

**Application of *Caesalpinia sappan* by Microwave
Extraction Method on Bamboo Cotton Woven Fabric**

By

**Uma, A.S
(13PTF017)**

A Thesis submitted to the

**Avinashilingam Institute for Home Science and Higher Education for
Women, Coimbatore - 641 043**

In Partial Fulfillment of the Requirements for the

Degree of Master of Science

in

Textiles and Fashion Apparel

March, 2015

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Certified as Bonafide Research Work


Signature of the
Head of the Department


Signature of the
Guide

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1. INTRODUCTION

“THINK GLOBALLY ACTS LOCALLY”- It is the slogan of tomorrow for the world textile industry. The world is becoming increasingly aware of environmental issues through discussions about the green house effect, ozone layer depletion, water pollution and waste disposal. The turn has led returning to a traditional or “more natural” way of life; biological farming, natural foods and the belief that all natural things are good for environmental purpose. Production of synthetic dyes involves many violent chemical reactions and products have to be discharged in water or in atmosphere, harmful effects of synthetic dyes have prompted the researcher to look era of revivalism, (Prabhu *et al.*, 2011).

The word textile comes from the latin word texture which was used by the Romans to mean to weave to braid or to construct. Textile have such as important hearing on our daily lives that every one needs to know something about them. From earliest times people have used textile of various types for covering, warmth personal adornment and even to display personal wealth, (Bernard,2007).

Color plays an important role while illustrating a picture gets attractive and lively through colours various emotion and feelings can be expressed through them, for example red corresponds with anger, danger, fire, your strength and yellow symbolizes joys uniqueness, wealth and prosperity, (Mussak, 2009).

It is one of the elements of nature that made the human living more aesthetic and fascinating. The whole spectrum of colors can be obtained from a multitude of plants, animals and fungi. This is useful to dye textiles to color our skin, our hair and the food w hat we eat. The discovery of the use of natural dyes and pigments contributed to the maintenance of the age-old bond between humankind nature could now help to revive and enhance it. But the art of natural dyeing wanted after the discovery of synthetic dyes in the mid-nineteenth century, (Mehta, 2014).

Natural dyes are eco-friendly; bio-degradable, non-toxic non-allergic in comparison to synthetic dyes has not only affected the flora and fauna but also caused threat to human safety. Thus eco-friendly natural dyes are gaining

importance not only for the safety of health and environment but also for the lustrous and production of varied colours, (Prusti *et al.*, 2010). In many of the world's developing countries, however, natural dyes can offer not only a rich and varied source of dyestuff, but also the possibility of an income through sustainable harvest and sale of these dye plants.

Many dyes are available from tree waste or can be easily grown in market gardens. (Vankar.*et al*, 2009). Up to the end of 19th century natural dyes were the main colorants for textiles. Recently, interest in the use of natural dyes has been growing rapidly due to the result of stringent environmental standards imposed by many countries in response to toxic and allergic reactions associated with synthetic dyes, (Anitha *et al.*, 2011).

Natural dyes have been used extensively since long periods. It was practiced during the Bronze age in Europe. The earliest written record of the use of natural dyes was found in china dated 2600 BC, (Siva, 2007). Dye yielding plants are important bio resources having huge economic potential as the demand for natural dyes in textile, food processing, cosmetic and a pharmaceutical industry is on the increase, (Dayal *et al.*, 2006).

Using natural dyes contributes to the added value to the textile and also responses to the increasing demand of compatibility with the environment. Recently there has been growing interest in the use of natural dyes in textile applications, (Choudhury, 2006).

Natural dyes are obtained from natural sources such as vegetable, fruits, minerals and insects. These dyes find use in the coloration of textiles, foods, drugs and cosmetics. Small quantities of dyes are also used in coloration of paper, leather, shoe polish, wood, cane, candles and such other products requiring coloration, (Gulrajani, 2001).

Any coloured substances can be termed as dyes, which have an affinity for the textile substances to which its is being applied. Dyes can be generally categorised into two categories in which natural dyes are obtained from natural origin and synthetic dyes are synthesised as per needs, (Ammayappan, *et al.*, 2013).

Caesalpinia sappan a natural dye yielding ornamental medicinal plant or east Indian red wood is multipurpose tree. The wood of sappan is more valued as the source of a red dye, (Badami, 2004). There are innumerable references for the use of wood in natural dyeing. Multifunctional finishes serves as a value addition for a consumer product. *Caesalpinia sappan* Linn being a common wood is chosen for the research in natural dyeing due to several properties such as antibacterial, antifungal, analgesic and wood rearing. Thus providing a natural dyed fabric with multiple properties, (Vainker *et al.*, 2004).

Mordants are the substances that have affinity for both textile fibers and dye, thus they act as a link between the fiber and dyestuff. Those dyes that do not have affinity for a fiber can be applied by using mordants, (saxena and Raja, 2014). Mordanting is very important for cotton as it is more difficult to dye than wool or silk due to the absence of amino and carboxyl groups that provide attachment sites to dye molecules. There are three types of mordants, oil mordants and tannins, (Raja,2013).

Dried myrobolan (*terminalia chebula*) fruits have high tannin content and also contain a natural dye that is used for producing bright yellow shades for all textile materials. Myrobolan is also used as a natural mordant to fix different natural dyes on textile materials. Myrobolan is a part of the famous ayurvedic preparation “triphala” and dyed materials are also imparted with medicinal properties such as antimicrobial, antifungal, and so on, (Saxena and Raja, 2014).

Bamboo is a unique biodegradable textile material. Bamboo comes from nature and returns to nature. It is praised as natural, green and eco-friendly textile material of 21st century. Apparel made from bamboo is called as “air conditioning dress”. Bamboo is a natural cellulosic fibre. The pulp from the stem of the bamboo plant is extracted and later spun into yarn. There are more than 70 genera of bamboo divided into about 1000 species, (Raja *et al.*, 2013).

As a regenerated cellulosic fibre, bamboo fibre is 100 percentage made from bamboo through a high-tech process. The raw material bamboo is well selected from non-pulled regions in Yunnan and sicuan province, china. They are all 3-4 year old new bamboo, of good character and ideal temperature.

The whole distilling and production process is a relatively green process without pollution. The supplier company manufactures bamboo fibre strictly according to iso 9000 and iso 14000, (Jayalakshmi and Soundanyaa, 2014).

Cotton is a soft, staple fibre that grows in a form known as a boll around the seeds of the cotton plant (*Gossypium* sp). cotton is used to make a number of textile products. These include terrycloth, used to make highly absorbent. Cotton also is used to make yarn used in crochet and knitting, (Meenakshi and Rastogi, 2009). Bamboo are the fastest growing woody plants in the world. Bamboo fabric is soft and absorbent in nature, which was appropriate for apparels. Bamboo fabric is very soft and can be worn directly next to the skin.

Many people who experience allergic reactions to other natural fibers, such as wool or hemp, but bamboo fabric does not have any such problem. Hence the investigator select bamboo cotton fabric for the study, (Raja et al., 2013). As bamboo cotton is an upcoming fibre it has been used for several applications. The exciting properties such as absorbency and biodegradability makes it considerable for the present study.

Considering the above facts in mind the investigator selected to study on **“Application of *Caesalpinia sappan* by Microwave Extraction Method on Bamboo Cotton Woven Fabric”** with following objectives to:

- Selection of the material
- Select the extraction method and natural sources
- Optimization of dyeing method
- Select suitable mordant and mordanting technique
- Dyeing the selected fabric with the extracted solution
- Evaluate the finished fabric with standard testing method

2. REVIEW OF LITERATURE

Reviews of literature for the present study on “**Application of *caesalpinia sappan* by Microwave Extraction Method on Bamboo Cotton Woven Fabric**” are discussed under the following headings:

2.1. Natural dye

- 2.1.1. Introduction
- 2.1.2. History
- 2.1.3. Classification
- 2.1.4. Advantages
- 2.1.5. Disadvantages
- 2.1.6. Types of natural dyes
 - 2.1.6.1. Vegetable dyes
 - 2.1.6.2. Mineral dyes
 - 2.1.6.3. Natural dyes from animal origin

2.2. Mordant

- 2.2.1. Types of Mordant
- 2.2.2. Mordanting Technique

2.3. *Caesalpinia sappan*

- 2.3.1. Taxonomic classification:
- 2.3.2. Botanical Description
- 2.3.3. Medicinal uses
- 2.3.4. Traditional uses
- 2.3.5. properties of the plant

2.4. weaving

2.5. Bamboo cotton

- 2.5.1. Introduction
- 2.5.2. History
- 2.5.3. cultivation

- 2.5.4. Properties of Bamboo Cotton
- 2.5.5. physical properties
- 2.5.6. chemical properties
- 2.5.7. Uses
- 2.5.8. Advantages of bamboo Cotton

2.6. Blending

2.7. Extraction of natural dyes

- 2.7.1. conventional method
- 2.7.2. Aqueous method
- 2.7.3. ultrasonic method
- 2.7.4. Microwave method
 - 2.7.4.1. optimization of microwave method
 - 2.7.4.2. optimizing of extraction

2.8 Application on fabric

- 2.8.1. Dip and dry method

2.1. Natural Dye

2.1.1. Introduction

Today, coloration of textiles is characterized by a high level of water pollution and health risk due to the use of synthetic dyes and harmful chemicals. Due to increasing awareness of environmental issues and pollution controls, natural dyes are once again gaining importance as they are obtained from renewable resources and they have no health hazards and some of them sometimes act as a health care product, (Prabhu *et al.*, 2011).

