EXTRACTION OF DYES FROM AGRO-WASTE AND THEIR APPLICATION ON TEXTILES

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(B.Sc. Home)

EXTRACTION OF DYES FROM AGRO-WASTE AND THEIR APPLICATION ON TEXTILES

A Dissertation Submitted in Partial Fulfilment of the Requirements
for the Degree of Master of Family and Community Sciences

By

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CERTIFICATE

This is to certify that the research work presented in this dissertation entitled "**Extraction of Dyes from Agro-waste and their Application on Textiles**" In pursuit of a Masters' Degree in Clothing and Textiles is her original bonafide work.

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CONTENT

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ABSTRACT

Agricultural wastes are byproducts of many agricultural operations that are not crops. The majority of these wastes are dumped, burned, and piled into landfills. Resources are wasted as a result, and the ecosystem is seriously endangered by their disposal. Effective use of this agro-waste would not only address disposal difficulties, but also give the farmers or processing firms that produce the trash an increase in income.

Agro-wastes such as barks, flowers, fruits, peels, leaves, roots, woods, and seeds that provide dyes are examples of agro-wastes. This study focuses on reutilization of agro-waste as a source of natural dyes on textiles or it becomes an alternative to direct disposal which would help in keeping the environment ecofriendly. Agro-waste can help reduce costs and promote environmental responsibility in the textile dyeing process.

The overall goal of the current study was to utilize agricultural waste as an alternative source for dye and mordant. Experiments were done to extract dye from agro-waste. For the study three dyes i.e., Indian almond leaves (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*) Onion peels (*Allium cepa*) were explored.

Varying percent shade (2%, 4%, 6% & 8%) and three natural mordants i.e., Banana red flower peel, Harda and Pomegranate rind were used on protein fabrics (wool and silk) and Nylon at three pH conditions ((Self which is acidic, Neutral and Alkaline) to obtain colour palette and strength the shades.

The dyed samples were evaluated for colour strength in terms of K/S and CIELAB values using spectrometer. Fastness properties of dyed samples were tested against washing, rubbing and light.

A colour palette of 432 shades was developed using various variables of the study. Olive green to brown shades were produced by the Indian almond leaves dye. While those dyed with Onion peels showed golden yellow, khaki, and brown shades. Annatto seeds produced tones of cream, orange, and

reddish orange. With all the dyes and fabrics used in the study, samples dyed with Pomegranate rind and Banana red flower peel mordants gave the best K/S results. At self pH (acidic), Indian almond leaves dye produced a deeper colour shade. While Onion peels gave the deeper colour at all pH levels. Annatto seeds gave the darker shade at an alkaline pH. The fastness properties (in terms of Washing, rubbing and light fastness) ranged from good to excellent. These dyes can be effectively used on silk, wool and Nylon.

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

India is largely has an agrarian economy and a huge amount of agro waste that is produced every year. India generates about 500 million tonnes of farm waste, and per capita Indian household waste is 50 kg food. The agro-wastes may be horticultural, aquacultural or kitchen wastes. Every year huge amount of agriculture residues or agro waste are released to the environment without proper disposal that causes harmful effect to the environment and to the human beings. Most of the agro based industrial wastes are left untreated and underutilized, which results in maximum disposal of it either by burning, dumping or unplanned landfilling resulting in the loss of natural resources.

The disposal of agricultural waste is one of the major environmental issues, which poses adverse effects on ecosystems due to the careless dumping of agricultural waste into the environment. Most reports say that untreated and underutilized agro-industrial waste is disposed of by burning, dumping, or placing it in a landfill. Untreated garbage contributes in emission of several greenhouse gases, which in turn exacerbate climate change in numerous ways. In addition to the negative effects on the climate, this also results in the release of additional, undesirable gaseous by-products.

This waste releases harmful gases into the atmosphere in bulk when burned. Now a day, it is the biggest source of smog (fog + smoke) and it poses a significant threat to common man's safety. It is therefore important to handle the waste strategically. Therefore, significant interventions are required for the sustainable use of agro-waste. This can take the form of the development of sustainable energy and the creation of value-added bioproducts. This new reality has initiated a model of sustainable development in recent years that calls for substantial changes in waste utilization.

High concentrations of complex carbohydrates, proteins, fibres, polyphenolic components, bioactive compounds, etc., are found in agro-wastes. Despite the fact that organic compound wastes, pose a threat to the environment, they could

be used as a raw material in a wide range of agricultural, food, pharmaceutical goods, new fibre and natural dyes.

Agricultural and food processing industries generate organic waste that still contains colouring pigments. Agro waste such as peels, flowers, woods, shells, fallen leaves, branches and seeds etc are rich source of pigments and natural dyes can be obtained from sources such as pomegranate, walnut, marigold, safflower, mango, tamarind, indigo, turmeric, peanut, strawberries, coconut calyx, beetle nut, eucalyptus etc.

Re-use of agro waste plays a vital role as a potential source of natural dyes, but this will also be helpful for disposal and protecting the environment and also provides variety in textiles, as new area of natural dyes has been explored by utilizing agro waste or agricultural by-product. Agro waste is an important topic for the fashion business. Fibres and dyes derived from the natural wastes are chemical free, bio-degradable and environment friendly.

Natural dyes are mostly eco-friendly, biodegradable, non-toxic as compared to synthetic dyes. The natural dyes having limited substantivity for the fibre, due to the weak interaction of the natural dyes with textile fibres and poor colour fastness require the use of mordant which enhances the fixation of the natural colorants on the fibre. Mordants not only give the affinity, but in many cases, they produce the different colour and improve the fastness of the dye. Metal mordants are usually relied upon to increase the affinity of dye with fibers to overcome these problems. However, in case of metal mordants the discharge of waste water containing heavy metal ions can also have a negative impact on the environment. Therefore, minimizing the usage of metal mordants and other chemicals in the dyeing process of natural dyes for textiles is important to achieve a green and healthy ecological environment.

Natural dyes produce unique, earthy, soothing, soft and pastel shades as compared to synthetic dyes. The non-reproducibility and non-uniformity of shades and colours from natural dyes make each design or product as a unique item thus further glorifying the use of natural dye.

1.1 PURPOSE OF THE STUDY

Nowadays, dyeing industry has been classified as one of the major pollutions causing industrial sector around the globe. The effluents produced by the dyeing are polluting the air, water sources. Dyeing is one of the major areas where the use of synthetic dyes has manifested due to ease of use, ready availability and cost factors. These dyes are synthesized from petrochemicals and in turn are quite hazardous for the environment during production as well as in effluents.

Textile wastewater treatment technologies are expensive, not all companies can fully afford them. Therefore, it is better to avoid wastes generation during textile processing by employing eco-dyeing and bio-finishing methods instead of using expensive and inefficient technologies to treat the effluents. Hence the natural dyes are important foe textile industry.

The rising awareness about the climate change and after formulation of U.N. sustainable goals in 2015 there is a change in consumer psychology and they are looking for environment friendly options in textiles and clothing. Researchers all over the world are searching for efficient green technologies and environmentally friendly and sustainable colorants. Natural dyes come into its existence.

Natural dyes behave differently with different fibres and use of different mordents on the same fibre will also produce different shades. Thus, to encourage its successful commercial use it is necessary to find out new sources to enhance the existing colour palette and standardize natural dyeing process. Keeping in mind the need gap, the following research is undertaken to explore natural dyes from agro waste.

The agro waste management is a critical issue pan-globe. Many researchers are working on sustainable disposal and reuse of this waste which otherwise harm the environment. This research is an attempt to utilize agro-waste for commercial production of natural dyes. The use of agro waste in textile dyeing can also make the process less expensive and more eco-friendly.

The broad aim of present study was to reduce the waste and utilization of agro waste as an alternative dye and mordant source from fallen leaves of Indian

almond (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*) Onion peels (*Allium cepa*), was studied for its potentiality for dyeing nylon and minor fibre i.e. for Eri Silk and Kutchi Wool and Banana red flower peel as a mordant.

1.2 OBJECTIVES OF THE STUDY

1.2.1 To explore the agro waste as source of natural dye and natural mordant.

1.2.2 To optimize the recipe for the selected dyes and mordant.

1.2.3 To develop shade card for each dye varying concentration of dye, natural mordant and pH.

1.2.4 To test dyed fabrics for its colour strength.

1.2.5 To evaluate the fastness properties of the dyed samples in terms of wash fastness, light fastness and rub fastness.

1.3 DE-LIMITATIONS OF THE STUDY

1.3.1 Three agro-waste dyes namely were Indian almond leaves (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*) Onion peels (*Allium cepa*) used.

1.3.2 Three mordants Banana red flower peel, Harda and Pomegranate rind were studied for the development of shade card.

CHAPTER II

REVIEW OF LITERATURE

One of the essential pre-requisites for any research program is to get the researcher acquitted with the up-to-date knowledge on the subject of research. It provides valuable information regarding the various aspects of the problems and enables the researcher to make a systematic planning of the research programme to yield results of great practical value. The review of literature for the present study was collected from the different secondary sources like books and journals also the websites which is important source of information. It has been supported through theories from textbook.

The review of literature had been broadly classified into two major sections and further divided in subsection.

2.1 Theoretical Review

2.1.1 Information about agro-waste

2.1.2 History of natural dyes

2.1.3 Classification and application of natural dyes

2.1.4 Natural dyes used in present study

2.1.5 Classification and application of mordants

2.1.6 Natural mordants used in present study

2.1.7 Review of the selected fabrics for the dye

2.2 Related research review

2.2.1 Research related to natural dyes and mordants

2.2.2 Research related to natural dyes obtained from agro-waste

2.1 Theoretical Review

2.1.1 Information about agro-waste

The waste material produced during farming practices that can be any chemical, pesticide or fertilizer is known as agro-waste. Agro-waste is also known as agricultural waste. Agricultural waste are plant residues from agriculture. Agricultural waste are all parts of crops that are not used for human or animal food. Crop residues consist mainly of stems, branches (in pruning), and leaves. It is estimated that, on average, 80% of the plant of such crops consists of agricultural waste.

Sometimes, agricultural waste is burnt, either as biomass in power plants or simply on land. Burning agricultural waste on land is called stubble burning and is still common in countries like China and India where a third of the world's population lives. Then, instead of being reused to make new products, valuable substances in agricultural waste are turned into CO_2, smog, particulate matter and ash.

Three categories of substances are mainly extracted from agricultural waste: proteins, materials containing cellulose and bioactive substances such as essential oils and carotenoids. The increasing ability to isolate such valuable substances in a pure form increases the economic value of agricultural waste.

Agriculture and food processing industries generate a large amount of organic waste that still contains colouring pigments. Their sustainable use in dyeing textiles will expectedly solve the problem of their disposal.

Various industries associated with the agriculture sector produces a large proportion of waste in different forms. Husk of different consumable seeds, peels of vegetables, and straw of some common agricultural crops are strong sources of natural dyes. These wastes are also a good source of protein, fibers, vitamins, carbohydrates, as well as different minerals. However, if this waste untreated disposal can cause considerable environmental pollution.

2.1.2 History of natural dyes

Dyeing is the application of dyes or pigments on textile materials such as fibers, yarns, and fabrics with the goal of achieving color with desired color fastness. Dyeing is normally done in a special solution containing dyes and particular chemical material. Dye molecules are fixed to the fiber by absorption, diffusion, or bonding with temperature and time being key controlling factors. The bond between dye molecule and fiber may be strong or weak, depending on the dye used. Dyeing and printing are different applications; in printing, color is applied to a localized area with desired patterns. In dyeing, it is applied to the entire textile.[43]

Dyes are an integral component of fashion in current times. It may be difficult to imagine a wardrobe restricted solely to one colour over the rest. This was a reality for the human beings of the past as well! Fabric dyeing is now a key component of a number of businesses across the global economy. The use of dyes plays more than just the role of adding colours to life. There are industries that often use dyes to minimize any overhead costs and maximize the use and selling of existing business materials. Dyes are revolutionary in their use, primarily because of the colour they impart to all fabrics in the market. Be it at home or the workplace, wearing fabrics dyed colours of your choice can have a significant impact on your mood and sense of self.[52]

The primary source of dye, historically, has been nature. Archaeologists have found evidence of textile dyeing dating back to the Neolithic period. In China, dyeing with plants, barks and insects has been traced back more than 5,000 years. The essential process of dyeing changed little over time. Typically, the dye material is put in a pot of water and heated to extract the dye compounds into solution with the water. Then the textiles to be dyed are added to the pot, and held at heat until the desired color is achieved. Textile fiber may be dyed before spinning or weaving ("dyed in the wool"), after spinning ("yarn-dyed") or after weaving ("piece-dyed").[48]

The art of dyeing was as old as human civilization. From the historical records, it is learnt that natural colorants were available to people during Greco-Roman

periods. Our Vedas, the Atharvaveda carries description of natural dyes. The use of natural dyeing materials is evident with the wall paintings of Ajanta, Ellora and Sithannvasal and they still demonstrate the efficacy of dyeing craft that had been inherited from ancient times in India. Ancient Egyptian hieroglyphs contain a thorough description of the extraction of natural dyes and their application in dyeing. Further developments extending over many thousands of years led to rather complicated dyeing process and high-quality dyeing.

Ever since primitive people could create, they have been endeavoring to add color to the world around them. They used natural matter to stain hides, decorate shells and feathers, and paint their story on the walls of ancient caves. Scientists have been able to date the black, white, yellow and reddish pigments made from ochre used by primitive man in cave paintings to over 15,000 BC. Natural dyes have been used since ancient times for coloring and printing fabrics. Until the middle of last century, most of the dyes were derived from plants or animal sources by long and elaborate processes. Among these Indigo, Tyrian purple, Alizarin, Cochineal and Logwood dyes deserve special mention.

2.1.3 Classification and application of natural dyes

Natural dyes are classified in three ways.

1. Based on their application – Natural dyes can be divided in to two subcategories based on their application i.e., Substantive and Adjective. Substantive dyes are chemically fixed to the fiber without any additional chemicals thus, it is also known as direct dyes. Adjective dyes are applied with some substance to get better fastness. Those additional chemicals are known as mordants. These adjective dyes are also known as mordant dyes.

2. Based on obtained shade – The natural dyes are classified based on their obtained shades i.e., Monogenetic dyes and Polygenetic dyes. Monogenetic dyes produce one colour only with or without mordant while Polygenetic dyes produce different colour shades based on their mordant type.

3. Based on their origin – There are mainly three types of natural dyes based on their origin. a) Plant/vegetable origin b) Insect/animal origin c) Mineral origin
    a) Plant/vegetable origin – The earliest dyes were of vegetable and plant origin, discovered by accidently staining garments with juices of fruits or plants. These are obtained from different parts of plant such as leaves, flowers, fruits, pods, bark, etc. These can be applied directly or with mordant.
    b) Insect/animal origin – Natural substances such as carminic acid, kermesic acid and laccaic obtained from either exudation or dried bodies of insect namely, cochineal, kermes and kerria lacca respectively are well known and these acid compounds are used for dyeing purpose from ancient times.
    c) Mineral origin - Dyes extracted from mineral sources are called mineral dyes. Chrome green-from a compound of chromium and oxygen, Chrome red-from from a compound of chromium and lead, Chrome yellow-from a compound of chromic acid and lead, and Prussian blue from a compound of iron and cyanide. As minerals are used for fixing or improving the fastness of vegetable dyes.

Table 1: List of plant base natural dyes

Sr. No.	Botanical name of the plant	Part used for dyeing	Colour obtained
1.	Acacia catechu Willd.	Wood	Reddish brown
2.	Acacia nilotica	Bark and pods	Yellow to brown
3.	Adenanthera pavonine Linn.	Wood	Red
4.	Anacardium occidentale Linn.	Pericarp	Light red
5.	Bauhinia purpurea Linn.	Bark	Purple
6.	Bixa Orellana Linn.	Seeds	Orange yellow
7.	Butea monosperma	Dried flowers	Brilliant yellow

8.	Caesalpinia sappan Linn.	Wood and pods	Red
9.	Carthamus tinctorius Linn.	Flowers	Red and yellow
10.	Cassia fistula Linn.	Bark and sapwood	Red
11.	Cassia tora Linn.	Seeds	Blue
12.	Curcuma longa Linn.	Rhizome	Yellow
13.	Curcuma zedoaria	Rhizome	Yellow
14.	Indigofera tinctoria Linn.	Green crop	Blue
15.	Isatis tinctoria Linn.	Leaves	Deep black, dark blue
16.	Lawsonia alba Linn.	Leaves	Brown
17.	Madhuca indica	Bark	Reddish yellow
18.	Mallotus philippensis	Fruits	Red
19.	Mangifera indica Linn.	Bark and leaves	Yellow
20.	Morinda citrifolia Linn.	Root bark	Dull red
21.	Nyctanthes arbor-tristic	Flowers	Yellow
22.	Nymphaea alba Linn.	Rhizome	Blue
23.	Pterocarpus marsupium Roxb.	Bark	Brownish red
24.	Punica granatum Linn.	Fruit rind	Mustard grey
25.	Rubia cordifolia Linn.	Stem and root	Reddish brown
26.	Rubia tinctorum Linn.	Wood and root	Red
27.	Terminalia arjuna	Bark	Light brown
28.	Terminalia chebula	Fruits	Yellow

Methods of dye extraction – The extraction method of dye basically depends on medium in which the dye is extracted. There are three methods for dye extraction.

a) Aqueous method – Dye is boiled in soft water for 45 minutes to 1 hour and then filtered.

b) Alkaline method – Dye is boiled in soft water with 1% alkaline solution of sodium carbonate for 45 minutes and then filtered.
c) Acidic method – Dye is boiled in soft water with 1% of acidic solution with 1 ml of HCl for 45 minutes and then filtered.

Techniques used for dyeing – There are mainly three techniques for dyeing the textiles.

a) Conventional dyeing – It is carried out by boiling the fabric in dyebath for 45 minutes. Huge amount of heat is consumed by the dye bath.
b) Sonicator dyeing – The process of dyeing from the dye bath to fabric using ultrasound energy is known as Sonicator dyeing.
c) Microwave dyeing – The microwave technique is a speedy way to dye fabric also when don't have more space or time. Only use microwave safe items while dyeing. Small samples can dye easily with this technique.

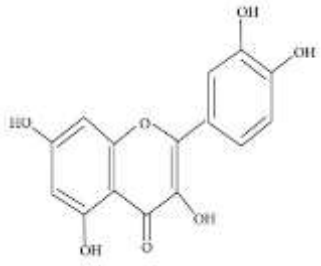
2.1.4 Natural dyes used in present study

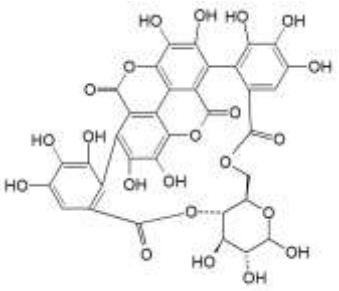
Indian almond leaves

The tree grows to 35 meters (115 feet) tall, with an upright, symmetrical crown and horizontal branches. The fruit are corky and light, and dispersed by water. As the tree gets older, its crown becomes more flattened to form a spreading, vase shape. Its branches are distinctively arranged in tiers. The leaves are large, 15–25 cm long and 10–14 cm broad, ovoid, glossy dark green, and leathery. They are dry-season deciduous; before falling, they turn pinkish-reddish or yellow-brown, due to pigments such as violaxanthin, lutein, and zeaxanthin.

Table 2: Scientific classification of Indian almond plant

Binomial Name	*Terminalia catappa*
Kingdom	Plantae
Family	Combretaceae
Genus	*Terminalia*
Species	*T. catappa*





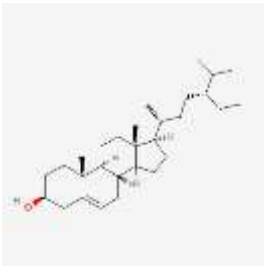


Figure 1: Flavonoids Figure 2: Punicalin tannin Figure 3: phytosterols

Fig. 1 Source: Flavonoid – Wikipedia

Fig. 2 Source: Punicalin – Wikipedia

Fig. 3 Source: Phytosterol – Wikipedia

Terminalia catappa is widely grown in tropical regions of the world as an ornamental tree, grown for the deep shade its large leaves provide. The fruit is edible, tasting slightly acidic. The seeds are edible raw or cooked when ripe and the source of it is 'almond' common names, but are small and difficult to extract. The wood is red and solid, and has high water resistance; it has been used in Polynesia for making canoes. The leaves contain several flavonoids (such as kaempferol or quercetin), several tannins (Like punicalin, punicalagin or tercatin), saponins and phytosterols.[57]

Due to this chemical richness, the leaves (and the bark) are used in different herbal medicines for various purposes. For instance, in Taiwan, fallen leaves are used as an herb to treat liver diseases. In Suriname, an herbal tea made from the leaves has been prescribed against dysentery and diarrhea. The leaves may contain agents for prevention of cancers (although they have no demonstrated anticarcinogenic properties) and antioxidants, as well as anticlastogenic characteristics. Extracts of *T. catappa* have shown activity against *Plasmodium falciparum*.

Keeping the leaves in an aquarium may lower the pH and heavy-metal content of the water. It has been used in this way by fish breeders for many years, and is active against some parasites and bacterial pathogens. It is also believed to help prevent fungus forming on the eggs of the fish.

Figure 4: Almond fresh leaves

Figure 5: Almond ripens leave

Figure 6: Almond dry leaves

Annatto Seeds

Annatto also known as Achiote, Lipstick Tree, or Bija is a shrub or small tree. Annatto is an orange-red condiment and food coloring derived from the seeds of the achiote tree (*Bixa Orellana*). It is often used to impart a yellow or orange color to foods, but sometimes also for its flavor and aroma. Its scent is described as "slightly peppery with a hint of nutmeg" and flavor as "slightly nutty, sweet and peppery". The color of Annatto comes from various carotenoid pigments, mainly bixin and norbixin, found in the reddish waxy coating of the seeds. The condiment is typically prepared by grinding the seeds to a powder or paste. Annatto and its extracts are now widely used in an artisanal or industrial scale as a coloring agent in many processed food products.

Fruits are heart-shaped, brown or reddish brown at maturity, and are covered with short stiff hairs. When fully mature, the fruit split open exposing its many strikingly beautiful seeds. Although it does not produce an edible fruit. The Annatto is widely grown for the vibrant orange-red pulp that covers the seeds.

To harvest Annatto, bag the seed heads to capture ripening seed, allow the seed heads to dry on the plants; remove and collect seeds once they are dried.

The Annatto tree *B. Orellana* is believed to originate in tropical regions from Mexico to Brazil. It was probably not initially used as a food additive, but for other purposes such as ritual and decorative body painting, sunscreen, insect repellent and for medical purposes. It was used for Mexican manuscript painting in the 16th century. It has various local names according to region.

The lipstick tree grows to 12 feet (4 m.) tall. It is an evergreen with a rounded canopy of green leaves. It graces your garden with its vivid pink flowers. Each of the ornamental flowers has five sepals and five petals. They grow in scarlet, heart-shaped capsules or pods that look a little like chestnut burs, with many spikey bristles. These capsules split open when they are ripe. The seeds are inside in a layer of orange pulp. The seeds contain bixin, a bright red carotenoid pigment.

Table 3: Scientific classification of Annatto plant

Binomial Name	*Bixa Orellana*
Kingdom	Plantae
Family	Bixaceae
Genus	*Bixa*
Species	*B. Orellana*

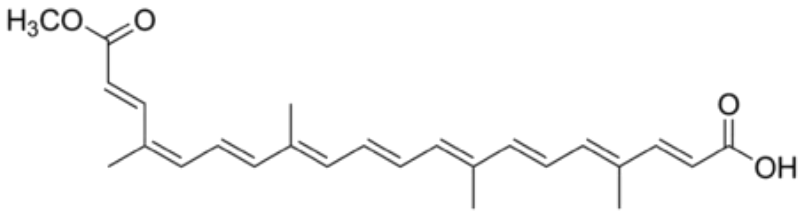


Figure 7: Bixin (the major apocarotenoid of Annatto)

Fig. 7 Source: https://en.wikipedia.org/wiki/Bixin

The yellow to orange color is produced by the chemical compounds bixin and norbixin, which are classified as carotenoids. The fat-soluble color in the crude extract is called bixin, which can then be saponified into water-

soluble norbixin. This dual solubility property of Annatto is rare for carotenoids. The seeds contain 4.5–5.5% pigment, which consists of 70–80% bixin. The more norbixin in an Annatto color, the more yellow it is; a higher level of bixin gives it a more orange shade.

Figure 8: Annatto fresh flower

Figure 9: Annatto dry flower

Figure 10: Annatto seeds

Onion peels

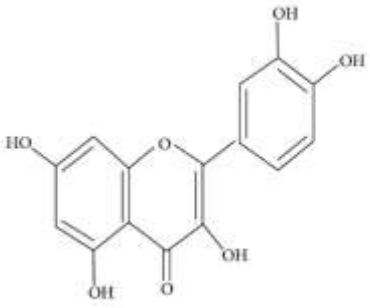
An Onion is a vegetable that is the most widely cultivated species of the genus *Allium*. The Onion is most frequently a biennial or a perennial plant, but is usually treated as an annual and harvested in its first growing season.

The Onion plant has a fan of hollow, bluish-green leaves and its bulb at the base of the plant begins to swell when a certain day-length is reached. The bulbs are composed of shortened, compressed, underground stems surrounded by fleshy modified scale (leaves) that envelop a central bud at the tip of the stem. In the autumn, the foliage dies down and the outer layers of the bulb become drier and brittle. The crop is harvested and dried. The Onions are ready for use or storage.

Onions are cultivated and used around the world. As a food item, they are usually served cooked, as a vegetable or part of a prepared savory dish, but can also be eaten raw or used to make pickles or chutneys. They are pungent when chopped and contain certain chemical substances which may irritate the eyes.

Table 4: Scientific classification of Onion plant

Binomial Name	*Allium cepa*
Kingdom	Plantae
Family	Amaryllidaceae
Genus	*Allium*
Species	*A. Cepa*



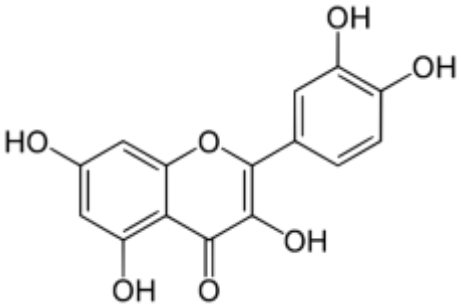


Figure 11: Flavonoids structure

Figure 12: Quercetin

Fig. 11 Source: Flavonoid – Wikipedia

Fig. 12 Source: https://en.wikipedia.org/wiki/Quercetin

The outer skin of Onions provides an exceptionally rich source of plant compounds called flavonoids, especially the powerful antioxidant and anti-inflammatory compound, quercetin.

Onion processing either at the household kitchen or industrial level generates an ample amount of waste, which includes its non-edible parts which are top and bottom parts, outer peels and skins and two outer layers. Furthermore, this waste can have detrimental effects on the environment if not disposed properly, as it is not suitable for fodder preparation considering the strong Onion aroma, nor can it be used as a fertilizer. Therefore, Onion wastes remain underutilized

even after being a rich source of bioactive compounds such as phenols, flavonoids and flavanols. Thus, valorization of Onion waste and its extracts in the textile dyeing, biomedicine and pharmaceutical fields can be an apt solution to reduce environmental damage and provide an economical low-cost substitute for the generation of therapeutic supplements or herbal based medicines and dyes.

Figure 13: Onions

Figure 14: Onion peels

2.1.5 Classification and application of mordants

Most of the natural dyes are adjective and require mordants to dye fixing to the fabric. Mordants are metallic salts that facilitate the bonding of the dyestuff to the fiber. Cellulose fibers also require a tannin in order to bond well. Tannins are not technically mordants (they are not metallic salts) but they are often included in mordant. Mordants prevent the colour from either fading with exposure to light or washing out. The creation of a bond between the colouring matter and fiber is called mordanting.

Different mordants gives different colour with the same dye. The word mordants came from the French word ‘modere’. There are two processes concerned with the dyeing of most plant based colour. The first is mordanting and the second is the actual dyeing. Mordant should not affect the physical characteristics of the fiber or fabric.

There are three types of mordants.

1. Metallic mordants – Metal salts of aluminum, chromium, iron, copper and tin are used.
2. Tannins – Myrobalan and sumach are commonly used in the textile industry.

3. Oil mordants – These are mainly used in dyeing turkey red colour from madder. The main function of the oil mordant is to form a complex with alum used as the main mordant.

Methods of mordanting – The percentage of chemicals and the weight of the material to be dyed are very important while mordanting. Quantity, temperature and time of the mordanting followed strictly. Mordants and dyes may be applied in three ways. They are as follow:

1. Pre-mordanting – This is the most commonly used method. The fiber is mordanted before dyeing. The mordant is dissolved and added to a bath containing water. The fiber is added and brought slowly to the boil over a period of about 30 minutes. Then it is allowed to cool and the fibers are moved gently.
2. Simultaneous mordanting – This type of mordanting gives the faster result. There is no need to do mordanting as separate stage. The mordant is first dissolved and added to dyebath containing the prepared dye solution. The wetted-out fiber is then added. It is brought to nearly boiling and the fiber is stirred with rod. Then the fiber is removed and rinsed with hot water.
3. After mordanting – In this type of mordanting, dyeing is done first and then mordanting is carried out. Dyed materials are added in the mordant solution for final five-ten minutes. Then material is removed and rinsed with water.

2.1.6 Natural mordants used in present study

Banana red flower peels

Musa acuminata is an evergreen perennial, not a tree. The trunk (known as the pseudostem) is made of tightly packed layers of leaf sheaths emerging from completely or partially buried corms. The leaves are at the top of the leaf sheaths, is up to 22 feet (seven meters) in length and 39 inches (one meter) wide.

The inflorescence grows horizontally or obliquely from the trunk. The individual flowers are white to yellowish-white in color and are negatively

geotropic (that is, growing upwards and away from the ground). Both male and female flowers are present in a single inflorescence. Female flowers are located near the base (and develop into fruit), and the male flowers located at the tip most top-shaped bud in between leathery bracts.

The rather slender fruits are berries, the size of each depends on the number of seeds they contain. Each fruit can have 15 to 62 seeds. Each fruit bunch can have an average of 161.76 ± 60.62 fingers with each finger around 2.4 by 9 cm in size.

The seeds of Musa acuminata are around 5 to 6 mm (3⁄16 to 1⁄4 in) in diameter. They are sub globose or angular in shape and very hard.

There are different parts in Banana plant which are following:

1. Root
2. Pseudostem
3. Corm
4. Leaf
5. Sucker
6. Inflorescence (Flower)
7. Fruit

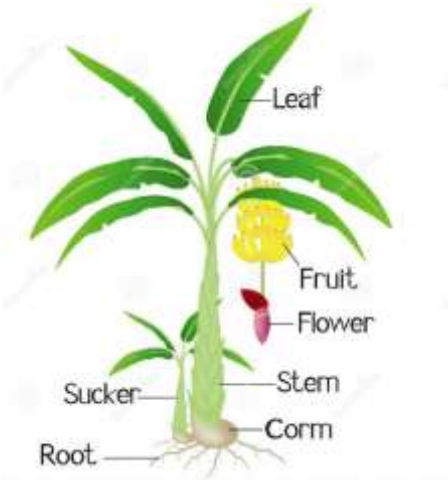


Figure 15: Parts of Banana plant

Fig. 15 Source: https://www.dreamstime.com/illustration-showing-parts-plant-Banana-beautiful-image117518465

Banana Red flower peels

The inflorescence is a complex structure that includes the flowers that will develop into fruits. The botanical term for the Banana inflorescence is a thyrse (an inflorescence in which the main axis continues to grow and the lateral branches have determinate growth). The main types of flowers are the female flowers, which develop into fruits.

Figure 16: Banana red flower

The female (pistillate) flowers appear first. In cultivated Bananas, the ovary develops into a seedless fruit by parthenocarpy (without being pollinated). As it lifts, the bract (a modified leaf associated with a reproductive structure) exposes a cluster of female flowers that are normally arranged in two rows. These flowers will develop into a hand of fruit. The number of hands in the bunch depends on the number of female clusters in the inflorescence, and varies depending on the genotype and environmental conditions.

Figure 17: Banana female flower

Fig. 17 Source: https://www.promusa.org/Morphology+of+Banana+plant

As the female flowers develop into fruit, the distal portion of the inflorescence elongates and produces clusters of males (staminate) flowers that produce pollen. In cultivated Bananas, the amount of pollen is reduced or may be absent.

Figure 18: Banana male flower

Fig. 18 Source: https://www.promusa.org/Morphology+of+Banana+plant

Harda

Terminalia chebula, commonly known as myrobalan, is a species of Terminalia, native to South Asia from India and Nepal east to southwest China and south to Sri Lanka, Malaysia, and Vietnam. In India, it is known as "Harada" in Hindi and "Haritaki" in Sanskrit.

Terminalia chebula is a medium to large deciduous tree growing to 30 m (98 ft) tall, with a trunk up to 1 m (3 ft 3 in) in diameter. The leaves are alternate to subopposite in arrangement, oval, 7–8 cm long and 4.5–10 cm broad with a 1–3 cm petiole. They have an acute tip, cordate at the base, margins entire, glabrous above with a yellowish pubescence below. The fruit is drupe-like, 2–4.5 cm long and 1.2–2.5 cm broad, blackish, with five longitudinal ridges. The dull white to yellow flowers are monoecious, and have a strong, unpleasant odor. They are borne in terminal spikes or short panicles. The fruits are smooth ellipsoid to ovoid drupes, yellow to orange-brown in colour, with a single angled stone.

Figure 19: Myrobalan fruit

Figure 20: Myrobalan fruit and powder

A number of glycosides have been isolated from Harda, including the triterpenes arjun glucoside I, arjungenin, and the chebulosides I and II. Other constituents include a coumarin conjugated with gallic acids called chebulin, as well as other phenolic compounds including ellagic acid, Chebulinic acid, gallic acid, ethyl gallate, punicalagin, terflavin A, terchebin, luteolin, and tannic acid. Chebulic acid is a phenolic acid compound isolated from the ripe fruits. Luetic acid can be isolated from the bark.

Terminalia chebula also contains terflavin B, a type of tannin, while Chebulinic acid is found in the fruits.

Pomegranate rind

The pomegranate (*Punica granatum*) is a fruit-bearing deciduous shrub in the family Lythraceous, subfamily Punicoideae, that grows between 5 and 10 m (16 and 33 ft) tall. The pomegranate was originally described throughout the Mediterranean region. It was introduced into Spanish America in the late 16th century and into California by Spanish settlers in 1769.

The fruit is typically in season in the Southern Hemisphere from March to May, and in the Northern Hemisphere from September to February. As intact juice, pomegranates are used in baking, cooking, juice blends, meal garnishes, smoothies, and alcoholic beverages, such as cocktails and wine.

A shrub or small tree growing 5 to 10 m (16 to 33 ft) high, the pomegranate has multiple spiny branches and is long-lived. P. granatum leaves are opposite or subopposite, glossy, narrow oblong, entire, 3–7 cm long and 2 cm broad. The flowers are bright red and 3 cm in diameter, with three to seven petals. Some fruitless varieties are grown for the flowers alone.

Red-purple in color, the pomegranate fruit husk has two parts: an outer, hard pericarp, and an inner, spongy mesocarp, which comprises the fruit inner wall where seeds attach. Membranes of the mesocarp are organized as nonsymmetric chambers that contain seeds inside sarcotestas, which are embedded without attachment to the mesocarp. Containing juice, the sarcotestas are formed as a thin membrane derived from the epidermal cells of the seeds. The number of seeds in a pomegranate can vary from 200 to about 1,400.

Pomegranate peel contains high number of polyphenols, condensed tannins, catechins, and PR delphinidins. The higher phenolic content of the peel yields extracts for use in dietary supplements and food preservatives.

Pomegranate is an aromatic dye that yields a green-yellow color and shifts to olive and dark gray with iron. Pomegranate can also be used as a tannin-rich mordant. Pomegranate peels are the leathery skins and seeds of pomegranate fruit. They are high in tannin and super useful as a natural dye.

Figure 21: Pomegranate dry rind

Figure 22: Pomegranate dry rind powder

2.1.7 Review of the selected fabrics for the dye

Eri Silk:

Eri silk is the product of the domesticated silkworm Samia ricini, found mainly in North, North East India and some part of China and Japan. It was imported to Thailand in 1974. The name "Eri" is derived from the Assamese word "era", which means "castor", as the silkworm feeds on castor plants. Eri silk is also known as endi or errandi in India. The woolly white silk is often referred to as the fabric of peace when it is processed without killing the silkworm. This process results in a silk called Ahimsa silk. Moths leave the cocoon and then the cocoons are harvested to be spun. The Eri silkworm is the only completely domesticated silkworm other than Bombyx mori.

Eri caterpillars eat a number of plants, including Kesseru. In India, it is grown in the states of Meghalaya, Assam, Nagaland, Manipur, Arunachal Pradesh, Bihar, Jharkhand, Chhattisgarh, Odisha, Karnataka, Andhra Pradesh and some small cities in other states. It has been grown in 28 provinces of Thailand since 1974 where the heavy rainfall and humid atmosphere of the region suits the Eri culture. The spun threads are often more "cottony" than most Bombyx silks, although some Eri yarns can be very soft and shiny. After 30–32 days, the silkworm crawls in search of a comfortable place among the leaves to spin its cocoon. In Thailand, Eri silkworms are fed cassava leaves as well as castor leaves.

Figure 23: Eri Silk warm

Figure 24: Eri Silk cocoons

Fig. 23 & 24 Source: https://en.wikipedia.org/wiki/Eri_silk

Kutchi Wool:

Kutchi, an important dual-purpose (meat & milk) goat breed, is found in Banaskantha, Patan, Mehsana and Kutch district of Gujarat (India). The breed derived its name from Kutch region of Gujarat. The breed is well adapted to the inhospitable agro-climatic, wider range of vegetation and management conditions of the hot humid region.

Kutch had a robust tradition of animal husbandry. The Rabari communities maintained large herds of camels and livestock like goats, sheep etc. Originally Kharad carpets were made from goat and camel hair wool. The Maldharis and Rabaris shear the hair from camels and goats. This was then given to the hand-spinners who specialized in making wool out of goat and camel hair. This wool was then used by the Kharad artisans. The Kharad artisans produced Kharad (used for spreading on the floor), Khurjani (used to keep on the back of a camel to carry heavy items), Rasa (thick cloth used to cover grains). They used to roam the villages of Banni, Pancham and Sindh for selling their products.

Figure 25: Kutchi Goat

Fig. 25 Source: https://nbagr.icar.gov.in/wp-content/uploads/2020/02/Kutchi-Goat.pdf

Nylon:

There are many polyamides, which have been developed as fibers. The general word for this fiber is ‘Nylon’. Nylon is a long chain synthetic polymeric amide which has recurring amide groups as an integral part of the main polymer chain which is capable to form filament.

Caprolactam (CL) is generally used to prepare Nylon-6. It is a white crystalline compound. When it is prepared from cyclohexane or phenol, it will give a high yield.

Warp and Weft both yarn of the fabric are made from 100% Nylon yarn. So, 100% Nylon fabric were used for the study.

2.2 Related research review

2.2.1 Research related to natural dyes and mordants

Patel F. & Pathan T. (2015) studied on Novel natural dye from *FUSARIUM SOLANI FUNGI* for Textile Application. In the present study, researcher explored the microbial realm of the natural dyes a fungi Fusarium solani which has tremendous potential because of its better biodegradability and its competence to dyes generated form plant sources in terms of environment and growth conditions and production cost. An experimental research design was adopted. Research design was divided in two phases in first phase exploration was done to get colour giving microorganisms. The samples were selected from purposively selected microorganisms that give pigment on media. In second phase dyeing was carried out through laboratory experimentation. Dyeing was done on fabric at various time, temperature to optimize dyeing variables. Assessment of dyeability was done through wash fastness test and spectrophotometer analysis.

Mohammad G. U. (2015) done the research on extraction of eco-friendly natural dyes from mango leaves and their application on silk fabric. The aim of the study was to evaluate the performance of dyes extracted from mango leaves in silk dyeing. Extraction medium was optimized by extracting dyes from fixed quantity of crushed leaves under pH values from 3 to 12. The maximum relative color strength of the extracted dye liquor was found to be at pH 10. The optimum dye extraction conditions i.e., the temperature, time, and material-to-liquor ratio were found to be 98 °C, 60 min, and 1:10, respectively. Dyeing was carried out

with the optimized dye extract on mordanted and un mordanted silk fabrics. The dyed materials were evaluated by measuring the color yield and fastness properties. It was concluded that the color values were found to be influenced by the addition of mordants, consequently different fashion hues were obtained from the same dye extract using different mordants. It can also be said that mango leaves have good potentiality for dyeing of silk fabric.

Kashyap R. (2012) studied on product diversification on jute fabric through Dabu printing. In this study, attempt had been made to print the jute fabric with traditional Dabu art and to explore the possibilities of maintaining the traditional art of block printing on the eco-friendly fabric, easily available in India. The study aimed to find out the acceptability of the products created for the export market. A range of product like dining mats, lunch box, floor cover and tea coasters were developed in jute fabric to the growing demand of eco-friendly products. The developed products were evaluated by a panel of 30 judges. The fabric gave good response to Dabu printing and the products were highly appreciated.

Samanta A. K., Konar A. & Datta S. (2012) conducted research on dyeing of jute fabric with tesu extract: part II – Thermodynamic parameters and Kinetics of dyeing. Thermodynamic parameters and dyeing kinetics for coloration of bleached and selectively double pre-mordanted jute fabric dyed with purified natural dye powder obtained from aqueous extract of tesu under optimized dyeing conditions have been studied to understand the physic-chemical interaction amongst dye, fiber and mordant. It is observed that this dyeing process is endothermic. Dye absorption isotherm of this particular fiber-mordant-dye system is found to be linear, following Nernst absorption isotherm. FTIR spectra of bleached, mordanted and purified natural dyed jute fabrics have also been compared. It is revealed that dyeing of selectivity pre-mordanted bleached jute fabric mostly occurs through H-bond formation along with minor possibility of coordinated complex formation for fixation of tesu colorant on the selectively double pre-mordanted jute fiber.

Patel F. (2010) conducted research on dyeing of minor fibers with natural dyes. Two cellulosic minor fibers and two protein minor fibers were taken for the

study. There were six dyes selected and three dye mixtures of two dyes were derived for the study. A total of 180 shades were produced. Products designed and exhibited were highly appreciated and showed a good applicability of the dyes used.

Nagrani J. (2007) studied on value addition of khadi silk fabric by natural dyes. Pre-mordanted khadi silk fabric was block printed and dyed with madder and turmeric. Metal mordants were used for mordanting. A variety of 48 shades was produced and kurtis were designed using these natural dyes and block printing with mordant at different percentages showed better results respect to physical as well as colour fastness properties. Fabric mordanted in 3% concentration performed best than the other two concentrations.

2.2.2 Research related to natural dyes obtained from agro-waste

Sanku L. P., Padma A., et al (2021) studied on dyeing of agro-waste castor fibers with *Eclipta Prostrata* dye. In the present study, castor fiber was dyed with *Eclipta Prostrata* plant extract and evaluated for colour fastness and colour strength properties. The colour fastness properties of castor fiber dyed with pre, simultaneous and post mordanting methods using four different mordants were tested.

Singh N. and Singh A. (2020) conducted research on coloring cotton fabric with waste Banana petaloids. Pre and post mordanting methods were used for mordanting. They evaluate their research by dye concentration, time, temperature, mordant concentration, colour obtained and colour fastness properties. Large range of worn white, Greenplay greys and Banana cream shades were obtained with various mordants and combination of mordants. The light, washing, rubbing and perspiration fastness of dyed sample were fair to good in range.

Mohan R., Geetha N., Haritha J. & Sivakumar V. (2020) conducted research on Natural Dye (Pelargonidin) extraction from Onion Peel and application in dyeing of Leather. The peels of Onions provide a prosperous source of plant

compounds called flavonoids, and a dye named Pelargodinin can also be obtained. The dye extraction was carried out by using acetic acid (10% solution) and compared with water-based extraction. The yield of natural dyes from Onion peel had analyzed using UV-VIS spectroscopy. Extraction using water gave a dark red dye. Acetic acid extraction yielded a dark pink dye. UV-VIS spectrometry and gravimetric analysis have been done for each dye extracted. Percentage Extract Yield of Dye is 20% and 23.3%, respectively, for the water and acetic acid-based extraction processes. A piece of leather was also dyed using Pelargonidin dye obtained from Onion peel, extracted using acetic acid.

Rosalina Y., Warsiki E. & Fauzi A. M. (2019) done the research on the potential of anthocyanin from red Banana peel as natural dye in smart packaging development. The colour in thermochromic leuco colouring changes from one colour to another. Therefore, the use of natural dyes as a colourant in thermochromic leuco dye is being considered. One of the local resources developed as a source of anthocyanins from agricultural product waste is red Banana peel. The study was undertaken to determine the potential of anthocyanins from red Banana peels based on the characteristics of changes in temperature and light and storage temperature stability as a source of natural dye for the development of thermochromic leuco dye. The results showed that the total anthocyanin content of red Banana peels was 55.139 mg/L using water and 5.038 mg/L using ethanol as solvent. Temperature treatments at 35ºC and 50ºC have shown a higher absorbance decline rate than temperature 30 and 40ºC. Storage of anthocyanins in UV lamps and sunlight showed colour changes compared to storage in 25-watt lamps. The results of this study were indicated that anthocyanins from red Banana peels had the potential to be used as a source of natural dye in the development of thermochromic leuco dye.

Purnama H., Eriani W. & Hidayati N. (2019) studied on natural dye extracted from tropical almond leaves and its characterization. The purpose of this study was to find out and utilize tropical almond leaves as a colour producer and determine the influence of process variables, i.e., maceration time and initial condition of the leaves. UV-Vis absorption and infrared spectra were used to analyze the extracted product. The result of infrared spectrophotometer analysis

was in accordance with previous studies to strengthen the exploitation of natural dyes extracted from *T. catappa* leaves.

Gogoi N., Sangma T. & Bhuyan S. (2019) conducted research titled Block printing on cotton and silk fabrics with Annatto (*Bixa Orellana*) dye and evaluation of its properties. In this study, evaluation of physical properties of Annatto block printed mulberry silk and cotton fabric was done. Alum and ferrous sulphate were used as mordant. Alkaline medium was chosen for extraction. Different printing variables such as dye material concentration, dye extraction, pH, dye paste and thicker ratio, viscosity of the dye liquor, fixer concentration, mordant concentration was optimized for making printing paste. Evaluation of colour fastness and physical properties of the printed fabric was done. The result shows that Annatto can be used for printing and had good colour fastness properties.

Nasim Z., Rahman L., et al (2018) conducted research on an eco-friendly approach of cotton fabric dyeing with natural dye extracted from Bixa Orellana Seeds employing different metallic mordants. The main aim of the research was to study the application of Bixa Orellana seed for dyeing of cotton knitted fabric and to satisfy the future demand for an eco-friendly as well as sustainable dyeing of cotton fabric. Natural dye was extracted by normal water extraction method with caustic soda. In this experiment cotton knitted single jersey structure fabric was used. Pre-mordanting method of cotton fabric samples were carried out using various metallic salts. Color strength of the dyed samples for different dyeing condition was assessed. To intensify the color strength various mordanting agents were used. Effect of mordanting agents had evaluated by means of K/S value. Best color strength was yield for the samples mordanted with CuSO4. Impact of electrolyte on color strength had also investigated by means of K/S value. Color fastness of the selected dyed samples to water, washing, perspiration and rubbing were evaluated. In all cases mordanted samples with CuSO4 exhibit best result.

Patel S. (2017) conducted research on Effect of various Pre-Treatments on the Dyeing Behavior of Jute with Natural Dyes. Bleaching and woolenization were the two pre-treatments that performed best for the present research. The samples

of jute were first bleached using three different bleaching agents i.e., hydrogen peroxide bleaching, peracetic acid bleaching, sequential bleaching and then pre-mordanted with a variety of mordants, including alum, harda, copper-nano, and their mixtures. Four natural dyes, namely madder, turmeric, eucalyptus leaves, and Indian almond leaves were used to colour all of these pre-mordanted samples. the woolenized samples after dyeing were darker than the simply bleached samples. Even in terms of brightness and whiteness indicators, the unbleached samples scored higher.

Vadwala Y. and Kola N. (2017) conducted research on natural dye extracted from waste leaves of terminalia catappa locally known as tropical almond tree. The study was done on silk and nylon fabric pretreated with eco-friendly and non-eco-friendly mordants. Result of the study was presented in terms of colour strength i.e., K/S values and colour fastness properties. Colour palate in both the fabrics were developed. Different shades on silk fabrics with good to excellent fastness properties have been obtained. After extraction of the dye, remaining matter was used as fertilizer. So, the process of dyeing was totally environment-friendly.

Doshi A. & Karolia A. (2016) conducted research on Optimization of enzyme treatment for Banana fiber. Banana fibers are potential textile fibers due to their excellent strength and luster, however lacks spin ability due to stiffness. Hence the softening of Banana fibers was done using enzymes. Four different enzymes were applied individually to optimize the concentration and conditions and a final treatment was standardized in combinations. The order of application of enzyme treatment as combination was also studied. The result showed that Banana fibers can be softened by using enzymes. The percent weight loss of the fibers supports that unwanted material is removed by the enzymes. The combination of enzymes in a specific order (first lacase followed by hemicellulase and then cellulase and pictinase) gave better results in terms of weight loss and the feel of the fiber.

Repon R., Memun A. & Islam T. (2016) presented a paper Eco-friendly Cotton Coloration Using Banana (*Musa Sapientum*) Waste: Optimization of Dyeing Temperature. Natural dye retrieved from Banana floral stem by roller

squeezer machine. The study was conducted to explore the effect of temperature, samples were dyed for 60℃, 70℃, 80℃, 90℃, 100℃ and 110℃ respectively by keeping constant time at 60 minutes. Effect of temperature variation on colorimetric appearance were expressed using CIE L* a * b* color space. The dye fiber bonding stability was accessed via color fastness to wash, water, perspiration, rubbing and light. Except light fastness property almost color fastness was good to excellent. Best result of K/S, bright index % and color levelness was recorded at 100 ℃. Excellent color fastness properties also appeared for 100℃.

Devi M., Ariharan V. N. & Prasad N. (2013) presented a paper on Annatto: Eco-friendly and potential source for natural dye. Usage of natural Annatto dye had good light fastness and may help in keeping the skin healthy by preventing allergy. This dye was bio-degradable and non-toxic. The dye was cheap, soothing, long lasting and it had anti-microbial property.

Sharan M., Yadav R. & Vashishtha P. (2013) conducted research on an experimental study on using waste flowers for extraction of dye and development of colour palette on silk and wool. this study focuses on reutilization of used flower as a source of natural dye. Experiments were done to extract dye from the different coloured waste flower and leaves. For the study marigold, rose and Bael leaves were used to get yellow, red and green colour respectively. Varying percent shade and two natural mordants i.e. lemon rind and Pomegranate rind and two metallic mordants i.e. copper sulphate and stannous chloride were used to obtain colour palette and strengthen the shades. The dyed samples were checked for the different performance properties. Their CIE and K/S values were obtained using spectrophotometer. On analysis of the results, it was found that dye can be extracted from the waste flowers and leaves and different shades of red, yellow and green were obtained. Application of different mordants gave better shades and higher depth of colour. Wash fastness and rub fastness of dyed sample were rated 5-3 on grey. scale. i.e., from excellent to good fastness. Light fastness of dyed samples was from maximum to good. Change in shades was also noticed in some samples after exposure to light. These dyes can be effectively used on silk and wool fabric.

