

**Application of Selected Natural Dyes for Designing and Developing of
Casual Wears**

By

GOPIKA. J

(20PBX004)

A Thesis submitted to the

**Avinashilingam Institute for Home Science and Higher
Education for Women Coimbatore -641043**

In Partial Fulfilment of the Requirement for the

Degree of Master of Science in

BIO-TEXTILES

MAY 2022

**Application of Selected Natural Dyes for Designing and Developing of
Casual Wears**

By

GOPIKA. J

(20PBX004)

A Thesis submitted to the

Avinashilingam Institute for Home Science and Higher

Education for Women Coimbatore -641043

In Partial Fulfilment of the Requirement for the

Degree of Master of Science in

BIO-TEXTILES

MAY 2022

Certified as Bonafide Research Work


Signature of the Head of the Department


Signature of the Supervisor

DECLARATION

I declare that the dissertation entitled “**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**” submitted by me for the degree of Master of science (M.Sc.,) is the record of work carried out by me during the period from 2021 to 2022 under the guidance of **Dr. (Tmt.) U. RATNA**, M.Sc., M.Phil., Ph.D. (Avinashilingam), Assistant Professor (SG), Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore-642 043 and has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning.



Signature of the Candidate

CERTIFICATE FROM THE SUPERVISOR

I certify that dissertation entitled “**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**” submitted for the degree of Master of science (M.Sc.) Bio-Textiles by **Gopika. J** is the record of project work carried out by her during the academic year 2021 to 2022 under my guidance and supervision and this work has not formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship, Titles in this University or any other similar institution of higher learning.


Signature of the HOD


Signature of the Supervisor with Designation

ACKNOWLEDGMENT

First and foremost, I would like to express my humble salutations and prayer to the **ALMIGHTY GOD** for his uncountable blessings showered upon me throughout the study.

I expresses my sincere thanks to the former chancellors of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, **Padmabushan, Dr.T.S.AVINASHILINGAM and HON.COL.PADMASHRI, Dr. (Tmt.) RAJAMMAL P.DEVADAS**, M.A., M.Sc., Ph.D. (Ohio state)Hon.D.SC. (Azad Agri.University, Kanpur),for heavenly blessing.

I am very grateful to **Dr.S.P THYAGARAJAN** chancellor of Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore, for providing the infrastructural facilities for the conduct of the study.

I records my gratitude to **Dr. (Mrs)V. BHARATHI HARISHANKAR**, Ph.D.,FRSA Vice chancellor of Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore, for providing all the amenities required for the conduct of the study.

I records myr gratitude to **Dr. (Mrs) S. KOWSALYA**, M.Sc., M.Phil., Ph.D., Registrar of Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore, for providing all the help for the smooth conduct of the study.

I also express my respectful gratitude to **Dr. (Tmt) N. VASUGI**, M.Sc., M.B.A., M.Phil., Ph.D. Dean, School of Home Science and Professor in Textiles and Clothing, Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore, for constant support, guidance and encouragement which have helped in the successful completion of this study.

I owe my respectful gratitude to **Dr. KALAIARASI**, M.Sc., M.Phil., Ph.D., Associate Professor and Head, Department of Textile and Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for constant guidance and encouragement which have helped in the successful completion of this study.

I am extremely proud and privileged for having worked under the guidance of my esteemed guide, **Dr. (Tmt.) U. RATNA**, M.Sc., M.Phil., Ph.D., Assistant Professor (SG), Department of Textiles and Clothing, Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore, for constant support, guidance and encouragement which have helped in the successful completion of this study.

It's my pleasure and privilege to express my deep sense of gratitude to **AMBROSE KOOLIYATH**, Director of Farmer's Share and to **Dr. MIRIUM M ABRAHAM**, Coordinator of Textile and Craft Department who helped me with their constructive suggestions at all times. I acknowledges my thanks to **Farmer's Share Charitable Trust in Shorannur** for providing the facilities for the study processes.

I also wish to thank all the **TEAHING, NON-TEACHING STAFF and STUDENTS** of the department of Textiles and Clothing who helped me to carry out the research work. I acknowledges my special thanks to **Avinashilingam Institute for Home Science Higher Education for Women, Coimbatore** for providing laboratory and library facilities.

I would like to express my deepest sense of gratitude to my **Beloved Parents, Family Members and Friends** for extending their support without them the Study would never have been seen the light of the day.

CONTENT

CHAPTER	TITLE	PAGE NO
	LIST OF TABLES	
	LIST OF FIGURES	
	LIST OF PLATES	
	LIST OF APPENDICES	
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	6
	2.1. Natural Dye	8
	2.1.1. Introduction	8
	2.1.2. History	8
	2.1.3. Classification Of Natural Dyes	9
	2.1.3.1. Natural Dyes Are Classified According To Their Hues	10
	2.1.3.2. Natural Dyes Can Be Classified As Follows Based On Their Application Method	11
	2.1.3.3. Natural Dyes Can Be Classified As Follows Based On Their Chemical Structure	12
	2.1.4. Functional Properties Of Natural Dyes	13
	2.1.4.1. Introduction	13
	2.1.4.2. Antimicrobial/ Antibacterial Property	14
	2.1.4.3. Uv Protection	15

	2.1.4.4. Deodorising	16
	2.1.4.5. Moth Proof And Insect Repellent	17
	2.1.4.6. Mosquito Repellent	17
	2.1.5. Advantages Of Natural Dyes	17
	2.1.6. Disadvantages Of Natural Dyes	18
	2.2. Khadi	18
	2.2.2. History	19
	2.2.3. Properties	19
	2.2.4. Advantages Of Khadi Cotton Fabrics	20
	2.3.Sources Of Natural Dye	20
	2.3.1. Introduction	20
	2.3.2. Rubia Cordifolia	20
	2.3.2.1. Composition	20
	2.3.2.2. Properties	21
	2.3.2.3. Uses	22
	2.3.2. Acacia Catechu	22
	2.3.3.1. Composition	23
	2.3.3.2. Properties	23
	2.3.3.3. Uses	24
	2.3.4. Terminalia Chebula	24
	2.3.4.1. Composition	24
	2.3.4.2. Properties	25

	2.3.4.3. Uses	25
	2.4. Mordanting	25
	2.4.1. Types Of Mordants	26
	2.4.2. Mordanting Techniques	26
	2.4.3. Extraction Of Natural Sources	27
	2.4.3.1. Extraction Techniques	27
	2.5. Design	28
	2.5.1. Elements Of Designs	28
	2.5.2. Principles Of Designs	30
	2.6. Fashion Portfolio	31
	2.6.1. Introduction	31
	2.6.2. Development Of Boards	32
	2.6.2.1. Theme Board	32
	2.6.2.2. Mood Board	32
	2.6.2.3. Color Board	32
	2.6.2.4. Fabric Swatches Board	32
	2.6.2.5. Sketch Board	32
3	METHODOLOGY	33
	3.1. Selection of Materials	35
	3.1.1. Selection of Fabric	35
	3.1.1.1. Pre-Treatment of Fabric	35
	3.1.1.1.1. Scouring	35

	3.1.2. Selection of Dye Sources	37
	3.1.2.1. Rubia Cordifolio	37
	3.1.2.2. Terminalia Chebula	37
	3.1.2.3. Acacia Catechu	38
	3.2. Selection of Mordants	39
	3.2.1. Alum	40
	3.2.2. Terminalia Chebula	40
	3.3. Techniques Used for Mordanting	40
	3.3.1. Pre-Mordanting	40
	3.4. Procedure for Dye Extraction	40
	3.5. Dyeing Process	42
	3.5.1. Dyeing	43
	3.5.2. Washing	45
	3.5.3. Drying	46
	3.6. Evaluation of Fabric	47
	3.6.1. Subjective Evaluation	47
	3.6.1.1. Visual Inspection	47
	3.6.2. Objective Evaluation	47
	3.6.2.1. Fabric Weight	47
	3.6.2.2. Fabric Thickness	48
	3.6.2.3. Fabric Stiffness Test	48
	3.6.2.4. Drape Test	49

	3.6.2.5.Colourfastness Test	49
	3.6.2.5.1. Fastness to Sunlight	50
	3.6.2.5.2. Fastness to Wet And Dry Pressing	50
	3.6.2.5.3. Fastness to Crocking	50
	3.6.2.5.4. Fastness to Washing	51
	3.7. Development Of Portfolio	52
	3.7.1. Mood Board	53
	3.7.2. Color Board	54
	3.7.3. Fabric Swatches	55
	3.7.4. Flat Sketch	56
	3.8.Development of Garments	59
	3.8.1. Drafting Patterns	59
	3.8.2. Construction of Garments.	60
	3.8.2.1. Tie and Dye Top	60
	3.8.2.2. Ombre Gown	61
	3.8.2.3. Tie and Dye Jumpsuit	62
	3.9.Statistical Analysis.	63
4	RESULTS AND DISCUSSION	65
	4.1.Subjective Evaluation	66
	4.1.1. Visual Inspection	66
	4.2. Objective Evaluation	67
	4.2.1. Physical Property Test	67

	4.2.1.1. Fabric Thickness	67
	4.2.1.2. Fabric Weight	68
	4.2.2. Comfort Property Test	70
	4.2.2.1. Drape Test	70
	4.2.2.2. Fabric Stiffness	71
	4.2.3. Color Fastness to Sunlight, Washing, Pressing Drying And Crocking	74
	4.3. Designed Garment	75
	4.3.1. Ombre Gown	75
	4.3.2. Tie and Dye Jumpsuit	76
	4.3.3. Tie and Dye Top	77
5	SUMMARY AND CONCLUSION	78
6	BIBLIOGRAPHY	82
7	APPENDICES	93

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
I	Some Vegetable Natural Dyes from Different Parts of Plants	12
II	Natural Dyes with Responsible Component for Antimicrobial Properties	15
III	Natural Dyes with Responsible Component for UV Protection Properties	16
IV	Nomenclature of the Sample	47
V	Visual Inspection	66
VI	Fabric Thickness	67
VII	Fabric Weight	69
IX	Fabric Drapability	71
X	Fabric Stiffness – Warp	72
XI	Fabric Stiffness - Weft	72

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
1	Natural Dyes Classification	9
2	Hues of Natural Dyestuffs	10
3	Elements of Design	29
4	Principles of Design	31
5	Fabric Thickness	68
6	Fabric Weight	70
7	Fabric Drapability	71
8	Fabric Stiffness in Warp	73
9	Fabric Stiffness in Weft	73

LIST OF PLATES

PLATE NO	TITLE	PAGE NO
I	Raw Fabric of Khadi	35
II	Scoured with Soap Berries	36
III	Washed with Plain Water	36
IV	Soap Berries	36
V	Dried Under Sunlight	36
VI	Dye Source of <i>Rubia cordifolia</i>	37
VII	Dye Source of <i>Terminalia chebula</i>	38
VIII	<i>Acacia catechu</i> Dye Powder	38
IX	Alum Mordant	39
X	Filtration of Dye Concentration	42
XI	Tied Upper Portion	43
XII	First Dip in Madder Dye	43
XIII	Second Dip in Madder Dye	43
XIV	Third Dip in Madder Dye	43
XV	Tied fabric for Spiral Tie and Dye	44
XVI	Dyeing in <i>T. chebula</i>	44
XVII	Mordanted with <i>T. chebula</i>	45
XVIII	Tied Vertically	45
XIX	Dyeing in <i>A. catechu</i>	45
XX	Washed in Plain Water	46
XXI	Madder Dyed Sample	46
XXII	Cutch Dyed Sample	46
XXIII	Myrobalan Dyed Sample	46

XXIV	Testing Equipments	51
XXV	Ombre Gown	76
XXVI	Tie and Dye Jumpsuits	77
XXVII	Tie and Dye Top	78

LIST OF APPENDICES

APPENDIX NO	TITLE	PAGE NO
I	Sample of Fabrics	93
II	Standard Body Measurements for Ladies Garment	94
III	Internship Certificate of Natural Dyeing	95

1. INTRODUCTION

The textile and fashion industry plays a major role in world wide economy. In recent years, it has seen enormous growth. One of the leading and largest industry is textile industry in India. It has nearly 40% of whole industrial production and almost 30% in export. With increasing days, consumers are increasing to the peak. By 2025, USD will reach 1.23 trillion and expanding CAGR of 4.24% (Compound Annual Growth). India's textile sector is also significant on a worldwide scale, ranking second to China in both cotton yarn and fabric production and fifth in synthetic fibres and yarns output (Dixit and Lal, 2019).

The majority of people in the globe currently wear is described as “world fashion”. There are several smaller and specialised fashion industry across the world that focus on national, regional, ethnic, or religious markets. The fashion system is a component of a wider social and cultural phenomena, it embraces both the business as well as the art and skill of fashion. Nowadays, technology and automation have posed a challenge to employees across all industries. Fabric and clothing manufacturing procedures need meticulous attention to detail that was previously only feasible with human hands (Vashisht and Rani, 2020).

The textile industry's major environmental detrimental effects include discharge of large amounts of chemical loads as a result of the high consumption of water and harmful chemicals used in this industry. It is associated with water pollution, high energy consumption in manufacturing processes, and its related air emissions, packaging and solid waste production issues. Noise pollution occurs in places where knitting and weaving are done and causes about 80% of hearing loss in people working here. The formation of unpleasant odours and water pollution caused by bleaching, dyeing, and printing processes releases harmful and toxic effluent water (Toprak and Anis, 2017).

The usage of harmful chemicals have a negative impact on the textile industry's long-term viability. The chemicals formed from the processes are very hazardous for the environment. Simultaneously, it reduces the clean water resources and increases the environment related issues. There is rapid growth in waste generation from industrializations. Besides these textile operations, water is consumed during cooling water, boiler, steam drying, and cleaning. A cotton shirt requires around 2,500-3,000 l of water to manufacture. Cotton farming requires large amount of water with wet textile production coming in second (Alkaya and Demirer, 2015).

In the eco-friendly environment, it is very important to assure that all the human beings live in the world of health and hygiene. The needs of human beings are mainly food, clothes and shelter, but one of the important aspects is that the environment should be clean and liveable with pure air and water. Therefore, "eco-friendly" is a word used to describe goods and services that are thought to cause little or no harm to the environment. (Suparna and Antony, 2016). The textile sector is often regarded as the most environmentally damaging sector in the world. Eco-friendly fabrics are hemp, wool, cotton, bamboo, jute and other natural fibres since they are free from dangerous chemicals and toxics (Shaikh, 2009).

Sustainability is the source of renewable and non-renewable resources on which civilization depends, and it shapes the societies in which we live in fundamental ways. A good-quality environment is necessary for our health and well-being, as well as our economic, social life, and safety. In practise, this means working to enhance all elements of the product's life cycle, from design through raw material production, manufacture, shipping, storage, marketing, and subsequent processing (Desore and Narula, 2018). The goal should be to minimise any negative environmental effects of the product's life cycle by ensuring the orderly and careful use of natural resources (water, energy, land, soil, animals, plants, biodiversity, ecosystems, and so on), opting for renewable energy sources at every stage, and maximising reuse, remake, repair, and recycling of the product and its components (Muthu, 2017).

Producing and purchasing better quality, environment friendly things is one way to keep sustainable fashion. There are certificates and labels which exhibit whether a fibre is environment friendly and sustainable. It is essential to check for such certificates before purchasing fabric or a garment (Gordon and Hill, 2010).

Another major aspect of the apparel industry is color theory. Colors derived from natural sources were initially utilized to create colored fabrics before synthetic colors were developed and popularized. The main objective of synthetic dye is to provide a brilliant and appealing color over the cloth, but the majority of the impact is generated from petrochemical sources, which are detrimental to the environment. The increased usage of chemicals in colors causes environmental difficulties to a large extent. As a result, organic products are revitalized, and an awareness of eco-friendliness is raised. (Carmen and Daniela, 2012)

Natural dyes were formed from the substrate of food items, or from animal skins includes wool, silk which used in ancient times. Although the old art skill of natural dyeing technology withstood the test of times, a decline in natural dyeing has occurred due to the

widespread availability of synthetic dyes at reasonable prices. As a result, natural dyes have been maintained in localized sector for specific items, while synthetic dyes were used in large scale in textile industry (Carmen and Daniela, 2012). Basic colors that are generated from plants and animals are red, orange, yellow, green, brown, black, and many more. They are defined depending on hues or saturation. Indigo, anthraquinone, flavonoids, and carotenoids are some of the unusual hues found in minerals. Each dyeing process is further divided into sub-categories (Fletcher and Tham, 2015).

Natural dyes provide a number of advantages over synthetic dyes, in addition to being environmentally beneficial. Natural colors are pleasant and relaxing to the eyes and they are immediately harmonized. These dyes are biodegradable and may be mixed and matched to create a variety of colors. Natural dyes provide the colored fabric therapeutic powers (Gupta, 2019). Natural dyes have the drawback of being unable to replicate the same color tone. Moreover, unlike manufactured or synthetic colours, natural dyes do not include any toxic chemicals or carcinogenic components. By choosing natural colours over alternative options, helps to conserve the environment and reduces the human reliance on deadly chemicals (Bhandari, 2018).

Plant based raw materials including stems, leaves, fruits, flowers, seeds and animal-based resources includes insects, cow urine, snails as well as others from minerals like iron, Prussian blue and manganese brown. Turmeric, beetroot, neem, sandalwood and padauk wood are some of the most often utilized natural plant sources. Natural herbs are generally eco-friendly, biodegradable, less poisonous, and less allergic, with antibacterial and antimicrobial characteristics (Alhamed et al., 2012).

Mordant are a type of dye that helps to set dyes on fabrics by establishing a coordination compound with the dye while mordanting, which is also known as dye fixatives. Mordanting is the name for process of using mordant. Pre-mordanting, simultaneous mordanting, and post mordanting are all types of mordant dyes. The sort of mordanting used with natural dyes is determined by factors such as cloth and intensity preference. Cotton, linen, bamboo, and a few other cellulose materials have a poor affinity for natural colors, especially when considering natural dyes. As a result, the mordanting technique is required to obtain more pigment in natural hues (Fletcher and Tham, 2015).

Mordanting comes in a variety of forms, including natural, synthetic, and mineral. Metal salts, tannic acid, and oil mordants are the three forms of natural mordants (Prabhu and

Bhute, 2012). The main objective of the mordant is to open up the pores so that colorant can enter into the fibers and aid in the fixation of dyestuffs on the substrate, while using the strong dyes. Thereby, it improves fastness properties of dyed material. (Singh and Bharati, 2014).

Fashion design is one form of art where all the designs, creativity, aesthetics are applied to the fabrics to produce new form of garments. Essentially, design is a combination of elements and design principles. There are numerous factors that can be relied on to demonstrate how fashion designs or illustrations can be created and projected. The uniqueness of clothing is determined by external factors as well as the designers' personal creativity. Therefore, customers may confirm to the very basic fashion but manipulate to make a creative and personal design statement (Jones, 2005). Designs can be done by manually and digitally. Some of the most popular fashion design software applications are: Digital Fashion Expert Illustrator by Adobe illustrator and Corel draw (McQuillan, 2020).

Clothing is one of the most essential requirements for mankind. It represents people's personalities and may be used to identify a group, community, family, region, or even a nation. Khadi cotton fabric is a manually spun and woven cloth that is known as Gandhi's fabric in the liberation movement. (Jain, 2014) Khadi fabric embodies cosiness and environmental sustainability. It is also known as "khaddar cloth." It differs significantly from cotton fabric in that each cloth has a distinct feel. It keeps us cool in hot weather and warm in cold weather. Natural dyed garments are made without any nasty toxins. It offers a variety of characteristics, including durability, absorbency, user comfort and hygiene. It has a wide range of subtle shades and soothing effects (Gogoi, 2021).

In light of environmental degradation and the need for sustainable alternatives in the textile sector by considering the idea of sustainability to make garments, the purpose of this study is to investigate “**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**”, with the following objectives:

- To select natural sources for dyeing
- Dye khadi fabric with selected natural sources
- To create theme-based portfolio
- Based on the theme, garments are designed and constructed.
- Evaluation of garments.