Textile processing industry is one of the major environmental polluters, synthetic dyes used abundantly in textile industry globally due to their availability, lower prices and wider ranges of bright shades with considerably improved colour fastness properties in comparison with natural dyes, (Sanad *et al.*, 2005).

One of the fascinating aspects of dyeing from natural sources is possible for a whole range of colours to be extracted from one plant or vegetable source by using different chemical mordants, as different parts of the plant itself will give a variety of colours. (Bhat, 2000). compared to synthetic colour, the colour obtained from natural sources are more soothing to human eyes. No synthetic dyes today have been made that match the subtle tones created by the natural dyes. Thus efforts should be made to explore different dye sources hidden in the beauty of nature.

Dyeing with natural dyes is traditional craft of India. Nature is not uniform and textile dyeing is concerned with organic compounds that can be dissolved in appropriate solvents, usually water dissolved. (Jayalakshmi and Soundanyaa, 2014). Natural dyes are known for their use in colouring of food substrate, leather as well as natural protein fibre like wool, silk and cotton as major areas of applications since pre-historic times, (samanta and Agarwal., 2009).

The use of non-allergic, non-toxic and eco-friendly natural dyes on textiles has become a matter of significant importance due to the increased environmental awareness in order to avoid some hazardous synthetic dyes. Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic

dyes, (samanta and Agarwal, 2009).Today, coloration of textiles is characterized by a high level of water pollution and health risk due to the use of synthetic dyes and harmful chemicals, (Katia and Werner, 2004).

Due to increasing awareness of environmental issues and pollution controls, natural dyes are once again gaining importance as they are obtained from renewable resources and they have no health hazards and some of them sometimes act as a health care product,(Prabhu *et al.*, 2011).

Natural dyes are considered eco-friendly as these are renewable and biodegradable; are skin friendly and may also provide health benefits to the wearer. Natural dyes can be used for dyeing almost all types of natural fibres. Recent research shows that they can also be used to dye some synthetics fibres.

Apart from their application in textiles, natural dyes are also used in the coloration of food, medicines, handicrafts items and toys, and in leather processing, and many of the dye-yielding plants are used as medicines in various traditional medicinal systems, (Saxena and Raja, 2014).

2.1.2. History

Colour has always fascinated man. For centuries man used colour derived from nature, for tinting his skin and later for the colouration of natural fabrics which he made from cloth, silk and wool. In every civilisation, from the remote ages to the present day, colour has played an important part in adding beauty to the world. It is difficult to tell when exactly people started making colours, but it must have been pretty early since their evolution, (Horrocks *et al.*, 2000).

coloured fragments of madder dyed cloth have been found in the ruins of the Indus valley civilization of Mohen-jo-daro and Harappa (3500 B.C.). Madder dye has been mentioned as “Majistha” in the Vedas. Quick reference of dyed cloth “Pitambar” indicate that the process of dyeing is thousands of year old, (Bhat, 2000).

The colouring matter present in the roots of *Rubia Cordifolia* is a mixture of Purpurin and Munjistin. Purpurin is the main colouring principal in roots while

Munjistin, an orange dye occur in the form of glucoside, (Vainker, 2004), (Resonance, 2010). The roots are credited with tonic, astringent, antidysentric and antiseptic properties. They form an ingredient of several medicines. The roots are credited with tonic, astringent, antidysentric and antiseptic properties. They form an ingredient of several ayurvedic medicines. The roots are also used for colouring medicines, (Sekhri, 2012).

India has a very rich tradition of using natural dyes. The introduction of synthetic dyes have, however adversely affected the tradition. Still the art and craft of preparing natural dyes is being practised in many villages in india. The evidence of use of natural dyes during pre-moghul and Moghul period of Indian history is much preserved in the form of paintings, manuscripts etc. the coloured exquisite silk and muslin fabrics of india had acquired fame throughout the world during the 16th and 17th centuries, (Bhat, 2000).

Dyeing, printing and painting were not the only uses of natural dyes in india. Natural dyes were also and being used till today in food and confectionery- examples, saffron, turmeric, Kashmir chilli etc. Natural dyes succumbed to synthetics because of inadequate fastness, time consuming process of preparation and lack of uniformity of colour shades, (Gulrajani and Gupta, 2001).

Like most Indian crafts, the knowledge and expertise of natural dyes was traditionally passed down from the master craftsmen to his disciple. Consequently, documentation on the source of such dye/colourants, the technique of extraction and application is meagre, (Bhat, 2012).

2.1.3. Classification

Natural dyes were classified in two groups namely, substantive and adjacent dyes by "Bancroft in his "Treatise on permanent colours". According to this classification, the dyes such as indigo, orchid, turmeric, which dye the fibres directly are classified as substantive dyes, while adjacent dyes only dye material mordant with metallic salt; examples of such dyes are logwood, madder, cochineal, fustic etc, (Jain, 2010),

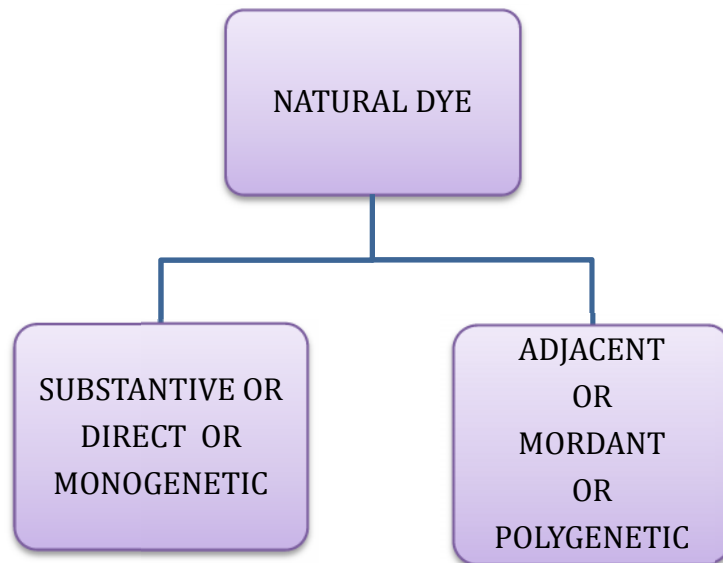


FIGURE 1
Classification of natural dye

In pure state the adjective dyes are generally slightly coloured and when used alone, they give poor dyeing. Natural dyes can also be classified as direct dyes and mordant dyes, (Flint, 2008). Another classification divided them into monogenetic dyes and polygenetic dyes. Monogenetic dyes produce only one colour irrespective of the mordant while the colour generated on the fibre by the polygenetic dye depends on the mordant used.

2.1.4. Advantages

- They are obtained from renewable resources.
- No health hazards, sometimes they act as health cure.
- Practically no or mild chemical reactions are involved in there preparation.
- No disposal problems.
- They are unsophisticated and harmonized with nature.
- Lot of creativity is required to use these dyes judiciously, (Gulrajani and Gupta 2001).

2.1.5. Disadvantages

- Limited number of suitable dyes.
- Allow only wool, natural silk, linen and cotton to be dyed.
- Great difficulty in blending dyes.
- Non-standardized.
- Inadequate degree of fixation.
- Inadequate fastness properties.
- Water pollution by heavy metals and large amounts of organic substances.

2.1.6. Types of natural dyes

2.1.6.1. Vegetable dyes

- Those derived from roots, bark, wood, leaves, flowers and fruits of the plants.

2.1.6.2. Mineral dyes

- Those derived from minerals and found in nature.

2.1.6.3. Natural dyes from animal origin

- Such as dyes derived from lac, cow urines etc.

There were about 400 fast natural dyes. Three countries were the earliest in the world to use dyes from natural sources, such as indigo, turmeric, madder and resin. In the near future, the fabric printed with natural dyes may have an increased demand, not only for safety of health and environment but also for their beauty and novelty, (Afrin et al., 2014).

Increased awareness for eco-friendly products in the developed countries has opened up a new channel for the export of hand printed fabrics printed with natural dyes, (Rathod and Kolhatkar, 2014).

2.2. Mordant

Mordants are considered as an integral part of the natural dyes or, to be more precise, the natural dyeing process by the most dyers of natural dyes. This

is an anomaly, which continues to be perpetuated by different authors and practitioners of natural dyeing, (Bernard, 2005). Natural dyes are either substantive which do not require any mordant or adjective which require mordant.

Natural dyes are pigments which do not contain any reactive group in their structure to react with the fibre. Most natural dyes need a chemical in the form of metallic salt to create an affinity between the fibre and the dye or pigment. These chemicals are known as “mordants”, the name being derived from Latin ‘mordere’, meaning to ‘bite’,(Bhattacharyya, 2010).

The significance of the term ‘mordant’ comes in when the dye has no affinity to the fibre. Most of the natural colourants are adjective in nature; they require an intermediate to fix in to the fibre, which is called mordant. They prevent the colour from either fading with exposure to light or washing. Ancient workers used natural mordants in the form of albumen from egg, ox-blood, urea, cowdung, rotten mud etc, (Jun *et al.*, 2008).

2.2.1. Types of Mordant

Generally, three types of mordants are used for dyeing purpose.