Sharan M., Yadav R. & Gohil M. (2013) done the research on a study of a coconut calyx on the textile materials for the development of colour palette and designing products taking inspiration from wood grain. In this study researcher has experimented with coconut calyx dye which is remains of coconut after consuming edible portion to extract dye from it. The waste i.e., coconut calyx was tried out on cotton and silk with two natural mordants namely Pomegranate rind and lemon rind and one metallic mordant alum at various per cent shade by varying the pH values for development of colour palette. K/S values of dyed samples were measured using spectrophotometer. Further the application of dye was done to design textiles taking inspiration from wood grain. And six cushion covers were prepared and visual assessment was taken. The results show that the coconut calyx developed good shades on cotton and silk by varying mordants and pH condition. K/S values spectrophotometer analysis showed that pomegranate mordanted samples possess good depth of colour as compared to alum and lemon rind mordanted samples. It was also observed that light and wash fastness properties of the sample ranges between very good to excellent except rub it ranges between medium to fairly good. Further for the value addition of fabric, investigator has made an effort to design textiles taking inspiration from wood grain with the different techniques in which mordants and dyes varies at their self pH. Coconut calyx dye also exhibits their use as an eco-friendly substance because it is not only reducing the waste but also produce eco-friendly dye.

Gogoi N. (2010) conducted research on Value addition of Eri silk with Annatto – a natural colourant. In present study, Eri silk fabric was dyed with Annatto dye. It enhances the fabric as well as its aesthetic value and marketability. Different dyeing conditions were optimized with different mordants. Little decrease in breaking strength was observed. Colour fastness of the dyed samples were good.

Joshi K. (2009) conducted research on application of walnut dye on wool and silk for development of a colour palette. For the present work leaf, bark and fruit covering of the walnut tree were used to extract dye and palette was obtained by varying different mordants with change of pH. Total 63 shades were

produced. K/S and fastness test were carried out under standard conditions. A product line of 3 bags and 3 stoles were developed and constructed with value addition tie and dye technique. The designed products were then displayed to assemble opinion of the respondents. Thus, the study received an appreciation and good response towards the constructed products.

CHAPTER III

METHODOLOGY

The main objectives of the study are to explore agro waste for the natural dye and to develop shade card by varying pH, natural mordants and different concentration of dye using three natural dyes (Indian almond leaves, Annatto seeds & Onion peels) and two natural mordants (Pomegranate rind & Banana red flower peel). So, this chapter serves the materials and methods followed for execution of experiment.

The experimental procedure of the study undertaken has been divided into the following subheads:

3.1 Research design

3.2 Selection and composition of the material used

3.2.1. Pilot Study

3.2.2. Selection of the fabric

3.2.3. Selection of Dyes and mordants

3.3 Preliminary data

3.3.1 Preliminary data of the selected fabrics

3.3.2 Preliminary data of selected natural dyes and natural mordants

3.4 Procedure for Fabric scouring

3.5 Procedure for Mordanting

3.6 Procedure for Dye Extraction

3.7 Dyeing of the samples with standardize recipe using different variables used for the study

3.7.1 Varying the mordants

3.7.2 Varying the dye concentration

3.7.3 Varying the pH of dye bath

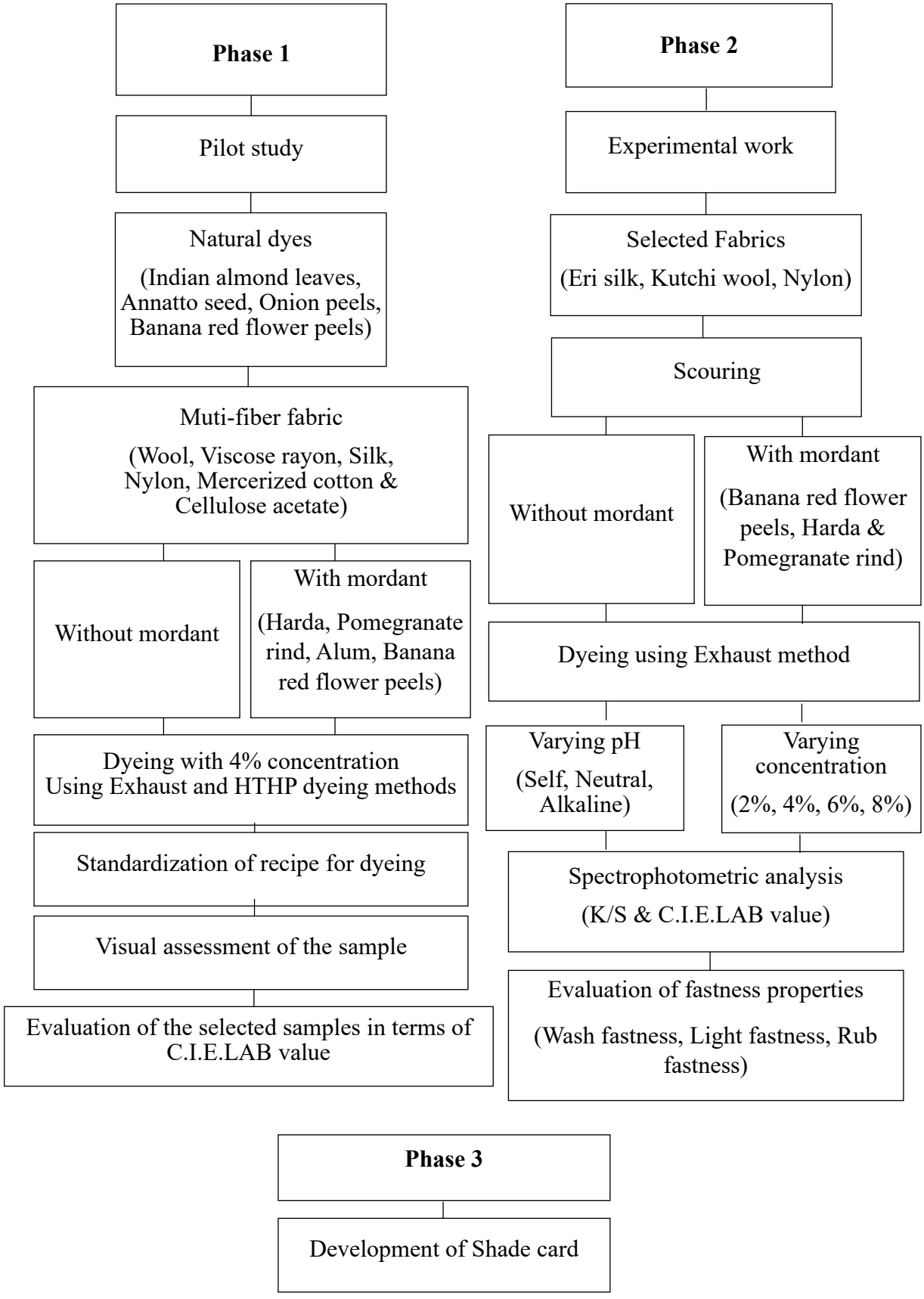
3.8 Testing of untreated and treated fabrics using relevant standard methods

3.8.1 Assessment of colour values of the dyed samples in terms of K/S and C.I.E.LAB values

3.8.2 Evaluation of fastness property of untreated and treated fabric

- Wash fastness
- Rubbing fastness
- Light fastness

RESEARCH DESIGN



3.2 Selection and composition of material used

3.2.1. Pilot study

For the pilot study, the multi-fiber fabric (which consists of cotton, silk, wool, viscose rayon, nylon and polyester) was selected. It was dyed using selected agro-waste natural dyes i.e., Indian almond leaves, Banana red flower peels, Onion peels and Annatto seeds.

The dyes were used with 4% concentration on the weight of the material with and without mordants. Three mordants (Alum, Harda and Pomegranate rind) and combination of mordants with Harda were used for the pilot study.

Dyeing was done by two methods i.e., Exhaust dyeing and High temperature high pressure dyeing machine. But the results were almost similar so open bath dyeing was selected for further experimental work.

The samples were treated in three pH condition for the more shade variation i.e., self, neutral and alkaline and the temperature being maintained at 80^0 to 85^0 C.

On the basis of visual assessment, it was found that Banana red flower peels dye didn't give colour on any fibers so, Banana red flower peels was tried as mordant with other three dyes.

It was found that the colours of Indian almond leaves, Onion peels and Annatto seeds were better obtained on wool, silk and nylon fibers. For the further experiment, three fabrics were considered. They were two protein fibers: Kutchi wool and Eri silk were selected along with Nylon fabric.

From the four mordants, Harda, Banana red flower peels and Pomegranate rind gave the better result so they were used for the further experiments.

3.2.2 Selection of the fabric

The selection of the fabrics was as per the results obtained in the pilot work. Three fabrics selected for the study were Kutchi wool, Eri silk and 100% Nylon. Kutchi wool was procured from local weaver of Bhujodi, Kutch, Gujarat. Eri

silk was procured from Pahartah fashion, Kangara, Himachal Pradesh and Nylon was procured from Moti nylon mill, Vesu, Surat.

3.2.3 Selection of Dyes and mordants

Three dyes were selected for the study i.e., Indian almond leaves, Onion peels and Annatto seeds. Indian almond leaves were collected from the campus of Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. Onion peels were collected from Khanderao vegetable market, Vadodara, Gujarat. Lower quality Annatto seeds (which was waste) was selected for the study. Annatto seeds were procured from Annatto processing unit, Vadodara-Halol highway, Vadodara, Gujarat.

Three mordants were selected for the study i.e., Banana red flower peels, Harda and Pomegranate rind. Banana red flower peels was procured from local farmer of Vadodara. Harda and Pomegranate rind were procured from local market of Vadodara.

3.3 Preliminary data

3.3.1 Preliminary data of the selected fabrics

The selected fabrics were evaluated for its Fiber content, Fabric count, GSM, Thickness and yarn diameter.

3.3.1.1 Determination of Fiber content of the fabric

Microscopic, solubility and burning tests were carried out for the determination of fiber content of the fabrics.

3.3.1.2 Determination of Fabric count and weave of the fabric (ASTM D3775-17el)

Fabric count was calculated by counting the number of threads per square centimeters in warp and weft direction, with the help of pick glass. Five readings were taken from the different part in each fabric and an average was taken as the final reading. For the determination of the weave of the fabric pick glass was used.

3.3.1.3 Determination of fabric weight per unit area (D3776-20)

For testing the GSM of the fabric, specimens were well ironed and laid on flat surface. 5 samples of 11.25 cm × 11.25 cm (4.5" × 4.5") were cut through the GSM cutter. After cutting these samples were then kept in the desiccators for 24 hours for conditioning. After 24 hours the samples were taken out and weighed accurately using an **Electronic Weighing Balance**. Five readings from each fabric were taken and an average was calculated for the final reading. Weight and final reading were calculated by using the following method:

Calculate the average weight of the cut samples in grams and multiply by 100 to give the weight per square meter in grams.

3.3.1.4 Determination of thickness of the fabric (ASTM D1777-96)

For testing the thickness of the fabrics fabric specimen conditioned in desiccator for 24 hours. The thickness of the fabric was studied by using thickness gauge. After conditioning, the sample was kept between the anvil and circular pressure foot. The dial indicator directly gave the thickness in mm. Five readings from each fabric were calculated and the mean value of all the readings determined thickness of the sample.

3.3.1.5 Determination of Yarn diameter (ASTM D629)

For testing Yarn diameter, direct method was used. Three yarns from warp and three yarns from weft of same size were drawn out from each selected fabric and then with equal stretch tape it on the slide. Microscope was arranged with micrometer scale and recorded the reading of each yarn. Entire scale is 1 mm divided into 1000 microns value (μ). Average was taken as final reading.

3.3.2 Preliminary data of selected natural dyes and natural mordants

The preliminary data of selected natural dyes and natural mordants in terms of its botanical name, the part used for the dyeing of samples in the study,

classification on the basis of the chemical constitution & application and the main colouring component of the dye.

Table 5: Preliminary data of the dyes and mordants used

Sr. No.	Name of dyes	Botanical name	Part Used
1.	Indian almond leaves	*Terminalia catappa*	Leave
2.	Annatto seeds	*Bixa Orellana*	Seed
3.	Onion peels	*Allium cepa*	Leftover skins
4.	Banana red flower peels	*Musa acuminata*	Flower peel
5.	Harda	*Terminalia chebula*	Fruit
6.	Pomegranate rind	*Punica granatum*	Dried Rind

3.4 Procedure for Scouring of the samples

The fabrics were first scoured to remove impurities in form of grease, dust as foreign matter before application of mordants and dyes. Silk, wool and nylon were scoured with 2 grams/litre of non-ionic detergent in a material liquor ratio of 1:40 for 45 minutes at 60° C. The fabrics were then rinsed thoroughly and air dried.

3.5 Procedure for Mordanting

Before the actual dyeing process, fabrics were mordanted with Banana red flower peels, Harda and Pomegranate rind. Banana red flower peels were extracted for 30 minutes, keeping MLR 1:50 at 90^0 C temperature. Pre-mordanting technique was used. The mordant extract was strained through the fine strainer. Eri silk, Kutchi wool and Nylon were mordanted with 10%

concentration in a material liquor ratio of 1:40 for 30 minutes at room temperature. Then the fabrics were rinsed and dried in shade.

3.6 Procedure for dye extraction

For the Indian almond leaves, the leaves were dried at room temperature and powder was done by grinder. Annatto seeds were grinded with grinder and Onion peels were used in dry form as they collected from the market. The extraction of each individual dye was carried out in enamel bowls. The dye extraction was carried out at boil for a period of 30 minutes, keeping the MLR 1:50 at 90° C temperature. The process of extraction was carried out in distilled water so as to make sure that it is free from all kind of metallic impurities. After all these the extract was strained through a fine strainer so as to remove the solid content and then this liquor was used as for dyeing.

3.7 Dyeing of the samples with standardize recipes using different variables used for the study

The dyeing was carried out by the standardized recipe following the variations under study. The dyeing standards followed were:

pH – Self, Neutral and Alkaline

Dyeing temperature – 80° C

Dyeing time – 30 minutes

Table 6: Standardized recipe for extraction of dye and mordants

Sr. No	Dye	Obtained as	M:L ratio	Time of extraction	Temperature of extraction	Time of dyeing
1.	Indian almond leaves	Leaves	1:50	30 min	90^0 C	30 min

2.	Annatto seeds	Seeds	1:50	30 min	90^0 C	30 min
3.	Onion peels	Leftover skins	1:50	30 min	90^0 C	30 min
4.	Banana red flower peels	Flower peels	1:50	30 min	90^0 C	30 min
5.	Harda	Fruits	1:50	30 min	90^0 C	30 min
6.	Pomegranate rind	Dried rind	1:50	30 min	90^0 C	30 min

Varying the dyeing conditions

The colour palette of dyed samples was obtained by varying different condition. The fabric was mordanted with different mordants Banana red flower peels, Harda and Pomegranate rind at different pH value (self, acid and alkaline) at 2%, 4%, 6% and 8% shade.

3.7.1 Varying the mordants

The variations in mordants were done to achieve a wider range of shades. There were three natural mordants i.e., Banana red flower peels, Harda and Pomegranate rind used for the experiment. Banana red flower peels were selected for the study as they are new agro-waste source for mordanting and Harda & Pomegranate rind were selected for the study as they are eco-friendly source for mordanting.

3.7.2 Varying the dye concentration

Different concentrations of dye were selected for the experiments so that wider range of colour shades could be achieved for colour palette. The four concentrations were selected for the dyeing that was 2%, 4%, 6%, 8%.

3.7.3 Varying the pH of dye bath

The colour palette of dyed samples were obtained by varying different dye bath condition. The dyeing was done with three pH that are self which is acidic, neutral and alkaline. Neutral and alkaline medium was obtained by adding sodium carbonate.

3.8. Testing of untreated and treated fabrics using relevant standard methods

3.8.1 Assessment of colour values of dyed samples in terms of K/S and C.I.E.LAB values

Premier Spectrophotometer based on C.I.E Lab was used to obtain the data in terms of colour strength values (K/S). D65 illuminate having a colour temperature of 6500*k (equivalent to average day light) and 10* visual angle measured at three different points across the visible spectrum (400-700nm).

The reflectance curves of controlled and dyed samples with each of three dyes used in the study were obtained. Most of the time, control sample means undyed white sample but here, the control sample means dyed sample without any treatment or mordanted. The wavelength at which the maximum K/S value obtained is indicative of colour strength and is termed as maxima. Thus, every dye has their own maxima.

3.8.2 Evaluation of the dyed samples in terms of fastness i.e., wash, light and rub fastness

Out of 432 dyed samples with different dyes, mordants and fabrics, 36 darker shades i.e., 12 with each dye were selected visually for fastness testing. Selected samples were tested in the laboratory. The tests were carried out under standard atmospheric condition of 65% $\pm$ 2% and 27^0 C $\pm$ 2^0 C. The samples were conditioned in the standard atmospheric condition at least for a period of 24 hours, before the tests were carried.

The dyed samples were assessed for the following parameters:

- Wash fastness
- Light fastness
- Rub fastness

3.8.2.1 Determination of wash fastness of selected dyed samples

The laundering test was done to evaluate wash fastness of the dyed samples carried out with launder-o-meter as per the A.A.T.C.C. standard test method IA 61 – 1962. Principle of launder-o-meter is that the specimens are laundered under appropriate conditions of temperature, alkalinity and abrasive action such that the desired loss of the colour is obtained in a conveniently short time. Two adjacent fabrics each of 10 × 4 cm were taken. Dyed fabric were cut and sandwiched between the two adjacent fabric of same fiber content by forming a layer of parallel length of it and sewn along all four sides to form a composite specimen.

Soap solution was made by dissolving 2 g/l of non-ionic detergent. The material liquor ratio was maintained at 1:40. The samples were placed in steel jars of 800ml capacity at room temperature. The test method comprised of one level of laundry for 45 minutes. The specimen was then removed, rinsed and squeezed. After that stitches were removed along the two long sides and one short side. Specimen was opened out and dried in air.

Note: The change in colour of the treated specimen and the degree of staining of the two species of the adjacent fabric was evaluated with the help of grey scales and the ratings were assigned from 1 to 5.

1- Poor

2- Medium

3- Fairly good

4- Good

5- Excellent/Very good

The geometric grey scale by ICI (as specified by Society of dyers and colourists) was used for visual assessment to evaluate the rate of staining and change in colour of dyed samples.

3.8.2.2 Determination of Light fastness of selected dyed samples

To test the light fastness of dyed samples, Digital light fastness tester was used as per the A.A.T.C.C standard test method 16A-1963. The specimens from the textile to be tested and a standard dyeing or dyeing are exposed simultaneously to a specified calibrated carbon-arc light under specified conditions for the standard fading hours.

The test specimens were prepared by cutting 3" × 1.5" of the dyed samples. These specimens were mounted on a cardboard having its face covered with black paper. The test specimens were then exposed to light for 5, 10 and 15 standard fading hours.

The geometric grey scale by ICI (as specified by Society of Dyers and Colourists) was used for visual assessment to evaluate the rate of fading of dyed samples after standard 5, 10 and 15 hours of exposure to light.

3.8.2.3 Determination of Rub fastness of selected dyed samples

The crocking test was done to evaluate the rubbing fastness (dry & wet) of dyed samples was carried out in the crock-o-meter as per the A.A.T.C.C standard test method 8, 1991. The crocking test method is prescribed for determination of colour fastness of textiles materials to rubbing and staining other materials. Colour transferred to the white cloth is assessed by a comparison with grey scale in the A.A.T.C.C chart for measuring transference of colour.

The test specimens were prepared by cutting 12.5 × 5 cm and fastened to the base of the crock-o-meter, so that it rests flat on the abrasive cloth. A square undyed fabric of size 5 × 5 cm was mounted over the end of the finger which projects downwards from weighed sliding arm. The white testing cloth was allowed to slide, onto the test specimen (dyed sample) back and forth twenty

times by making ten complete turns of the crank at the rate of one turn per second. For wet crocking test, white testing sample were thoroughly wet out in distilled water and were squeezed between filter Wet pick up was brought to 65% + 5%. Care was taken to prevent evaporation from reducing the moisture content. The remaining procedure was same as the dry crocking test.

The degree of staining of the piece of undyed cloth was evaluated with the help of geometric grey scale (staining) and rating were assigned by ICI (as specified by Society of Dyers and Colourists) was used for the visual assessment.

CHAPTER IV

RESULTS AND DISCUSSION

Natural dyes which are extracted from natural materials such as plant leaves, fruit peels, roots, bark, insect secretions, and minerals are generally sustainable, eco-friendly and can provide a wide range of beautiful shades. Utilization of agro waste materials as source of natural dyes plays an important role as a potential source of natural dyes, which can assist in the protection of the environment by being helpful for disposal of waste and also decrease the cost of natural dyeing. The broad aim of present study was to reduce the waste and utilize agro waste as an alternative dye and mordant source. Dyeing was done using three natural agro-waste dyes, three natural mordants and three fabrics with different pH and % shade. Further K/S value and CIE L*a*b* values were measured and fastness (rubbing, washing and light) were evaluated.

The results of the study have been given and discussed under the following subheads:

4.1 Pilot study

4.2 Selection of materials and standardization of the dyeing recipe

4.3. Preliminary data

4.3.1. Preliminary data of the fabrics

4.3.2. Preliminary data of dyes and mordants used

4.4. Effect of mordant on selected fabrics

4.5. Development of colour palette using Indian almond leaves dye, Onion peels dye and Annatto seeds dye with different fabrics, natural mordants, dye concentration and pH

4.6. Evaluation of the colour yield of the dyed samples

4.7 Fastness properties of the selected dyed samples.

4.7.1 Evaluation of Wash durability of the selected samples

4.7.2 Evaluation of light permanence of the selected samples

4.7.3 Evaluation of rub fastness of the selected samples

4.1 Pilot study

Before execution of the final experiment procedure researcher has conducted pilot study. In Pilot study multifiber fabric (Cotton, Wool, Silk, Nylon, Viscose rayon, Cellulose acetate) was pre mordanted with alum, Harda, Pomegranate rind and Banana red flower peels at 10% Conc. For dyeing four natural agro-waste dyes i.e., Indian almond leaves (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*) Onion peels (*Allium cepa*) and Banana red flower peels (*Musa acuminata)* were used. The dye was used with 4% concentration on the weight of the material at different pH conditions.

Table 7: Parameters used in pilot study

Fabric	Multi-fiber fabric
Dyes	Indian almond leaves, Onion peels, Annatto seeds, Banana red flower peels
Mordants	Alum, Harda, Pomegranate rind, Banana red flower peels
Mordanting process (Concentration, M:L, time, temperature)	Pre-mordanting technique M:L = 1:40 Concentration = 10% Time = 30 minutes Temperature = Room temperature
Dye extraction process (M:L, time, temperature)	M:L = 1:50 Time = 45 minutes Temperature = 90° C
Dye concentration	4%
Dyeing method	Exhaust dyeing & HTHP dyeing machine

Dyeing time, temperature and M:L	M:L = 1:30 Time = 30 minutes Temperature = 85° C

Mordants play very important role for natural dye in imparting colour to the fabric by making a chemical bond between fiber and dye. They bond with dyes easily than the fiber and improve the colour fastness of dyed fabrics. To produce possible shades on selected substrate pre-mordanted with three mordants namely Banana red flower peels, Harda and Pomegranate rind. Pre-mordanting was experimented with 10% conc. keeping M:L ratio as 1:40 at room temperature for 30 mins.

Extraction method used in the study was boiling method. For extraction 1gm/50 ml (weight of dye in gram: amount of water in ml) of dye powder in distilled water was boiled for 45 mins. The mixture was cooled before straining and then extract was used to dye fabric.

Pre-mordanted samples were dyed with 4 % conc. of Indian almond leaves, Annatto seeds, Onion peels and Banana red flower peels at self pH using exhaust and HTHP dyeing methods. After that, the dyed fabrics were rinsed and air dried. Indian almond Dyed samples were evaluated for CIELAB values.

L* values explain lightness and darkness in the samples where low number indicates dark and a high number indicates light (L* = 0 yields black and L*= 100 indicates diffuse white, specular white may be higher). a* describe presence of red and green colour component on mordanted and dyed sample, if values are positive, it has red colour component while negative values show presence of green colour component. b* describes presence of yellow and blue colour component on mordanted and dyed sample, if values are positive, it has yellow colour component while negative values show presence of blue colour component.

Colour yield of multi fibre fabric dyed with Indian almond with different mordants using exhaust and HTHP methods were discussed below:

Table 8: Dyeing of Wool fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*
Wool	Without mordant	54.416	4.533	37.661	52.520	4.126	25.183
Wool	Harda	57.571	3.465	38.297	35.948	2.303	40.610
Wool	Alum	55.513	4.204	41.916	45.766	4.564	33.701
Wool	Pomegranate rinds	39.769	6.704	45.440	25.333	11.106	41.535

It was observed from the Table 8 that wool dyed at self pH using Indian almond leaves exhibited highest L* values (57.571) with wool pre-mordanted with Harda using exhaust dyeing methods followed by alum and least in HTHP dyeing method using Pomegranate as a mordant 25.333 using HTHP method. It was concluded from a* value maximum presence of red was found on the dyed sample. While in b* value obtain in the range of 25.18 to 45.44, hence all the values of b are near the yellow line.

Table 9: Dyeing of Silk fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*
Silk	Without mordant	46.845	5.728	42.937	41.232	6.574	34.156
Silk	Harda	50.157	4.647	41.082	30.444	-4.705	37.038

Silk	Alum	49.348	3.116	50.058	43.828	5.203	46.055
Silk	Pomegranate rinds	35.710	5.169	43.605	27.173	-4.058	39.443

Colour strength of dyed silk yarn was measured in terms of L*, a*, b* colour scale. The tabulated values are given in table 9. 1. From the results it was concluded that maximum lightness was observed on the sample mordanted with Harda at self pH (50.157) using exhaust method, while maximum darkness was observed on the sample mordanted with Pomegranate rind (35.710) using exhaust methods. While in case of HTHP, the sample mordanted with Alum showed maximum lightness (43.828) and the sample mordanted with Pomegranate rind showed the maximum darkness (27.173). In exhaust method, a* value had positive range indicated that the samples had presence of red. In case of HTHP, a* value was in the positive to negative range indicate all the colour values are in green to red region. While in b* value obtain in the range of 34.15 to 50.05 so all the values of b are near the yellow line.

Table 10: Dyeing of Nylon fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*
Nylon	Without mordant	59.596	2.692	34.290	49.465	6.586	25.377
Nylon	Harda	53.867	2.706	35.335	46.734	-0.429	31.695
Nylon	Alum	59.504	3.281	38.289	46.238	5.627	32.421
Nylon	Pomegranate rinds	50.535	3.646	37.081	41.547	-0.231	37.623

Table 10 showed the effect of Colour strength of dyed Nylon in terms of L, a, b colour scale. It was evident that higher L* value (lightness) was found in self

pH with Harda (53.867) using exhausted methods while least was found in Pomegranate rinds mordanted nylon fabric using HTHP method. a* value it was in the positive to negative range so all the colour values are very less in green to red region. While in b* value obtain in the range of 25.37 to 38.28, hence all the values of b are near the yellow line.

Table 11: Dyeing of Cotton fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*
Cotton	Without mordant	66.533	2.411	26.461	59.068	3.212	20.041
Cotton	Harda	63.822	2.988	30.949	48.891	-0.223	32.809
Cotton	Alum	61.242	2.165	40.367	50.835	3.917	37.417
Cotton	Pomegranate rinds	58.328	4.643	43.963	45.060	-0.414	45.038

Degree of colour yield of cotton with different mordants using exhaust and HTHP methods was showed in Table 11. The result was obtained in the range of 45.06 to 66.53. The darkest shade was obtained with Pomegranate rinds using HTHP methods (45.060). and a* value it was in the positive to negative range indicate all the colour values in green to red region. While in b* value obtain in the range of 20.04 to 45.03 so all the values of b* were near the yellow line.

Table 12: Dyeing of Viscose fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*

Viscose	Without mordant	65.587	20792	33.735	60.140	2.495	23.873
Viscose	Harda	64.550	0.886	40.674	49.096	-0.236	37.299
Viscose	Alum	60.844	1.837	48.986	44.344	5.104	49.984
Viscose	Pomegranate rinds	55.645	6.413	45.619	37.306	-0.180	39.988

Table 12 showed the effect of mordants and dyeing methods on the CIE Lab value of Viscose yarn dyed with Indian almond leaves. Without mordant using exhaust methods showed the highest L* values (65.587) and least L* value with Pomegranate rind (37.306) indicates the lighter tone without mordanted dyed same using exhausted methods and darker tone by Pomegranate rind mordanted samples with HTHP method. Positive to negative range was seen a* value which showed that all the colour values in little green to red region. While in b* value obtain in the range of 23.87 to 49.98 so all the values of b are near the yellow line.

Table 13: Dyeing of Cellulose acetate fiber with Indian almond leaves using Exhaust dyeing and HTHP dyeing machine at 4%

Fiber content	Mordant	Exhaust dyeing			HTHP dyeing		
		L*	a*	b*	L*	a*	b*
Cellulose acetate	Without mordant	68.296	1.449	26.813	59.525	4.594	20.340
Cellulose acetate	Harda	65.254	1.403	28.751	52.882	-2.181	22.622
Cellulose acetate	Alum	65.588	1.726	31.536	57.463	3.450	26.244

Cellulose acetate	Pomegranate rinds	62.088	3.665	34.197	38.933	-1.676	30.371

Colour strength of dyed cellulose acetate yarn was measured in terms of L*, a*, b* colour scale. The tabulated values are given in table 13. From the table it was concluded that L* value ranged of 38.93 to 68.29, it means that all the samples are at dark side but near the lighter region and for a* value it was in the positive to negative range so all the colour values are in less green to red region. While in b* value obtain in the range of 20.34 to 34.19 so all the values of b are near the yellow line.

The multifibre fabric were also dyed with Annatto seeds (*Bixa Orellana*), Onion peels (*Allium cepa*) and Banana red flower peels (*Musa acuminata)* using same recipe. By visual assessment it was found that in case of Annatto seeds and Onion peels best results were obtained on silk, wool and Nylon. It was also found that Banana Red Flower peel only stain the fabric it was not giving any colour so it was tried as a mordant which were giving good colour yield with other selected dyes.

4.2 Selection and standardization of the dyeing recipe

Different variables of the study were finalised for further experiment based on the result of pilot study. The mordant were selected on the basis of their functionality. To produce possible shades on selected substrate three natural mordants were selected namely Banana red flower peels, Harda and Pomegranate rind with the dye concentration 2%, 4%, 6%, 8% in three pH condition i.e., Self, Neutral and Alkali. Good results were observed in Nylon, Wool and Silk. So for further study silk, wool and nylon were selected. HTHP dyeing and Exhaust dyeing gave almost similar results thus exhaust dyeing was selected for further experiment. Through the pilot study recipe for dye extraction and dyeing was standardized which was given in Table 14.

Table 14: Standardized recipe for dye extraction and dyeing

Sr. No.	Dye sources	Part used	Procedure of extract	Time, Temperature & MLR for extraction	Time, Temperature & MLR for dyeing
1.	Indian almond	Leaves	Powdered and soaked overnight	30 Minutes 90^0 C 1:50 MLR	30 Minutes 85^0 C 1:30 MLR
2.	Onion	Peels	Soaked for 10 minutes	30 Minutes 90^0 C 1:50 MLR	30 Minutes 85^0 C 1:30 MLR
3.	Annatto	Seeds	Powdered and soaked for 10 minutes	30 Minutes 90^0 C 1:50 MLR	30 Minutes 85^0 C 1:30 MLR

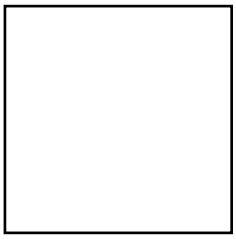
4.3 Preliminary data

4.3.1. Preliminary data of the fabrics

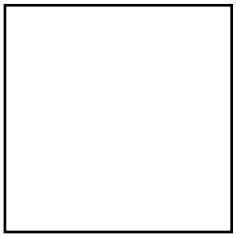
Protein Fabrics i.e., Kutchi wool, Eri silk and Nylon fabrics were tested for its preliminary data. For its preliminary data the following parameters: fiber content, fabric count, weight per unit area (GSM), yarn diameter and thickness of the fabric were studied and has been given in Table 15.

Table 15: Preliminary data of the fabrics

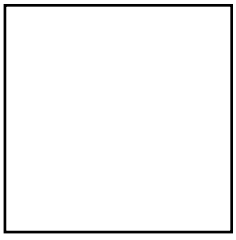
Sr. No.	Fiber content	Fabric count		Yarn diameter (µ)	Weight/unit area (gms/mt^2)	Fabric thickness (mm)
		Ends per cm	Picks per cm			
1.	100%Eri Silk	26	30	200	104	0.30
2.	100%Kutchi Wool	8	6	800	200	0.45
3.	100%Nylon	31	36	200	154	0.35



Eri Silk Fabric



Kutchi Wool Fabric



100% Nylon Fabric

Plate 1: Eri Silk, Kutchi wool and 100% Nylon undyed fabrics

The selected fabric was scoured and dried and kept in desiccator. To confirm the fiber content three tests were conducted i.e., microscopic analysis, chemical solubility test, burning test. The result showed that fiber types tested were 100% Silk, 100% Wool and 100% Nylon respectively.

All the fabrics had plain weave structure. Eri Silk fabric had balanced fabric count i.e., 26 ends per cm and 30 picks per cm. Kutchi Wool and Nylon had also balanced fabric count i.e., 8 ends per cm & 6 picks per cm and 31 ends per cm & 36 picks per cm respectively.

Eri Silk and Nylon yarn had 200 microns yarn diameter and Kutchi Wool yarn had 800 microns yarn diameter. It shows that wool fabric had coarser yarn.

Eri Silk fabric had weight per unit area 104 gm/m^2, Kutchi Wool fabric had weight per unit area 200 gm/m^2 and Nylon had 154 gm/m^2. Hence, Eri Silk and Nylon fabric were light weight fabric whereas Kutchi Wool was medium weight fabric.

Thickness of the Eri Silk was 0.30 mm, Kutchi Wool was 0.45 mm thick and Nylon was 0.35 mm thick. So, all the fabrics were medium thick fabrics.

4.3.2. Preliminary data of dyes and mordants used

In the present study, Indian almond leaves (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*) and Onion peels (*Allium cepa*) were selected as agro-waste natural dyes. To produce different shades on selected fabrics three natural mordants were selected i.e., Banana red flower peels (*Musa acuminata*), Harda (*Terminalia chebula*) and Pomegranate rind (*Punica granatum*). The preliminary data of the dye and mordants has been given in Table 16 and Table 17 respectively.

Table 16: Preliminary data of the dyes used

Sr. No.	Name of dyes	Botanical name	Class of dye based on its application	Colour giving component	pH
1.	Indian almond leaves	*Terminalia catappa*	Acid	Punicalin tannin	4

2.	Annatto seeds	*Bixa Orellana*	Acid	Bixin, Orellin, Methyl bixin	5.5
3.	Onion peels	*Allium cepa*	Acid	Quercetin	3.5

Indian almond leaves:

Figure 26: Dry Indian almond leaves

Fig. 26 Source: https://us.123rf.com/450C/olecnx/olecnx1804/olecnx180400003/98959168-dry-leaves-of-indian-almond-tree-terminalia-catappa-in-different-sizes-on-the-ground.jpg

Botanical name: *Terminalia catappa*

Colour giving component: Punicalin tannin

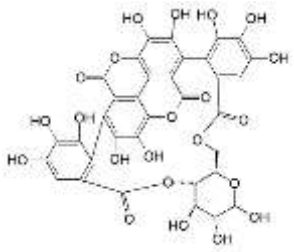


Figure 27: Punicalin tannin

Fig. 27 Source: https://en.wikipedia.org/wiki/Punicalin

Tannin or tanning substance is used for a range of natural polyphenols. It acts as an acid, soluble in alcohol, water etc. Tannin is defined as naturally occurring water soluble polyphenolic compounds of high molecular weight (about 500-3000) containing phenolic hydroxyl groups to enable them to form effective crosslink between proteins and other macromolecules. Punicalin tannin is an ellagitannin. It can be found in *Terminalia catappa* leaves. The molecule contains a gallagic acid component link to a glucose.

Annatto seeds:

Figure 28: Annatto seed powder

Botanical name: *Bixa Orellana*

Colour giving components: Bixin, Orellin, Methyl bixin

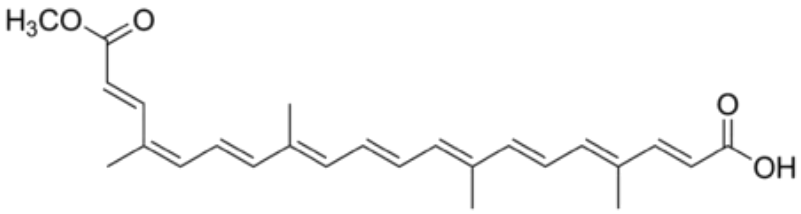


Figure 29: Bixin molecular structure

Fig. 29 Source: https://en.wikipedia.org/wiki/Bixin

Bixin, a red-coloured carotenoid, is the pigment present in high concentration in the Annatto seed aril. It is the main substance responsible for the dyeing characteristics of seeds, where its concentration can be as high as 5%. Different seeds may have different levels of concentration also less than 2%. It consists of a chain of 25 carbons and has the molecular formula $C_{25}H_{30}O_4$. It has a carboxylic acid and methyl ester group at the ends of the chain. Many other carotenoids occur in *Bixa Orellana* in minor percentage i.e., Norbixin, Methyl Bixin, Orellin, Beta-carotenoid, etc.

Onion peels:

Figure 30: Dry Onion peels

Botanical name: *Allium cepa*

Colour giving component: Quercetin

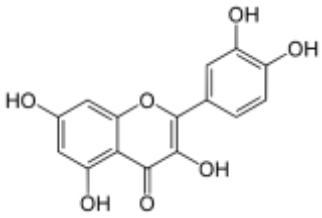


Figure 31: Quercetin molecular structure

Fig. 31 Source: https://en.wikipedia.org/wiki/Quercetin

Onion is rich in a variety of phytochemicals with beneficial functions, including organosulfur compounds, phenolic compounds, polysaccharides and saponins. The phenolic compounds are responsible for colouring textiles. It includes quercetin and quercetin glucosides. Red Onion contains 32 mg quercetin per 100 grams.

Table 17: Preliminary data of the mordants used

Sr. No.	Name of mordants	Botanical name	Class of dye based on its application	Colour giving component	pH
1.	Banana red flower peels	*Musa acuminata*	Acid	Tannins & Saponins	5.5
2.	Harda	*Terminalia chebula*	Acid	Chebulinic acid	3
3.	Pomegranate rind	*Punica granatum*	Acid	Flavogallol	4

Banana red flower peels:

Figure 32: Banana red flower

Botanical name of Banana red flower: *Musa acuminata*

Botanical name of Banana red flower peels: *Thyrse*

Colour giving component: Tannic acid

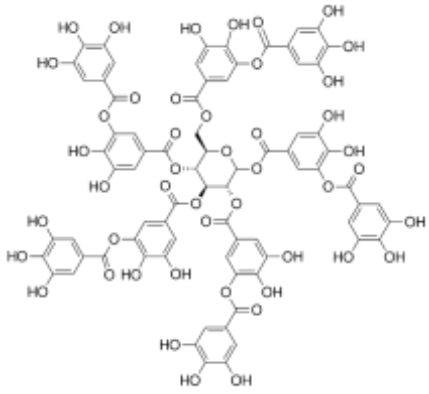


Figure 33: Tannic acid molecular structure

Fig. 33 Source: https://en.wikipedia.org/wiki/Tannic_acid

Banana red flower peels contain many phytochemicals i.e., Gallic acid, quercetin, rutin, catechin, tannic acid etc. Tannic acid is the main sources of colour in Banana flower red peels. 21.39 $\pm$ 2.56 mg/kg tannic acid is present in Banana red flower peels.

Harda:

Figure 34: Harda powder

Botanical name: *Terminalia chebula*

Colour giving component: Chebulinic acid

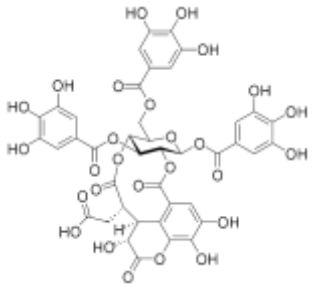


Figure 35: Chebulinic acid molecular structure

Fig. 35 Source: https://en.wikipedia.org/wiki/Chebulinic_acid

The phytochemical screening of the Harda revealed the presence of gallic acid, tannic acid, ethyl gallate, Chebulinic acid, etc. Main colour giving compound in Harda is Chebulinic acid. Harda is used as mordant because it improves the fastness properties of natural dyed fabrics.

Pomegranate rind:

Figure 36: Pomegranate rind powder

Botanical name: *Punica granatum*

Colour giving component: Flavogallol

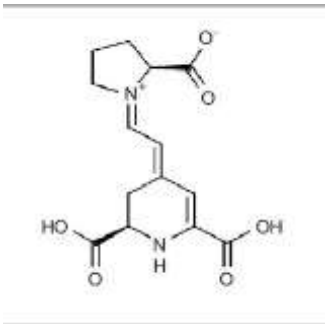


Figure 37: Granatonine molecular structure

Fig. 37 Source: https://www.researchgate.net/figure/Chemical-structure-of-granatonine_fig4_301789080

4.4. Effect of Mordant on selected fabrics

On Eri Silk and Kutchi Wool: Silk and Wool both are protein fibers. Most of the mordants are metallic salts. Here, all the mordants act as acid dye. Natural protein fiber has the affinity for acid dye. Tannic acid, Chebulinic acid and Flavogallol are reacted with Amino groups of Fibers.

On Nylon: All the mordants act as acid dye. Nylons and acid dyes linked with salt links or ionic bonds. Here, all the mordants are bonded with amino groups of Nylon fiber.

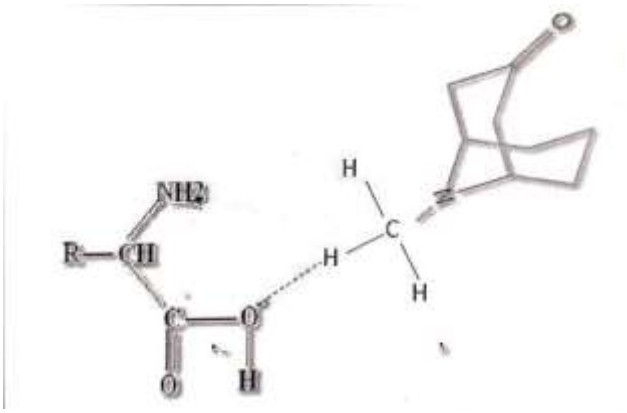


Figure 38: Bond formation between Protein and Nylon with granatonine

Fig. 38 Source: Gohil M. (2013)

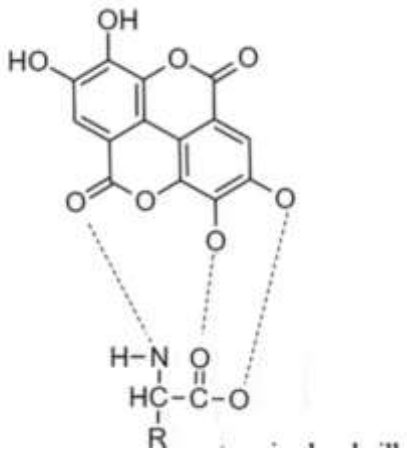


Figure 39: Bond formation between Protein and Nylon with Natural tannins

Fig. 39 Source: https://www.intechopen.com/chapters/73161

4.5. Development of colour palette using Indian almond leaves dye, Onion peels dye and Annatto seeds dye with different fabrics, natural mordants, dye concentration and pH

All the samples were pre-mordanted and then dyed. A colour palette of 432 shades were developed with three different natural mordants, i.e., Banana red flower peels (*Musa acuminata),* Harda (*Terminalia chebula),* Pomegranate rind (*Punica granatum*). Three dyes (Indian almond leaves (*Terminalia catappa*), Annatto seeds (*Bixa Orellana*), Onion peels (*Allium cepa*)) were used for the production of the colour palette and each dye at 4 different percent shade i.e., 2%, 4%, 6%, 8% at three different pH values i.e., acid, neutral and alkaline was tried with all three mordants. Eri Silk, Kutchi Wool and Nylon fabric used for the dyeing.

Indian almond leaves dye produces Olive green to brown colour shades with different variables of the study. Annatto seeds dye produces the colour shades from cream to orange and reddish orange with various pH, dye concentrations and fabrics. Onion peels dye gave the different colour shades with different pH. It produces golden and light brown to dark brown shades with different mordants, fabrics and dye concentration.