2. REVIEW OF LITERATURE

Literature reviews are relevant to determine what has been published on a subject, determining the extent to which a certain research area reveals any interpretable trends, gathering empirical facts relevant to a certain research problem in order to promote evidence-based practise, developing new frameworks and theories and identifying subjects or problems that require further inquiry (Pare et al., 2015). This chapter deals with following topics:

2.6. Natural Dye

2.6.1. Introduction

2.6.2. History

2.6.3. Classification of Natural Dyes

2.6.3.1. Natural dyes are classified according to their hues

2.6.3.2. Natural dyes can be classified as follows based on their application method

2.6.3.3. Natural dyes can be classified as follows based on their chemical structure

2.6.4. Functional Properties of Natural Dyes

2.6.4.1. Introduction

2.6.4.2. Antimicrobial/ Antibacterial property

2.6.4.3. UV protection

2.6.4.4. Deodorising

2.6.4.5. Moth proof and insect repellent

2.6.4.6. Mosquito repellent

2.6.5. Advantages of Natural Dyes

2.6.6. Disadvantages of natural dyes

2.7. Khadi

2.7.1. Introduction

2.7.2. History

2.7.3. Properties

2.7.4. Advantages of Khadi cotton fabrics

2.3. Sources of natural dye

2.3.1. Introduction

2.3.2. Madder

2.3.2.1. Composition

2.3.2.2. Properties

2.3.2.3. Uses

- 2.3.3. Acacia catechu
 - 2.3.3.1. Composition
 - 2.3.3.2. Properties
 - 2.3.3.3. Uses
- 2.3.4. Terminalia chebula
 - 2.3.4.1. Composition
 - 2.3.4.2. Properties
 - 2.3.4.3. Uses
- 2.4. Mordanting
 - 2.4.1. Types of Mordants
 - 2.4.2. Mordanting Techniques
 - 2.4.2.1. Pre-mordanting
 - 2.4.2.2. Simultaneous mordanting
 - 2.4.2.3. Post-mordanting
 - 2.4.3. Extraction of Natural sources
 - 2.4.3.1. Extraction techniques
- 2.5. Design
 - 2.5.1. Elements of designs
 - 2.5.1.1. classification
 - 2.5.2. Principles of designs
 - 2.5.2.1. classification
- 2.6. Fashion Portfolio
 - 2.6.1. Introduction
 - 2.6.2. Development of Boards
 - 2.6.2.1. Theme Board
 - 2.6.2.2. Mood Board
 - 2.6.2.3. Color Board
 - 2.6.2.4. Fabric Swatches Board
 - 2.6.2.5. Sketch Board

2.1.Natural Dye

2.1.1. Introduction

All dyes generated from natural sources such as plants, animals, and minerals are referred to as "natural dyes." Natural dyes are usually non-substantive and must be applied to textiles using mordants, which are usually metallic salts with affinity for both the colouring substance and the fibre. When a textile material is impregnated with such metallic salt (i.e. mordanted) and dyed with different natural dyes, which usually have some mordant groups facilitating fixation of such dye, transition metal ions can act as a bridging material to create substantivity of natural dyes (Kamboj et al., 2021).

2.1.2. History

Color was added to textile materials like natural and synthetic for added value, aesthetic appeal, and client demand. Historically, the purpose of colouring textiles was initiated using natural colours until synthetic dye were invented and commercialised. Because of the ready availability of pure synthetic dyes of various types as well as the cost advantages, most textile dyers have shifted to the use of synthetic colourant. Almost all synthetic colourants are synthesised from petrochemical sources using hazardous chemical processes, posing a threat to their environmental friendliness (Samanta and Konar, 2011).

The term "natural dye" refers to all dyes derived from natural sources such as plants, animals, and minerals (Pubalina et al, 2018). Until the discovery of the first synthetic dye in 1856, the only dyes available to mankind for the colouring of textiles were those derived from natural materials such as plant leaves, roots, bark, insect secretions, and minerals (Verma and Gupta, 2017). Natural source dyes were phased out in favour of synthetic dyes, which could be mass-produced with consistent color tones. Natural dyes are well-known for their usage in the coloring of food substrates, leather, and natural fibres such as wool, silk, and cotton (Samanta and Konar, 2011). Indians are credited with pioneering the art of natural dyeing.

The global textile consumption is estimated to be around 30 million tonnes. The dyeing of this massive amount of textiles requires approximately 700,000 tonnes of dyes, resulting in the release of waste into the environment. Such a large quantity of textile materials cannot be dyed with natural dyes alone. As a result, the use of eco-friendly synthetic dyes is also essential. However, eco-safe natural dyes can always be used to supplement and manage a portion of coloured textiles (Gogoi, 2021).

2.1.3. Classification of Natural Dyes

Natural dyes can be classified in a variety of ways, including origin, hue type, chemical structure, and colour components. Natural dyes or colourants are those derived from plants, invertebrates, or minerals (Sid, 2019). The majority of natural dyes are vegetable dyes derived from plant sources such as roots, berries, bark, leaves, and wood, as well as other biological sources such as fungi.

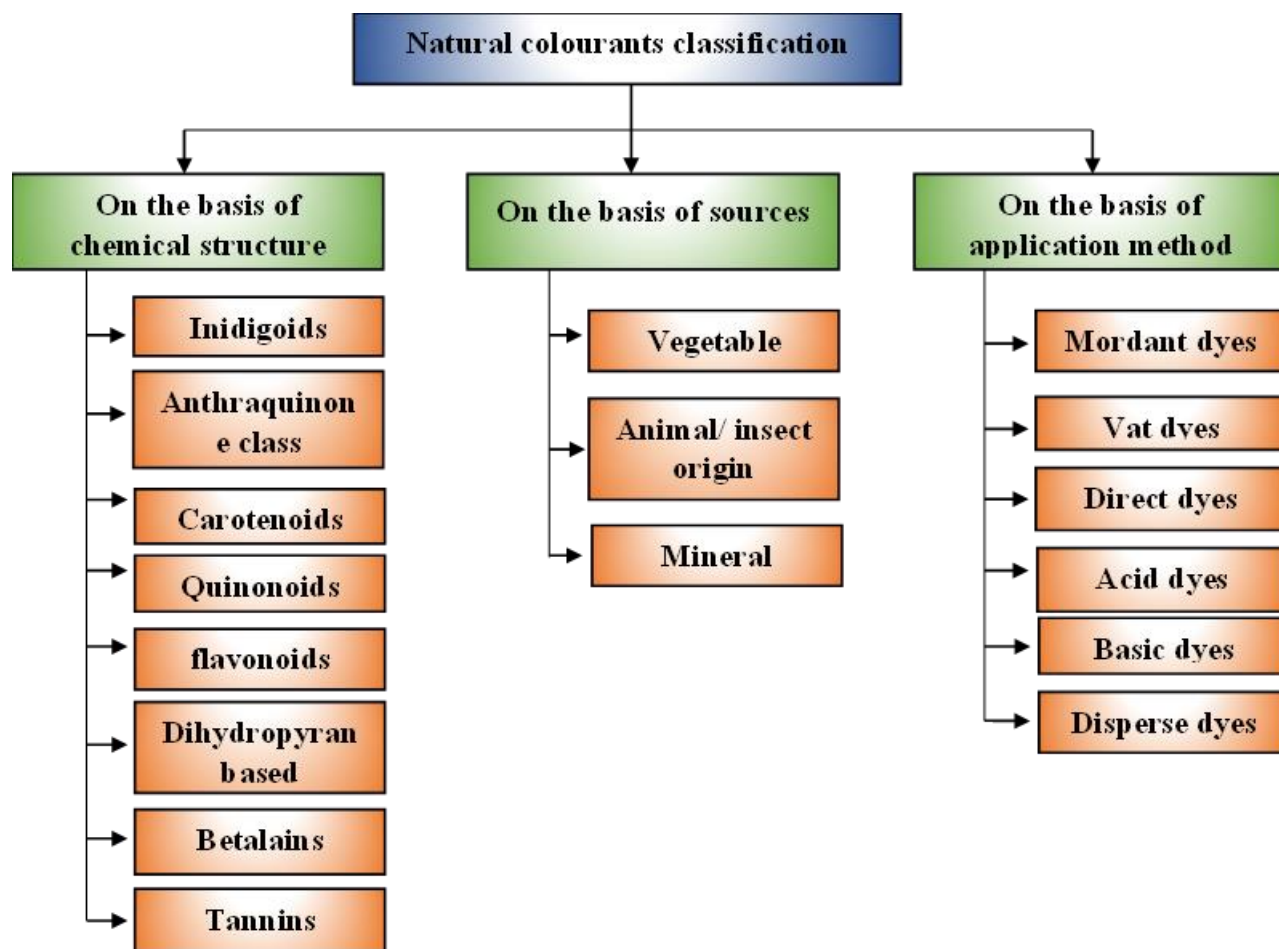


FIGURE 1

Natural Dyes Classification (Sid, 2019)

2.1.3.1. Natural dyes are classified according to their hues as follows:

- i. Red coloured dyes: The Color Index contains 32 natural red dyes. Maddar, manjistha, Brazil wood, Morinda, cochineal, and lac dyes are among the most prominent members.

- ii. Blue colour dyes: There are four naturally occurring blue dyes. Indigo, Kumbh, and Japanese Tsuykusa flowers are some of the most prominent colours. Natural indigo blue has been used to dye cotton and wool since ancient times.
- iii. Yellow colour dyes: There are 28 natural yellow dyes available for use in the dyeing of wool, silk, and cotton. Examples include barberry, tesu flowers, Kamala, turmeric, and marigold.
- iv. Green: Green plants are extremely rare; they are created by combining yellow and blue primary colours. Green is produced by woad and indigo.
- v. Black and brown colour dye: There are six black natural dyes and six brown natural dyes. Brown hue is made using cutch, whereas black shade is made with lac, carbon, and caramel.
- vi. Orange colour dye: The colour orange is created using natural dyes that give red and yellow hues. Barbeny and annatto are two orange-colored plants.



FIGURE 2

Hues of natural dyestuffs (Bhandari et al., 2018).

TABLE I**Some vegetable natural dyes from different parts of plants, (Samanta and Konar, 2011)**

Part of the plants	Dyestuffs
Root	Turmeric, Madder (Manjista), Onions, Beet-root
Branches	Purple bark, Red Sandalwood, Cutch tree,
Leaf	Indigo, Henna, Eucalyptus, Tea, Cardamon, Lemon Grass
Fruits/Seeds	Pomegranate rind, Beetle nut, Myrobalan

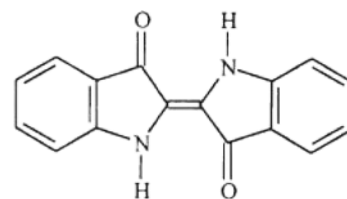
2.1.3.2. Natural dyes can be classified as follows based on their application method:

- i. **Mordant dyes** are dyestuffs that require a mordant to be applied because they have no affinity for the fiber being dyed. A mordant dye should contain electron-donating groups capable of forming a complex with the transition metal salt, for example, madder, fustic, persian, berries, kermes, cochineal, and so on.
- ii. **Vat dyes** are water insoluble dyes that are transformed to water soluble colours (by reducing with Na-hydrosulphite and then solubilizing with alkali) before being applied to the fibres. Only oxidation followed by treatment with a hot soap solution, such as indigo, produces the real colour.
- iii. **Direct dyes** are dyes that have a strong affinity for cellulosic fibres. They're coloured in a dye bath that's been brought to a boil. Turmeric, harda, pomegranate rind, and other natural colours are just a few examples.
- iv. **Acid dyes** are applied to a surface that is acidic. Sulphonic or carboxylic groups on the dye molecules can establish an electrovalent interaction with the amino groups of wool and silk. Black tanning, a post-treatment with tannic acid, improves the fastness of certain colours, such as saffron.
- v. **Ionization of basic or cationic dyes** produces coloured cations, which create an electrovalent bond with wool and silk's $-\text{COOH}$ group. The pH of these colours ranges from neutral to somewhat acidic ($\text{pH} = 4-5$). Berberine, for example, has a low light fastness.

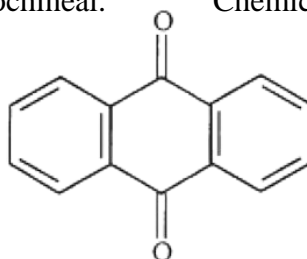
- vi. **Disperse dyes**, the molecular mass of dye is modest, and it has a poor solubility and no strong solubilizing groups. From neutral to somewhat acidic pH, disperse dyes can be applied to hydrophobic synthetic fibre. They can be used on silk and wool as well (Miah et al, 2016).

2.1.3.3. Natural dyes can be classified as follows based on their chemical structure:

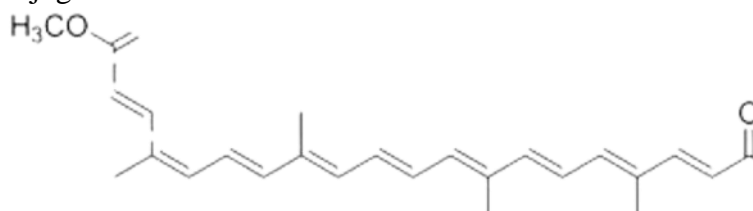
- i. **Indigoid class:** Indigo blue and Tyrian purple are two important dyes in this category. It appears in the plant as a glucoside indicator. Woad, which belongs to the same chemical class as blue dye, is another blue dye. The chemical structure of the indigoid class is shown.



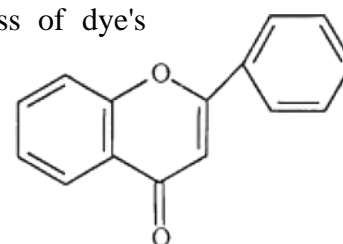
- ii. **Anthraquinone class:** It is derived from plant and insect and the dyes fall in these categories have an anthraquinone structure. Unique color of this class is red. Examples are madder, lac, kermes and cochineal. Chemical structure of this class is as shown.



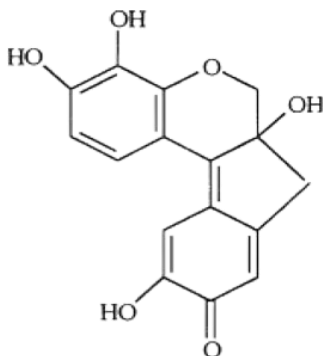
- iii. **Carotenoids:** This class includes saffron and annatto of natural colors. Its structure has long chain conjugated double bonds. The chemical structure is as shown.



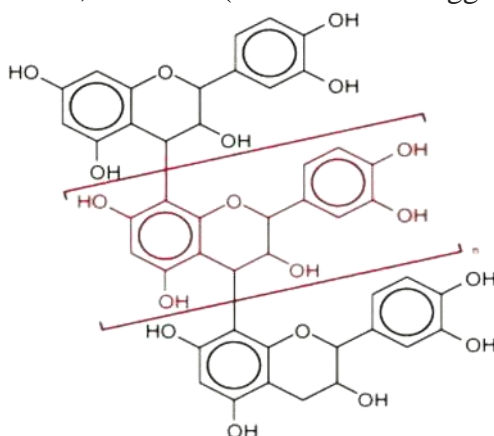
- iv. **Flavones:** The dyes are yellow in colour. The majority of the dyes are hydroxyl and methoxy substituted flavones or isoflavones. This class of dye's chemical structure is depicted.



- v. **Dihyropyrans:** Logwood and sappan wood are two colours that fall within this category. On silk, wool, and cotton, a natural dye called logwood produces a dark black tint (Gupta, 2019).



- vi. **Tannins:** They are polymeric polyphenols with a typical aromatic ring structure and hydroxyl constituents that have a high molecular weight. There are two types of tannins found in plants: (a) hydrolysable tannins and (b) proanthocyanidins (condensed tannin) (Seigler, 1998). Tannins are found in plant cells and are particularly concentrated in epidermal tissues. Tannins can be found in a variety of plant materials, including wood, leaves, buds, stems, florals, and roots (Julkunen and Haggman, 2009)



2.1.4. Functional Properties of Natural Dyes

Natural colours are both biodegradable and harmless. In terms of safe discharge, these colours are better for the environment. Microbes, moth insects, and UV rays are all inflicting various types of harm to humans. Currently, humans do not wear garments just for modesty. As hygiene, cleanliness, and protection have become key concerns, so has the demand for practical clothing. Natural dyed textile applications may be expanded to a variety of fields such as athletics and medicine due to its numerous functional features such as antibacterial and UV protection (Kamboj et al., 2021).

Natural dyes with functional groups such as OH, NH₂, COOH, and others, as well as textile fibres with active sites (-OH, -SO₃H, COOH, C₆H₅OH, -NH₂), can form complexes

with or without mordant. Many functional properties with fastness can be achieved due to the different interactions of dye and fabric (Kabir et al., 2022).

2.1.4.1. Antimicrobial/ Antibacterial property

Humans are surrounded by a variety of microorganisms, including bacteria and other microbes that are invisible to the naked eye. Bacterium is a single-celled organism. It is commonly categorised into two, Gram-positive and gram-negative which is *Staphylococcus aureus* and *E. coli* respectively. *Staphylococcus aureus*, *Streptococcus epidermidis*, and *Bacillus cereus* are examples of Gram-positive bacteria, while *Escherichia coli*, *Klebsiella pneumoniae*, *Shigella flexneri*, and *Proteus vulgaris* are examples of Gram-negative bacteria (Lowfy, 2009).

Clothing primarily covers the human skin or the area in close proximity to the human skin that is in direct contact with it. Thus, the growth of these microbes on fabric has an impact on the wearer because clothing on the human body provides a favourable environment for microbial growth by providing warmth, oxygen, and water, as well as nutrients from sweat. The proliferation of these microbes can also harm the fabrics themselves (Boryo, 2013).

Cotton is one of the materials that is most impacted by these bacteria. These bacteria can be protected by naturally dyed textiles. Natural colours have antimicrobial effects due to the inclusion of different components such as anthraquinones, flavonoids, tannins, naphthoquinones, and others (Yusuf et al, 2017). Various antimicrobial compounds are found in natural dye for common human pathogens, but only a few have been recorded in the case of textiles with respect to human pathogenic strains, as the testing procedure for testing against textiles is different. Many plants that have traditionally been used for dyeing are also thought to have medicinal properties that protect against these harmful microorganisms. The antibacterial properties of madder (alizarine functional group) and safflower with carthamin, alum, Zn-sulphate, and tannic acid were also imparted to the dyed polyamide-6 fabric (Ibrahim, et al, 2013).

TABLE II

Natural Dyes with Responsible Component for Antimicrobial Properties (Source: Pargai et al, 2020, Functional properties of natural dyed textiles).

Name of the natural dye	Botanical Name	Component present for antimicrobial properties
Pomegranate	<i>Punica granatum</i>	Tannins
Henna	<i>Lawsonia inermis</i>	Lawsonone
Neem	<i>Melia azedarach</i>	Phenolic compounds and flavonoids
Madder	<i>Rubia tinctorum</i>	di- and trihydroxyanthraquinones
Cutch tree	<i>Acacia catechu</i>	Condensed tannins and flavonoids
Myrobalan	<i>Terminalia chebula</i>	Tannins
Golden dock	<i>Rumex maritimus</i>	Tannins
Oak galls	<i>Quercus infectoria</i>	Tannins
Clove	<i>Syzygium aromaticum</i>	Eugenol
Turmeric	<i>Curcuma longa</i>	Curcumin

2.1.4.2. UV protection

As the harmful effects of climate change become more apparent, the need for UV protection has increased in order to avoid incidences of UV-induced skin damage. Various sunscreens and synthetic UV absorbers for textile fabric are currently available on the market, but research is being conducted to find eco-friendly alternatives, such as natural dyes, to

improve the aesthetic as well as the UV protection property of the fabric. The UV protection properties of dyed fabric are evaluated using the fabric's UPF. The ultraviolet protection factor (UPF) of a fabric indicates its UV protection properties. The use of natural dyes on fabric improves the fabric's UPF significantly. The absorption characteristics of natural dyes influence the UPF of fabric (Feng et al, 2007).

TABLE III

Natural dyes with responsible component for UV protection properties (Source: Pargai et al, 2020, Functional properties of natural dyed textiles.).

Name of the natural dye/mordant used	Botanical name	Main component for UV protection	Fabric	UPF range
Jamun leaves	<i>Syzygium cumini</i>	Flavonoids catechin	Cotton	Excellent
Madder	<i>Rubia cordifolia</i>	anthraquinone	Cotton, Himalayan nettle	Very good
Cutch	<i>Acacia catechu</i>	Catechin (condensed tannin)	Cotton, Himalayan nettle	Excellent
Myrobalan	<i>Terminalia chebula</i>	Tannins	Cotton, Himalayan nettle	Excellent
Pomegranate peels	<i>Punica granatum</i>	Tannin	Cotton	Excellent

2.1.4.3. Deodorizing

Bacterial colonies in textiles cause odour due to favourable conditions such as perspiration (Callewaert et al, 2014). Gallnut-based natural dyes for cotton, wool, and silk fabrics also have a superior deodorizing effect against ammonia, trimethylamine, and acetaldehyde. The following formulae are used to calculate the dyed fabric's deodorising capacity:

$$\text{Deodorization performance (\%)} = (C_b - C_s) / C_b * 100,$$

where C_b represents the gas concentration (ppm) in a test tube without fabric (blank state) and C_s represents the concentration in a tube with fabrics (Hwang et al, 2008).

2.1.4.3. Moth proof and insect repellent

Woollen textiles suffer significant losses due to moth larvae that are usually hidden. Due to the presence of protein in the wool, approximately 2.5 pounds of wool fibre are consumed in a year (Medha et al., 2021). Wool is used to make a variety of products, including carpets, blankets, namda shawls, and knitwear. Consumers' eco-consciousness has increased the usage of natural anti-moth agents. In the case of natural dyes, the chemical structure of the dye also influences its anti-moth properties. Natural dyed anti-moth properties have a scarcity of information. Anti-moth properties were observed in saffron flower waste, onion skin, henna, myrobolan, silver oak leaf, madder, wall nut, dholkalanli, and yellow roots (Shakyawar et al, 2015).