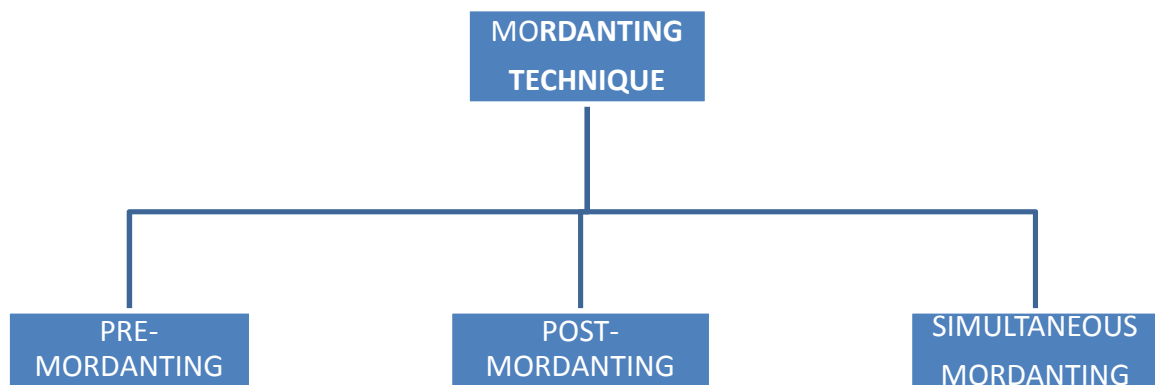
- **Metallic mordants:** salts of aluminium, chromium, iron, copper, tin, zinc, cobalt, and rare earth metals are used as metallic mordants, (Ammayappan *et al.*, 2013).
- **Tannin :** The name “tannin” is derived from the French “tannin’ and is used for a range of natural polyphenols. Tannin is an astringent vegetable product found in a wide variety of plants. Plant parts include bark, wood, fruit, fruit pods, leaves, roots and plant galls. Tannins are high molecular weight water soluble polyphenolic compounds.
- Myrobalan and sumach are the commonly used mordants in the dyeing of textile fibers. Natural mordants exist in bark of the tree and give dark shades i.e. brown and grey shades. It might resist bacterial growth on fiber, (jun *et al.*, 2008).
- **Oil mordants:** oil mordants are used mainly in the dyeing of deep red colour from madder. The main function of the oil mordant is to form a

complex with alum used as the main mordant. Sulphonated oil is used as mordant in the dyeing of Turkey red colour from madder, (Ammayappan *et al.*, 2013).

2.2.2. Mordanting Technique

Mordanting is the treatment of textile fabric with metallic salts or other complex forming agents which bind the natural mordant able dyes onto the textile fibres (Samanta and Agarwal , 2009). Mordanting can be achieved by either pre-mordanting, simultaneously mordanting or post-mordanting. Different types and selective mordants or their combination can be applied on the textile fabrics to obtain varying colour or shade, to increase the dye uptake and improve the colour fastness behaviour of any natural dye, (Kalpana *et al.*, 2009).

FIGURE 2
Mordanting technique



Pre-mordanting

In this method, samples were pre-treated with the solution of different chemical and natural mordants and then dyed with dye extract.

Post-mordanting

In this method, dyed cotton samples were treated with solution of different chemical and natural mordants, (Mehta, 2014).

Simultaneous mordanting

In this method, the cotton samples were dyed with dye extract as well as different chemical and natural mordants.

2.3. *Caesalpinia sappan*

Caesalpinia sappan L is a traditional medicine plant produced in india, mayanmar, Vietnam, srilanka and the malay peninsula and distributed domestically in china in yunnan, guizhou, Sichuan, Guangdong, guangxi, Fujian, and Taiwan, (Katia and Werner, 2004). *Caesalpinia sappan* L is widely distributed in Thailand, Indonesia, Vietnam, Burma, India, South and Southwest china.

The dried heartwood of this plant, sappan lignum, is popularly used as a traditional Chinese medicine for the treatment of menorrhagia, cardiovascular and cerebro vascular diseases. Previous investigations revealed that the extract of sappan lignum presented diverse and remarkable bioactivities, and therefore could be used as an anti-inflammatory, anti-microbial agent and to improve the blood circulation and purification, (Chenz, *et al.*, 2013).

caesalpinia sappan is a species of flowering tree in the legume family, Fabaceae that is native to southeast Asia and the malay archipelago common name include sappan wood. It possesses medicinal abilities as an antibacterial and for its anticoagular properties, (Muthu and subramanian 2014).

TABLE I

DIFFERENT NAMES OF *CAESALPINIA SAPPAN*

Language	Name
Kannada	Chekke sappange
Malayalam	Chappgam
Europe	Brezel wood
Sanskrit	Patanga
English	Sappan wood
Tamil	Padhimugam
Hindi	Bakam

2.3.1. Taxonomic classification:

Kingdom:	plantae
Division:	magnoliophyta
Class:	magnoliopsida
Order:	Fabales
Family:	Fabeaceae
Genus:	<i>caesalpinia</i>
Species:	sappan

2.3.2. Botanical Description

Caesalpinia sappan is a small thorny tree, 6-9 m in height and 15-25 cm in trunk diameter with a few prickly branches. Leaves are double-compound, alternately arranged, 20-45 cm long, 10-20 cm broad, with 8-16 pairs of up to 20 cm long side-stalks. Side-stalks are prickles at the base and with 10-20 pairs of oblong, 10-20 mm x 6-10 mm long leaflets, very oblique at base, rounded to notched at the tip. Yellow flowers are borne panicles in leaf axils and at the end of branches. Flowers fragrant, 2-3 cm long, 5-merous. Stamens are waxy-white, filaments densely woolly at the base, (Ericlichtfouse *et al.*, 2013).

Fruits are woody pods, compressed with a hard recurved short beak, with 3-4 seeds. The heartwood which is used in medicine is light yellow when freshly cut, but it quickly changes to red. The colour diffuses out easily in hot water. In about 7-10 hours the extract becomes deep orange in colour. Sappan-wood was a major trade good during the 17th century, when it was exported from southeast Asian nations aboard red seal ships to japan, (Rathod and Kolhatkar, 2014).

Caesalpinia sappan is a small to medium-sized, shrubby tree, 4-8 m tall; trunk up to 14 cm in diameter; bark with distinct ridges and many prickles, greyish brown; young twigs and buds hairy, brownish. Leaves stipulate, bipinnate, alternate, 20-25 cm long, 10-20 cm broad, with 8-16 pairs of up to 20 cm long pinnae; Flowers in terminal panicles, fragrant, fruit a dehiscent pod, glabrous,

thick, flattened. Seeds ellipsoid, flattened, 18-20 mm x 10-12 mm, brown, (Horrocks *et al.*, 2000).

2.3.3. Medicinal uses

The dye is extracted by putting chips or powered wood in water. The bark and of the tree also contain orange yellow or red dye used as a colour in agent for cakes. sappan can prevent and cure diseases like certain types of cancer, kidney, disorder, cholesterol, blood purification, skin diseases, heart diseases etc, (Badami *et al.*, 2004). It is a natural dye yielding medicinal plant and is a small theory spreading tree which groups up to 30 feet in height and its wood reaches 15-30 cm in diameter. The dye is extracted by boiling chipped wood pieces in water while extracting few paddy grains are thrown into boiling liquid to check if the extraction is completed, (Chandraprabha *et al.*, 2007).

2.3.4. Traditional uses

The heartwood of the plant is widely used in traditional medicine. The wood is a component of 'vicco vajradanti', a famous tooth paste and tooth powder of india. The powerful astringent, haemostatic, healing properties of the wood helps to stop bleeding in gums and give firmness and strength to the gums and hence, it is useful in mobile teeth, aphthous ulcers, stomatitis and gum erosions because of its strong healing action, (Mehta and Jahan, 2014).

The wood is very bitter, stops bleeding from the chest and lungs, heals wounds, ulcers, improves complexion and useful in rheumatism. It has been used as a haemostatic, analgesic, anti-inflammatory agent and as a medical treatment for confusion and thrombosis in traditional oriental medicine. sappan leaves are a component of *jamu*, a traditional herbal medicine in java. The small core of heartwood produces a dark red solution in water and is being used as herbal drinking water in kerala, since time immemorial for its antithirst, blood purifying, antidiabetic, complexion enhancer and several other properties, (Badami *et al.*, 2007).

2.3.5. Properties of the plant

Plant dyes were the dominant materials used for textile dyeing in ancient china, Japan, India and many other countries. Sappan wood was one of the most widely used plant dye for its red colour. It was exported from southeast Asia to Europe as dried wood chips. The red wood obtained from this species is similar to the wood obtained from *caesalpinia sappan*, (Jun *et al.*, 2008).

2.4. weaving

It is the interlacing of two sets of yarn which inter-lace at right angles to each other. The length-wise threads are known as warps, individually they are called ends. The cross-wise threads are known as filling or weft; individually they are known as picks. Weaving is done on a loom which makes it possible to interlace the warp and filling threads according to a pre-arranged manner. The length-wise edges of the fabric are called selvages, (Kalpana *et al.*, 2005).

2.5. Bamboo Cotton

2.5.1. Introduction

Bamboo is a natural cellulosic fiber. The pulp, from the stem of the bamboo plant is being extracted, later spun into yarn. There are more than 70 genera of bamboo divided into about 1000 species. They are found in diverse climates, from cold mountains to hot tropical regions, avers, (Muthu and Subramanian, 2014). The bamboo are a group of woody perennial plants in the true grass family Poaceae, subfamily bambusodiaie, tribe. Some are giant bamboos, the largest members of the grass family. Bamboos are the fastest growing woody plants in the world, (Kozlowski, 2012).

