, perspiration, rubbing or washing that can remove or destroy the color. It's the most important quality parameter of fabric. There are different types color-fastness test:

- Color-fastness to wash.
- Color-fastness to rubbing.
- Color-fastness to water.
- Color-fastness to light.
- Color-fastness to perspiration.

3.3.1 Color-fastness to wash

Color fastness to wash refers the color fading of dyed sample after detergent washing. In this experiment the wash fastness of dyed sample are assessment following by ISO 105 c06 method.

At first testing specimen are cut by the scissor & attached with multifiber fabric. Then make a solution of 4gm/L ECE detergent & 1gm/L sodium perborate & take 150ml on each pot. Fabric are immersed on the pot with 10pices steel-ball. Then solution pot feed on the Gyrowash machine and run 30min in 40degree c temperature. After completing the process samples are washed by cooled water and dried by drier machine. Finally, the multifiber are assessment with Gray-Scale & find out the color fading or staining grade.

3.3.2 Color fastness to rubbing

Rubbing fastness of a colored sample refers the color transformation of sample due to rubbing. This test held on both dry & wet condition. The testing procedure carried out on lab following ISO EN 105*12.

- **Dry rubbing test:** At first the specimen setup on crockmeter, a white rubbing cotton cloth install the finger of crockmeter by a clip. Then fixed the finger over the specimen & move 10times forward & backward. After rubbing test is carried out the degree of staining is assessed with gray scale.
- **Wet rubbing test:** It's similar to dry rubbing test just a wet white rubbing cotton cloth used instead of dry rubbing cloth.

3.3.3 Color variation test

In this test we are using computer color matching system (CCMS) in DATACOLOR machine. We are used disperse dye (EVERSHINE disperse red FB) in different concentration (1%, 2%, 3%, 4%). That's why we are make shade to shade comparison like 2% with 2% after bring chemically change in same concentration.

3.4 Machinery used in project

1. Sample dyeing machine

Fig no 03: ECO DYER

Specification:

- Equipment Name: Eco Dyer
- Brand : Xiamen rapid co. ltd
- Capacity : 24 pot
- Origin : China

2. Wash fastness tester

Fig no 04: GYROWASH

Specification:

- Equipment Name: GYROWASH
- Brand : James heals
- Model : 13158
- Origin : UK

3. Rubbing fastness tester

Fig no 05: Crockmaster

Specification:

- Equipment Name: Crockmaster
- Brand : James heals
- Model : 670 hand driven crockmeter
- Origin : UK

4. Light box

Fig no 06: Light box

Specification:

- Equipment Name: Light box
- Brand : Test Tex
- Model : TU300A
- Origin : China

5. Spectrophotometer

Fig no 07: Spectrophotometer

Specification:

- Equipment Name: Spectrophotometer
- Brand : Datacolor
- Model : Datacolor 800
- Origin : USA