2.1.4.4. Mosquito repellent

The growth of mosquitoes, and thus the spread of dangerous diseases like malaria, yellow fever, and dengue fever, is aided by global warming (Niang et al, 2018). Pomegranate peel dyed cotton fabric with various concentrations of polyvinyl alcohol repels mosquitos by 80% (Pargai et al, 2020). Organic mosquito repellents may be one of the most effective methods for preventing vector-borne diseases in humans.

2.1.5. Advantage of Natural Dyes

- Natural dyes have a low environmental impact because they are made from natural materials. Natural colours are biodegradable and do not pollute the environment when discarded (Karadag and Torgan, 2016).
- Renewable: Natural dyes are obtained from renewable sources, ensuring that they do not affect the environment.

- Chemical reactions: During dye preparation, there are no or few chemical interactions.
- Antimicrobial properties are found in many natural dyes. They can easily be used to replace synthetic dyes in children's clothing (Affat, 2021).
- Disposal: There are no disposal issues.
- Natural shades: Natural dyes might help you achieve a delicate hue or relaxing tint if you're striving for that aesthetic.
- Safe: When consumed, some natural colours, do not cause harm or health problems (Choudury, 2018).

2.1.6. Disadvantage of natural dyes

- Cost: In comparison to synthetic dyes, a larger amount of natural dyes may be required to colour a specific amount of fabric (Siva, 2017).
- Standardization: It is difficult to standardise and blend.
- Natural dyes have poor brightness and fastness qualities, and their colour pay-off fades quickly.
- Availability: Another problem with natural colours is their scarcity. It can be difficult to create since raw materials availability varies from season to season, location to place, and species to species, whereas synthetic dyes can be made in laboratories all year round (Choudury, 2018).
- Time consumption, Lengthy dyeing procedure (Yin, 2016).

2.2. Khadi

2.2.1. Introduction

Khadi is not merely a textile in India; it is a movement launched by Mohandas Karamchand Gandhi. The Khadi movement attempted to promote Indian items while rejecting imported ones, hence boosting India's economy. In the 1920s, Mahatma Gandhi promoted the spinning of Khadi for rural self-employment and self-reliance (rather than utilising cloth made industrially in Britain), making Khadi a vital aspect and emblem of the Swadeshi movement. The usage of Khadi fabrics and the dumping of foreign-made clothing was vital to the liberation movement (Choudhuri, 2018). Gandhi saw the process of creating Khadi as a means of achieving independence and freedom from foreign rule, as well as equality among all classes. When Gandhi first started spreading the idea of the Khadi movement, he envisioned a more self-sufficient India, and it changed his life (Ross, 2015).

In India, Bangladesh, and Pakistan, Khadi or Khaddar is a name for hand-spun and hand-woven textile. Cotton, silk, or wool are among the raw materials spun into threads on a charkha spinning wheel. It's a flexible fabric that keeps you cool in the summer and toasty in the winter. However, because it is a coarser sort of material, it wrinkles considerably more quickly than other cotton preparations (Sinha, 2018).

Many leading designers have taken on the fashion challenge of reinventing khadi into high-fashion wear and showcasing contemporary cuts and styles. Khadi as a fashion statement has a variety of styles intended for young people. They highly advise young people to consider wearing it on a regular basis (Parashar, 2022).

2.2.2. History

Khadi, a fabric that symbolises both a past and a future viewpoint, is an emblem of Indian textile tradition (Sinha, 2019). Wearing cotton clothing, which was significantly more pleasant in the warmth than their usual woollens. The textile used by Indians is made of cotton growing on trees. Several paintings in Maharashtra's Ajanta Caves portray the process of removing cotton fibres from seeds (known ginning) along with people spinning cotton thread in the 5th century. By late 17th century, Handwoven muslin, calico, and chintz from India dominated European markets (Aravind and SB, 2022).

As India entered the 21st century, a new generation of Indian designers experimented with this adaptable fabric, guaranteeing that khadi remained fashionable. While the eco-friendly fabric was already well-known for its tough texture, comforting feel, and capacity to keep people warm during the winter and cool in summer, its modern yet distinctly Indian reinterpretation has made it particularly popular to the millennial generation. As a result, the portrait of Gandhi in his charkha is more than simply a historical document, it encapsulates the essential spirit of India's decades-long battle for independence (Aravind and SB, 2022).

2.2.3. Properties

- Khadi material is a body-friendly fabric that does not cause any allergies or irritations, unlike other synthetic fabrics.
- The handloom used to make Khadi cotton fabric combines the threads to enable maximum air permeation, which is quite relaxing, especially in the summer.
- Khadi materials are extremely long-lasting and durable (Chatterjee et al., 2011).

- Khadi cloth have a smooth finish and are soft, pleasant. They are widely used to make a range of clothes.
- The appearance of Khadi fabric enhances with each wash (Mitra, 2022).

2.2.4. Advantages of Khadi cotton fabrics

- Handmade self-textured patterns making it unique.
- It is lighter in weight and breathable, and it lasts a long time.
- It is used to manufacture both casual and formal clothing. Keeps the user warm in the winter and cool in the summer (Mishra, 2014).
- Can be combined with various fibres to form a range of mixes with improved qualities,
- Most significantly, the production method of khadi includes no environmental damage; hence it is incredibly environmentally friendly (Ambre and Lad, 2017).
- It substantially aids rural craftsmen in earning a wage.
- Apparels and home textiles, furniture and rich ornate occasional dress, are also available (Kumari and Singh, 2019).

2.3.Sources of natural dye

2.3.1. Introduction

Dyes are the colourant matters which penetrate into the fibre and appear to become a part of it (Kajla and Srivastava, 2006). Natural colours are more biodegradable and environmentally friendly than synthetic dyes. They are non-toxic, non-allergic, and non-carcinogenic since they are derived from animals or plant materials without the use of chemicals (Mia et al., 2022). The main sources of natural dyes are classified as vegetable dyes, animal dyes and minerals (Moses and Venkatachalen, 2001).

2.3.1. Rubia cordifolio

2.3.1.1. Compositiion

Kingdom: Plantae

Order: Gentianales

Family: Rubiaceae

Genus: Rubia

Species: *R. cordifolio*

Madder roots contain colours with an anthraquinonic (anthracene-9, 10-dione) structure, which correspond to heterosidic and aglycone molecules. The compounds that make up heterosidic dyes have an anthraquinonic portion (aglycone) and a primeverose part (6-O—D-xylopyranosyl—D-glucose) (Sisubalan et al., 2018).

Madder's dye has several species from the family of Rubia genus. Some of them were *R. tinctorum*, *R. peregrina* and *R. cordifolia* obtained from India native of hilly districts, its main parts are small yellowish flowers grew in clusters and leaves of lance shape grew in whorls. The common madder is also known as *R. tinctorum* and *R. cordifolia*, which gives red in colour and found in ground-up roots from the plant. It is used as textile dyes, mummy portrait, and applied in medicinal treatment (Hosseinnezhad et al., 2022).

2.3.1.2. Properties

Ethno-medicinal property

- *R. cordifolia* can be used to treat inflammations, ulcers, haematemesis, haematuria, and skin conditions.
- It is an essential ayurvedic component source that is used to make Chadanasava and includes 5-10% self-produced alcohol.
- Manjisthadi Taila is used to treat headaches, ringworms, and other fungal illnesses.
- In comparison to bactigauz, Manjistadi Taila and Kadalipatra prevent the formation of discolouration, eschar, and contracture in burn patients (Shekokar et al., 2013).
- Manjistha was used to treat significant burns and freckles and blemishes on the skin, and it was blended with honey to treat freckles and blemishes.
- It remained an effective treatment for stubborn skin conditions including erysipelas and oedema. In Ayurveda, it's also used as a febrifuge and to treat blood diseases (Priya and Siril, 2014).
- To cure fractures, manjistha and *Glycyrrhiza glabra* are crushed with sours and administered as a paste.
- Eczema is treated using a whole plant oil extract (Singh and All, 2012).

Modern Pharmacology

- Anti-acne property: *R. cordifolia* gel fights *Propionibacterium acnes* and *Staphylococcus aureus*.
- Anti-cancer property: its root extracts were proven in vitro and/or in bioassays using animal models.
- Wound- healing activity: It has been described as an effective wound healing principle in experimental animals (Biswas and Mukherjee, 2003).
- Anti- microbial property: The antibacterial efficacy of *R. cordifolia* root extracts against several pathogenic bacteria has been examined. The elements of the root extract, such as anthraquinones and flavonoids, inhibited the action of *Gossypium* phytopathogens (Naidu et al., 2009)

2.3.1.3. Uses:

- Utilized as a color plant in Asia where red color separated from roots and stems have been utilized to color silk, material, cotton textures (chintz) and woolen covers.
- *Rubia cordifolia* is known for its antiphlogistic, antitussive, astringent, diuretic, emmenagogue, expectorant, styptic, tonic, and vulnerary properties.
- Pharmacological uses like anti-cancer, anti-microbial, anti-inflammatory effect, anti-oxidant, and anti-diabetic (Naidu et al., 2009).
- In textile industry, it act as an coloring agent.
- Apart from the medical uses, parts of madder plants have been used in different sector such as textile dye, hair dye, food colour, syrups and etc (Singh and All, 2012).

2.3.2. Acacia catechu

2.3.2.1. Composition

Kingdom: Plantae

Order: Myrtales

Family: Combretaceae

Genus: *Terminalia*

Species: *T. chebula*

Catechin, rutin, isorhamnetin, epicatechin, kaempferol, 4-hydroxybenzoic acid, 3,4',7-trihydroxyl-3',5-dimethoxyflavone, quercetin, afzelechin, epiafzelechin, mesquitol, aromadendrin, ophioglonin, and phenol are some of the chemical compounds extracted and

described from *A. catechu* (Modi et al., 2013). By scavenging free radicals, catechins, rutin, and isorhamnetin have antioxidant properties. These chemicals are abundant in *A. catechu* heartwood extract and may contribute to the species' biopotency.

Acacia catechu belongs to family "Mimosaceae". It is a major medicinal plant found in comparatively drier portions of India such as Punjab, Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh, Orissa, and Andhra Pradesh, and is also known as khadira, khair, karingali, and katha (Devi et al., 2011).

Khadirarishta is a well-known Ayurvedic skin tonic made from *A. catechu*. The heartwood extract Khadira Sara is utilised in several medications, including Lavangadi Vati. Cough, dysentery, skin ulcerations, and blemishes are treated with "Ercha," a traditional Chinese medication made from catechu heartwood extract. Black catechu, a sticky extract of the wood, is used as an anodyne, astringent, and bactericide. Asthma, bronchitis, colic, diarrhoea, boils, skin ailments, sores, and stomatitis are all treated with heartwood extract. Anti-helminthic, antipyretic, and anti-inflammatory activities have been discovered in the bark. Bronchitis, ulcers, psoriasis, anaemia, and gum problems are all treated with it (Shen et al., 2006). In the southern portion of India, particularly in Kerala, a decoction made from the heartwood of this plant is used for drinking.

2.3.2.2. Properties

- *Acacia catechu*, sometimes known as catechu, is a medicinal shrub that is used for a variety of reasons.
- This plant's bark has potent antioxidants, astringents, anti-inflammatory, anti-bacterial, and antifungal properties (Shen et al., 2006).
- Cutch typically has a tannin concentration of 55-60%.
- Cutch has been discovered to be useful against liver disorders, which has been related to the existence of (+)cyanidanol-3, a d-form of catechin.
- The heartwood has a light reddish-brown colour that darkens with exposure and is quite robust and durable (Sunil et al., 2019).

2.3.2.3. Uses

- Dark "catechu" or "Pegu cutch" is used to tan heavy hides into sole leather in India and Burma, frequently in a blend of tan-stuffs.
- Extraction of Catechu is used for the preservation of fishing nets and ropes as well as to dye fabrics (Sunil et al., 2019).

- It gives viscosity modifier in on-shore oil wells.
- It is used medicinally, particularly for the treatment of coughs and sore throats.
- It has been stated that the seeds contain antimicrobial properties (Akram, 2014).

2.3.3. *Terminalia chebula*

2.3.3.1. Composition

Kingdom: Plantae

Order: Fabales

Family: Fabaceae

Genus: *Acacia*

Species: *A. catrchu*

The components of *Terminalia chebula* are Tannic acid, Chebulinic acid, gallic acid, and other astringent compounds are found in fruits. Resin, as well as a purgative ingredient found in anthraquinone and sennoside (Yusuf et al., 2017).

Terminalia chebula (myrobalan) is a popular plant in Indian traditional medicine that has also been utilised in Iranian traditional medicine (ITM). Myrobalan has a long history of usage in traditional medicine for illness treatment. ITM based medicine use on the temperament of the drug. Because these temperaments cannot be described using laboratory criteria, myrobalan was evaluated using current scientific standards in order to compare traditional and modern scientific results. The fruit is the major therapeutic component of myrobalan (Jokar et al., 2016). The following are the parts of *Terminalia chebula*:

- Tree: It is a deciduous tree with glabrescent and woody younger stems.
- Leaves: These are 10–20 cm long, sub–opposite, simple; exstipulate; petiolate; laminae broadly elliptic to elliptic oblong, occasionally ovate, bases obtuse, margins entire, tips sharp, glabrescent (Lee et al., 2010)
- Fruit: It is the major therapeutic component. Tannic acid, Chebulinic acid, gallic acid, and other astringent compounds are found in fruits. Resin, as well as a purgative ingredient found in anthraquinone and sennoside, are present (Das et al., 2011).
- Seed: These are ellipsoids that are solitary and rough (Lee et al., 2010).

2.3.3.2. Properties

- *Terminalia chebula* has a high phenolic content, particularly hydrolyzable tannins, anthraquinone, flavonol, carbohydrates, glucose, and sorbitol, as well as carbohydrates, glucose, and sorbitol (Das et al., 2011).
- *Terminalia chebula* extract has been extensively studied for its numerous pharmacological properties.
- Due to the obvious presence of phenolic chemicals in its extract, *Terminalia chebula* has been shown to have high antioxidant capabilities (Naik et al., 2009).
- The *Terminalia chebula* extracts, Gallic acid and its ethyl ester were isolated as two powerful antibacterial compounds that reduced the score of methicillin-resistant *Staphylococcus aureus* strains (Naik et al., 2009).

2.3.3.3.Uses

- *Terminalia Chebula* extract used as Anti-oxidant, anti-diabetic, anti-bacterial, anti-microbial and so on (Gupta, 2012).
- Used as a colouring agent in textile clothing.
- In Traditional Ayurvedic Medicine, chebolic myrobalan is used as a bowel tonic and light laxative.
- Myrobalan is a light buttery yellow dye that may be used in the mordanting process or as a dye (Gupta, 2012).

2.4. Mordanting

2.4.1. Introduction

Natural dyes, which have a limited substantivity for the fibre, necessitate the employment of a mordant, which improves the fixing of the natural colourant on the fibre by the development of a complex with the dye. Alum, potassium dichromate, ferrous sulphate, copper sulphate, zinc sulphate, tannin, and tannic acid are some of the primary mordants utilised (Maulik and Pradhan, 2005). The term mordant is derived from the Latin word "mordere," which means "to bite." A mordant is a chemical that may be fastened to the fibre as well as create a chemical link with the natural colourants. It aids in the absorption and fixing of natural dyes as well as the prevention of colour bleeding and fading, hence improving the fastness qualities of coloured materials.

2.4.2. Types of Mordants

- Metal salts or Metallic mordants: Aluminium, chromium, iron, copper, and tin metal salts are utilised. Alum, Copper sulphate, Ferrous sulphate, Potassium dichromate,

Stannous Chloride, and Stannic Chloride are some of the typical mordants utilised. These metallic mordants are further split into two varieties based on the final colour created with natural dyes, namely Brightening Mordants and Dulling Mordants. Brightening mordants include alum, potassium dichromate, and tin (stannous chloride), whereas dulling mordants include copper sulphate and ferrous sulphates (Chakraborty, 2015).

- **Tannin:** Seguin used the word 'tannin' in 1796 to describe the process of turning animal skins into leather by extracting plant extract from various portions of various plant species. Tannin is an astringent plant component that may be found in a wide range of plants. Bark, wood, fruit, fruit pods, leaves, roots, and plant galls are examples of plant parts. The structure of tannins is split into two types based on the type of phenolic nuclei involved and how they are linked. The first category is known as hydrolysable tannins, whereas the second is known as condensed tannins (Khanbabaee and Van Ree, 2001).
- **Oil Mordant:** Oil mordanting is primarily employed in the dyeing of Turkey Red from madder. The primary purpose of oil mordants is to form a complex with alum, which is employed as a primary mordant. Natural colouring oil comprises fatty acids and glycerides such as palmitic, stearic, oleic, and others. Complex metal used with mordant dyes such as madder to produce Turkey Red with outstanding fastness and colour (Prabhu and Bhute, 2012)

2.4.3. Mordanting Techniques

- **Pre-mordanting:** The mordants are melted in warm water at a rate of 1-50, depending on the weight of the fibre. After boiling for few hours, the wet fibre is suffocated in this mordanting water. The fabric is twisted and prepared for dyeing after it has been removed from the mordanting water (Sanli et al., 2011).
- **Simultaneous-mordanting:** While immersing the fabric in the extracted solution, the predetermined mordant is applied. The fabric is coloured and mordanted at the same time. They are boiled for respected hours and then let to cool at the end of the 1 hour. After cooling, they are washed and dried in a well-ventilated, low-light environment (Merdan et al., 2017).
- **Post-mordanting:** The fabrics are coloured using a procedure that does not need mordanting. Then it is immersed in water, depending on the weight of the fabric in a required proportion, resulting in the final mordanting. They are cleaned with cold water and coloured in a low light after they have cooled (Sanli et al., 2011).

2.4.3. Extraction of Natural sources

The most significant phases in the production of natural dyes are extraction and purification. Because the extraction process is so complicated, it is critical to assess the solubility of the natural dyes before beginning. The traditional chemical separation approach, which is being employed today, is widely utilised for the extraction and separation of natural resources. It is primarily based on the concepts of varying active component solubility in varying solvents, although crystallisation and other approaches can also be explored. This procedure does not require any extra equipment and is simple to use (Sanli et al., 2011).

2.4.3.1. Extraction techniques

- Solvent extraction: Depending on the nature of the native colourant, water or hydrophilic organic solvents such as ethanol, methanol, and acetone are used to extract water-soluble pigments. Hexane, dichloromethane, and petroleum ether, are used to remove fat-soluble pigments. When compared to the aqueous approach, the efficiency of water/alcohol extraction is greater (Zielińska et al., 2020).
- Aqueous extraction: The aqueous extraction method is traditional, straightforward, and excellent for extracting plant components that can be distilled with steam without affecting the molecular structure. To increase the efficiency, the coloured materials are chopped into small pieces, crushed into powder, and held overnight in a steel container or longer to release the cell structure (Merdan et al., 2017). These compounds are insoluble in water or just slightly soluble in water, and they have a specific vapour pressure at a boiling point of 100 °C. When the water boils, the material may be taken away with the steam. It is separated by an oil-water separator to separate the water in order to acquire the essential plant components (Zielinska et al., 2020).
- Enzymatic extraction and Fermentation: There are a number of enzymes that can breakdown plant tissues gently, speed up the release of useful components, and increase extraction rates. The enzyme extraction approach offers the benefit of softer extraction conditions as well as consistent characteristics of active compounds physically and chemically (Chaves et al., 2020).
- Ultrasonic Extraction: One of the most recent extraction processes is ultrasonic extraction. The ultrasonic wave's strong cavitation effect, high acceleration, mechanical vibration, emulsification, diffusion, crushing, and stirring can enhance the frequency

and speed of material molecules, as well as the solvent's penetration (Sivakumar et al., 2011)

- Alkaline and Acid Extraction: The extraction process is enhanced by the addition of these acids and alkalis due to the hydrolysis of glucosides. Furthermore, this technique boosts the colour intensity (Chaves et al., 2020).

2.5. Design

2.5.1. Introduction

Design is made up of simple parts that are assembled into a framework that conveys a message. These are the basic components need to put together your design. These objects can be grouped in any way as part of your composition; this is referred to as the design principles. These are fundamental notions that can assist you in organising the basic structural aspects of a page (Baird and Collias, 2014).

2.5.2. Elements of Design

Elements are the foundations of art and design. Every element has unique and important qualities, and the combination of these elements has a significant influence (Neacsu et al., 2017). Elements can be used alone or in combination depending on the design and work.