		
EAlCS2	EAlC72	EAlC92
		
EAlBS2	EAlB72	EAlB92
		
EAlHS2	EAlH72	EAlH92
		
EAlPS2	EAlP72	EAlP92

Key: E=Eri Silk, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 2: Colour palette of Indian almond leaves dye on Eri Silk fabric with 2% dye concentration, different mordants and pH

		
EAlCS4	EAlC74	EAlC94
		
EAlBS4	EAlB74	EAlB94
		
EAlHS4	EAlH74	EAlH94
		
EAlPS4	EAlP74	EAlP94

Key: E=Eri Silk, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 3: Colour palette of Indian almond leaves dye on Eri Silk fabric with 4% dye concentration, different mordants and pH

		
EAlCS6	EAlC76	EAlC96
		
EAlBS6	EAlB76	EAlB96
		
EAlHS6	EAlH76	EAlH96
		
EAlPS6	EAlP76	EAlP96

Key: E=Eri Silk, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 4: Colour palette of Indian almond leaves dye on Eri Silk fabric with 6% dye concentration, different mordants and pH

		
EAlCS8	EAlC78	EAlC98
		
EAlBS8	EAlB78	EAlB98
		
EAlHS8	EAlH78	EAlH98
		
EAlPS8	EAlP78	EAlP98

Key 4: E=Eri Silk, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 5: Colour palette of Indian almond leaves dye on Eri Silk fabric with 8% dye concentration, different mordants and pH

		
WAlCS2	WAlC72	WAlC92
		
WAlBS2	WAlB72	WAlB92
		
WAlHS2	WAlH72	WAlH92
		
WAlPS2	WAlP72	WAlP92

Key: W=Kutchi Wool, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 6: Colour palette of Indian almond leaves dye on Kutchi Wool fabric with 2% dye concentration, different mordants and pH

		
WAlCS4	WAlC74	WAlC94
		
WAlBS4	WAlB74	WAlB94
		
WAlHS4	WAlH74	WAlH94
		
WAlPS4	WAlP74	WAlP94

Key: W=Kutchi Wool, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 7: Colour palette of Indian almond leaves dye on Kutchi Wool fabric with 4% dye concentration, different mordants and pH

		
WAlCS6	WAlC76	WAlC96
		
WAlBS6	WAlB76	WAlB96
		
WAlHS6	WAlH76	WAlH96
		
WAlPS6	WAlP76	WAlP96

Key: W=Kutchi Wool, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 8: Colour palette of Indian almond leaves dye on Kutchi Wool fabric with 6% dye concentration, different mordants and pH

		
WAlCS8	WAlC78	WAlC98
		
WAlBS8	WAlB78	WAlB98
		
WAlHS8	WAlH78	WAlH98
		
WAlPS8	WAlP78	WAlP98

Key: W=Kutchi Wool, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 9: Colour palette of Indian almond leaves dye on Kutchi Wool fabric with 8% dye concentration, different mordants and pH

NAlCS2	NAlC72	NAlC92
NAlBS2	NAlB72	NAlB92
NAlHS2	NAlH72	NAlH92
NAlPS2	NAlP72	NAlP92

Key: N=Nylon, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 10: Colour palette of Indian almond leaves dye on Nylon fabric with 2% dye concentration, different mordants and pH

		
NAlCS4	NAlC74	NAlC94
		
NAlBS4	NAlB74	NAlB94
		
NAlHS4	NAlH74	NAlH94
		
NAlPS4	NAlP74	NAlP94

Key: N=Nylon, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 11: Colour palette of Indian almond leaves dye on Nylon fabric with 4% dye concentration, different mordants and pH

NAlCS6	NAlC76	NAlC96
NAlBS6	NAlB76	NAlB96
NAlHS6	NAlH76	NAlH96
NAlPS6	NAlP76	NAlP96

Key: N=Nylon, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 12: Colour palette of Indian almond leaves dye on Nylon fabric with 6% dye concentration, different mordants and pH

		
NAlCS8	NAlC78	NAlC98
		
NAlBS8	NAlB78	NAlB98
		
NAlHS8	NAlH78	NAlH98
		
NAlPS8	NAlP78	NAlP98

Key: N=Nylon, Al=Almond leaves dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (4 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 13: Colour palette of Indian almond leaves dye on Nylon fabric with 8% dye concentration, different mordants and pH

		
EAnCS2	EAnC72	EAnC92
		
EAnBS2	EAnB72	EAnB92
		
EAnHS2	EAnH72	EAnH92
		
EAnPS2	EAnP72	EAnP92

Key: E=Eri Silk, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 14: Colour palette of Annatto seeds dye on Eri Silk fabric with 2% dye concentration, different mordants and pH

		
EAnCS4	EAnC74	EAnC94
		
EAnBS4	EAnB74	EAnB94
		
EAnHS4	EAnH74	EAnH94
		
EAnPS4	EAnP74	EAnP94

Key: E=Eri Silk, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 15: Colour palette of Annatto seeds dye on Eri Silk fabric with 4% dye concentration, different mordants and pH

		
EAnCS6	EAnC76	EAnC96
		
EAnBS6	EAnB76	EAnB96
		
EAnHS6	EAnH76	EAnH96
		
EAnPS6	EAnP76	EAnP96

Key: E=Eri Silk, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 16: Colour palette of Annatto seeds dye on Eri Silk fabric with 6% dye concentration, different mordants and pH

EAnCS8	EAnC78	EAnC98
EAnBS8	EAnB78	EAnB98
EAnHS8	EAnH78	EAnH98
EAnPS8	EAnP78	EAnP98

Key: E=Eri Silk, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 17: Colour palette of Annatto seeds dye on Eri Silk fabric with 8% dye concentration, different mordants and pH

WAnCS2	WAnC72	WAnC92
WAnBS2	WAnB72	WAnB92
WAnHS2	WAnH72	WAnH92
WAnPS2	WAnP72	WAnP92

Key: W=Kutchi Wool, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 18: Colour palette of Annatto seeds dye on Kutchi Wool fabric with 2% dye concentration, different mordants and pH

WAnCS4	WAnC74	WAnC94
WAnBS4	WAnB74	WAnB94
WAnHS4	WAnH74	WAnH94
WAnPS4	WAnP74	WAnP94

Key: W=Kutchi Wool, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 19: Colour palette of Annatto seeds dye on Kutchi Wool fabric with 4% dye concentration, different mordants and pH

		
WAnCS6	WAnC76	WAnC96
		
WAnBS6	WAnB76	WAnB96
		
WAnHS6	WAnH76	WAnH96
		
WAnPS6	WAnP76	WAnP96

Key: W=Kutchi Wool, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 20: Colour palette of Annatto seeds dye on Kutchi Wool fabric with 6% dye concentration, different mordants and pH

		
WAnCS8	WAnC78	WAnC98
		
WAnBS8	WAnB78	WAnB98
		
WAnHS8	WAnH78	WAnH98
		
WAnPS8	WAnP78	WAnP98

Key: W=Kutchi Wool, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 21: Colour palette of Annatto seeds dye on Kutchi Wool fabric with 8% dye concentration, different mordants and pH

NAnCS2	NAnC72	NAnC92
NAnBS2	NAnB72	NAnB92
NAnHS2	NAnH72	NAnH92
NAnPS2	NAnP72	NAnP92

Key: N=Nylon, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 22: Colour palette of Annatto seeds dye on Nylon fabric with 2% dye concentration, different mordants and pH

NAnCS4	NAnC74	NAnC94
NAnBS4	NAnB74	NAnB94
NAnHS4	NAnH74	NAnH94
NAnPS4	NAnP74	NAnP94

Key: N=Nylon, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 23: Colour palette of Annatto seeds dye on Nylon fabric with 4% dye concentration, different mordants and pH

NAnCS6	NAnC76	NAnC96
NAnBS6	NAnB76	NAnB96
NAnHS6	NAnH76	NAnH96
NAnPS6	NAnP76	NAnP96

Key: N=Nylon, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 24: Colour palette of Annatto seeds dye on Nylon fabric with 6% dye concentration, different mordants and pH

NAnCS8	NAnC78	NAnC98
NAnBS8	NAnB78	NAnB98
NAnHS8	NAnH78	NAnH98
NAnPS8	NAnP78	NAnP98

Key: N=Nylon, An=Annatto seeds dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (5.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 25: Colour palette of Annatto seeds dye on Nylon fabric with 8% dye concentration, different mordants and pH

		
EOCS2	EOC72	EOC92
		
EOBS2	EOB72	EOB92
		
EOHS2	EOH72	EOH92
		
EOPS2	EOP72	EOP92

Key: E=Eri Silk, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 26: Colour palette of Onion peels dye on Eri Silk fabric with 2% dye concentration, different mordants and pH

		
EOCS4	EOC74	EOC94
		
EOBS4	EOB74	EOB94
		
EOHS4	EOH74	EOH94
		
EOPS4	EOP74	EOP94

Key: E=Eri Silk, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 27: Colour palette of Onion peels dye on Eri Silk fabric with 4% dye concentration, different mordants and pH

EOCS6	EOC76	EOC96
EOBS6	EOB76	EOB96
EOHS6	EOH76	EOH96
EOPS6	EOP76	EOP96

Key: E=Eri Silk, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 28: Colour palette of Onion peels dye on Eri Silk fabric with 6% dye concentration, different mordants and pH

		
EOCS8	EOC78	EOC98
		
EOBS8	EOB78	EOB98
		
EOHS8	EOH78	EOH98
		
EOPS8	EOP78	EOP98

Key: E=Eri Silk, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 29: Colour palette of Onion peels dye on Eri Silk fabric with 8% dye concentration, different mordants and pH

		
WOCS2	WOC72	WOC92
		
WOBS2	WOB72	WOB92
		
WOHS2	WOH72	WOH92
		
WOPS2	WOP72	WOP92

Key: W=Kutchi Wool, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 30: Colour palette of Onion peels dye on Kutchi Wool fabric with 2% dye concentration, different mordants and pH

		
WOCS4	WOC74	WOC94
		
WOBS4	WOB74	WOB94
		
WOHS4	WOH74	WOH94
		
WOPS4	WOP74	WOP94

Key: W=Kutchi Wool, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 31: Colour palette of Onion peels dye on Kutchi Wool fabric with 4% dye concentration, different mordants and pH

WOCS6	WOC76	WOC96
WOBS6	WOB76	WOB96
WOHS6	WOH76	WOH96
WOPS6	WOP76	WOP96

Key: W=Kutchi Wool, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 32: Colour palette of Onion peels dye on Kutchi Wool fabric with 6% dye concentration, different mordants and pH

WOCS8	WOC78	WOC98
WOBS8	WOB78	WOB98
WOHS8	WOH78	WOH98
WOPS8	WOP78	WOP98

Key: W=Kutchi Wool, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 33: Colour palette of Onion peels dye on Kutchi Wool fabric with 8% dye concentration, different mordants and pH

		
NOCS2	NOC72	NOC92
		
NOBS2	NOB72	NOB92
		
NOHS2	NOH72	NOH92
		
NOPS2	NOP72	NOP92

Key: N=Nylon, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 2=2% dye concentration

Plate 34: Colour palette of Onion peels dye on Nylon fabric with 2% dye concentration, different mordants and pH

		
NOCS4	NOC74	NOC94
		
NOBS4	NOB74	NOB94
		
NOHS4	NOH74	NOH94
		
NOPS4	NOP74	NOP94

Key: N=Nylon, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 4=4% dye concentration

Plate 35: Colour palette of Onion peels dye on Nylon fabric with 4% dye concentration, different mordants and pH

		
NOCS6	NOC76	NOC96
		
NOBS6	NOB76	NOB96
		
NOHS6	NOH76	NOH96
		
NOPS6	NOP76	NOP96

Key: N=Nylon, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 6=6% dye concentration

Plate 36: Colour palette of Onion peels dye on Nylon fabric with 6% dye concentration, different mordants and pH

NOCS8	NOC78	NOC98
NOBS8	NOB78	NOB98
NOHS8	NOH78	NOH98
NOPS8	NOP78	NOP98

Key: N=Nylon, O=Onion peels dye, C=Control sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind, S=Self pH (3.5 pH), 7=7 pH, 9=9 pH, 8=8% dye concentration

Plate 37: Colour palette of Onion peels dye on Nylon fabric with 8% dye concentration, different mordants and pH

4.6 Assessment of the colour yield of the dyed samples

One of the major objectives of the study was to develop a varied colour palette by different permutation combinations of the selected dye with mordants. In order to obtain variation in colour yield various concentration and pH of the dye liquor was done. The research also proposed to evaluate the dyed samples in terms of its colour strength values. Evaluation was done by Premier Spectrophotometer with standard procedure. Colour strength values were evaluated of all 432 dyed samples with three natural dyes, three natural mordants, three different fabrics, dye concentration and pH.

L* value indicates the lightness and darkness index of the sample. The L* value of pure white fabric is 100. The **a*** indicates Redness and Greenness index. If a* is less than zero, it is classified as greener in shade and if the value is more than zero, it is classified as reddish in shade. The **b*** value indicates Yellowness and Blueness index. If b* value is less than zero, then it is classified as blues and if the value is more than zero, it is classified as yellower. **c*** value shows the brightness and dullness of the sample, positive c* value is brighter and negative c* is duller. **DL*** value shows the lightness and darkness of the dyed sample with compare to control sample (Here, the control sample means without mordanted only dyed sample). positive DL means same is lighter and negative means its darker. **DE*** value differentiate the colour change of the dyed samples from the original one which is control sample. **K/S** values depict the colour depth in the shade.

The shade card obtained as a result of the exploration of various dye fiber and mordants and spectrophotometric data of the dyed samples has been discussed below:

4.6.1. Effect of percent concentration of the dye CIELAB values

Table 18: Effect of 2% concentrated Indian almond leaves dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	56.728	3.087	38.758	38.881	-	-	26.336
B4pH	64.409	0.381	39.873	39.875	7.681	8.218	54.870
H4pH	64.633	1.376	39.409	39.433	7.905	8.114	45.734
P4pH	59.303	2.897	37.926	38.036	2.575	2.713	36.044
Control	57.572	3.826	39.185	39.371	-	-	22.551
B7pH	55.713	3.010	40.828	40.939	2.141	2.819	23.812
H7pH	56.538	3.253	38.169	38.307	0.966	1.515	21.635
P7pH	65.823	1.156	39.565	39.582	10.251	10.600	57.279
Control	58.496	4.075	35.777	36.008	-	-	9.848
B9pH	60.565	4.426	38.751	39.003	2.069	3.640	12.895
H9pH	67.303	0.733	37.988	37.995	8.807	9.676	25.733
P9pH	62.101	2.818	35.734	35.845	3.605	3.818	17.409

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 18 gives the colour yield values of 2% concentrated almond leaves dyed Eri Silk samples with various mordants and three different pH i.e., Acidic, Neutral and Alkaline.

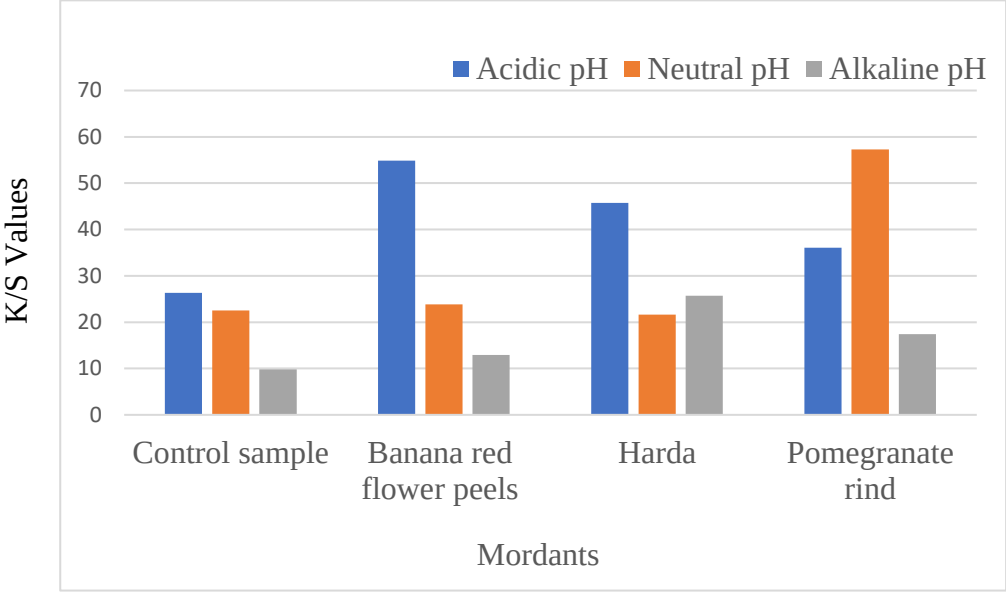
The Harda mordanted sample had a higher L* value (67.303) at an alkaline pH, while the Banana red flower peel mordanted sample had a lower L* value (55.713) at a neutral pH. This indicates that the Harda mordanted sample was lighter at an alkaline pH than all other dyed samples, while the Banana red flower peel mordanted sample was darker at a neutral pH.

From all the positive a* and b* value we can conclude that all the samples contain red and yellow shade. The sample with the highest a* value was a Banana red flower peel mordanted sample at alkaline pH (4.426), which

indicates that it contains more red colour than any other dyed samples. Pomegranate rind mordanted sample at alkaline pH had the lowest b* value while the highest b* value was found in the Banana flower red peel mordanted sample at neutral pH with a value of 40.828, indicating that it was more yellow in colour.

C* indicates the brightness of the colour. Positive c* value showed that the sample were brighter in shade. The sample with the highest c* value (40.939) was a neutral pH sample of Banana red flower peel, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at alkaline pH had the lowest c* value (35.845); as a result, it was a little dull than the other dyed samples.

DL * value showed the lightness and darkness of the shade and the maximum lightness was obtained with Pomegranate rind at neutral pH. From the findings for the DE* values, it can be concluded that the neutral pH Pomegranate rind mordanted sample exhibits more colour change from the control sample.



Graph 1: K/S values of 2% concentrated Indian almond leaves dyed Eri Silk samples with different mordants at various pH

Colour depth of Indian almond leaves as a colorant was shown in Graph 1. Highest colour depth was obtained with Pomegranate rind mordanted sample at

neutral pH (57.279) followed by Banana red flower peel mordanted (54.870) at acidic pH. And Harda mordant at Acidic pH.

Table 19: Effect of 4% concentrated Indian almond leaves dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	55.190	3.458	38.686	38.840	-	-	37.029
B4pH	58.292	2.149	40.117	40.175	3.102	3.658	47.036
H4pH	52.924	4.013	37.430	37.645	-2.266	2.650	24.836
P4pH	60.697	2.420	39.403	39.477	5.507	5.650	60.962
Control	54.981	3.916	39.214	39.409	-	-	24.416
B7pH	53.602	4.053	38.888	39.099	-1.379	1.424	22.573
H7pH	55.925	3.267	37.629	37.771	0.944	1.956	24.352
P7pH	65.209	1.416	39.490	39.515	10.228	10.533	56.542
Control	57.835	3.798	36.935	37.130	-	-	12.431
B9pH	56.727	4.149	36.792	37.025	-1.108	1.171	12.525
H9pH	57.682	2.903	35.610	35.728	-0.153	1.606	16.738
P9pH	60.626	3.110	36.552	36.684	2.793	2.902	20.582

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 19 gives the degree of colour yield of Eri silk samples dyed with 4% concentration of Almond leaves at three different pH i.e., Self (Acidic), Neutral and Alkaline.

At neutral pH, the Pomegranate rind mordanted sample had a greater L* value (65.209), whereas at acidic pH, the Harda mordanted sample had a lower L* value (52.924). This shows that the Pomegranate rind mordanted sample was lighter at neutral pH and the Harda mordanted sample was darker at acidic pH than the other dyed samples.

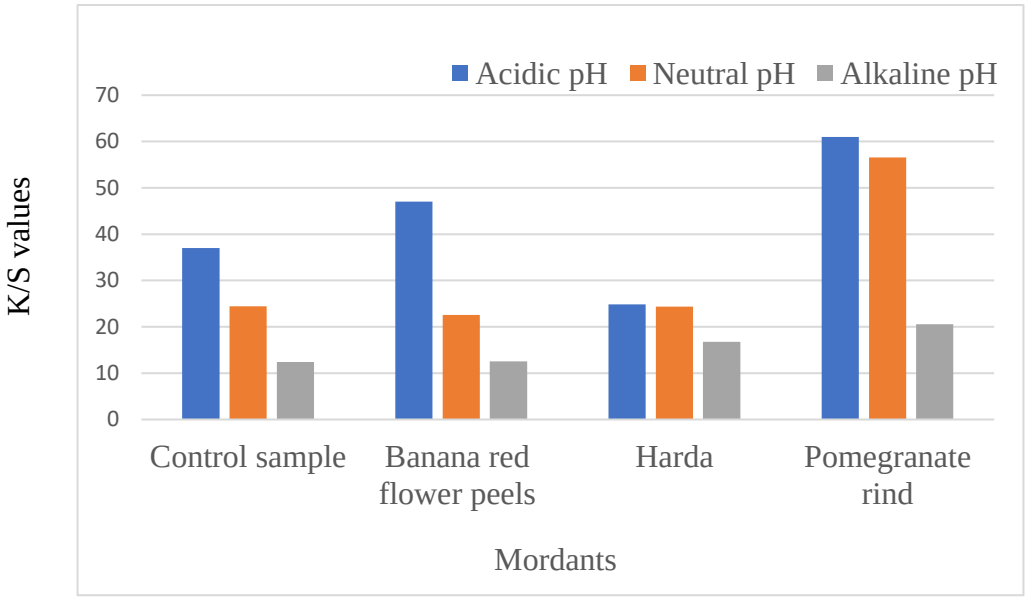
In every sample, positive a* values were observed. This demonstrates that the obtained colour comprises a higher percentage of red than green. The sample

with the highest a* value Banana red flower peel mordanted sample at neutral pH (4.149), meaning it had more red colour than any other dyed samples.

The b* readings of all samples were positive. This shows that the yellow colour component is greater in all samples than the blue colour component. The Harda-mordanted sample had the lowest b* value (35.610), whereas the Banana flower red peel-mordanted sample had the highest b* value (40.117), indicating that it was more yellow in colour and was at a self-pH.

Every sample in this case was brighter in the shade because every c* value was positive. The sample that had the greatest c* value (40.175) and was the brightest of all the dyed samples was Banana red flower peel mordanted sample at acidic pH while at alkaline pH, the Harda mordanted sample exhibited the lowest c* value (35.728), making it appear a little dull than the other dyed samples.

Maximum darkness of the shade was observed with Harda mordanted at acidic pH as it exhibited higher DL* value (-2.266). The Pomegranate peel sample exhibits higher colour change at neutral pH than the control sample, according to the results for the DE* values.



Graph 2: K/S values of 4% concentrated Indian almond leaves dyed Eri Silk samples with different mordants at various pH

Graph 2 showed the K/S value of Eri silk dyed with Indian almon leaves at 4% concentration. On analysis it was found that the Pomegranate rind mordanted sample at self pH has the darkest colour, with a value of 60.962 followed by Banana red flower peels (47.036) at self pH whereas the without mordanted control sample at alkaline pH has the lowest value for colour strength, with a value of 12.431. This was determined from all K/S measurements.

Table 20: Effect of 6% concentrated Indian almond leaves dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	58.956	3.222	32.422	32.582	-	-	30.814
B4pH	58.644	2.988	32.956	33.091	-0.312	0.661	38.470
H4pH	61.335	2.988	33.629	33.761	2.379	2.678	31.645
P4pH	58.553	3.891	31.547	31.786	-0.403	1.173	36.299
Control	54.362	4.109	39.915	40.126	-	-	13.154
B7pH	57.003	2.766	40.512	40.606	2.641	3.022	18.251
H7pH	55.496	3.418	38.494	38.645	1.134	1.945	22.288
P7pH	69.306	0.191	40.065	40.065	14.944	15.551	21.313
Control	57.538	4.007	37.450	37.664	-	-	8.534
B9pH	58.248	3.655	37.750	37.927	0.710	0.847	9.642
H9pH	61.678	2.695	38.579	38.673	4.140	4.487	9.085
P9pH	59.996	3.166	36.709	36.845	2.458	2.702	8.729

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 20 gives the colour yield of 6% concentrated almond leaves dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The Harda treated sample had lower L* value (55.496) at neutral pH while the Pomegranate rind mordanted sample had a higher L* value (69.306). This indicates that the Harda mordanted was darker at neutral pH than all other dyed

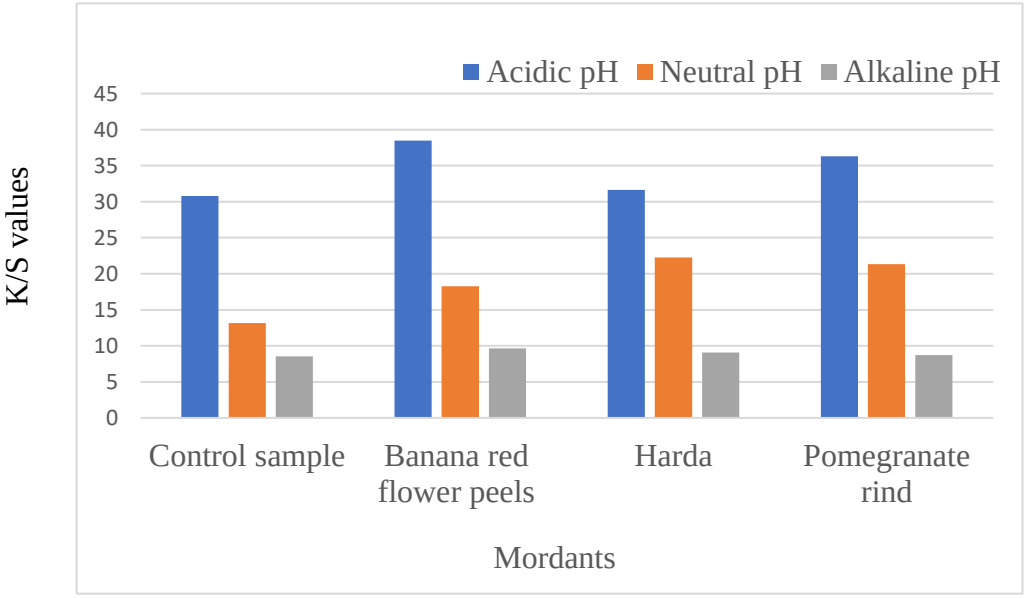
samples, whereas the Pomegranate rind mordanted sample was lighter at neutral pH.

In every sample, positive a* values were observed. This demonstrates that the obtained colour comprises a higher percentage of red component than green. The sample with the highest a* value was control sample at neutral pH (4.109), which means it contains more red colour than any other dyed sample.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Pomegranate rind mordanted sample at self pH had the lowest b* value (31.547) while the highest b* value was found in the Banana flower red peel mordanted sample at neutral pH with a value of 40.512, indicating that it was more yellow in colour.

Every sample in this case was brighter in the shade because every c* value was positive. The Banana red flower peel mordanted sample at neutral pH that had the greatest c* value (40.606) was the brightest of all the dyed samples. Although the Pomegranate rind mordanted sample had the lowest c* value (31.786) compared to the other dyed samples, it appeared a little dull.

Highest DL* value (-0.403) and DE* value (15.551) obtained with Pomegranate rind mordanted sample at acidic pH and neutral pH respectively.



Graph 3: K/S values of 6% concentrated Indian almond leaves dyed Eri Silk samples with different mordants at various pH

Graph 3 represent the K/S value of Indian almond leaves at 6% concentration. The Banana red flower peels mordanted sample at acidic pH has the darkest colour, with a value of 38.470, whereas the without mordanted control sample at alkaline pH has the lowest value for colour strength, with a value of 8.534.

Table 21: Effect of 8% concentrated Indian almond leaves dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	57.003	3.060	38.642	38.763	-	-	29.721
B4pH	61.728	1.143	39.517	39.534	5.274	5.679	54.808
H4pH	56.398	3.367	38.035	38.184	0.944	1.164	27.977
P4pH	62.669	1.895	39.167	39.213	6.215	6.345	55.438
Control	57.403	3.243	37.555	37.695	-	-	15.544
B7pH	62.660	1.496	39.978	40.006	5.257	6.046	27.961
H7pH	67.612	0.331	38.710	38.711	10.209	10.679	40.603
P7pH	76.760	0.501	37.420	37.503	19.357	20.192	45.134
Control	58.066	3.487	37.651	37.812	-	-	13.862
B9pH	60.606	3.036	38.806	38.925	2.540	2.826	22.573
H9pH	58.903	3.032	36.984	37.108	0.837	1.163	17.302
P9pH	56.804	3.741	35.489	35.686	-1.262	2.516	15.648

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 21 gives the colour strength values of 8% concentrated Indian almond leaves dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

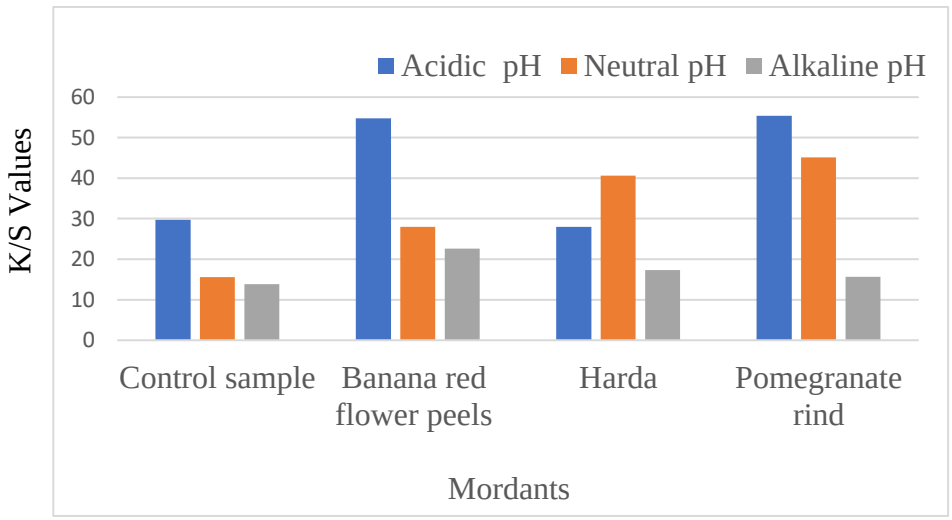
The Pomegranate rind mordanted sample had a higher L* value (76.760) at neutral pH, while the Harda mordanted sample at acidic had a lower L* value (56.393) at acidic pH. This indicates that the Pomegranate rind mordanted sample was lighter at neutral pH than all other dyed samples, while the Harda mordanted sample was darker at self pH.

Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was Pomegranate rind mordanted sample at alkaline pH (3.741), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Pomegranate rind mordanted sample at alkaline pH had the lowest b* value (35.489) while the highest b* value was found in the Banana flower red peel mordanted sample at neutral pH with a value of 39.978, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (40.006) was a neutral pH sample of Banana red flower peel, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at alkaline pH had the lowest c* value (35.686); as a result, it was a little dull than the other dyed samples.

Highest darkness was observed the sample dyed in alkaline pH (-1.262) of Pomegranate rind mordanted sample rest of the samples showed lightness. From the findings for the DE* values, it can be concluded that the Pomegranate rind mordanted sample at neutral pH (20.192) exhibits more colour change from the control sample.



Graph 4: K/S values of 8% concentrated Indian almond leaves dyed Eri Silk samples with different mordants at various pH

Graph 4 showed the K/S values of Indian almond leaves at 8% concentration. The Banana red flower mordanted sample at self (acidic) pH has the deepest colour with a value of 55.438 and the without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 13.862.

Table 22: Effect of 2% concentrated Indian almond leaves dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	51.736	3.001	37.155	37.276	-	-	71.050
B4pH	65.456	-0.308	40.178	40.179	13.720	14.434	80.206
H4pH	60.048	1.585	39.716	39.748	8.312	8.812	74.113
P4pH	97.246	-5.026	13.116	14.046	45.510	42.091	79.994
Control	48.909	4.701	38.407	38.694	-	-	65.493
B7pH	42.509	6.728	37.671	38.267	-6.400	6.754	32.274
H7pH	40.205	5.660	32.973	33.455	-8.704	10.306	24.507
P7pH	40.223	6.210	33.402	33.974	-8.686	10.138	23.353
Control	54.092	6.833	36.973	37.599	-	-	12.709
B9pH	55.342	5.161	36.514	36.877	1.250	2.137	13.849
H9pH	55.617	4.537	35.129	35.421	1.525	3.316	11.723
P9pH	59.011	3.917	37.739	37.942	4.919	5.769	18.273

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 22 gives the colour yield of 2% concentrated Indian almond leaves dyed Kutchi Wool fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The L* value of the Harda mordanted sample was lower (40.205) at neutral pH compared to the Pomegranate rind mordanted sample, which had a higher L* value (97.246) at acidic pH. This indicates that, in comparison to the other dyed samples, the Pomegranate rind-mordanted sample was lighter at a acidic pH, but the Harda-mordanted sample was darker at a neutral pH.

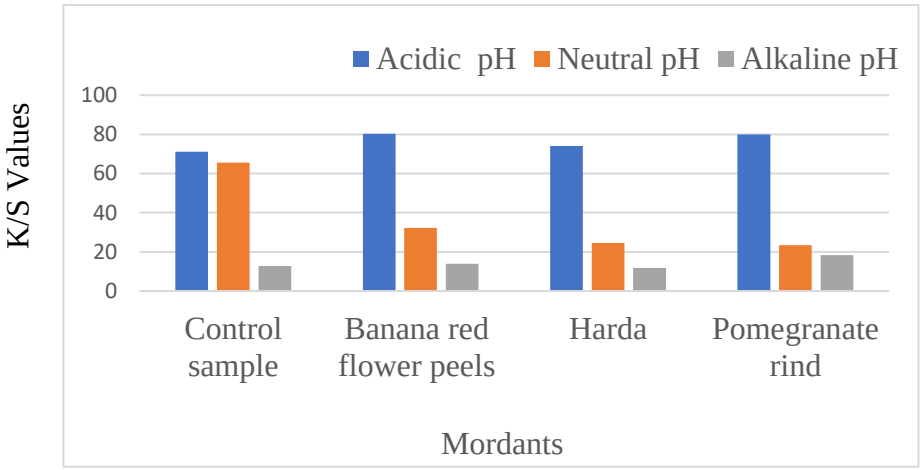
Positive a* values were seen in most of the sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (6.883), which indicates that it contains more red colour than any other dyed samples.

In every sample, the b* values were positive. This demonstrates that more yellow than blue was present in each sample. The Pomegranate rind mordanted sample had the lowest b* value (13.116), whereas the Banana red flower peel mordanted sample had the highest b* value (40.178 at acidic pH in both the cases indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (40.179) was acidic pH sample of Banana red flower peel mordant, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at self pH had the lowest c* value (14.046); as a result, it was a little dull than the other dyed samples.

The majority of the samples had DL* values that were higher than 0. Only samples with an alkaline pH showed DL* values below zero.

Higher DL values (negative) and maximum darkness was observed on the Banana red flower peel mordanted samples (-6.400) at neutral pH. The Pomegranate rind mordanted sample at self pH demonstrates higher colour change from the control sample (42.091).



Graph 5: K/S values of 2% concentrated Indian almond leaves dyed Kutchi Wool samples with different mordants at various pH

From all K/S values, it was found from the Graph 5 that the Harda mordanted sample at alkaline pH had the lowest value for colour strength, with a value of 11.723 and the Banana red flower peel mordanted sample at acidic pH had the deepest colour with a value of 80.206.

Table 23: Effect of 4% concentrated Indian almond leaves dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	52.086	2.726	36.791	36.892	-	-	58.106
B4pH	97.216	-5.226	13.627	14.595	45.130	51.347	70.101
H4pH	97.471	-4.888	12.396	13.325	45.385	52.085	62.458
P4pH	97.490	-4.838	12.465	13.371	45.404	52.062	72.655
Control	49.589	4.265	37.755	37.995	-	-	51.142
B7pH	50.687	5.114	40.466	40.788	1.098	3.046	46.806
H7pH	89.295	-5.667	26.974	27.563	39.706	42.325	45.291
P7pH	51.858	4.929	38.938	39.249	2.269	2.644	50.498
Control	51.813	6.455	37.816	38.363	-	-	18.909
B9pH	52.882	6.086	38.856	39.330	1.069	1.536	19.915
H9pH	54.046	4.508	37.224	37.496	2.233	3.021	17.335
P9pH	57.746	4.092	39.899	40.108	5.933	6.717	28.180

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 23 gives the Colour yield values of 4% concentrated Indian almond leaves dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

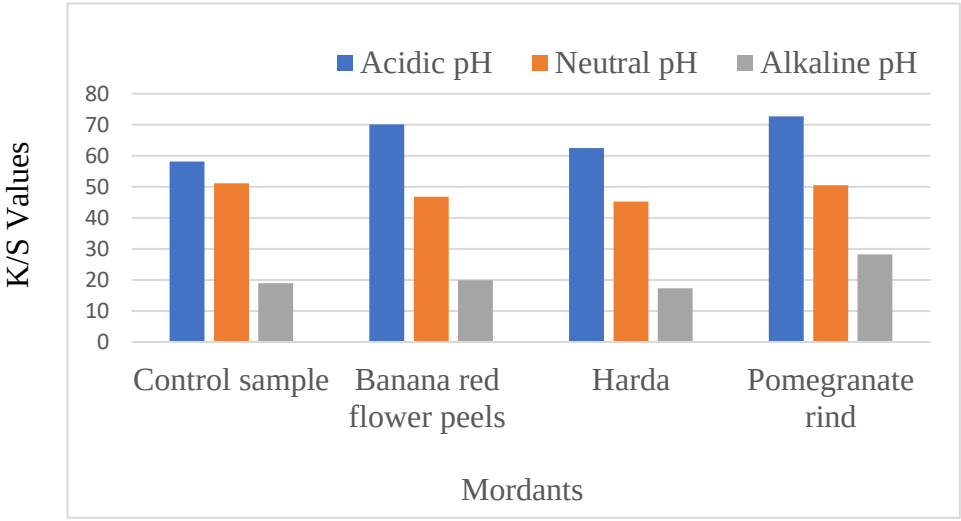
The Pomegranate mordanted sample had a higher L* value (97.490) at acidic pH, while the control sample had a lower L* value (49.589) at a neutral pH. This indicates that the Pomegranate rind mordanted sample was lighter at self pH than all other dyed samples, while the control sample was darker at a neutral pH.

Positive a* values were seen in most of the sample. This shows that the obtained colour, contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (6.455), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Harda mordanted sample at self pH had the lowest b* value (12.396) while the highest b* value was found in the Banana flower red peel mordanted sample at neutral pH with a value of 40.466, indicating that it was more yellow in colour.

In this case, every sample's c* value was positive, making it brighter in the shade. The brightest of all the dyed samples, the neutral pH sample of Banana red flower peel had the greatest c* value (40.788). The sample that was Harda mordanted at acidic pH had the lowest c* value (13.325), making it a bit dull than the other dyed samples.

Highest lightness was observed on the Pomegranate rind at acidic pH (45.404). From DL* value it can be concluded that the Harda mordanted sample at acidic pH exhibits more colour change (52.085) from the control sample.



Graph 6: K/S values of 4% concentrated Indian almond leaves dyed Kutchi Wool samples with different mordants at various pH

The K/S values in Graph 6 were discussed. It was discovered that the Pomegranate rind mordanted sample at acidic pH has the deepest colour with a value of 72.655 and the Harda mordanted sample of alkaline pH has the lowest value for colour strength with a value of 17.335.

Table 24: Effect of 6% concentrated Indian almond leaves dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	56.780	3.305	30.933	31.109	-	-	21.233
B4pH	59.172	2.691	32.996	33.106	2.392	3.218	30.761
H4pH	61.869	2.838	35.466	35.579	5.089	6.831	27.580
P4pH	60.213	3.701	34.220	34.420	3.433	4.769	61.976
Control	54.312	4.145	37.769	37.996	-	-	21.707
B7pH	71.213	1.207	43.168	43.168	16.901	18.268	27.499
H7pH	58.939	2.939	38.544	38.656	4.627	4.844	14.109
P7pH	67.443	0.767	40.017	40.024	13.131	13.744	26.451
Control	51.145	6.878	38.575	39.183	-	-	9.443
B9pH	54.545	5.774	40.973	41.378	3.400	4.305	11.837
H9pH	50.700	4.508	35.072	35.361	0.445	4.253	13.502
P9pH	55.908	4.874	40.190	40.484	4.763	5.414	12.359

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 24 exhibits the colour yield of 6% concentrated almond leaves dyed Kutchi Wool fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

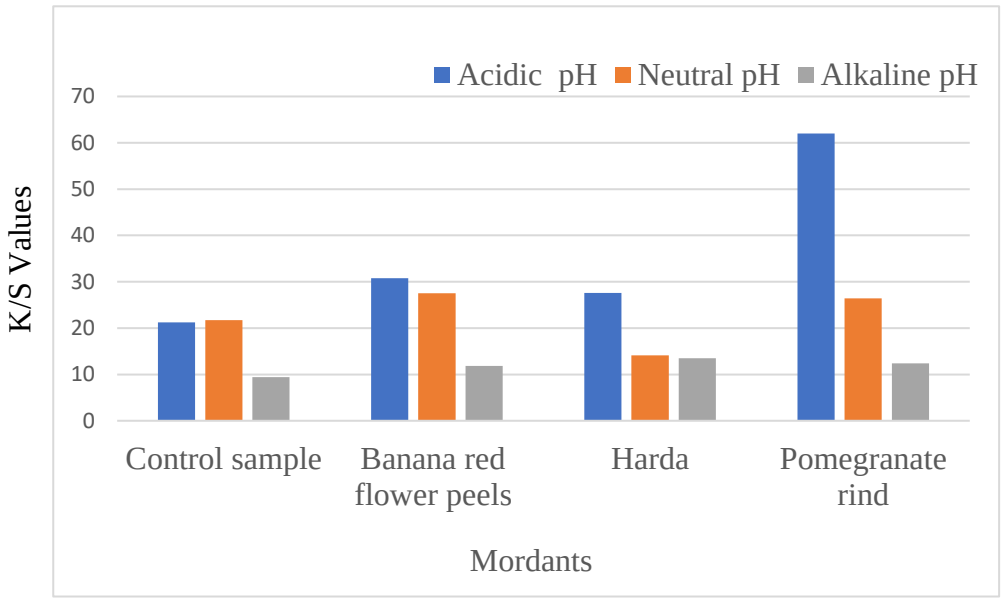
The Banana red flower peel mordanted sample had a higher L* value (71.213) at neutral pH, while control sample had a lower L* value (51.145) at alkaline pH. This indicates that the Banana red flower peel mordanted sample was lighter at neutral pH than all other dyed samples, while the control sample was darker at alkaline pH.

Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (6.878), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The control sample at self pH had the lowest b* value (30.933) while the highest b* value was found in the Banana flower red peel mordanted sample at neutral pH with a value of 43.168, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (43.168) was a neutral pH sample of Banana red flower peel, making it the brightest of all the dyed samples. Control sample at acidic pH had the lowest c* value (31.109); as a result, it was a little dull than the other dyed samples.

All of the samples had DL* values greater than 0. This indicates that all of the samples were somewhat lighter than the control standard samples. From the findings for the DE* values, it can be concluded that the neutral pH Banana red flower mordanted sample exhibits more colour change from the control sample.



Graph 7: K/S values of 6% concentrated Indian almond leaves dyed Kutchi Wool samples with different mordants at various pH

Maximum depth of colour was seen in Pomegranate rind mordanted sample at self pH and it showed highest K/S value (61.976) as depicted in Graph 7 and the without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 9.443.

Table 25: Effect of 8% concentrated Indian almond leaves dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	51.775	3.138	35.961	36.098	-	-	45.046
B4pH	65.944	-0.270	40.129	40.130	14.169	15.157	58.773
H4pH	65.998	-0.310	39.150	39.151	14.223	14.978	49.953
P4pH	97.649	-4.859	12.335	13.258	45.874	52.217	59.528
Control	52.101	4.085	37.035	37.260	-	-	28.197
B7pH	57.426	3.907	41.877	42.059	5.325	7.199	38.942
H7pH	60.192	2.193	39.697	39.758	8.091	8.725	39.167
P7pH	58.962	3.335	39.633	39.773	6.861	7.375	43.929
Control	53.033	5.841	36.944	37.403	-	-	16.363
B9pH	53.678	5.074	37.225	37.569	0.645	1.041	16.497
H9pH	56.268	3.196	36.079	36.220	3.235	4.267	15.103
P9pH	60.699	3.275	39.388	39.524	7.666	8.445	27.695

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Colour yield 8% concentrated almond leaves dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline was discussed in Table 25.

The control sample exhibited a lower L* value (51.775) at a acidic pH, whereas the Pomegranate rind mordanted sample had a higher L* value (97.649). This shows that compared to the other dyed samples, the Pomegranate rind

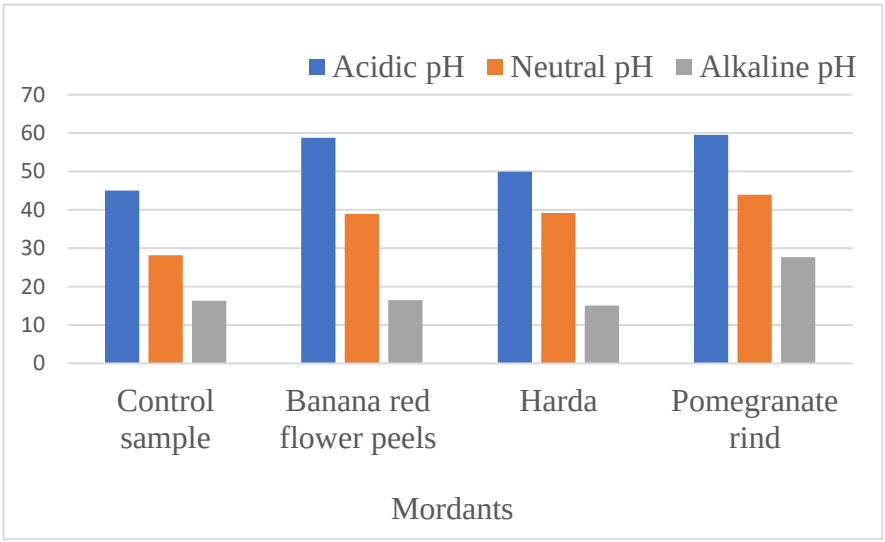
mordanted sample was lighter at a acidic pH, whereas the control sample was darker at self pH.

Positive a* values were seen in most of the sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (5.841), which indicates that it contains more red colour than any other dyed samples.

The b* readings of all samples were positive. This shows that the yellow colour component is greater in all samples than the blue colour component. The Banana red flower peel mordanted sample at neutral pH had the highest b* value with a value of 41.877, suggesting that it was more yellow in colour. The Pomegranate rind mordanted sample at self pH had the lowest b* value (12.335).

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (42.059) was a neutral pH sample of Banana red flower peel mordant, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at self pH had the lowest c* value (13.258); as a result, it was a little dull than the other dyed samples.

Highest Lightness and highest colour change from the original sample was observed on the sample dyed in acidic medium at 4 pH with Pomegranate rind (45.874) and (52.217) respectively.



Graph 8: K/S values of 8% concentrated Indian almond leaves dyed Kutchi Wool samples with different mordants at various pH

It was analysis from the Graph 8 that the Pomegranate rind mordanted sample at acidic pH has the deepest colour with a value of 59.528 and the Harda mordanted sample of alkaline pH has the lowest value for colour strength with a value of 15.103.

Table 26: Effect of 2% concentrated Indian almond leaves dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	70.178	0.135	39.764	39.764	-	-	11.351
B4pH	63.904	1.135	37.082	37.099	-6.274	6.896	6.039
H4pH	64.476	1.995	37.936	37.988	-5.702	6.270	5.666
P4pH	63.041	4.370	38.042	38.292	-7.137	8.476	6.700
Control	72.315	0.777	33.556	33.565	-	-	5.002
B7pH	68.236	0.109	32.580	32.580	-0.324	1.226	5.986
H7pH	74.010	0.226	34.509	34.510	-0.538	1.225	3.435
P7pH	65.200	1.700	33.489	33.532	-1.898	2.112	5.020
Control	70.801	0.524	32.665	32.669	-	-	4.278
B9pH	58.333	0.886	32.248	32.260	-0.402	0.683	4.329
H9pH	69.320	4.147	29.947	30.233	-6.839	8.203	1.458
P9pH	61.857	2.927	29.630	29.774	-7.964	8.855	2.013

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

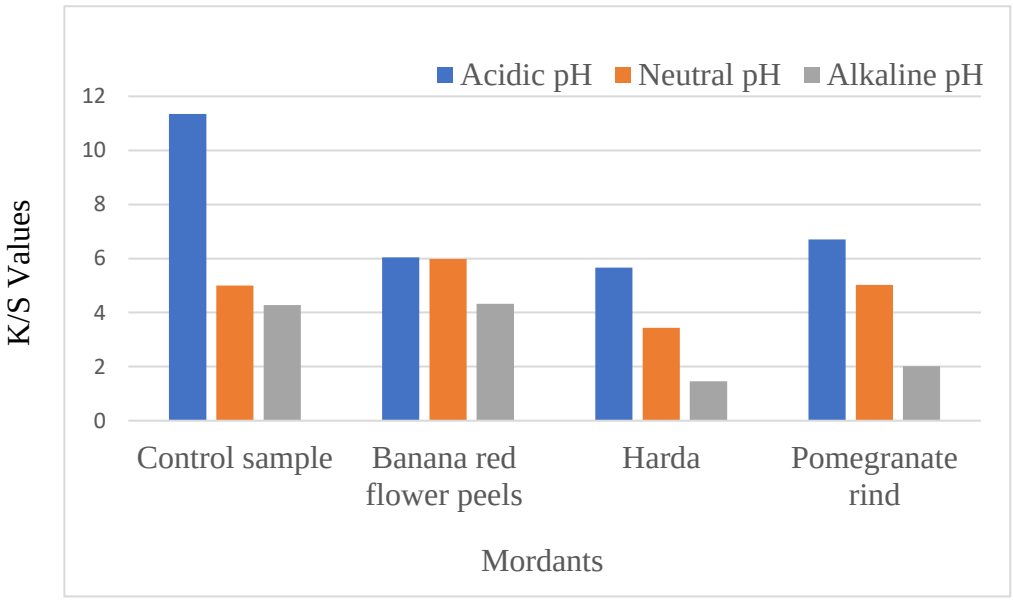
Table 26 gives the Colour yield of 2% concentrated almond leaves dyed Nylon samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The Harda mordanted sample had a higher L* value (74.010) at neutral pH, while the Banana red flower peel sample had a lower L* value (58.333) at alkaline pH. This indicates that the Harda mordanted sample was lighter at neutral pH than all other dyed samples, while the Banana red flower peel sample was darker at alkaline pH.

The sample with the highest a* value was Pomegranate rind mordanted sample at self pH (4.370), which indicates that it contains more red colour than any other dyed samples. The control sample at self pH had the highest b* value (39.764) while the lowest b* value was found in the Pomegranate rind mordanted sample at alkaline pH with a value of 29.630, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (39.764) was a control sample at self pH, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at alkaline pH had the lowest c* value (29.774); as a result, it was a little dull than the other dyed samples.

Highest darkness was observed in the sample dyed in alkaline pH with Pomegranate rind (-7.964). Sample dyed Pomegranate rind at alkaline pH exhibits (8.855) more colour change than the control sample.



Graph 9: K/S values of 2% concentrated Indian almond leaves dyed Nylon samples with different mordants at various pH

It was observed from the Graph 9 that the control sample at acidic pH has the deepest colour with a value of 11.351 and the Harda mordanted sample of alkaline pH has the lowest value for colour strength with a value of 1.458.

Table 27: Effect of 4% concentrated Indian almond leaves dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	69.672	0.730	41.793	41.799	-	-	13.210
B4pH	62.978	1.784	38.057	38.099	-6.694	7.738	7.145
H4pH	64.426	2.531	38.946	39.028	-5.246	6.235	6.522
P4pH	58.354	5.268	36.851	37.226	-11.318	-11.318	4.934
Control	70.655	0.328	27.229	27.231	-	-	2.385
B7pH	69.418	-1.523	28.380	28.421	4.756	5.232	8.076
H7pH	64.663	-1.767	29.511	29.564	4.886	5.785	4.337
P7pH	60.963	-0.297	30.109	30.110	3.673	4.709	5.264
Control	71.114	1.026	32.268	32.284	-	-	4.136
B9pH	71.556	0.766	31.673	31.682	0.442	0.785	5.354
H9pH	66.182	3.344	29.895	30.081	-4.932	5.944	1.973
P9pH	64.193	3.468	29.506	29.709	-6.921	7.842	1.865

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Colour yield values of 4% concentrated almond leaves dyed Nylon samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline was given in Table 27.

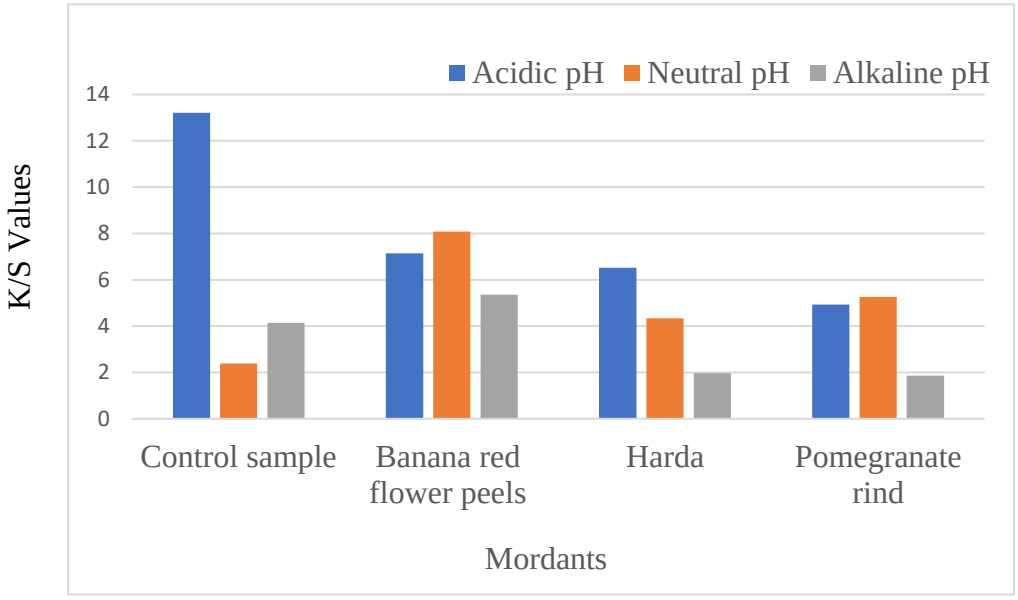
The Banana red flower peels mordanted sample had a higher L* value (71.556) at alkaline pH, while the Pomegranate rind mordanted sample and lower L* value (58.354) at acidic pH.

Only neutral pH mordanted samples had negative a* values. This shows that all the dyed sample contains a greater proportion of red component than green accept neutral pH mordanted samples. The sample with the highest a* value was Pomegranate rind mordanted sample at acidic pH (5.268), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The control sample at neutral pH had the lowest b* value (27.229) while the highest b* value was found in the control sample at self pH with a value of 41.793, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (41.799) was control sample at acidic pH, making it the brightest of all the dyed samples. Control sample at neutral pH had the lowest c* value (27.231); as a result, it was a little dull than the other dyed samples.

Highest lightness was observed on the sample dyed in neutral pH with Harda (4.886) and sample dyed in showed the darkness in the Pomegranate mordanted at acidic sample (-11.318). From the findings for the DE* values, it can be concluded that the Pomegranate rind sample at acidic pH exhibits (-11.318) more colour change than the control sample.



Graph 10: K/S values of 4% concentrated Indian almond leaves dyed Nylon samples with different mordants at various pH

From Graph 10 it was analyzed that the K/S values of control sample at acidic pH has the deepest colour with a value of 13.210 and the Pomegranate

mordanted sample at alkaline pH has the lowest value for colour strength with a value of 1.865.

Table 28: Effect of 6% concentrated Indian almond leaves dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	72.769	0.361	36.643	36.645	-	-	5.466
B4pH	69.582	0.730	34.920	34.928	-3.187	3.642	8.192
H4pH	70.331	1.268	35.424	35.447	-2.438	2.873	3.020
P4pH	67.324	3.432	34.100	34.272	-5.445	6.749	3.831
Control	65.014	0.780	25.489	25.501	-	-	2.016
B7pH	67.265	-2.896	27.067	27.221	7.897	8.852	3.725
H7pH	68.369	-2.103	28.427	28.505	6.756	7.911	4.228
P7pH	61.546	-1.068	28.196	28.216	4.769	5.787	5.189
Control	65.852	0.547	34.424	34.428	-	-	4.920
B9pH	67.633	1.185	33.127	33.148	-1.493	2.078	5.114
H9pH	71.200	4.157	30.427	30.710	-7.987	9.633	1.747
P9pH	69.635	3.623	29.819	30.038	-9.519	11.013	1.893

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 28 gives the colour yield values of 6% concentrated almond leaves dyed Nylon samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The control sample had a higher L* value (72.769) at acidic pH, while the Pomegranate mordanted sample had a lower L* value (61.546) at a neutral pH. This indicates that the control sample was lighter at self pH than all other dyed samples, while Pomegranate mordanted sample was darker at a neutral pH.