CHAPTER- 04

RESULTS & DISCUSSION

4.1 Shade% variation of dyed fabric

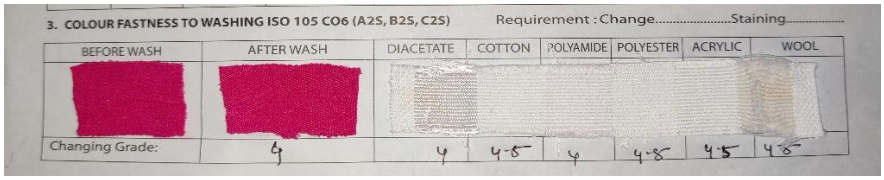
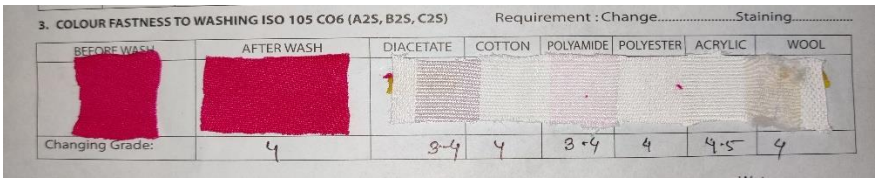
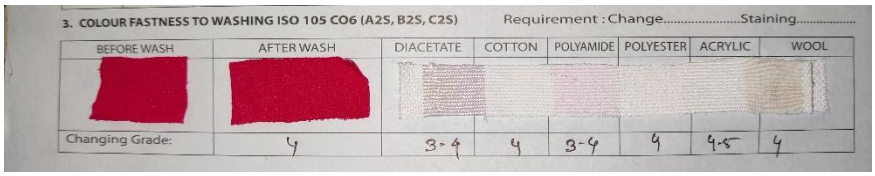
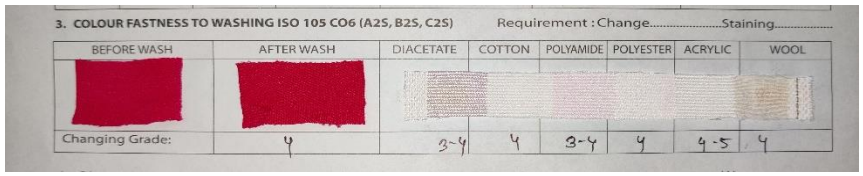
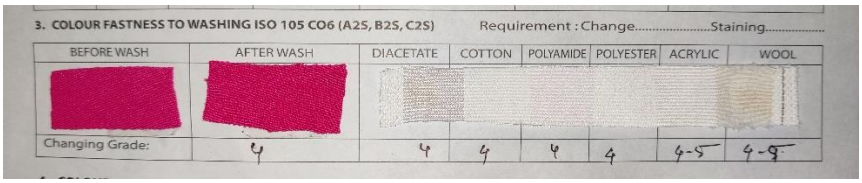
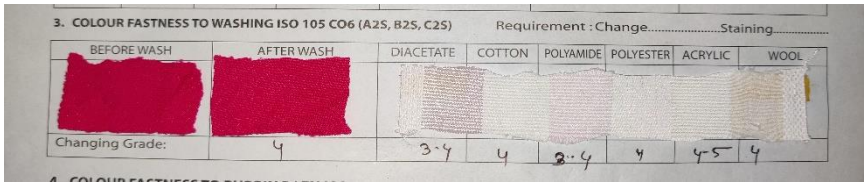
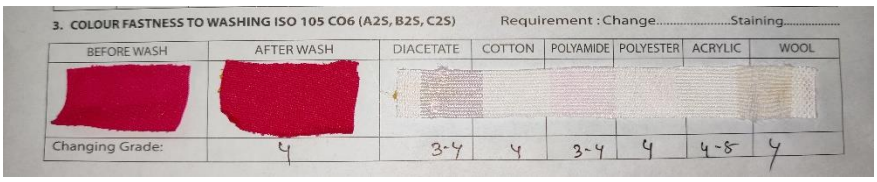
After completing dyeing of 8 sample following the same dye color (EVERSHINE disperse red FB) same dye concentration (1%, 2%, 3%, 4%), same pH & temperature, just bring chemically change in recipe the shade is produced. Here 4 sample shade is produced by conventional dyeing chemical (Acetic acid & dispersing agent) and other 4 sample shade is produced by natural acid-buffer (Citric acid & sodium citrate).

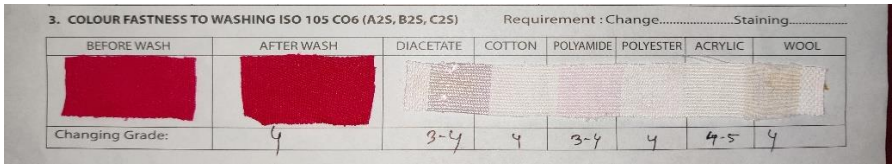
The shade difference between them shown below:

Dye concentration	Conventional dyeing method	Natural acid-buffer
1% (EVERSHINE disperse red FB)		
2% (EVERSHINE disperse red FB)		
3% (EVERSHINE disperse red FB)		
4% (EVERSHINE disperse red FB)		