- Line: The most fundamental element is line, which comes in a variety of forms, sizes, and colours. It can be straight, curved, zigzag, dotted, or any other shape that changes the mood of the line based on the design (Sorger and Udale, 2017).
- Colour: It reveals a person's personality or qualities. It might draw attention to a certain location. This element has various properties, including Hue, Shade, Tint, Tone, and Saturation (Sorger and Udale, 2017).
- Shape: The outcome of enclosed lines forming a border is a shape. Geometric, organic, and abstract shapes are examples of two-dimensional shapes (Ravi et al., 2019).
- Form: It is also known as Positive space. The positive element of form dominates the negative element of space. When a dot, line, or shape is placed on a page, it becomes a form (Vaccaro et al., 2017).
- Value: The degree of brightness and darkness of a certain colour is referred to as its value. Since yellow is nearer to white, yellow has a greater value than purple. Value changes generate contrast. Low value refers darkest color and high value refers light colors (Sorger and Udale, 2017).

- Space: The region that is not filled by any items is known as negative space. It forms a form inside the space (Ravi et al., 2019).
- Texture: Texture gives a design arrangement a tactile look. Consider how a piece of design would feel if you touched it. The purpose of texture is to provide depth to a two-dimensional surface. Texture can be applied graphically in the form of patterns, which can be either digitally made or images that imitate the desired pattern (Ravi et al., 2019).

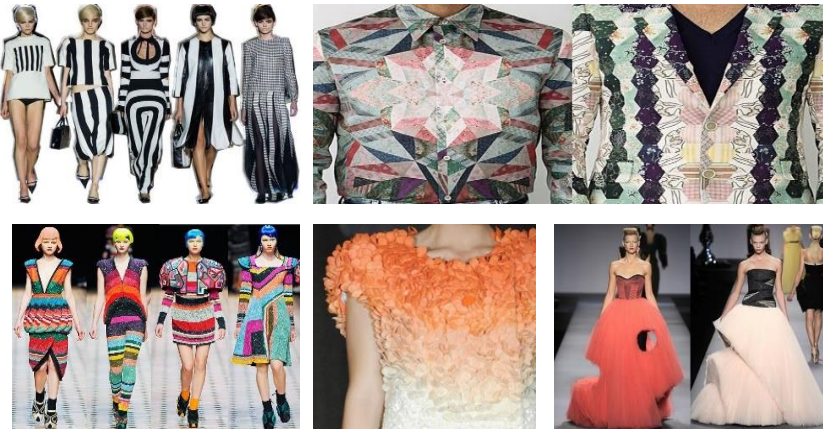


FIGURE 3

Elements of Design (Sorger and Udale, 2017).

2.5.3. Principle of Design

The principles of design are a collection of criteria that designers may use to create aesthetically appealing work while building a composition. The goal of these guidelines is to convey a message in the most ordered and useful manner possible. The following are the major components of principle (Volpintesta, 2014):

- Balance: It stabilises or balances the design. It might be symmetrical or asymmetrical in nature. Symmetrical designs are those that are easy to balance and appear bored. Similarly, designs with varying weights appear asymmetrical (Gyamfi et al., 2020).
- Unity: The harmony established by all of the aspects in a design work is referred to as unity. Using comparable hues that complement and integrate items naturally.
- Contrast: Contrast is the degree of difference between design components that is used to establish visual hierarchy. Contrast may direct the viewer's attention to select features by creating a focal point. Contrast may also be employed to establish balance and harmony by ensuring that elements are evenly placed (Gyamfi et al., 2020)..
- Emphasis: Emphasis is a technique for drawing a viewer's attention to a particular design aspect. This can take many different forms, including a button, a webpage, or a

picture. The goal is to make something that stands out from the crowd (Gyamfi et al., 2020).

- Repetition: It is when a single piece is repeated throughout the design. A grid may be defined as the repetition of lines that produces a sense of uniformity.
- Pattern: The recurrence of more than one design element is known as a pattern. While repetition refers to the repeating of a single element, pattern refers to the repetition of numerous components across a design (Siaw et al., 2014).
- Rhythm: When a combination of components is employed frequently and with variety, the visual pace creates the impression of structured movement. The ideas of repetition and pattern are less difficult than rhythm (Siaw et al., 2014).
- Movement: Within a composition, movement depicts action and generates a sense of motion. It also acts as a roadmap for the eye to follow through one element to another (Volpintesta, 2014).
- Proportion: Proportion is a design aspect that refers to the proportional size of the components that make up an item. When two items are compared, proportion is largely about scale and size (Volpintesta, 2014).
- Variety: To generate contrast and tension, variety provides something fascinating to the design. It provide a layer of intricacy and visual intrigue to their work.
- Harmony: The sensation of cohesion between the elements of a composition is known as harmony. The elements need not be identical or wholly dissimilar, but should be connected in some way (Siaw et al., 2014).

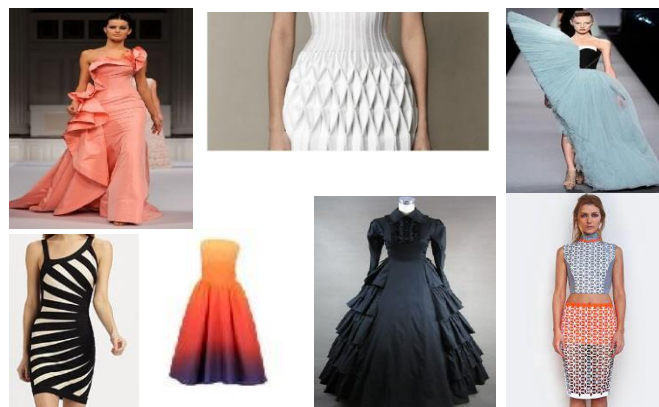


FIGURE 4

Principles of Design (Hopkins, 2021).

2.6. Fashion Portfolio

2.6.1. Introduction

A standard fashion design portfolio should comprise fashion drawings, an inspiration or mood board with textile samples, flat sketches & "floats," and CADs. It may also be described as a collection of samples carried by a tailor to demonstrate his or her abilities to a potential leader or fashion faculty (Agarwal, 2019). Fashion portfolios can be created in two ways: manually or digitally. Manual fashion portfolios are developed by hand making drawings, illustrations, and picture collections. It appears to be more realistic and creative art, but it is not transportable, unlike digital fashion portfolios are. Digital design artists are required for online tools. Digital portfolios outperform the finest in current technologies (Marinho et al., 2021).

2.6.2. Development of Boards

There are numerous boards that accurately explain the design evolution. The following are important steps to develop a fashion portfolio:

2.6.2.1. Theme Board

Theme boards depicts the theme of the product. The board's goal is to assist a person in determining the theme they want to express in a work. When building a new web design, graphic designers will create a theme board based on the task to provide vision for the emerging design (Burke and Sinclair, 2015).

2.6.2.2. Mood Board

A fashion mood board (or inspiration board) is a real or digital collage of ideas and objects that promotes a certain aesthetic style. They are a useful tool that helps designers keep on track and consistent with their design concept. They are utilised before the design process begins. They are a simple and imaginative technique of presenting a high concept notion. Mood boards should be able to communicate the tale of your design. Designers may do this with a number of images (Agarwal, 2019).

2.6.3. Color and Fabric Swatches Board

The colour scheme for the whole collection. Fabric, in addition to graphics, is one of a fashion designer's most important tools. A strong portfolio should include gorgeous fabric collages and colour combinations (Kim, 2016).

2.6.3. Sketch Boards

Sketches can be flat or create figures. Both have their own set of benefits. Creative designers should prioritise the art in their portfolio, designer may demonstrate the ability to create high-fashion graphics (Kim, 2016).

4. METHODOLOGY

Methodology pertaining the study on “**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**” are discussed under the following headings:

4.1. Selection of materials

4.1.1. Selection of Fabric

4.1.1.1. Pre-treatment of fabric

4.1.1.1.1. Scouring

4.1.2. Selection of Dye Sources

4.1.2.1. Rubia cordifolio

4.1.2.2. Terminalia chebula

4.1.2.3. Acacia catechu

4.2. Selection of mordants

4.2.1. Alum

4.2.2. Terminalia chebula

4.3. Techniques used for mordanting

4.3.1. Pre-mordanting

4.4. Procedure for dye extraction

4.5. Dyeing process

4.5.1. Dyeing

4.5.2. Washing

4.5.3. Drying

4.6. Evaluation of fabric

4.6.1. Subjective Evaluation

4.6.1.1. Visual Inspection

4.6.2. Objective Evaluation

4.6.2.1. Fabric weight

4.6.2.2. Fabric Thickness

4.6.2.3. Fabric Stiffness test

4.6.2.4. Drape test

4.6.2.5. Colourfastness test

4.6.2.5.1. Fastness to sunlight

4.6.2.5.2. Fastness to wet and dry pressing

4.6.2.5.3. Fastness to crocking

4.6.2.5.4. Fastness to washing

4.7. Development of Portfolio

4.7.1. Mood board

4.7.2. Color board

4.7.3. Fabric swatches

4.7.4. Flat sketch

4.8. Development of garments

4.8.1. Drafting Patterns

4.8.2. Construction of garments.

4.8.2.1. Tie and Dye Top

4.8.2.2. Ombre Gown

4.8.2.3. Tie and Dye Jumpsuit

4.9. Statistical Analysis.

3.1.Selection of materials

Material selection is choosing the best fabric material and dye source to satisfy the needs of a certain application.

3.1.1. Selection of fabric

“Khadi” is another name for hand-spun and hand-woven material. It is safe for the body and does not cause allergies or other skin problems. It is soft, resilient, antibacterial, and air permeable with a smooth texture that is comfortable to wear in both summer and winter (Kumari and Singh, 2019). Hence 100% khadi cotton fabric was selected and sourced from Farmer’s Share in Shorannur. Selected Khadi fabric is shown (Plate I).



PLATE I

Raw Fabric of Khadi

3.1.1.1. Pre-treatment of fabric

It is the preparatory procedure for improving fabric quality by eliminating contaminants and evenly preparing the cloth for the subsequent step (Harane and Adivarekar, 2017).

3.1.1.1.1. Scouring

Scouring is the process of removing soluble and insoluble contaminants using several methods to make the fabric highly hydrophilic (Zaid et al., 2019).

Procedure:

Soapberries - 15%
Thermometer - 40-80°C

In terms of fabric weight, 15% of the soapberries were taken. To prepare the solution, soaked it in hot water. The cloth was dipped into the solution and boiled for 2 hours at 40 degrees Celsius and 1 hour at 80 degrees Celsius before being soaked overnight (Plate II). The cloth was then thoroughly washed (Plate III). Then it was exposed to the direct sunlight to dry (Plate IV).



PLATE II

Scoured with Soap Berries



PLATE III

Washed with Plain Water



PLATE IV

Soap Berries



PLATE V

Dried Under Sunlight

3.1.2. Selection of dye sources

Plants, animals, and minerals are used to make natural dyes. The most of natural dyes are derived from vegetable plant source. It is more biodegradable, eco-friendly and originates from a huge variety of renewable sources (Sanjeeda and Taiyaba, 2014).

3.1.2.1. *Rubia Cordifolia*

Rubia cordifolia is highly valuable for medicinal plant in Ayurveda. The extraction of Indian *Rubia cordifolia* is found red in color. It has various properties includes antioxidant, cardioprotective, anti-bacterial and anti-microbial which prevents the growth of bacteria (Chandrashekar et al., 2018). Hence this was one of the dye source selected for fabric dyeing. Ombre is another way of dyeing in which a colour is graduated from light to dark or vice versa. Hence this was the strategy used here with *R.cordifolia* source and it was collected from Farmer's Share in Shorannur (Plate V).



PLATE VI

Dye Source of *Rubia cordifolia*

3.1.2.2. *Terminalia chebula*

The Combretaceae family's *Terminalia chebula* is regarded in Tibet as the "King of Medicine." It is one of the most powerful healing system (Bag et al., 2013). It's a natural colourant that's good for the environment and hence used to dye textiles. It contains antibacterial, wound healing, antioxidant, and antimicrobial effects. It act as both dye source as well as mordant. (Sharma and Geetika, 2022). Tie dye is a another concept of dyeing, it creates a vast range of design including spirals, diamonds, and various aesthetic effects (Denissa et al., 2022). As a

result, this dye was chosen as a second dye sourced from Farmer's Share in Shorannur (Plate VI), and the tie dye process was introduced.



PLATE VII

Dye Source of *Terminalia chebula*

3.1.2.3. *Acacia catechu*

Acacia catechu is a member of the order Fabales and the family Fabaceae, and it has wide variety of applications including textiles and pharmaceutical properties such as antioxidant, antimicrobial and UV protection (Adhikari et al., 2021). When dyeing khadi cotton, a brown hue will be obtained. Hence this dye was selected as a third dye sourced from Farmer's Share in Shorannur (Plate VII) and established tie dye process to create designs.



PLATE VIII

***Acacia catechu* Dye Powder**

3.2. Selection of mordants

Mordants are substances that help the dyestuff adhere to the fibre more easily. It increases the fabric's colour fastness qualities by giving the dye an affinity. A mordant can be

applied using a variety of techniques. Metallic salts, tannins, and oil mordants are the three types of mordants that may be found (Singh and Kumar, 2014).

3.2.1. Alum

Alum mordant is a metallic salt use to color protein fibres with natural dyes. It can be used for yellow, orange, red, lovat and purple. This mordant is one of the most often used to get the desired dye hue. Alum was used as a mordant to the R.cordifolio and T.chebula dyes to get the same hue since it has no impact on the colour of the dye. Alum is shown and collected from Farmer's Share in Shorannur (Plate VIII).



PLATE IX

Alum Mordant

3.2.2. Terminalia chebula

Terminalia chebula is an Indian myrobalan that is used as a mordant and dyestuff. When applied to textiles, it produces a soft buttery yellow. The lightness value of the cloth falls as the dye source concentration increases. *Terminalia chebula* produces improved colour fastness and colour strength (Shabbir et al., 2017). Hence *T.chebula* (Plate VI) was selected as another mordant for the dye source *Acacia catechu* to generate multiple shades.

3.3. Techniques used for mordanting

Mordanting is the process of preparing and applying mordant to textiles. There are numerous mordanting strategies, including pre-mordanting, simultaneous mordanting, and post-mordanting (Hosseinnezhad et al., 2022).

3.3.1. Pre mordanting

The mordant was applied to the substrate, followed by the dye. To achieve better results, mordanting ingredient was soaked along with the de-sized cloth and boiled for few hours.

Alum (Hot method)

Mordanted with alum by hot technique for which 10% of alum was chosen based on cloth weight. Alum was diluted and dipped the cleansed cloth in it, then boiled it for 2 hours at 60⁰C to 80⁰C while stirring constantly to avoid sedimentation. The fabric was then properly rinsed, wrung and hung to dry in the shade.

Terminalia chebula (Hot method)

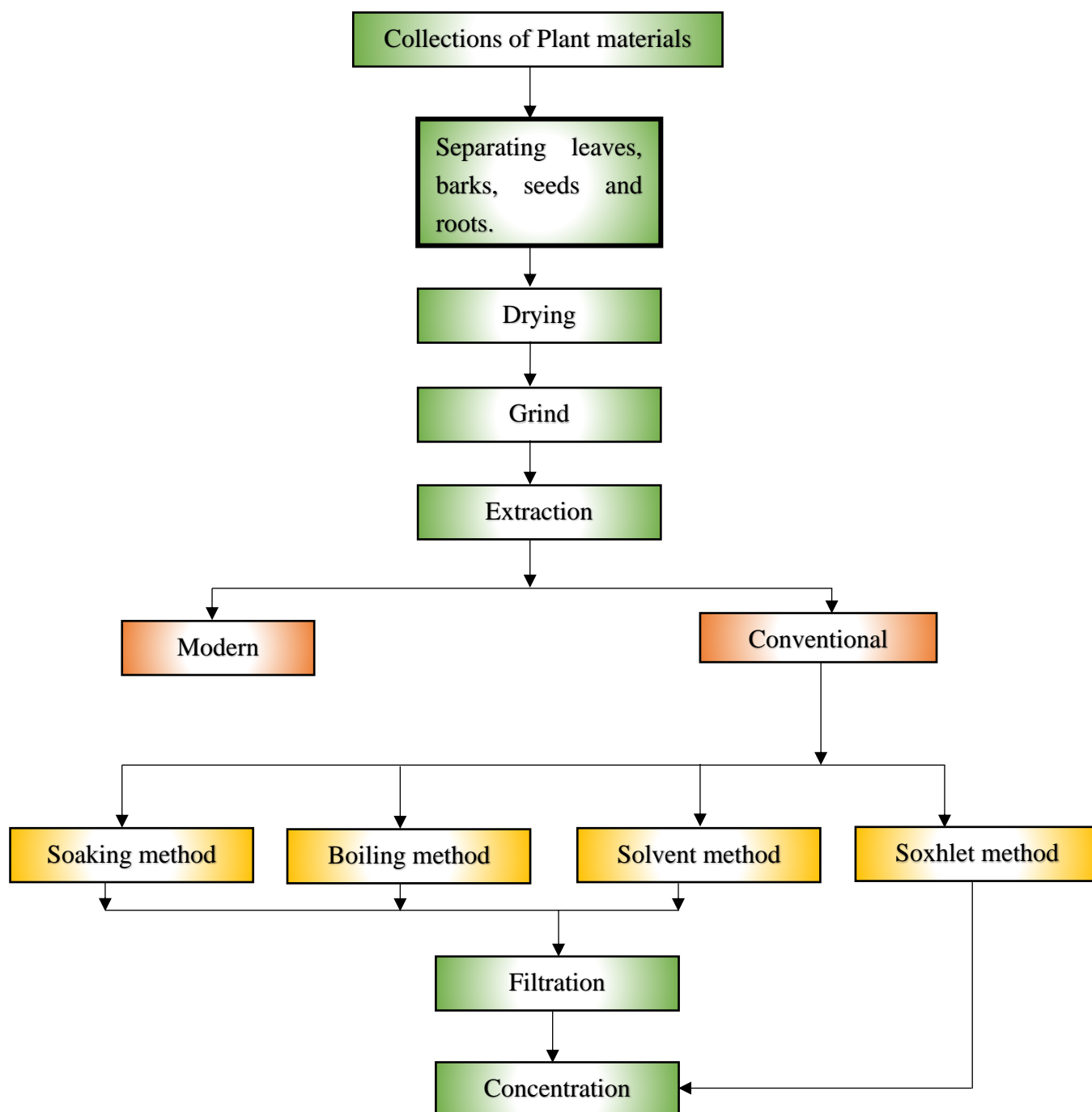
Mordanted with myrobalan by hot technique for which 10% of myrobalan was taken based on cloth weight. Alum was diluted and dipped the cleansed cloth in it, then boiled it for 2 hours at 60⁰C to 80⁰C while stirring constantly to avoid sedimentation. The fabric was then properly rinsed, wrung and hung to dry in the shade. It acquired butter yellow hue aids in dye affinity.

3.4. Procedure for dye extraction

Natural dyeing is the technique of employing natural dyes extracted from natural sources such as plants, minerals, and insects. Beautiful colours can be extracted from leaves, flowers, bark, roots, rocks, fruits, and vegetables. Every stage of the procedure is critical and must be completed in the correct order (Mansour, 2018).

The following is a flow chart for extracting dye components from plant resources

DYE EXTRACTION METHOD



Initially, dye resources were taken from plants and separated into sections. It was then dried and exposed to sunlight for 5 to 7 days. The dry pieces were ground. Since boiling processes have a stronger affinity for colour, the concentration was extracted using the traditional boiling method. The solution was filtered and then taken for further processing (Plate X).