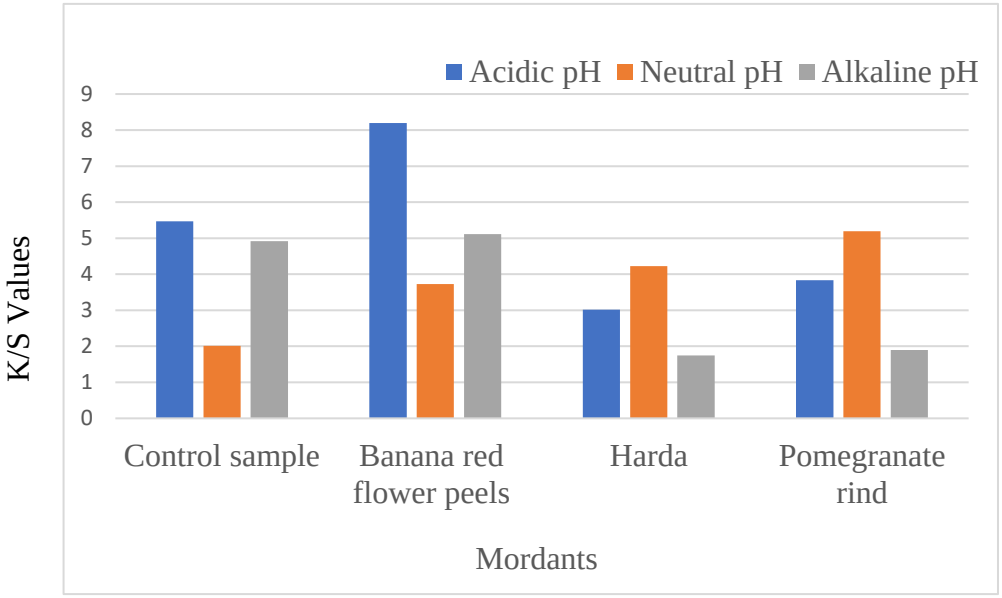
Positive a* values were seen in most of the sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was Harda mordanted sample at alkaline pH (4.157), which indicates that it contains more red colour than any other dyed samples.

All the mordanted samples at neutral pH mordanted samples had negative a* values.

All samples had positive b* values. Control sample at neutral pH had the lowest b* value (25.489) while the highest b* value was found in the control sample at acidic pH with a value of 36.643, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (36.645) was control sample at self pH, making it the brightest of all the dyed samples. Control sample at neutral pH had the lowest c* value (25.501); as a result, it was a little duller than the other dyed samples.

Highest DL* value was seen in Pomegranate rind mordanted sample at alkaline pH (-9.519) which means the shade is darker and DE* valued was observed highest in same sample (11.013).



Graph 11: K/S values of 6% concentrated Indian almond leaves dyed Nylon samples with different mordants at various pH

The K/S values in Graph 11, Shows that the Banana red flower peel mordanted sample at self pH has the deepest colour with a value of 8.192 and Harda mordanted sample of alkaline pH has the lowest value for colour strength with

a value of 1.747. Vadwala Y. and Kola N. (2017) also reported similar result at self pH with metallic mordants.

Table 29: Effect of 8% concentrated Indian almond leaves dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	69.979	0.271	40.525	40.526	-	-	12.317
B4pH	64.461	1.257	37.983	38.004	-5.518	6.155	7.711
H4pH	64.936	2.398	38.962	39.036	-5.043	5.692	5.957
P4pH	61.682	4.228	37.353	37.592	-8.297	9.724	7.022
Control	70.633	0.782	28.328	28.339	-	-	4.707
B7pH	68.024	-2.324	29.569	29.660	5.869	6.755	6.150
H7pH	64.685	-2.102	29.728	29.802	5.438	6.313	4.881
P7pH	60.522	-0.681	30.022	30.030	4.082	4.655	6.025
Control	70.460	0.921	33.175	33.188	-	-	2.441
B9pH	71.546	0.355	33.074	33.076	1.086	1.229	5.409
H9pH	64.326	3.469	29.821	30.022	-6.134	7.441	1.868
P9pH	62.748	3.308	29.172	29.359	-7.712	9.011	2.106

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 29 gives the Colour yield of 8% concentrated almond leaves dyed Nylon samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The Banana red flower peel mordanted sample had a higher L* value (71.546) at alkaline pH, while the Pomegranate rind mordanted sample had a lower L* value (61.682) at self pH. This indicates that the Banana red flower peel mordanted sample was lighter at an alkaline pH than all other dyed samples, while the Pomegranate rind mordanted sample was darker at self pH.

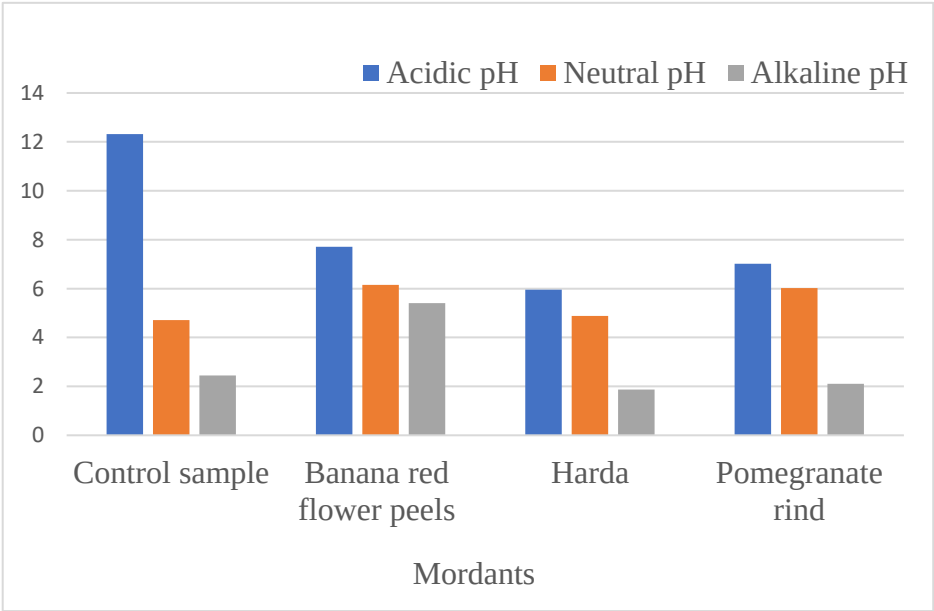
Positive a* values were seen in most of the sample. The sample with the highest a* value was Pomegranate rind mordanted sample at self pH (4.228), which indicates that it contains more red colour than any other dyed samples. All the

sample mordanted at neutral pH had negative a* value which shows that the obtained colour contains a greater proportion of green component.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. Control sample at neutral pH had the lowest b* value (28.328) while the highest b* value was found in the control sample at self pH with a value of 40.525, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (40.526) was control sample at self pH, making it the brightest of all the dyed samples. Control sample at neutral pH had the lowest c* value (28.339); as a result, it was a little dull than the other dyed samples.

Pomegranate at acidic pH had maximum darkness value (-8.297) and it also exhibits more (9.724) colour change than the control sample.



Graph 12: K/S values of 8% concentrated Indian almond leaves dyed Nylon samples with different mordants at various pH

From the Graph 12 it was analysis that the control sample at acidic pH has the deepest colour with a value of 12.317 and Harda mordanted sample of alkaline pH has the lowest value for colour strength with a value of 1.868.

Table 30: Effect of 2% concentrated Annatto seeds dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	66.659	19.448	44.187	48.277	-	-	3.509
B5.5pH	61.565	11.350	37.048	38.748	-5.094	11.937	2.680
H5.5pH	61.666	9.844	40.077	41.268	-4.993	11.578	2.275
P5.5pH	64.475	13.434	43.560	45.584	-2.184	6.429	5.548
Control	66.565	22.090	47.287	52.192	-	-	4.196
B7pH	69.233	18.989	51.487	54.877	2.668	5.863	7.914
H7pH	64.368	19.490	46.317	50.251	-2.197	-2.600	5.119
P7pH	59.517	15.164	40.984	43.699	-7.048	11.721	4.147
Control	66.095	27.064	53.659	60.098	-	-	6.520
B9pH	72.475	22.386	61.695	65.631	6.380	11.277	24.339
H9pH	62.352	22.289	52.550	57.082	-3.743	6.168	8.034
P9pH	66.598	20.351	58.560	61.995	0.503	8.327	22.095

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 30 gives the CIELAB values of 2% concentrated Annatto seed dyed Eri Silk fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

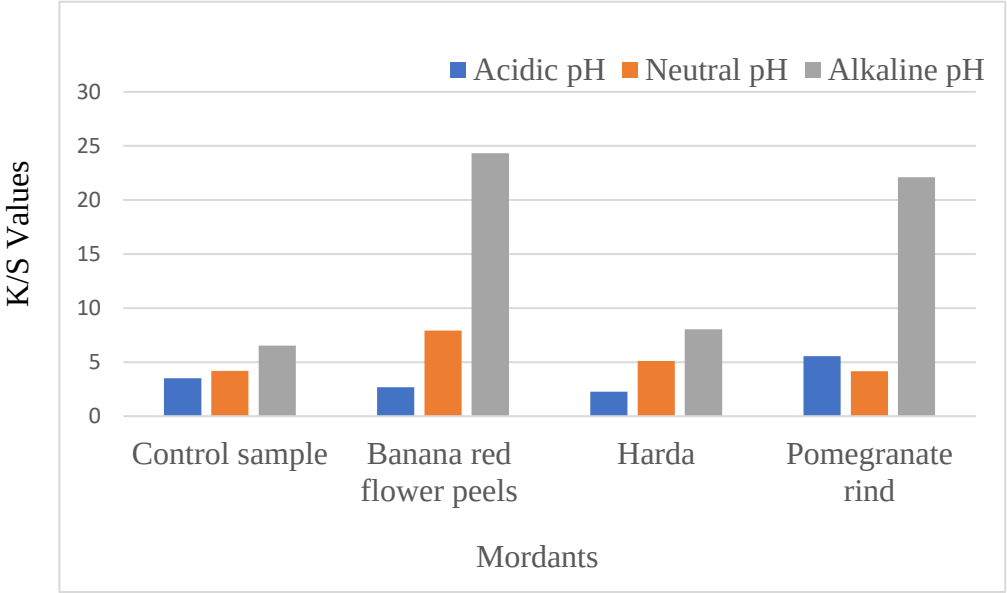
The Pomegranate rind mordanted sample had a lower L* value (59.517) at a neutral pH whereas the Banana red flower peel mordanted sample had a higher L* value (72.475) at an alkaline pH. This shows that the Pomegranate rind mordanted sample was darker at a neutral pH, and the Banana red flower peel mordanted sample was lighter at an alkaline pH than all other dyed samples.

In each sample, positive a* values were observed. This indicates that the obtained colour has a higher proportion of red than green. The sample with the highest a* value was the control sample at an alkaline pH (27.064), indicating that it contains more red colour than any other dyed samples.

The b* values of all samples were positive. This shows that the yellow colour component is greater in all samples than the blue colour component. The Banana red flower peel mordanted sample with self pH had the lowest b* value (37.048), whereas the sample with alkaline pH had the highest b* value (61.695), indicating that it was more yellow in colour.

Every c* value was positive in this case, making every sample brighter in the shade. The sample with the highest c* value (65.631) was Banana red flower peel mordanted sample at alkaline pH, making it the brightest of all the dyed samples. The Banana red flower peel mordanted sample at self pH had the lowest c* value (38.748); as a result, it was a little dull than the other dyed samples.

Maximum darkness of the shade was observed with Pomegranate rind mordanted sample at neutral pH (-7.048) followed by Banana red flower feel at self-acidic pH (-5.094). Based on the results for the DE* values, it can be said that the sample of Banana red flower peel that has been mordanted at self pH shows a higher colour change (11.937) from the control sample.



Graph 13: K/S values of 2% concentrated Annatto seeds dyed Eri Silk samples with different mordants at various pH

From all K/S values, it was found from the Graph 13 the Harda mordanted sample at self pH has the weakest value for colour strength, measuring 2.275,

while the Banana red flower peel mordanted sample at alkaline pH has the darkest colour, measuring 24.339.

Table 31: Effect of 4% concentrated Annatto seeds dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	65.586	20.512	46.589	50.905	-	-	4.188
B5.5pH	64.710	15.956	45.841	48.539	-0.876	4.699	4.577
H5.5pH	62.197	13.249	44.523	46.452	-3.389	8.277	3.029
P5.5pH	64.256	14.673	47.173	49.402	-1.330	6.017	7.790
Control	62.711	26.688	55.781	61.837	-	-	8.725
B7pH	58.641	21.991	51.421	55.926	-4.070	7.592	6.067
H7pH	55.094	22.587	47.841	52.905	-7.617	11.742	5.185
P7pH	49.705	17.499	41.262	44.819	-13.006	21.550	4.338
Control	63.445	30.757	65.024	71.931	-	-	14.086
B9pH	55.411	24.920	53.897	59.379	-8.034	14.914	9.321
H9pH	55.145	26.709	55.282	61.396	-8.300	13.428	10.453
P9pH	55.663	24.523	55.880	61.024	-7.782	13.529	15.021

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 31 gives the colour yield values of 4% concentrated Annatto seeds dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The control sample had a higher L* value (65.586) at self (acidic) pH, while the Pomegranate rind mordanted sample had a lower L* value (49.705) at a neutral pH. This indicates that control sample was lighter at self pH than all other dyed samples, while the Pomegranate rind mordanted sample was darker at a neutral pH.

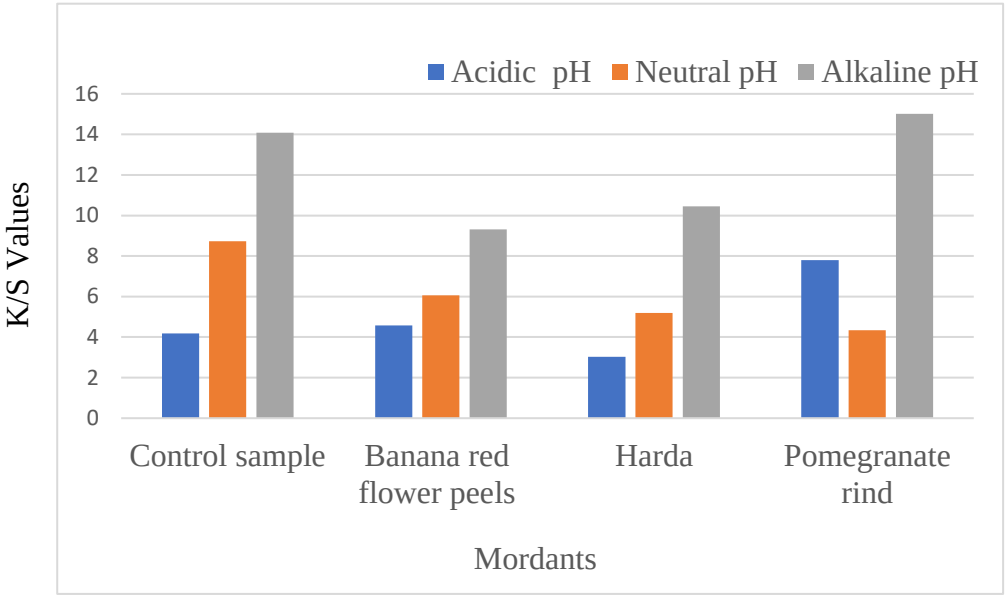
Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample

with the highest a* value was control sample at alkaline pH (30.757), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Pomegranate rind mordanted sample at neutral pH had the lowest b* value (41.262) while the highest b* value was found in the control sample at alkaline pH with a value of 65.024, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (71.931) was control sample at alkaline pH, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at neutral pH had the lowest c* value (44.819); as a result, it was a little dull than the other dyed samples.

Maximum darkness of shade was observed with Pomegranate rind at neutral pH as it exhibited highest DL* value (-13.006). It also showed highest DL* value.



Graph 14: K/S values of 4% concentrated Annatto seeds dyed Eri Silk samples with different mordants at various pH

Graph 14 showed that the Pomegranate rind mordanted sample at alkaline pH has the deepest colour with a value of 15.021 and the Harda mordanted sample of self pH has the lowest value for colour strength with a value of 3.029.

Table 32: Effect of 6% concentrated Annatto seeds dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	67.086	18.544	44.316	48.039	-	-	3.408
B5.5pH	65.879	14.775	42.574	45.065	-1.207	4.324	4.277
H5.5pH	61.671	10.021	39.255	40.514	-5.415	11.295	2.094
P5.5pH	68.334	13.913	48.366	50.327	1.248	6.277	7.870
Control	62.689	26.829	58.670	64.513	-	-	5.743
B7pH	58.222	21.979	52.748	57.144	-4.467	8.863	7.895
H7pH	53.217	21.714	47.518	52.244	-9.472	15.500	4.631
P7pH	50.768	18.746	44.571	48.353	-11.921	20.155	5.241
Control	66.907	27.662	52.482	59.326	-	-	9.698
B9pH	67.215	25.084	52.885	58.532	0.308	2.627	9.818
H9pH	63.231	23.394	50.096	55.289	-3.676	6.117	6.789
P9pH	63.674	22.861	49.119	54.178	-3.233	6.694	11.461

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 32 gives the CIELAB values of 6% concentrated Annatto seeds dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

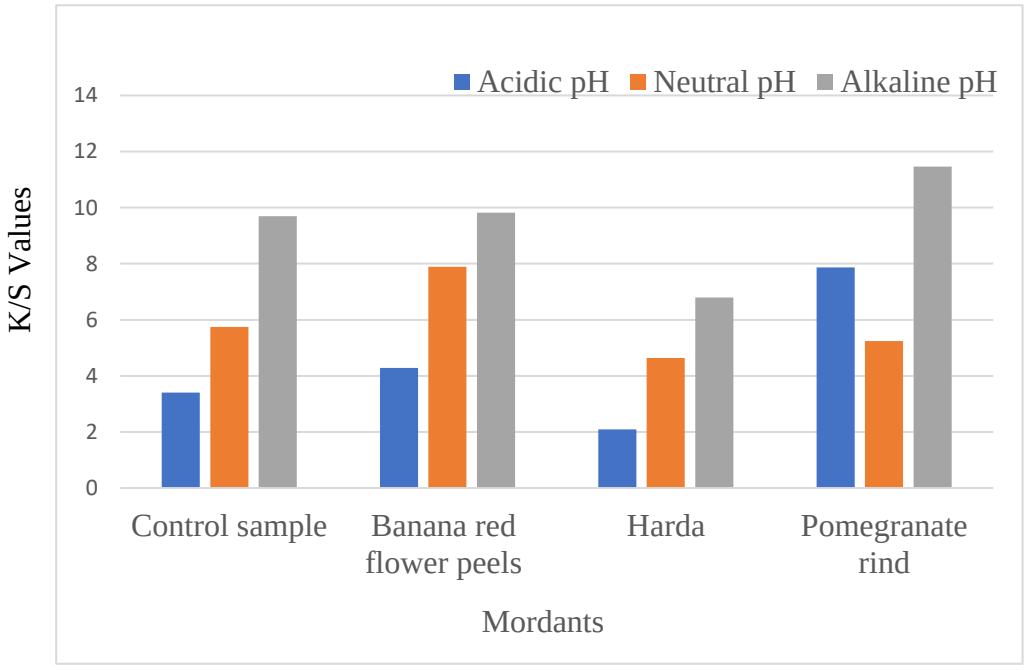
While the Pomegranate rind mordanted sample had a lower L* value (50.768) at neutral pH, it had a greater L* value (68.334) at self pH. This shows that the Pomegranate rind mordanted sample was darker at a neutral pH than the other dyed samples, and lighter at self pH.

All the positive a* values showed that the shade of the samples contains red colour component. Highest a* value was control sample at alkaline pH (27.662), which indicates that it contains more red colour than any other dyed samples.

All the sample exhibit positive b* values and the control sample at neutral pH had b* value of 58.670, suggesting that it was more yellow in colour than the Harda mordanted sample at self pH, which had a b* value of 39.255.

Every sample in this case was brighter in the shade because every c* value was positive. The sample with the greatest c* value (64.513), which makes it the brightest of all the dyed samples, was the control sample at neutral pH. As a result of having the lowest c* value (40.514) among the dyed samples, the Harda-mordanted sample at self pH appeared a little dull.

Maximum darkness for shade was observed with Pomegranate rind at neutral pH (-11.921). From the findings for the DE* values, it can be concluded that Pomegranate rind mordanted sample at neutral pH exhibits more (20.155) colour change than the control sample.



Graph 15: K/S values of 6% concentrated Annatto seeds dyed Eri Silk samples with different mordants at various pH

The K/S values were shown in Graph 15. From all K/S measurements, it was discovered that the Pomegranate rind mordanted sample at alkaline pH has the deepest colour with a value of 11.461 and the Harda mordanted sample of self pH has the lowest value for colour strength with a value of 2.094. Gogoi N.

(2010) also reported in his study that Annatto seeds dye gave best result at Alkaline medium with Eri Silk fabric.

Table 33: Effect of 8% concentrated Annatto seeds dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	61.590	25.843	64.304	69.303	-	-	3.134
B5.5pH	48.133	18.216	43.994	47.616	-13.457	25.530	4.219
H5.5pH	47.833	16.610	45.243	48.196	-13.757	25.255	3.709
P5.5pH	46.761	17.916	43.031	46.612	-14.829	27.116	5.011
Control	63.581	25.009	55.427	60.808	-	-	7.605
B7pH	60.398	20.066	51.470	55.243	-3.183	7.087	7.540
H7pH	55.951	20.495	47.328	51.575	-7.630	12.008	4.213
P7pH	54.411	18.129	45.763	49.223	-9.170	14.994	5.156
Control	55.744	32.554	79.559	85.962	-	-	28.801
B9pH	24.712	20.777	41.898	46.767	-31.032	50.200	25.521
H9pH	21.192	19.591	38.305	43.024	-34.552	55.351	21.194
P9pH	47.242	28.086	72.199	77.469	-8.502	12.100	25.025

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 33 gives the CIELAB values of 8% concentrated Annatto seeds dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

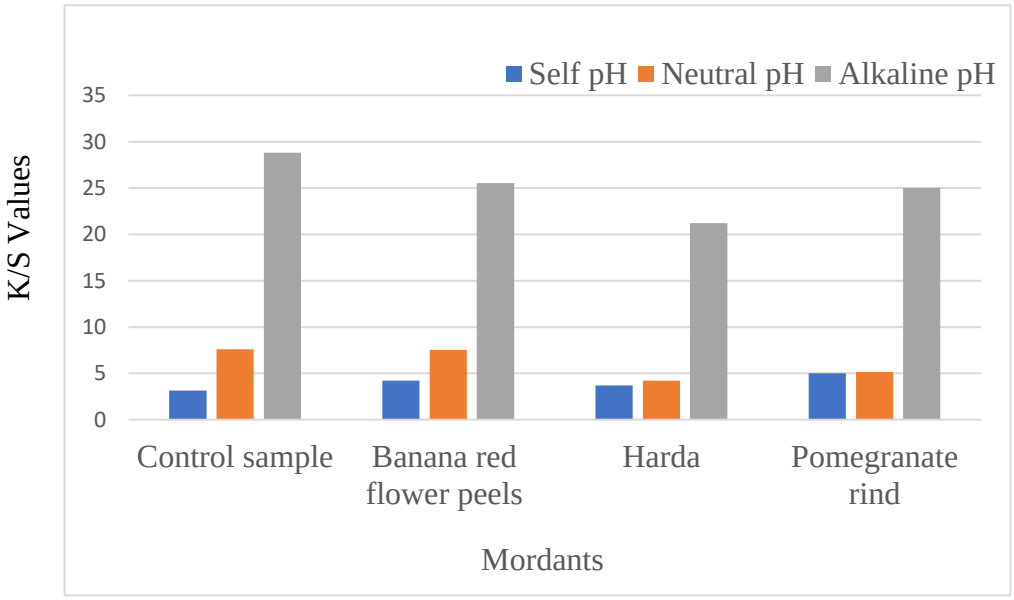
The control sample had a higher L* value (63.581) at neutral pH, while the Harda mordanted sample had a lower L* value (21.192) at alkaline pH. This indicates that the control sample was lighter at an neutral pH than all other dyed samples, while the Harda mordanted sample was darker at alkaline pH.

Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (32.554), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. Harda mordanted sample at alkaline pH had the lowest b* value (38.305) while the highest b* value was found in the control sample at alkaline pH with a value of 79.559, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (85.962) was control sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at alkaline pH had the lowest c* value (43.024); as a result, it was a little dull than the other dyed samples.

DL * value showed the maximum darkness of the shade with Harda at neutral pH (-34.552). The highest colour change from the original samples was observed in Harda mordanted sample at alkaline pH (55.351).



Graph 16: K/S values of 8% concentrated Annatto seeds dyed Eri Silk samples with different mordants at various pH

Graph 16 exhibits K/S values of 8% Concentrated Annatto seed dyed Eri silk samples, the higher colour depth was acquired by control sample dyed in alkaline medium 28.801 and followed by Banana red flower peel dyed in alkaline medium (25.521). Without mordanted control sample at self (acidic) pH has the lowest value for colour strength with a value of 3.134.

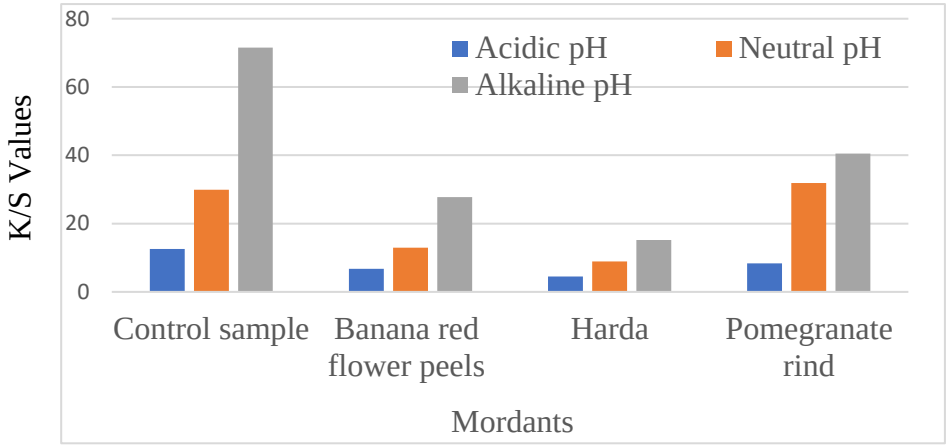
Table 34: Effect of 2% concentrated Annatto seeds dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at self pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	56.671	20.652	55.730	59.433	-	-	12.598
B5.5pH	52.226	16.646	47.699	50.520	-4.445	10.015	6.771
H5.5pH	47.931	11.974	38.376	40.201	-8.740	21.280	4.498
P5.5pH	51.818	15.723	45.812	48.435	-4.853	12.092	8.381
Control	53.635	29.643	82.680	87.833	-	-	29.936
B7pH	24.721	18.928	39.334	43.651	-28.914	53.195	12.911
H7pH	19.843	16.815	31.725	35.906	-33.792	62.473	8.930
P7pH	28.835	21.137	45.839	50.478	-24.800	45.218	31.838
Control	54.063	30.871	76.054	82.072	-	-	71.572
B9pH	44.552	27.479	62.405	68.187	-9.511	16.971	27.728
H9pH	35.357	23.473	48.874	54.219	-18.706	33.807	15.165
P9pH	43.753	25.400	62.081	67.076	-10.310	18.199	40.465

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 34 exhibits the CIELAB values of 2% concentrated Annatto seeds dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

Control sample had a higher L* value (56.671) at self (acidic) pH, while the Harda mordanted sample had a lower L* value (19.843) at neutral pH. This indicates that the control sample was lighter at self pH than all other dyed samples, while the Harda mordanted sample was darker at a neutral pH. Maximum presence of red was seen in control sample at alkaline pH (30.871), Maximum present of yellow was found in the control sample at neutral pH with a value of 82.680, Maximum brightness (87.833) seen in control sample at neutral pH. Maximum DL* values (-33.792) and highest colour change (62.473) from the original was observed in the Harda mordanted sample at neutral pH.



Graph 17: K/S values of 2% concentrated Annatto seeds dyed Kutchi Wool samples with different mordants at various pH

From Graph 17 it was discovered that the control sample at alkaline pH has the deepest colour with a value of 71.572 and the Harda mordanted control sample at self pH has the lowest value for colour strength with a value of 4.498

Table 35: Effect of 4% concentrated Annatto seeds dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	58.649	20.009	54.238	57.811	-	-	9.900
B5.5pH	58.754	18.081	53.772	56.731	0.105	1.986	10.564
H5.5pH	54.925	12.869	44.743	46.557	-3.724	12.450	6.357
P5.5pH	56.269	15.506	48.056	50.496	-2.380	8.010	11.684
Control	54.100	29.681	86.302	91.263	-	-	8.626
B7pH	17.184	16.729	33.948	37.846	-36.916	65.357	15.981
H7pH	7.624	9.422	18.078	20.386	-46.476	85.000	14.779
P7pH	11.924	12.290	18.166	21.933	-42.176	81.999	11.963
Control	54.025	26.805	70.208	75.151	-	-	41.961
B9pH	56.883	21.834	73.957	77.113	2.858	6.851	49.459
H9pH	50.539	26.933	70.395	75.371	-3.486	3.493	38.595
P9pH	46.333	23.666	62.045	66.405	-7.692	11.647	28.438

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 35 presented the CIELAB values of 4% concentrated Annatto dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

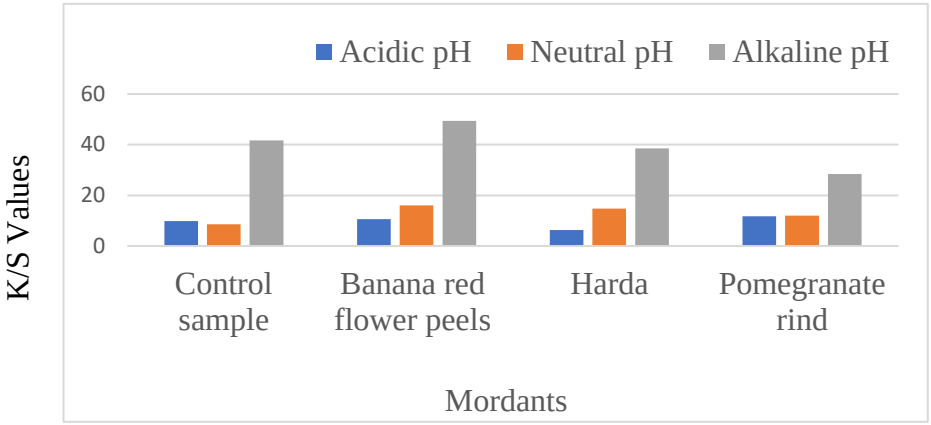
Banana red flower peel mordanted sample had a higher L* value (58.754) at self (acidic) pH, while the Harda mordanted sample had a lower L* value (7.624) at a neutral pH. This indicates that the Banana red flower peel mordanted sample was lighter at self pH than all other dyed samples, while the Harda mordanted sample was darker at neutral pH.

Positive a* values were seen in every sample. The sample with the highest a* value was a control sample at neutral pH (29.681), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. The Harda mordanted sample at neutral pH had the lowest b* value (18.078) while the highest b* value was found in the control sample at neutral pH with a value of 86.302, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (91.263) was control sample at neutral pH, making it the brightest of all the dyed samples. Harda mordanted sample at neutral pH had the lowest c* value (20.386); as a result, it was a little dull than the other dyed samples.

Maximum DL* values was found in Harda at neutral pH (-46.476) followed by Pomegranate rind (-42.176) at neutral pH. From DE* values, it was observed the Harda mordanted sample at neutral pH exhibits more colour change than the control sample.



Graph 18: K/S values of 4% concentrated Annatto seeds dyed Kutchi Wool samples with different mordants at various pH

The K/S values in Graph 18 it was discovered that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour with a value of 49.459 and the Harda mordanted sample of self pH has the lowest value for colour strength with a value of 6.357.

Table 36: Effect of 6% concentrated Annatto seeds dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	58.367	19.577	54.476	57.887	-	-	10.399
B5.5pH	60.890	18.981	58.286	61.299	2.523	4.608	14.515
H5.5pH	51.208	13.398	40.907	40.045	-7.159	16.539	4.723
P5.5pH	56.527	16.220	49.707	52.286	-1.840	6.115	12.485
Control	55.668	28.201	73.911	79.108	-	-	13.490
B7pH	51.813	26.772	68.044	73.121	-3.855	7.164	29.533
H7pH	39.822	23.604	49.853	55.159	-15.846	29.172	13.324
P7pH	41.431	21.544	51.403	55.735	-14.237	27.452	17.747
Control	54.480	32.198	59.748	67.871	-	-	27.747
B9pH	52.024	26.359	55.690	61.613	-2.456	7.523	35.449
H9pH	51.501	28.387	55.256	62.121	-2.979	6.601	15.441
P9pH	48.811	25.762	50.632	56.809	-5.669	12.516	20.532

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 36 gives the colour yield values of 6% concentrated Annatto seed dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

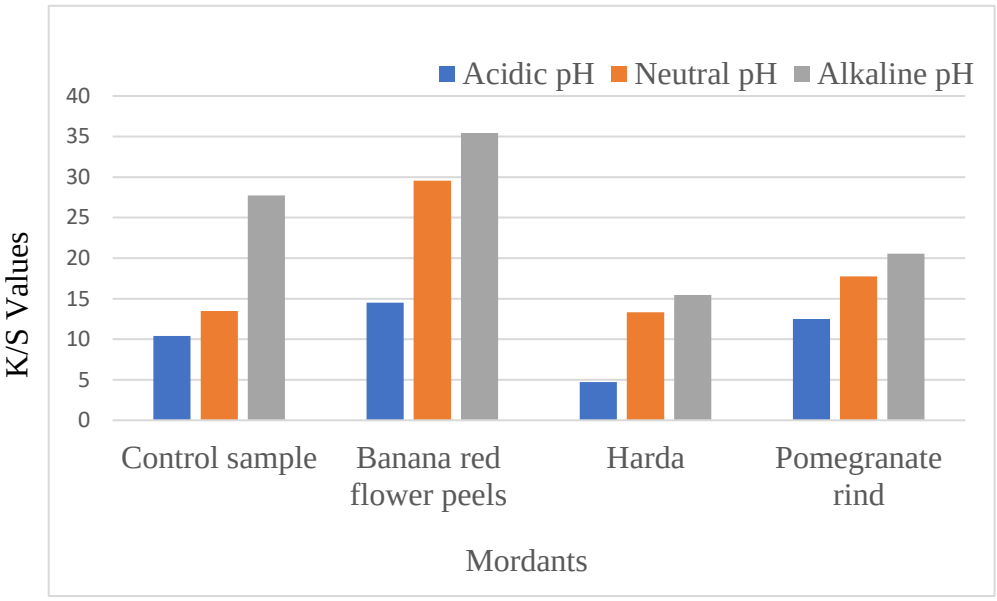
The Banana red flower peel mordanted sample had a higher L* value (60.890) at alkaline pH, while the Pomegranate rind sample had a lower L* value (41.431) at a neutral pH. This indicates that the Banana red flower peel mordanted sample was lighter at self pH than all other dyed samples, while the Pomegranate rind mordanted sample was darker at a neutral pH.

Each sample had an a* value that was positive. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was control sample at alkaline pH (32.198), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. Harda mordanted sample at self pH had the lowest b* value (40.907) while the highest b* value was found in control sample at neutral pH with a value of 73.911, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (79.108) was control sample at neutral pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (40.045); as a result, it was a little dull than the other dyed samples.

Maximum darkness (-15.846) and highest DE* value (29.172) was observed in Harda mordanted sample at neutral pH.



Graph 19: K/S values of 6% concentrated Annatto seeds dyed Kutchi Wool samples with different mordants at various pH

From all K/S measurements in Graph 19 it was discovered that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour with a value of 35.449 and the Harda mordanted sample of self pH has the lowest value for colour strength with a value of 4.723.

Table 37: Effect of 8% concentrated Annatto seeds dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	61.321	15.861	47.692	50.260	-	-	6.353
B5.5pH	62.283	15.408	49.561	51.901	0.962	2.150	8.878
H5.5pH	61.875	11.274	41.363	42.872	0.554	7.836	6.379
P5.5pH	66.276	10.721	46.191	47.419	4.955	7.296	15.850
Control	58.415	23.411	65.001	69.088	-	-	18.744
B7pH	60.349	22.731	68.230	71.917	1.934	3.825	26.036
H7pH	47.332	20.625	48.262	52.484	-11.083	20.268	8.385
P7pH	50.811	21.107	53.762	57.757	-7.604	13.764	14.939
Control	50.211	31.018	89.508	94.730	-	-	30.499

B9pH	59.235	-34.451	23.783	41.863	-49.976	105.373	25.993
H9pH	50.416	-27.121	24.095	36.278	-49.795	100.690	43.603
P9pH	57.397	-27.747	24.063	36.728	-49.814	101.083	49.130

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

In the Table 37 discussion of the CIELAB values of 8% concentrated Annatto seed dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline was shown.

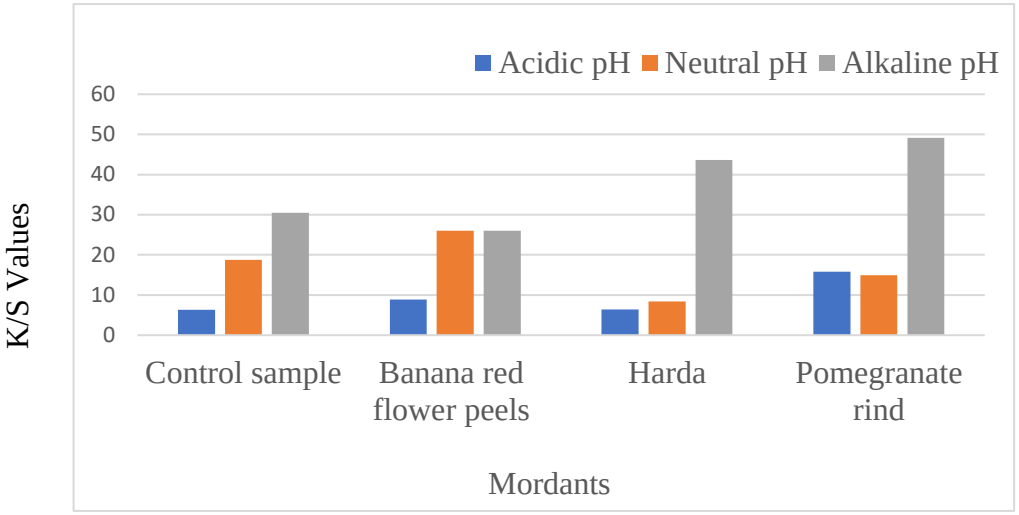
The Pomegranate rind mordanted sample had a higher L* value (66.276) at self pH, while the Harda mordanted sample had a lower L* value (47.332) at a neutral pH. This indicates that the Pomegranate rind mordanted sample was lighter at self pH than all other dyed samples, while the Harda mordanted sample was darker at a neutral pH.

The sample with the highest a* value was a control sample, which had an alkaline pH (31.018), meaning it had more red colour than any other dyed samples.

Highest b* value was seen in the control sample at alkaline pH, which indicated that it was more yellow in colour, whereas the Banana red flower peel mordanted sample had the lowest b* value (23.783).

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (94.730) was control sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at alkaline pH had the lowest c* value (36.278); as a result, it was a little dull than the other dyed samples.

The values showed darkness in the shade, highest value (-49.976) found on Banana red flower peel at alkaline pH and also the same sample had maximum percent (105.373) of colour change.



Graph 20: K/S values of 8% concentrated Annatto seeds dyed Kutchi Wool samples with different mordants at various pH

With regard to the K/S measurements, it was found that the Pomegranate rind mordanted sample at alkaline pH has the deepest colour, with a value of 49.130, while the without mordanted control sample at self pH has the weakest colour, with a value of 6.353.

Table 38: Effect of 2% concentrated Annatto seeds dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	66.944	30.504	57.529	65.116	-	-	6.546
B5.5pH	61.432	26.857	49.813	56.592	-5.512	10.160	3.419
H5.5pH	61.250	24.346	52.568	57.932	-5.694	9.744	2.188
P5.5pH	62.377	23.191	55.657	60.295	-4.567	8.823	4.736
Control	67.019	31.830	54.607	63.207	-	-	6.280
B7pH	69.848	32.692	55.741	64.621	2.829	3.167	13.611
H7pH	64.525	32.945	50.444	60.249	-2.494	4.979	4.018
P7pH	67.296	28.098	56.016	62.668	0.277	3.999	9.107
Control	68.148	32.315	50.435	59.899	-	-	15.179
B9pH	77.298	26.491	59.286	64.935	9.150	13.999	30.397
H9pH	73.754	31.351	53.287	61.825	5.606	6.363	19.479
P9pH	65.405	27.193	50.923	57.729	-2.743	5.831	24.192

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 38 conferred the CIELAB values of 2% concentrated Annatto seed dyed Nylon fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

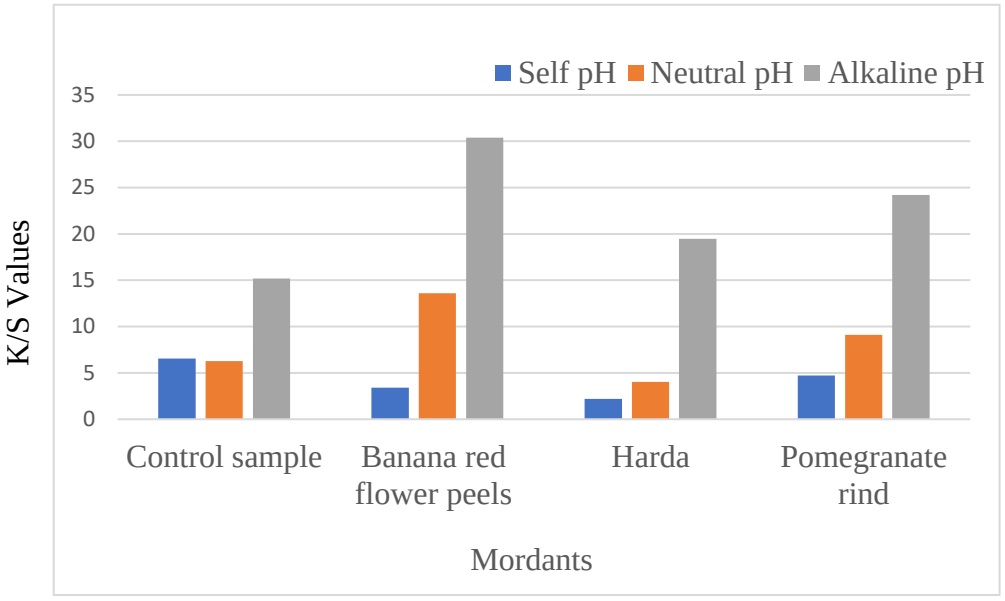
The table denoted L* values which showed highest (77.298) in alkaline pH of Banana red flower peel mordanted sample while the Harda mordanted sample had a lower L* value (61.250) at self pH. This indicates that the Banana red flower peel mordanted sample was lighter at alkaline pH than all other dyed samples, while the Harda mordanted sample was darker at self pH.

The Maximum a* value viewed in Harda mordanted sample at neutral pH (32.945), which indicates that it contains more red colour than any other dyed samples.

The Banana red flower peel mordanted sample at self pH had the lowest b* value (49.813) while the highest b* value was found in the Banana flower red peel mordanted sample at alkaline pH with a value of 59.286, indicating that it was more yellow in colour.

Here, every c* value was positive. The sample with the highest c* value (65.116) was control sample at self pH, making it the brightest of all the dyed samples. Banana red flower peel mordanted sample at self pH had the lowest c* value (56.592); as a result, it was a little dull than the other dyed samples.

Greatest DL* value (-5.694) was found in Harda mordanted at self (acidic) pH. From the findings for the DE* values, it can be concluded that the Banana red flower peel mordanted (13.999) sample at alkaline pH exhibits more colour change than the control sample.



Graph 21: K/S values of 2% concentrated Annatto seeds dyed Nylon samples with different mordants at various pH

From the Graph 21 it was discovered that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour with a value of 30.397 and the Harda mordanted sample at self pH has the lowest value for colour strength with a value of 2.188.

Table 39: Effect of 4% concentrated Annatto seeds dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	67.323	25.258	58.757	63.956	-	-	6.183
B5.5pH	62.761	28.674	51.832	59.235	-4.562	8.969	3.864
H5.5pH	63.158	25.015	52.404	58.068	-4.165	7.600	2.991
P5.5pH	64.807	21.016	54.728	58.624	-2.516	6.368	5.839
Control	67.371	30.247	52.547	60.631	-	-	9.450
B7pH	73.430	31.808	55.332	63.823	6.059	6.849	8.184
H7pH	69.637	33.148	51.963	61.636	2.266	3.727	9.907
P7pH	66.796	28.296	50.951	58.281	-0.575	2.585	7.630
Control	66.952	34.982	54.310	64.601	-	-	17.034

B9pH	76.584	28.652	61.554	67.896	9.632	13.613	21.476
H9pH	76.156	30.884	56.056	64.001	9.204	10.225	18.001
P9pH	66.189	32.439	54.608	63.516	-0.763	2.672	20.223

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

The CIELAB values for 4% concentrated Annatto seed dyed Nylon fabric samples with different mordants and three different pH, namely self (acidic), neutral, and alkaline, are provided in Table 39.

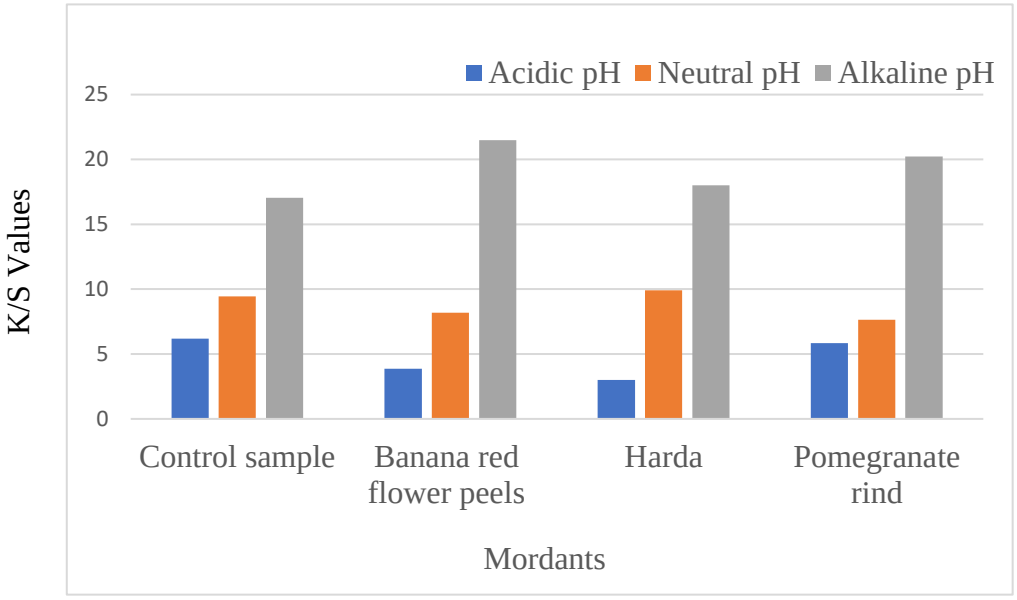
Whereas the Banana red flower peel sample had a lower L* value (62.761) at self pH, the Banana red flower peel mordanted sample had a higher L* value (76.584) at alkaline pH. This shows that the Banana red flower peel sample that had been mordanted was darker at self pH than all other dyed samples and lighter at alkaline pH.

Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was a control sample at alkaline pH (34.982), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. The Banana red flower peel mordanted sample at self pH had the lowest b* value (51.832) while the highest b* value was found in the Banana flower red peel mordanted sample at alkaline pH with a value of 61.554, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (67.896) was Banana red flower peel mordanted sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (58.068); as a result, it was a little duller than the other dyed samples.

Greatest DL* value (-4.562) observed in Banana red flower peel at self (Acidic) condition and DE* values (13.613) in Banana red flower peel mordanted sample at alkaline pH exhibits more colour change than the control sample.



Graph 22: K/S values of 4% concentrated Annatto seeds dyed Nylon samples with different mordants at various pH

From the Graph 22 it was noted that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour with K/S value of 21.476 and the Harda mordanted sample at self pH has the lowest value for colour strength with a K/S value of 2.991.

Table 40: Effect of 6% concentrated Annatto seeds dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	65.498	31.138	59.213	66.901	-	-	2.854
B5.5pH	59.846	29.523	50.628	58.607	-5.652	10.405	3.775
H5.5pH	60.110	25.992	54.275	60.178	-5.388	8.938	2.781
P5.5pH	58.083	22.342	53.631	58.099	-7.415	12.787	3.628
Control	66.465	32.937	54.983	64.093	-	-	7.993
B7pH	70.371	33.000	56.086	65.074	3.906	4.059	9.359
H7pH	68.602	33.614	53.237	62.961	2.137	2.841	8.552
P7pH	63.439	28.894	53.344	60.667	-3.026	5.309	4.587
Control	72.287	29.355	44.793	53.555	-	-	10.764

B9pH	74.388	29.031	47.505	55.673	2.101	3.446	16.448
H9pH	74.349	30.140	46.483	55.399	2.062	2.779	11.517
P9pH	71.888	27.320	45.604	53.161	-0.399	2.227	5.426

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

The Table 40 explain the CIELAB values of 6% concentrated Annatto seeds dyed Nylon fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

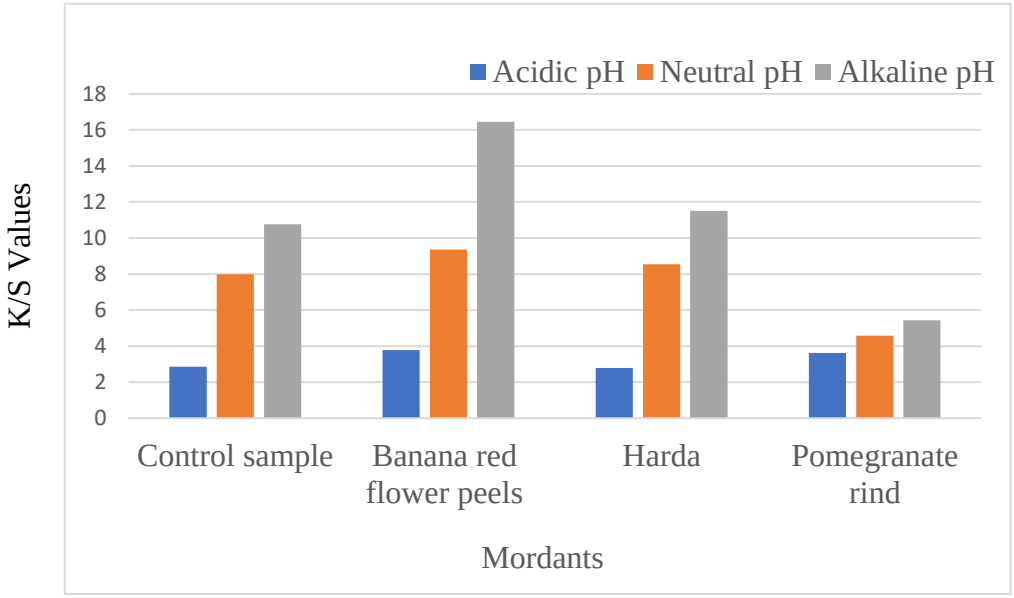
Maximum lightness value was observed in the Banana red flower peel mordanted sample (74.388) at alkaline pH, while the Pomegranate rind mordanted sample (58.083) at self pH was darker.