Their growth rate upto 60 centimeters 24/day is due to a unique rhizome dependant system, but it is highly dependant on local soil and climate conditions. Bamboo fabric is very soft and can be worn directly next to the skin. Bamboo is highly water absorbent, able to take up three times its weight in water. Bamboo clothing today has become popular as an innovative buster in the apparel industry, (Ramani *et al.*, 2013).

Its in- built natural antibacterial and antifungal properties are an added advantage in the area of textiles. Bamboo fabric is very soft and can be worn directly next to the skin, (Shah and Sabale, 2010). Many people who experience allergic reactions to other natural fibers, such as wool or hemp, do not complain of this issue with bamboo. The fibre is naturally smooth and round without chemical treatment, meaning that there are no sharp spurs to irritate the skin, (Rathod and Kolhatkar, 2014).

Bamboo is highly water absorbent and able to take up three times its weight in water. In bamboo fabric, this translates to an excellent wicking ability that will pull moisture away from the skin so that it can evaporate. For this reason, clothing made of bamboo fiber is often worn next to the skin. Cotton is a soft, staple fibre that grows in a form known as a boll around the seeds of the cotton plant, (Ericlichtfouse *et al.*, 2013).

Cotton is a cellulosic fibre obtained from natural sources. Cotton fibre quality is strongly influenced by the grade, colour, length, and characteristics of the fibre. The countries that produce most of the cotton fibre are the united states, India, china, Egypt, Pakistan, Sudan, and Eastern Europe. Cotton fibre into two major categories: long staple fibre having a length more than 28 mm and short staple fibre having a length shorter than 28 mm, (Muthu and Subramanian, 2014).

2.5.2. History

Bamboo plants are commonly cultivated in Asian countries. It is one kind of grass with hollow and woody stem. There are so many varieties of bamboo plant across the world. Nowadays, bamboo is widely used in the field of building and construction because of its toughness and other properties, (Rathod and Kolhatkar, 2014).

A few decades ago, bamboo was traditionally used for making a variety of household goods such as furniture, sporting goods, handbags, flooring and cutting board, etc. Nowadays, due to developments in manufacturing processes, it is possible to produce fibre from bamboo stem, which has remarkable properties for its use in yarn and fabric. Bamboo fabric absorbs and evaporates sweat very easily, hence it gives a comfortable feel, (Kamani et al., 2013).

Fabric made of bamboo fibre possesses better moisture transmission property, softer, handle, drapability and easy drying, (Rathod, 2014). Cotton was cultivated by the inhabitants of the Indus valley civilization by the 5th millennium BCE-4th millennium BCE. The Indus cotton industry was well developed and some methods used in cotton spinning and fabrication continued to be used until the modern industrialization of india, (Meenakshi and Rastogi, 2009).

2.5.3. Cultivation

Bamboo fabric is soft and absorbent in nature, which was appropriate for apparels. Bamboo is the fastest –growing plant on earth; it has been clocked surging skyward as fast as 121 cm in a 24-hour period, and can also reach maximal growth rate exceeding one meter per hour for short periods of time. Many prehistoric bamboos exceeded heights of 250 feet, (Poornima and Devi, 2014).

Primarily growing in regions of warmer climates during the cretaceous, vast fields existed in what is now Asia. Modern bamboos can only sustain their maximal growth rate for short periods of time. Bamboo can grow six or more inches a day though there exceptions, (Meenakshi and Rastogi, 2009).

Successful cultivation of cotton requires a long frost-free period, plenty of sunshine, and a moderate rainfall, usually from 600 to 1200mm. soils usually need to be fairly heavy, although the level of nutrients does not need to be exceptional, (Poornima and Devi, 2009).

2.5.4. Properties of Bamboo Cotton

Cotton is hypoallergenic meaning it doesn't irritate sensitive skin or cause allergies. It is very soft, which is why it is particularly favoured in underwear ranges and other garments that get close to the skin, (Fung, 2002).The ends of cotton fibres are spun very tightly into the yarn so that the fabric doesn't irritate skin or cause static electricity. It is long lasting if well looked after. Cotton can be easily blended with other fibres such as synthetics, (Poornima and Devi 2014).Stains can be easily removed from cotton.

- Cotton is a good conductor of heat. In other words, it draws heat away from your skin to keep you cool, making it very comfortable to wear.
- Cotton absorbs moisture easily and can take up to one fifth of its weight in water before it actually feels damp.
- Cotton does not contain any chemicals and therefore is a natural product.
- Bamboo fibre is a regenerated cellulosic fibre produced from bamboo.
- Strong durability, stability and tenacity.
- It has much better moisture absorption and ventilation.
- Moisture absorbency is twice than that of cotton with extraordinary soil release.
- Natural antibacterial elements in bamboo fibre keep bacterial away from bamboo fabrics, (Siva, 2007).
- Bamboo fibre is eco-friendly and bio-degradable.
- Bamboo absorbs the dyestuffs faster and shows the colours better.
- Anti-ultraviolet nature of bamboo fibre has made it suitable for summer clothing, especially for the protection of pregnant and children from the effect of ultraviolet radiation.

2.5.5. physical properties

Tenacity

The strength of cotton fibre is attributed to the good alignment of its long polymers i.e its polymer system is about 70 percentage crystalline, due to the countless continuous hydrogen bond formations between adjacent polymers, and the spiralling fibrils in the primary and secondary cell walls, (Hansen, 2012).

Elasticity

Relatively it is elastic due to its crystalline polymers system and for its cause cotton textiles wrinkle and crease readily, (Mahesh and Anitha, 2014).

Thermal properties

cotton is not thermoplastic and hence excessive application of heat energy reasons the cotton fibre to char and burn, without prior melting.

Lustre

Lintreated cotton has no pronounced lustre. Therefore in order to make it lustrous they need to be mercerized

2.5.6. Chemical properties

Effect of alkalies

cotton fibres are resistant to alkalies and are comparatively unaffected by normal laundering, (Kozlowski, 2012).

Effect of acids

cotton fibres are weakened and destroyed by acids.

Effect of bleaches

The most common bleaches used on cotton textile materials are sodium hypochlorite and sodium perborate.

Effect of sunlight and weather

The ultra-violet rays of sunlight provide photo chemical energy whilst the infra-red rays provide heat energy essential to degrade the cotton polymers in the presence of atmospheric oxygen, moisture and air pollutants.

Colour fastness

cotton is easy to dye and print. The classes of dye which may be used to colour cotton are azoic, direct, reactive, sulphur and vat dyes.

2.5.7. Uses

Cotton is used to make a number of textile products. These include terrycloth, used to make highly absorbent bath towels and robes, denim, used to make blue jeans, chambray, popularly used in the manufacture of blue work shirts and corduroy, seersucker, and cotton twill. Socks, underwear, and most T-shirts are made from cotton. Bed sheets often are made from cotton. Cotton also is used to make yarn used in crochet and knitting, (Bhattacharyya, 2010).

In textiles, bamboo fibre is a revolutionary new fabric, which has unparalleled advantages including strength, versatility, luxurious and softness. Bamboo fabrics are used in different end use of clothing includes shirts, dresses, shorts and slacks because of their antimicrobial properties. Other areas include sports socks, dress socks, towel, seamless inner wears, T-shirts, dress shirts, etc., work wear, defence uniform, (Anitha, 2011).

It is also used for household furnishing bed sheets, pillowcases and drapery materials. It is particularly suitable for performance and exercise wear. The bamboo plant has an extraordinary range of uses such as baskets, blinds, boats, bridges, charcoal, chopsticks, clothing, diapers, firewood, furniture, handicrafts, hats, musical instruments, paper, particle board, ply, roofing, toys, umbrellas, (Mahesh and Anitha, 2014).

2.5.8. Advantages of bamboo Cotton

- Naturally soft
- Allergy reduced
- Thermal regulating
- Absorbs moisture
- Breathable
- Anti-bacterial
- UV protection
- Good strength
- Abrasion resistant, (Jain, 2010).

2.6. Blending

Blending of different fibres is a very common practice in the spinning industries. The blending is primarily done to enhance the properties of resultant fibre mix and to optimize the cost of the raw material. The properties of blended yarns primarily depend on the properties of constituent fibres and their compability. Moreover, the proportion of fibres in the blend also plays a significant role. It has been observed that the stronger component has to be mixed at least

by a certain proportion in order to gain in terms of tensile properties, (Ramani and Raja, 2013).

The sort of material for blending is also very important because not all materials can be mixed together. Wrong combinations can result in shrinkage or very weak structure of fabric. So, it becomes essential for the researcher to design and introduce novel and vibrant yarns to the market to satisfy the consumers with various tastes and variety of and applications, (Anitha, 2011).

In the cotton spinning process, blending has the objective of producing yarn with acceptable quality and reasonable cost. A good quality blend requires the use of adequate machines, objective techniques to select bales and knowledge of its characteristics. Bamboo and bamboo-cotton blended yarns are a kept part of the 'natural product' theme and are recommended for use in "soft look and soft feel" textiles, like towels, knits and socks, as well as in home-textiles, (Ramani and Raja, 2013).

2.7. Extraction of natural dyes

Extraction involves the separation of active portions of plant or animal tissues from the inactive or inert components by using selective solvents in standard extraction procedures. The products so obtained from plants are relatively impure liquids, semisolids or powders intended only for oral or external use, (Bhattacharyya, 2010).

