UTILIZATION OF FRUIT WASTE FOR ECO-FRIENDLY DYEING OF LINEN:A COMPARATIVE STUDY ON SHADE DEVELOPMENT USING FERROUS SULPHATE

DISSERTATION SUBMITTED

In Partial Fulfillment of the Requirement for the Award of the Degree of

MASTER'S PROGRAMME IN FASHION DESIGNING

BY

NIHALA IBRAHIM

(Reg No. SM24MFD004)

DEPARTMENT OF FASHION DESIGNING

WOMEN'S STUDY CENTRE

ST. TERESA'S COLLEGE (AUTONOMOUS)

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THE FEAR OF THE LORD IS THE BEGINNING OF WISDOM

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DECLARATION

I, **Nihala Ibrahim**, hereby declare that the project entitled **"Utilisation of Fruit Juice Waste for Eco-Friendly Dyeing of Linen: A Comparative Study on Shade Development using Ferrous Sulphate"** is submitted in partial fulfillment of the requirement for the award of the degree of Master's Programme in Fashion Designing. This record is original research done by me under the supervision and guidance of **Smt. Aneetta V.J,** Assistant Professor, Department of Fashion Designing, St. Teresa's College, Ernakulam. This work has not been submitted in part of fill or any other Degree, Diploma, Associateship/Fellowship of this or any other university.

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INTRODUCTION

INTRODUCTION

In response to the growing environmental concerns posed by synthetic dyes, recent research has turned toward bio-based alternatives, with fruit peel waste emerging as a sustainable and abundant source of natural pigments. Since ancient times, natural dyes have been used to color food, clothing, and other objects. Synthetic dyes are very well-liked because of their ease in application, variety of hues, and colour fastness. However, there are serious health and environmental risks associated with their use. Natural dyes have seen a resurgence in popularity recently because of their eco-friendliness, readiness, sustainability, non-toxicity, affordability, and accessibility. As a result, natural colours are quickly becoming more and more well-liked as superior substitutes for synthetic ones. The textile, printing, cosmetics, and food industries can all benefit from the wide variety of plant species found in nature, each with unique hues and characteristics.

The ancient art of dying precedes written history. It was practiced as early as the Bronze Age in Europe. Sticking plants to fabric or pressing crushed pigments onto fabric were examples of early dyeing methods (Jothi, 2008). Man has known from the beginning of time how to apply colour to improve our look and the environment around us. Natural dyes made from fruits, vegetables, flowers, insects, and fish have been used since 3500 BC, according to historical documents. The primary draw of any cloth is its colour. No matter how good its constitution is, it will fail as a commercial product if it is not coloured appropriately. Previously, fabric was dyed using natural dyes. These, however, provided a small and drab spectrum of hues. In addition, they had poor colour fastness in the presence of sunlight and washing. To fix the fibre and dye together, they therefore need a mordant to create a dye complex, which made the dyers job tiresome. Since W. H. Perkins discovered synthetic dyes in 1856, a variety of color-fast dyes with a greater colour spectrum and more vibrant hues have become available (Kant, 2012). Pigments and dyes have the power to beautify the world. They are being used since long time and find wide applications in various fields such as food, textile, artifacts and paper industries. As a result, a great deal of study has been done on creating natural colourants from natural sources. The advantages of using natural colorants are manifolds as they are eco-friendly, safe, easily obtained from renewable sources soft, lustrous and soothing to the human eye. They do not cause health hazards, offers/ offer no disposal problems. There is still a market for natural dyes despite their drawbacks, which include their availability, fastness, and shade replication. Despite the abundance of raw resources and our nation's great biodiversity, a sustainable connection between cultivation, collecting, and usage needs to be established (Kanchana et al., 2013).

Large amounts of liquid and solid waste, which are potential contaminants and have related disposal issues, are produced by the food business. These leftovers are either composted, disposed of, or fed to animals. However, wastes from pressed berries, grapes, distillation residues, wastes and peels from vegetable processing containing dyestuff are available at almost free cost. Fruit juice production produces a significant amount of organic waste, such as pulp, peels, and seeds, which are frequently thrown away even though they contain important bioactive chemicals. Significant concentrations of natural pigments, including anthocyanins, carotenoids, and flavonoids, which can function as efficient natural dyes, are known to be present in these by-products. In addition to addressing waste management concerns, using fruit juice waste provides a sustainable and affordable source of natural colourants.

This study explores the extraction of natural dyes from selected fruit juice waste materials, with the aim of optimizing extraction methods, evaluating the dyeing potential of the pigments, and assessing their stability under various conditions. By valorizing waste materials through dye extraction, this study contributes to a circular economy model and supports environmentally conscious practices in industries that rely on colorants.

According to Singhee, 2020 "A significant amount of organic waste produced by the food industry and agricultural sectors still contains coloring pigments. The issue of their disposal will presumably be resolved by their sustainable use in textile dyeing. In order to serve as a guide for future research, this chapter documents a few experiments addressing the use of agricultural and industrial waste. A list of some specific wastes that have been utilized by various writers to color textiles has been provided, together with information on their composition, manufacturing process, and methodical explanation of how they are employed. To illustrate the various methods used by the writers to explain the efficacy of such wastes as a source of textile colorants, the documented investigations have been arranged as case studies. According to certain investigations, the dye that was recovered from the waste also served as a mordant. Regarding the fabrics dyed with such wastes, the majority of research also show good dyeability with notable fastness. It has also been observed that certain wastes have given the dyed fabric antimicrobial and light/sun protection qualities".

The objectives of the study are to:

- Extract natural dyes from Pomegranate rind and Grape pomace
- Identify a metallic mordant which can improve the colour fastness and develop shade variation
- Dyeing using the extracted solution and developing value added products
- Obtain information about the preference for linen fabrics naturally dyed with fruit juice waste

CHAPTER 2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Colorants have been used since the Stone Age, and many ancient cultures expanded their use of dyes to textiles once weaving techniques advanced (Yusuf et al., 2017 and Decelles 1949). While ochre, limestone, and charcoal were significant pigments, other common ancient colours include madder, blue indigo, and yellow made from saffron or turmeric (Decelles 1949). The review pertaining to this research work is carried under the following headings:

2.1 Natural Dyes

2.1.1 Sources of Natural Dyes

2.1.2 Natural Dyes from Fruit Peel

2.2 Natural Dyeing using Pomegranate Rind

2.3 Natural Dyeing using Grapes Pomace

2.4 Natural Mordants and Mordanting Techniques

2.4.1 Metallic Mordent

2.4.2 Ferrous Sulphate

2.5 Natural Dyeing on Cellulose Fabric

2.5.1 Natural Dyeing on Linen

2.6 Limitation of Natural Dye

2.7 Recent Advancement in Natural Dye

2.1 Natural Dyes

All coloring compounds that are extracted or obtained from nature—that is, from plant, animal, mineral, or microbiological sources—and used to color a range of textile fabrics are referred to as natural dyestuffs. Since the beginning of time, people have utilized these dyes to color textile items, and it has been a common practice in daily life. However, the use of natural dyes in textiles has drastically decreased since the second half of the nineteenth century due to the introduction of synthetic dyes and extensive research into synthetic dyestuffs. This is because natural dyes have a limited range of colors, are not reproducible, have uneven shades, have poor color yield, have poor to moderate color fastness properties, and there is a lack of information about how to improve the fastness and color value. However, because of their accessibility, affordability, brilliant hues, and superior color fastness, synthetic dyes are appealing as textile colorants. Regrettably, some of these dyes have been shown to be allergic, carcinogenic, and harmful to both human health and the environment. Because of their great environmental compatibility and the abundance of practical natural coloring supplies, there has been a resurgence of interest in the use of non-allergic, non-toxic, and environmentally friendly natural dyes in textile fibers (Bhuiyan et al.,2017).

These dyes, called pelargonidin (3,5,7,4-tetrahydroxyanthocyanidin), function similarly to acid dyes and have a high dyeing efficiency for protein fibers. Using a Soxhlet equipment, a specific solvent extraction technique revealed a 2.25% pelargonidin content. Four hydroxy groups (also known as auxochrome groups) give pelargonidin its favourable dyeing qualities when used to dye natural fabrics (Gias Uddin and Mohammad 2014).

Structural Features of Natural Dyes:-

Based on their chemical structure, natural dyes can be categorized into several main groups. Carotenoids, polyphenols, porphyrins, alkaloids, and quinones are among their principal constituents (Li et al.,2022).

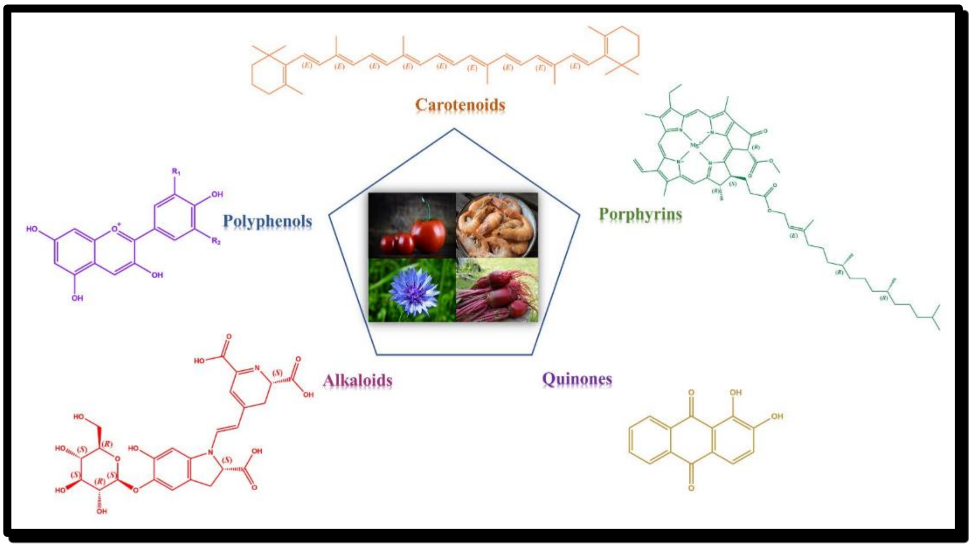


Figure 1. The major categories of natural dyes divided by chemical structure

Sticking plants were one of the earliest dyeing methods to textiles or applying crushed pigments to textiles. As time went on, the procedure improved by employing natural colours made from crushed fruits, berries, and other plant materials that were cooked into the fabric. Additionally, tests for water and light fastness (resistance) were created (Jothi, 2008).

Among the well-known ancient dyes were blue indigo from the leaves of *Indigo feratinctoria*, yellow from the roots of the Rubiatinctorium, and madder, a red dye the saffron plant's *(Crocus sativuls L)* stigma. Trian purple, mentioned in the Bible, was the most well-known and highly valued color throughout history. It was made from the spiny dye-murex mollusk. It was prepared by the Phoenicians until the Arab conquerors destroyed their dyeing facilities in the seventh century. Cochineal, a vivid scarlet, was extracted from a Mexican native bug and these yielded excellent dark colors (Siva, 2007).