Positive a* values were seen in every sample. The sample with the highest a* value was Harda mordanted sample at neutral pH (33.614), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. Control sample at alkaline pH had the lowest b* value (44.793) while the highest b* value was found in the control sample at self pH with a value of 59.213, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (66.901) was control sample at self pH, making it the brightest of all the dyed samples.

DE* value (-7.415) and DL* values (12.787) was found to be highest on the Pomegranate rind mordanted sample at self (acidic) pH.



Graph 23: K/S values of 6% concentrated Annatto seeds dyed Nylon samples with different mordants at various pH

The K/S values in Graph 23 were discussed as they represent the depth of colour. It was Observed that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour value (16.448) and the Harda mordanted sample of self pH has the lowest value for colour strength with a value of 2.781.

Table 41: Effect of 8% concentrated Annatto seeds dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	66.941	30.239	56.066	63.701	-	-	6.130
B5.5pH	63.516	27.419	51.422	58.275	-3.425	6.423	4.181
H5.5pH	61.820	24.790	51.902	57.518	-5.121	8.559	2.070
P5.5pH	61.978	21.788	54.015	58.244	-4.963	10.013	4.133
Control	66.301	33.967	57.226	66.548	-	-	7.591
B7pH	68.276	34.445	56.956	66.562	1.975	2.050	14.090
H7pH	64.870	33.531	54.374	63.882	-1.431	3.221	6.954
P7pH	63.528	28.891	54.667	61.832	-3.043	6.448	6.435
Control	67.408	32.563	52.716	61.962	-	-	15.943

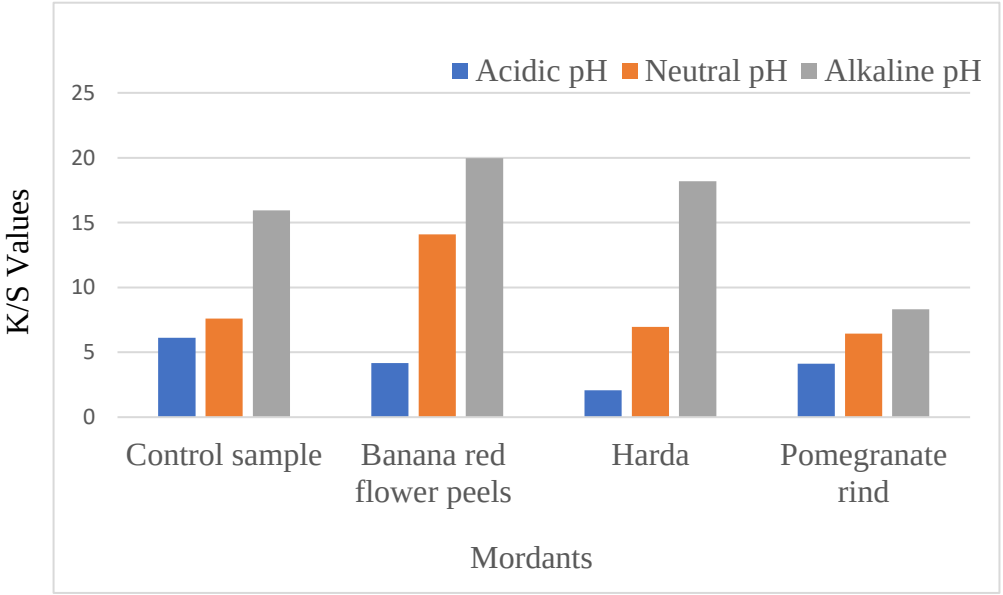
B9pH	78.168	25.653	62.110	67.199	10.760	15.867	19.967
H9pH	72.333	32.715	53.888	63.041	4.925	5.065	18.192
P9pH	67.724	31.590	52.639	61.390	0.316	1.026	8.321

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

As shown in Table 41 the result described that the Banana red flower peel mordanted sample had a higher L* value (78.168) at alkaline pH, while the Harda mordanted sample had a lower L* value (61.820) at self pH. This indicates that the Banana red flower peel mordanted sample was lighter at alkaline pH than all other dyed samples, while the Harda mordanted sample was darker at self pH.

Positive a* values were seen in every sample. Maximum presence of red was observed in Banana red flower peel mordanted sample at neutral pH (34.445), while maximum present of yellow was observed in the Banana flower red peel mordanted sample at alkaline pH with a value of 62.110. Maximum brightness was in (67.199) Banana red flower peel mordanted sample at alkaline pH.

Highest darkness (-5.121) Harda at acidic condition and colour change in Banana red flower peel sample at alkaline condition.



Graph 24: K/S values of 8% concentrated Annatto seeds dyed Nylon samples with different mordants at various pH

The K/S values in Graph 24 shown that the Banana red flower peel mordanted sample at alkaline pH has the deepest colour with a value of 19.967 and the Harda mordanted sample at self pH has the lowest value for colour strength with a value of 2.070.

Table 42: Effect of 2% concentrated Onion peels dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	55.813	6.880	35.455	36.116	-	-	28.197
B3.5pH	83.360	-2.830	30.702	30.832	27.547	29.592	53.949
H3.5pH	52.440	8.991	29.782	31.110	-3.373	6.929	40.057
P3.5pH	46.780	8.840	28.794	30.120	-9.033	11.393	53.649
Control	59.547	5.861	47.245	47.607	-	-	30.098
B7pH	32.644	7.627	34.457	35.291	-26.903	29.840	33.997
H7pH	45.182	12.037	34.740	36.766	-14.365	20.022	45.004
P7pH	42.398	9.398	35.032	36.271	-17.149	21.348	40.603
Control	61.182	3.280	49.599	49.707	-	-	22.922
B9pH	48.146	6.435	39.432	39.945	-13.036	16.830	15.026
H9pH	74.649	1.271	37.774	37.795	13.467	18.034	30.569
P9pH	64.803	5.088	36.628	36.980	3.621	13.588	44.091

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

CIELAB values of 2% concentrated Onion peels dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline was given in Table 42.

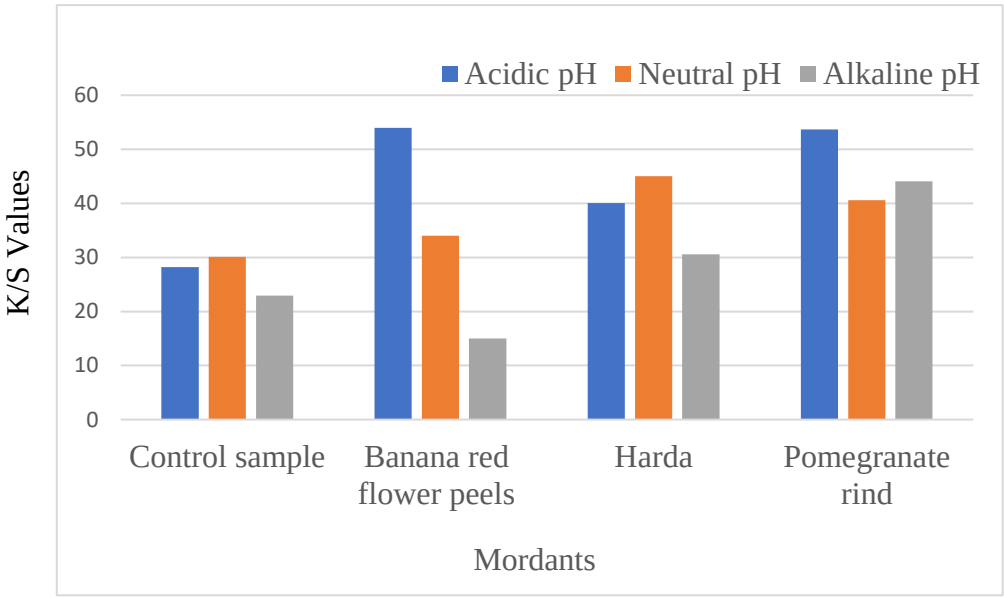
It was observed from the Table 42 that the Banana red flower peel sample had a lower L* value at neutral pH, and had a higher L* value (83.360) at self (Acidic) pH. This shows that the sample made from Banana red flower peel mordanted was darker at neutral pH than all other dyed samples, and lighter at self pH.

Highest a* value was observed in Harda mordanted sample with a neutral pH of 12.037 indicating presence of red colour component,

It was concluded from the b* value maximum presence of yellow was found on control sample at alkaline pH with a value of 49.599.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (49.707) was control sample at alkaline pH, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at self pH had the lowest c* value (30.120); as a result, it was a little dull than the other dyed samples.

DL* values showed the maximum darkness of the shade with Banana red flower peel at neutral pH (-26.903), it also shows the highest colour change DL* value (29.840) from the original sample



Graph 25: K/S values of 2% concentrated Onion peels dyed Eri Silk samples with different mordants at various pH

The K/S values in Graph 25 were examined, it was observed that the Banana red flower peel mordanted sample at self pH has the darkest colour with a value of 53.949 and the Banana red flower peel mordanted sample at alkaline pH has the lowest value for colour strength with a value of 15.026.

Table 43: Effect of 4% concentrated Onion peels dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	55.413	8.993	35.951	37.059	-	-	40.938
B3.5pH	77.250	1.019	34.493	34.508	21.837	23.293	75.915
H3.5pH	43.350	10.795	29.697	31.598	-12.063	13.707	60.771
P3.5pH	46.496	10.838	29.767	31.679	-8.917	11.007	56.948
Control	58.894	6.468	45.932	46.385	-	-	50.255
B7pH	32.958	8.272	34.737	35.708	-25.936	28.307	36.909
H7pH	47.508	11.665	35.399	37.271	-11.386	16.358	45.400
P7pH	47.267	8.474	37.828	38.766	-11.627	14.314	43.728
Control	55.734	5.679	51.157	51.471	-	-	30.770
B9pH	16.310	6.508	24.677	25.521	-39.424	47.499	29.777
H9pH	23.695	9.144	28.206	29.651	-32.039	39.563	44.254
P9pH	23.655	10.083	24.723	26.700	-32.079	41.800	50.077

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 43 gives the CIELAB values of 4% concentrated Onion peels dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

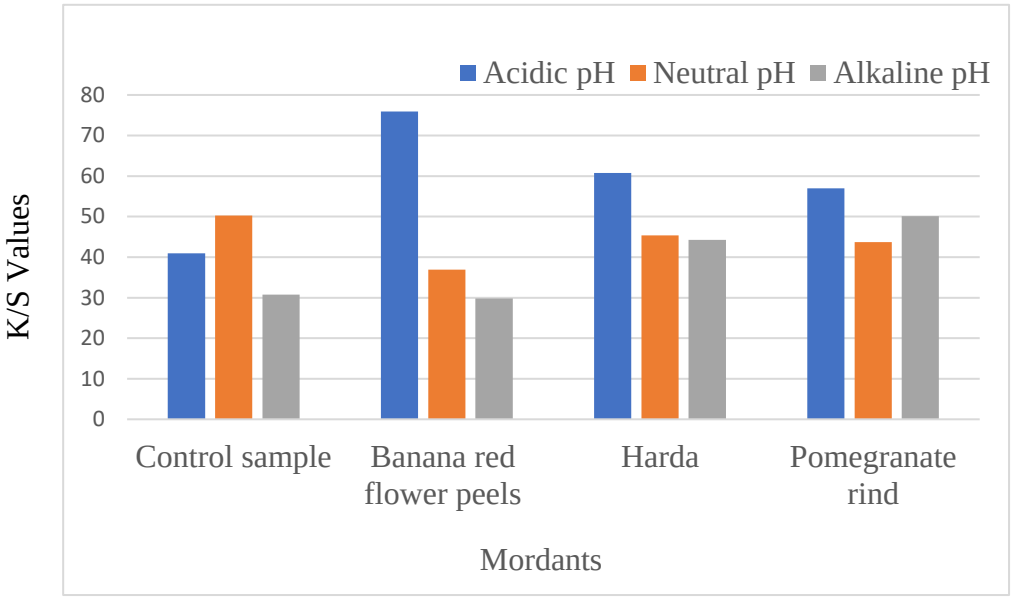
The Banana red flower peel mordanted sample had a higher L* value (77.250) at self pH, while the Banana red flower peel sample had a lower L* value (16.310) at alkaline pH. This indicates that the Banana red flower peel mordanted sample was lighter at an alkaline pH than all other dyed samples, while the Banana red flower peel sample was darker at alkaline pH.

Positive a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of red component than green. The sample with the highest a* value was Harda mordanted sample at neutral pH (11.665), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Banana red flower peel mordanted sample at alkaline pH had the lowest b* value (24.677) while the highest b* value was found in the control sample at alkaline pH with a value of 51.157, indicating that it was more yellow in colour.

The sample with the highest c* value (51.471) was control sample at alkaline pH, making it the brightest of all the dyed samples. Banana red flower peel mordanted sample at alkaline pH had the lowest c* value (25.521); as a result, it was a little dull than the other dyed samples.

Banana red flower peel mordanted at alkaline pH exhibits maximum darkness (DL* -39.424) it also exhibits more colour change (DE*47.499) from the control sample.



Graph 26: K/S values of 4% concentrated Onion peels dyed Eri Silk samples with different mordants at various pH

From Graph 26 it was observed that the Banana red flower peel mordanted sample at self pH has the deepest colour with a value of 75.915 and the Banana red flower peel mordanted sample of alkaline pH has the lowest value for colour strength with a value of 29.777.

Table 44: Effect of 6% concentrated Onion peels dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	59.246	8.831	31.804	33.042	-	-	49.923
B3.5pH	57.541	9.076	32.448	33.693	-1.705	1.827	81.142
H3.5pH	55.168	11.712	26.453	28.930	-4.078	7.345	67.393
P3.5pH	57.016	9.297	27.920	29.427	-2.230	4.534	57.917
Control	58.969	6.315	47.119	47.540	-	-	50.593
B7pH	33.540	8.511	37.126	38.089	-25.429	27.410	56.278
H7pH	37.386	13.057	31.921	34.488	-21.583	27.244	53.889
P7pH	30.693	10.406	28.405	30.251	-28.276	34.154	50.694
Control	60.188	4.342	46.727	46.928	-	-	39.190
B9pH	57.026	4.332	44.456	44.667	-3.162	3.893	40.353
H9pH	81.951	-2.123	33.991	34.057	21.763	26.031	51.614
P9pH	66.062	4.244	36.679	36.924	5.874	11.639	58.784

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

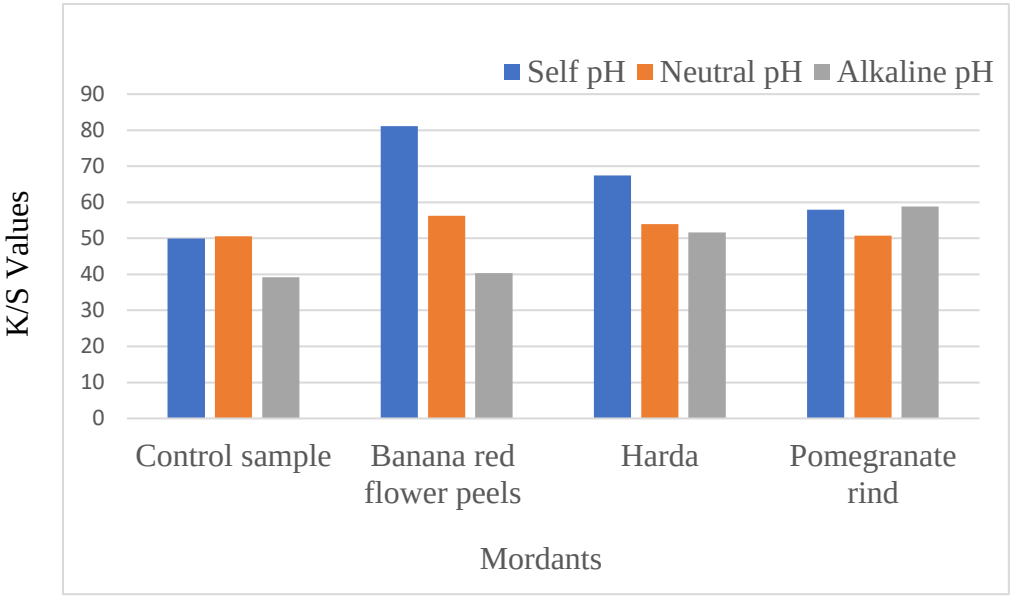
Table 44 gives the CIELAB values of 6% concentrated Onion peels dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The Harda mordanted sample had a higher L* value (81.951) at an alkaline pH, while the Pomegranate rind mordanted sample had a lower L* value (30.693) at a neutral pH. This indicates that the Harda mordanted sample was lighter at an alkaline pH than all other dyed samples, while the Pomegranate rind mordanted sample was darker at a neutral pH.

From all positive a* and b* value we can conclude that all the samples contain red and yellow colour in it. Highest a* value is obtained with Harda mordanted sample at neutral pH (13.057). The highest b* values were obtained with the control sample at neutral pH (47.119).

Value c* value exhibit the brightness of the colour. Positive C* value showed that the samples were brighter in shade. The control sample at neutral pH had the highest c* value (47.540), making it the brightest of all the dyed samples.

Maximum DL* values was observed with Pomegranate rind at neutral pH (-28.276). From the findings for the DE* values, it can be concluded that the Pomegranate rind at neutral pH exhibits (34.154) more colour change than the control sample.



Graph 27: K/S values of 6% concentrated Onion peels dyed Eri Silk samples with different mordants at various pH

Graph 27 showed the K/S value of 6% conc. Onion dyed peels with various mordant at different pH. On analysis it was found that highest colour strength was obtained with Banana red flower peel mordanted sample at self pH (81.142) and the without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 39.190.

Table 45: Effect of 8% concentrated Onion peels dyed samples on CIELAB values of Eri Silk fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	54.521	9.306	37.562	38.698	-	-	52.609
B3.5pH	55.399	8.695	39.224	40.176	0.878	1.976	82.537
H3.5pH	37.977	12.532	27.496	30.217	-16.544	19.633	69.984
P3.5pH	41.242	11.078	29.869	31.857	-13.279	15.448	59.394
Control	59.063	6.519	45.154	45.622	-	-	54.619
B7pH	47.691	7.154	45.277	45.839	-11.372	11.390	58.528
H7pH	48.146	11.638	35.232	37.104	-10.917	15.615	54.446
P7pH	49.348	9.260	36.264	37.428	-9.715	13.451	56.579
Control	60.324	3.982	49.431	49.591	-	-	49.785
B9pH	47.864	6.609	41.726	42.246	-12.460	14.884	45.391
H9pH	68.675	3.068	41.320	41.434	8.351	11.677	56.229
P9pH	59.055	5.948	38.454	38.911	-1.269	11.224	67.438

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 45 gives the CIELAB values of 8% concentrated Onion peels dyed Eri Silk samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

From the table it was evident that higher L* value obtained with Harda mordant (68.675) at alkaline pH, while the Harda mordanted sample had a lower L* value (37.977) at self (acidic) pH. This indicates that the Harda mordanted sample was lighter at an alkaline pH than all other dyed samples, while the Harda mordanted sample was darker at a self pH.

Positive a* values were seen in every sample. The sample with the highest a* value was a Harda mordanted sample at self pH (12.532), which indicates that it contains more red colour than any other dyed samples.

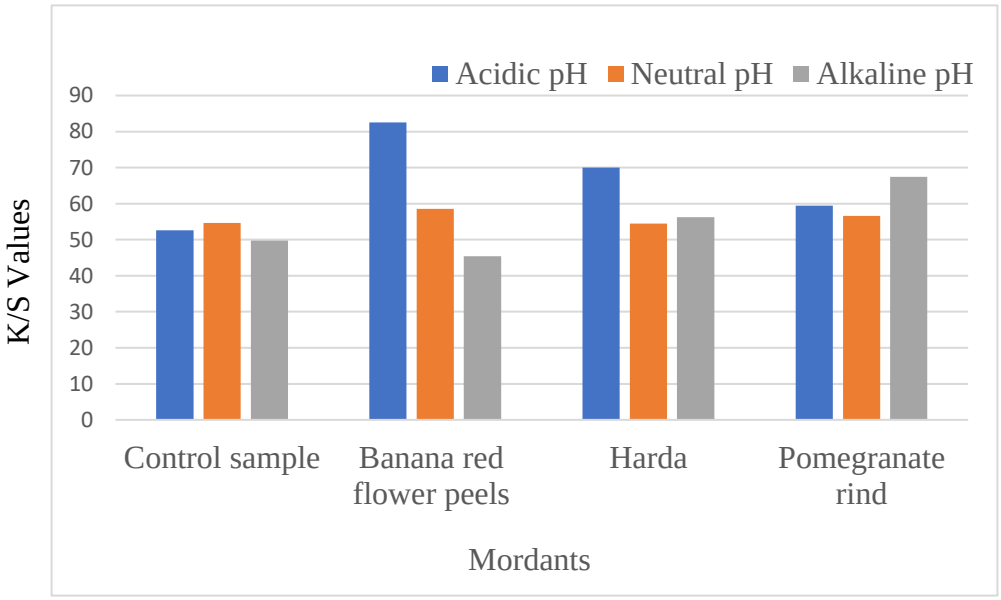
All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. Harda mordanted sample

at self pH had the lowest b* value (27.496) while the highest b* value was found in the control sample at alkaline pH with a value of 49.431, indicating that it was more yellow in colour.

Here, every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (49.591) was control sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (30.217); as a result, it was a little dull than the other dyed samples.

The negative DL* indicated that all the samples were darker than the standard samples. The maximum darkness (-16.544) was observed on sample dyed with Harda at acidic condition.

From the reading obtained for DE* values, it can be concluded that Harda mordanted sample at self pH exhibits more colour change than the control sample.



Graph 28: K/S values of 8% concentrated Onion peels dyed Eri Silk samples with different mordants at various pH

From the Graph 28 for K/S value of the Onion peels dyed samples at various %pH with different mordants. It was observed the Banana red flower peel

mordanted sample at self pH has the deepest colour with a value of 82.537 and the Banana red flower peel mordanted sample at alkaline pH has the lowest value for colour strength with a value of 45.391.

Table 46: Effect of 2% concentrated Onion peels dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	48.049	8.987	52.745	53.505	-	-	88.486
B3.5pH	48.480	7.718	51.933	52.503	0.431	1.567	94.532
H3.5pH	46.545	12.013	45.340	46.904	-1.504	8.140	89.683
P3.5pH	49.471	8.918	45.411	46.278	1.422	7.471	95.291
Control	50.505	6.681	62.318	62.675	-	-	69.725
B7pH	45.012	8.173	62.274	62.808	-5.493	5.692	72.222
H7pH	48.448	8.707	60.828	61.448	-2.057	3.249	61.985
P7pH	47.825	6.080	58.090	58.407	-2.680	5.042	75.655
Control	48.696	5.706	62.783	63.042	-	-	48.002
B9pH	45.677	6.728	60.402	60.776	-3.019	3.978	69.105
H9pH	47.479	6.755	55.069	55.482	-1.217	7.880	51.888
P9pH	46.201	16.664	18.235	24.702	-47.495	68.853	68.281

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 46 gives the degree of colour yield of 2% concentrated Onion peels dyed Kutchi Wool samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

Control sample had a higher L* value (50.505) at neutral pH, while the Banana red flower peel sample had a lower L* value (45.012) at neutral pH. This indicates that the control sample was lighter at neutral pH than all other dyed samples, while the Banana red flower peel sample was darker at neutral pH.

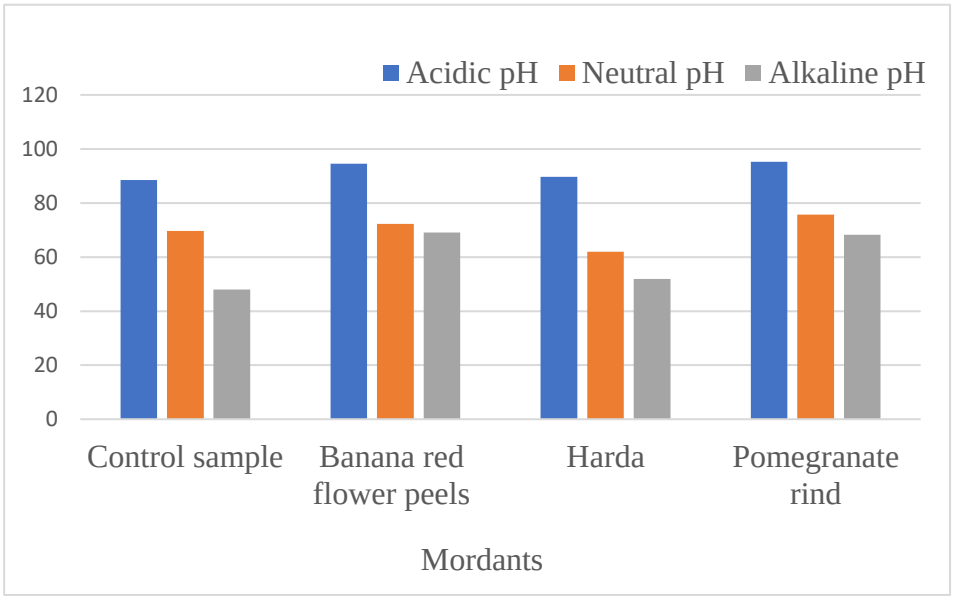
The value of a* were positive for all the test indicating the presence of red component. The highest a* value was observed in case of Pomegranate rind

mordanted sample at alkaline pH (16.664), which indicates that it contains more red colour than any other dyed samples.

All the dyed showed the positive b* value. This shows that the yellow colour component is greater in all samples than the blue colour component. The control sample at alkaline pH had the highest b* value, which indicated that it was more yellow in colour, whereas the Pomegranate rind mordanted sample had the lowest b* value (18.235).

All the samples were brighter in the shade because every c* value was positive. The sample with the highest c* value (63.042), which makes it the brightest of all the dyed samples, was the control sample at an alkaline pH. With a lower c* value (24.702) than the other dyed samples, the Pomegranate rind mordanted sample at an alkaline pH appeared a little dull.

The maximum darkness was observed on Pomegranate mordant sample dyed at alkaline pH (-47.495). From the findings for the DE* values, it can be concluded that the Pomegranate rind mordanted sample at alkaline pH exhibits more colour change than the control sample.



Graph 29: K/S values of 2% concentrated Onion peels dyed Kutchi Wool samples with different mordants at various pH

The K/S values in Graph 29 showed that control sample at self pH has the deepest colour with a value of 94.532 and the without mordanted control sample at alkaline pH has the lowest value for colour strength with a value of 48.002.

Table 47: Effect of 4% concentrated Onion peels dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	45.460	10.659	52.588	53.657	-	-	93.984
B3.5pH	46.948	8.950	52.122	52.885	1.488	2.313	95.235
H3.5pH	38.539	18.177	48.703	51.984	-6.921	10.932	91.906
P3.5pH	44.356	12.616	47.536	49.182	-1.104	5.529	95.669
Control	45.973	8.815	62.523	63.141	-	-	72.655
B7pH	44.339	8.678	61.646	62.254	-1.634	1.860	78.990
H7pH	49.294	9.633	59.199	59.982	3.321	4.775	65.278
P7pH	48.362	10.259	59.163	60.046	2.389	4.368	80.782
Control	48.486	6.038	62.463	62.754	-	-	55.741
B9pH	46.325	7.381	58.695	59.157	-2.161	4.547	71.950
H9pH	46.614	8.127	58.272	58.836	-1.872	5.043	53.647
P9pH	44.721	6.989	53.109	53.567	-3.765	10.128	70.548

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 47 showed the CIELAB values for samples of dyed Kutchi Wool at 4% concentration with Onion peels and various mordants in three different pH ranges: self (acidic), neutral, and alkaline.

While the Harda mordanted sample had a lower L* value (38.539) at self pH, it had a higher L* value (49.294) at neutral pH. This shows that the Harda mordanted sample was darker at self pH than all other dyed samples, and lighter at neutral pH than all other dyed samples.

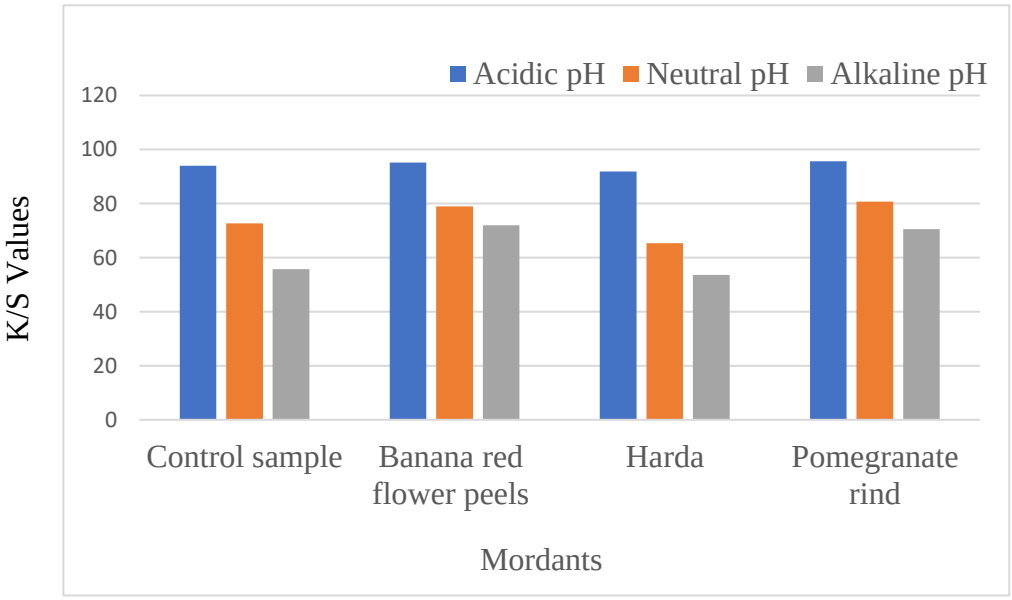
All sample showed positive a* values. This demonstrates that the obtained colour has a higher proportion of red than green. Harda mordanted samples at

self pH (18.177) had the highest a* values, indicating that they contain more red colour than other dyed samples.

b* readings were positive for each sample. This shows that more yellow than blue coloration is present in all of the samples. The b* value of the Pomegranate rind mordanted sample at self pH was the lowest (47.536), but the control sample at neutral pH had the greatest value (62.523), indicating that it was more yellow in colour.

Control sample at neutral pH (63.141) showed highest brightness. Pomegranate rind mordanted sample at self pH had the lowest c* value (49.182); as a result, it was a little duller than the other dyed samples.

DL * value showed the maximum darkness of the shade with Harda at acidic condition (-6.921). The highest colour change from the original samples was observed in Harda mordanted sample at acidic pH (10.932).



Graph 30: K/S values of 4% concentrated Onion peels dyed Kutchi Wool samples with different mordants at various pH

As they represent the depth of colour, the K/S values in Graph 30 were discussed. The Pomegranate rind mordanted sample at self pH has the deepest colour, with a value of 95.669, and the Harda mordanted sample at alkaline pH

has the weakest colour, with a value of 53.647, according to all K/S measurements.

Table 48: Effect of 6% concentrated Onion peels dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	50.337	10.787	39.876	41.309	-	-	94.588
B3.5pH	50.065	11.178	39.771	41.312	-0.272	0.488	95.705
H3.5pH	48.972	15.055	35.654	38.702	-1.365	6.157	93.577
P3.5pH	50.037	13.755	36.545	39.048	-0.300	4.472	95.733
Control	46.463	6.562	61.499	61.848	-	-	73.809
B7pH	43.082	8.938	60.226	60.886	-3.381	4.324	80.652
H7pH	49.889	6.490	59.249	59.603	3.426	4.099	68.220
P7pH	47.415	6.642	57.577	57.959	0.952	4.037	85.096
Control	48.203	6.201	63.465	63.767	-	-	58.562
B9pH	46.164	6.905	57.305	57.720	-2.039	6.527	75.214
H9pH	45.948	8.394	57.600	58.208	-2.255	6.655	58.369
P9pH	45.681	5.247	53.586	53.842	-2.522	10.240	74.364

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 48 gives the CIELAB values of 6% concentrated Onion peels dyed Kutchi Wool fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

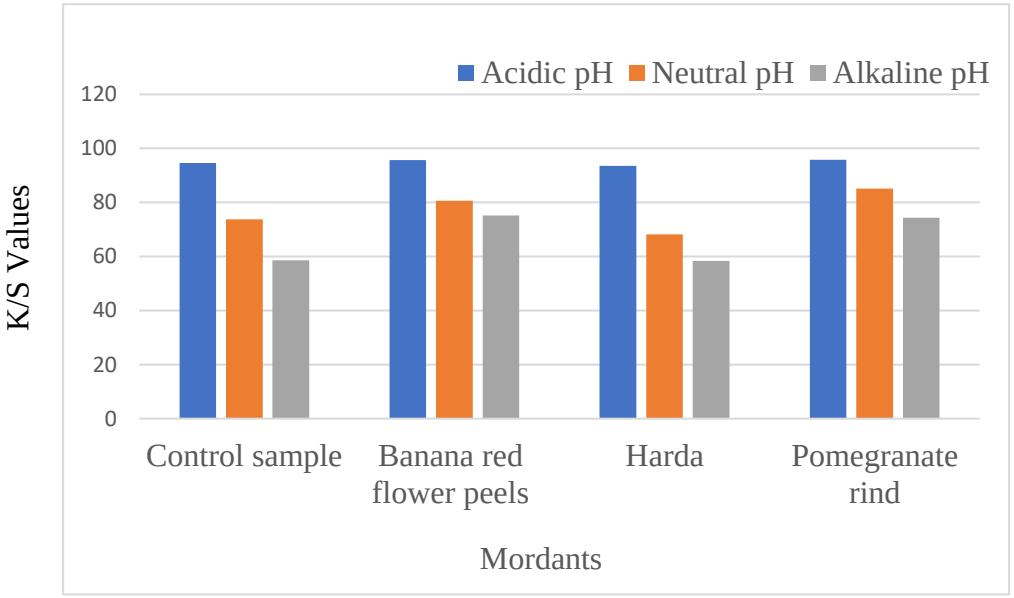
Control sample had a higher L* value (50.337) at self pH, while the Banana red flower peel sample had a lower L* value (43.082) at neutral pH. This indicates that the control sample was lighter at self pH than all other dyed samples, while the Banana red flower peel sample was darker at neutral pH.

Highest a* value was observed in Harda mordanted sample at self pH (15.055), which indicates that it contains more red colour than any other dyed samples.

All samples had positive b* values. Harda mordanted sample at self pH had the lowest b* value (35.654) while the highest b* value was found in the control sample at alkaline pH with a value of 63.465, indicating that it was more yellow in colour.

Highest c* value (63.767) was observed in control sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (38.702); as a result, it was a little dul than the other dyed samples.

Highest DL* values was observed in Harda mordanted at neutral pH (-3.381) and highest colour change was observed in Pomegranate rind mordanted sample at alkaline pH (10.240) than the control sample.



Graph 31: K/S values of 6% concentrated Onion peels dyed Kutchi Wool samples with different mordants at various pH

It was discovered from Graph 31 that the Pomegranate rind mordanted sample at self pH has the deepest colour with a value of 95.733 and the Harda mordanted sample at alkaline pH has the lowest value for colour strength with a value of 58.369.

Table 49: Effect of 8% concentrated Onion peels dyed samples on CIELAB values of Kutchi Wool fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	48.131	8.480	51.538	52.231	-	-	95.026
B3.5pH	46.939	8.984	52.777	53.536	-1.192	1.792	96.802
H3.5pH	48.941	11.285	45.025	46.418	0.810	7.137	94.092
P3.5pH	48.693	9.547	45.309	46.304	0.562	6.345	96.545
Control	47.588	7.330	60.852	61.292	-	-	78.497
B7pH	46.242	7.595	60.933	61.405	-1.346	1.374	84.579
H7pH	48.322	5.839	58.553	58.843	0.734	2.837	70.003
P7pH	53.059	7.386	61.101	61.546	5.471	5.477	86.215
Control	51.654	3.888	62.715	62.835	-	-	68.492
B9pH	51.004	4.333	61.595	61.747	-0.650	1.369	84.625
H9pH	47.341	7.207	59.696	60.129	-4.313	6.224	72.155
P9pH	46.659	4.314	53.280	53.454	-4.995	10.684	81.245

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

The CIELAB values for the 8% concentrated Onion peel dyed Kutchi Wool fabric samples with different mordants and three different pH, namely self (acidic), neutral, and alkaline, are provided in Table 49.

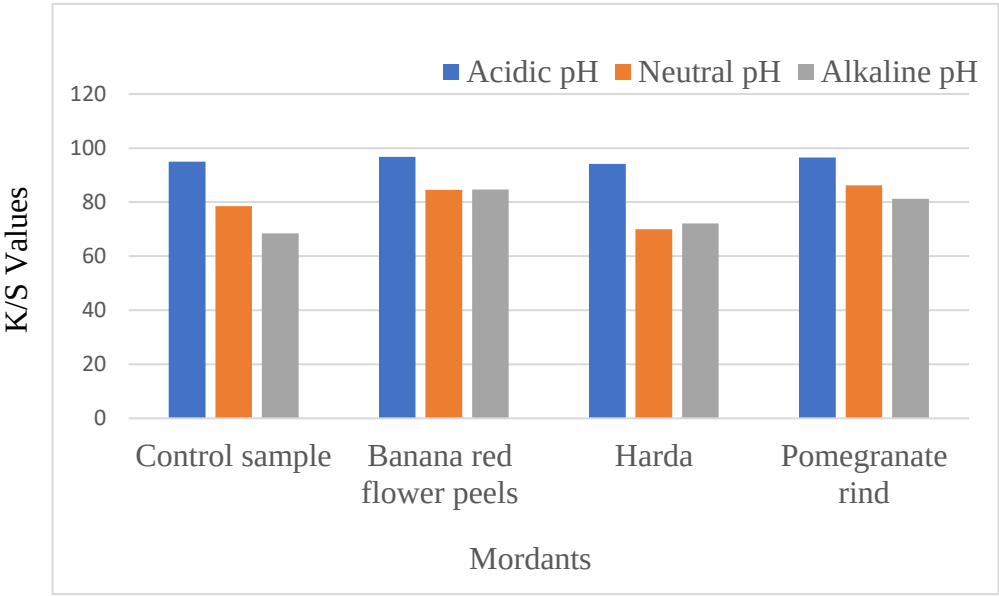
At neutral pH, the Banana red flower peel sample showed a lower L* value (46.242), whereas the Pomegranate rind mordanted sample had a higher L* value (53.059). This shows that the Banana red flower peel sample was darker at neutral pH than the other dyed samples, while the Pomegranate rind mordanted sample was lighter.

Positive a* values were seen in every sample. With Harda mordanted sample at self pH (11.285) exhibit the highest a*, which indicates that it contains more red colour than any other dyed samples.

Harda mordanted sample at self pH had the lowest b* value (45.025) while the highest b* value was found in the control sample at alkaline pH with a value of 62.715, indicating that it was more yellow in colour.

Brightness in the shades were noticed in all the samples. Maximum darkness (62.835) was obtained with control sample at alkaline pH, making it the brightest of all the dyed samples. Pomegranate rind mordanted sample at self pH had the lowest c* value (46.304); as a result, it was a little dull than the other dyed samples.

Maximum DL* value means darkness was found in Pomogranate rind at alkaline condition (-4.995). From the rading obtained for DE* value, it can concluded that Pomegranate rind mordanted sample (10.684) at alkaline pH exhibits higher colour change than the control sample.



Graph 32: K/S values of 8% concentrated Onion peels dyed Kutchi Wool samples with different mordants at various pH

The K/S values of dyed samples at 8% concentrated Onion peels was shown in Graph 32. Highest K/S obtained at self pH (acidic condition) with Banana red flower peel mordanted sample at self pH has the deepest colour with a value of

96.802 and the without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 68.492.

Table 50: Effect of 2% concentrated Onion peels dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	64.430	3.964	41.561	41.750	-	-	24.651
B3.5pH	63.963	2.903	37.748	37.859	-0.467	3.985	30.841
H3.5pH	97.917	-4.687	11.757	12.657	33.487	45.656	26.335
P3.5pH	97.661	-4.453	11.872	12.680	33.231	45.350	28.365
Control	64.723	-1.655	56.383	56.407	-	-	29.245
B7pH	66.602	-4.898	62.644	62.835	1.879	7.297	32.584
H7pH	65.371	-1.771	40.683	40.722	0.648	15.714	24.009
P7pH	66.238	-4.442	52.515	52.703	1.515	5.002	37.664
Control	66.325	-2.638	62.963	63.018	-	-	31.584
B9pH	66.759	-5.075	67.741	67.931	0.434	5.381	39.242
H9pH	65.369	-6.125	59.003	59.320	-0.956	5.362	34.993
P9pH	65.255	-2.395	60.695	60.742	-1.070	2.519	43.001

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 50 gives the CIELAB values of 2% concentrated Onion peels dyed Nylon fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

The Harda mordanted sample had a higher L* value (97.917) at self pH, while the Banana red flower peel sample had a lower L* value (63.963) at self pH. This indicates that the Harda mordanted sample was lighter at self pH than all other dyed samples, while the Banana red flower peel sample was darker at self pH.

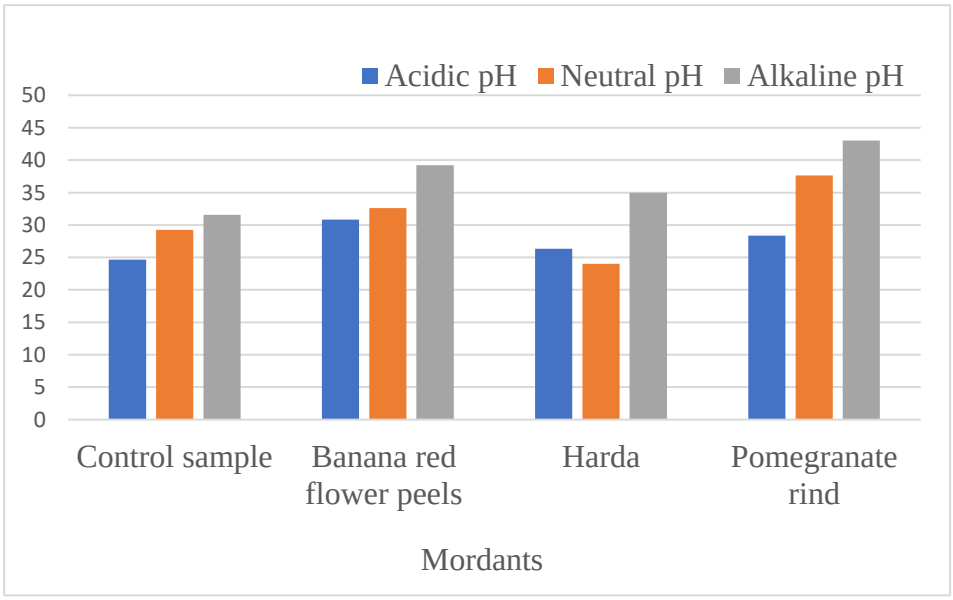
Negative a* values were seen in most of the sample except control and Banana red flower peels at self (acidic) pH. This shows that the obtained colour contains

a greater proportion of green component than red. The sample with the highest a* value was a Harda mordanted sample at alkaline pH (-6.125), which indicates that it contains greener colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Harda mordanted sample at self pH had the lowest b* value (11.757) while the highest b* value was found in the Banana flower red peel mordanted sample at alkaline pH with a value of 67.741, indicating that it was more yellow in colour.

The sample with the highest c* value (67.931) was Banana red flower peel mordanted sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (12.657); as a result, it was a little dull than the other dyed samples.

Highest darkness was obtained with Harda at alkaline pH (-0.956). DE* value of Harda mordanted sample at self pH exhibits more colour change than the control sample.



Graph 33: K/S values of 2% concentrated Onion peels dyed Nylon samples with different mordants at various pH

From K/S values in Graph 33 it was observed that the Pomegranate rind mordanted sample at alkaline pH has the deepest colour with a value of 43.001 and the Harda mordanted sample at neutral pH has the lowest value for colour strength with a value of 24.009.

Table 51: Effect of 4% concentrated Onion peels dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	58.295	6.300	44.764	45.205	-	-	32.110
B3.5pH	53.062	-4.515	14.078	14.784	-55.233	64.104	44.660
H3.5pH	50.443	-29.169	17.972	34.261	-57.852	72.957	35.213
P3.5pH	57.181	7.870	40.664	41.419	-1.114	4.529	31.332
Control	64.536	-1.193	54.879	54.892	-	-	33.221
B7pH	63.561	-2.021	56.116	56.152	-0.975	1.779	39.651
H7pH	62.854	-6.104	54.606	55.830	-1.682	3.829	31.750
P7pH	63.309	-1.657	54.327	54.352	-1.227	1.423	43.065
Control	64.471	-2.937	54.908	54.986	-	-	32.203
B9pH	62.764	-7.143	59.728	58.981	-1.707	1.155	39.360
H9pH	65.591	-5.075	51.506	51.755	1.120	4.171	41.037
P9pH	64.516	-3.031	52.171	52.259	0.045	2.739	45.008

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 51 gives the CIELAB values of 4% concentrated Onion peels dyed Nylon samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

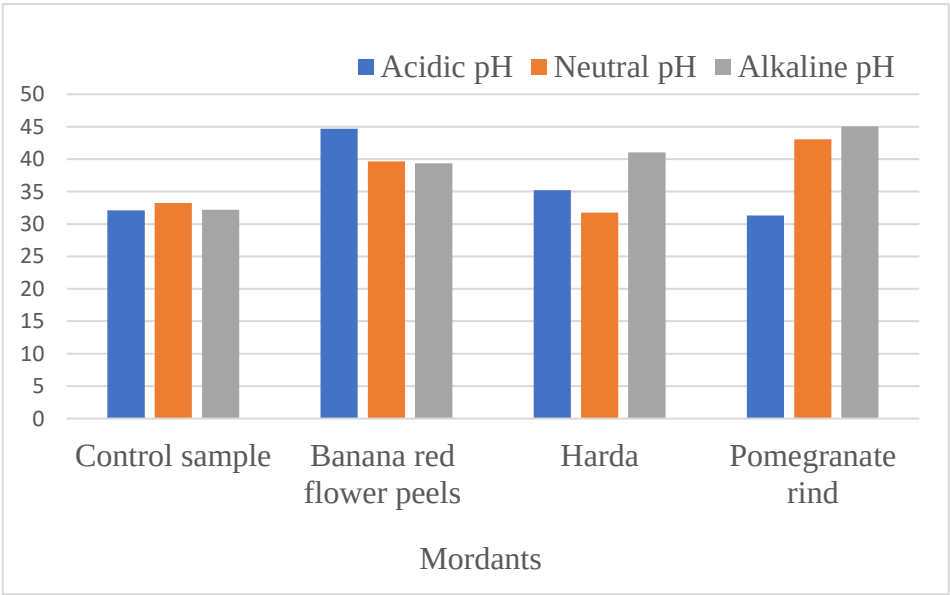
The table denoted L* value showed highest value in Harda mordanted sample (65.591) at alkaline pH, while the Banana red flower peel mordanted sample had a lower L* value (53.062) at self pH. This indicates that the Harda mordanted sample was lighter at alkaline pH than all other dyed samples, while the Banana red flower peel mordanted sample was darker at self pH.

Most of the sample had negative a* values. This demonstrates that the resulting colour has a higher percentage of green component than red component. Harda mordanted sample at self pH has the highest a* value (-29.169), indicating that it contains more green colour than any other dyed samples.

The b* readings of all samples were positive. The Banana flower red peel mordanted sample at self pH had the lowest b* value (14.078), but the sample at alkaline pH had the highest b* value, measuring 59.728, indicating that it was more yellow in colour.

Here, every c* values were positive, each sample showed more brightly in the shades. The sample with the highest c* value (58.981) was a sample that had been mordanted with Banana red flower peel at an alkaline pH, making it the brightest of all the dyed samples. With a lower c* value (14.784) than the other coloured samples, the Banana red flower peel mordanted sample at self pH appeared a little duller.

Maximum darkness (-1.707) with Banana red flower peel mordanted at alkaline pH and highest DE* value was observed in the Harda mordanted sample at self pH exhibited more colour change than the control sample.



Graph 34: K/S values of 4% concentrated Onion peels dyed Nylon samples with different mordants at various pH

With regards to the K/S measurement, it was analyzed from the Graph 34 that the Pomegranate rind mordanted sample at alkaline pH has the deepest colour with a value of 45.008 and the Pomegranate rind mordanted sample of self pH has the lowest value for colour strength with a value of 31.332.

Table 52: Effect of 6% concentrated Onion peels dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	65.168	8.318	38.558	39.347	-	-	41.486
B3.5pH	66.627	5.289	37.434	37.806	1.459	3.515	48.671
H3.5pH	61.892	11.072	33.201	34.999	-3.276	6.779	37.115
P3.5pH	64.288	8.511	36.622	37.598	-0.880	2.045	38.976
Control	64.610	-1.210	55.098	55.111	-	-	40.326
B7pH	64.536	-4.284	64.501	64.643	-0.074	9.893	45.552
H7pH	64.950	0.357	65.481	65.485	-5.660	7.633	38.369
P7pH	63.135	-1.581	52.238	52.262	-1.475	3.239	50.029
Control	65.525	-3.269	58.867	58.958	-	-	36.622
B9pH	66.617	-5.374	66.860	67.076	1.092	8.337	43.999
H9pH	68.019	-6.986	55.152	55.593	2.494	5.817	42.003
P9pH	64.711	-4.289	62.957	63.103	-0.814	4.293	48.747

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 52 gives the CIELAB values of 6% concentrated Onion peels dyed Nylon fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline.