2.7.1. Conventional method

Conventional dye extraction was carried out using varying amounts of the dye materials (0.1g – 1.0 g) for different time intervals (15-120 mins) and at different temperature (50 -80⁰c) using water, (Song *et al.*, 2011).

2.7.2. Aqueous method

Different amounts of natural dye powered (0.1g – 1.g) was take in Erlenmeyer flasks (250 ml) and 50 ml of water was added in each flask and the flasks were incubated at different temperatures (60⁰c, 70⁰c, 80⁰c and 90⁰c) in a shaker incubator. Extract samples were taken at different time intervals (30 min,

45 min, 60 min, 90 min, 120 min and 180 min), filtered and dried. The solution pH was maintained as 1.96 – 9.5. The optical density of the sample was analysed by the UV visible spectrophotometer and the total weight of the extracted dye pre gram was determined, (Sekhri, 2012).

2.7.3. Ultrasonic method

There is a growing demand for developing suitable extraction techniques for more efficient and effective extraction of available active matters from plant materials, (Vankar *et al.*, 2009). Power ultrasound is commonly employed for a wide variety of chemical and physical processes, such as accelerating chemical reaction, emulsification, degassed, extraction, etc., wet textile process consumes much energy and water, and release enormous amounts of effluent to the environment. in textile process, ultrasound can offer a potential benefits for shortening process time, reducing pollution load and getting improvement in product quality, (Sung *et al.*, 2010).

2.7.4. Microwave method

2.7.4.1. Optimization of microwave method

Safe environment and usage of minimal energy are the slogan of today. In this regard non-conventional energy sources such as ultrasound and microwave has been used extensively in the recent times. Since microwave has recently become extremely popular to accelerate organic reactions by providing high heat efficiency, remarkable rate enhancement and dramatic reduction in reaction times, we considered using microwave irradiation in improving the Baeyer's synthesis for indigo, (Vankar *et al.*, 2001).

The process of microwave assisted extraction method was performed in experimental microwave equipment at a power of 330 W. Different amounts of powdered samples (0.1 g, 0.2 g,...1 g) were weighed and transferred into 100 ml beaker and 50 ml of distilled water was poured. The effect of microwave on the yield of colorant was examined at different time intervals of 10, 30, 50, 60, 75, 90 and 120 sec with the different extraction power (330, 600, 800, w), (Sekhri *et al.*, 2012).

2.7.4.2. Optimizing of extraction

Ultrasonic extraction was carried out in 100 ml water using varying amounts of the dye materials (2 – 12%) at different temperatures (50 -80⁰c) using different sonic power (100 – 500W) and for different time intervals (20 – 120 min).

After filtration and certain dilution, the optical density of the dye liquor was measured.

2.8. Application on fabric

2.8.1 Dip and dry method

The bath liquor was prepared by taking material: liquor ratio as 1:20. 1% of mordant was added to the bath as binder. The desized bamboo cotton fabric was then dipped in the prepared bath for 45 minutes at 80⁰c. The fabric was then dried at room temperature. After the fabric had been completely dried, it was then cured for three minutes at 150⁰c in the hot air oven, (Karolia and Mendapara, 2007).

3. EXPERIMENTAL PROCEDURE

Experimental procedure pertaining to the study on “**Application of *Caesalpinia sappan* by Microwave Extraction Method on Bamboo Cotton Woven Fabric**” are discussed under the following headings:

3.1. Selection of fabric

3.2. Preparation of fabric

3.3. Pilot study

3.1.1. Selection of natural dyes

3.1.3. Selection of shade

3.4. Extraction of natural dye

3.4.1. Conventional extraction method

3.4.2. Microwave dye extraction method

3.5. Optimization of various parameters for dye extraction

3.5.1. Solvents

3.5.2. Dye Concentration

3.5.3. Time

3.5.4. pH

3.6. Dyeing

3.6.1. Selection of Mordants

3.6.2. Selection of Mordanting techniques

3.6.3. Dyeing Parameters

3.7. Dyeing of selected fabric using dyes extracted by conventional, microwave assisted methods

3.8. Evaluation of dyed fabrics

3.8.1. Subjective Evaluation – Visual Inspection

3.9. Objective Evaluation- Physical and Mechanical property

3.9.1. Fabric Weight

3.9.2. Fabric Thickness

3.9.3. Abrasion Resistance

3.9.4. Tensile Strength

3.9.5. Drape Test

3.9.6. Pilling Resistance

3.9.7. Fabric Count

3.10. Wettability and absorbency test

3.10.1. Drop Test

3.10.2. Sinking Test

3.10.3. Capillary Rise Test

3.11. Colour fastness test

3.11.1. Fastness to crocking

3.11.2. Fastness to sunlight

3.11.3. Fastness to wet and Dry Pressing

3.11.4. Fastness to Washing

3.12. Statistical analysis

3.13. Nomenclature

3.1. Selection of fabric

Natural cellulosic fibres are biodegradable fibres. Cotton the “king of fibres” is the most famous textile material (Raja et al., 2013). It has unique characters such as soft, comfortable, good colour retention and has a high degree of acceptability to wear next to skin such as shirts, blouses, etc, because of its high absorption and swelling capacity. Plain weave is relatively inexpensive for construction and can be extensively used for bamboo cotton fabrics. They ravel out less than other weaves (Kalpana et al., 2005). So cotton fabric made out of plain weave was selected for present study. The detail of the selected material is given in the Appendix 1.

3.2. Preparation of fabric

The sizing is a protective coating applied to the warp yarns to give strength during fabrication. The desizing step is designed to remove the warp sizing material. It is preparatory process carried out before applying any kind of finish to the fabric, (Behery, 2005). So, the sized bamboo Cotton fabric was subjected to desizing to remove the sizing matter from the fabric. For desizing, the fabric was immersed in detergent solution prepared using softwater which was boiled for half an hour. Then the fabric was taken out, rinsed thoroughly and dried in shade. The detail of desized material is given in the Appendix 1.

3.3. Pilot study

A pilot study was carried out in order to select natural dye source, mordants, mordanting techniques and dyeing procedure. Pilot study is a pre-study of main project. Wise researchers would always go for a pilot study, (Collins, 2010).

3.1.1. Selection of natural dyes

Natural dyes are colorants extracted from vegetable matter, minerals or insects. These dyes are considered as eco-friendly dyes or mordant dyes as they require the inclusion of one or more metallic salts (Hunger, 2007). The natural dye namely *caesalpinia sappan* can be used as a brighter shade of natural dye on textiles especially Bamboo- cotton. It is non-carcinogenic in nature and so does not affect human body or environment. Hence, the research select the *caesalpinia sappan* for this study (Plate I and II).



Plate - I

***Caesalpinia sappan*-Bark**



Plate - II

***Caesalpinia sappan* – Powder**



Plate – III

Mordant - Myrobolan



Plate – IV

Conventional extraction - Dye



Plate – V

Microwave Extraction



Plate – VI

Microwave Extraction - Dye

3.1.3. Selection of shade

The shade of dyeing is expressed as a percentage of dye and fabric. The material to liquor ratio is also a unique quantity. This represents the percentage of dye stuff and the material to liquor ratio which reflects the concentration of the dye bath, (Song, 2011).

3.4. Extraction of natural dye

3.4.1. Conventional Extraction

5 g of *Caesalpinia sappan* wood powder which was taken in a beaker containing 100 ml of water and allowed to boil for one hour at 90⁰c. The resulting dye extract was filtered and used as dye solution. The optimal density of the dye solution was measured using a UV- Vis spectrophotometer at 362 nm, (Bhattacharyya, 2010) (Plate IV).

3.4.2. Microwave Dye Extraction

8 g of *caesalpinia sappan* wood powder was taken and 100 ml of water was added to it and placed in microwave bath for one hour. Colour intensity was determined using spectrophotometer at 362 nm, (Darwekar, 1999) (Plate V and VI).

3.5. Optimization of various parameters for dye extraction

3.5.1. Solvents

To determine the suitable solvent for dye extraction, 5 g of *caesalpinia sappan* wood powder are mixed with different solvents such as H₂O, ethanol, methonal, 2% NaOH individually and placed in both conventional and microwave bath for one hour. The resulting dye extract was filtered and the colour intensity was measured at 362 nm using spectrophotometer. The solvent which showed higher absorbance was selected as the suitable solvent and used for further studies extraction, (Ammayappan et al., 2013).

3.5.2. Dye Concentration

To determine the optimum concentration of the dye source *sappan* wood powder at various concentration such as (1, 2, 3, 4, 5, 6, 7, 8, 9, 10%) were taken individually and placed in microwave bath and conventional dye bath for one hour.

The optical density of the dye solution was analysed spectrophotometer at 362 nm. The concentration at which the absorbance was maximum was fixed for the subsequent study.

3.5.3. Time

To determine the optimum incubation time, the dye extraction was carried out at different time intervals such as (30 -150 mins). In both microwave and conventional dye bath. The dye solutions were analysed spectrophotometrically at 362 nm. The time at which the absorbance was maximum are selected as optimum time.

3.5.4. pH

To determine the optimum pH for dye extraction, the pH of the solvent was adjusted to 6, 7, 9, 10 and 12 using 1n Hcl or 1n NaoH. Optical density of the dye solution was determined.