2.1.1 Sources of Natural Dyes

Natural dyes are often more environmentally friendly and have superior biodegradability. They don't cause harm or allergies and non-carcinogenic since they are made from vegetables or animals without the use of chemicals (Pruthi et al., 2008). Natural dyes are extracts of several components with undetermined quantities; the structure of the primary component is decided Singh and Parmer, 1998; Khan et al., 2005).

Plant/Vegetable Dye:

In nature, plants' leaves, roots, flowers, and fruits are all significant sources of natural dyes which are what give various plant parts their color. Examples are anthocyanins, which give flowers and fruits their orange to dark blue hue, carotenoids, which give them their yellow and red hues, and chlorophylls, which give plants their green hue. Lycopene and carotenes are linked to tomato and mango color, respectively. Anthocyanins are abundant in strawberries, mulberries, blueberries, and cornflowers. The vivid red or yellow color of beetroot is caused by betalains found in plant vacuoles. Seasons shift, plant leaves turn from green to yellow or red, and the various combinations of chlorophylls, carotenoids, and anthocyanins determine how the leaves change color during senescence. Natural dyes can be obtained from plant materials such as leaves, flowers, fruits, and roots, which are renewable resources (Li et al., 2022).

Animal/insect dyes: -

Natural dyes can also be found in animals. The most widely used ones are lac dyes, astaxanthin, and carmine acid. The natural dye carmine acid, which ranges in color from pink to reddish-purple, is taken from the dried corpses of female Dactylopius coccus Costa (cochineal) insects. Various countries' food regulations permit the use of carmine acid in the manufacturing of food, cosmetics, medicines, and textiles (Borges et al.,2012 and Fernández-López et al.,2013).
In nature, astaxanthin is abundant, particularly in aquaculture products like fish, crab, and shrimp (Scurria et al.,2020). Lac dyes are organic colorants that are pink, red, and purple. They are made from insects and include a number of ingredients, including laccaic acid A, B, C, D, and E (Santos et al.,2015). Hypalocrinus naresianus, a deep-sea crinoid, has recently yielded some novel quinone dyes (Vemulapalli et al.,2021 and Wolkenstein et al.,2018). Deep-sea creatures are anticipated to emerge as possible new sources of natural dyes as marine resources grow.

Mineral dyes: -

Primarily used for painting, handicrafts, antiques, and the restoration of cultural artifacts, mineral dyes are developed from natural minerals. Cinnabar (HgS) has been used as a red dye from ancient times. It was frequently used in Roman art, as an ornament, and in medieval manuscripts with colored drawings or patterns (Neiman et al.,2015).

Microorganisms: -

The most widely dispersed living things are communities of microorganisms. They are an essential component of the biosphere and ecosystem and have tight relationships with plants, animals, and other microbes through parasitism, symbiosis, and saprophytic states. One significant source of natural colors is microorganisms, such as bacteria, fungi, and some algae. Carotenoids (β-carotene, canthaxanthin, and astaxanthin), bacteriochlorophylls, flavins, indigoids, melanins, pheomelanin, prodigiosin, violacein, glaukothalin, phycocyanin, and xanthomonadin are among the remarkable variety of microbial pigments that are currently present in a variety of situations (Li et al., 2022).

2.1.2 Natural Dyes from Fruits Peel

Fruits and vegetables are important in our daily lives. As the world's population has grown, so too has the demand for these essential commodities (Schieber et al.,2001). Large-scale consumption has increased the production of byproducts and caused a disposal issue (Sagar et al.,2018). By-products of fruits and vegetables may be a significant and lucrative source of natural chemicals (Trigo et al.,2022). The produced compounds are excellent sources of phenolics, natural acids, sugar, pigments, and minerals, according to numerous studies. Bioactive properties like antibacterial, anticancer, antifungal, antiviral, antimutagenic, and cardioprotective properties are displayed by several of these natural substances (Dilas et al.,2009 and Yahia et al.,2019).

Given the growing volumes of waste generated throughout their manufacturing processes, the food and agriculture sectors are especially susceptible to waste disposal and/or reuse. Data from 2012 to 2018 showed that 3,037,092 tons of vegetable waste were created in Italy alone, with the food, beverage, and tobacco industries accounting for 96% of this total (Adella and Mariotta, 2014 and Vulcano and Ciccarese, 2018)

According to recent studies, there is growing interest in the nutri-energetics sector, an industrial sector that aims to turn agro-food waste into textile fiber goods, protein and organic fertilizers, and nutraceutical products. Heather Youngs, a bioenergetics analyst at Berkley University's Energy Bioscience Institute, believes that the potential to produce new food items from agro-processing industry residues could be an intriguing solution to the non-hazardous waste management issue and could be more economical and successful than producing biodiesel (Ali and Watson, 2014).

In one study, pomegranate peel was utilized to extract natural dye, which was then applied to cotton using pre-, simultaneous-, and post-mordanting agents. Additionally, beta vulgaris and olive leaves have been used to extract dyes for use in textile materials.In one study, cotton was dyed using Rubia cordifolia, which has an organic reddish orange color in its roots, stem, and leaves. The bark of Macaranga peltata was studied for its ability to extract yellow color, and the results demonstrated a notable color fastness. Neem natural dye has demonstrated color efficiency and commercial significance. The dyes that were taken out of cotton fabric, mango peel and leaves have demonstrated some exceptional color fastness properties (Ali et al.,2014).

Malaysia and Indonesia developed mangosteen peel as a plant-based ingredient for the manufacture of natural dyes since it contains a lot of red coloration is produced by anthocyanin chemicals, while brown coloration is produced by tannin. The processes for preparing and using mangosteen dye extract for cotton dyeing are not, however, optimized or standardized. standards for the creation and use of extract from mangosteen peel dyes on silk fabrics, which are known to absorb color better than other types of cloth. Based on Basitah's research, silk fabric can profit from the use of mangosteen peel as a dyeing agent by producing brown, red, and purple hues through pre-, simultaneous, and post-mordanting techniques (Kusumawati et al.,2017).

In this study, the extraction of dyestuff from citrus fruits is examined, and its color, lightness, rubbing, and sweat-fastness are evaluated. Three citrus fruit varieties—orange, lemon, and grapefruit—were selected for the experimental investigation in order to extract dye from their peels. The traditional aqueous method was used to apply the dye to two different types of fabrics: 100% cotton and a blended fabric composed of 50% polyester and 50% cotton (PC). With a slight preference for PC cloth in terms of washing fastness, the results showed that orange dye was remarkably effective on both types of fabric and had great color fastness qualities. On the other hand, lemon dye showed significant staining potential and improved washing fastness characteristics on the materials that were tested. When it came to water and sweat fastness, grapefruit dye did remarkably well. To improve color absorption and penetration, future studies could concentrate on refining citrus fruit dye extraction methods. The efficiency and efficacy of natural dyes in diverse industrial applications could be improved by determining alternative solvents, dyeing times, and temperature settings. In order to evaluate the environmental effects of employing citrus peels as a natural dye source to synthetic dyes in the textile sector, more research could potentially perform life cycle assessments (Noor et al.,2024).

According to El-sayed, H., & El-Shemy, N. (2021). The use of natural colorants in textile printing and dyeing has advanced the manufacturing of textile products. Both the economy and the environment benefit from the extraction of natural dyes from waste products and their application in textile coloring. In this investigation, wool fabric was dyed with red apple (Malus domestica) peel extract while a mordant was present. Using pre-, meta-, and post-mordanting techniques, wool was dyed with red apple peel (RAP) extract using four different mordants: Fe+2, Cu+2, Al+3, and Sn+2.

2.2 Natural dyeing using Pomegranate Rind

China has long farmed pomegranates (*Punica granatum*) as a fruit crop. This crop is commonly grown in Mediterranean nations like Egypt, China, and India, and it originated in Iran and the Himalayan (Dhinesh and Ramasamy 2016). China produces around 5,000 tons of pomegranate juice and over 100,000 tons of fresh pomegranates annually, with almost 95% of these goods going overseas (Zhao and Jing 2019). According to (Tutak, Acar and Akman 2014), this agricultural waste product might be used to create natural dyes, which would amount to the recycling of 20,000–30,000 tons of pomegranate peel trash annually in China alone.

Numerous secondary metabolites, primarily phenolic acids (such as gallic, ellagic, and caffeic acids), flavonoids (such as catechin, gallocatechin, and epicatechin), anthocyanins, and hydrolyzable tannins (such as gallotannins and ellagitannins) are found in high concentrations in pomegranate peels. These phenolic compounds have been linked in several in vitro and in vivo investigations to a variety of biological activities and health advantages, including anti-inflammatory, anti-mutagenic, anti-carcinogenic, antihypertensive, and antioxidant properties. Additionally, their existence has been linked to the prevention and treatment of a number of chronic pathological disorders, such as diabetes, obesity, Alzheimer's disease, and cardiovascular diseases. According to this theory, the bioactive chemicals found in pomegranate peels could be used as functional components and provide the pomegranate business with extra value (Kaderides et al., 2021). For a plant-based yellow dye, the pomegranate (Punica granantum) was selected as a representative source. Tannin and certain components of pelletierine, known as tanante, are the colors present in pomegranates. Along with pelettierine, the fruit's rind also has a significant quantity of tannin (about 19%). Along with agar, gel-like substances, and glycosides, some of its isomers can also be found in fruit rinds 10–12. The purpose of this study is to determine whether pomegranates in fine powder form are suitable for textile extraction, dyeing, and characterisation (Adeel et al,.2009).

The powdered rind, or skin, of the pomegranate (Punica granatum) can be used as a tannin mordant, as well as a dye to obtain peachy yellow with alum mordant, and to get gray to moss green with iron mordant. Pomegranate rind was also used as a color source for painting medieval illuminated manuscripts. The age of the fruit affects the color of the dye: the less ripe the fruit, the greener the yellow (Singh et al.,2018).

Because people are becoming more environmentally conscious, the use of natural dyes has multiplied during the last few years. The purification of natural dyestuffs derived from the widely distributed plant "Punica granatum" is the focus of this research. Granatonine, which is found in the alkaloid form N-methyl granatonine, is the primary coloring component in pomegranate peel. The dye was extracted using the solvent extraction method. Two mordants, ferrous sulphate and copper sulphate, were employed in 1:1, 1:3, and 3:1 ratios to dye scoured cotton fabric using pomegranate peel dye.Techniques for premordanting, simultaneous mordanting, and postmordanting were used in conjunction with dyeing. An investigation into dyed clothing fastness tests was conducted. Because different mordant ratios and combinations were used, a wide variety of hues were produced. An estimate of the pomegranate peel dye's production costs was made (Kulkarni et al.,2011).