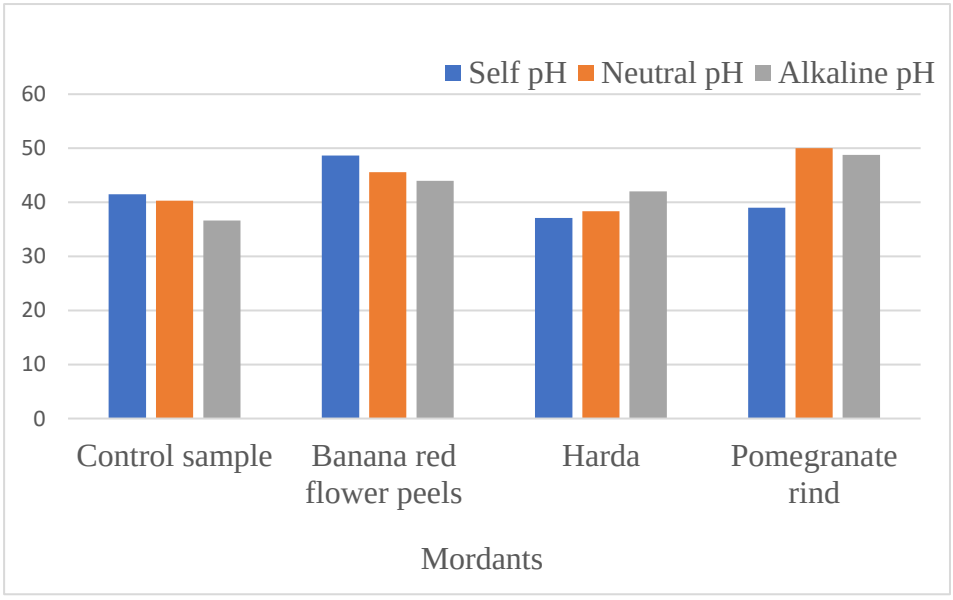
The Harda mordanted sample had a higher L* value (68.019) at alkaline pH, while the Harda mordanted sample had a lower L* value (61.892) at self pH. This indicates that the Harda mordanted sample was lighter at alkaline pH than all other dyed samples, while the Harda mordanted sample was darker at self pH.

Negative a* values were seen in most of the samples. This shows that the obtained colour contains a greater proportion of green component than red. The sample with the highest a* value was Harda mordanted sample at alkaline pH (-6.986), which indicates that it contains more green colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. The Harda mordanted sample at self pH had the lowest b* value (33.201) while the highest b* value was found in the Banana flower red peel mordanted sample at alkaline pH with a value of 66.860, indicating that it was more yellow in colour.

Every c* value was positive, making every sample brighter in the shade. The sample with the highest c* value (67.076) was Banana red flower peel mordanted sample at alkaline pH, making it the brightest of all the dyed samples. Harda mordanted sample at self pH had the lowest c* value (34.999); as a result, it was a little duller than the other dyed samples.

Greatest DL* value was found with Harda at neutral pH(-5.660). From the findings for the DE* values, it can be concluded that the Banana red flower peel mordanted sample at neutral pH exhibits more colour change than the control sample.



Graph 35: K/S values of 6% concentrated Onion peels dyed Nylon samples with different mordants at various pH

From K/S values in Graph 35, it was observed that the Pomegranate rind mordanted sample at neutral pH has the deepest colour with a value of 50.029 and the without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 36.622.

Table 53: Effect of 8% concentrated Onion peels dyed samples on CIELAB values of Nylon fabric with different mordants at various pH.

Samples	L*	a*	b*	c*	DL*	DE*	K/S
Control	6.691	-6.119	14.026	14.480	-	-	43.200
B3.5pH	1.256	-15.597	15.481	21.976	-60.435	69.112	49.363
H3.5pH	1.599	-13.258	15.265	20.219	-60.092	68.192	45.040
P3.5pH	0.967	-19.343	16.629	25.508	-60.724	70.221	52.966
Control	65.658	-1.228	55.271	55.285	-	-	43.110
B7pH	65.922	-3.893	61.813	61.935	0.264	7.069	52.551
H7pH	60.976	-2.626	61.644	62.504	-4.682	7.795	41.630
P7pH	62.680	-0.470	53.258	53.260	-2.978	3.674	55.009
Control	64.698	-3.525	65.123	65.218	-	-	41.330
B9pH	65.362	-3.551	65.002	65.099	0.664	0.675	46.201
H9pH	69.741	-7.050	51.962	52.438	5.043	14.528	44.495
P9pH	63.743	-3.625	53.770	53.892	-0.955	11.394	50.127

Key: B=Banana red flower peels, H=Harda, P=Pomegranate rind

The CIELAB values of 8% concentrated Onion peels dyed Nylon fabric samples with various mordants and three different pH i.e., Self (Acidic), Neutral and Alkaline in Table 53.

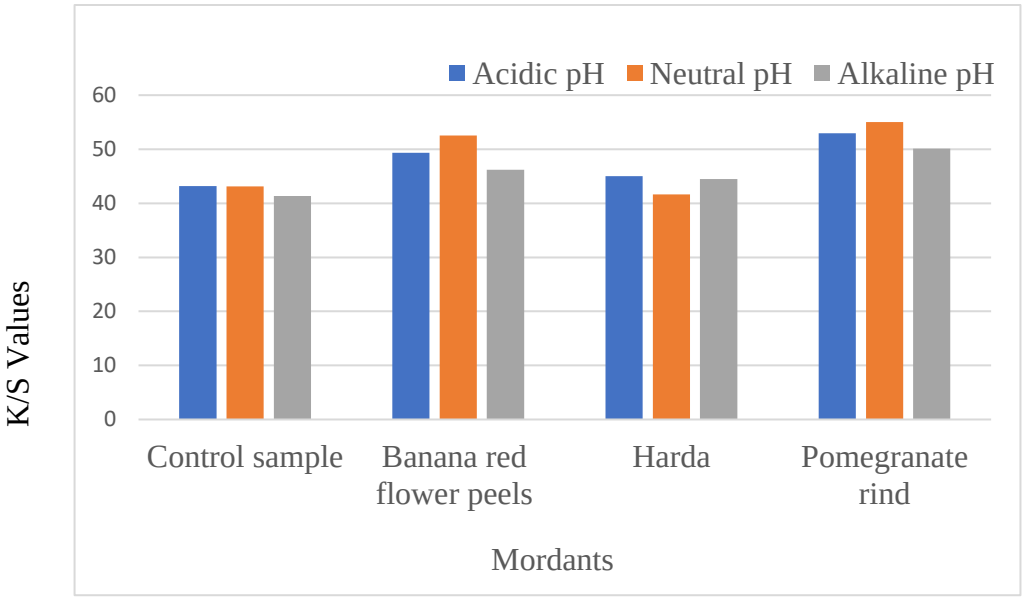
The Harda mordanted sample had a higher L* value (69.741) at alkaline pH, while the Pomegranate rind mordanted sample had a lower L* value at self pH. This indicates that the Harda mordanted sample was lighter at alkaline pH than all other dyed samples, while the Pomegranate rind mordanted sample was darker at self pH.

Negative a* values were seen in every sample. This shows that the obtained colour contains a greater proportion of green component than red. The sample with the highest a* value was a Pomegranate rind mordanted sample at self pH (-19.343), which indicates that it contains more green colour than any other dyed samples.

All samples had positive b* values. This indicates that all of the samples have more yellow component than blue colour component. Control sample at self pH had the lowest b* value (14.026) while the highest b* value was found in the control sample at alkaline pH with a value of 65.123, indicating that it was more yellow in colour.

Highest c* value (65.218) observed with control sample at alkaline pH, making it the brightest of all the dyed samples. Control sample at self pH had the lowest c* value (14.480); as a result, it was a little duller than the other dyed samples.

The DL* values showed darkness in the shade, highest value (-60.724) found with Pomegranate rind acidic pH and also had maximum colour change than the control sample.



Graph 36: K/S values of 8% concentrated Onion peels dyed Nylon samples with different mordants at various pH

The K/S values in Graph 36 showed that the Pomegranate rind mordanted sample at neutral pH has the deepest colour with a value of 55.009 and the

without mordanted control sample of alkaline pH has the lowest value for colour strength with a value of 41.330.

4.7 Fastness properties of the selected dyed samples

Colour fastness refers to a material's durability to changes in any of its colour characteristics, including the transfer of its dyes to adjacent materials. If the colour fastness is good, the quality of the fabric will be high; if it is bad, the quality will be low.

Light, wash, and rub fastness tests were performed on the dyed material. The loss of colour intensity in the original sample typically serves as a measure of colour fastness, as does the staining scale. By exposing the dyed materials to direct xenon light for 5, 10 and 15 hour, the materials' light fastness was evaluated. The dyed fabric was washed in non-ionic detergent (2gpl) to test wash fastness. By rubbing the cloth and looking for colour fading, the rub fastness of the dyed fabric was tested. The evaluation of the dyed samples' fastness properties was done using a grayscale. Each pair of standard grey chips represents a variation in colour or brightness (shade and strength), and each pair corresponds to a numerical fastness grade. The difference between the colours of stained and unstained fabric was compared to the difference represented by the scale in order to score the outcomes of colour fastness tests.

Out of 432 dyed samples, 36 dyed samples were visually chosen by the 5 experts for evaluation. 12 samples of each type of dye i.e., from Indian almond leaves dyed samples at self pH with 6% dye concentration, Annatto seed dyed samples at alkaline pH with 6% dye concentration and Onion peels dyed samples at self pH with 6% dye concentration were examined.

4.7.1 Evaluation of Wash durability of the selected samples

Indian almond leaves dye, Annatto seeds dye and Onion peel dyed samples were evaluated for wash fastness, samples were rated using geometric grey scale.

Table 54: Wash fastness rating of Indian almond leaves dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Change in colour	Staining on white
1.	EC	5	4/5
2.	EB	5	4/5
3.	EH	4/5	4/5
4.	EP	5	4/5
5.	WC	5	5
6.	WB	5	5
7.	WH	5	5
8.	WP	5	5
9.	NC	5	5
10.	NB	5	5
11.	NH	5	5
12.	NP	5	5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 54 showed the wash fastness rating of Indian almond leaves dyed samples. Change in dyed sample and staining on adjacent fabric were rated on grey scale. The rating for colour changes in dyed samples was rated 5 except for the Harda mordanted Eri Silk sample, and the rating for staining on adjacent fabric was also 5 except for few samples that have a 4/5 rating. This indicates that the sample of Indian almond leaves dye has good to very good wash fastness.

Table 55: Wash fastness rating of Annatto seed dyed samples with different fabrics and mordants at alkaline pH with 6% dye concentration

Sr. No.	Samples	Change in colour	Staining on white
1.	EC	5	5
2.	EB	5	5

3.	EH	5	5
4.	EP	5	5
5.	WC	4/5	4/5
6.	WB	5	5
7.	WH	5	5
8.	WP	5	4/5
9.	NC	5	5
10.	NB	5	5
11.	NH	5	5
12.	NP	5	5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, An=Annatto seeds dye, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

The wash fastness rating of samples dyed with Annatto seeds was displayed in Table 55. On a grey scale, the dyed sample's change and any staining on adjacent fabric were evaluated. Except for the control Kutchi Wool sample, all dyed samples showed a rating of 5, and all adjacent fabric samples gave a rating of 5 except for the control sample and Pomegranate rind-mordanted Kutchi Wool samples, which had a rating of 4/5. It was observed that the sample of Annatto seed dye has good to very good wash fastness.

Table 56: Wash fastness rating of Onion peels dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Change in colour	Staining on white
1.	EC	4	4
2.	EB	4	4
3.	EH	3/4	4
4.	EP	3/4	4
5.	WC	3/4	3/4
6.	WB	4/5	4
7.	WH	4/5	4

8.	WP	4/5	4/5
9.	NC	5	4
10.	NB	3/4	4
11.	NH	5	4/5
12.	NP	4	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, O=Onion peels dye, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

The wash fastness rating of the samples dyed with Onion peels was displayed in Table 56. Gray scale ratings were given for the dyed sample's change and the staining of adjacent fabric. The scale for colour change in dyed samples was 3/4 to 5, and the scale for staining on adjacent fabric was 3/4 to 4/5. This shows that the sample's wash fastness ranges from fairly good to excellent for Onion peels dye.

4.7.2 Evaluation of light permanence of the selected samples

Indian almond leaves dye, Annatto seeds dye and Onion peel dyed samples were evaluated for light fastness, samples were rated using geometric grey scale.

Table 57: Light fastness rating of Indian almond leaves dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Rating at 5 hours	Rating at 10 hours	Rating at 15 hours
1.	EC	4	4	4
2.	EB	4/5	4	4
3.	EH	4/5	4	4
4.	EP	4/5	4/5	3/4
5.	WC	4	4	3
6.	WB	4	3/4	3
7.	WH	4	3/4	2

8.	WP	3/4	3	2
9.	NC	4	3/4	3
10.	NB	4	3/4	3/4
11.	NH	4	3/4	3/4
12.	NP	4/5	4/5	4

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, Al=Indian almond leaves dye, C=Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

The results for Indian almond leaves dyed sample with different mordant and fabrics for light fastness after 5 hours for exposer indicated fairly good to very good fastness which gave the rating from 3/4 to 4/5. After 10 hours exposer, rating was ranged also from 3/4 to 4/5 which means fairly good to very good fastness and after 15 hours of exposer rating was 2 to 4 means medium to good fastness. After 15 hours, shades were bit darker on Kutchi Wool samples.

Table 58: Light fastness rating of Annatto seed dyed samples with different fabrics and mordants at alkaline pH with 6% dye concentration

Sr. No.	Samples	Rating at 5 hours	Rating at 10 hours	Rating at 15 hours
1.	EC	5	5	5
2.	EB	5	5	5
3.	EH	5	5	4/5
4.	EP	5	5	5
5.	WC	4	3/4	3/4
6.	WB	3/4	3	3
7.	WH	4/5	4	4
8.	WP	4/5	4	4
9.	NC	5	5	4/5
10.	NB	5	5	5
11.	NH	5	5	4/5
12.	NP	5	5	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, An=Annatto seeds dye, C=Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

Results for a sample of Annatto seeds dyed with various mordants and fabrics for light fastness after 5 hours of exposure showed fairly good to very good fastness, which was rated from 3/4 to 5. After 10 hours of exposure, the rating varied from 3/4 to 5, indicating fair to excellent fastness, and after 15 hours of exposure, the rating ranged from 3 to 5, indicating fair to excellent fastness. Shades on Kutchi Wool samples were somewhat darker after 15 hours.

Table 59: Light fastness rating of Onion peels dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Rating at 5 hours	Rating at 10 hours	Rating at 15 hours
1.	EC	5	5	4/5
2.	EB	5	4/5	4
3.	EH	5	5	5
4.	EP	5	5	4/5
5.	WC	5	5	5
6.	WB	5	5	5
7.	WH	5	5	5
8.	WP	5	5	5
9.	NC	5	5	4/5
10.	NB	5	4/5	4/5
11.	NH	5	5	5
12.	NP	5	5	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, O=Onion peels dye, C=Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

Results for a sample of Onion peel dyed with various mordants and fabrics for light fastness after 5 hours of exposure showed excellent fastness. After 10

hours of exposure, the rating was 5 with the exception of two samples, meaning the samples had very good light fastness. After 15 hours of exposure, the rating varied from 4 to 5, meaning the samples had good to very good light fastness. Only a slight amount of fading was seen; there was no shade change.

4.7.3 Evaluation of rub fastness of the selected samples

Indian almond leaves dye, Annatto seeds dye and Onion peel dyed samples were evaluated for Rub fastness, samples were rated using geometric grey scale.

Table 60: Dry & Wet Rub fastness rating of Indian almond leaves dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Change in colour		Staining on white	
		Dry	Wet	Dry	Wet
1.	EC	5	5	3/4	3
2.	EB	4/5	5	3/4	3
3.	EH	4/5	4	4	3/4
4.	EP	5	5	4	3/4
5.	WC	5	5	4/5	4
6.	WB	5	5	4/5	4
7.	WH	5	5	4/5	4/5
8.	WP	5	5	4/5	4
9.	NC	5	5	4/5	4/5
10.	NB	5	5	5	5
11.	NH	5	5	4/5	4/5
12.	NP	5	5	4/5	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

Result of Indian almond leaves dyed sample with different mordants and fabrics were discussed in table 60. Colour fastness for dry rubbing gave good to very

good result with rating ranged from 3/4 to 5 and for wet rubbing it ranged from 3 to 5 means fairly good to very good rub fastness. Colour change in dyed sample in dry rubbing gave the excellent fastness where as in wet rubbing gave the good to very good fastness rating. Staining on white fabric in dry and wet rubbing gave the good to very good rubbing fastness.

Table 61: Dry & Wet Rub fastness rating of Annatto seeds dyed samples with different fabrics and mordants at alkaline pH with 6% dye concentration

Sr. No.	Samples	Change in colour		Staining on white	
		Dry	Wet	Dry	Wet
1.	EC	5	4/5	4/5	4/5
2.	EB	5	4/5	4/5	4
3.	EH	4/5	4/5	3/4	3/4
4.	EP	4/5	4/5	3/4	3/4
5.	WC	4/5	4/5	3/4	4
6.	WB	5	4/5	4/5	4
7.	WH	5	4/5	4/5	4
8.	WP	5	5	4/5	4/5
9.	NC	5	5	4/5	4/5
10.	NB	5	4/5	4/5	4/5
11.	NH	5	5	4/5	4/5
12.	NP	5	4/5	4	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

The outcomes of a sample of Annatto seeds dyed with various mordants on various fabrics were described in table 61. For wet rubbing, the ratings varied from 3/4 to 5, which indicates fairly good to very good rub fastness, while for dry rubbing, the ratings went from 3/4 to 5. Dry rubbing of a dyed sample produced very good fastness, but wet rubbing produced a good fastness rating. With both dry and wet rubbing, staining on white fabric produced rubbing fastness that was between fairly good and good.

Table 62: Dry & Wet Rub fastness rating of Onion peels dyed samples with different fabrics and mordants at self pH with 6% dye concentration

Sr. No.	Samples	Change in colour		Staining on white	
		Dry	Wet	Dry	Wet
1.	EC	5	4/5	4/5	4
2.	EB	5	4/5	4/5	4
3.	EH	5	4/5	4/5	4
4.	EP	5	5	4/5	4/5
5.	WC	5	5	5	4/5
6.	WB	5	5	4/5	4/5
7.	WH	5	5	4/5	4/5
8.	WP	5	5	4/5	4/5
9.	NC	5	5	5	4/5
10.	NB	5	5	5	4/5
11.	NH	5	4/5	5	4/5
12.	NP	5	5	5	4/5

Key: E=Eri Silk, W=Kutchi Wool, N=Nylon, C= Control Sample, B=Banana red flower peels, H=Harda, P=Pomegranate rind

Table 62 evaluated the outcomes of Onion peel dyed samples on various fabrics and with various mordants. Colour fastness for dry rubbing yielded very good results with ratings of 4/5 and 5, and for wet rubbing, the range was 4 to 5, which denotes good to very good rub fastness. With dry rubbing, the colour changes in the dyed sample had excellent fastness, whereas in wet rubbing, the colour change had good to very good fastness. The rubbing fastness of stains on white fabric in both dry and wet rubbing was good to very good.

CHAPTER V

SUMMARY AND CONCLUSION

Disposal of waste, generated as by-products by agriculture, forestry and industries pose a serious threat to the environment. With the environmental awareness and scarcity of space for landfills, wastes or by-product utilization becomes an attractive alternative to direct disposal. Thus, a promising concept for production of natural dyes with lowered cost could involve the use of plant materials discarded as waste or by-products from different sources.

Agro-wastes may include, among other materials, harvest-wastes including barks, flowers, fruits, leaves, roots, woods and seeds yield dyes.

Tree's waste could be considered the most sustainable, because they grow each year and processed for value-addition and uneatable parts of the fruits like peels and seeds are thrown away as waste. Agro-waste such as peels, shells, seeds, etc., are rich sources of pigments and natural dyes can be obtained from them. Use of fallen leaves and branches having a rich dye content is another sustainable approach.

Several researchers are striving to utilize and dispose off this garbage in an environmentally responsible manner. The goal of this research is to use agricultural waste in the commercial manufacturing of natural dyes. The process of dyeing textiles can be made more affordable and environmentally beneficial by using agricultural waste.

Mordants are typically used to strengthen the affinity of dye with fibers in order to overcome issues caused by the weak interaction of natural dyes with textile fibers and poor colour fastness. However, using metal mordants can significantly change the fibers' ultimate colour, and releasing wastewater containing heavy metal ions might be harmful to the environment. As a result, reducing the use of metal mordants and other chemicals during the dyeing of natural dyes for textiles continues to be a difficult task.

Bio-mordants or natural mordants are reported as sustainable and ecologically correct alternatives to metal mordants, providing satisfactory dyeing and solidity properties. Natural mordant sources are plants with high tannin content.

Some natural mordants, such as Pomegranate peel, rosemary and thuja leaves were proposed as promising alternatives for aluminum, iron sulphate II, copper sulphate II, stannous chloride and potassium dichromate. Natural polyphenols, also called tannins, are obtained from various parts of plants, such as bark, wood, fruits, fruit peels, leaves, roots and plant galls. Other studies describe the presence of tannin in the Banana tree pseudostem.

Although, use of natural dye for coloration of textile is confined only to handloom sectors and small-scale exporters dealing with the production and sale of high valued textiles, it appears from the continuous effort put by the scientific workers and also from rising popularity of natural dye, that there remains possibility of use some natural dyes in the near future by the organized sectors of the textile industries. It is also felt that an overview of the present state of affairs related to use of natural dyes on textile may be some benefit for the dyers and users of the textile industry.

Being waste, this source of natural dyes will not require additional land for cultivation and looking at its use for supply chain can be maintained for bulk use. Agro waste can help reduce costs and promote environmental responsibility in the textile dyeing process. Thus, this research was undertaken to reduce waste by utilizing agricultural waste as an alternative dye such as Onion peels (Allium cepa), Annatto seeds (Bixa Orellana), and fallen leaves of the Indian almond (Terminalia catappa) and using natural mordant source, like Harda, Pomegranate rind and Banana red flower peels.

5.1 OBJECTIVES OF THE STUDY

5.1.1 To explore the agro waste as source of natural dye and natural mordant.

5.1.2 To optimize the recipe for the selected dyes and mordant.

5.1.3 To develop shade card for each dye varying concentration of dye, natural mordant and pH.

5.1.4 To test dyed fabrics for its colour strength.

5.1.5 To evaluate the fastness properties of the dyed samples in terms of wash fastness, light fastness and rub fastness.

The literature review for this study focused on the historical facets of natural dyes, information about agro-waste, classification and application of natural dyes and mordants, information about natural dyes and mordants which was used in study, review of the fabrics used for the study. Research reviews relevant to studies on natural dyes and mordants have also been gathered.

5.2 MATERIALS AND METHODS

The three different agro-waste natural dyes i.e., Indian almond leaves, Annatto seeds, and Onion peels were investigated with various factors including different fabrics, natural mordants, dye concentrations and pH levels of dye bath for the current study.

Using a multi-fiber fabric made of six different fibers—cotton, silk, wool, viscose rayon, nylon, and polyester—a pilot study was carried out. In the pilot study, natural agro-waste dyes such as Indian almond leaves, Banana red flower peels, Onion peels, and Annatto seeds were used and three mordants—Alum, Harda, and Pomegranate rind—as well as combinations of mordants with Harda were applied. The dyes were applied at a concentration of 4% on the material's weight. Banana red flower peels were tested as a mordant with the other three dyes after that it was determined through visual observation that the dye from Banana red flower peels only stained on the fibres.

Based on the findings of the pilot study, various study variables were selected for the further experimentation. Based on their usefulness, the three mordants that were selected were Banana red flower peels, Harda, and Pomegranate rind. Three agro-waste dyes selected for the study were Onion peels, Annatto and Indian almond leave. In order to produce a colour palette, dye concentrations of 2%, 4%, 6%, and 8% in three different pH conditions—self, neutral, and alkali

was decided. Based on CIELAB values, good results for the multi-fiber fabric dyed with Indian almond leaves were seen on nylon, wool, and silk. HTHP dyeing and exhaust dyeing produced almost similar results and hence, exhaust dyeing was selected for further experimentation.

Fabrics selected were Eri Silk, Kutchi Wool and Nylon for the further experiment. Fabric confirmation was done by Burning, Microscopic and Solubility tests. Preliminary data of the fabrics were tested for Fabric count, GSM, fabric thickness and yarn diameter.

Fabrics were first scoured with 2 grams/litre of non-ionic detergent keeping M:L of 1:40 for 45 minutes at 60^0 C. Pre-mordanting was done with 10% concentration in M:L of 1:40 for 30 minutes at room temperature. Dye extraction was carried out with soaking of powdered dye and boiling it at 90^0 C temperature for 30 minutes keeping M:L ratio as 1:50.

The colour palette of dyed samples were obtained by varying different condition. The fabric was dyed with different natural mordants Banana red flower peels, Harda and Pomegranate rind with different pH value (self, acid and alkaline) at 2%, 4%, 6% and 8% shade. Dyeing was done with M:L ratio1:30 for 30 minutes at 80^0 C.

The K/S and CIELAB values of the dyed sample were measured using a spectrophotometer analysis. Under controlled circumstances, the dyed samples were evaluated for light fastness, wash fastness, and rub fastness. The loss of colour intensity in the original sample is typically used to evaluate colour fastness, or the staining scale is used. By placing the dyed materials under a xenon lamp for 5, 10, and 15 hours, light fastness was evaluated. The dyed fabric was washed with non-ionic detergent (2 grams/litre) to test wash fastness. By rubbing the fabric and looking for colour fading, the rub fastness of the dyed fabric was tested.

5.3 RESULTS AND DISCUSSION

The following subheads have been used to discuss the results and discussion of the research.

5.3.1 Preliminary data of the fabrics

The results of preliminary data revealed that fabric type was 100% Eri Silk, 100% Kutchi Wool and 100% Nylon. Eri Silk fabric had 26 ends per cm & 30 picks per cm with 200 micro meter yarn diameter and 104 grams/square meter weight with 0.30 mm thickness of the fabric. Kutchi Wool had 8 ends per cm & 6 picks per cm with 800 micro meter yarn diameter, 200 grams/square meter weight and 0.45 mm thickness while Nylon had 31 ends per cm & 36 picks per cm with 200 micro meter yarn diameter, 154 grams/square meter weight and 0.35 mm thickness.

5.3.2 Developing colour palette using three dyes under study

Multiple variables, including three natural mordants, three fabrics, various dye concentrations, and three pH levels, were investigated in order to establish a colour palette.

Three natural dyes namely Indian almond leaves (Terminalia catappa), Annatto seeds (Bixa Orellana) and Onion peels (Allium cepa) were combined with three natural mordants (Banana red flower peel, Harda, and Pomegranate rind) to create a colour palette with a total of 432 shades on three different fabrics (Eri silk, Kutchi wool, and 100% nylon) at three different pH (Self which was acidic, neutral & alkaline).

Different fabrics treated with different mordants showed different shades. Indian almond leaves dyed samples gave the olive green to khaki to brown shades. Annatto seeds dye gave the cream to orange to reddish orange shades and Onion peels dyes gave the yellow golden to brown shades.

5.3.3 Evaluation of the colour yield

The results of the Indian almond leaves, Annatto seeds and Onion peels dye revealed that Kutchi wool fabric absorbed more dye and displayed darker hues than Eri silk and Nylon fabrics. It was because of wool fabric had an open weave and higher yarn diameter. Pomegranate rind and Banana red flower peel as a

mordant both have higher K/S values with all of the fabrics. It was observed that Pomegranate rind mordant showed a higher DE* values.

Indian almond leaves dyed samples gave better results at self pH, Annatto seeds dyed samples gave better results at alkaline pH and Onion peels dyed samples gave better results at all pH. It gave different shades with different pH. Kutchi Wool produced the darkest hues followed by Eri Silk and Nylon fabric, dyed with Indian almond leaves dye. Darker shades were produced with Annatto seeds dye and Onion peels dye on Kutchi Wool, followed by Nylon and Eri Silk fabric.

Banana red flower peel and Pomegranate rind mordanted samples displayed the higher K/S values as compare to Harda mordanted samples with all three dyes.

It was also concluded from the results that the shade of the samples became darker with increase in percent shade but after 6% shade there were no such change in colour noticed. For the fastness test, samples with 6% shade were taken.

5.3.4 Colour fastness properties

The dyed samples were tested for their fastness by washing, rubbing and exposure to light. The results of the dyed specimens' fastness, as determined by the grey scale, are discussed below.

Indian almond leaves dyed samples had good to very good wash fastness for all the dyed samples and also for the staining on white. Eri Silk fabric had good and Kutchi wool & Nylon had very good wash fastness. The samples dyed with Indian almond leaves had medium to good light fastness after 15 hours of exposer to light. Kutchi Wool fabric samples were somewhat poor light fastness. In case of rub fastness, the samples showed overall good to very good rub fastness. Dry and wet both rub fastness was very good for change in colour of dyed sample but for staining it was fairly good to very good. Eri silk fabric had slightly poor rub fastness.

Annatto seeds dyed samples gave very good wash fastness. The outcome was same for both, staining on white and the colour change in the dyed sample. After being exposed to light for 15 hours, it demonstrated acceptance to excellent light fastness. Kutchi Wool showed a little poor light fastness. It exhibited fair to excellent rub fastness overall. When it came to changing the colour of a dyed sample, both dry and wet rub fastness were good, but when it came to staining, it was fair to excellent. Eri Silk fabric had a bit of weak rub fastness.

Onion peels dyed samples had fairly good to good wash fastness. The outcome for the dyed sample changing colour and the stains on white was very similar. In comparison to the other two fabrics, nylon fabric performed well in terms of washability. After being exposed to light for 15 hours, it demonstrated good to excellent light fastness. Here, the light fastness of the Eri Silk fabric was not very good. Overall, the rub fastness was good to excellent. For changing the colour of the dyed sample, both dry and wet rub fastness was very good, but for staining it was good to very good. The wet rubbing fastness of Eri Silk fabric was slightly poor.

5.3 CONCLUSION:

The research came to the conclusion that the tone and tone effect created by the agro-waste as a source of natural dyes makes the colour produced by them fascinating and beautiful. Various shades obtained with the combination of dye and mordants.

1. Agriculture is associated with the production of large amount of organic wastes that can adversely affect environmental quality and human health if not properly managed. These wastes are biodegradable and abundant in colour giving components like tannins, flavones, carotenoids, etc. Therefore, using agricultural waste as a natural dye provides the advantages of waste reusing and an environmentally friendly sources of natural dyes.

2. Kutchi Wool fabric gave the highest K/S with all the dyes followed by Eri Silk and Nylon. Indian almond leaves, Annatto seeds and Onion peels dyes gave higher K/S with Banana red flower peel and Pomegranate rind mordant.

3. Indian almond leaves dye gave best result at self pH which was acidic (4 pH), Annatto seeds dye gave best result at alkaline pH (9 pH) and Onion peels dye gave the best result at all pH with different shades.

4. Wash fastness of Indian almond leaves dye was excellent with Kutchi Wool and Nylon fabrics followed by Eri Silk. Annatto seeds dye was excellent with Eri Silk and Nylon fabrics followed by Kutchi Wool whereas Onion peels dye was good with Nylon fabric followed by Kutchi Wool and Eri Silk.

5. Indian almond leaves dye had moderate light fastness with Eri Silk and Nylon followed by Kutchi Wool after 15 hours of exposer to light. Annatto seeds dye had excellent fastness with Nylon and Eri Silk followed by Kutchi Wool while Onion peels dye had excellent light fastness with Kutchi Wool and Nylon followed by Eri Silk.

6. Dry and wet rub fastness of all the dyes gave good to excellent results. Indian almond leaves dye in terms of change in colour of dyed samples were excellent with all the fabrics and in terms of staining on white they were fair with Eri Silk and good with Kutchi Wool and Nylon fabrics. Annatto seeds dye in terms of change in colour of dyed samples and also in terms of staining, they were good to very good with all fabrics. Onion peels dye gave the very good fastness to changing of colour and good result to staining on white with all the fabrics.

5.4 RECOMMENDATIONS

1. Use of wastes from various sources for dyeing textiles is important because it provide novel sources for dyeing textiles at lower costs and also provide sustainable solution to the management of waste disposal. Although literature has reported use of agro, forest and industry waste in dyeing of textile, research in this field is limited, scanty and sporadic. There are numerous varieties of agro-waste that are easily accessible and plentiful. Investigating other dye sources from agricultural waste will offer a more effective and sustainable approach.

2. So other alternative source for natural dye mainly from waste can be done in a systemic and scientific manner. Systematic collection of waste from the source and suitable alternatives to convert the waste into concentrates and appropriate recipes for dyeing to produce reproducible shades needs to be explored.

3. In the present study few agro-wastes were used as potential source for textile colourants, as sky is the limit to produce endless shades from them, a very wide spectrum of hues can be created using other mordants. As per literature review used dyes are also associated with multi-functional properties which can also be tested and used further studies can be undertaken for functional properties.

4. A common database on waste used as natural dyes in dyeing textiles is not available, which can be done, hence naturally dye textiles shall help the entrepreneurs to take up this venture.

5. Exhaust dyeing was used in the present study, however non-conventional dyeing method (infrared dyeing, microwave dyeing, ultrasonic wave dyeing) can be used for the dyeing.

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APPENDIX

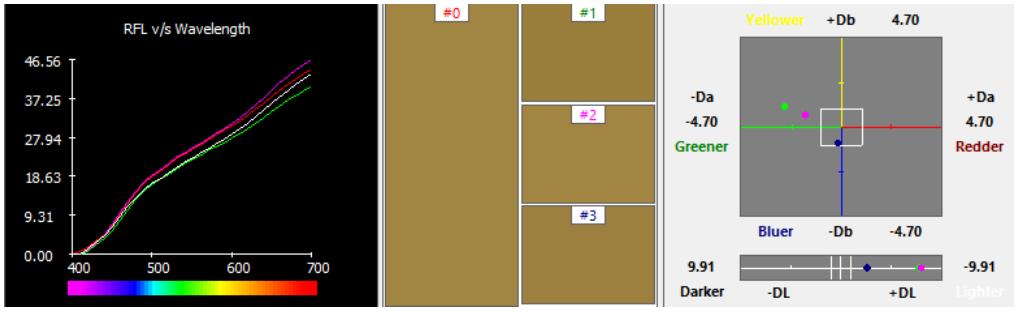

Figure 40: Reflectance value of 2% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 4 pH

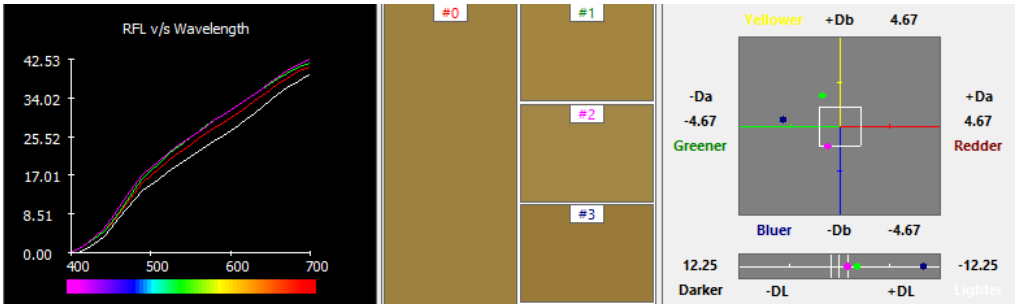

Figure 41: Reflectance value of 2% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 7 pH

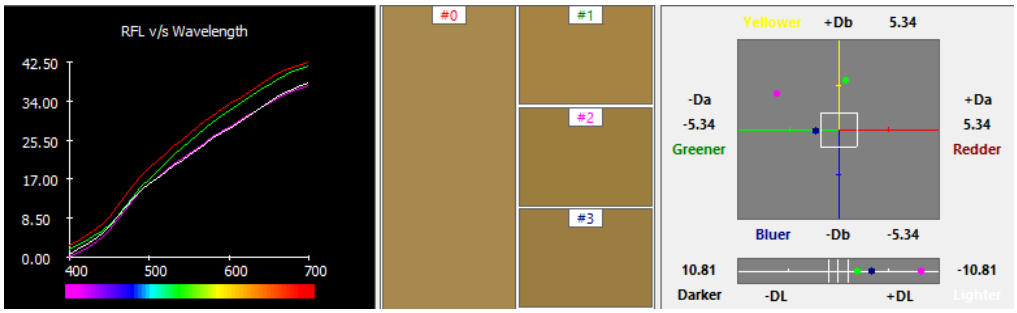

Figure 42: Reflectance value of 2% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 9 pH

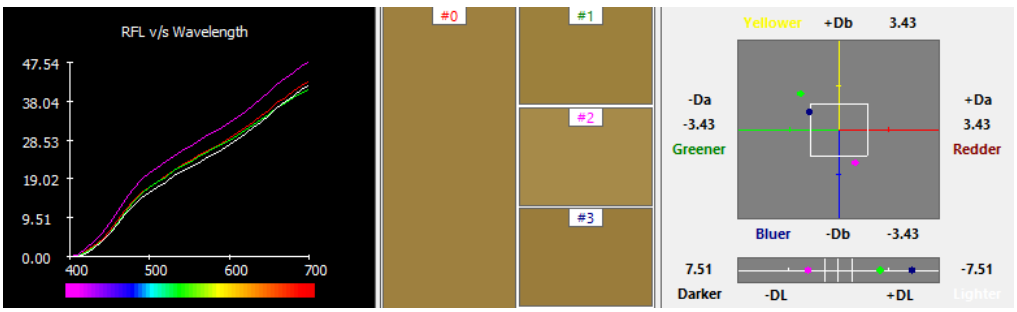

Figure 43: Reflectance value of 4% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 4 pH

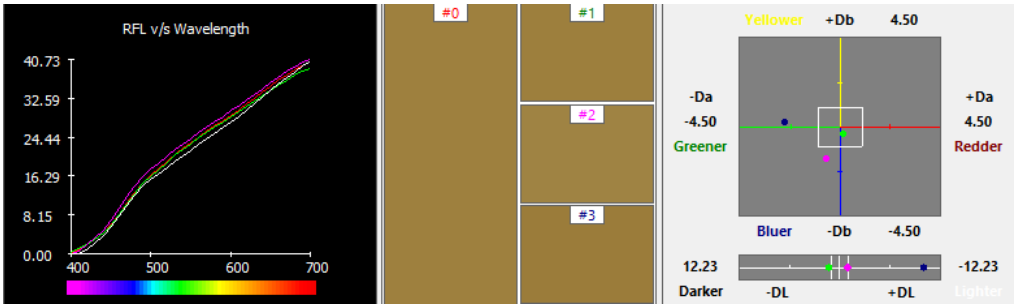

Figure 44: Reflectance value of 4% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 7 pH

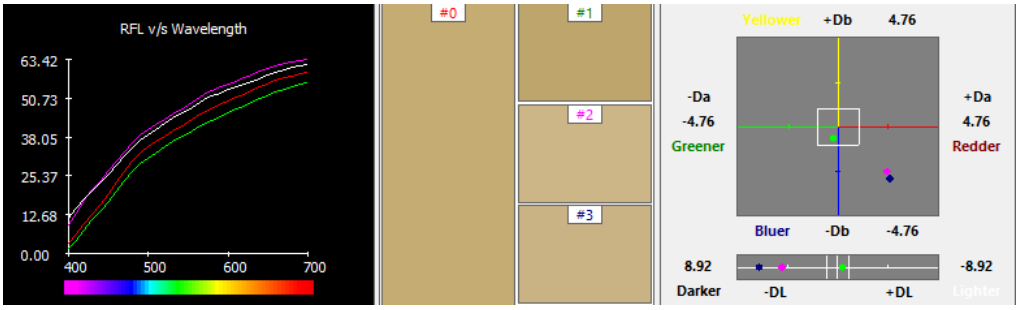

Figure 45: Reflectance value of 4% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 9 pH

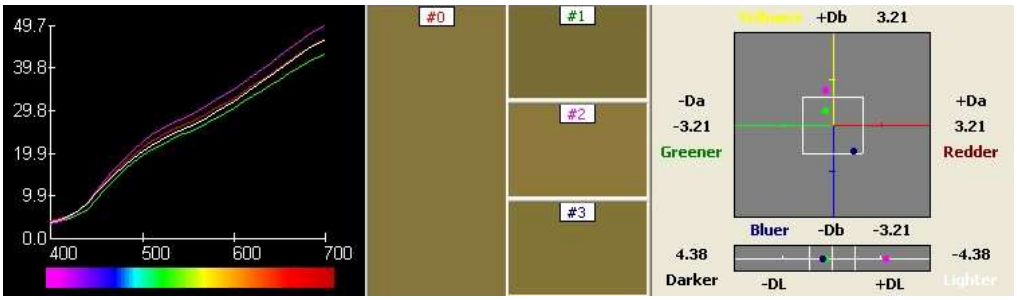

Figure 46: Reflectance value of 6% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 4 pH

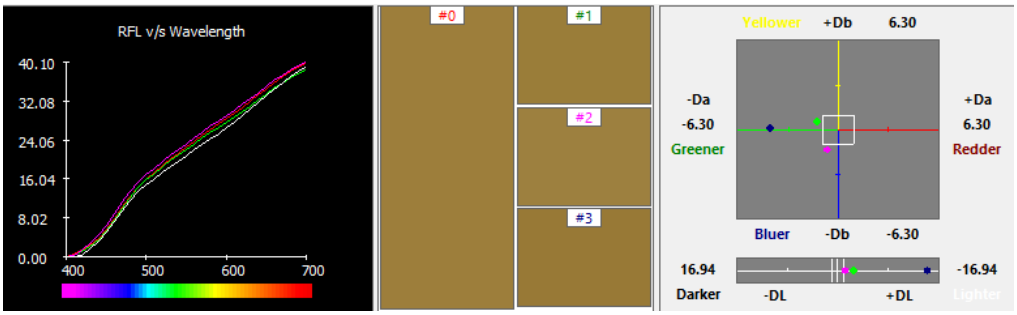

Figure 47: Reflectance value of 6% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 7 pH

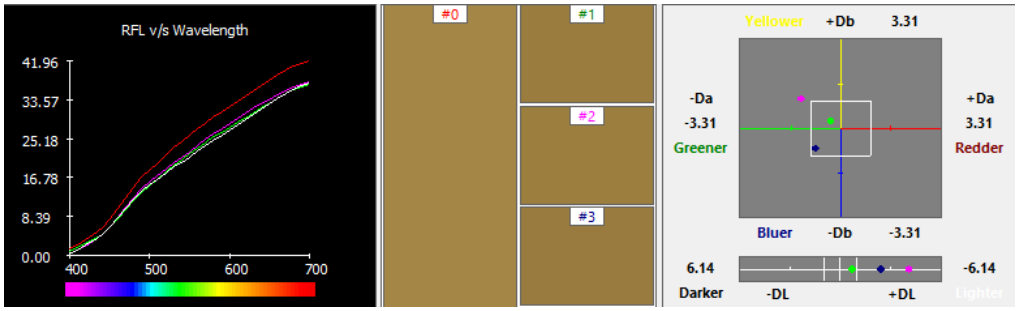

Figure 48: Reflectance value of 6% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 9 pH

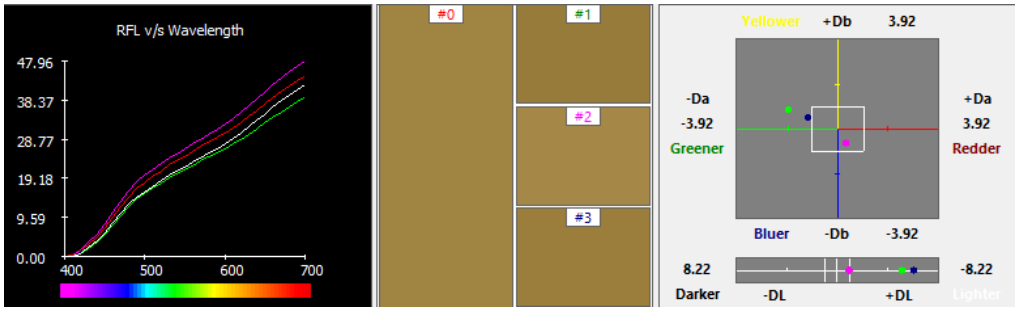

Figure 49: Reflectance value of 8% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 4 pH

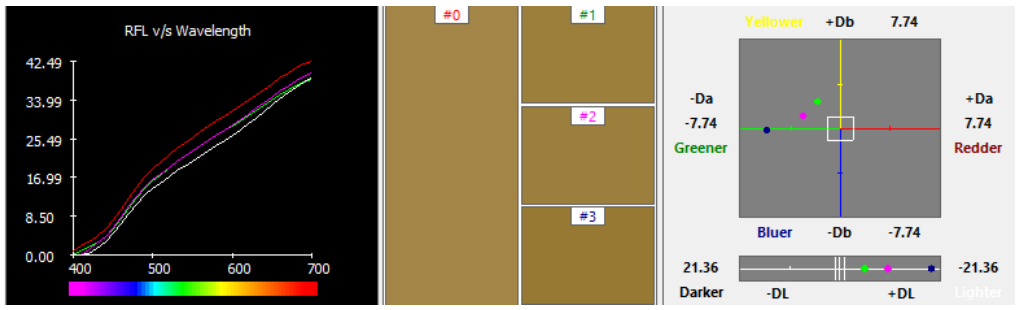

Figure 50: Reflectance value of 8% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 7 pH

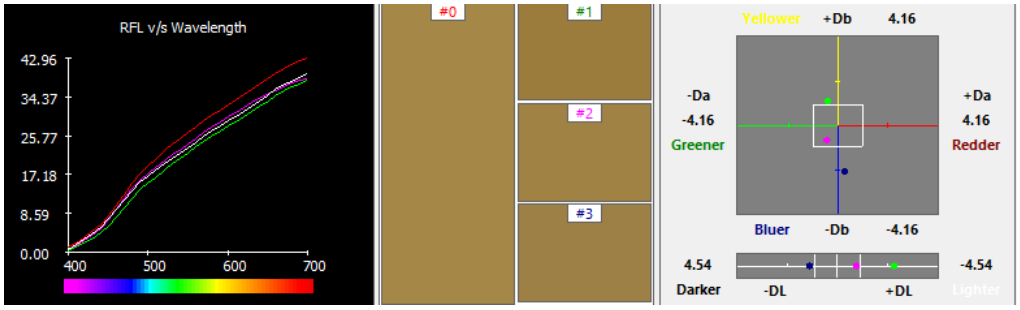

Figure 51: Reflectance value of 8% concentrated Indian almond leaves dye on Eri Silk fabric with different mordants at 9 pH

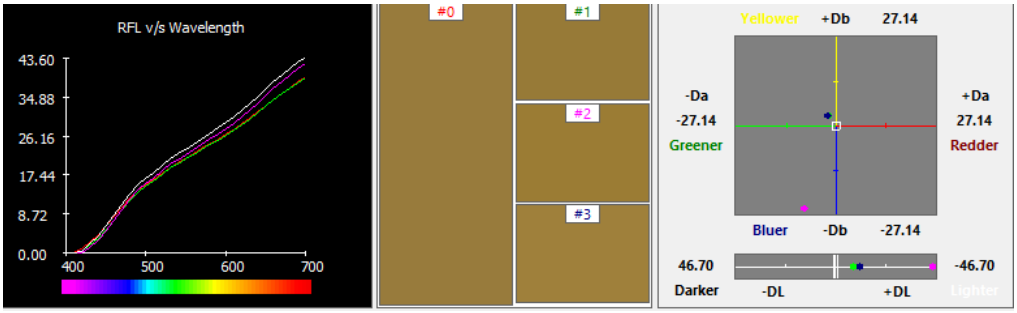

Figure 52: Reflectance value of 2% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 4 pH

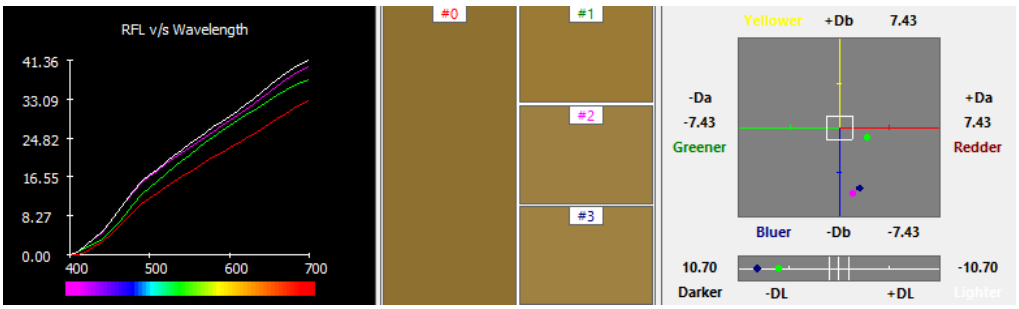

Figure 53: Reflectance value of 2% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 7 pH

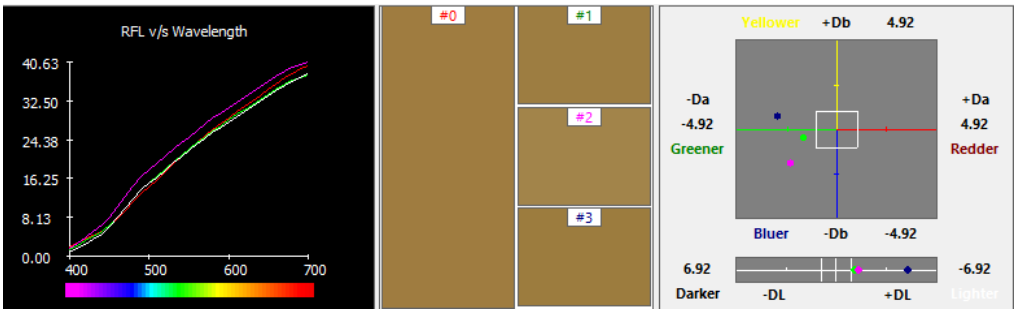

Figure 54: Reflectance value of 2% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 9 pH

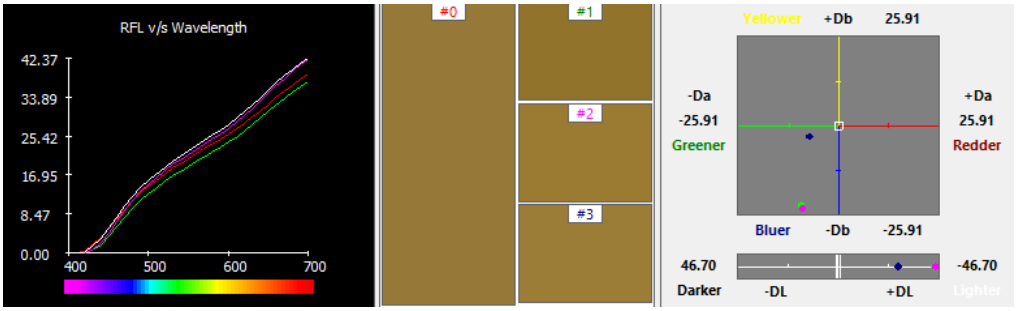

Figure 55: Reflectance value of 4% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 4 pH

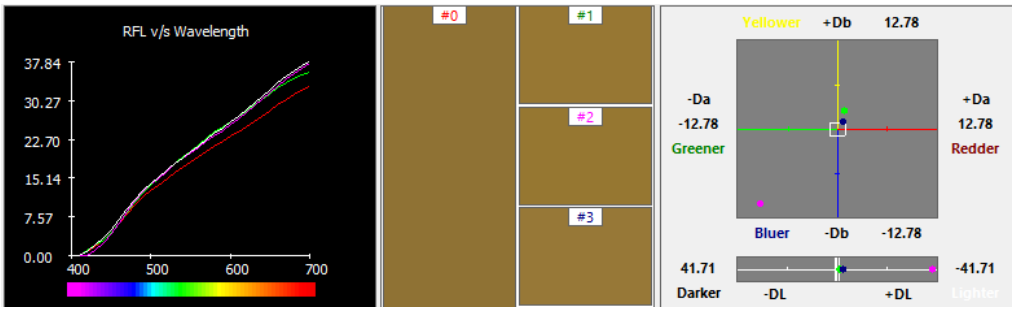

Figure 56: Reflectance value of 4% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 7 pH