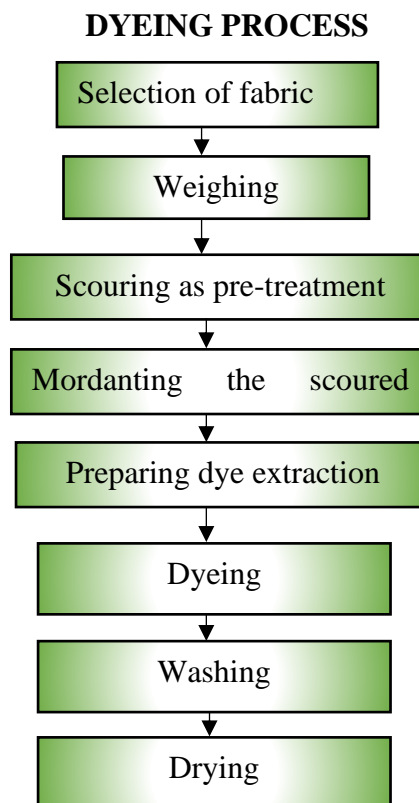


PLATE X

Filtration of Dye Concentration

3.5.Dyeing process

Dyeing is the transfer of dyes from an aqueous solution to a fibre source. Dyeing can be done at any step of textile production, including fibre, yarn, fabric, and completed textile products such as garments and clothing. Color fastness is determined by two factors: the selection of the appropriate dye for the textile material to be dyed and the procedure for dyeing the fibre, yarn, or cloth (Haddar et al., 2014). The following are the steps of this process:



3.5.1. Dyeing

Rubia cordifolio

The roots of *Rubia cordifolio* were collected and dried for 5-7 days before being crushed into a fine powder. In proportion to the weight of the fabric, 35 percent of the powder was extracted and blended in ordinary water overnight. The solution was then boiled at 40-80 degrees Celsius for 2 hours. The dye solution was prepared. To eliminate the colour concentration, cooled it and strained it. A dye bath was used to dilute the dye concentration. Alum-mordanted khadi cotton fabric was dipped in it. It was soaked for 2 hours at (40-80)0C, stirred frequently. After the dyeing process was completed, the fabric was properly cleaned and dried in indirect sunlight. The fabric was then dipped into the dye solution three times in order to get distinct ombre hues of the colour on the appropriate amount of material, with the remaining fabrics being knotted to avoid colouring. The dyed sample is given (Plate IX, X, XI and XII)



PLATE XI

Tied Upper Portion



PLATE XII

First Dip in Madder Dye



PLATE XIII

Second Dip in Madder Dye



PLATE XIV

Third Dip in Madder Dye

Terminalia chebula

T. chebula was collected and dried for 5-7 days before being crushed into a fine powder. It serves as both a mordant and a dye. Thirty five percent of *T.chebula* was collected and blended in ordinary water overnight, based on its fabric weight. At 40⁰C-80⁰C, boiled the solution for 2 hours. After that, it was strained to remove the colour concentration before being diluted in a dye bath. The alum mordanted cloth was immersed into the prepared solution for 2 hours at 40-80 degrees Celsius, while it was constantly stirred. After the dyeing process was completed, the cloth was carefully cleaned and dried in the shade. Before dyeing the fabric, knotted it wherever tie dye designs are required. The sample that has been knotted and coloured is presented (Plate XIII and XIV).



PLATE XV

Tied the Fabric for Spiral Tie and Dye



PLATE XVI

Dyeing in *T.chebula*

Acacia catechu

Collected The leaves of *A. catechu* were dried for 5-7 days before being crushed into a fine powder. It serves as both a mordant and a dye. In proportion to the fabric weight, 35 percent of the powder was extracted and properly mixed in ordinary water overnight. At 40-80⁰C, boiled the solution for 2 hours. After that, it was squeezed to eliminate the colour concentration. A dye bath was used to dilute the dye concentration. In a dye bath, immersed the mordanted (myrobalan) khadi cotton material. Soaked it for 2 hours at (40-80)⁰C, stirred regularly. Fabric was rinsed thoroughly after dyeing. It was then dried in indirect

sunlight to avoid stains. Before dyeing the fabric, wrapped it in the desired symmetrical pattern. The dyed sample is given (Plate XV, XVI and XVII)



PLATE XVII

Mordanted with *T.chebula*



PLATE XVIII

Tied Vertically



PLATE XIX

Dyeing in *A.catechu*

3.5.2. Washing

Following the dye process, washing is one of the most essential processes in removing contaminants from the cloth. After rinsed it was immersed in plain water for 15 minutes to eliminate contaminants. The fabric was continuously washed until the color bled ceases. Washing images are shown (Plate XVIII).



PLATE XX

Washed in Plain Water

3.5.3. Drying

Drying under sunlight keeps cloth safe and prevent fading, after every dye bath. Heat helps to set the colour and prevent it from fading over time. The samples are shown (Plate XIX, XX and XXI). The nomenclature of dyed samples are given in Table IV



PLATE XXI

Madder Dyed Sample



PLATE XXII

Cutch Dyed Sample



PLATE XXIII

Myrobalan Dyed Sample

TABLE IV

NOMENCLATURE OF THE SAMPLE

Samples	Code
Original	O
De-sized	D
Madder dyed fabric	A
Myrobalam dyed fabric	B
Cutch dyed fabric	C

3.6. Evaluation of fabric

The process of measuring, examining, and assessing the features and properties of textile fibres is known as textile testing. It is a vital step in the manufacturing, research, and development of textile materials. It ensures product quality and can avoid complications in the production process (Ahmad, 2017).

3.6.1. Subjective Evaluation

3.6.1.1. Visual Inspection

The coloured samples were judged by 25 textile specialists and postgraduate students from the Textile and Clothing Department at Avinashilingam Institute of Higher Education for Women in Coimbatore. The coloured samples were exhibited for simple examination, and they were asked to evaluate them. The grading criteria were evenness in dyeing, brilliancy in colour, texture, design, and design and appearance. Finally, the information gathered was compiled and reviewed.

3.6.2. Objective Evaluation

3.6.2.1. Fabric weight

The fabric weight tests were performed in accordance with ASTM test method D 3776 option C - 2002. For testing, cloth samples were cut at random using GSM cutter. The samples were preconditioned in accordance with ASTM D 1776 standards.

Fabric weight is a fabric's relative weight stated in grams per square metre. GSM is computed by dividing the weight of the related cloth by the unit area (Das, 2013). A sample was sliced with a GSM cutter and weighed with an electronic weighing balance (Plate XXIII a).

Gram Square Meter (GSM) calculation formula:

$$GSM = \frac{\textit{Weight of the fabric X Square meter}}{\textit{Unit area}}$$

The same process was used to determine the fabric weight of the original, scoured and the three samples madder, myrobalan and cutch respectively, and the mean value was computed and noted.

3.6.2.2. Fabric thickness

The thickness of the fabric was measured using ASTM D 1777-2002 test technique. The samples were preconditioned in accordance with ASTM D 1776 standards.

The Hungary thickness tester was used. It was composed of two parts: the anvil and the pressure foot, which worked in tandem via a level spring action. A known arbitrary pressure should be applied and maintained between the plates (Das, 2013). It will help to determine the thickness of fabric.

Loading weight 4.14kPa is utilised while inserting the fabric between the plates. Each division of the dial read 0.01mm. The dial reading was recorded for every samples. Then the readings were noted and calculated the mean value of ten readings from the original, scoured, dyed samples of madder, myrobalan and cutch (Plate XXIII-d).

3.6.2.3. Fabric Stiffness test

To determine the stiffness of a cloth, test the warp and weft individually. Shirley Stiffness tester is made up of a template scale and a smooth low friction platform. The platform is supported by two metal sides. It is made up of a bended mirror with an index line. It is used to assess the fabric's ability to stand on its own without any support (Plate XXIII-b).

The samples were conditioned in the standard using the ASTM test method D 1388-2002.

A rectangular strip of 6" x 1" was fixed on a horizontal pedestal. The scale(cm) was mounted over the cloth and placed on a smooth surface. The scale was moved forward slightly with the cloth until the strip of fabric falls down gently and reaches the index line. The action is stopped immediately and readings were noted from the scale. Similarly, three warp and three weft samples were collected and determined the stiffness from the original, as well as scoured and coloured madder, myrobalan, and cutch samples. To achieve better findings, three weft samples and three samples from each sample were collected (Basu, 2006).

3.6.2.4. Drape test

Drape is used to describe the fabric hangings with its own weight. Also, to determine free curves found from the samples (Memon, 2021).

For assessing a fabric's drapability, the Eureka drape metre was employed. The drape metre is made up of two circular discs of varying sizes. One was a large 31cm template, while the other was a little 18cm disc. A 31cm brown sheet was cut with a large template and weighed (P_w). A light source was set beneath the projected lens, and a fabric sample was placed on the surface of the little disc, then a brown paper was mounted above a glass cover so that the shade of a sample could be viewed and carefully drawn in a brown sheet. Finally, the shape was cut and weighed as W_{pa} (Plate XXIII-c). Then the brown paper of size 18cm was weighed (W_{sda}).

$$F = \frac{W_{pa} - W_{sda}}{P_w} \times 100,$$

Where, F = represents Drape coefficient percentage;

P_w = weight of annular ring of paper;

W_{pa} = weight of projected area of paper;

W_{sda} = weight of supported disc area of paper.

3.6.2.5. Color Fastness test

Textile colour fastness is a popular and required test technique for staining and pigment strength. It has diverse fibres and colours, and its pigments have variable staining and toughness. In everyday wear, there is frequently a broad region of colour fading of various textiles. When the garments are cleaned and rubbed, the general colour tone becomes uneven, reducing the overall attractiveness of the clothes. As a result, it is critical to assess the degree of colour staining and stiffness of textile pigments induced by friction. Color fastness test can

be done by different methods includes color fastness by sunlight, washing, pressing and crocking test (Lei, 2020). Evaluating the color staining and color change grade by using AATCC grey scales (Plate XXIII – e) (Pujiarti and Putri, 2021).

3.6.2.5.1. Fastness to sunlight

Color-fastness test was done by AATCC test method -2004. Color fastness to light is a resistance of a material to change in its color characteristics by sunlight or artificial light (Pujiarti and Putri, 2021).

Each coloured samples from madder, myrobalan and cutch with a size of (16X5) cm were used for the test. The samples were then split and marked into eight equal halves for each of the seven days. The entire sample with black chart paper was covered to protect it from direct sunlight for the next 7 days, and the other pieces were exposed in the same manner as the first. The first section was exposed to sunlight for seven days, the second for six days, and so on. As a consequence, the colour shift of dyed samples is compared and graded using the AATCC grey scale.

3.6.2.5.2. Fastness to wet and dry pressing

Each coloured sample was cut into 5cm X 5cm squares for testing. For dry pressing, the samples were sandwiched between two white fabrics of the same size. The cloth was then ironed for at least 5 seconds using a hot iron set to 350°F. The colour transferred from the sample to the white cloth was then graded and assessed using the AATCC grey scale (Kumar et al., 2022). To test the colour fastness quality by using wet and dry pressing, the same technique was performed for each coloured samples of madder, myrobalan and cutch.

3.6.2.5.2.1. Fastness to crocking

Sasmira crock metre was employed to evaluate the fastness of coloured materials to wet and dry crocking. The test metre is made up of two metal blocks, the bottom of which is immovable and the upper of which is moveable through a turning handle on the side of the block. To hold the white cloth for testing, there was a knob attached to the upper block component (Lei, 2020). The samples were cut into 20cm X 10cm squares and secured with the aid of the foundation block's easy-to-rub surface in lengthwise direction. A 5cm X 5cm white cloth was held on a knob. The handle was rotated upto 50 times to transfer the colour of the dyed cloth on the white fabric. After removing the white cloth from the knob, the staining is

assessed using the AATCC grey staining scale. Repeat for the remaining samples. Dried white cloth was used for dry crocking, whereas wet white fabric was used for wet crocking.

3.6.2.5.3. Fastness to washing

The colour fastness properties of textile fabric can be determined by the fastness to wash using both laundry and hand washing technique. It depends on the methods of dyeing. For this, 10 % of soap berries per cloth weight were soaked in hot water at 50⁰ C. The sample was cut into 5cm X 5cm squares and immersed in soap solution. Then it cleaned and dried in the shade. The colour shift of the dyed sample was graded using the AATCC grey scale. Similarly, the additional samples used by the same were determined. Repeated the same for 3 days to get better results.

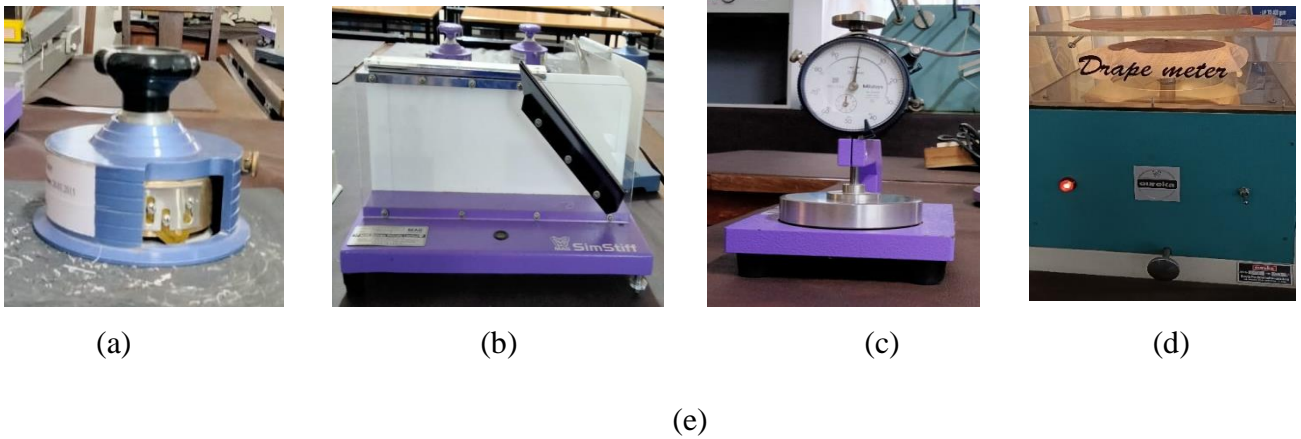


PLATE XXIV

TESTING EQUIPMENTS: (a) GSM cutter, (b) Fabric Stiffness, (c) Drape meter, (d) Fabric thickness, (e) AATCC Gray Scale for Color change and Color Staining

3.7. Development of Portfolio

Fashion Portfolio was created to show off works using visual boards. It demonstrated relevant talents and created innovative designs on various boards such as theme board, mood board, colour board, fabric swatches, and sketch boards.

The theme board illustrated the concept of "Chroma Le Pastel," which represented a quality of combination of pastel hues and its saturations. Pastel colours evoke feelings of openness and tranquillity. These colours were considered soothing, calming and they expressed neutrality. They belong to the colour family that is psychologically uplifting. They worked well with neutral colours to create a feeling of earthiness and elegance. Pastel hues with sustainable products provided the person and the environment a fresh feeling. The objective of this theme was to focus on visions of implementing pastel hues on casual wears. Casual outfits suggest a relaxed and comfortable look. An employee morale can improve in casual work environments because people are less concerned about their appearance.

Corel Draw and Adobe Illustrator software were used to create the illustrations. A number of boards have been created to demonstrate the vision on theme-based portfolio, which are listed below.