2.3 Natural Dyeing using Grapes Pomace

The basic components of grape pomace are the stems, seeds, and skins that are left behind after grapes are pressed to extract juice or wine (Arunkumar & Pachiyappan, 2025). According to Saeed et al., 2010 Environmental problems result from the frequent disposal of these by-products, which are frequently regarded as waste. Around 4 million metric tons of grapefruit are produced annually in all tropical and subtropical regions of the world. As a result, grapefruit peel (GFP) is widely accessible worldwide. Numerous water-soluble and insoluble monomers and polymers are present in GFP. Pectin, cellulose, hemicellulose, and lignin make up between 50% and 70% of the insoluble fraction, whereas glucose, fructose, sucrose, and some xylose are present in the water-soluble fraction. These polymers may bind cationic dye molecules in aqueous solution because they are abundant in carboxyl and hydroxyl functional groups. The goal of the current study was to assess the potential of GFP, which is rich in cellulose and pectin, as an affordable and environmentally friendly adsorbent for the treatment of wastewaters that contain the cationic crystal violet (CV) dye. There is currently no report on the removal of any dye by GFP, which makes the study even more unusual. The effects of temperature, pH, biomass dosage, and dye concentration were among the parameters examined for dye sorption. The functional groups in the grapefruit peel were identified using FTIR analysis, and the sorbent peel's suitability for multiple repeated uses was assessed using dye desorption. A variety of kinetics and isotherms equations have been fitted in an effort to understand the results based on the ion exchange mechanism.

According to Jeong 2016 we conducted a number of dyeing tests to determine the ideal conditions for dying textiles using leftover grape juice in order to create natural dyeing materials from the leftover plant elements. Experiments with dyeing were conducted under various dyeing circumstances, including temperature, time, pH, and concentrations of dyebath and post-dyeing mordants. Cotton, hemp, ramie, and silk were the materials used in the experiments. Measurements were made of the silk-dyed materials' color fastness to light, perspiration, rubbing, dry cleaning, and Munsell's HV/C as well as their color difference The dyed silk was light purple, while the cotton, ramie, and hemp were light red purple. The color variances of the dyed experimental materials rose very slightly with the length of the dying process. As the dyeing temperature rose, the color variations of the experimentally dyed cloths diminished and the color got lighter. As the dyebath's pH rose, the hue of the colored experimental materials changed from light purple to blue, reducing color variations. As the dyebath concentration rose, the color variations of the dyed experimental textiles increased somewhat. The mordant process caused the dyed fabric's color to alter, and the experimental fabrics' colors varied as well. Overall, the Al and Fe mordants raised the blue tone, while the Cu mordant increased the green tone. Dye-dyed silk fabrics have poor color fastness to light, washing, and perspiration, but good color fastness to rubbing and dry cleaning.

The current study emphasizes the value of using grape pomace, a by-product of wine production, as a potential source of biodye for the textile industry. By tackling the difficulties in fabric dyeing, the approach seeks to promote sustainability and circularity in textile production, which is consistent with the circular economy's tenets and helps to reduce waste and encourage more sustainable practices. The research emphasizes the continuous need to enhance dyeing techniques in order to make the use of biodyes made from grape pomace more efficient and profitable. Nevertheless, it is important to understand that the textile industry's transition to more sustainable practices calls for sustained efforts and cooperation across various sectors. With an astounding collection of more than 300 grape varieties, Portugal stands out as a nation with an unmatched diversity of grape sorts(Swiatkiewicz 2021). Various by-products are produced throughout the winemaking process and account for around 30% of the overall grape use. These byproducts include lees, pomace, grape stalks, and vine pruning. Between 25% and 45% of the total weight of the grapes can be made up of grape pomace, which is a mixture of the skins, seeds, and stem that are left over after grape pressing (Genisheva et al.,2023).

2.4 Natural Mordants and Mordanting Techniques

According to Choudhury, 2013, A material that can be bonded to a fabric and chemically combines with natural colorants is called a mordant. Natural dyes fall into two categories: substantive dyes and non-substantive dyes, depending on their intended application. Before applying the substantial colors (such as turmeric, orchil, and indigo), the fabric does not need to be prepared. On the other hand, non-substantive dyes (such fustic, cochineal, madder/alizarin, or logwood) can only color materials that have already been mordanted or work when a mordant is added to the dyebath. There are three types of pretreatments: direct (for cotton, like safflower or turmeric); acid (for silk and wool, like lac or saffron); or basic (for silk and wool, like berberine). Turmeric (diarylol methane), saffron, annatto (carotenoid), barberry (alkaloids), henna (quinonoid), French marigold, sandal (flavonoid), safflower (benzoquinone), alroot, and oyam (anthraquinone) are the basic families of natural dyes based on their chemical structures.

Mordanting is a necessary stage in the dyeing process because the majority of natural dyes do not have a strong affinity for textile fibers, particularly cellulosic ones. Since cotton lacks the amino and carboxyl groups that act as attachment sites for dye molecules, it is more difficult to dye than wool or silk and must be mordanted (Saxena and Raja 2014). Adeel et al. (2017) divided mordants into three categories: recently discovered mordants, acidic mordants (bio-mordants), and basic mordants (chemical mordants). Every mordanting method has an impact on the fabric's fastness characteristics and the kind of mordant that is used to dye it. Similarly, common mordanting methods used in dyeing processes include pre-mordanting, post-mordanting, and meta-mordanting (simultaneous mordanting). Choosing the right mordanting method is essential to achieving the required colors and fastness characteristics (Yassasri et al., 2019).

Since ancient times, mordanting chemicals have been used to dye protein and cellulose fibers. More depth of shade and color fastness have been achieved in the past by using a wide variety of inorganic (such as minerals, salts, crusts, mud, etc.) and organic (such as urine, excrement, blood, animal and vegetable fats, plant juices, wood ash, etc.) materials as mordanting or fixing agents (Cardon 2007 and Casselman 2013).

Chromium, tin, iron, copper, and aluminum metallic salts make up the majority of mordanting agents. Compounds containing copper and chromium, such as potassium dichromate and copper sulfate, were historically commonly employed as mordants, but their use has decreased due to toxicity concerns. The color and texture of the dyed fabric can also be impacted by iron and tin mordants, such as tin chloride and iron sulfate. When applying natural dyes to cellulosic textiles, aluminum mordanting chemicals are widely employed and regarded as some of the safest. Pre-mordanting, the one bath (on-mordant or simultaneous) technique, and post-mordanting after dyeing are the three ways to apply mordants. The pre-mordanting procedure is the most popular and frequently produces the greatest outcomes (Bohmer,2002; Cardon,2007; Dean,2007). Multiple batches of fabric can be prepared ahead of time using pre-mordanting, and unlike with the one bath procedure, the dyebath is not chemically changed (Cardon 2007). Nevertheless, it has also been demonstrated that the mordanting technique has little effect on color fastness to laundering. Therefore, the application approach employed in this investigation was pre-mordanting (Sarkar & Seal,2003).

2.4.1 Metallic Mordent

Applying metal salts, often known as metal mordanting, is a popular technique for enhancing the light fastness of natural colorants. In order to determine the degree of correlation between mordant-induced effects (color and color depth changes) and light fastness changes, as well as the mechanisms underlying mordant-induced improvements in light fastness and the comparison between salt levels used in coloration processes and the limits on metal levels in wastewater and on dyed substrates, this review presents the findings of a survey of the literature on metal mordanting. There are no discernible connections between the effects of the mordant and the enhancements in light fastness. Empirical correlations seem to be the primary source of knowledge regarding the mechanisms underlying the mordant effect on light fastness. However, the relationships are not always valid because light fastness is influenced by a wide range of circumstances. Remaining metal levels in used dye/mordanting liquors are typically not disclosed. Rough calculations, however, indicate that the metal contents in used liquors surpass environmental release limitations, even at the lowest reported salt concentrations. Similar estimations indicate that the heavy metal amounts on dyed substrates (when copper and chromium salts are employed as mordants) also exceed limitations, however the metal contents on dyed substrates are not typically reported either. The authors offer recommendations for components to be included in studies aimed at advancing the use of natural colorants in textile dyeing based on these data (Manian et al., 2016).

According to (Singh et al.,2018) Typically, they are metal salts of tin, copper, iron, chromium, and aluminum. There are two kinds of metallic mordants.

- Brightening mordants:
  a) Potash alum, b) Chrome (potassium dichromate), c) Tin (stannous chloride)
- Dulling mordants :
  a) Copper (cupric sulphate), b) Iron (ferrous sulphate)

However, utilizing a mordant became more important as interest in natural plant dyes grew. For the majority of natural dyes to permanently set in any textile, some kind of mordant is needed. In order to create coordination bonds with the dye molecules and render them insoluble in water, the metal ions of mordants serve as electron acceptors for electron donors (Mongkholrattanasit et al., 2011). This results in improved dye absorption and retention, which enhances color fastness and shade depth (Böhmer et al.,2002). Alum, chrome, stannous chloride, copper sulphate, ferrous sulphate, and so on are examples of common mordants (Kulkarni et al., 2011). After a certain amount of exposure, chrome and copper are regarded as undesirable heavy metals that are bad for human skin Mud, blood, and cow dung are examples of organic materials that have been employed as mordants. Natural mordants like tannins are also advised to lessen the effects of some toxic mordants because they can give textiles properties that are comparable to those of synthetic mordants (Dweck and A. C. 2002).

2.4.2 Ferrous sulphate

The formula FeSO4.7H2O indicates ferrous sulphate heptahydrate, which is known commercially as copperas. Ferrous sulfate heptahydrate is used as a chromate reducer to prepare soil or to bind toxic chromium compounds in cement. A considerable amount of ferrous sulfate is utilized in waste water treatment, and this worldwide, application is growing daily. Fertilizer, phosphate precipitation in sewage water purification, sewage slurry conditioning, iron chlorosis treatment in horticulture, and iron oxide pigment production as a raw material are additional uses for ferrous sulfate heptahydrate which is then utilized to make ferrites. Additionally, it is utilized as a mordant in the dyeing of wool and in the production of inks (iron gall ink). Its main application has been in the management of anemia in both humans and animals. Copperas can be prepared using two different methods: the byproduct method and the sulfuric acid leaching method is the alternative. It is mostly made as a byproduct of pickling steel with sulfuric acid and producing TiO2 from ilmenite using the sulphate process. In the sulfuric acid leaching process, hydrated ferrous sulphate is produced from scrap iron.

According to Tolkien et al.,2015 Approximately 4.7 million people in the UK suffer from iron deficiency anemia (IDA) each year. Those with higher iron requirements, such as children and pregnant women, as well as those with higher iron losses, such as premenopausal women and patients with inflammatory bowel disease (IBD), are the groups most at risk. Ferrous iron (Fe(II)) salts administered orally are the first line of treatment. For instance, simple Fe(II) salts accounted for 97.6% of the more than 6.8 million oral iron prescriptions written in England in 2012. Nausea, gas, stomach pain, diarrhea, constipation, and black or tarry stools are among the most often reported adverse effects linked to oral iron supplementation. Oral iron therapy has long been primarily concerned with patient side effects, but more recently, research has consistently demonstrated that soluble oral iron also has a detrimental effect on the colonic microbiota, favoring the growth of potentially harmful bacteria over beneficial ones. Concerns about "available" iron in the colon as a risk factor for colorectal carcinogenesis and inflammatory signaling have arisen most recently. However, up to 50% of patients have non-adherence as a result of the GI side effects, regardless of the underlying mechanism of these side effects that seem to be connected to oral iron therapy. This results in major treatment failures and needless follow-up research.