3.5.5. Temperature

To determine the optimum temperature, the dye extraction was carried out at different temperature such as 30-100^oc. The optical density of the dye solution was analysed spectrophotometrically at 362 nm. The temperature at which the absorbance was maximum was selected as optimum temperature for dye extraction.

3.6. Dyeing

3.6.1. Selection of Mordants

A mordant is a substance used to set dyes on fabrics or tissue sections by forming a co-ordinating complex with the dye which then attaches to the fabric or tissue. The selected metal mordants for this study are chloride, ferrous sulphate, potassium alum, aluminium sulphate and copper sulphate.

The selected natural mordants for this study are pomegranate rind, guava leaves, myrobolan and orange peel. Pilot study was carried out by conventional method.

Among natural and metallic mordants, myrobolan gave better colour when simultaneous mordanting technique was followed, so myrobolan was selected for this study.

3.6.2. Selection of Mordanting techniques

Mordanting is a process of impregnating textiles with a mordant usually salt or acid to faster the dye stuff, which is applied before (or) after the dye stuff. The three ways of mordanting or pre-mordanting, post-mordanting and simultaneous mordanting.

In the pre-mordanting technique the sample is mordanted and then dyed. In post-mordanting technique the sample is first dyed and then mordanted. Simultaneous mordanting is which mordanting and dyeing are carried out at the same time (Herbst and Hunger, 2006).

Among these three mordanting technique, the simultaneous technique which gave better results when treated with myrobolan, which is a natural mordant was selected for this study (Plate III).

3.6.3. Dyeing Parameters

As suggested by lakshmi and purushothaman (2007), dyeing parameters namely dye concentration, dyeing time, mordant concentration and mordanting time were selected and followed for the study. The parameter for dyeing the selected cotton fabric as follows:

Material liquor ratio	:	1:20
Dye soaking time	:	1 hour
Dyeing temperature	:	90 ⁰ c
Mordant soaking time	:	1 hour
Mordanting temperature	:	90 ⁰ c

3.7. Dyeing of selected fabric using dyes extraction by conventional, microwave assisted methods

The dye solution extracted from conventional, microwave assisted method was filtered. The selected cotton fabric was dyed with dye solution obtained by the three methods. i.e. conventional, microwave assisted methods. Dyeing was carried out for one hour at 90⁰c with a M:L ratio of 1:20.

3.8. Evaluation of dyed fabrics

3.8.1. Subjective Evaluation – Visual Inspection

The fabric samples dyed with sappan was evaluated visually by the panel members comprising of 25 PG students specializing in the field of textile and clothing, evaluated the fabric for general appearance, brilliancy of shade and evenness of dyeing.

3.9. Objective Evaluation- Physical and Mechanical Property

Textile testing is the process of inspecting, measuring and evaluating characteristics and properties of textile materials. Textile testing is a valuable aid to those engaged in the production, distribution and consumption of textile if the instruments and techniques are used effectively. The bleached silk fabric and the dyed samples with mordant were tested by using the sample pieces from the same relative portions of the material for their respective laboratory tests namely, fabric weight, thickness, strength, wet ability and absorbency tests and colour fastness property.

3.9.1. Fabric Weight

Fabric weight or fabric mass describes how much a fabric weighs for a given area or length of fabric. Fabric weight is important because it is used to identify fabric appropriateness for end use, (Vankar et al., 2009).A sample of 100cm x 25cm was cut using a GSM cutter. And electronic weighting balance was used to find out the weight of the samples. The inference obtained is calculated using the formula:

$$\text{Grams per square meter (GSM)} = \frac{\text{weight of the fabric} \times \text{square meter}}{\text{Area of square}}$$

Weight of the fabric	= x (grams)
Square of the fabric	= 100cm x 100cm =10000cm ²
Area of square	= length x breath square unit

The same procedure was followed to find out the fabric weight of original and Desized, dyed fabrics are carefully recorded and the mean value was calculated (Plate VII).

3.9.2. Fabric Thickness

Fabric thickness is an important variable in determining fabric stiffness and hence extent to which the fabric will drape and comfort. Fabric thickness is the important variable determining the rate of heat transfer and hence the so called 'warmth' of the fabric. Fabric thickness affects air permeability and moisture absorbency and also has a great influence on the abrasion resistance, (Au and K.F, 2011).

The thickness tester has a broad anvil, upon which a pressure foot is pressed by spring. The dial indicated the thickness of the material in thousand of an inch between the anvil and the pressure foot. Each division of the dial read 0.01mm. the sample were placed on the anvil without tension or creases and the pressure foot was lowered onto the sample for two seconds at 2kg pressure.

The dial reading was recorded. The readings were calculated similarly and mean value of ten readings from the original, desized and dyed bamboo-cotton material was tabulated (Plate VIII).

3.9.3. Abrasion Resistance

Abrasion is defined as the wearing a way of any part of the fabric by rubbing against another surface. Fabrics are subjected to abrasion during their lifetimes and this may result in wear, deterioration, damage and a loss of performance. However, the abrasion resistance, is only one of several factors contributing to wear performance or durability. Abrasion can occur in many ways and can include fabric to fabric rubbing when sitting, fabric to ground abrasion during crawling, (Hu, 2008).

For an abrasion test, the specimen is mounted on a motor-driven rotating lower plate where it is abraded uniformly in all directions by the motion of the effect rotating abradant rotate in the same direction with approximately the same angular velocity, 250 rpm, each about its own axis. The axis are space 1 in apart and are parallel. The abradant is loaded with a standard weight. A count record the number of revolutions (Panda, 2010) (Plate IX).

3.9.4. Tensile Strength

A measurement of tensile stress-stain properties is the most mechanical measurement on fabrics. It is used to determine the behaviour of a sample while under an axial stretching load. From this, breaking load and elongation can be obtained. The principle of the tensile strength test is simple: a test piece is held in two or more places and extended until it breaks, (Hu, 2008).

Instron 5566 is employed to measure the tensile strength of the test sample, as specified in ASTM D5035-06 standard test method for breaking force and elongation of textile fabrics. Ten samples taken each along the machine direction (MD) and cross machine (CD) have a size of 25.4mm x 180mm. The distance between the fixtures is 75mm, and the tensile speed is 300+10mm/min (chenz et al., 2013). Ten readings were taken from original and finished sample. Then their mean value was calculated and tabulated (Plate X).

3.9.5. Drape Test

Drape is the term used to describe the way a fabric hangs under its own weight. It is one of the most important fabric characteristics. Since it shows how good a garment looks in use. In the drape test, the specimen deforms with multi-directional curvature and consequently the results are dependent to a certain amount upon the shear properties of the fabric, but are mainly dependent on the bending stiffness, (Song, 2011).



Plate VII
Fabric weight



Plate VIII
Fabric thickness



Plate IX
Abrasion resistance



Plate - X
Tensile Strength and Elongation

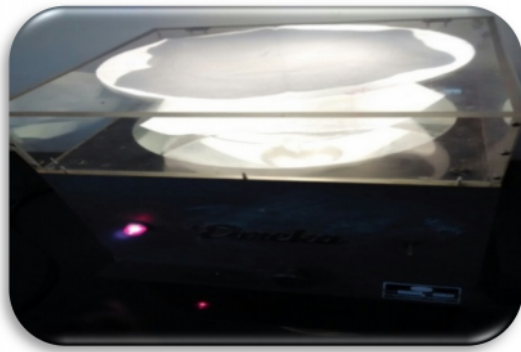


Plate – XI
Drape Test

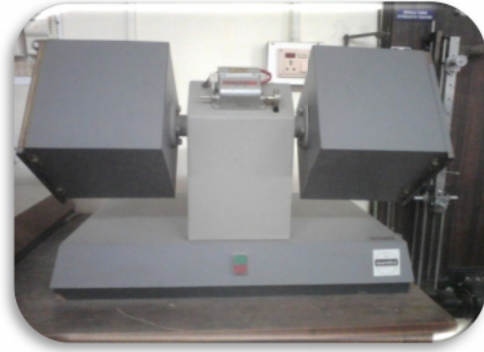


Plate – XII
Pilling Resistance

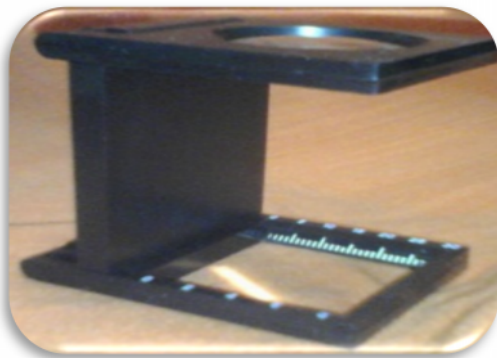


Plate – XIII
Fabric Count

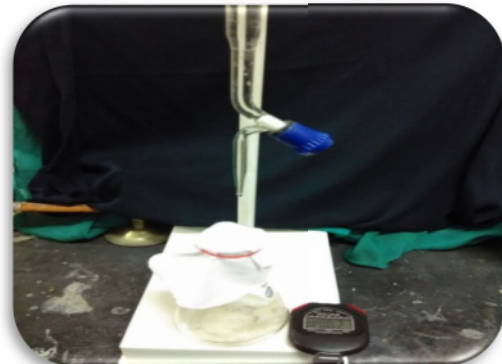


Plate – XIV
Drop Test



Plate – XV
Sinking Test



Plate – XVI
Capillary Rise Test

The most commonly used instrument for measuring the drape value is cusick drape meter. A circular piece of fabric was held by two small circular plates, so that its free edges drape down under their own weight. For ordinary textile fabrics, a satisfactory spread of difference in drape behaviour is obtained, when the diameter of fabric specimen is 30cm and the diameter of the disc is 18cm.