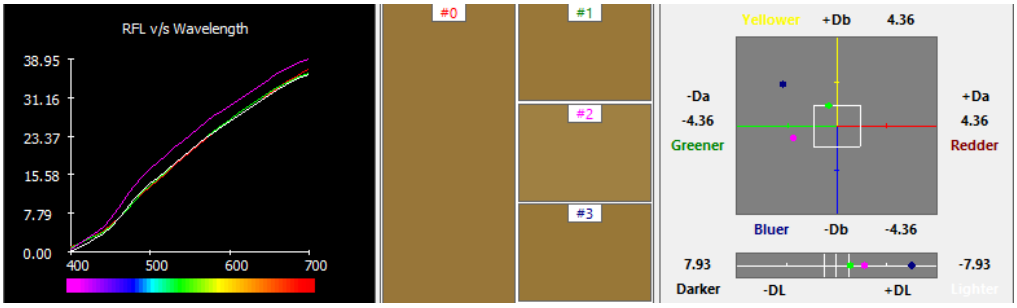

Figure 57: Reflectance value of 4% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 9 pH

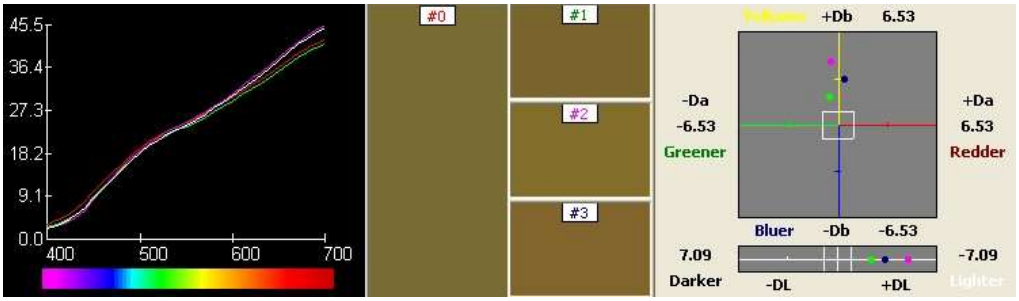

Figure 58: Reflectance value of 6% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 4 pH

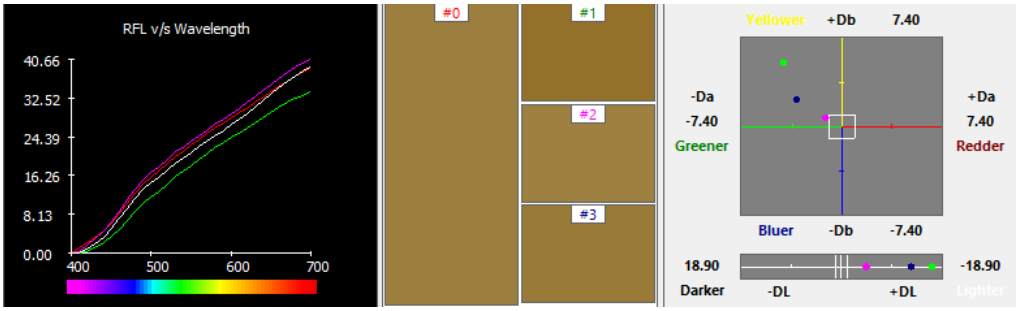

Figure 59: Reflectance value of 6% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 7 pH

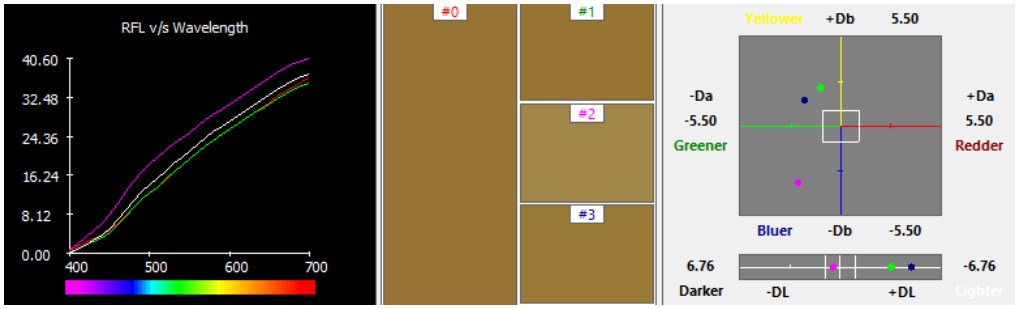

Figure 60: Reflectance value of 6% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 9 pH

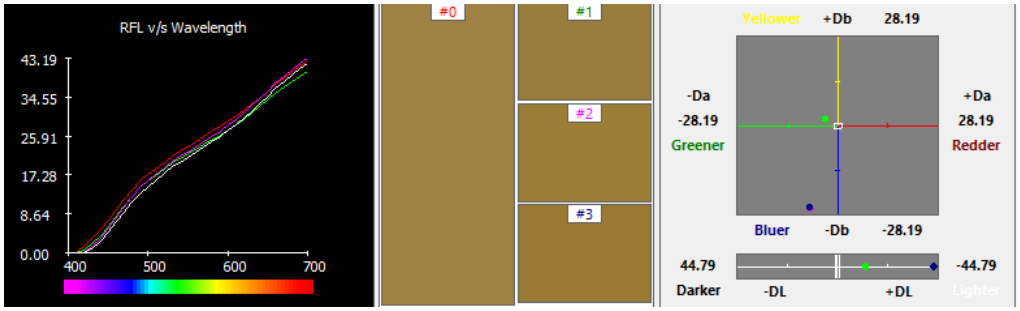

Figure 61: Reflectance value of 8% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 4 pH

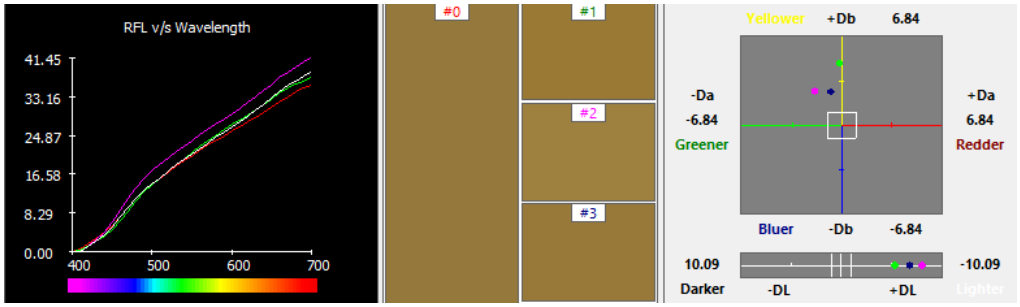

Figure 62: Reflectance value of 8% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 7 pH

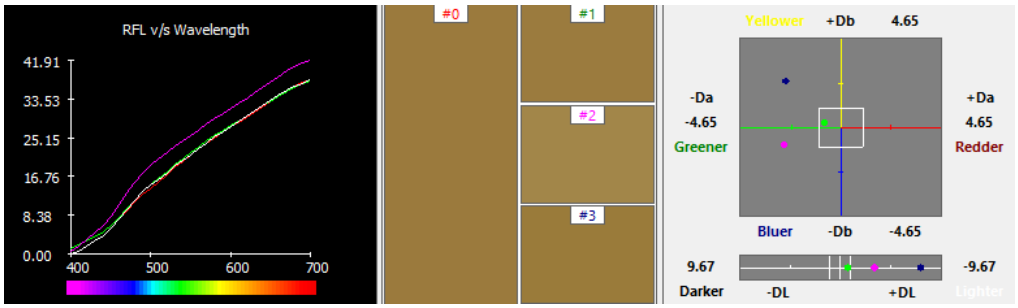

Figure 63: Reflectance value of 8% concentrated Indian almond leaves dye on Kutchi Wool fabric with different mordants at 9 pH

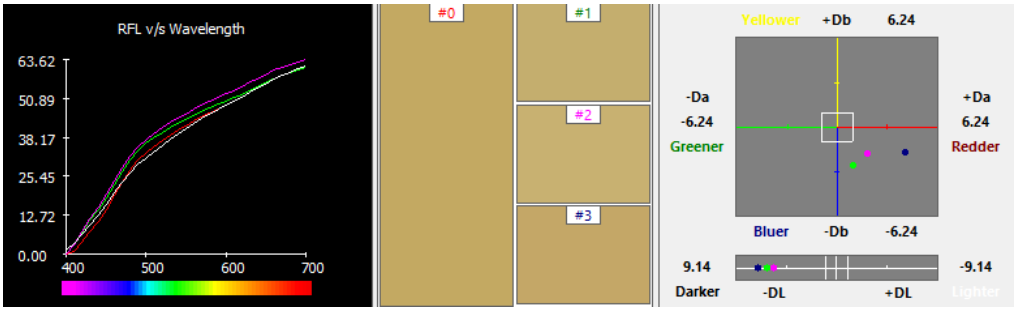

Figure 64: Reflectance value of 2% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 4 pH

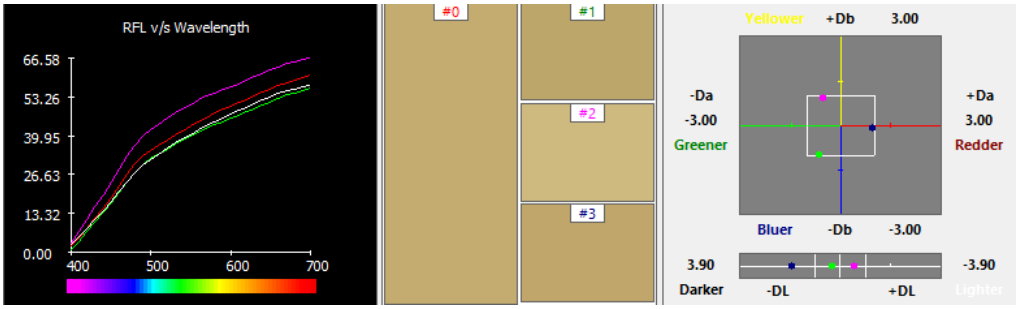

Figure 65: Reflectance value of 2% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 7 pH

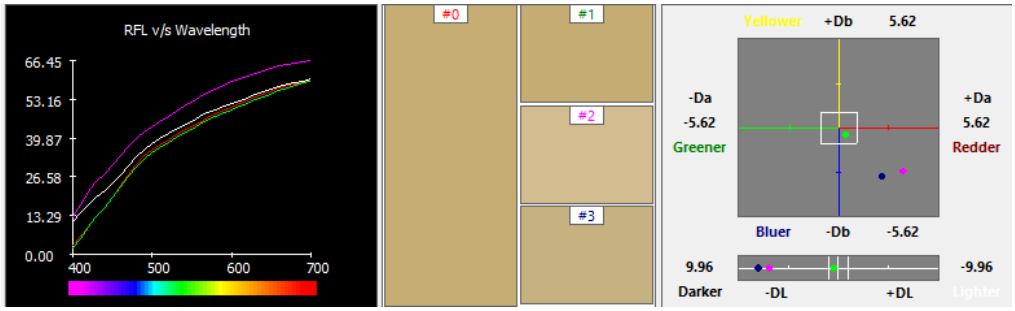

Figure 66: Reflectance value of 2% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 9 pH

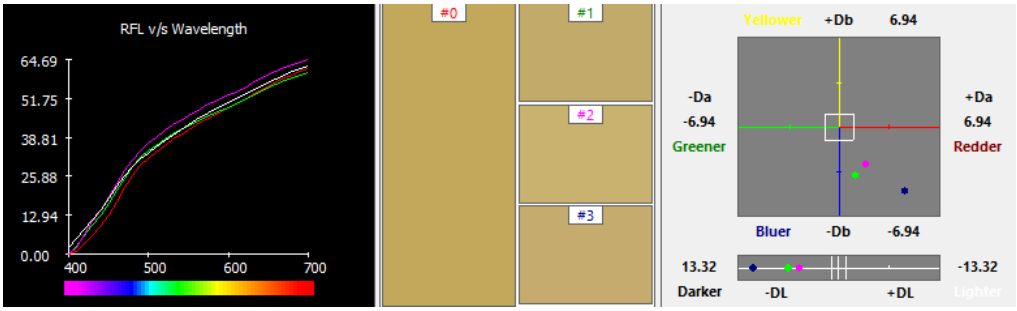

Figure 67: Reflectance value of 4% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 4 pH

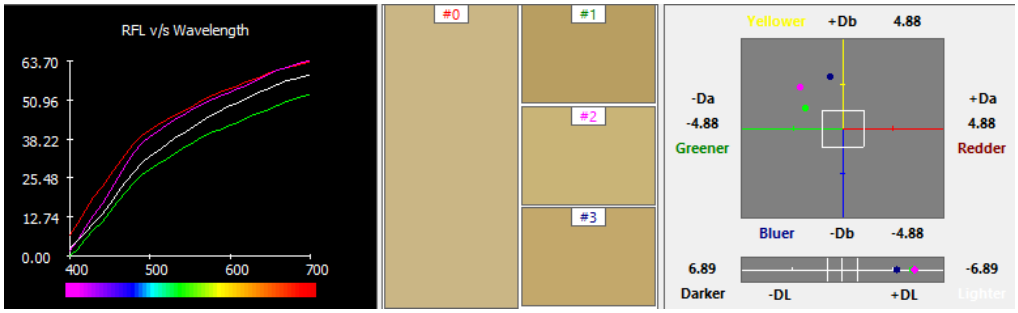

Figure 68: Reflectance value of 4% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 7 pH

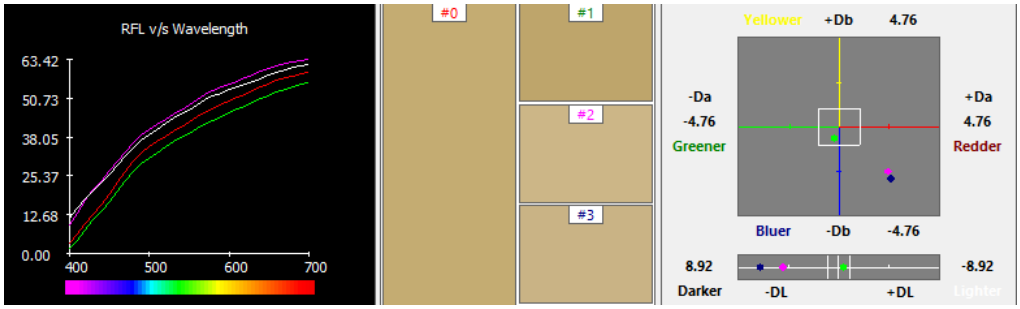

Figure 69: Reflectance value of 4% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 9 pH

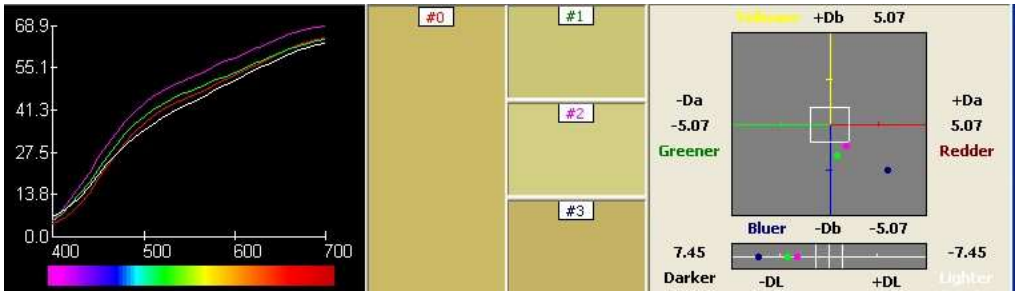

Figure 70: Reflectance value of 6% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 4 pH

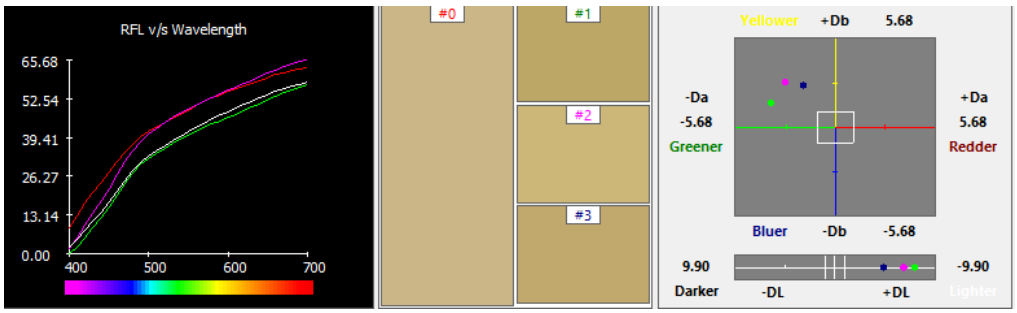

Figure 71: Reflectance value of 6% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 7 pH

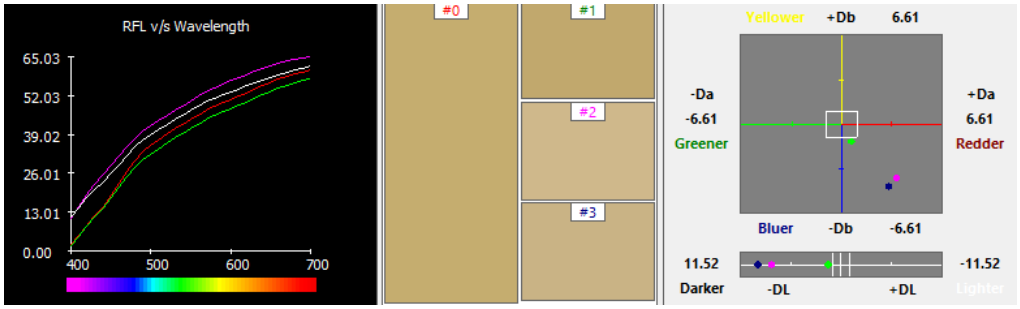

Figure 72: Reflectance value of 6% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 9 pH

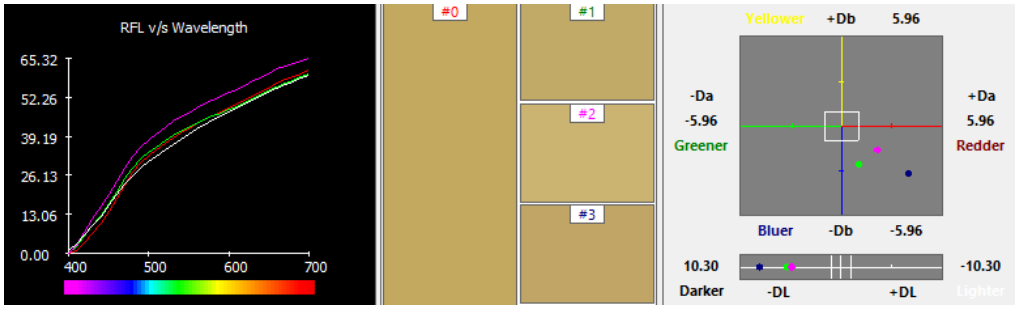

Figure 73: Reflectance value of 8% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 4 pH

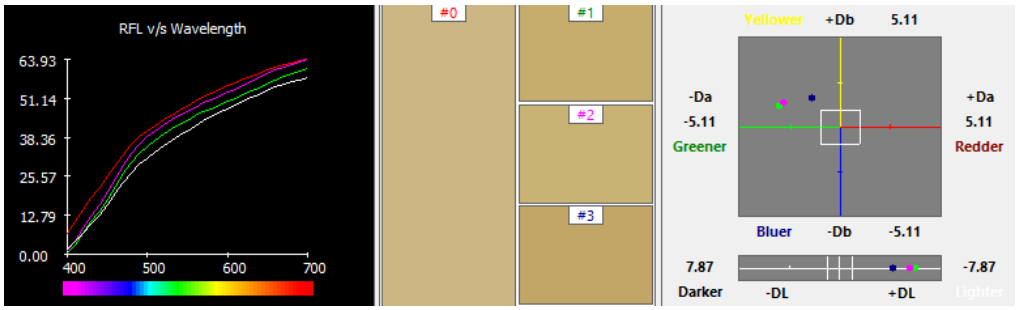

Figure 74: Reflectance value of 8% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 7 pH

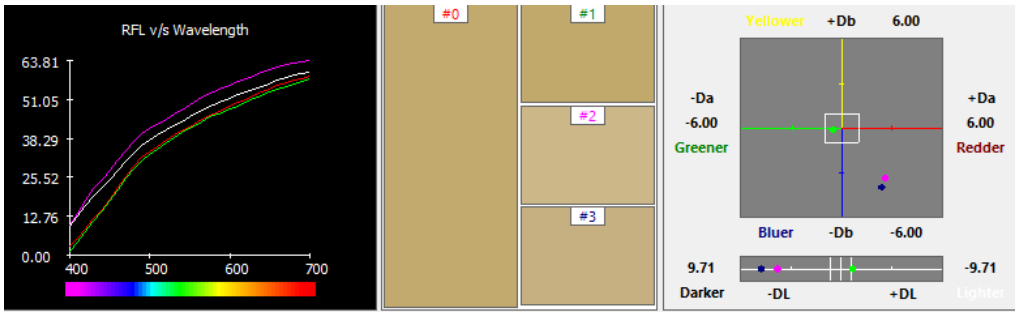

Figure 75: Reflectance value of 8% concentrated Indian almond leaves dye on Nylon fabric with different mordants at 9 pH

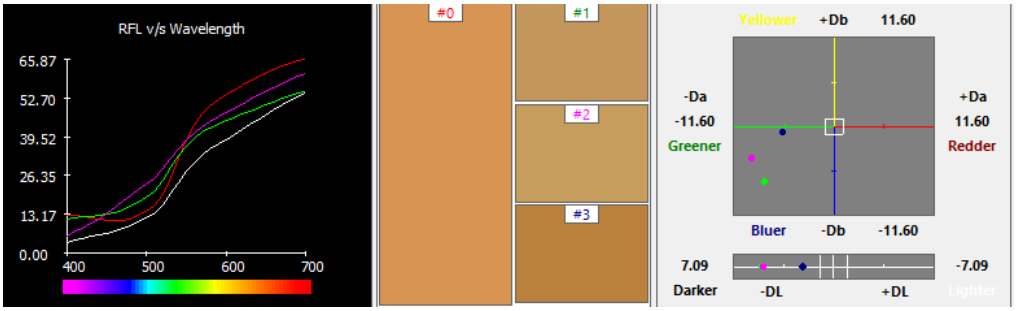

Figure 76: Reflectance value of 2% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 5.5 pH

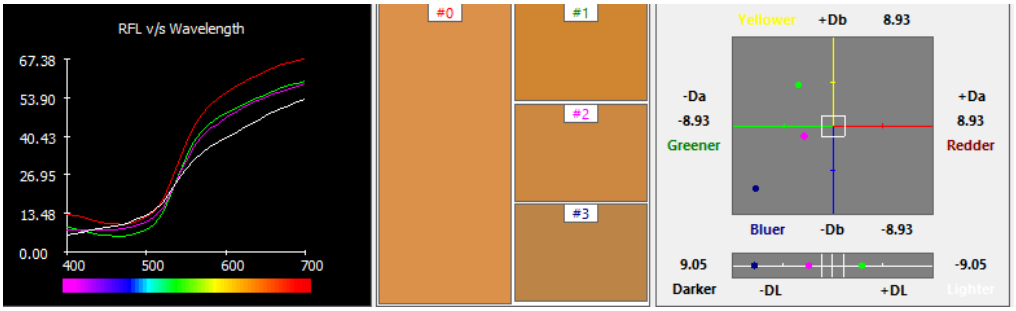

Figure 77: Reflectance value of 2% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 7 pH

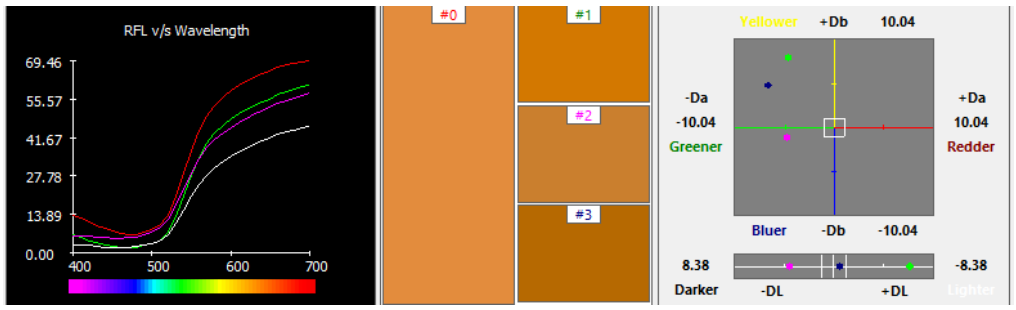

Figure 78: Reflectance value of 2% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 9 pH

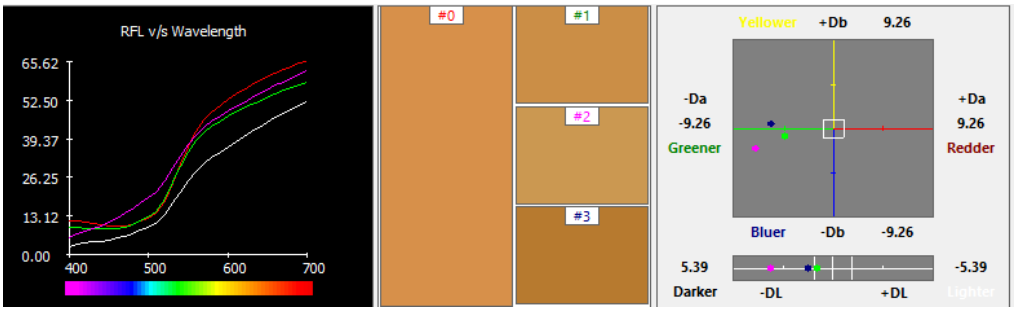

Figure 79: Reflectance value of 4% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 5.5 pH

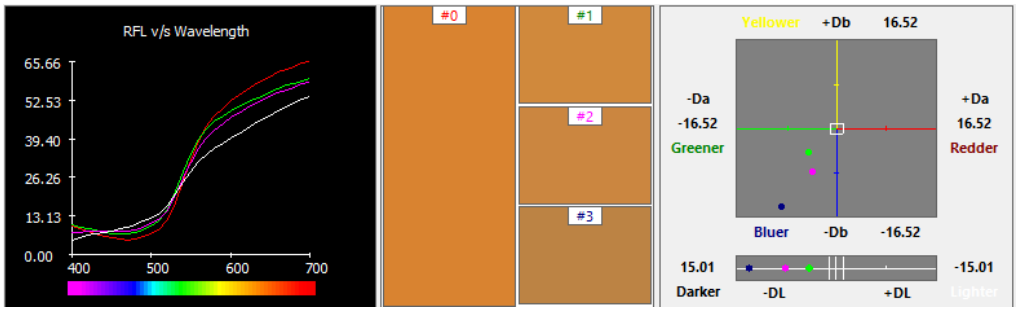

Figure 80: Reflectance value of 4% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 7 pH

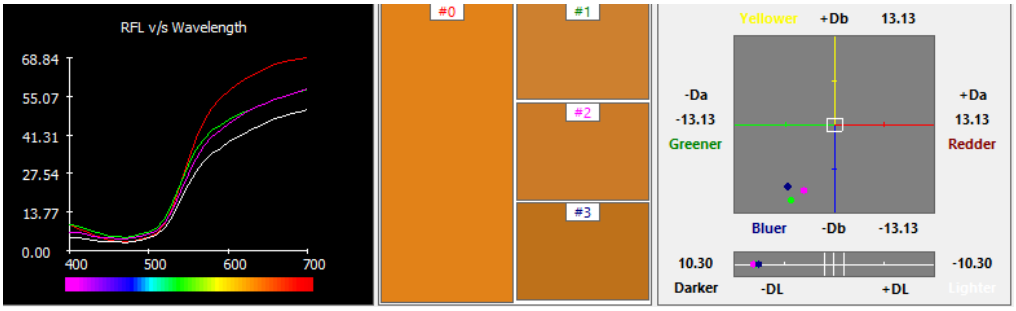

Figure 81: Reflectance value of 4% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 9 pH

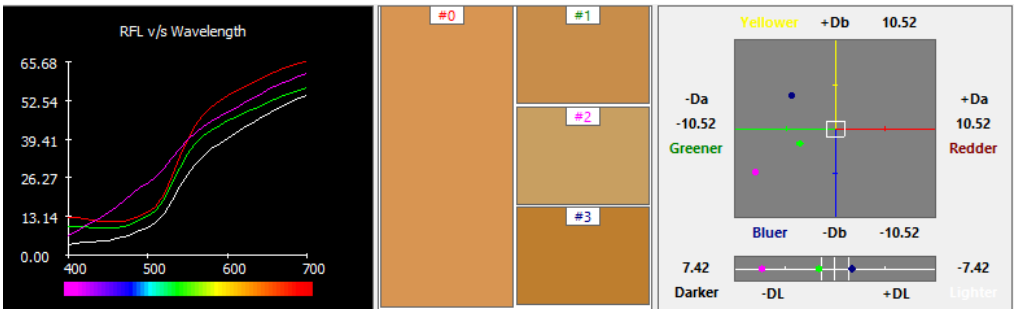

Figure 82: Reflectance value of 6% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 5.5 pH

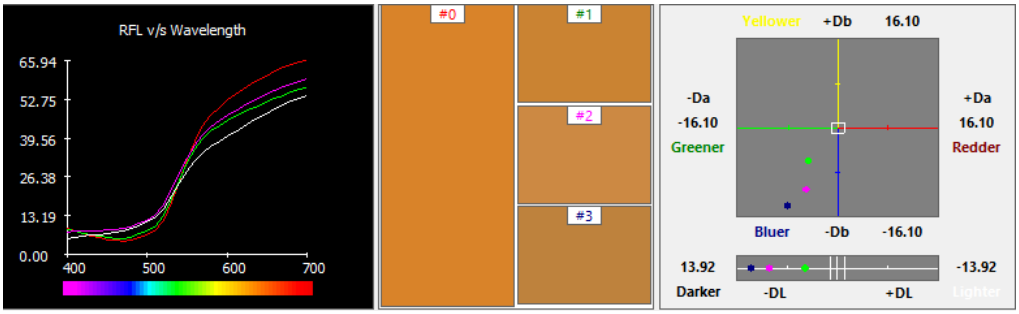

Figure 83: Reflectance value of 6% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 7 pH

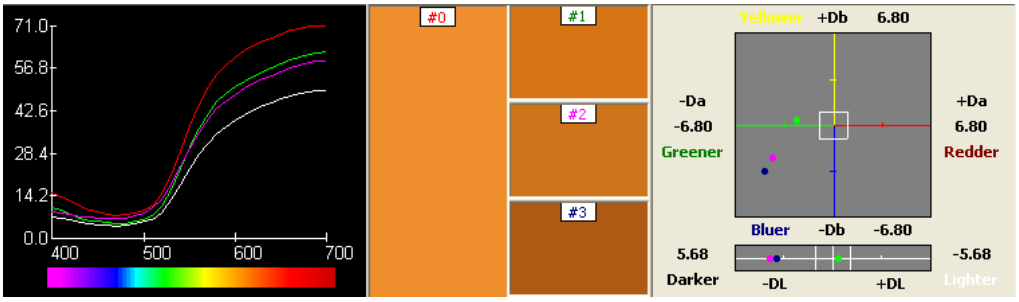

Figure 84: Reflectance value of 6% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 9 pH

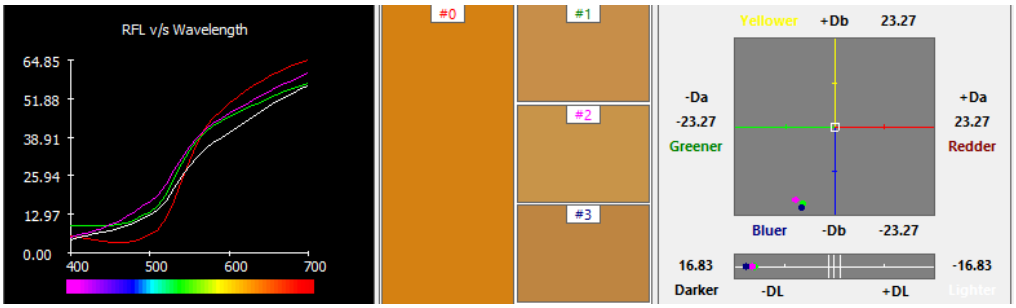

Figure 85: Reflectance value of 8% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 5.5 pH

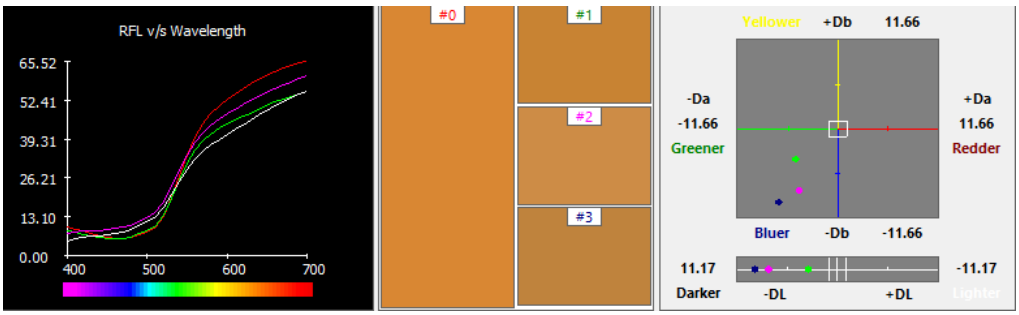

Figure 86: Reflectance value of 8% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 7 pH

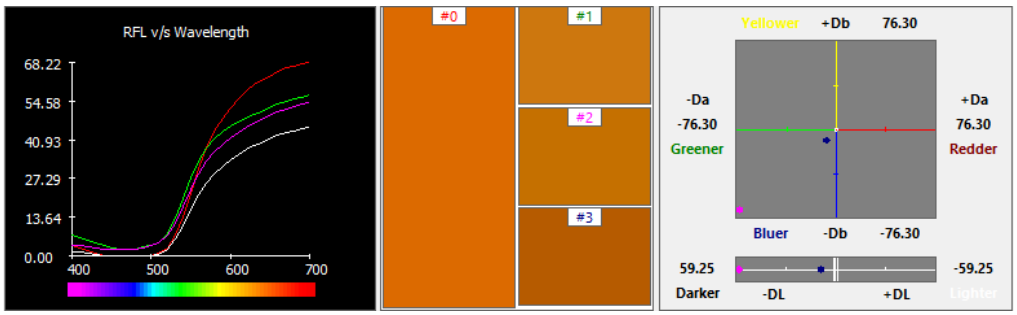

Figure 87: Reflectance value of 8% concentrated Annatto seeds dye on Eri Silk fabric with different mordants at 9 pH

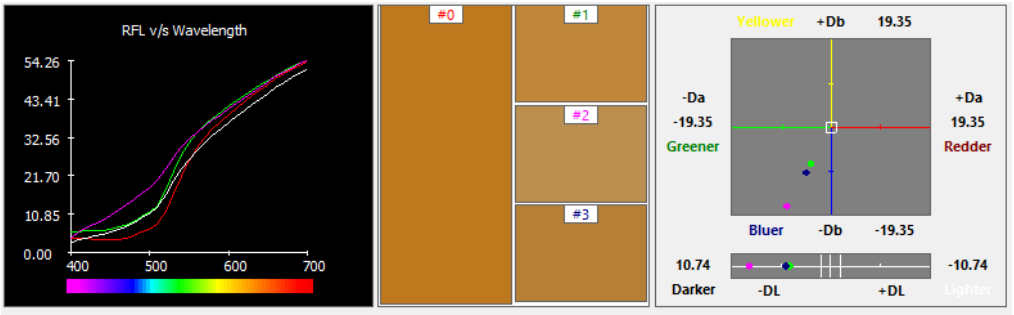

Figure 88: Reflectance value of 2% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 5.5 pH

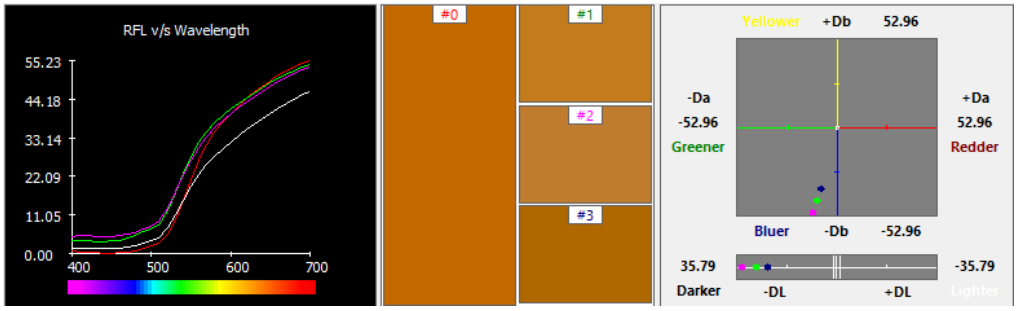

Figure 89: Reflectance value of 2% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 7 pH

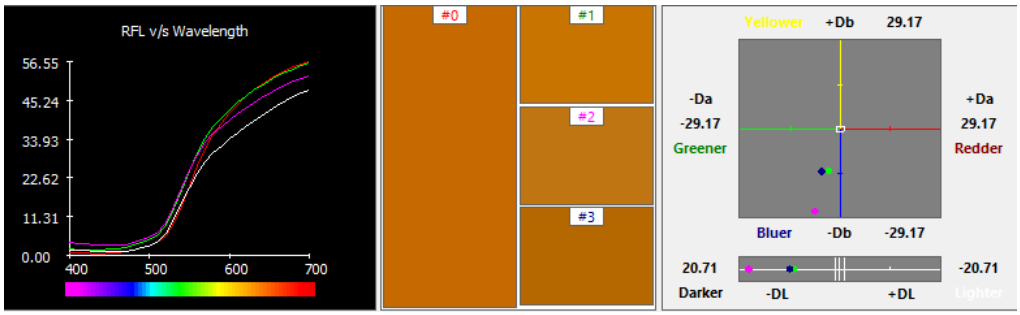

Figure 90: Reflectance value of 2% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 9 pH

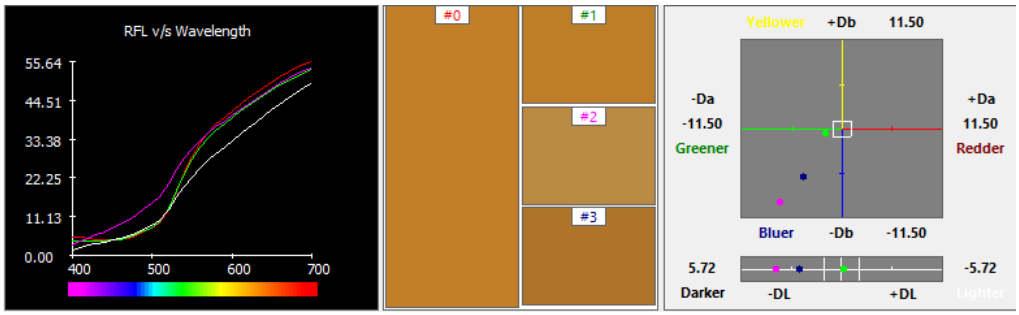

Figure 91: Reflectance value of 4% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 5.5 pH

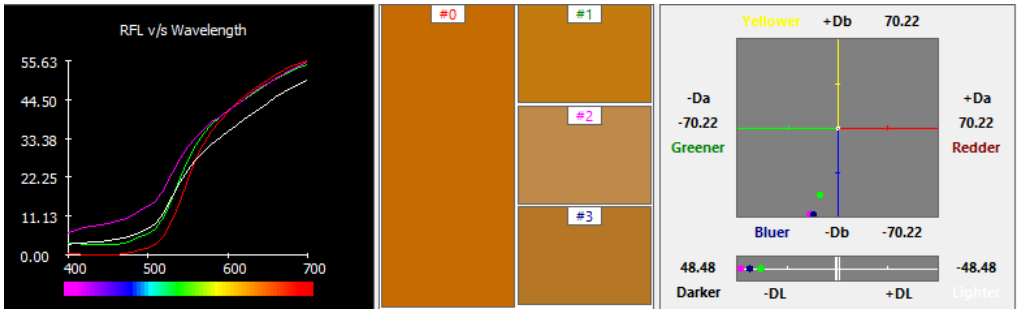

Figure 92: Reflectance value of 4% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 7 pH

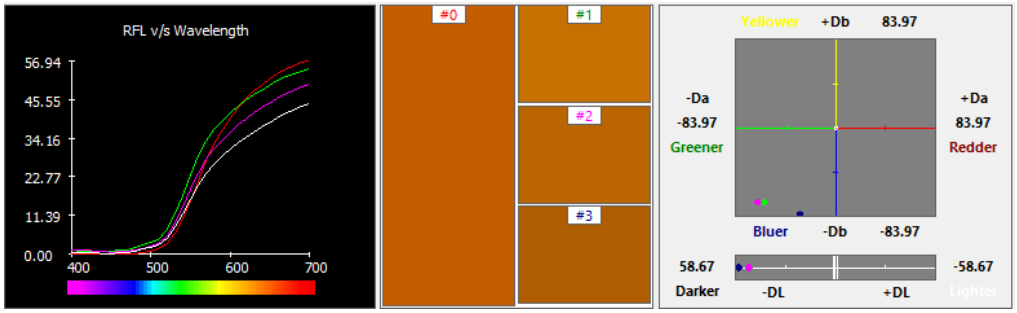

Figure 93: Reflectance value of 4% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 9 pH

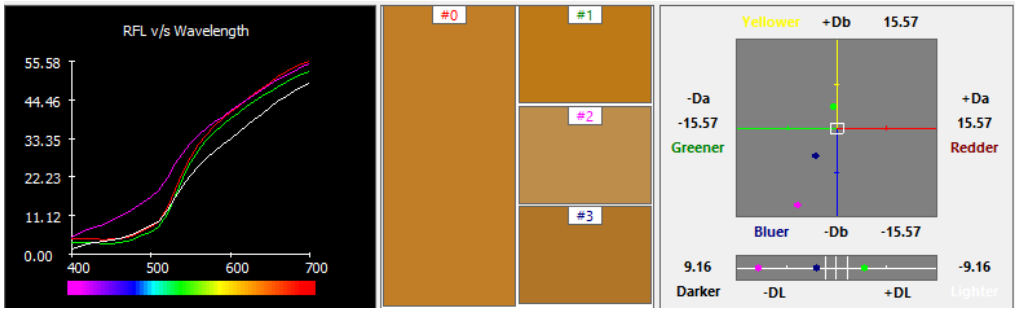

Figure 94: Reflectance value of 6% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 5.5 pH

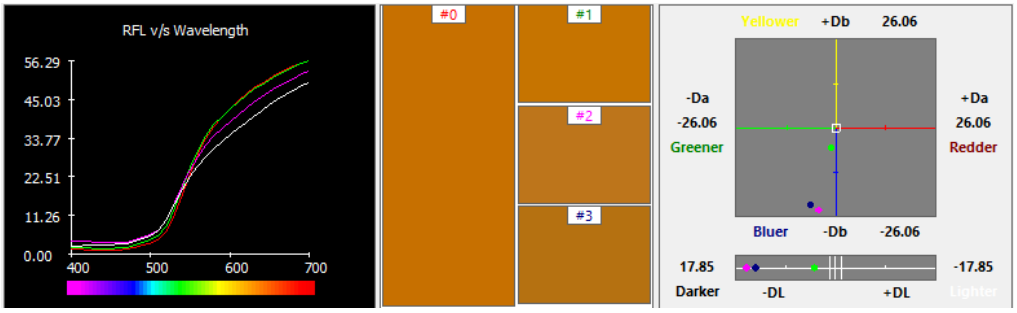

Figure 95: Reflectance value of 6% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 7 pH

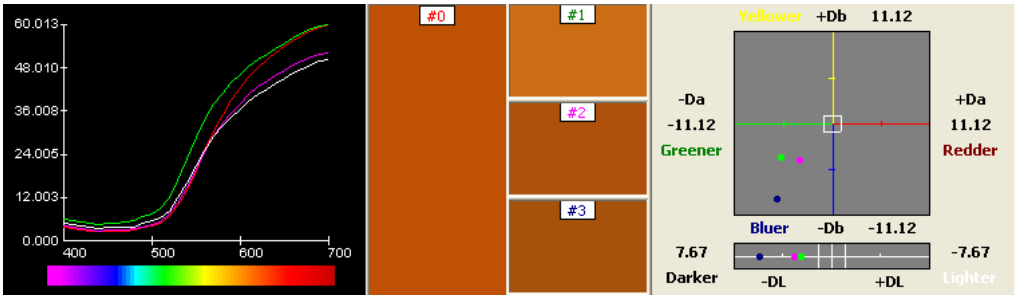

Figure 96: Reflectance value of 6% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 9 pH

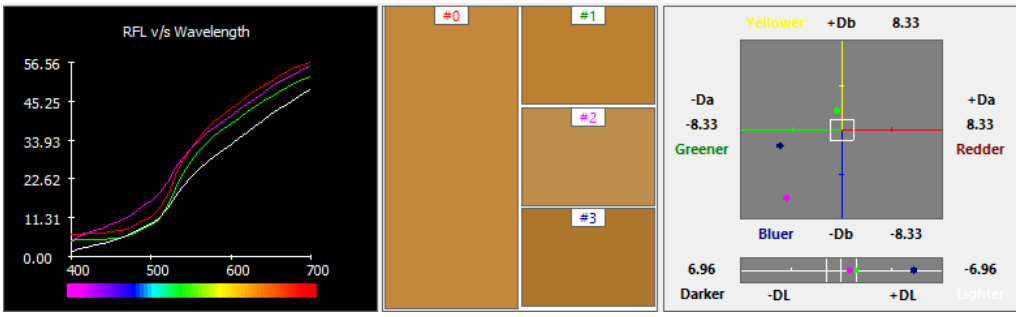

Figure 97: Reflectance value of 8% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 5.5 pH

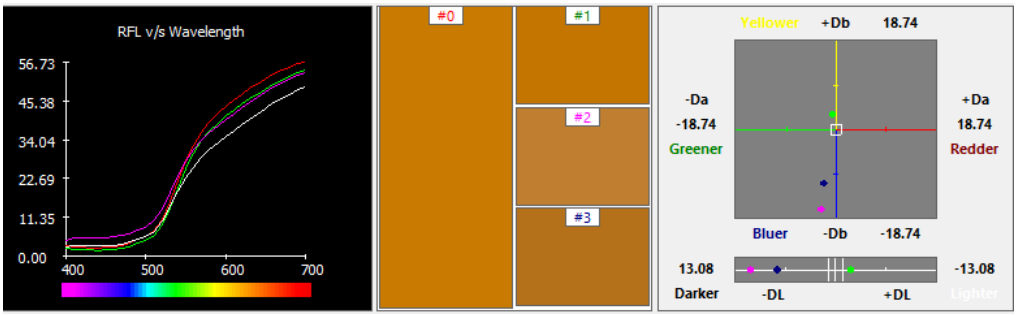

Figure 98: Reflectance value of 8% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 7 pH

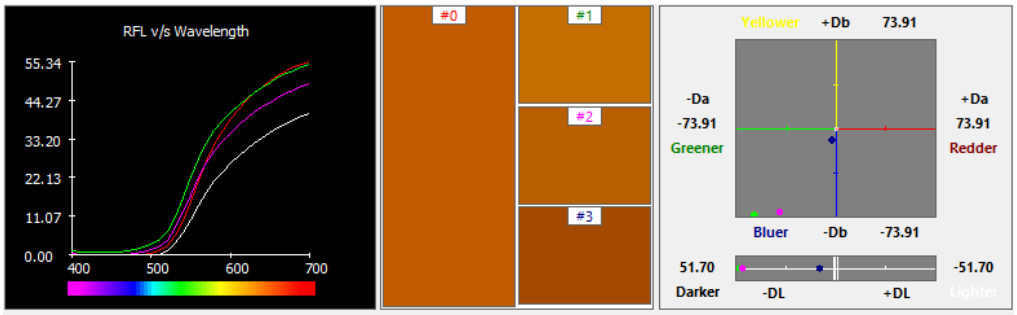

Figure 99: Reflectance value of 8% concentrated Annatto seeds dye on Kutchi Wool fabric with different mordants at 9 pH

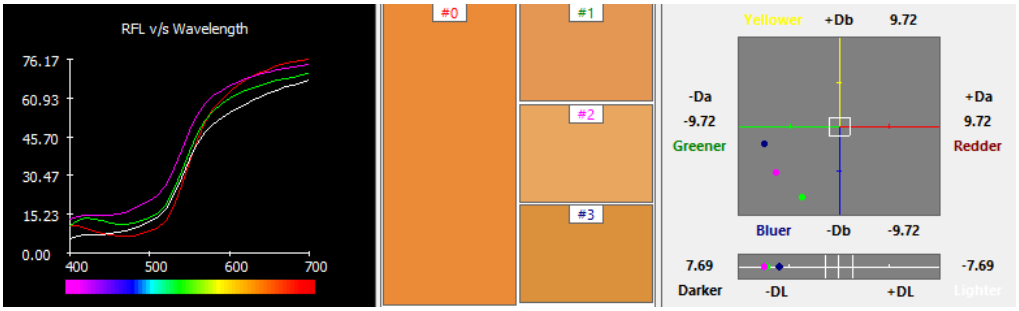

Figure 100: Reflectance value of 2% concentrated Annatto seeds dye on Nylon fabric with different mordants at 5.5 pH

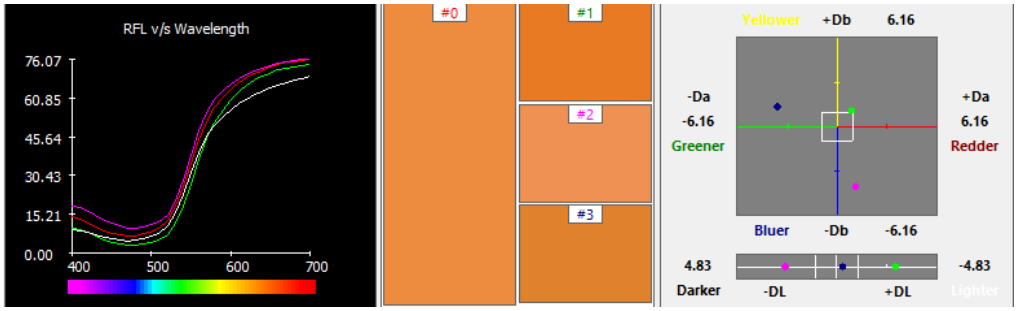

Figure 101: Reflectance value of 2% concentrated Annatto seeds dye on Nylon fabric with different mordants at 7 pH