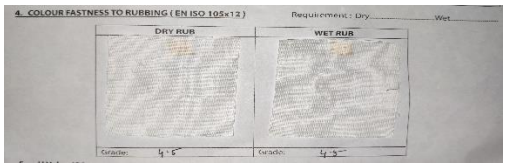
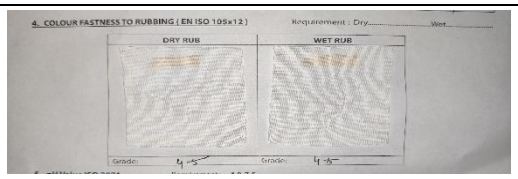
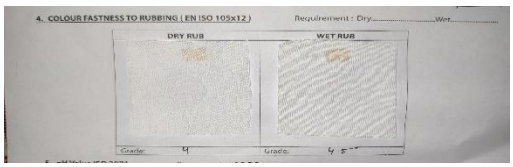
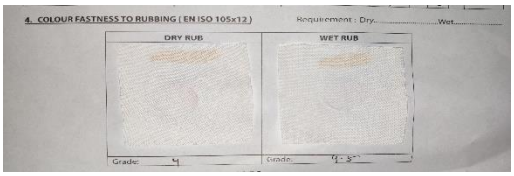
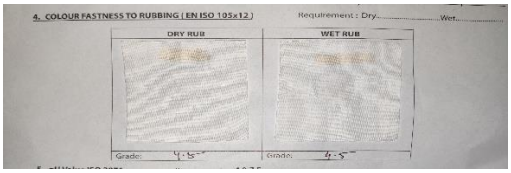
4.2 Sample attachment

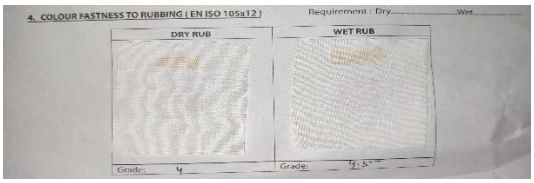
4.2.1 Color fastness to wash test sample:

Sample (Dye concentration + chemical)	Attachment
1% (EVERSHINE disperse red FB)+ Conventional dyeing method	
2% (EVERSHINE disperse red FB) + Conventional dyeing method	
3% (EVERSHINE disperse red FB) + Conventional dyeing method	
4% (EVERSHINE disperse red FB) + Conventional dyeing method	
1% (EVERSHINE disperse red FB) + Natural acid-buffer	
2% (EVERSHINE disperse red FB) + Natural acid-buffer	
3% (EVERSHINE disperse red FB) + Natural acid-buffer	

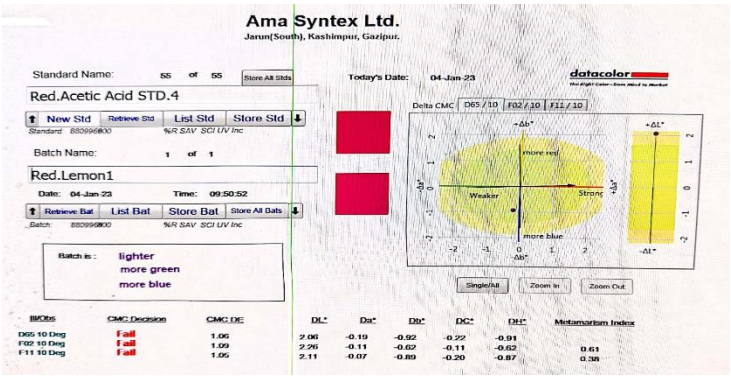
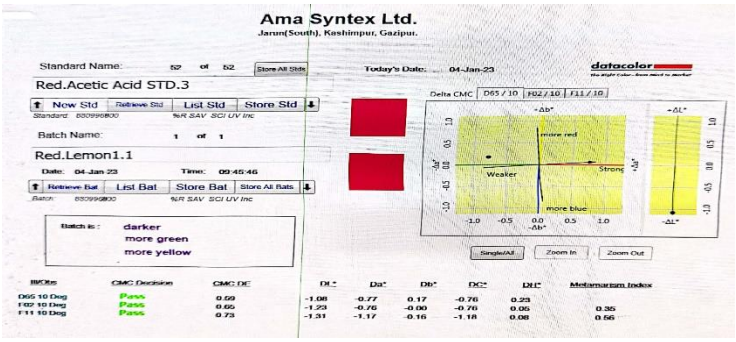
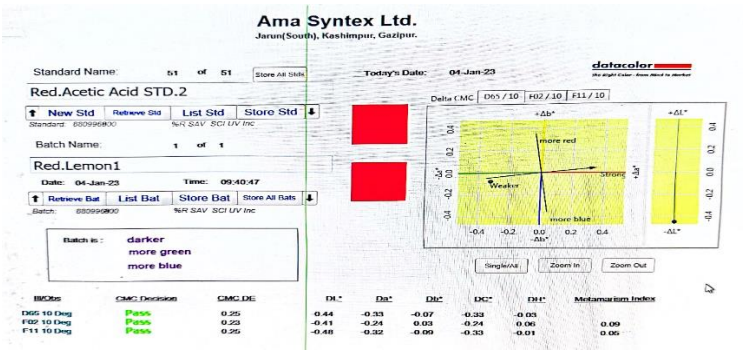
4% (EVERSHINE disperse red FB) + Natural acid-buffer	