A value known as drape co-efficient F1 is determined by considering the following,

A_D --- the area of the specimen

A_d -- the area of the supporting disc

A_s – the actual projected area of the specimen

The drape co-efficient is given by

$$F = \frac{A_s - A_d}{A_D - A_d} \times 100$$

Thus, ten readings were taken from original and all finished samples. Then their mean value was calculated and tabulated (Plate XI).

3.9.6. Pilling Resistance

Martindale Pilling Box was used to assess the surface pilling of the samples. The samples were conditioned and the tests were carried out in standard atmosphere. A sample was cut using template by thirteen centimetres and sewn so as to be firm when placed around a polyurethane tube sixteen centimetres long and three centimetres outside diameter and quarter centimetre thick, (Raja et al., 2013) (Plate XII).

The sewn sample was wrapped around the rubber tube with the help of jig. Four such tubes were placed in each cubic box lined with cork quarter centimetre thick. The machine was operated and the boxes rotated at the rate of sixty revolutions per minute for five continuously. After tumbling the extent of pilling

was assessed with the standards as recommended for rating of the samples as given below:

- 5 – No visual change
- 4 – Slight surface oiling
- 3 – Moderate surface pilling
- 2 – Distinct surface pilling
- 1 – Severe pilling

3.9.7. Fabric Count

The fabric count refers to the closeness of the ends of the fabric which is the number of threads per inch. It is also referred to as thread count which is measured by one inch pick glass and counted through the small microscope and the number per square inch are recorded interprets. The fabric count for the original, desized, natural dyed and natural printed fabrics, were calculated at ten different places and noted, (Panda, 2010) (Plate XIII).

3.10. Wettability and absorbency test

The wettability and absorbency tests include drop test, sinking test and capillary rise test.

3.10.1. Drop Test

A burette filled with distilled water was clamped in a stand was mounted in an embroidery frame and was placed at the base of the stand. The distance between the sample and the burette nozzle was kept constant. The nozzle of the burette was opened just to allow a drop of water to fall on the sample. The stop watch was started simultaneously and it was stopped when the drop of water fully sank into the material. The time taken for this was noted. The same procedure was repeated for ten times for the original, bleached and dyed samples and then mean value was calculated and recorded, (Fung, 2002) (Plate XIV).

3.10.2. Sinking Test

A 100ml beaker was filled with distilled water. The samples were dropped on the surface of the water from a standard height. The stop watch was started when the fabric struck the surface of water and stopped when the last corner sank below the water surface and the time required for the sample to sink was noted. The same procedure was repeated for all samples. The mean value was calculated, (Choudhury, 2006) (Plate XV).

3.10.3. Capillary Rise Test

The samples were cut into sizes of 15cm length and 25cm width from the original bleached and dyed samples. One end of the samples strip was pasted with a glass rod which was placed on heavy wooden blocks and at the other end, two grams weight was attached to keep the sample straight. At the weighed end 2cm of the sample was allowed to immerse in a tray of distilled water. The rate of the water level in the sample was measured after 60 seconds, (MacDonald, 2008) (Plate XVI).

3.11. Colour fastness test

Dyed textiles are exposed to a variety of treatments during subsequent manufacturing steps and later in daily use. Standard manufacturing steps test methods have been developed to evaluate the colour fastness, (Hunger, 2007). AATCC (1995) established a standard terminology for rating colour fastness properties of fabric to different test methods and also evaluating colour staining and colour transfer in fabrics.

3.11.1. Fastness to crocking

Sasmira crock meter was used for ascertaining the fastness of dyed textiles to wet and dry crocking. It consists of two metal blocks. The base block was stationary, while the upper block had an arrangement to move to and from the base by means of a rotating handle. There was a finger knob attached to the upper block to hold the silk material with ring, (Sanad et al., 2005).

The samples were cut into pieces with the size of 20cm x 10cm, the sample was fixed on the base block with longer side in the direction of rubbing the white sized original material (5cm x 5cm) was fixed on the finger knob of upper movable block with a ring. The number of rubs given was standardized and fixed as ten rubs.

The white material was rubbed to and fro against the dyed samples along a track of 10cm with pressure of 900 grams on the finger. The colour transfer from the dyed sample to the white material was assessed with AATCC grey scale for staining. The same procedure was repeated for all the samples of the dyed material. For wet crocking, the damp white material was used and the same procedure was repeated for all the dyed samples. The colour staining of each dyed material to dry and wet crocking was carefully observed and recorded carefully, (Fung, 2002).

3.11.2. Fastness to sunlight

A sample of 16cm x 5cm was taken from each of the dyed materials. The entire samples were divided into eight parts by marking distance of two inches in the larger side marked up to eight. Each sample was covered with black paper to prevent the samples from direct sunlight for the successive seven days the other portions were exposed accordingly along with the first portion. The first portion got seven days exposure to sunlight. The changes in colour of the dyed samples were compared with the original and the specimen were rated using greys scale, (Horrocks *et al.*, 2000).

3.11.3. Fastness to wet and Dry Pressing

Test samples were cut in 5cmx10cm. They were sandwiched between the white material of same size, for dry pressing a hot iron was placed on each of the composite specimen 5 seconds at a temperature of 350 Fahrenheit. The colour transfer from the dyed samples was assessed using AATCC grey scales. The same procedure was repeated for all the samples of the dyed materials. Thus the colour fastness of each dyed materials to wet and dry pressing was carefully observed and recorded separately, (Annis, 2012).

3.11.4. Fastness to Washing

The wash fastnesses of all the dyed samples were tested according to ISO 105-106: 1994 washing test using laundrometer. The laundrometer consists of central axis with four rods with four rods with eight stainless steel jars with tight fitting lids which rotates inside the hot water bath in forward direction when the machine is in working condition. Due to the high alkali sensitivity of natural dyes, it is recommended that these textiles can be washed with non-alkaline soap only. Hence the non-alkaline soap ECE detergent was used for washing. The composite sample, measured 10x4cm was washed with 4gm/1000ml of water at 40°C for 45 minutes in a laundrometer. The change in colour of the treated test specimens and the degree of staining of the two adjacent undyed fabrics were evaluated using grey scale, (Herbst and Hunger, 2006).

3.12. Statistical Analysis

The results of laboratory tests were analysed statistically using tests for analysis of variance (ANOVA) is an extremely useful technique for analyzing multiple samples. ANOVA is essentially a procedure for testing the difference among different group of data for homogeneity. ANOVA is commonly used to test difference among the means of several independent groups. Analysis was carried out mainly to see whether the test results vary due to the difference in the dyes, mordants and techniques.

3.13. Nomenclature

Table-II

Nomenclature of the dyed sample

Code	Samples
OS	Original sample
CDS	Conventional dyed sample
MDS	Microwave dyed sample

4. RESULTS AND DISCUSSION

The results of the study on “**Application of *Caesalpinia sappan* by Microwave Extraction Method on Bamboo Cotton Woven Fabric**”, presented in results and discussion are as follows.

4.1. Optimization of various parameters for extraction of natural dye

- 4.1.1 solvent
- 4.1.2 Dye concentration
- 4.1.3. Time
- 4.1.4 pH
- 4.1.5. Temperature

4.2 Evaluation of dyed fabric

- 4.2.1. Visual inspection

4.3 Objective evaluation

4.3.1. Physical and mechanical Property Test

- 4.3.1.1. Fabric Weight
- 4.3.1.2 Fabric Thickness
- 4.3.1.3. Fabric Stiffness
- 4.3.1.4 Fabric Strength
- 4.3.1.5. Fabric Elongation
- 4.3.1.6. Fabric Count

4.3.2 Absorbency Test

- 4.3.2.1. Sinking Test
- 4.3.2.2. Capillary Rise Test
- 4.3.2.3. Drop Test

4.3.3. Comfort Property

- 4.3.3.1. Drapability
- 4.3.3.2. Crease Recovery Tests

4.3.4. Colour Fastness Test

4.3.5. Colour Strength

4.1. Optimization of various parameters for extraction of natural dye

4.1.1 Solvent

The effect of various solvents on dye extraction was studied and the results were presented in Table III and Figure 3.

Table III

Selection of solvent

Solvents	Optical density at 362 nm	
	Conventional extraction	Microwave Extraction
Water	3.467	4.761
NaoH	0.776	0.712
Ethanol	0.039	0.206

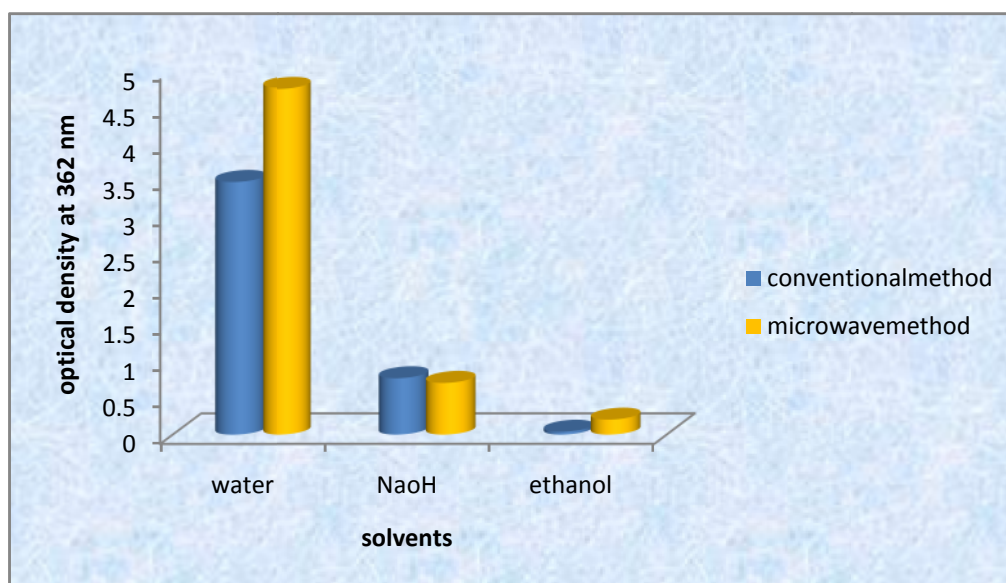


FIGURE 3

Selection of solvent

From Table III and Figure 3, it is clear that maximum absorbance was exposed in water extraction irrespective of the methods.