2.5 Natural Dyeing on Cellulose Fabric

According to Chen et al.,2001 and Daria et al.,2020; since the beginning of recorded human history, textile dyeing has been regarded as an art form. Textile fragments uncovered during archaeological digs provide evidence of dyeing throughout civilizations. dyeing was done in the past by using colors that came from natural sources. The use of natural dyes for textile dyeing drastically decreased after the invention of synthetic dyes in 1856. Natural dyes have generally supplanted synthetic dyes in recent decades because of their greater fastness, ease of application, and consistency in color. All of this has been feasible due to the rapid industrialization of the textile industry and coordinated research into synthetic colors. Most prevalent chemicals, auxiliary substances, and colorants (dyes and pigments) with mutagenic and carcinogenic potential are used by the textile industry. In particular, the majority of dyes containing Azure-B have been demonstrated to have substantial effects on deoxyribonucleic acid (DNA). Cellulosic fibers, which have been connected to acute toxicity and mutagenicity, are frequently colored using reactive dyes that include anthraquinone. Furthermore, a number of problems arise from the discharge of microfibers (also known as microplastics or fiber fragments) from textile materials. In particular, the inclusion of synthetic dyes and chemicals slows down the biodegradation of both natural and artificial cellulosic fibers, which mostly affects marine life. Once released into the sea, these dyes and chemicals interact with microfiber fragments, often known as microplastics, to worsen the situation for marine life (Periyasamy and A. P.,2022).

Many different types of natural fibers are colored using natural dyes. Because of their softer texture, more organic colors, deodorizing qualities, and compatibility with other natural ingredients, customers today favor natural colorants (Mirjalili et al.,2011and Mahdi et al.,2020). Color fastness, especially lightfastness, may be a significant obstacle to the widespread application of natural dyes in textiles (Brady 1992 & Criatea and Vilarem,2006). Consequently, in order for the natural dye to react with the fiber and improve its performance, mordants must be used (Singh and Bharati 2014). The fastness characteristics of naturally colored textile materials are greatly influenced by the interactions between fiber, mordant, and dye as well as the chemical makeup of mordants.

Cotton dominates the kind, despite the fact that the term "cellulosic fibers" is commonly employed. Jute, viscose rayon, linen, cuprammonium rayon, and other fibers that have been incorporated as cellulosic can be dyed using similar dyes to those used on cotton. Leather and paper can be dyed in a similar way. Despite having a distinctly cellulosic structure, cellulose acetates act considerably differently from cotton and are colored with disperse-type hydrophobic dyes. According to a 1982 survey, 15.5 million tons, or 42.8%, of the world's fiber production came from the production of cotton. One Therefore, the overall output of synthetic fibers was equivalent to the production of cotton. Cotton's significance, either by itself or in fiber blends—especially with polyester—is obvious, and as the dye business has grown, a number of dye classes have been developed for its coloring (Waring 1990).

2.5.1 Natural Dyeing on Linen

Unmatched qualities of linen, a natural bast fibre, including a sensation of freshness and a stunning brilliance. It gives the wearer a sense of satisfaction and flair and is incredibly hygienic. The weather during the growing season has a significant impact on the quality of linen produced. Linen and linen-blended fabrics have become more prestigious and well-known due to the fashion trend towards natural, cosy, yet sophisticated textiles. Therefore, it is essential to promote both the manufacture and use of linen by educating consumers about its unparalleled features and mixtures. The handle and comfort characteristics of linen and linen-blend materials have been examined in this regard. In order to ascertain the total hand value (THV) and total appearance value (TAV) at both the gray and finished stages, the low stress mechanical properties of linen and linen-blended fabrics have been examined. One of the most crucial elements of all clothing is comfort, and numerous scholars have written a great deal about it. Nonetheless, there hasn't been much written on the comfort qualities of linen and its mixtures. Therefore, the different transmission qualities of linen fabrics are also researched in addition to the fabric hand (Behera 2007).

According to Patel et al.,2017 pigmentary molecules, which give materials their color, are the natural dyes found in plants and animals. These compounds, which have an aromatic ring structure and a side chain, are typically necessary for resonance and, consequently, for color effect. The literature only has a small number of research that describe the use of binary mixtures of natural dyes. In the presence of natural mordants such as *Terminalia chebula*, *Terminalia belerica*, and orange peel, the current study aims to optimize the dying parameters for linen fabric using a binary mixture of dried and powdered leaves of the *Mangifera indica* (mango) and *Azadirachta indica* (neem) plants. The document also reports the results of color fastness testing, color data, and color strength (K/S) rating.

2.6 Limitation of Natural Dye

Given the substantial amounts of water, energy, and chemicals needed for the wet processing stages, the dyeing and finishing step is undoubtedly a hotspot in the textile supply chain. Researchers are increasingly focusing on natural dyes as more sustainable substitutes for synthetic ones in an effort to address environmental concerns. The topic of natural dyes is covered in this review, along with an overview of recent studies in the field that specifically address the following areas of sustainable innovation: extraction methods, substrate preparation, the mordanting process, and the dyeing process. It also describes the primary characteristics of natural dyes and how they differ from synthetic dyes. According to the literature review, promising new technologies and techniques have been successfully used to improve the sustainability and performance of natural dyeing processes. However, a number of limitations, including the poor fastness properties of natural dyes, their low affinity for textile substrates, challenges with shade reproducibility, and other factors like cost-effectiveness considerations, make it difficult for the industry to adopt natural dyes on a larger scale. Further research will be necessary to expand their use beyond certain niche applications (Pizzicato et al.,2023).

Natural dyes provide a number of benefits over synthetic dyes, but they also have some significant drawbacks. While there are many benefits to using natural dyes in terms of health and allergy issues, the main drawbacks are the poor yield on the one hand and the color-fixing difficulty on the other. Because it is difficult to store the extracted dyes for an extended length of time in dry conditions, the majority of natural dyeing enterprises use them to fix or color the garments instantaneously. It is frequently very difficult to get the desired color on fabrics because it depends on a number of factors, including water quality, pH, mordant quantity, concentrations, coloring time, and many more. For these reasons, thorough research and skilled expertise are crucial. Furthermore, the hue of plant-based natural dyes is dependent on processing and harvesting time because they are usually a mixture of secondary metabolites. Creating secondary colors from original colors by mixing them in the right amounts is similarly fraught with difficulties. If the government could properly preserve and document all of the dye-producing plants and traditional methods, Nepal's vast plant biodiversity could serve as a research center. If natural dyeing methods could be created using locally available natural mordants such rock salts, lemon juice, and mango bark juice, that would be a huge accomplishment. Though more costly than synthetic dyes, natural dyes would be more affordable, safer, and sustainable in the long run if they were grown and processed commercially in significant quantities (Bhandari et al.,2020).

2.7 Recent Advancement in Natural Dye

Environmentally friendly and non-toxic bioresource goods are becoming more and more popular in various areas of our life as a result of the public's increased awareness of health and safety issues. Natural dyes, which come from plants, insects, and minerals, are sustainable bioresources that have no effect on the environment. They have been used since ancient times to color textiles as well as food and cosmetic ingredients. The usage of natural colorants fell precipitously when W.H. Perkin discovered the synthetic colorant "mauve" in 1856 and the ensuing increase in the study, manufacture, and use of synthetic dyes. However, the use of many synthetic dyes has negative environmental impacts and is linked to hazardous, poisonous, allergic, and cancer-causing reactions. In the face of mounting environmental and health concerns, eco-friendly, non-toxic natural dyes have resurfaced as a promising "Green chemistry" alternative or co-partner to some degree to synthetic dyes. Research and development on the manufacturing and use of natural dyes has recently increased due to the growing demand for more environmentally friendly lifestyles centered on organically sustainable products. The stunning hues of the natural flora and fauna captivate people and draw them to a wide range of opportunities. Numerous sources of color have been found in plants, animals, and insects, and their varied applications include food coloring, cosmetic dye-sensitized solar cells, textile dyeing and functional finishing histological staining, pH indicator, and several other application disciplines. Over the past few decades, researchers have focused more on different facets of the applications of natural dyes, and there is a lot of research and development going on in this field all over the world. The goal of this research paper is to compile the scattered data regarding the most current advancements in both conventional and recently identified uses of natural dyes from 1998 to 2013. The scientific advancements in natural textile dyeing and their use in food coloring, dye-sensitized solar cells, and functional textile finishing have received particular attention. In order to make natural dyes a competitive alternative to synthetic dyes, this review study also identifies some problems that need to be addressed (Shahid et al.,2013).

Since a plant's matrix contains a small amount of dye—typically between 0.5 and 5%—as well as a number of other components like water-insoluble fibers, carbohydrates, protein, chlorophyll, and tannins, among others, extracting colorant from natural sources is an essential step in creating purified natural dyes. The assessment of the dyeing materials' nature and solubility should serve as the foundation for choosing the best extraction method (Saxena and Raja 2014). The classic technique of aqueous extraction involves first reducing the dye matter to powder or small pieces, and then submerging it in water to boost the process' effectiveness and relax the cell structure. Boiling is used to create the dye solution, which is subsequently filtered. It is possible to repeat the extraction and filtration procedure multiple times (Merdan et al., 2017). The extract can be readily applied to fabrics, and aqueous extraction is a safe and sustainable method. Its lengthy extraction process, high water requirements, and low dye yield—only the water-soluble color components are extracted—are its drawbacks. Moreover, the color is removed together with sugars and other water-soluble substances. High temperatures decrease the yields of heat-sensitive dyes. Extraction with organic solvents such as ethanol or methanol, or a combination of the two, is similar to aqueous extraction but yields a greater yield. Lower temperatures can be employed, reducing the risks of deterioration. Water/alcohol extraction can extract both water-soluble and insoluble components. Furthermore, the solvents can be easily extracted by distillation and reused. A disadvantage is the existence of harmful leftover solvents. Furthermore, the extracted material is not easily soluble in water; co-extraction of other substances such as chlorophylls and waxy components may occur.

CHAPTER 3

METHODOLOGY

METHODOLOGY

An experimental approach was conducted to assess the study on "Sustainable Dyeing of Linen fabric with selected mordanting techniques." This chapter outlines the research methodology employed to investigate the extraction, application, and evaluation of natural dyes derived from fruit juice wastes. The experimental procedures pertaining to the study are discussed under the following headings:

3.1 Selection of Fabric

3.2 Pre-treatment of Fabric

3.3 Sourcing of Materials

3.4 Selection of Source for Dyeing

3.5 Selection of Source for Mordanting

3.6 Extraction of Dye from Pomegranate Rind

3.7 Extraction of Dye from Grape Pomace

3.8 Ferrous sulphate as Mordant

3.9 Dyeing Using Pomegranate Rind

3.10 Dyeing Using Grape Pomace

3.11 Post Mordanting

3.12 Survey on Preference for Natural Dyes Extracted from Fruit Juice Waste

3.13 Evaluation

3.1 Selection of Fabric

Linen fabric has been selected for natural dyeing due to its excellent dye absorption and sustainable qualities, making it eco-friendly and a natural choice for textile dyeing. Linen dries more quickly than cotton and is incredibly robust and absorbent. Because of these qualities, linen is appreciated for use in clothing and is comfortable to wear in hot weather (Sayed et al., 2023). The detail of the selected material is given in the Appendix 1.