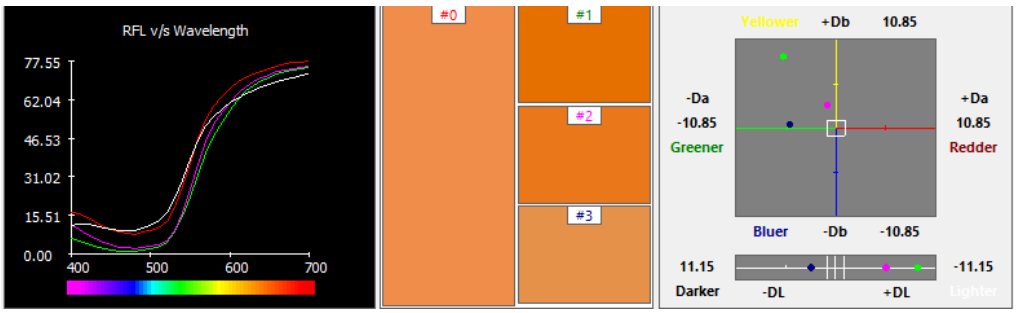

Figure 102: Reflectance value of 2% concentrated Annatto seeds dye on Nylon fabric with different mordants at 9 pH

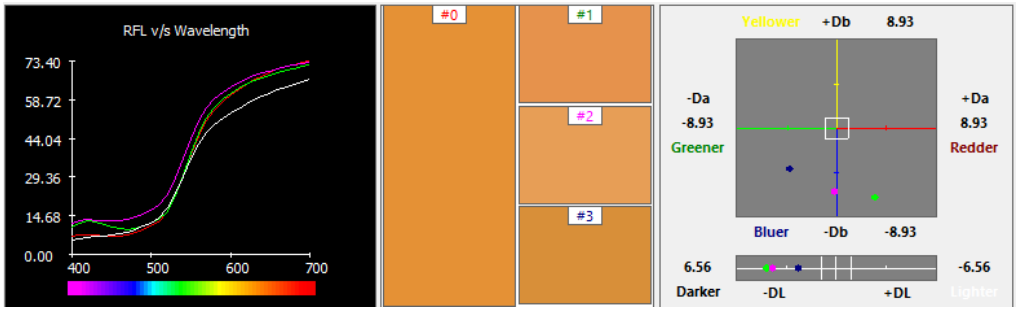

Figure 103: Reflectance value of 4% concentrated Annatto seeds dye on Nylon fabric with different mordants at 5.5 pH

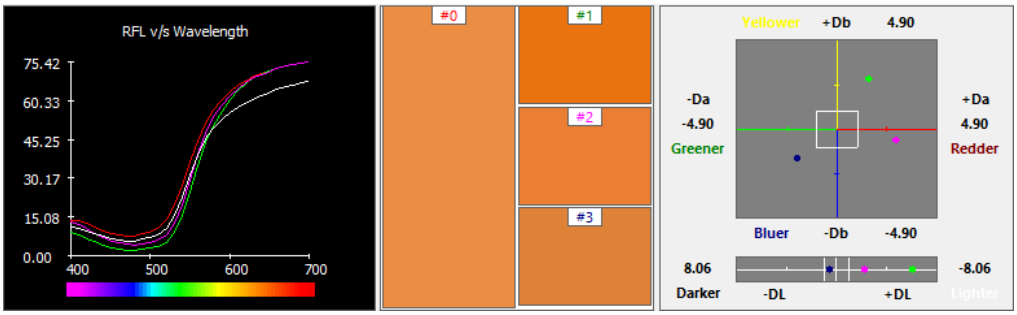

Figure 104: Reflectance value of 4% concentrated Annatto seeds dye on Nylon fabric with different mordants at 7 pH

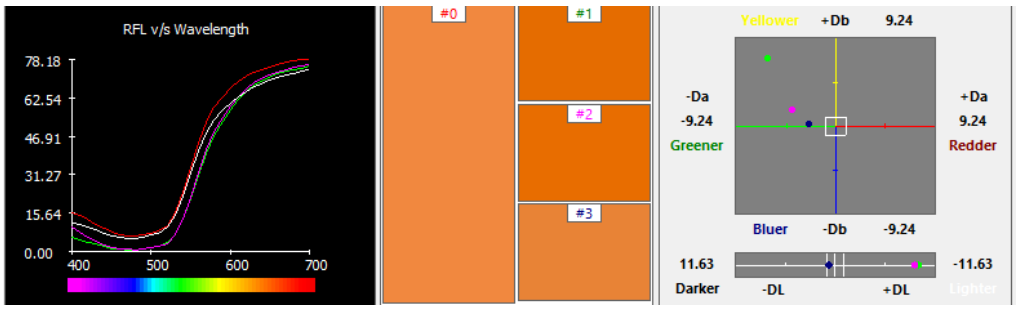

Figure 105: Reflectance value of 4% concentrated Annatto seeds dye on Nylon fabric with different mordants at 9 pH

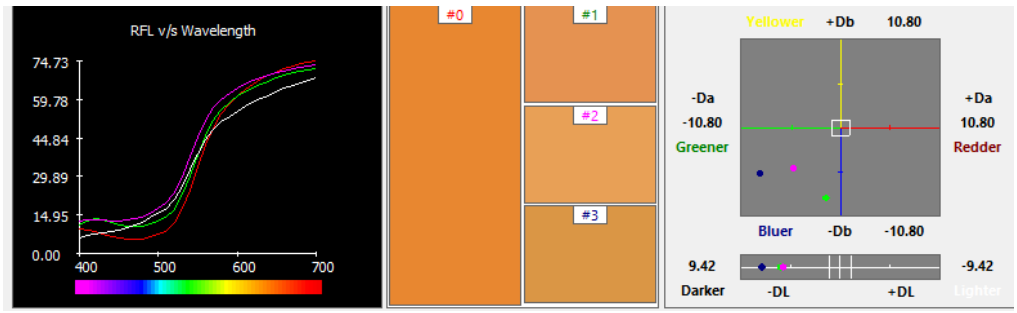

Figure 106: Reflectance value of 6% concentrated Annatto seeds dye on Nylon fabric with different mordants at 5.5 pH

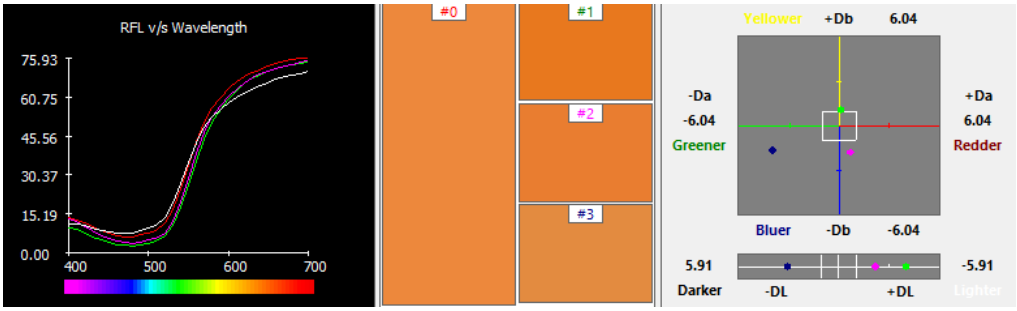

Figure 107: Reflectance value of 6% concentrated Annatto seeds dye on Nylon fabric with different mordants at 7 pH

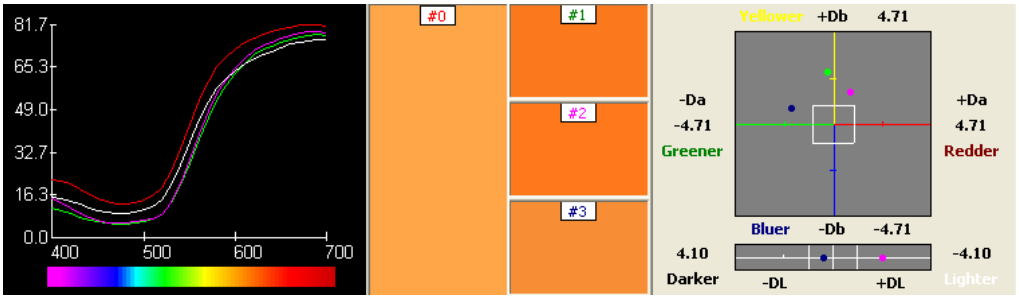

Figure 108: Reflectance value of 6% concentrated Annatto seeds dye on Nylon fabric with different mordants at 9 pH

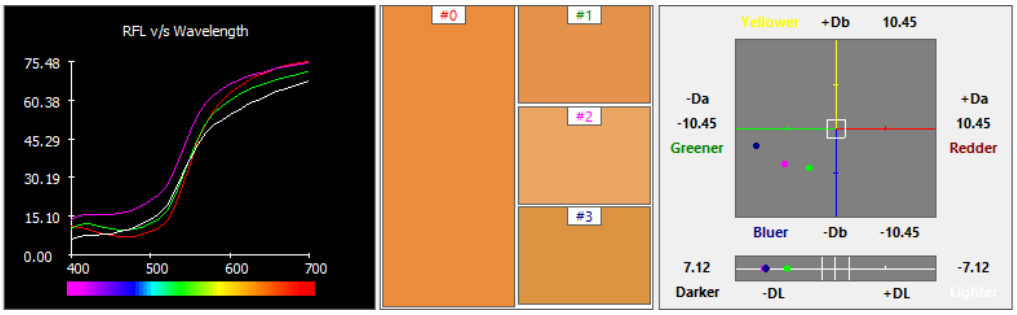

Figure 109: Reflectance value of 8% concentrated Annatto seeds dye on Nylon fabric with different mordants at 5.5 pH

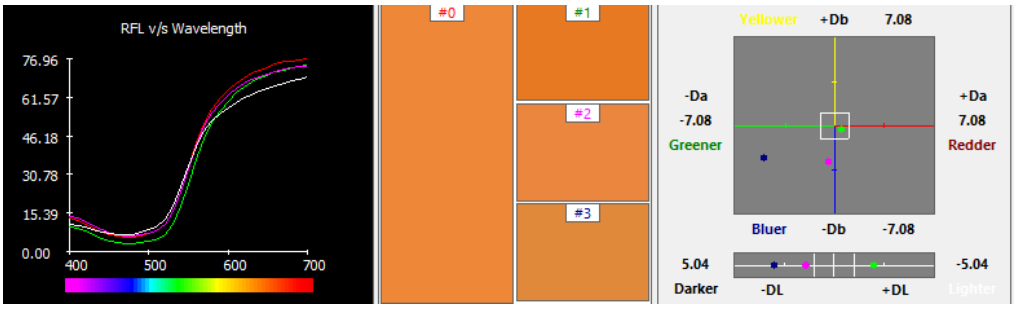

Figure 110: Reflectance value of 8% concentrated Annatto seeds dye on Nylon fabric with different mordants at 7 pH

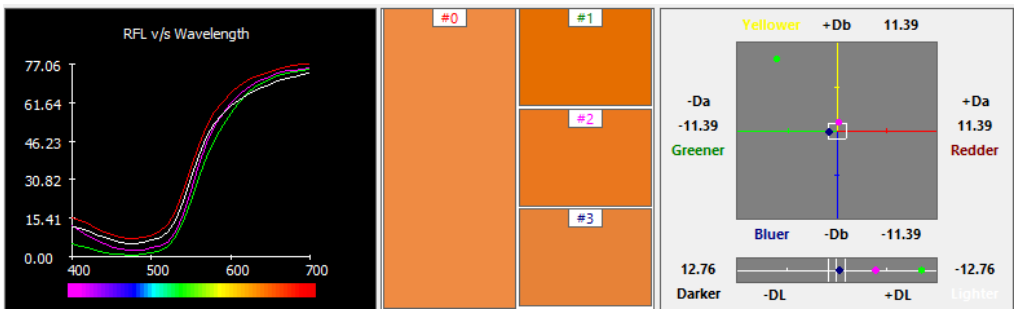

Figure 111: Reflectance value of 8% concentrated Annatto seeds dye on Nylon fabric with different mordants at 9 pH

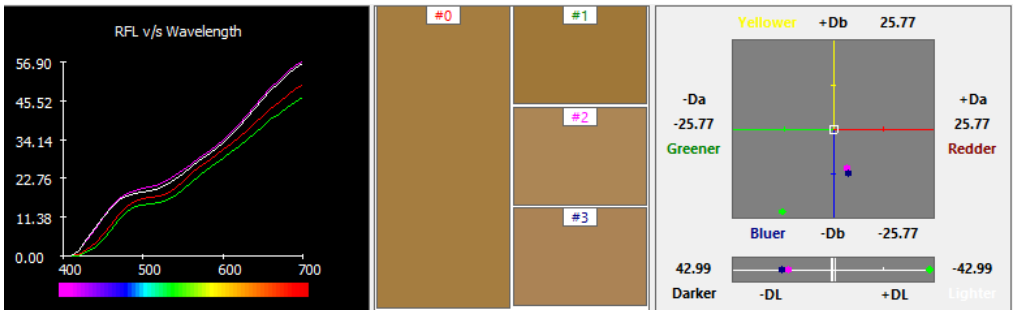

Figure 112: Reflectance value of 2% concentrated Onion peels dye on Eri Silk fabric with different mordants at 3.5 pH

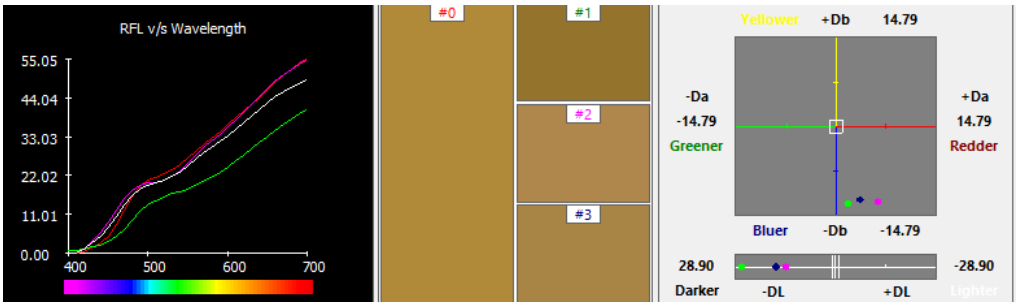

Figure 113: Reflectance value of 2% concentrated Onion peels dye on Eri Silk fabric with different mordants at 7 pH

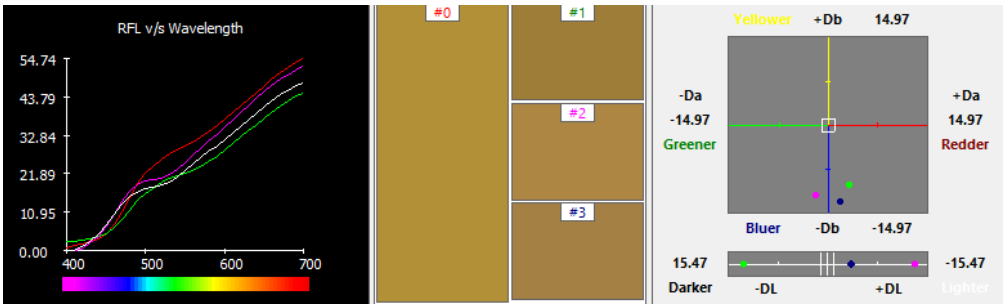

Figure 114: Reflectance value of 2% concentrated Onion peels dye on Eri Silk fabric with different mordants at 9 pH

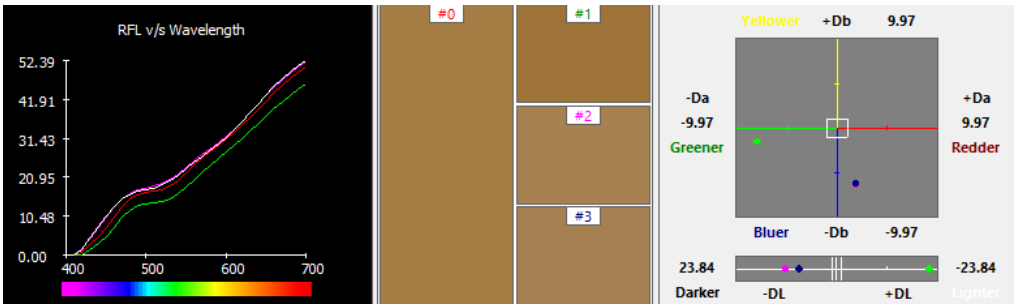

Figure 115: Reflectance value of 4% concentrated Onion peels dye on Eri Silk fabric with different mordants at 3.5 pH

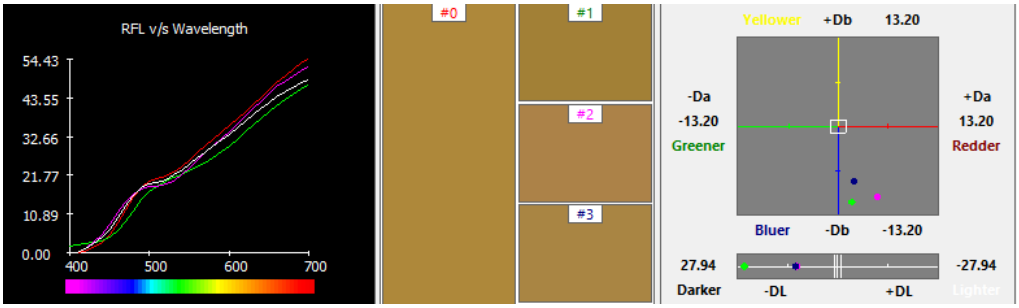

Figure 116: Reflectance value of 4% concentrated Onion peels dye on Eri Silk fabric with different mordants at 7 pH

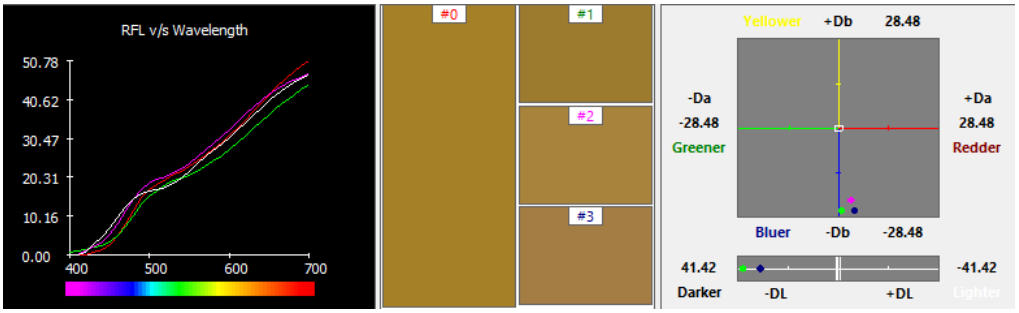

Figure 117: Reflectance value of 4% concentrated Onion peels dye on Eri Silk fabric with different mordants at 9 pH

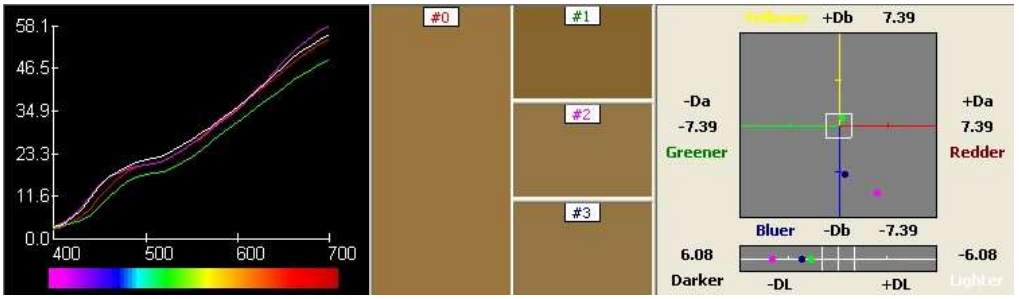

Figure 118: Reflectance value of 6% concentrated Onion peels dye on Eri Silk fabric with different mordants at 3.5 pH

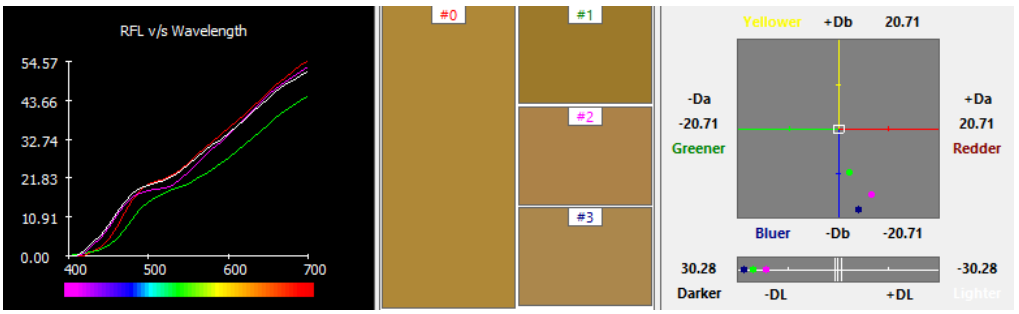

Figure 119: Reflectance value of 6% concentrated Onion peels dye on Eri Silk fabric with different mordants at 7 pH

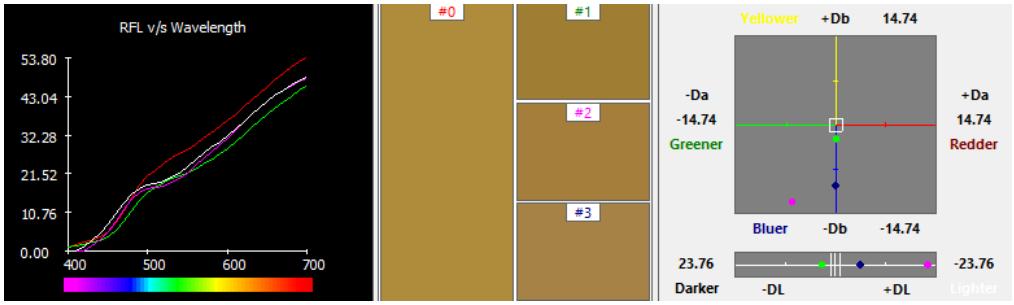

Figure 120: Reflectance value of 6% concentrated Onion peels dye on Eri Silk fabric with different mordants at 9 pH

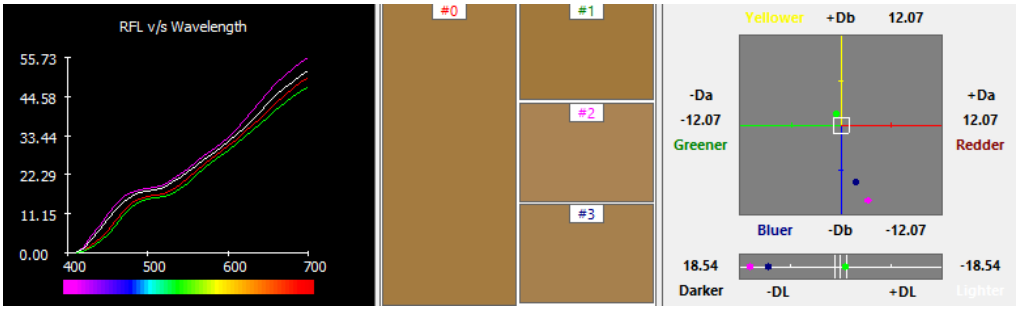

Figure 121: Reflectance value of 8% concentrated Onion peels dye on Eri Silk fabric with different mordants at 3.5 pH

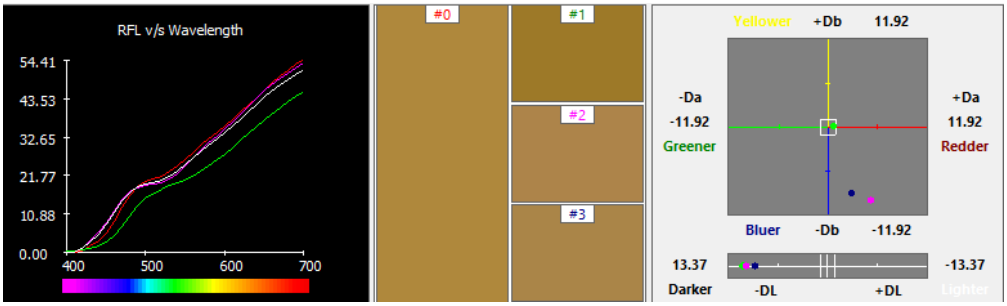

Figure 122: Reflectance value of 8% concentrated Onion peels dye on Eri Silk fabric with different mordants at 7 pH

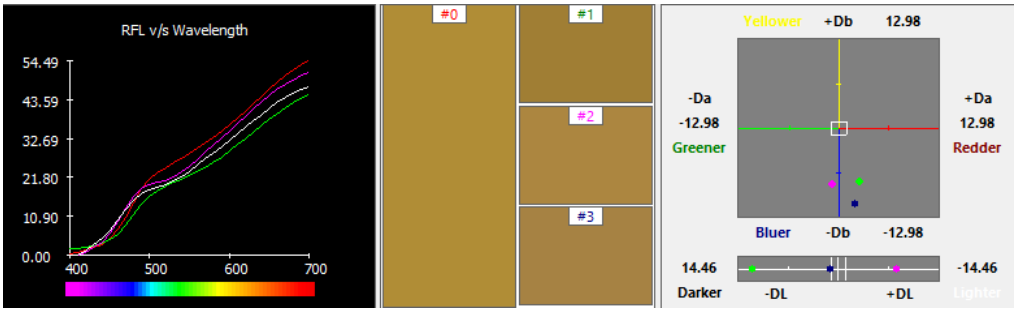

Figure 123: Reflectance value of 8% concentrated Onion peels dye on Eri Silk fabric with different mordants at 9 pH

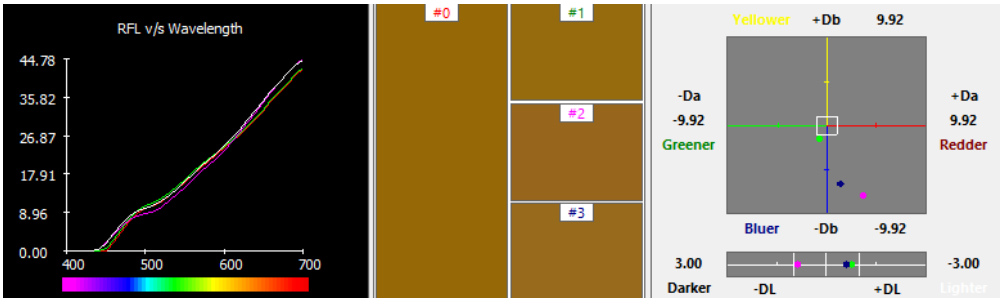

Figure 124: Reflectance value of 2% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 3.5 pH

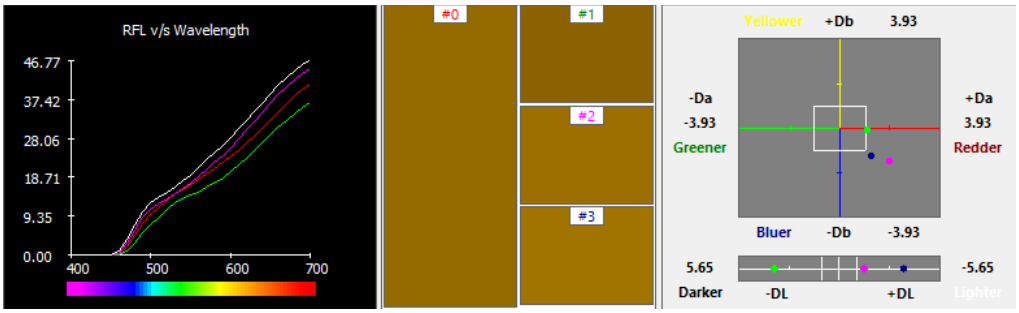

Figure 125: Reflectance value of 2% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 7 pH

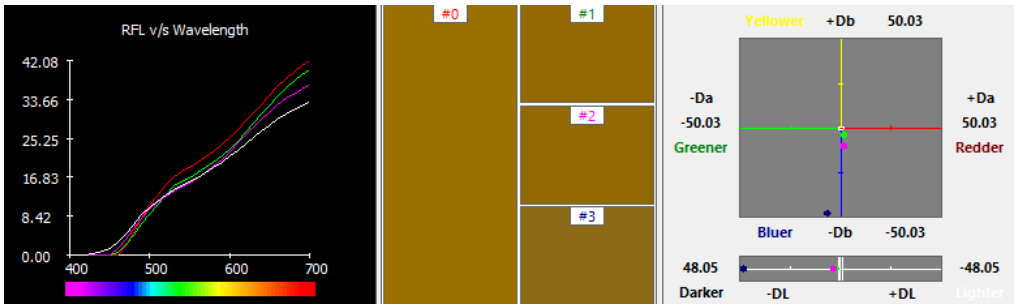

Figure 126: Reflectance value of 2% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 9 pH

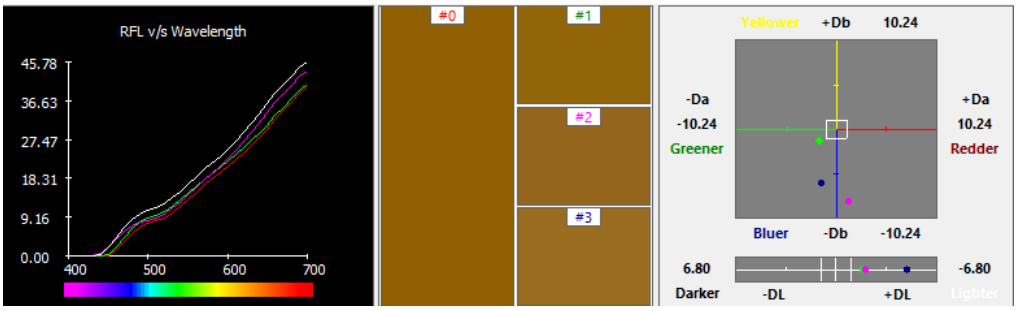

Figure 127: Reflectance value of 4% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 3.5 pH

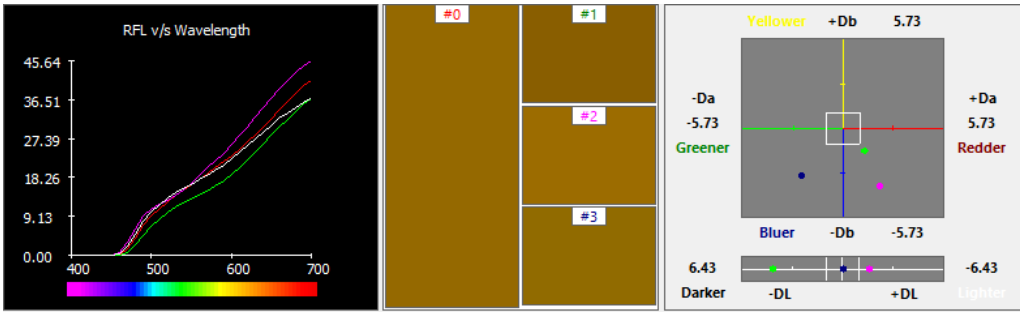

Figure 128: Reflectance value of 4% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 7 pH

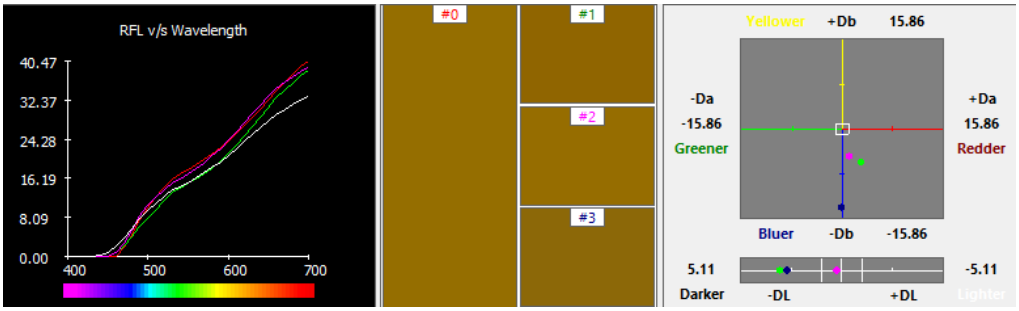

Figure 129: Reflectance value of 4% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 9 pH

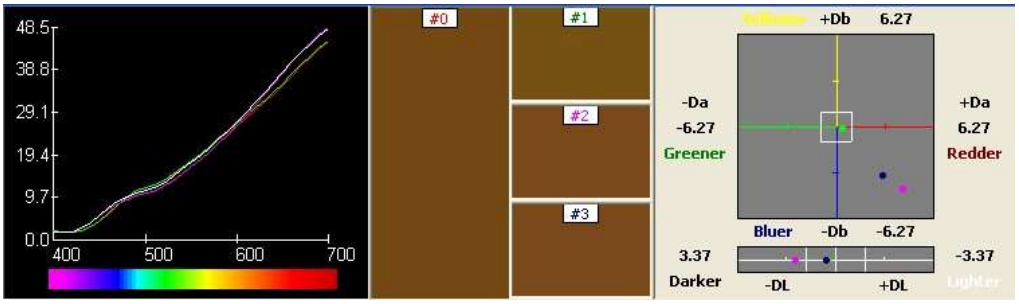

Figure 130: Reflectance value of 6% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 3.5 pH

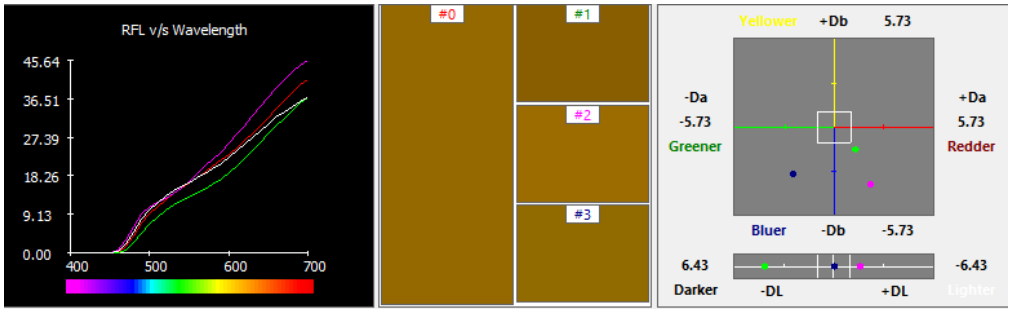

Figure 131: Reflectance value of 6% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 7 pH

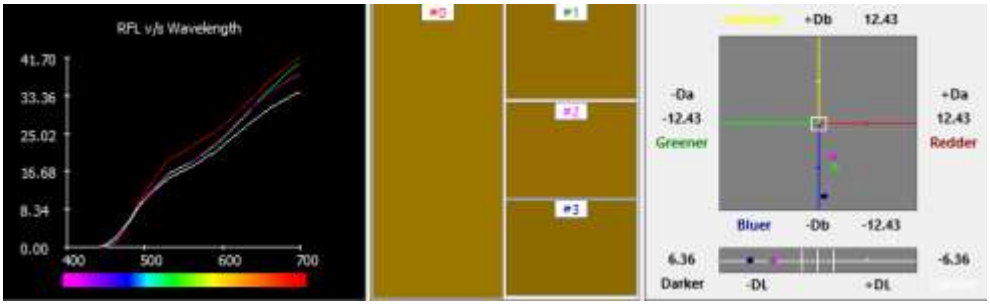

Figure 132: Reflectance value of 6% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 9 pH

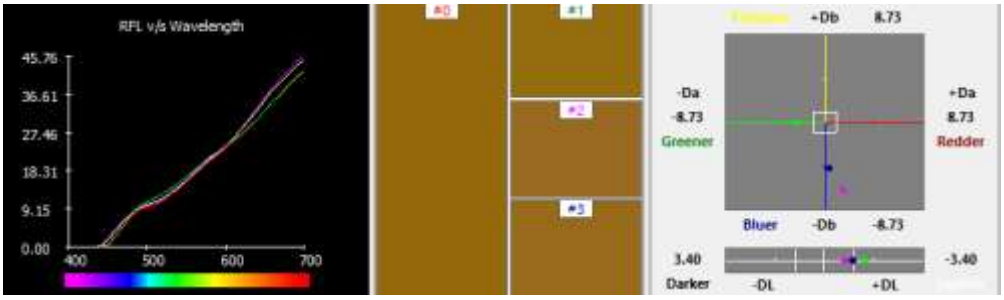

Figure 133: Reflectance value of 8% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 3.5 pH

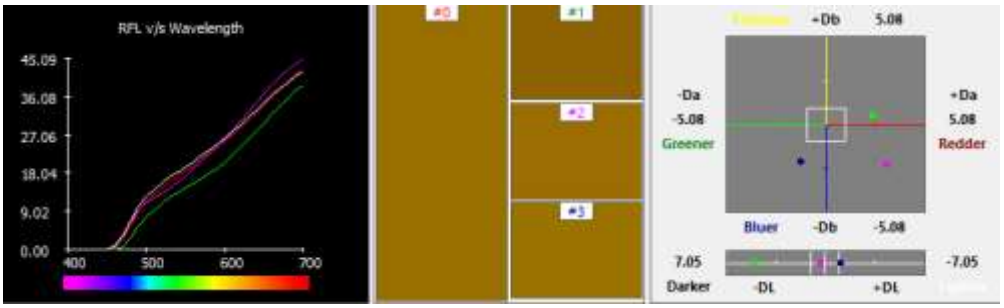

Figure 134: Reflectance value of 8% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 7 pH

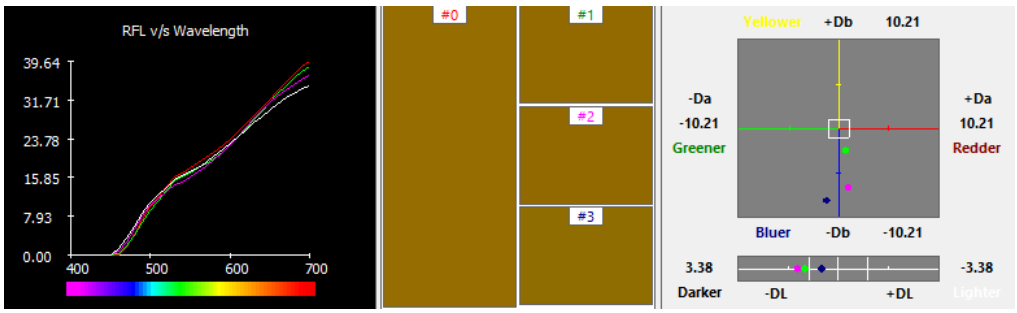

Figure 135: Reflectance value of 8% concentrated Onion peels dye on Kutchi Wool fabric with different mordants at 9 pH

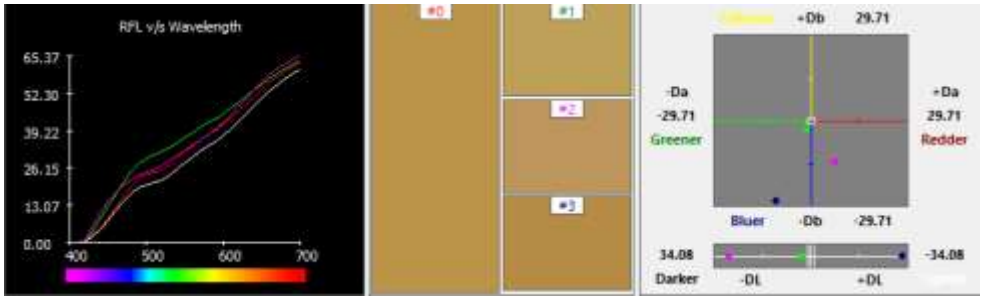

Figure 136: Reflectance value of 2% concentrated Onion peels dye on Nylon fabric with different mordants at 3.5 pH

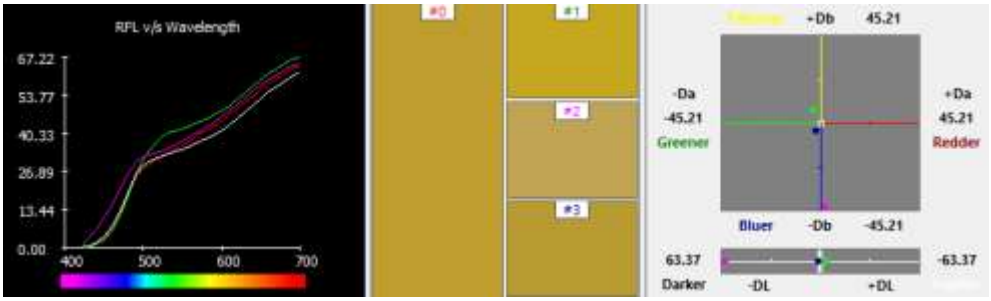

Figure 137: Reflectance value of 2% concentrated Onion peels dye on Nylon fabric with different mordants at 7 pH

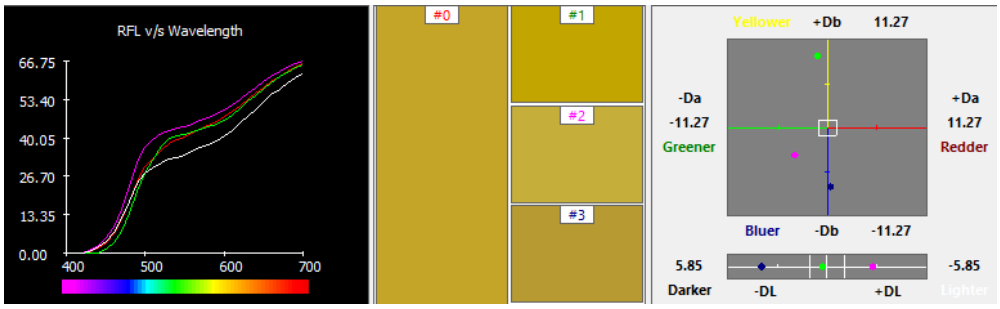

Figure 138: Reflectance value of 2% concentrated Onion peels dye on Nylon fabric with different mordants at 9 pH

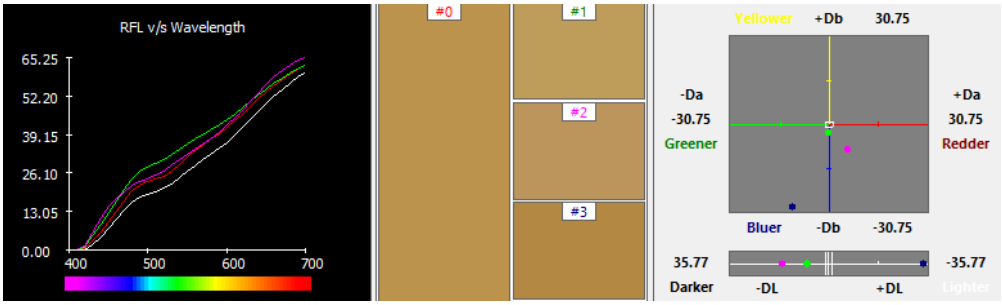

Figure 139: Reflectance value of 4% concentrated Onion peels dye on Nylon fabric with different mordants at 3.5 pH

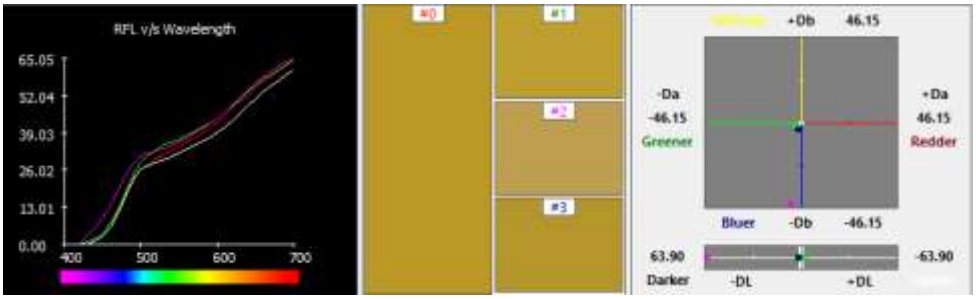

Figure 140: Reflectance value of 4% concentrated Onion peels dye on Nylon fabric with different mordants at 7 pH

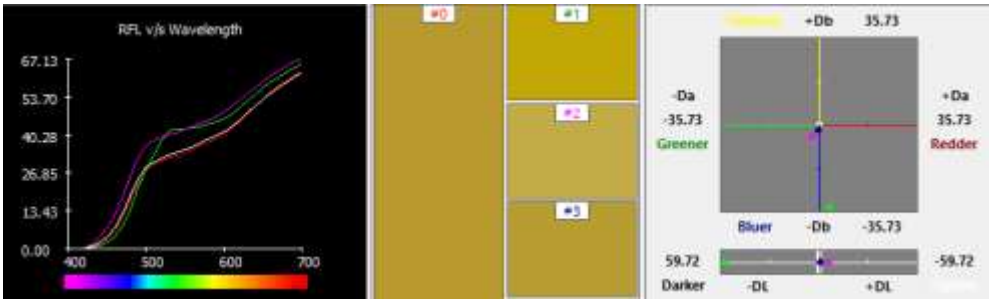

Figure 141: Reflectance value of 4% concentrated Onion peels dye on Nylon fabric with different mordants at 9 pH

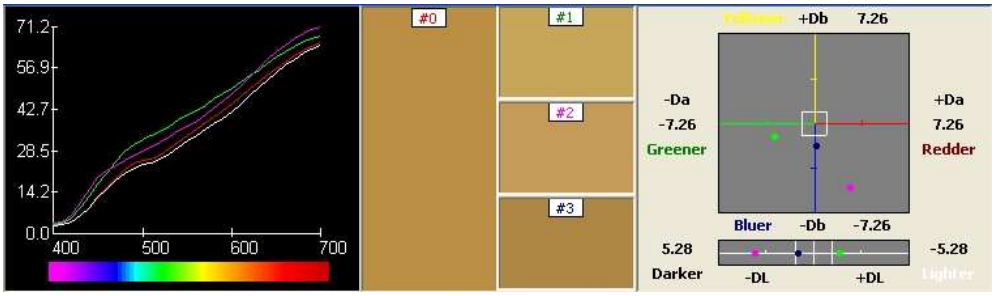

Figure 142: Reflectance value of 6% concentrated Onion peels dye on Nylon fabric with different mordants at 3.5 pH

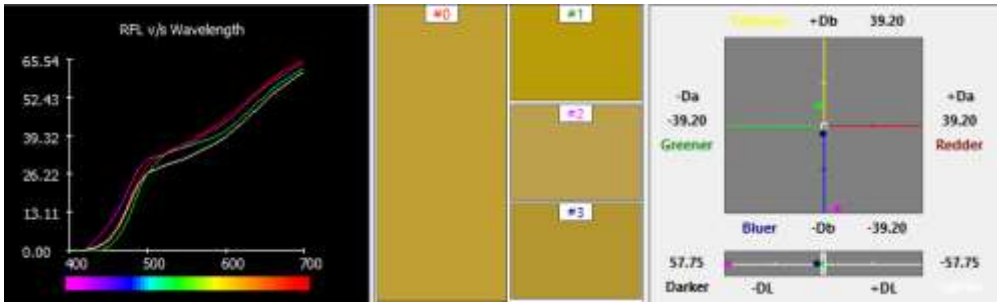

Figure 143: Reflectance value of 6% concentrated Onion peels dye on Nylon fabric with different mordants at 7 pH

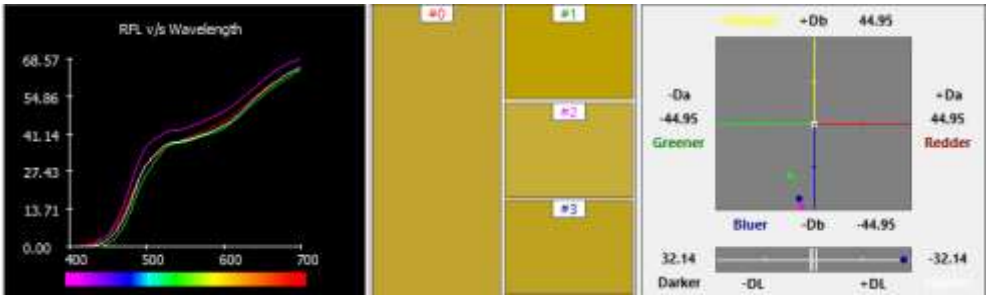

Figure 144: Reflectance value of 6% concentrated Onion peels dye on Nylon fabric with different mordants at 9 pH

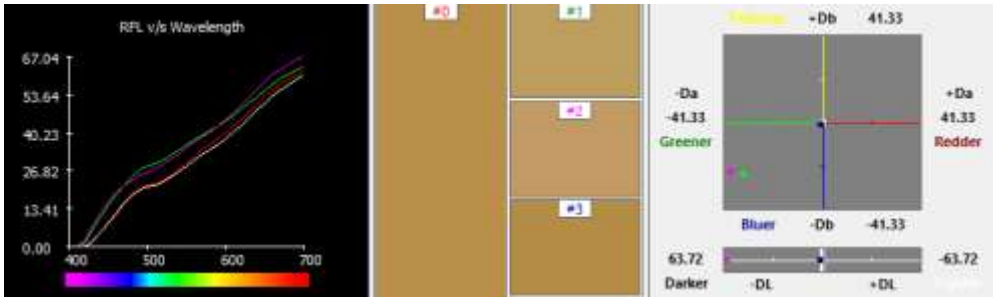

Figure 145: Reflectance value of 8% concentrated Onion peels dye on Nylon fabric with different mordants at 3.5 pH

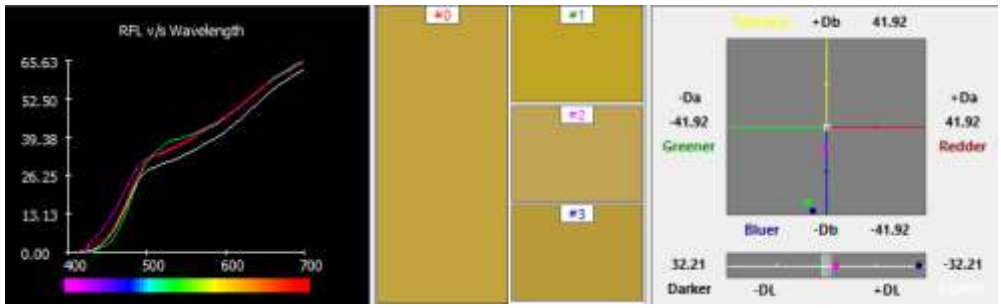

Figure 146: Reflectance value of 8% concentrated Onion peels dye on Nylon fabric with different mordants at 7 pH

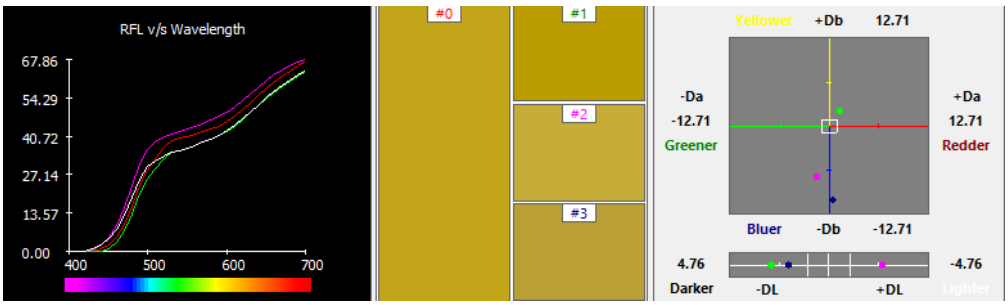

Figure 147: Reflectance value of 8% concentrated Onion peels dye on Nylon fabric with different mordants at 9 pH