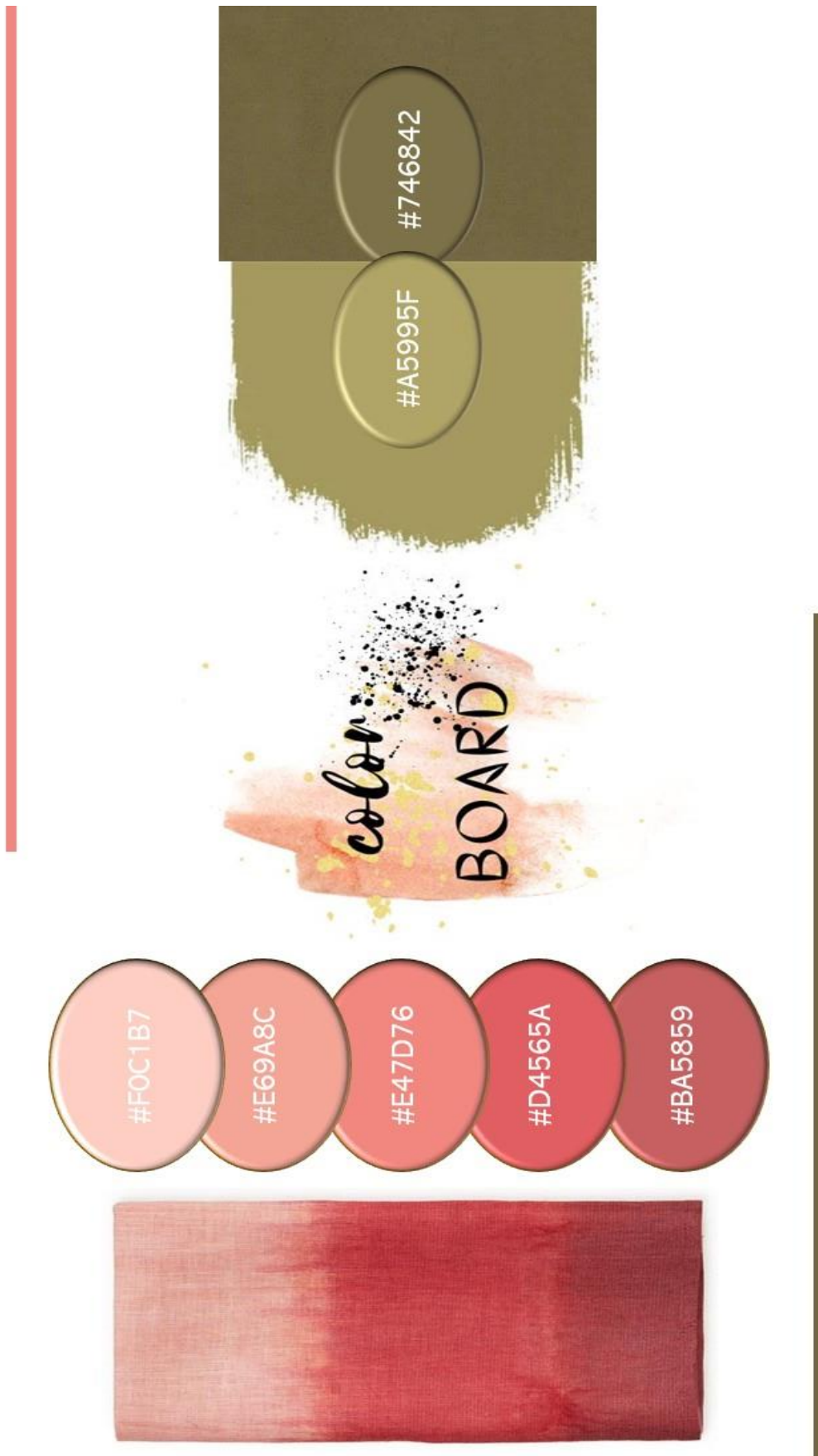
3.7.1. Theme Board



3.7.2. Mood Board



3.7.3. Color Board

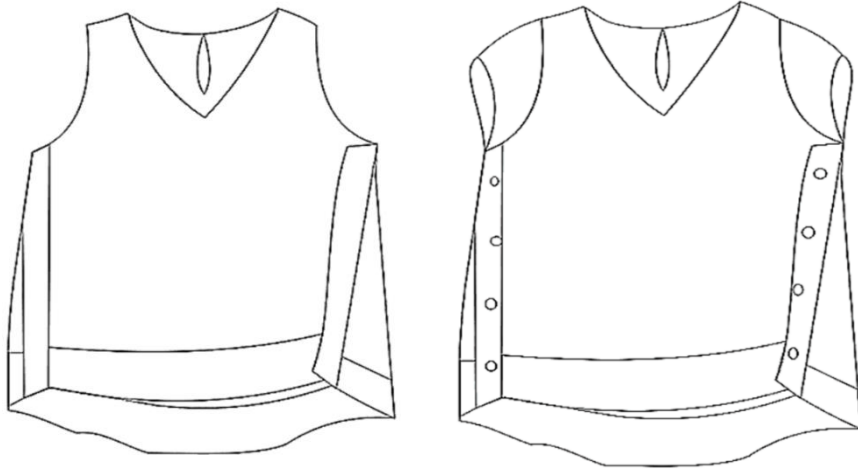


3.7.4. Fabric Swatch



3.7.5. Flat Sketches

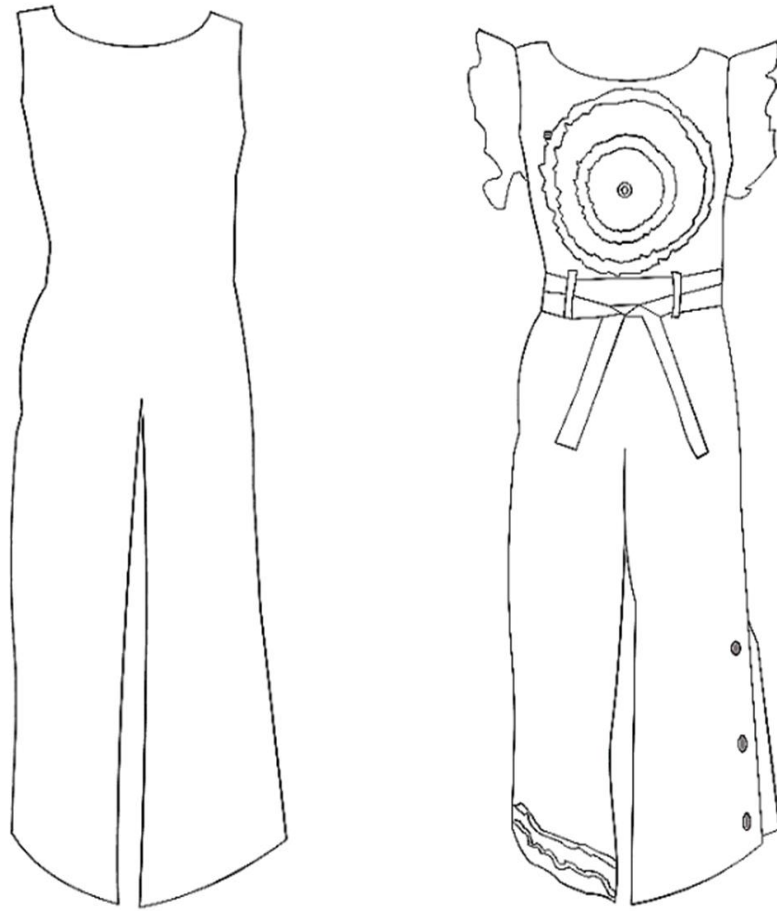
3.7.5.1. Tie and Dye Top



3.7.5.2. Ombre Gown



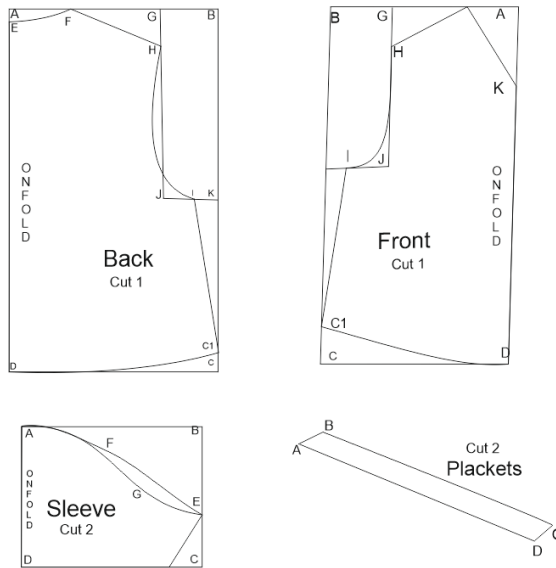
3.7.5.3. Tie and Dye Jumpsuit



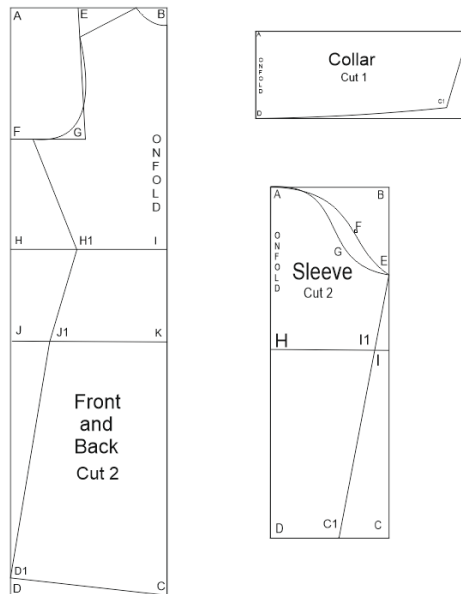
3.8. Development of Garment

3.8.1. Drafting Patterns

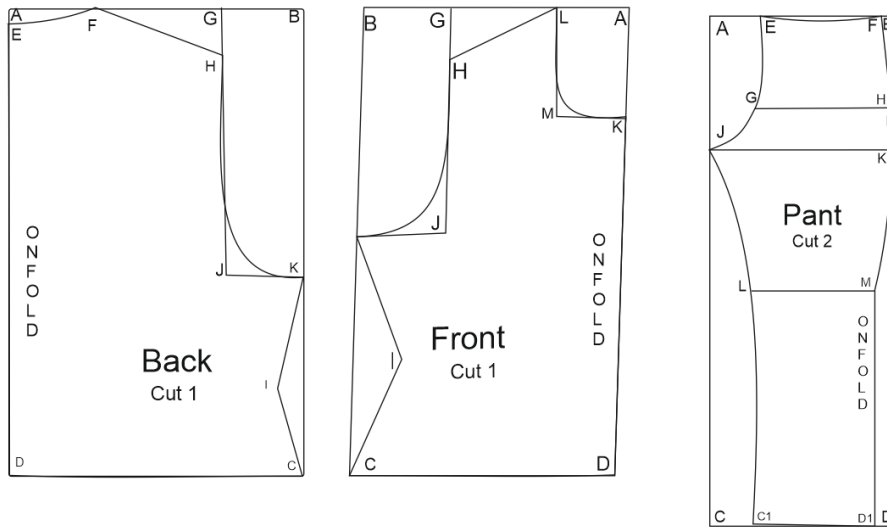
Tie and Dye Top



Ombre Gown



Tie and Dye Jumpsuit



3.8.2. Construction of Garments

3.8.2.1. Tie and Dye Top

Front

$$AB = 10'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$BC = 23'' + \frac{3}{4}'' \text{ seam allowance}$$

$$AK = 5''$$

$$AG = 7.5'' + \frac{1}{2}'' \text{ seam allowance}$$

$$CC1 = 2'' \text{ inch}$$

$$GI = 7 \frac{3}{4} + \frac{1}{2}'' \text{ seam allowance}$$

$$GH = 1 \frac{1}{2}''$$

Back

$$AB = 10'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$BC = 23'' + \frac{3}{4}'' \text{ seam allowance}$$

$$GI = 7 \frac{3}{4}'' + \frac{1}{2}'' \text{ seam allowance}$$

$$AE = 2'' \text{ inch}$$

$$AF = 4'' \text{ inch}$$

$$GH = 1 \frac{1}{2}'' \text{ inch}$$

$$CC1 = 1.5'' \text{ inch}$$

Sleeve

$$AD = 4'' + \frac{3}{4}'' \text{ seam allowance}$$

$$AB = 7''$$

$$AE = 5'' + \frac{1}{2}'' \text{ seam allowance}$$

Cut parts were collected and front and rear lining cloths of the same colour were attached separately. Then, using biased cloth, gave final stitch on both sides. Finished the neckline and sewn the cap sleeves onto both sides. To add greater aesthetic appeal, added a bottom stitch and buttons to both sides of the front pattern.

3.8.2.2. Ombre Gown

Front and Back

$$BE = 7 \frac{1}{2}'' + \frac{1}{2}'' \text{ seam allowance}$$

$$BC = 67'' + \frac{1}{2}'' \text{ seam allowance}$$

$$FF1 = 36'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$H11 = 26'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$J1K = 36'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$D1C = 25'' + \frac{1}{2}'' \text{ seam allowance}$$

$$EF = 7 \frac{3}{4}'' + \frac{1}{2}'' \text{ seam allowance}$$

Sleeve

$$AD = 19'' + \frac{3}{4}'' \text{ seam allowance}$$

$$AB = 7''$$

$$AE = 5'' + \frac{1}{2}'' \text{ seam allowance}$$

$$HI1 = 8 \frac{1}{2}'' + \frac{1}{2}'' \text{ seam allowance}$$

Collar

$$AB = 7'' + \frac{1}{2}'' \text{ seam allowance}$$

$$AD = 2'' + \frac{1}{2}'' \text{ seam allowance}$$

$$BC1 = 6.5'' + \frac{1}{2}'' \text{ seam allowance}$$

Cut portions were gathered and sewed together with lining cloth. Then join the front and back patterns. Attached the zip to the back side centre, then the collar band to the neck. C connected and completed the sleeve component on the left with full hand sleeve and right side with pleated sleeve. Then completed the bottom and side of the gown by closing the side seams from top to bottom.

3.8.2.3. Tie and Dye Jumpsuit

Front

$$AB = 10'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$BC = 23'' + \frac{3}{4}'' \text{ seam allowance}$$

$$AG = 7 \frac{1}{2}'' + \frac{1}{2}'' \text{ seam allowance}$$

$$AK = 5''$$

$$AG = 7.5'' + \frac{1}{2}'' \text{ seam allowance}$$

$$GI = 7 \frac{3}{4} + \frac{1}{2}'' \text{ seam allowance}$$

$$GH = 1 \frac{1}{2}''$$

Back

$$AB = 10'' + 2 \frac{1}{2}'' \text{ seam allowance}$$

$$BC = 23'' + \frac{3}{4}'' \text{ seam allowance}$$

$$GI = 7 \frac{3}{4}'' + \frac{1}{2}'' \text{ seam allowance}$$

AE = 2" inch

AF = 4" inch

GH = 1 ½" inch

AG = 7 ½" + ½" seam allowance

Pant

AC = 45" + 1" seam allowance

EF = 6 ½" + ¾" seam allowance

JK = 9" + ¾" seam allowance

LM = 7" + ¾" seam allowance

C1D1 = 7 ½" + ½" seam allowance

Cut parts were carefully chosen. Sewing was divided into two phases: the top section and the bottom pant piece. The upper portions of the neck pieces were finished in the first phase, and the rear and front portions were carefully joined. The sleeves were then ruffled on both sides and connected. The top pieces were completed and the side seams were joined. Phase two involved taking the bottom sections, joining them to the side, and finishing the pant bottom. Finally, sew the top and bottom pieces together to create a jumpsuit. As a belt, strips of fabric are used as an added element.

3.9. Statistical Analysis

The results of laboratory tests were statistically analysed using analysis of variance of one-way test (ANOVA), which is a very effective approach for analysing multiple samples. The purpose of the analysis was to examine if the results differed owing to differences in dyes, mordants, and procedures (Liu and Wang, 2021).

4. RESULTS AND DISCUSSION

The following are the findings of the research on "**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**", which are as follows:

4.4. Subjective Evaluation

4.4.1. Visual inspection

4.5. Objective Evaluation

4.5.1. Physical property test

4.5.1.1. Fabric thickness

4.5.1.2. Fabric Weight

4.5.2. Comfort Property test

4.5.2.1. Drape test

4.5.2.2. Fabric Stiffness

4.5.3. Color fastness to sunlight, washing, pressing drying and crocking

4.6. Designed Garment

4.6.1. Ombre Gown

4.6.2. Tie and Dye Jumpsuit

4.6.3. Tie and Dye Top

4.1. Subjective evaluation

4.1.1. Visual Inspection

As shown in Table V, 25 staffs and postgraduate students from the textiles and clothing department were chosen to evaluate the coloured fabric. They were asked to evaluate on the basis of Evenness in dyeing, Brilliancy of color, Texture and Designs and Appearance.

TABLE V
VISUAL INSPECTION

S. No	Sample	Rating in Percentage											
		Evenness in dyeing			Brilliancy of color			Texture			Design and appearance		
		Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
1	Madder	85	10	5	97	3	-	90	10	-	95	-	-
2	Myrobalan	90	10	-	85	15	-	90	10	-	85	15	-
3	Cutch	97	3	-	95	5	-	96	4	-	92	8	

It is clear from Table V that the majority of the judges ranked 85% of madder sample as good in evenness of dyeing. Ninety seven percent ranked good in brilliancy of colour whereas 90% ranked good in texture and 95% good in designs and appearance. Then with regard to the sample myrobalan fabric, 90% good in evenness of dyeing, 85% in brilliancy of color, 90% good in texture and 85% good in designs and appearance. According to the cutch dyed fabric, majority of 97% ranked good in evenness of dyeing, 95% ranked good in brilliancy of coloring, 96% ranked good in texture and 92% good in designs and appearance.

4.2. Objective evaluation

4.2.1. Physical property

4.2.1.1. Fabric thickness

Fabric thickness and analysis of variance of original, scoured and dyed madder, myrobalan and cutch are shown in Table VI and Figure 5

TABLE VI
FABRIC THICKNESS

S. No	Sample	Mean Value	Standard deviation	Gain or Loss over Original	Percentage of Gain or Loss over Original (%)	F value
1	O	0.428	0.0154	-	-	91.749*
2	D	0.422	0.0198	(+) 0.006	1.42	
3	A	0.428	0.0154	(+) 0.006	1.42	
4	B	0.537	0.0149	(+) 0.115	27.25	
5	C	0.525	0.0267	(+) 0.103	24.40	

*-Significant at 1% level

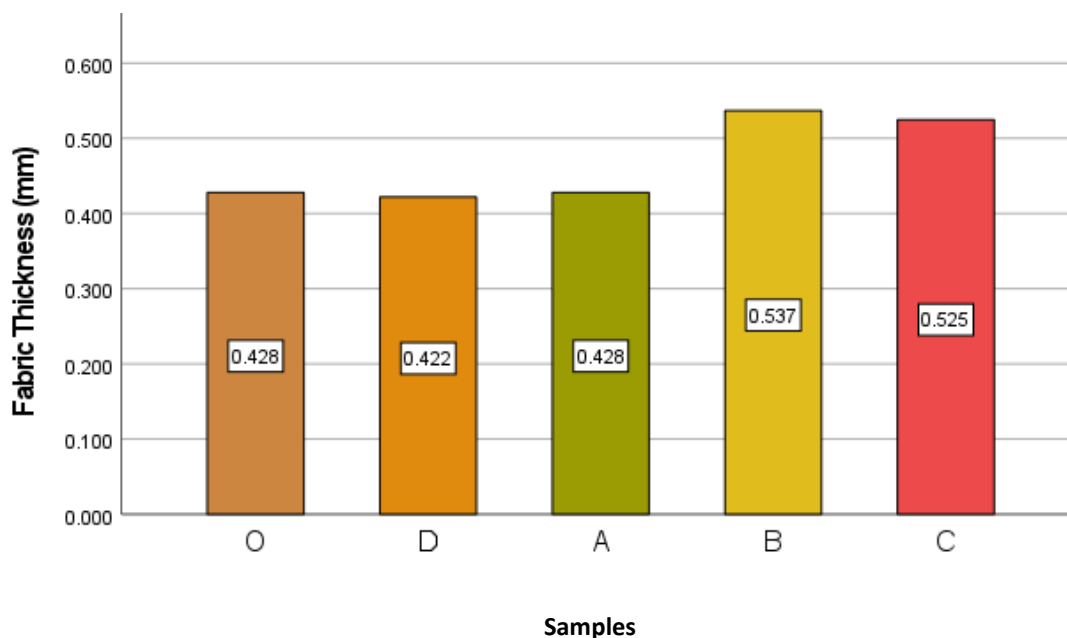


FIGURE 5

FABRIC THICKNESS

Table VI and Figure 5 shows that the fabric thickness of the de-sized, dyed madder sample remained constant, 1.42% when compared to the original fabric. Myrobalan fabric thickness increased by 24.40 %, while the dyed cutch sample increased by 27.25 %. Overall F value obtained is 91.749*.

4.2.1.2. Fabric Weight

Fabric weight and analysis of variance of original, scoured and dyed madder, myrobalan and cutch are shown in table VII and Figure 6

TABLE VII
FABRIC WEIGHT

S. No	Sample	Mean Value	Standard deviation	Gain or Loss over Original	Percentage of Gain or Loss over Original (%)	F value
1	O	142.65	1.863	-	-	543.90*
2	D	108.80	2.193	(+) 33.85	31.11	
3	A	146.02	2.931	(+) 37.22	34.20	
4	B	143.15	2.698	(+) 34.35	31.57	
5	C	152.17	1.612	(+) 43.37	28.50	

*Significant at 1% level

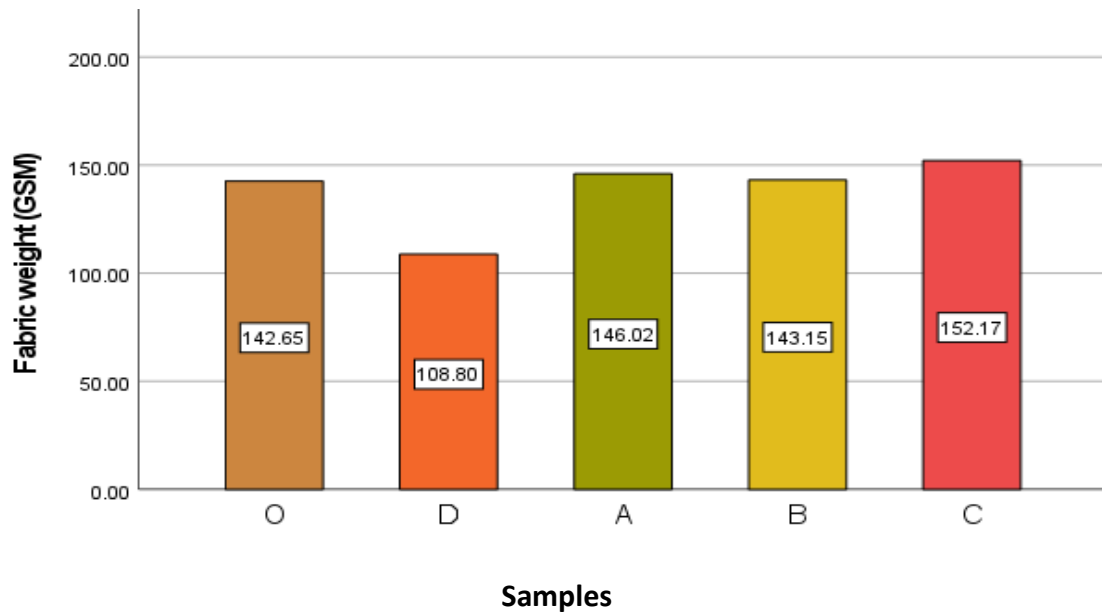


FIGURE 6

FABRIC WEIGHT

Table VII and Figure 6 shows that the fabric weight of the de-sized and coloured madder sample increased by 31.11% and 34.20% respectively. Myrobalan fabric weight increased by 31.57 %, while the dyed cutch sample increased by 28.50 %. Overall F value obtained is 543.90*.

4.2.2. Comfort Property Test

4.2.2.1. Drape test

Fabric drapability and analysis of variance of original, scoured and dyed madder, myrobalan and cutch are shown in table VIII and Figure 7.

TABLE VIII
FABRIC DRAPABILITY

S.No	Sample	Mean Value	Standard deviation	Gain or Loss over Original	% of Gain or Loss over Original	F value
1	O	43.43	0.2589	-	-	241.54*
2	D	41.52	0.2173	(-) 1.91	4.39	
3	A	43.07	0.2426	(-) 0.36	0.82	
4	B	42.32	0.3023	(-) 1.11	2.55	
5	C	45.01	0.3020	(+) 1.58	3.63	

*-Significant at 1% level, NS-Not Significant

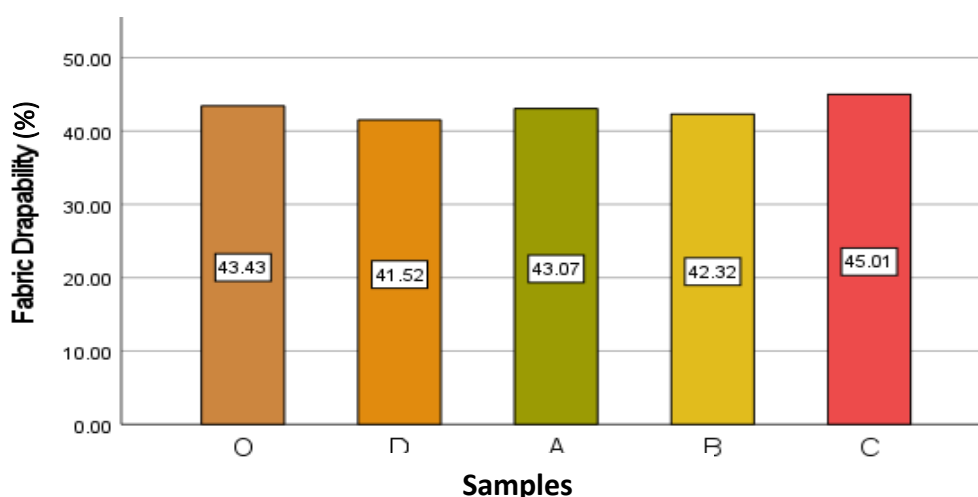


FIGURE 7

FABRIC DRAPABILITY

Table VIII and Figure 7 shows that the fabric drapability of the de-sized and coloured madder sample decreased by 4.39% and 0.82% respectively. Fabric drapability of myrobalan decreased by 2.55%, while the dyed cutch sample increased by 3.63%. Overall F value obtained is 241.54*.

4.2.2.2. FABRIC STIFFNESS

TABLE IX
FABRIC STIFFNESS - WARP

S.No	Sample	Mean Value	Standard deviation	Gain or Loss over Original	% of Gain or Loss over Original	F value
1	O	2.625	0.3783	-	-	1.618 ^{NS}
2	D	2.487	0.0449	(-) 0.138	5.25	
3	A	2.438	0.0828	(-) 0.187	7.12	
4	B	2.467	0.0457	(-) 0.158	6.01	
5	C	2.516	0.0794	(-) 0.109	4.15	

NS-Not Significant.

TABLE X
FABRIC STIFFNESS – WEFT

S.No	Sample	Mean Value	Standard deviation	Gain or Loss over Original	% of Gain or Loss over Original	F value
1	O	2.296	0.1270	-	-	24.289*
2	D	2.100	0.1432	(+) 0.196	9.33	
3	A	2.018	0.2180	(-) 0.082	3.90	
4	B	2.515	0.0698	(+) 0.415	19.76	
5	C	2.448	0.0771	(+) 0.348	16.57	

*-Significant at 1% level.