3.2 Pre-treatment of Fabric

The aim of the pretreatment procedure is to increase the fabric's quality by consistently eliminating impurities and foreign materials, making it appropriate for the next processes or uses (Anthappan et al.,2006). (Plate 1)

3.3 Sourcing of Materials

100% linen fabric with plain weave was purchased from Milan boutique, Kochi and the mordant for natural dyeing ferrous sulphate was purchased from Isochem Laboratories Angamaly.

3.4 Selection of Source for Dyeing

Colorants derived from plants, animals, or various fruits and vegetables are known as natural dyes. Using natural dyes derived from fruit juice waste presents a sustainable and eco-friendly alternative to synthetic dyes. This innovative approach not only minimizes organic waste generated by the juice and food processing industries but also reduces the environmental impact associated with conventional dyeing, which often involves toxic chemicals and heavy metals. Pomegranate Rind are high in tannin, and it produce ochre yellow dye and Grape pomace has an attractive golden purple shade; hence this by products taken for dyeing Linen Fabric.

3.5 Selection of Source for Mordanting

Ferrous Sulphate used as chemical mordant. It acts as a mordant, improve the binding of the dye to the fabric. It can alter the hue of the dye, producing shades that range from muted tones to vibrant colours (plate 2).

3.6 Extraction of Dye from Pomegranate Rind

The Pomegranate rind was collected from local juice shop, Kochi, Kerala. The pomegranate peels dried under shade in sunlight for about 2-3 days until moisture gets dry. Once the peels are dried, they are powdered by grinding it and the finely powdered peel is filtered before processing.

The preparation steps of pomegranate powder shown below

Pomegranate peel powder and purified water were combined with a resource-liquid ratio of 1:10 to perform the color extraction, and the mixture was then boiled for about an hour. 500ml of water were mixed with 50 grams of powdered pomegranate peel and allowed to boil for 60 minutes. The colorful water that was produced was to be utilized as a dye bath. Using a fine cloth, the mixture was strained to remove the powdered pomegranate peels (plate 3,4,5,6 & 7).

3.7 Extraction of Dye from Grape Pomace

The Grape Pomace were collected from local juice shop in Kochi, Kerala. The extraction was performed by boiling the grape pomace for one hour. 50 grams grape pomace were added to 500 ml of water and boiled for 60 minutes. The resultant solution was to be used as dye bath. The grape pomace was removed by straining the mixture using a fine cloth (plate 8,9 & 10).

3.8 Ferrous sulphate as Mordant

In natural dyeing, ferrous sulphate, sometimes referred to as iron, is a multipurpose mordant that improves color fastness, shifts colors, and darkens hues, especially when mixed with dyes high in tannin.

3.9 Dyeing Using Pomegranate Rind

To dye the linen fabric using Pomegranate rind, the sample was put in a beaker with 300 millilitres dye solution, swirled with a glass rod, and boiled for approximately an hour. The dyed sample was then removed from the dye solution and allowed to dry in a location with adequate ventilation and shade (Adeel et al., 2009) (plate 11 & 12).

3.10 Dyeing Using Grape Pomace

To dye the linen fabric using Grape pomace, the sample was put in a beaker with 300 millilitres dye solution, swirled with a glass rod, and boiled for approximately an hour. The dyed sample was then removed from the dye solution and allowed to dry in a location with adequate ventilation and shade (plate 13 & 14)

3.11 Post Mordanting

The samples were post mordanted using ferrous sulphate. The fabric sample was placed in 50 ml of respective mordant solution and heated at 60°C for one hour. The fabric was dried in open air.

3.12 Survey on preference for natural dyes extracted from fruit juice waste

A survey was conducted by the researcher to determine the percentage of people who preferred natural dyes that are extracted from fruit juice waste. The questionnaire consists of preference in natural dyed textiles, its design, cost and colour. And a convenient sampling method was adopted to collect the required data from 85 respondents from in an around Ernakulam.

3.13 Evaluation

The dyed fabric samples were evaluated for wash fastness, fastness to sunlight and fastness to hot iron.

Plate 1. Pre- treatment of fabric

Plate 2. Ferrous Sulphate

Plate 3. Pomegranate Rind

Plate 4. Dried Pomegranate Rind

Plate 5. Pomegranate Rind Powder

Plate 6. Extraction of dye

Plate 7. Extracted dye solution

Plate 8. Grape Pomace

Plate 9. Extraction of dye

Plate 10. Extracted dye solution

Plate 11. Dyeing using Pomegranate Rind

Plate 12. Samples after dyeing

Plate 13. Dyeing using Grape Pomace

Plate 14. Sample after dyeing

Plate 15. Post mordanting on pomegranate dyed sample

Plate 16. Sample after post-mordanting

Plate 17. Post mordanting on grape pomace dyed

Plate 17. Sample after post-mordanting

CHAPTER 4

RESULT AND DISCUSSION

RESULT AND DISCUSSION

In order to elicit information regarding the study on "Sustainable Dyeing of Linen fabric with selected Mordanting Techniques", experimental procedure was the method carried out in laboratory conditions. As Natural dye and different mordanting techniques was applied on the fabric, it was essential to check the physical fabric properties as well as its colour fastness properties and the following were the results.

4.1 Colour Fastness test of the dyed fabric

4.1.1 Colour Fastness to Washing

4.1.2 Colour Fastness to Hot Iron

4.1.3 Colour Fastness to Sunlight

4.2 Survey on Preferences for Natural dyes extracted from fruit juice waste

4.2.1 Consumer Awareness of Natural dyes

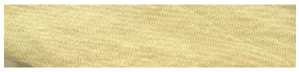
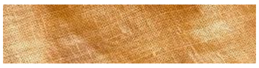
4.2.2 Product preferences among consumers

4.1 Colour Fastness test of the dyed fabric

4.1.1 Colour Fastness Test: Washing

To determine the colour fastness of the dyed fabric wash fastness test was carried out to assess the durability of dyes in textiles when subjected to typical domestic laundering conditions. This test determines the resistance of coloured fabrics to fading.

Table 1. Wash Fastness of Dyed fabric samples

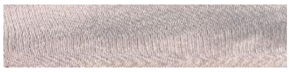
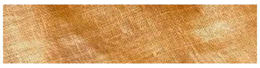
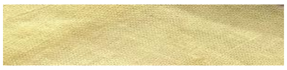
Sample	Before Washing	After Washing
Pomegranate Rind Dyed fabric		
Post-mordanted pomegranate rind dyed fabric		
Grape Pomace Dyed fabric		
Post-mordanted Grape pomace fabric		

From Table1. It is clear that the color of the natural dyed samples experienced slight fading compared to the post-mordant samples, which retained more vibrant hues. This suggests that the mordanting process enhanced color fastness and durability. The mordant likely formed a stronger bond between the natural dye and the material, reducing color loss. Overall, mordanting appears to improve the stability and longevity of natural dyes.

4.1.2 Colour Fastness Test: Hot Iron

The colour fastness of the linen fabric that was naturally dyed was evaluated by hot ironing. The naturally dyed and post mordanted sample were hot ironed, the result shows that the colour of the natural dyed samples faded a little more than compared to the post mordant sample.

Table 2. Hot Iron test of Dyed fabric samples

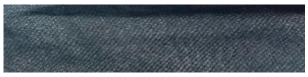
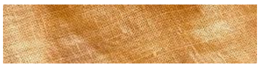
Sample	Before Washing	After Washing
Pomegranate Rind Dyed fabric		
Post-mordanted pomegranate rind dyed fabric		
Grape Pomace Dyed fabric		
Post-mordanted Grape pomace fabric		

The hot iron test is a simple yet effective method used to assess the heat resistance and colour stability of natural dyed fabrics when exposed to high temperatures, such as those encountered during ironing. Table 2. Clearly depicts tha the hot iron test, the post-mordant samples had superior color retention, but the naturally colored samples showed some color fading. This suggests that mordanting reduced fading and discoloration by improving the natural dyes' color fastness to heat. The fabric's resilience to heat-induced deterioration was probably increased by the mordant's enhanced binding of the natural dye.

4.1.3 Colour Fastness Test: Sunlight

The colour fastness of the linen fabric that was naturally dyed was evaluated under sunlight. The naturally dyed and post mordanted sample were put under sunlight, the result shows that the colour of the natural dyed samples faded a little more than compared to the post mordant sample.

Table 3. Sunlight test of Dyed fabric samples

Sample	Before	After
Pomegranate Rind Dyed fabric		
Post-mordanted pomegranate rind dyed fabric		
Grape Pomace Dyed fabric		
Post-mordanted Grape pomace fabric		

From Table2. Both naturally colored and mordanted samples showed only minor color changes in the sunlight color fastness test, suggesting strong resistance to fading caused by sunlight. This implies that the natural dyes have moderate to good lightfastness, whether or not they are mordanting. These dyes are appropriate for applications where color stability is crucial because of the low color change that suggests they can tolerate exposure to sunlight without suffering severe deterioration.

4.2 Survey on Preferences for Natural dyes extracted from fruit juice waste

4.3.1 Consumer Awareness of Natural dyes

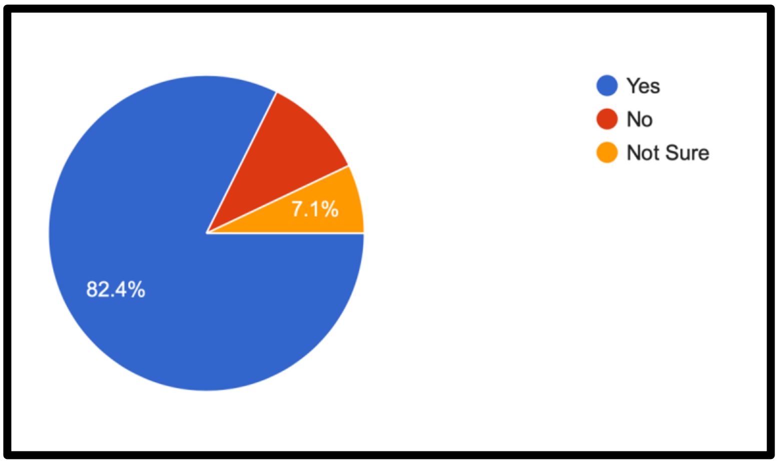


Fig1. Consumer Awareness about Natural dyes

With regard to the awareness about natural dyes made from fruit or vegetable waste (e.g., juice pulp or peels) (Fig.1)82.4% of the respondents said "yes," demonstrating their knowledge of natural dyes derived from food waste. 7.1% said they weren't sure, while 10.6% said no. This indicates that participants are very conscious of the use of natural dyes derived from leftover fruit and vegetable ingredients.