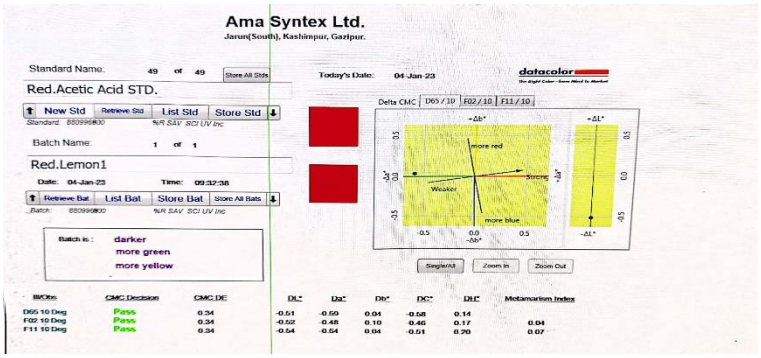
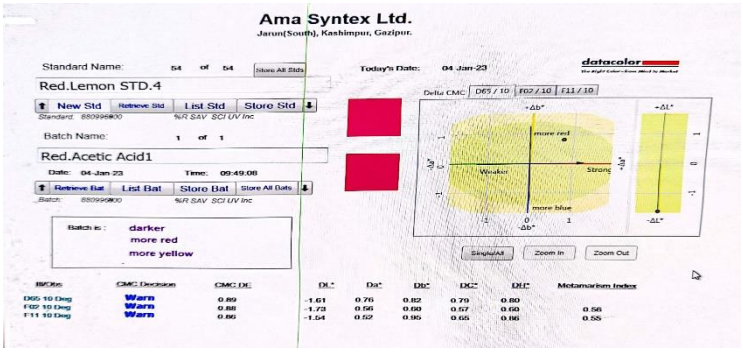
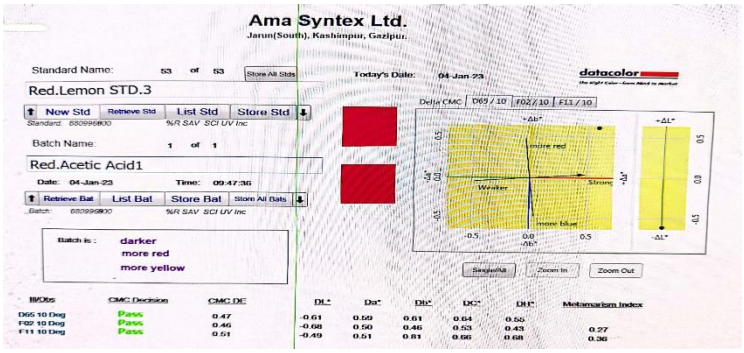
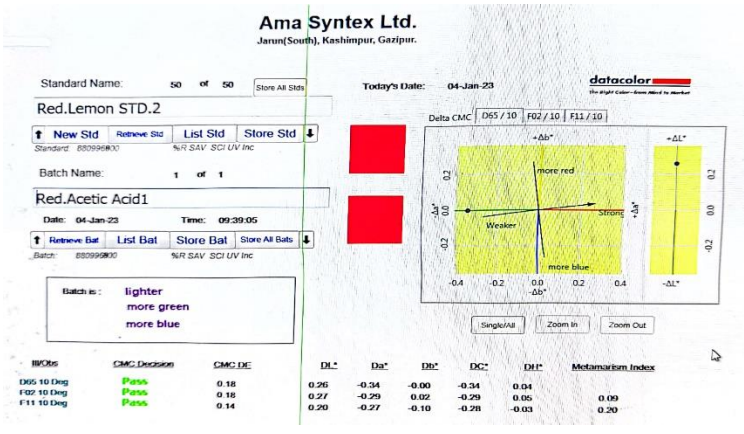
4.2.2 Color fastness to rubbing fastness sample:

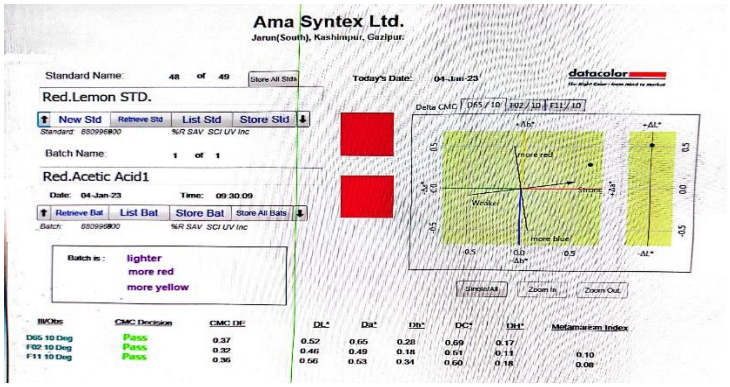
Sample (Dye concentration + chemical)	Attachment
1% (EVERSHINE disperse red FB) + Conventional dyeing method	
2% (EVERSHINE disperse red FB) + Conventional dyeing method	
3% (EVERSHINE disperse red FB) + Conventional dyeing method	
4% (EVERSHINE disperse red FB) + Conventional dyeing method	
1% (EVERSHINE disperse red FB) + Natural acid-buffer	
2% (EVERSHINE disperse red FB) + Natural acid-buffer	
3% (EVERSHINE disperse red FB) + Natural acid-buffer	

4% (EVERSHINE disperse red FB) + Natural acid-buffer	

4.2.3 Spectrophotometer assessment test sample:

Sample (Dye concentration + chemical)	Sample (Dye concentration + chemical)	Attachment
1% (EVERSHINE disperse red FB) + Conventional dyeing method	1% (EVERSHINE disperse red FB) + Natural acid-buffer	
2% (EVERSHINE disperse red FB) + Conventional dyeing method	2% (EVERSHINE disperse red FB) + Natural acid-buffer	
3% (EVERSHINE disperse red FB) + Conventional dyeing method	3% (EVERSHINE disperse red FB) + Natural acid-buffer	

4% (EVERSHINE disperse red FB) + Conventional dyeing method	4% (EVERSHINE disperse red FB) + Natural acid-buffer	
1% (EVERSHINE disperse red FB) + Natural acid-buffer	1% (EVERSHINE disperse red FB) + Conventional dyeing method	
2% (EVERSHINE disperse red FB) + Natural acid-buffer	2% (EVERSHINE disperse red FB) + Conventional dyeing method	
3% (EVERSHINE disperse red FB) + Natural acid-buffer	3% (EVERSHINE disperse red FB) + Conventional dyeing method	

4% (EVERSHINE disperse red FB) + Natural acid-buffer	4% (EVERSHINE disperse red FB) + (Acetic acid & dispersing agent)	

4.3 Rating of color fastness to wash

Color fastness to wash is the most important quality parameter of fabric. Here a multifiber attach with sample. Multifiber contain different types of fiber like acetate, bleached cotton, polyamide, polyester, acrylic, wool. After assessment all this sample find slightly difference between the staining of acetate & polyamide parts. Here the rating of color fastness to washing of dyed sample are provide:

Sample	**Change of color**	**Staining**					
		Acetate	Cotton	Polyamide	Polyester,	Acrylic	Wool
1% (Conventional dyeing method)	4	4	4/5	4	4/5	4/5	4/5
2% (Conventional dyeing method)	4	3/4	4	¾	4	4/5	4
3% (Conventional dyeing method)	4	3/4	4	3/4	4	4/5	4

4% (Conventional dyeing method)	4	3/4	4	¾	4	4/5	4
1% (Natural acid-buffer)	4	4	4	4	4	4/5	4/5
2% (Natural acid-buffer)	4	3/4	4	¾	4	4/5	4
3% (Natural acid-buffer)	4	3/4	4	¾	4	4/5	4
4% (Natural acid-buffer)	4	3/4	4	¾	4	4/5	4

Table no 04: Rating of color fastness to wash

4.4 Rating of color fastness to rubbing

Rubbing fastness refers the transformation of color from dyed fabric to testing due to rubbing it can be asses by two way dry rubbing & wet rubbing. Here the rating of color fastness to rubbing of dyed sample are provide:

Sample	Rating	
	Dry	Wet
1% (Conventional dyeing method)	4/5	4/5
2% (Conventional dyeing method)	4/5	4/5
3% (Conventional dyeing method)	4	4/5
4% (Conventional dyeing method)	4	4/5
1% (Natural acid-buffer)	4/5	4/5
2% (Natural acid-buffer)	4/5	4/5
3% (Natural acid-buffer)	4/5	4/5
4% (Natural acid-buffer)	4	4/5

Table no 05: Rating of color fastness to rubbing

4.5 Spectrophotometer assessment

A spectrophotometer is an apparatus that can be used to identify the constituent elements of a material. Spectrophotometer uses the principle of interaction between the light spectrum that has a certain frequency with the material so that it can be measured the transmittance or absorbance of the sample as a function of concentration [8]. Here,

- DL* = Lightness/Darkness (+ = Lighter/ - = Darker)
- Da* = Red/Green (+ = Redder/ - = Greener)
- Db* = Yellow/Blue (+ = Yollower/ - = Bluer)
- Dh° = Hue
- Dc* = Chromacity or Saturation (+ = more saturated/ - = less satureted)
- DE* = Total color difference

Here the rating of color difference assessment by spectrophotometer of dyed sample are provide:

Standard	Sample	Illuminance	DE*	DL*	Da*	Db*	DC*	DH*
1% (Conventional dyeing method)	1% (Natural acid-buffer)	D65 10 DEG	1.06	2.06	-0.19	-0.92	-0.22	-0.91
		F02 10 DEG	1.09	2.26	-0.11	-0.62	-0.11	-0.62
		F11 10 DEG	1.05	2.11	-0.07	-0.89	-0.20	-0.87
2% (Conventional dyeing method)	2% (Natural acid-buffer)	D65 10 DEG	0.59	-1.08	-0.77	0.17	-0.76	0.23
		F02 10 DEG	0.65	-1.23	-0.76	-0.00	-0.76	0.05
		F11 10 DEG	0.73	-1.31	-1.17	-0.16	-1.18	0.08
3% (Conventional dyeing method)	3% (Natural acid-buffer)	D65 10 DEG	0.25	-0.44	-0.33	-0.07	-0.33	-0.03
		F02 10 DEG	0.23	-0.41	-0.24	0.03	-0.24	0.06
		F11 10 DEG	0.25	-0.48	-0.32	-0.09	-0.33	-0.01
4% (Conventional dyeing method)	4% (Natural acid-buffer)	D65 10 DEG	0.34	-0.51	-0.59	0.04	-0.58	0.14
		F02 10 DEG	0.34	-0.52	-0.48	0.10	-0.46	0.17
		F11 10 DEG	0.34	-0.54	-0.54	0.04	-0.51	0.20
1% (Natural acid-buffer)	1% (Conventional dyeing method)	D65 10 DEG	0.89	-1.61	0.76	0.82	0.79	0.80
		F02 10 DEG	0.88	-1.73	0.56	0.60	0.57	0.60
		F11 10 DEG	0.86	-1.54	0.52	0.95	0.65	0.86
2% (Natural acid-buffer)	2% (Conventional dyeing method)	D65 10 DEG	0.47	-0.61	0.59	0.61	0.64	0.55
		F02 10 DEG	0.46	-0.68	0.50	0.46	0.53	0.43
		F11 10 DEG	0.51	-0.49	0.51	0.81	0.66	0.68