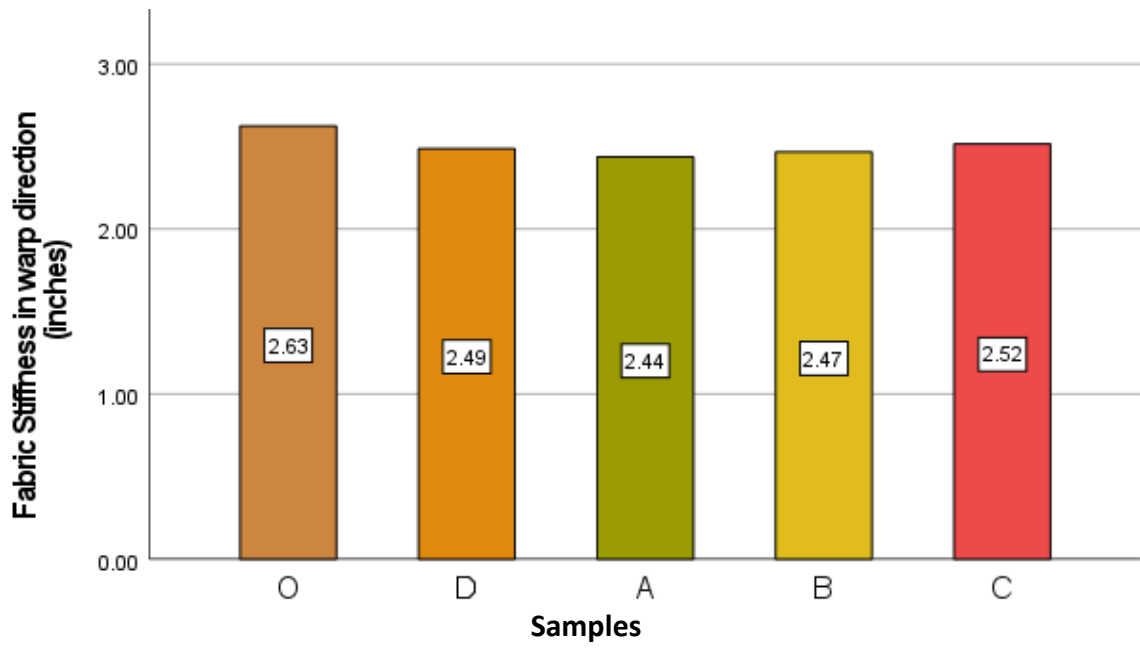


FIGURE 8

FABRIC STIFFNES IN WARP

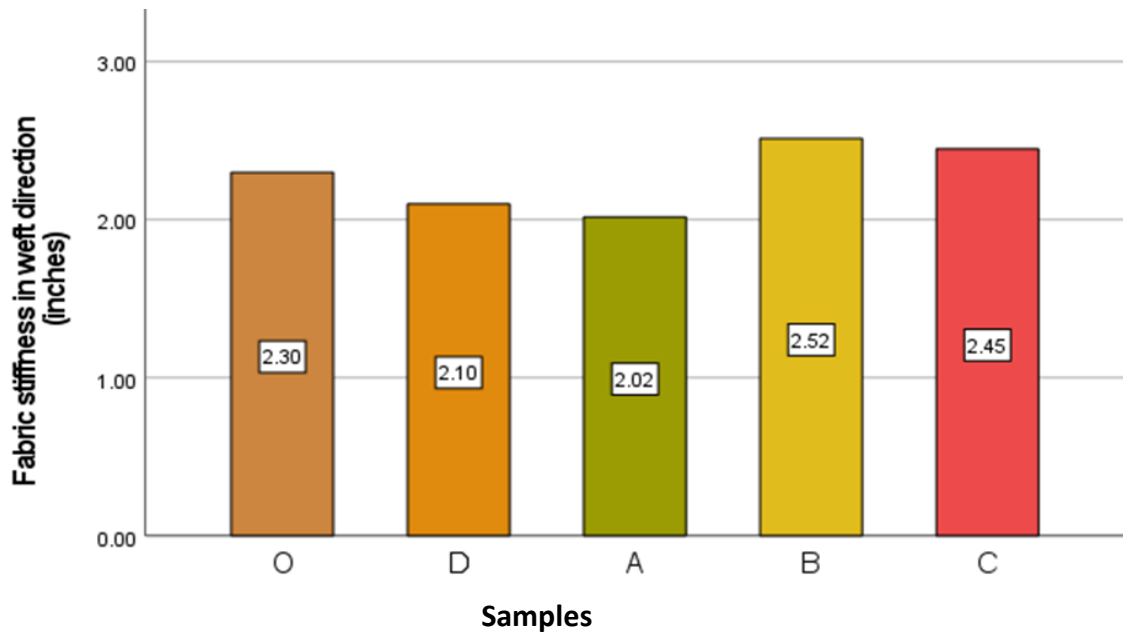


FIGURE 9

FABRIC STIFFNES IN WEFT

Table IX and Figure 8 shows that the fabric stiffness - warp of the de-sized and coloured madder sample decreased by 5.25% and 7.12% respectively. Myrobalan fabric stiffness decreased by 6.01%, while the dyed cutch sample decreased by 4.15%. Overall F value obtained is 1.618^{NS}.

Table X and Figure 9 shows that the fabric stiffness - weft of the de-sized fabric increased by 9.33% and coloured madder sample decreased by 3.90%. Myrobalan fabric stiffness increased by 19.76 %, while the dyed cutch sample increased by 16.57 %. Overall F value obtained is 24.289*.

4.2.3. Color fastness to sunlight, washing, pressing drying and crocking

The colour fastness to sunshine, washing, dry and wet pressing, and dry and wet crocking of dyed samples is shown in Table XI.

TABLE XI
COLOR FASTNESS TO SUNLIGHT, WASHING, PRESSING DRYING AND CROCKING

Sample	Sunlight		Washing		Crocking				Pressing			
	Color change	Staining	Color change	Staining	Dry		Wet		Dry		Wet	
					Color change	Staining	Color change	Staining	Color change	Staining	Color change	Staining
Madder	5	5	5	4/5	5	4/5	5	4	5	5	5	4
Myrobalan	5	5	5	4/5	5	4/5	5	4	5	5	5	4
Cutch	5	4/5	4/5	4	5	4	5	4	5	5	5	4

5 – Excellent, 4 – Very Good, 3 – Good, 2 – Fair, 1 – Poor

The Table XI shows that the color fastness to washing, sunlight, wet and dry crocking, wet and dry pressing of dyed samples. The majority of the dyed samples of madder, myrobalan, and cutch scored 5 on colour fastness tests against washing, sunlight, crocking, and pressing, respectively. The AATCC grading scale of colour change and colour staining yielded outstanding results for grade 5. As a result, the dyed three samples of madder, myrobalan, and cutch obtained the highest grade and had excellent colour fastness properties.

4.3. Designed Garmentts

4.3.1. Ombre Gown

An ombre coloured pattern outfit was dyed with the source madder is shown in Plate XXIV.



FRONT VIEW

SIDE VIEW

PLATE XXV

OMBRE GOWN

4.3.2. Tie and Dye Jumpsuits

Jumpsuits made of khadi cloth dyed with myrobalan and embellished with tie and dye designs (Plate XXV).



FRONT VIEW



SIDE VIEW

PLATE XXVI
TIE AND DYE JUMPSUITS

4.3.3. Tie and Dye Top

Vertical stripes of Tie and Dye was created to provide a appeal to the eye when dyed with Cutch and made a waist length top (Plate XXVI).



FRONT

BACK

SIDE

PLATE XXVII

TIE AND DYE TOP

5. SUMMARY AND CONCLUSION

One of the leading and largest industry is textile industry in India. USD will reach 1.23 trillion by 2025, with a compound annual growth rate of 4.24% (Dhanabhakym, 2009). The usage of harmful chemicals has a negative impact on the textile industry's long-term viability. A good-quality environment is necessary for our health and well-being, as well as our economic, social life, and safety. Sustainable textiles are made from eco-friendly materials such as natural fibres and recyclable materials. Sustainable textiles not only assist to decrease negative environmental consequences, but also enable millions of employees to earn fair salaries and work in safe circumstances (Muthu, 2017).

Natural colourants have captured the attention of everyone in today's world of increased environmental concern. The technique of dyeing using vegetable dyes have gained popularity not only for its health and environmental benefits, but also for its beauty and originality. Natural dyes are biodegradable, non-toxic, and non-allergenic, making them better for the environment and for usage in close proximity to humans (Vashisht and Rani, 2020).

The strength of handloom is the ease with which new patterns may be introduced, something that the power loom industry cannot match. Khadi fabric embodies cosiness and environmental sustainability. It has helpful qualities, such as being porous and providing breathing comfort, making it suitable for body-fitting garments. It is also comfortable, long-lasting, and attractive. In the freedom movement, it is also known as Gandhi's fabric. Khadi cloth with natural dyes produces delicate hues and relaxing effects. Khadi as a fashion statement has a variety of styles intended for young people. They highly advise young people to consider wearing it on a regular basis (Parashar, 2022).

Considering the above facts in mind, the present study designed on “**Application of Selected Natural Dyes for Designing and Developing of Casual Wears**”, with following objectives:

- To select natural sources for dyeing
- Dye khadi fabric with selected natural sources
- To create theme-based portfolio
- Based on the theme, garments are designed and constructed.
- Evaluation of garments.

Findings of the Study

Three natural dye sources were selected and extracted using the boiling process. Khadi cloth was chosen and de-sized to eliminate soluble and insoluble pollutants. Before dyeing, it was mordanted with alum and myrobalan. *Rubia cordifolia*, *Terminalia chebula*, and *Acacia catechu* were three natural resources considered. Dyed three pieces of cloth with three distinct dye sources using three different colours integrating saturation and tie dye patterns to create more appealing effect.

Corel Draw and Adobe Illustrator software were used to create and develop clothing illustrations. Digital Fashion portfolio was created as a simple visual manner to display a group of works digitally. Theme boards, mood boards, colour boards, fabric samples, and flat drawings are all included in the digital fashion portfolio. Finally, three garments were opted from three distinct coloured materials: an ombre madder gown, a top, and a jumpsuit in cutch and myrobalan coloured fabrics with tie and dye patterns respectively.

The muslin patterns was built according to the fundamental pattern drafting for the clothes. The garments were stitched using measurements based on the pattern of design developed. Constructed garments were appraised for fitting and appearance by trying on mannequin. The subject was chosen based on the standardised body measurement. Twenty-five experts and postgraduate students from the Textiles and Clothing Department at Avinashilingam Institute for Home Science and Higher Education for Women in Coimbatore were requested to rate the manufactured clothes using a visual inspection form. Details such as physical properties of dyed fabric as well as colourfastness properties were evaluated and recorded.

Subjective Evaluation

According to the subjective evaluation of visual inspection study, madder, myrobalan, and cutch coloured material feels better than original cloth, and the ombre and tie dye effects of colours offered a calming aesthetic add on quality to the finished garments. The majority of participants rated it a score of 90 % or more for its texture, colour brilliancy, evenness in dyeing, and design and appearance.

Objective Evaluation

- Fabric thickness of de-sized, dyed with madder, myrobalan and cutch are 1.42%, 1.42%, 27.25% and 24.40% respectively when compared with original fabric at one percent level significance.
- The fabric weight of the de-sized and coloured madder sample increased by 31.11% and 34.20% respectively. Myrobalan fabric weight increased by 31.57 %, while the dyed cutch sample increased by 28.50 %.
- The fabric drapability of the de-sized and coloured madder sample decreased by 4.39% and 0.82% respectively. Fabric drapability of myrobalan decreased by 2.55%, while the dyed cutch sample increased by 3.63%.
- The fabric stiffness - warp of the de-sized and coloured madder sample decreased by 5.25% and 7.12% respectively. Myrobalan fabric stiffness decreased by 6.01%, while the dyed cutch sample decreased by 4.15% .
- The fabric stiffness - weft of the de-sized fabric increased by 9.33% and coloured madder sample decreased by 3.90%. Myrobalan fabric stiffness increased by 19.76 %, while the dyed cutch sample increased by 16.57 %.
- The majority of the dyed samples of madder, myrobalan, and cutch scored 5 on colour fastness tests against washing, sunlight, crocking, and pressing tests respectively. The AATCC grading scale of colour change and colour staining yielded outstanding results. As a result, the dyed three samples of madder, myrobalan, and cutch received the highest grade and had excellent colour fastness properties.

Conclusion

The handloom weavers are part of social spectrum with tradition of using sustainable resources. The fashion system is a component of a wider social and cultural phenomena, it embraces both the business as well as the art and skill of fashion. Sustainability is the source of renewable and non-renewable resources on which civilization depends, and it shapes the societies in which we live in fundamental ways. Natural dyes will be the next big thing, and it is only a matter of time until we recognize the depleting resources and deleterious impacts on the environment in order to make the transition feasible. Natural colours are both biodegradable and harmless. In terms of safe discharge, these colours are better for the environment. Microbes, moth insects, and UV rays are all inflicting various types of harm to humans health.

Nowadays, humans do not wear garments just for modesty. As hygiene, cleanliness, and protection have become key concerns, so has the demand for practical clothing. Developing garments made from eco-friendly textiles and dyes provides antimicrobial as well as physical benefits that are healthier for the skin and protects against skin ailments. Since today's youth especially women are more susceptible to a variety of ailments, natural dyed garments provide a better relaxation and calming impacts for both physical and mental health. By choosing natural dyed fabrics over synthetic dyed fabrics, help to conserve the environment and reducing human reliance on dangerous materials.

BIBLIOGRAPHY

- Adhikari, B., Aryal, B., & Bhattarai, B. R. (2021). A Comprehensive Review on the Chemical Composition and Pharmacological Activities of *Acacia catechu* (Lf) Willd. *Journal of Chemistry*, 2021.
- Affat, S. S. (2021). Classifications, Advantages, Disadvantages, Toxicity Effects of Natural and Synthetic Dyes: A review. *University of Thi-Qar Journal of Science*, 8(1), 130-135.
- Agarwal, S. (2019). Fashion portfolio and its uses in modern fashion industry. *International Journal of Multidisciplinary Research and Development Online* ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72 Received: 18-08-2019; Accepted: 20-09-2019 www.allsubjectjournal.com Volume 6; Issue 6; June 2019; Page No. 118-121
- Ahmad, S., Rasheed, A., Afzal, A., & Ahmad, F. (Eds.). (2017). *Advanced textile testing techniques*. CRC Press.
- Akram, M., Hamid, A., Khalil, A., Ghaffar, A., Tayyaba, N., Saeed, A., ... & Naveed, A. (2014). Review on medicinal uses, pharmacological, phytochemistry and immunomodulatory activity of plants. *International Journal of Immunopathology and pharmacology*, 27(3), 313-319.
- Alhamed, M., Issa, A. S., & Doubal, A. W. (2012). Studying of natural dyes properties as photo-sensitizer for dye sensitized solar cells (DSSC). *Journal of electron Devices*, 16(11), 1370-1383.
- Alkaya, E., & Demirer, G. N. (2015). Sectoral assessment of the Turkish textile industry for the diffusion of sustainable production approach. *The Journal of The Textile Institute*, 106(11), 1212-1225.
- Ambre, P. P., & Lad, S. (2017). Khadi–Awareness and Promotion among Youth. *International Research Journal of Engineering and Technology*, 4(07).
- Aravind, V., & SB, G. (2022). Khadi Textiles, Women and Rural Development: An Analysis from Past to Present. *TEXTILE*, 1-18.
- Bag, A., Bhattacharyya, S. K., & Chattopadhyay, R. R. (2013). The development of *Terminalia chebula* Retz.(Combretaceae) in clinical research. *Asian Pacific journal of tropical biomedicine*, 3(3), 244-252.
- Baird, D. G., & Collias, D. I. (2014). *Polymer processing: principles and design*. John Wiley & Sons.

- Basu, A. (2006). *Textile Testing: Fibre, Yarn & Fabric*. South India Textile Research Association.
- Bhandari, B., Singh, S. S. J., & Rose, N. M. (2018). Effect of sericin treatment conditions on dye ability of cotton fabric. *Journal of Applied and Natural Science*, 10(1), 102-106.
- Bhandari, B., Singh, S. S. J., & Rose, N. M. (2018). Effect of sericin treatment conditions on dye ability of cotton fabric. *Journal of Applied and Natural Science*, 10(1), 102-106.
- Biswas, T. K., & Mukherjee, B. (2003). Plant medicines of Indian origin for wound healing activity: a review. *The international journal of lower extremity wounds*, 2(1), 25-39.
- Boryo, D. E. A. (2013). The effect of microbes on textile material: a review on the way-out so far. *The International Journal of Engineering and Science (IJES)*, 2(8), 09-13.
- Burke, S., & Sinclair, R. (2015). Computer-aided design (CAD) and computer-aided manufacturing (CAM) of apparel and other textile products. In *Textiles and Fashion* (pp. 671-703). Woodhead Publishing.
- Callewaert, C., De Maeseneire, E., Kerckhof, F. M., Verliefde, A., Van de Wiele, T., & Boon, N. (2014). Microbial odor profile of polyester and cotton clothes after a fitness session. *Applied and Environmental Microbiology*, 80(21), 6611-6619.
- Carmen, Z., & Daniela, S. (2012). Textile organic dyes-characteristics, polluting effects and separation/elimination procedures from industrial effluents-a critical overview (Vol. 3, pp. 55-86). Rijeka: IntechOpen.
- Chakraborty, J. N. (Ed.). (2015). *Fundamentals and practices in colouration of textiles*. CRC Press.
- Chandrashekar, B. S., Prabhakara, S., Mohan, T., Shabeer, D., Bhandare, B., Nalini, M., ... & Anbazhagan, K. (2018). Characterization of *Rubia cordifolia* L. root extract and its evaluation of cardioprotective effect in Wistar rat model. *Indian journal of pharmacology*, 50(1), 12.
- Chatterjee, K. N., Das, D., & Nayak, R. K. (2011). Study of Handle and Comfort Properties of Poly-Khadi, Handloom and Powerloom Fabrics. *Man-Made Textiles in India*, 39(10).

- Chaves, J. O., De Souza, M. C., Da Silva, L. C., Lachos-Perez, D., Torres-Mayanga, P. C., Machado, A. P. D. F., ... & Rostagno, M. A. (2020). Extraction of flavonoids from natural sources using modern techniques. *Frontiers in Chemistry*, 864.
- Choudhuri, P. K. (2018). Scope of Design Development in Khadi Fabrics Exploiting Yarn Character.
- Das, A. (2013). Testing and statistical quality control in textile manufacturing. In *Process Control in Textile Manufacturing* (pp. 41-78). Woodhead Publishing.
- Das, N. D., Jung, K. H., Park, J. H., Mondol, M. A. M., Shin, H. J., Lee, H. S., ... & Chai, Y. G. (2011). Terminalia chebula Extract Acts as a Potential NF-κB Inhibitor in Human Lymphoblastic T Cells. *Phytotherapy Research*, 25(6), 927-934.
- Denissa, L., Permanasari, R., Rosethalia, C., Tania, A., Ngo, V. H., Gunawan, F., ... & Aurelia, C. (2022). Development of Tie-Dye Technique on T-shirts in RT02 RW04 Sukawarna Village, Sukajadi District, Bandung. *Journal of Innovation and Community Engagement*, 3(1), 41-58.
- Desore, A., & Narula, S. A. (2018). An overview on corporate response towards sustainability issues in textile industry. *Environment, Development and Sustainability*, 20(4), 1439-1459.
- Devi Priya, M., & Siril, E. A. (2014). Traditional and modern use of indian madder (*Rubia cordifolia* L.): an overview. *Int J Pharm Sci Rev Res*, 25(1), 154-164.
- Devi, V. G., John, A., Devi, R. S., & Prabhakaran, V. A. (2011). Pharmacognostical studies on *Acacia catechu* Willd and identification of antioxidant principles. *IJPSR*, 3, 108-111.
- Dixit, P., & Lal, R. C. (2019). Inclusive Growth and Social Responsibility-A Critical Analysis of Indian Textile Industry. *MERC Global's International Journal of Management*, 7(2), 202-210.
- Feng, X. X., Zhang, L. L., Chen, J. Y., & Zhang, J. C. (2007). New insights into solar UV-protective properties of natural dye. *Journal of Cleaner Production*, 15(4), 366-372.
- Fletcher, K., & Tham, M. (Eds.). (2015). *Routledge handbook of sustainability and fashion*. London: Routledge.
- Gogoi, M. (2021). *Exotic Natural Dye of North East India* (Vol. 1). Sarv Bhasha Trust.
- Gogoi, M. (2021). *Exotic Natural Dye of North East India* (Vol. 1). Sarv Bhasha Trust.