4.3.2 Importance of Sustainability among consumers

According to the respondents, sustainability is very essential to 38.1% of respondents, while 33.3% think it is fairly important, 8.3% answered it is not important, while 13.1% said it is rather important. Only about 7.1% of respondents said sustainability was very essential. According to these findings, the majority of participants place some degree of value on sustainability, and a sizable percentage give it top consideration when making decisions about what to buy Fig.2

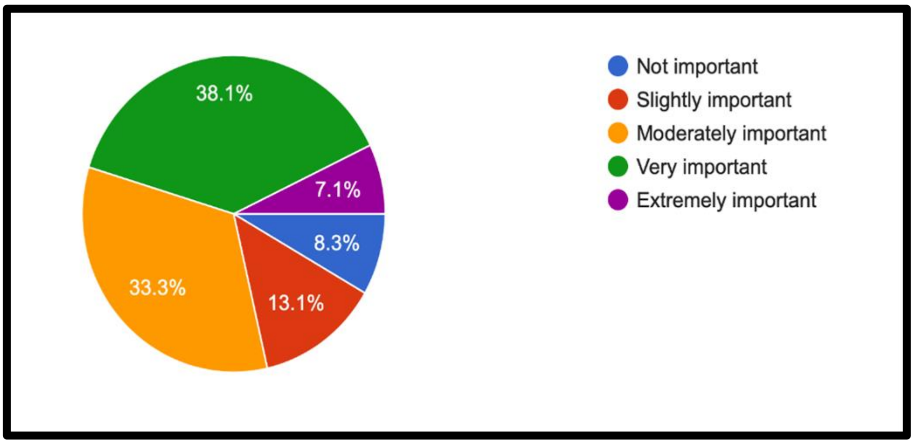


Fig:2 Importance of Sustainability among consumers

4.3.3 Product preferences among consumers

According to the data presented in Figure 3, a majority of consumers, 66.3%, expressed a preference for the product by answering "Yes." Meanwhile, 26.7% of respondents indicated "Maybe," showing some hesitation or conditional interest. Only a small portion, 7%, responded "No," suggesting they would not prefer the product. This indicates that overall consumer interest in the product is predominantly positive, with a notable portion remaining uncertain.

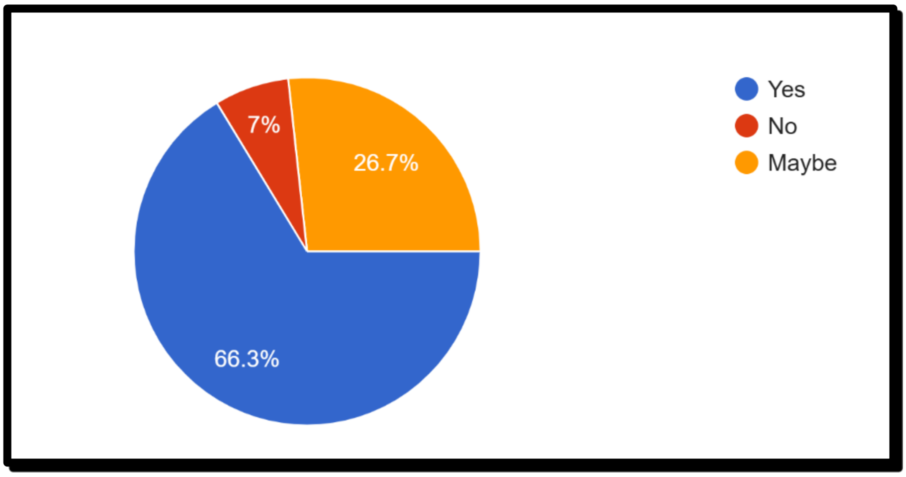


Fig:3 Product preferences among consumers

4.3.4 Green Shopping: Natural dye interest

According to the graphic. 65.9% of respondents said "yes," indicating a high level of interest in these kinds of products. Just 7.1% said no, whereas 27.1% said maybe, suggesting possible interest based on other grounds. This implies that consumers have a generally favorable attitude about buying goods dyed naturally from juice waste (Fig:3).

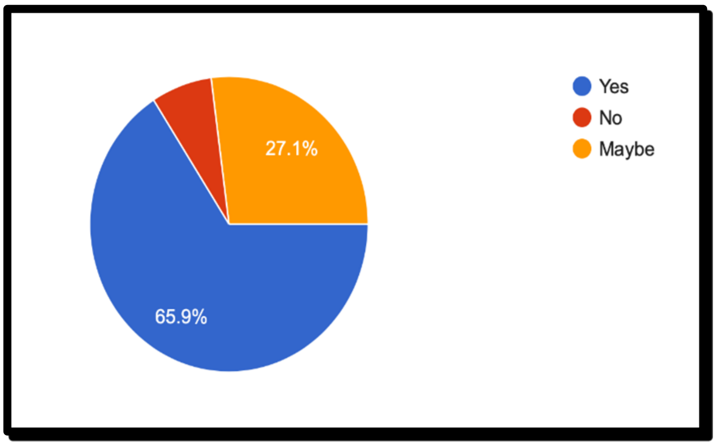


Fig:4 Green Shopping: Natural dye interest

4.3.5 Consumer Preference for Natural Dye Products

Environmental impact was chosen by the majority, 40.5%, as the most important factor. Certifications of quality and durability (such as organic and eco-friendly) came next, at 28.6%, and distinctive look or color, at 21.4%. 3.6% of respondents were swayed by shop price and brand transparency, whereas 6% were affected by story price and brand transparency. These findings suggest that consumers' decisions about naturally dyed products are heavily influenced by confirmed quality standards and environmental factors as shown in (Fig:5).

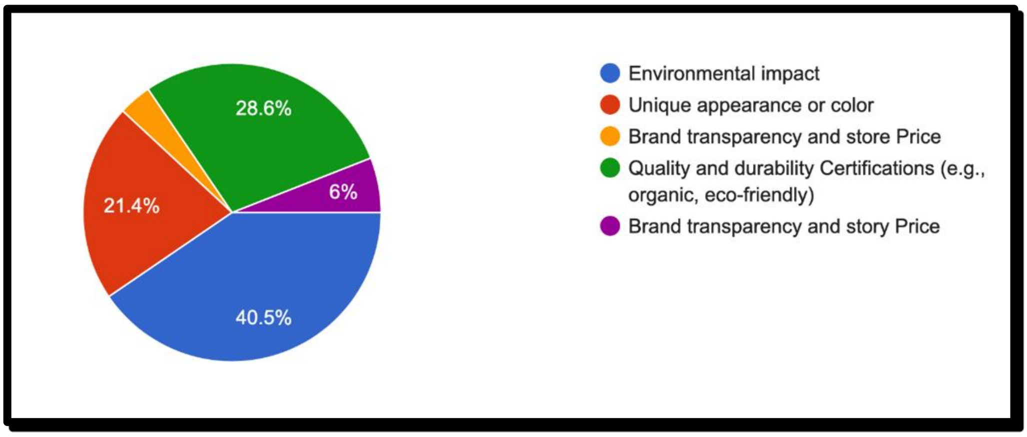


Fig:5 Consumer Preference for Natural Dye Products

4.3.6 Consumer demand for natural dyes in products

The results showed that safety and hygiene were the most important issues, with 40.7% of respondents expressing such worries. After that, 20.9% expressed concern regarding durability and color fastness. Approximately 16.3% of respondents said they were completely unconcerned. While 8.1% of respondents were concerned with aesthetics, such as color scheme and design, 14% of respondents were concerned about price(Fig:6).

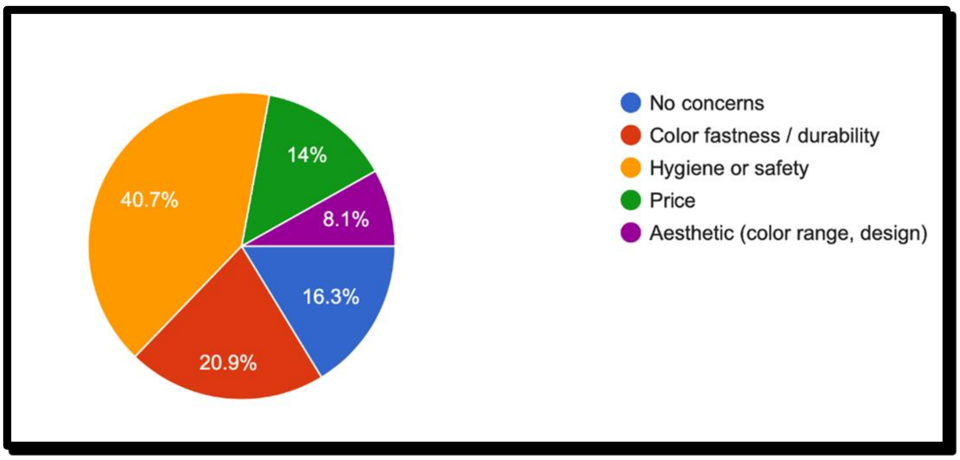


Fig:6 Consumer demand for natural dyes in products

4.3.7 Eco-friendly product categories: A consumer survey

The survey 84 respondents were asked in the poll which product categories they would most like to see uses of natural dyes in. Fashion-related items like apparel and accessories piqued the curiosity of the majority, 44%. 21.4% of respondents said they favored household textiles like curtains and beds. Gift wrap and product boxes were among the packaging goods that 17.9% of the respondents were interested in. Products related to stationery, such as cards and notebooks, received 9.5% of the interest, whilst furniture and home décor, such as wall art and cushions, received the least, at 7.1% (Fig:7).

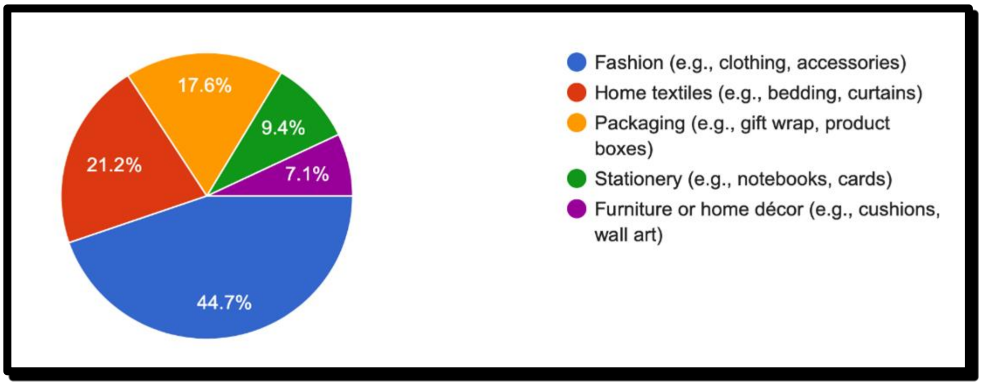


Fig:7 Eco-friendly product categories: A consumer survey

4.3.8 Natural dye in fashion consumer choice

Eighty-five persons answered the question regarding what fashion products they would buy if they were dyed using waste from natural juice. Dresses were the most preferred option, chosen by 35.3% of those surveyed. Each category earned 27.1% of the vote, indicating equal interest in T-shirts and handbags or accessories. Scarves were the least popular choice, selected by just 10.6% of participants (Fig:8).