3% (Natural acid-buffer)	3% (Conventional dyeing method)	D65 10 DEG	0.18	0.26	-0.34	-0.00	-0.34	0.04
		F02 10 DEG	0.18	0.27	-0.29	0.02	-0.29	0.05
		F11 10 DEG	0.14	0.20	-0.27	-0.10	-0.28	-0.03
4% (Natural acid-buffer)	4% (Conventional dyeing method)	D65 10 DEG	0.37	0.52	0.65	0.28	0.69	0.17
		F02 10 DEG	0.32	0.46	0.49	0.18	0.51	0.11
		F11 10 DEG	0.36	0.56	0.53	0.34	0.60	0.18

Table no 06: color difference assessment by spectrophotometer

CHAPTER-5

CONCLUSION

5.1 Conclusion

In this study, the main observed factor is the effect of citric acid & sodium citrate use as alternative of acetic acid & dispersing agent in the dyeing of 100% polyester fabric with same concentration disperse dye & try to compare the shade variation, color-fastness difference. In here we following same dye concentration, pH & temperature.

After completing dyeing dyed fabric are evaluated by spectrophotometer, we see the shade difference between them. We have found the natural acid-buffer dyed sample are slightly lighter than conventionally dyed sample.

The rubbing fastness quality are check by crockmeter but there is not too much difference are found. Both dry & wet rubbing test sample rating are around similar, which is mentioned in table no 5.

The wash fastness quality of dyed sample are found good. We have found similarity in both sample, but some staining are occurred in acetate & polyamide part of multifiber.

After analysing all this project it can be say that, citric acid & sodium citrate is the good alternative of acetic acid & dispersing agent. It's safe for environment & reduce water pollution. If the cost is maintained & source is easily availeable then it's a good option.

Reference:

[1] H. El-Sayed, L. K. El-Gabry*, and A. Kantouch, Replacement of Acetic Acid with Citric Acid in Dyeing of Textile Fabrics, Textile Processing: State of the Art & Future Developments, April 2005, Vol.2 (1), P-61-68

[2] Zhan, B.J. and Poon, C.S. (2015) Study on feasibility of Reutilizing Textile Effluent Sludge for Producing Concrete Blocks. Journal of Cleaner Production, 101, 174-179. https://doi.org/10.1016/j.jclepro.2015.03.083

[3]Al-Mousawi, S.M., El-Apasery, M.A. and Elnagdi, M.H. (2013) Microwave Assisted Dyeing of Polyester Fabrics with Disperse Dyes. Molecules, 18, 11033-11043. https://doi.org/10.3390/molecules180911033

[4]Soccol, C.R., Vandenberghe, L.P.S., Rodrigues, C. and Pandey, A. (2006) New Perspectives for Citric Acid Production and Applications. Food Technology and Biotechnology, 44, 141-149. http://www.ftb.com.hr/images/pdfarticles/2006/April-June/44-141.pdf

[5]Angumeenal, A.R. and Venkappayya, D. (2013) An Overview of Citric Acid Production. Food Science and Technology, 50, 367-370.

[6] Islam, Md.R. and Fatema, U.K. (2021) A Comparative Analysis of Polyester Fabric Properties between Dyed with Indigo and with Disperse Dyes. Journal of Textile Science and Technology, 7, 77-90. https://doi.org/10.4236/jtst.2021.72007

[7]Alya M. Al-Etaibi, Morsy Ahmed El-Apasery, Dyeing Performance of Disperse Dyes on Polyester Fabrics Using Eco-Friendly Carrier and Their Antioxidant and Anticancer Activities, *Int. J. Environ. Res. Public Health* **2019**, *16*(23), 4603; **https://doi.org/10.3390/ijerph16234603**

[8] Anis Yuniati and Rochan Rifai, Study of simple spectrophotometer design using LDR sensors based on arduino uno microcontrolle 2019 J. Phys.: Conf. Ser. 1153 012099 doi:10.1088/1742-6596/1153/1/012099