- Gordon, J, F and Hill, C. (2010). Sustainable Fashion Past, Present and Future. New York, USA: Bloomsbury.
- Gupta, P. C. (2012). Biological and pharmacological properties of Terminalia chebula Retz.(Haritaki)-An overview. *Int J pharm pharm Sci*, 4(3), 62-68.
- Gupta, V. K. (2019). Fundamentals of natural dyes and its application on textile substrates. *Chemistry and technology of natural and synthetic dyes and pigments*, 2019.
- Gupta. V.K., 2019, Fundamentals of Natural Dyes and Its Application on Textile Substrates. 10.5772/intechopen.89964
- Gyamfi, V. A., Abbey, L., & Yeboah, A. (2020). Elements and Principles of Design in Garment Production among Small Scale Producers of Berekum Municipal In Ghana.
- Haddar, W., Ticha, M. B., Guesmi, A., Khoffi, F., & Durand, B. (2014). A novel approach for a natural dyeing process of cotton fabric with Hibiscus mutabilis (Gulzuba): process development and optimization using statistical analysis. *Journal of Cleaner Production*, 68, 114-120.
- Harane, R. S., & Adivarekar, R. V. (2017). Sustainable processes for pre-treatment of cotton fabric. *Textiles and clothing sustainability*, 2(1), 1-9.
- Hopkins, J. (2021). *Fashion Design: The Complete Guide*. Bloomsbury Publishing.
- Hosseinnezhad, M., Gharanjig, K., Rouhani, S., Razani, N., & Imani, H. (2022). Environmentally friendly dyeing of wool yarns using of combination of bio-mordants and natural dyes. *Environmental Progress & Sustainable Energy*, e13868.
- Hosseinnezhad, M., Gharanjig, K., Rouhani, S., Razani, N., & Imani, H. (2022). Environmentally friendly dyeing of wool yarns using of combination of bio-mordants and natural dyes. *Environmental Progress & Sustainable Energy*, e13868.
- Hwang, E. K., Lee, Y. H., & Kim, H. D. (2008). Dyeing, fastness, and deodorizing properties of cotton, silk, and wool fabrics dyed with gardenia, coffee sludge, Cassia tora. L., and pomegranate extracts. *Fibers and Polymers*, 9(3), 334-340.
- Ibrahim, N. A., El-Zairy, W. M., El-Zairy, M. R., & Ghazal, H. A. (2013). Enhancing the UV-protection and antibacterial properties of Polyamide-6 fabric by natural dyeing. *interactions*, 8, 9.
- Jain, E. (2014). Khadi: A cloth and beyond. *Gandhi Marg Quarterly*, 223-240.
- Jokar, A., Masoomi, F., Sadeghpour, O., Nassiri-Toosi, M., & Hamedi, S. (2016). Potential therapeutic applications for Terminalia chebula in Iranian traditional medicine. *Journal of Traditional Chinese Medicine*, 36(2), 250-254.

- Julkunen-Tiitto, R., & Haggman, H. (2009). Tannins and tannin agents. *Handbook of natural colorants*, 8, 201.
- Kabir, F., Bhuiyan, M. M. H., Hossain, M. R., Manir, M. S., Rahaman, M. S., Islam, M. T., & Ullah, S. M. (2022). Refining of red spinach extract for the enhanced photovoltaic performance of natural dye-based DSSC and degradation study. *Optik*, 251, 168452.
- Kajla, A. and Srivastava, M. (2006). A comparative study on color development and fastness evaluation of Manjistha on polyester fabric and its blends. *Textile Trends*, XLVIX (8): 37-40.
- Kamboj, A., Jose, S., & Singh, A. (2021). Antimicrobial activity of natural dyes—a comprehensive review. *Journal of Natural Fibers*, 1-15.
- Karadag, R., & Torgan, E. (2016). Advantages and importance of natural dyes in the restoration of textile cultural heritage. *International Journal of Conservation Science*, 7.
- Khanbabae, K., & Van Ree, T. (2001). Tannins: classification and definition. *Natural product reports*, 18(6), 641-649.
- Kim, Y. K. (2016, November). Fashion Image: Interdisciplinary and Collaborative Approach to Portfolio Presentation. In *International Textile and Apparel Association Annual Conference Proceedings* (Vol. 73, No. 1). Iowa State University Digital Press.
- Kumar, M. R., Kumar, T. S., Prakash, C., & Jayakumari, M. (2022). Investigation on fastness properties of plated interlock knitted fabrics. *Cleaner Engineering and Technology*, 8, 100474.
- Kumari, T. A. N. V. I., & Singh, D. R. (2019). Khadi: A Sustainable Fabric.
- Lee, H. S., Koo, Y. C., Suh, H. J., Kim, K. Y., & Lee, K. W. (2010). Preventive effects of chebulic acid isolated from Terminalia chebula on advanced glycation endproduct-induced endothelial cell dysfunction. *Journal of Ethnopharmacology*, 131(3), 567-574.
- Lei, Z. (2020, March). Study on Test of Color Fastness to Rubbing of Textiles. In *IOP Conference Series: Materials Science and Engineering* (Vol. 793, No. 1, p. 012017). IOP Publishing
- Liu, Q., & Wang, L. (2021). t-Test and ANOVA for data with ceiling and/or floor effects. *Behavior Research Methods*, 53(1), 264-277.
- Lowy, F. (2009). Bacterial classification, structure and function. *New York, USA: Columbia University*, 1-6.

- Mansour, R. (2018). Natural dyes and pigments: Extraction and applications. *Handbook of renewable materials for coloration and finishing*, 9, 75-102.
- Marinho, P., Fernandes, P., & Pimentel, F. (2021). The digital portfolio as an assessment strategy for learning in higher education. *Distance Education*, 42(2), 253-267.
- MAULIK, S. R., & PRADHAN, S. C. (2005). Dyeing of wool and silk with Hinjal bark, Jujube bark and Himalayan rhubarb. *Colourage*, 52(9), 67-71.
- McQuillan, H. (2020). Digital 3D design as a tool for augmenting zero-waste fashion design practice. *International Journal of Fashion Design, Technology and Education*, 13(1), 89-100.
- Medha, K., Rajna, S., Devi, L. J., Samant, L., & Jose, S. (2021). A comprehensive review on moth repellent finishing of woolen textiles. *Journal of Cultural Heritage*, 49, 260-271.
- Memon, H., Chaklie, E. B., Yesuf, H. M., & Zhu, C. (2021). Study on effect of leather rigidity and thickness on drapability of sheep garment leather. *Materials*, 14(16), 4553.
- Merdan, N., Eyupoglu, S., & Duman, M. N. (2017). Ecological and sustainable natural dyes. In *Textiles and Clothing Sustainability* (pp. 1-41). Springer, Singapore.
- Mia, R., Islam, M. M., Ahmed, T., Waqar, M. A., Khanam, N. J., Sultana, S., ... & Uddin, M. N. (2022). Natural dye extracted from *Triadica sebifera* in aqueous medium for sustainable dyeing and functionalizing of viscose fabric. *Cleaner Engineering and Technology*, 8, 100471.
- Miah, M. R., Hossain, M. A., Dipto, A. I., Telegin, F. Y., & Quan, H. (2016). Eco-dyeing of Nylon Fabric Using Natural Dyes Extracted from Onion Outer Shells: Assessment of the Effect of Different Mordant on Color and Fastness Properties. *International Journal of Scientific & Engineering Research*, 7(9), 1030-1042.
- Mishra, P. (2014). Khadi-Sustaining the Change in Generation Gap. *Asian Journal of Marketing*, 8(2), 86-97.
- Mitra, A. (2022). Selection of Khadi fabrics for optimal comfort properties using multi-criteria decision-making technique. *Research Journal of Textile and Apparel*.
- Modi, M., Dezzutti, C. S., Kulshreshtha, S., Rawat, A. K. S., Srivastava, S. K., Malhotra, S., ... & Gupta, S. K. (2013). Extracts from *Acacia catechu* suppress HIV-1

replication by inhibiting the activities of the viral protease and Tat. *Virology journal*, 10(1), 1-17.

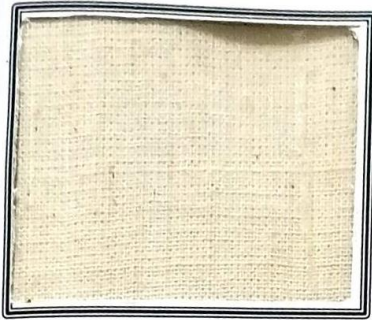
- Moses, J.J. and Venkatachalam, A. (2001). Natural dyeing on cellulosic and protein textile materials. In conventional proceedings natural dyes. Department of Textile Technology, December 17-18, IIT, Delhi. pp. 121-131.
- Muthu, S. S. (2017). Evaluation of sustainability in textile industry. In *Sustainability in the textile industry* (pp. 9-15). Springer, Singapore.
- Naidu, K. C., Lalam, R., & Bobbarala, V. (2009). Antimicrobial agents from *Rubia cordifolia* and *Glycyrrhiza glabra* against phytopathogens of *Gossypium*. *Int J Pharm Tech Res*, 1, 1512-8.
- Naik, G. H., Priyadarsini, K. I., Bhagirathi, R. G., Mishra, B., Mishra, K. P., Banavalikar, M. M., & Mohan, H. (2005). In vitro antioxidant studies and free radical reactions of triphala, an ayurvedic formulation and its constituents. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 19(7), 582-586.
- Neacșu, N. A., BĂLĂȘESCU, S., BĂLTESCU, C. A., & Boșcor, D. (2017). The influence of design and aesthetics elements in choosing clothing. *De Redactie*, 375.
- Niang, E. H. A., Bassene, H., Fenollar, F., & Mediannikov, O. (2018). Biological control of mosquito-borne diseases: the potential of *Wolbachia*-based interventions in an IVM framework. *Journal of tropical medicine*, 2018.
- Parashar, S. (2022). A Study on Khadi: A Swadeshi Fabric Among the New Era. *ECS Transactions*, 107(1), 15407.
- Paré, G., Trudel, M. C., Jaana, M., & Kitsiou, S. (2015). Synthesizing information systems knowledge: A typology of literature reviews. *Information & Management*, 52(2), 183-199.
- Pargai, D., Jahan, S., & Gahlot, M. (2020). Functional properties of natural dyed textiles. *Chemistry and technology of natural and synthetic dyes and pigments*, 1-19.
- Prabhu, K. H., & Bhute, A. S. (2012). Plant based natural dyes and mordants: A Review. *J. Nat. Prod. Plant Resour*, 2(6), 649-664.
- Prabhu, K. H., & Bhute, A. S. (2012). Plant based natural dyes and mordants: A Review. *J. Nat. Prod. Plant Resour*, 2(6), 649-664.

- Pubalina, S., Singhee, D., Samanta, A. K. (2018). Fundamentals of natural dyeing of textiles: Pros and Cons. *Current Trends in Fashion Technology & Textile Engineering*, 2(4) ID.555593
- Pujiarti, R., & Putri, O. A. (2021, November). Coconut (*Cocos nucifera* Linn.) Root Extraction and Application as A Fabric Dye with Different Particle Sizes and Extraction Methods. In *IOP Conference Series: Earth and Environmental Science* (Vol. 891, No. 1, p. 012020). IOP Publishing.
- Ravi, A., Patro, A., Garg, V., Rajagopal, A. K., Rajan, A., & Banerjee, R. H. (2019). Teaching DNNs to design fast fashion. *arXiv preprint arXiv:1906.12159*.
- Ross, C. B., (2015). *Freedom and Unity: The Incredible Story of Khadi weaving*. The Sustainable Fashion Collective.
- Samanta, A. K., Konar, A. (2011). Dyeing of textiles with natural dyes, Institute of Jute Technology, University of Calcutta India, 30-31, 44. Available from: <http://www.intechopen.com/books/natural-dyes/dyeing-of-textiles-with-natural-dyes> (Accessed: 1 October, 2020).
- Sanjeeda, I., & Taiyaba, A. N. (2014). Natural dyes: Their sources and ecofriendly use as textile materials. *Journal of Environmental Research and development*, 8(3A), 683.
- Sanli, H., Kayabasi, N., & Olmez, F. (2011). Dyeing techniques and mordanting methods applied in natural dyeing of wool in Turkey. *Asian Journal of Chemistry*, 23(8).
- Seigler, D. S. (1998). *Plant secondary metabolism*. Springer Science & Business Media.
- Shabbir, M., Islam, S. U., Bukhari, M. N., Rather, L. J., Khan, M. A., & Mohammad, F. (2017). Application of *Terminalia chebula* natural dye on wool fiber—evaluation of color and fastness properties. *Textiles and Clothing Sustainability*, 2(1), 1-9.
- Shaikh, M. A. (2009). Environmental issues related with textile sector. *Pakistan Textile Journal*, 10, 36-40.
- Shakyawar, D. B., Raja, A. S. M., Kumar, A., & Pareek, P. K. (2015). Antimoth finishing treatment for woollens using tannin containing natural dyes. *Indian Journal of Fibre & Textile Research (IJFTR)*, 40(2), 200-202.
- Sharma, & Geetika. (2022). Antioxidant and Anticancer Enhancing Potential of Various Fruit Extracts on *Terminalia chebula*. *Shodhganga : a reservoir of Indian theses*. 10603/374372

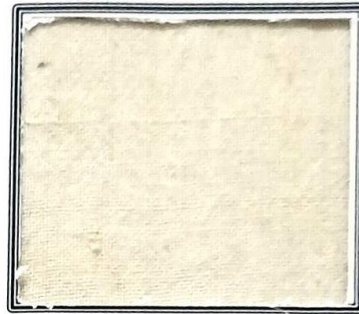
- Shekokar, A. V., Borkar, K. M., Pandao, P. O., & Londe, S. S. (2013). A Case Study of Manjistadi Taila with Kadalipatra and Bactigauze for Local Application in the Management of Burn. *Int. J. Adv. Ayurveda, Yoga, Unani, Siddha and Homeopathy*, 2, 112-118.
- Shen, D., Wu, Q., Wang, M., Yang, Y., Lavoie, E. J., & Simon, J. E. (2006). Determination of the predominant catechins in *Acacia catechu* by liquid chromatography/electrospray ionization– mass spectrometry. *Journal of agricultural and food chemistry*, 54(9), 3219-3224.
- Siaw, S.D., Kermevor, A. K., Dzamedo, B. Ed. (2014). THE APPROPRIATE EFFECTS OF ELEMENTS AND PRINCIPLES OF DESIGNING APPAREL IN FASHION. *Global Journal of Arts Humanities and Social Sciences Vol.2, No.9*, pp.1-12
- Sid, N. (2019). High-performance natural dyes for cellulosic fibers review-part 1. *Journal of Textiles, Coloration and Polymer Science*, 16(1), 1-13.
- Singh, H. B., & Kumar, A. B. (2014). *Handbook of natural dyes and pigments*. Woodhead Publishing India Pvt Limited.
- Singh, P., & Ali, S. J. (2012). Ethnomedicinal plants of family rubiaceae of eastern UP. *Indian Journal of Life Sciences*, 1(2), 83-87
- Sinha, S. (2019). The Story of Khadi, India's Signature Fabric. *Culture Trip*, 18.
- Sisubalan, N., Ramkumar, V. S., Pugazhendhi, A., Karthikeyan, C., Indira, K., Gopinath, K., ... & Basha, M. H. G. (2018). ROS-mediated cytotoxic activity of ZnO and CeO₂ nanoparticles synthesized using the *Rubia cordifolia* L. leaf extract on MG-63 human osteosarcoma cell lines. *Environmental Science and Pollution Research*, 25(11), 10482-10492.
- Siva, R. (2007). Status of natural dyes and dye-yielding plants in India. *Current science*, 916-925.
- Sivakumar, V., Vijaeeswarri, J., & Anna, J. L. (2011). Effective natural dye extraction from different plant materials using ultrasound. *Industrial Crops and Products*, 33(1), 116-122. 41.
- Sorger, R., & Udale, J. (2017). *The fundamentals of fashion design*. Bloomsbury Publishing.

- Sunil, M. A., Sunitha, V. S., Radhakrishnan, E. K., & Jyothis, M. (2019). Immunomodulatory activities of Acacia catechu, a traditional thirst quencher of South India. *Journal of Ayurveda and Integrative Medicine*, 10(3), 185-191.
- Suparna, M. G., & Rinsey Antony, V. A. (2016). Eco-friendly textiles. *International journal of science technology and management*, 5(11), 67-73.
- Toprak, T., & Anis, P. (2017). Textile industry's environmental effects and approaching cleaner production and sustainability, an overview. *J Textile Eng Fashion Technol*, 2(4), 429-442.
- Vaccaro, K., Shivakumar, S., Ding, Z., Karahalios, K., & Kumar, R. (2016, October). The elements of fashion style. In *Proceedings of the 29th annual symposium on user interface software and technology* (pp. 777-785).
- Vashisht, P. and Rani, N. (2020). Automation and the Future of Garment Sector Jobs in India', *Indian Journal of Labour Economics*. Springer India, 63(2), pp. 225–246. doi: 10.1007/s41027-020-00224-7
- Verma, S., & Gupta, G. (2017). Natural dyes and its applications: A brief review. *International Journal of Research and Analytical Reviews*, 4(4), 57-60.
- Volpintesta, L. (2014). *The language of fashion design: 26 principles every fashion designer should know*. Rockport Pub.
- Yin, J. (2016). The application of natural dyes in Dye-sensitized solar cells. *International Conference on Machinery, Materials, Environment, Biotechnology and Computer (MMEBC)*, 6, 1297-1300
- Yusuf, M., Shabbir, M., & Mohammad, F. (2017). Natural colorants: Historical, processing and sustainable prospects. *Natural products and bioprospecting*, 7(1), 123-145.
- Yusuf, M., Shabbir, M., & Mohammad, F. (2017). Natural colorants: Historical, processing and sustainable prospects. *Natural products and bioprospecting*, 7(1), 123-145.
- Zaid, M., Yazdanfar, Z., Chowdhury, H., & Alam, F. (2019). A review on the methods used to reduce the scouring effect of bridge pier. *Energy Procedia*, 160, 45-50.
- Zielińska, A., Alves, H., Marques, V., Durazzo, A., Lucarini, M., Alves, T. F., ... & Souto, E. B. (2020). Properties, extraction methods, and delivery systems for curcumin as a natural source of beneficial health effects. *Medicina*, 56(7), 336.

APPENDIX – I
SAMPLE OF FABRICS



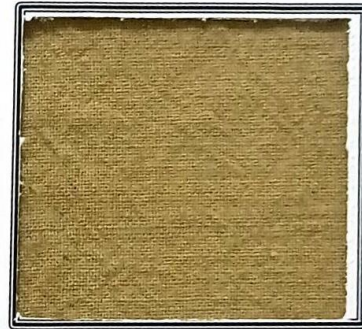
Original Khadi Fabric



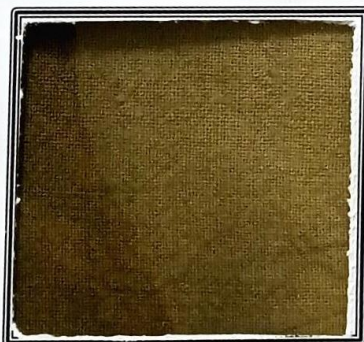
De-sized Khadi Fabric



Fabric Dyed with Madder



Fabric Dyed with Myrobalan



Fabric Dyed with Black Cutch

APPENDIX – II

STANDARD BODY MEASUREMENTS FOR LADIES GARMENT

SAMPLE MEASUREMENTS FOR LADIES' GARMENTS
(All measurements are in inches)

Bust (circumference)	28	30	32	34	36	38	40	42
Waist (circumference)	24	24½	25	26	28	30	32	33
Hip (circumference)	30	32	34	36	38	40	42	44
Back width	14	14	14½	15	1 ¼	15½	15¾	16
Armseye depth	6½	7	7½	7½	7¾	8	8¼	8½
Distance between bust points . . .	6	6½	6½	7	7½	7½	8	8½
Lower arm (circumference)	9½	9¾	10	10¼	10½	11	11¼	11½
Wrist (circumference)	6½	6½	6½	6½	6½	7	7½	7½
Back waist length*	13	to	16					
Shoulder to bust*	7½	to	9½					
Full sleeve length*	20	to	23					
Short sleeve length*	7	to	10					
Waist to hip*	7	to	9					
Waist to ground*	38	to	44					
Choli length*	12	to	14					
Pant top length*	18	to	23					
Kurta length*	38	to	42					
Maxi dress length*	52	to	56					
Maxi skirt length*	38	to	44					
Middy skirt length*	24	to	28					

* These measurements depend on the height of the person.

APPENDIX – III

INTERNSHIP CERTIFICATE OF NATURAL DYEING



Farmer's Share

Certificate Of Internship

This is to certify that *Ms. Gopika. J.*, pursuing MSc Bio textiles from Avinashilingam University, Coimbatore has successfully completed 14 days (from January 14, 2022 to January 28, 2022) internship program in the area of “*Natural dyeing for health benefits*” at Farmer's Share under our guidance. During the period of her internship program with us, she was found sincere, hard working and a keen learner. We wish her all the best for her future endeavors.

<p><i>Ambrose Kooliyath</i> (Director, Farmer's Share)</p> 	<p><i>Dr Mirium M Abraham</i> (Coordinator, Textile and Craft Department)</p> 
--	--



Farmer's Share Charitable Trust
Project Office: Mundaya - Shoranur, Kerala.

Date: 02-2-2022