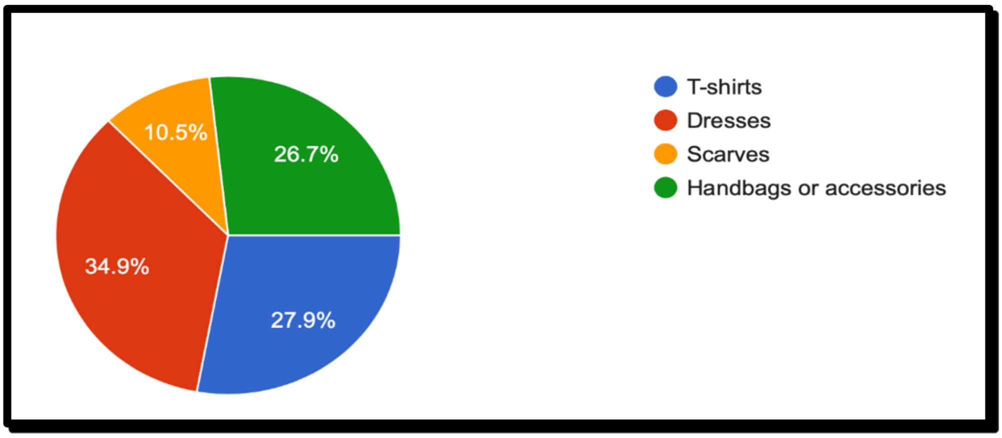


Fig:8 Natural dye in fashion consumer choice

4.3.9 Consumer views on sustainability in fashion and home products

In (Fig:9) Half of the participants (50%) in a survey of 84 respondents said that eco-friendliness is highly essential in product categories like fashion or home textiles. 42.9% more people thought it was somewhat important. Just 2.4% of respondents said it was not important at all, compared to 4.8% who said it was not very essential. In general, eco-friendly activities in these product categories were strongly preferred by the majority of respondents.

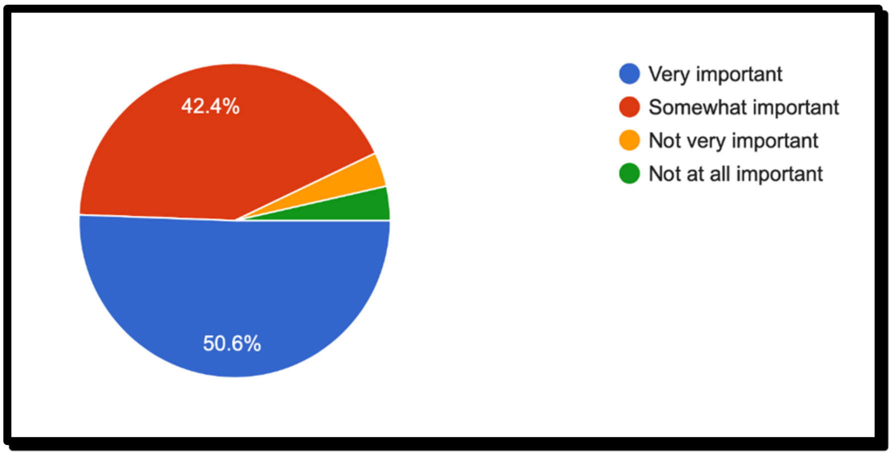


Fig:9 Consumer views on sustainability in fashion and home products

4.3.10 Consumer response to natural dye book covers

Nearly half (49.4%) of the 85 respondents who participated in the poll thought that natural dyed book covers were a highly appealing idea. A further 24.7% thought it was somewhat appealing, and 23.5% had no opinion. Just 2.4% of respondents thought the concept was unappealing. In general, the notion was well received by most respondents (Fig:10).

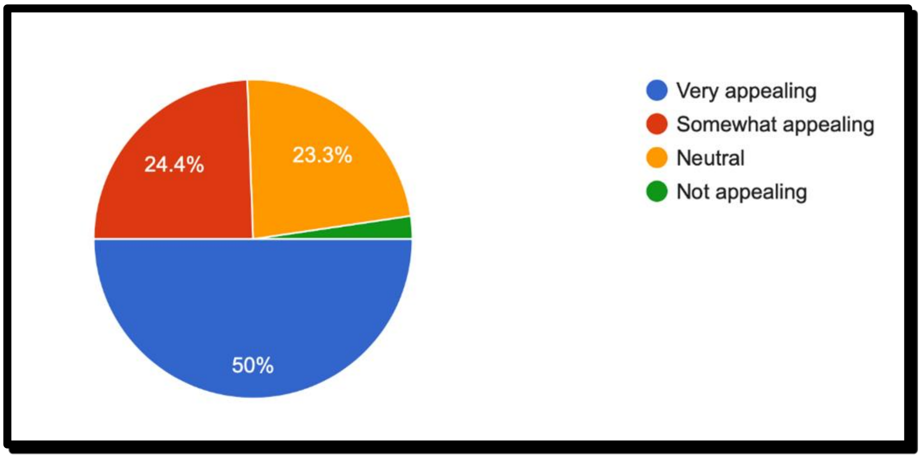


Fig:10 Consumer response to natural dye book covers

4.3.11 Consumer opinion on book cover design

The pie chart (Fig:11) shows that 75% of respondents thought the design was "Good," 19% thought it was "Fair," and 6% thought it was "Average." This suggests that the majority of participants thought the book cover design was good

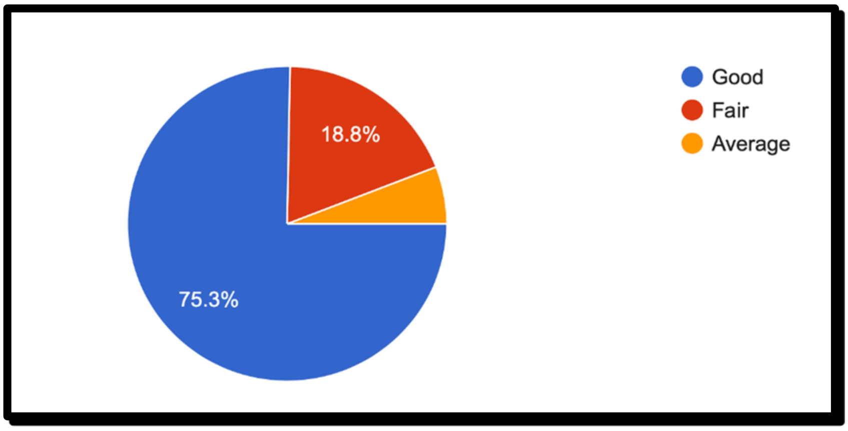


Fig:11 Consumer opinion on book cover design

4.3.12 Willingness to pay for eco-friendly book covers

The findings showed (Fig. 12) that 50.6% of respondents said, "Maybe, depending on price," 43.5% said, "Yes, definitely," and 5.9% said, "No." The fact that price is a major consideration for many participants suggests that most of them are amenable to paying more for environmentally friendly book covers.

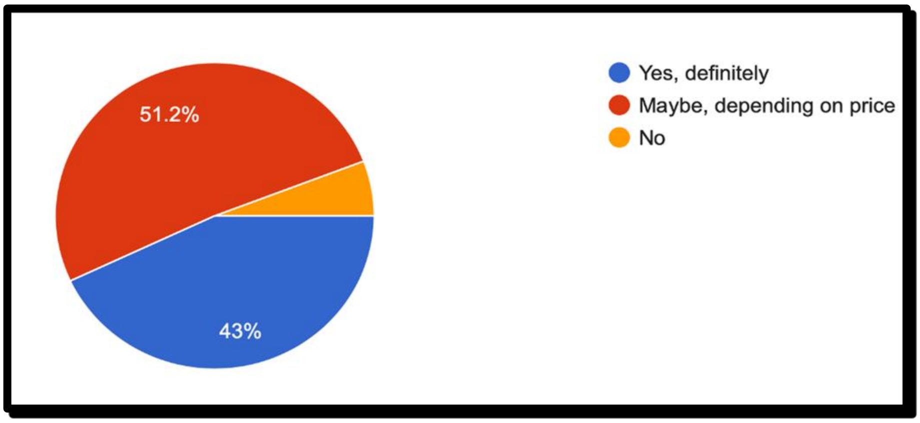


Fig:12 Willingness to pay for eco-friendly book covers

4.3.13 Artist folder usage among respondents

"Do you currently use an artist folder (portfolio folder, sketch folder, etc.)?" is the survey question. 85 answers were obtained. Of the participants, 45.9% said they did not utilize an artist folder, whereas 54.1% said they did. This implies that a small majority of participants use an artist folder at the moment (Fig:13).

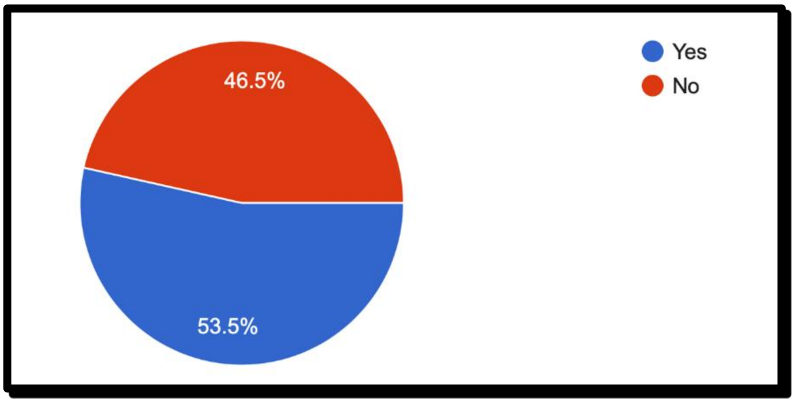


Fig:13 Artist folder usage among respondents

4.3.14 Response on sustainable artist folders

"If yes, how appealing do you find the concept of artist folders dyed with natural materials?" was the poll question. 64.2% of the 81 respondents thought the idea was extremely appealing. Furthermore, 25.9% of those surveyed thought it was moderately appealing. Only a very small fraction did not find it appealing at all, and a smaller portion, 8.6%, remained neutral. All things considered, the idea was well welcomed (Fig:14).

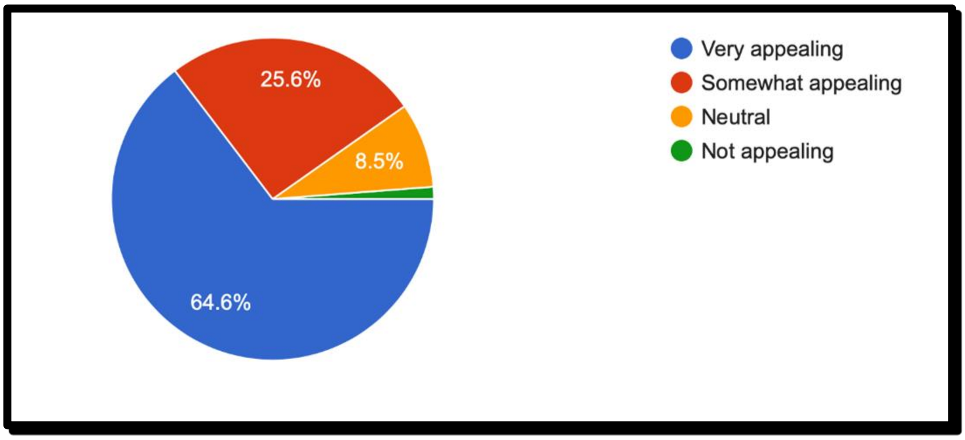


Fig 14 Response on sustainable artist folders

4.3.15 Consumer attitude towards natural dyes

In the poll, participants were asked what variables might affect their decision to buy items manufactured using natural dyes from fruit juice waste in the future. Because they are attracted to eco-friendly, sustainable items, 45.9% of the 85 respondents said they are very likely to do so. A further 41.2% stated that, depending on the product and its design, they are somewhat likely. 9.4%, on the other hand, were neutral, indicating no clear choice. Just 1.2% of respondents said they are very unlikely to consider eco-conscious products at this time, while a small percentage (2.4%) said they are unlikely to be interested in buying such products. This indicates a general high level of interest in making sustainable purchases (Fig:15).

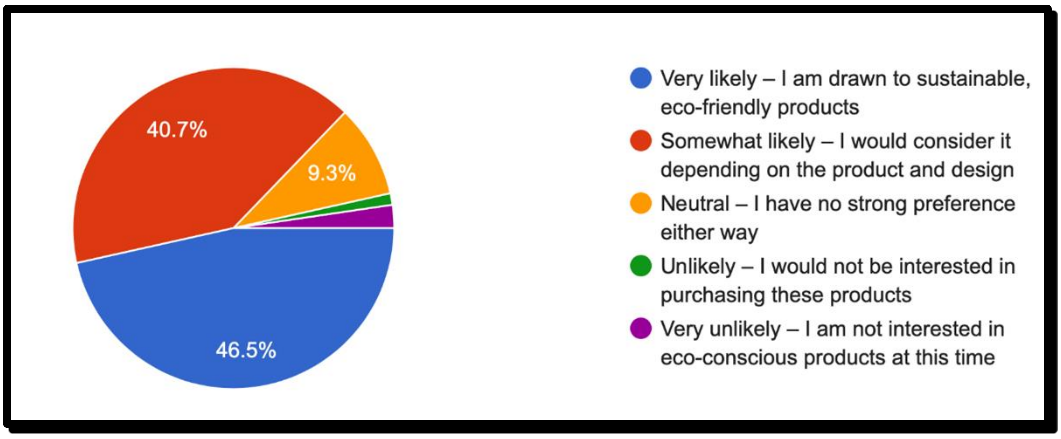


Fig :15 Consumer attitude towards natural dyes

SUMMARY AND CONCLUSION

Natural dye extraction in textile dyeing produces more delicate and appealing natural colors. An essential component of the textile industry is dyeing. It involves applying pigments or dyes to textile materials like yarns, textiles, and fibers with the intention of attaining the necessary fastness of color. Nowadays, synthetic dyes are used to color 90% of apparel. Over 735 tons of synthetic dyes are generated annually worldwide, and it is believed that over 10,000 distinct dyes and pigments are utilized in industry (Whittle, 2006). Production of synthetic dyes is dependent on petrochemical source, and some of the synthetic dyes contain toxic/ carcinogenic amines which are not eco-friendly (Deo and Paul R, 2000).

Synthetic dyes have received harsh criticism in recent decades, and consumers are reluctant to use them; as a result, they favor natural colorants (Freund et al., 1988). These hazardous or environmentally harmful byproducts must be released into the sky, ponds, or rivers. Researchers are searching for alternatives to create environmentally friendly products and technologies that use natural dyes for dyeing because of the disadvantages of synthetic dyes (Samanta et. al., 2003).

Dyeing of Linen fabric using two natural dye extracts from pomegranate rind and grape pomace, and Ferrous sulphate used as mordant. The study mainly focuses on using natural dyes and metallic mordant to understand the effect of ferrous sulphate on the shades, tone and depth of natural dye. Ferrous sulphate, is a frequently used mordant in natural dyeing, particularly when working with cellulose fabrics like linen. It changes the final color by binding the dye to the fiber. Considering the above facts in mind the study on "Utilization of Fruit Juice Waste for Eco-Friendly Dyeing of Linen: A Comparative Study on Shade Development using Ferrous Sulphate" have the following objectives:

- Extract natural dyes from Pomegranate rind and Grape pomace
- Identify a metallic mordant which can improve the colour fastness and develop shade variation
- Dyeing using the extracted solution and developing value added products
- Obtain information about the preference for linen fabrics naturally dyed with fruit juice waste

Findings of the study:

- Colour fastness to washing was conducted to determine the resistance of coloured fabrics to fading. It is clear that the color of the natural dyed samples experienced slight fading compared to the post-mordant samples, which retained more vibrant hues. This suggests that the mordanting process enhanced color fastness and durability.
- The hot iron test is a simple yet effective method used to assess the heat resistance and colour stability of natural dyed fabrics when exposed to high temperatures, such as those encountered during ironing.the hot iron test, the post-mordant samples had superior color retention, but the naturally colored samples showed some color fading. This suggests that mordanting reduced fading and discoloration by improving the natural dyes' color fastness to heat. The fabric's resilience to heat-induced deterioration was probably increased by the mordant's enhanced binding of the natural dye.
- Strong resistance to fading from sun exposure was demonstrated by the naturally colored and mordanted samples' little color changes during the sunshine color fastness test. This implies that, independent of mordanting, the natural dyes utilized have moderate to good lightfastness. These dyes are ideal for applications where color stability and endurance in the presence of sunlight are crucial because of their low degree of color alteration.
- The study's findings indicate a high level of awareness about natural dyes made from fruit or vegetable waste, with 82.4% of respondents affirming their knowledge. This suggests that participants are conscious of sustainable and eco-friendly dyeing options. The results imply a growing interest in environmentally responsible practices and potential demand for products utilizing natural dyes derived from food waste.
- The majority of customers (66.3%) made it apparent that they preferred the product. Furthermore, "Maybe" was selected by 26.7% of respondents, suggesting some hesitancy or conditional interest. Just 7% of respondents said "No," indicating that they would not favor the product. These results show that while a sizable percentage of consumers are still unsure, overall consumer interest in the product is overwhelmingly positive.
- According to the study, when selecting naturally dyed products, consumers are most concerned with the environmental impact (40.5%), followed by durability and quality certificates (28.6%). Of those surveyed, 21.4% were swayed by aesthetic appeal, such as distinctive color or design. With a combined impact on just 9.6% of participants, price and brand transparency were the

least significant considerations. These findings demonstrate a clear preference for confirmed quality and sustainability over price.

CONCLUSION

The sustainable use of fruit waste, particularly pomegranate peel and grape pomace, as a source of natural dyes for linen textiles was successfully investigated in this study. In addition to providing an environmentally benign substitute for synthetic colors, the process of extracting natural pigments from these agricultural wastes also solved the problem of managing fruit waste. The findings showed that both grape pomace and pomegranate rind produced rich, aesthetically pleasing colorants that might be used in textile applications.

The endurance of the dye was considerably increased by post-mordanting, according to an assessment of the color fastness of naturally dyed linen fabrics under various circumstances. Naturally dyed samples without post-mordanting showed a little greater fading than post-mordanted samples when exposed to sunshine and heated to a high temperature. In a similar vein, the wash fastness test revealed that materials that had been mordanted retained more color and were more resistant to fading when washed. In general, post-mordanting improves the naturally colored linen fabrics' color fastness qualities, increasing their suitability for everyday usage.

The value-added items that were created from the dyed linen fabrics demonstrated the commercial feasibility of natural dyes in contemporary textile design. The natural hues and textures that the dyes produced gave these products a distinctive appeal in addition to embodying environmental conscience. Lastly, an analysis of customer preferences revealed that linen fabrics dyed with leftover fruit juice were well received. Respondents valued the items natural beauty, sustainability, and uniqueness, indicating a rising demand for eco-dyed fabrics. The study concludes by making a strong argument for the use of leftover fruit juice as a natural dye source, creating new avenues for the fashion and fabric industries to adopt circular economy models and sustainable textile practices.

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APPENDIX-1

APPENDIX-2

The questionnaire of the survey conducted during the study is as follows:

1.Have you heard about natural dyes made from fruit or vegetable waste (e.g., juice pulp or peels)?

- Yes
- No
- Not Sure

2.How important is sustainability to you when purchasing products?

- Not important
- Slightly important
- Moderately important
- Very important
- Extremely important

3. Would you be interested in buying products that use natural dyes from juice waste?

- Yes
- No
- Maybe

4.What would most influence your decision to purchase a product dyed with natural juice waste?

- Environmental impact
- Unique appearance or color
- Brand transparency and story Price
- Quality and durability Certifications (e.g., organic, eco-friendly)

5. Do you have any concerns about using products dyed with natural juice waste?

- No concerns
- Color fastness / durability
- Hygiene or safety
- Price

- Aesthetic (color range, design)

6. In which of the following product categories would you be most interested in seeing natural dye applications?

- Fashion (e.g., clothing, accessories)
- Home textiles (e.g., bedding, curtains, towels)
- Packaging (e.g., gift wrap, product boxes)
- Stationery (e.g., notebooks, cards)
- Furniture or home décor (e.g., cushions, wall art)
- Personal care products (e.g., soaps, creams with natural colorants)

7. Which of the following fashion items would you consider buying if they were dyed using natural juice waste?

- T-shirts
- Dresses
- Scarves
- Handbags or accessories
- Shoes

8. How important is eco-friendliness in products categories like fashion or home textiles ?

Very important

- Somewhat important
- Not very important
- Not at all important

9. How appealing do you find the idea of natural dyed book covers?

- Very appealing
- Somewhat appealing

- Neutral
- Not appealing

10. How would you rate the design of the book cover

- Good
- Fair
- Average

11. Would you be willing to pay more for a book with a natural dyed, eco-friendly cover?

- Yes, definitely
- Maybe, depending on price
- No

12.Do you currently use an artist folder (portfolio folder, sketch folder, etc.)?

- Yes
- No

13. If yes, How appealing do you find the concept of artist folders dyed with natural materials? Give

- Very appealing
- Somewhat appealing
- Neutral
- Not appealing

14. Based on your responses, how likely are you to purchase products made with natural dyes from fruit juice waste in the future, and what factors would influence your decision?"

- Very likely – I am drawn to sustainable, eco-friendly products
- Somewhat likely – I would consider it depending on the product and design
- Neutral – I have no strong preference either way
- Unlikely – I would not be interested in purchasing these products
- Very unlikely – I am not interested in eco-conscious products at this time

15. Please share any additional thoughts or suggestions regarding products made with natural dyes from

fruit juice waste