4.1.2 Dye concentration

The effect of various concentration of *Caesalpinia sappan* powder was studied and the results are presented in Table IV and Figure 4.

Table IV
Dye concentration

Concentration of <i>Caesalpinia sappan</i> wood powder (%)	Optical density at 362 nm	
	Conventional extraction	Microwave Extraction
1	0.570	0.702
2	1.001	0.853
3	1.048	0.934
4	1.079	1.757
5	2.103	1.173
6	1.852	1.563
7	1.815	1.538
8	1.791	1.275
9	1.718	1.206
10	1.648	0.985

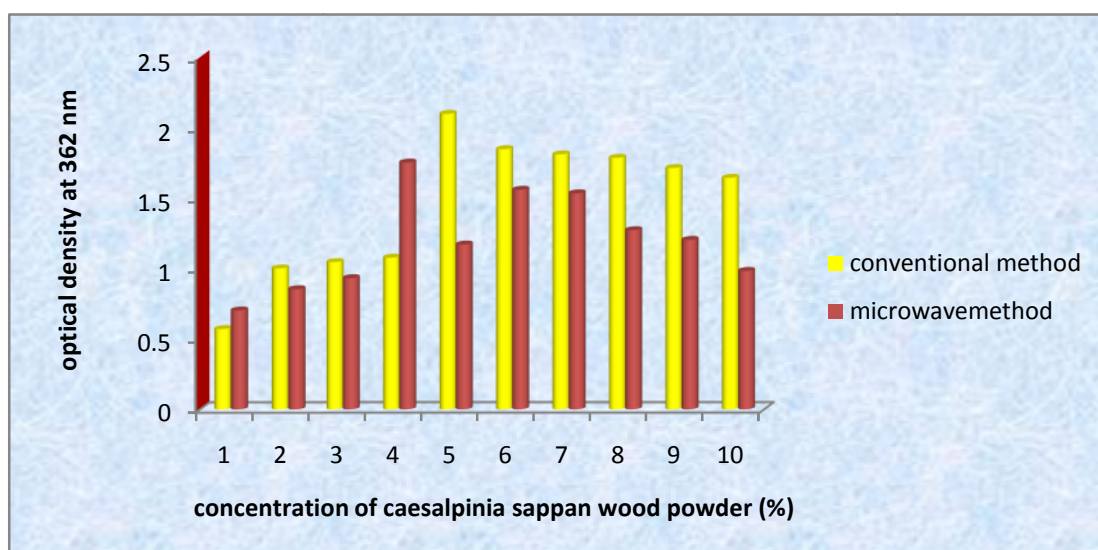


FIGURE 4

Dye concentration

Table 4 and Figure 4, clearly indicates that the optimum dye concentration is 5 per cent and 4 per cent with the colour intensity of 2.103 and 1.757 respectively in conventional and microwave extraction.

4.1.3. Time

The effect of time on the extraction of dye was determined and the results were shown in Table V and Figure 5.

Table V
Optimization Of contact time

Time (min)	Optical density at 362 nm	
	Conventional extraction	Microwave Extraction
30	1.613	1.146
60	2.206	1.331
90	2.761	0.996
120	2.146	0.816
150	2.034	0.759
180	2.011	0.603

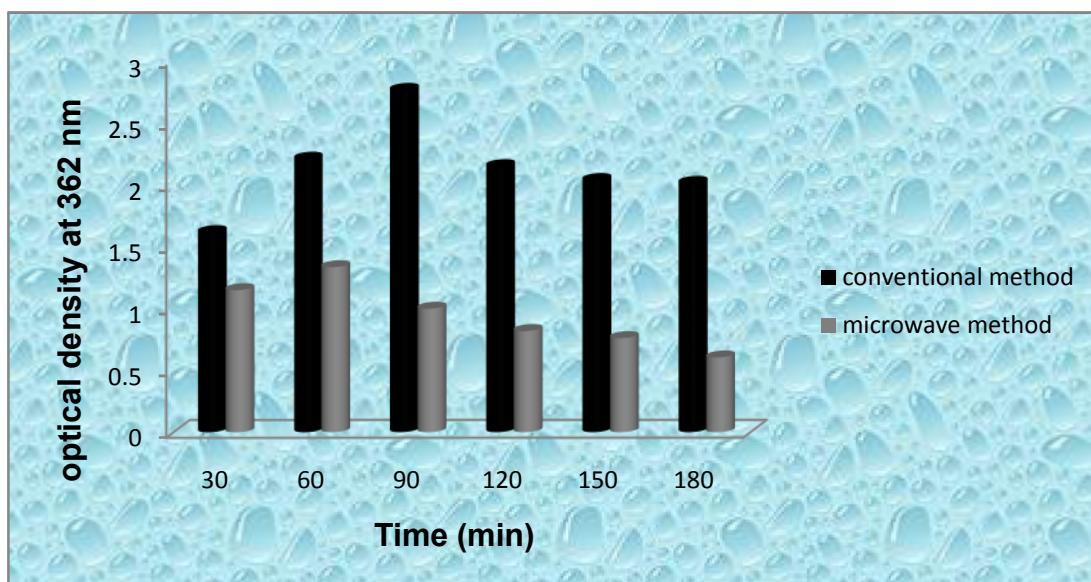


FIGURE 5
Optimization of Contact time

From Table V and Figure 5, it is evident that there was not much difference in optical density between 60 and 90 mins. Hence, the optimum time for extraction of dye was selected as 60 min and 90 min for all the two extraction methods.

4.1.4 pH

To determine the optimum pH for the effective colouration of natural dye, the adsorption capacities of the adsorbents were studied at pH range from 7 and results were shown in Table VI and Figure 6.

Table VI
Optimization of pH

pH	Optical density at 362 nm	
	Conventional extraction	Microwave Extraction
1	0.022	0.027
5	0.103	0.062
6	0.521	0.173
7	0.777	0.410
9	0.413	0.021
10	0.291	0.021

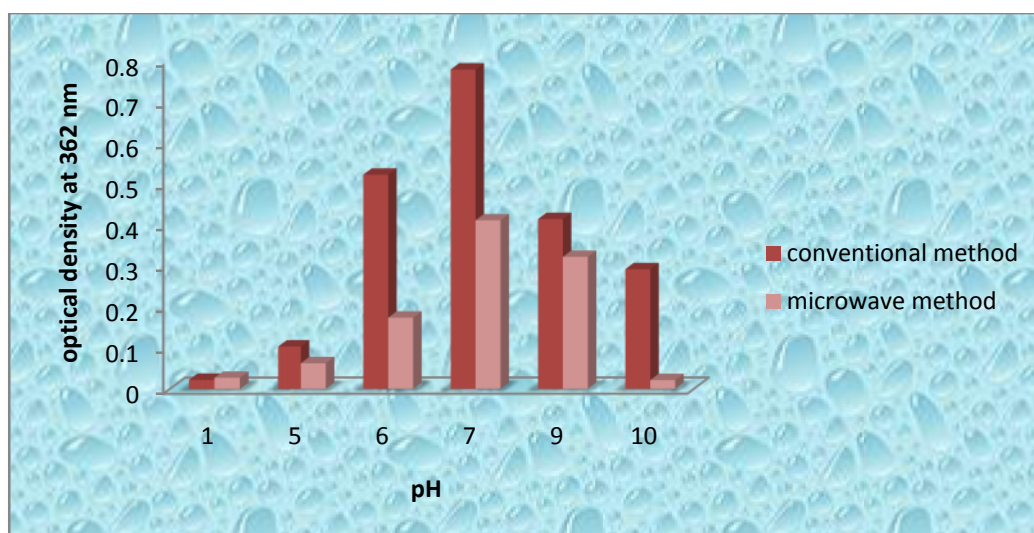


FIGURE 6

Optimization of pH

Table VI and Figure 6, clearly indicates that pH 7 is the optimum pH for maximum dye colouration (95%) and further increase in pH decrease the per cent colourization. Hence pH 7 was optimum for the extraction procedure.

4.1.5. Temperature

The effect of temperature on the extraction of dye was determined and the results were shown in Table VII and Figure 7.

Table VII
Optimization of Temperature (°C)

Temperature (°C)	Optical density at 362 nm	
	Conventional extraction	Microwave Extraction
30	1.131	0.788
60	1.254	0.822
70	1.359	1.000
80	1.668	1.797
90	1.811	1.682
100	1.705	1.607

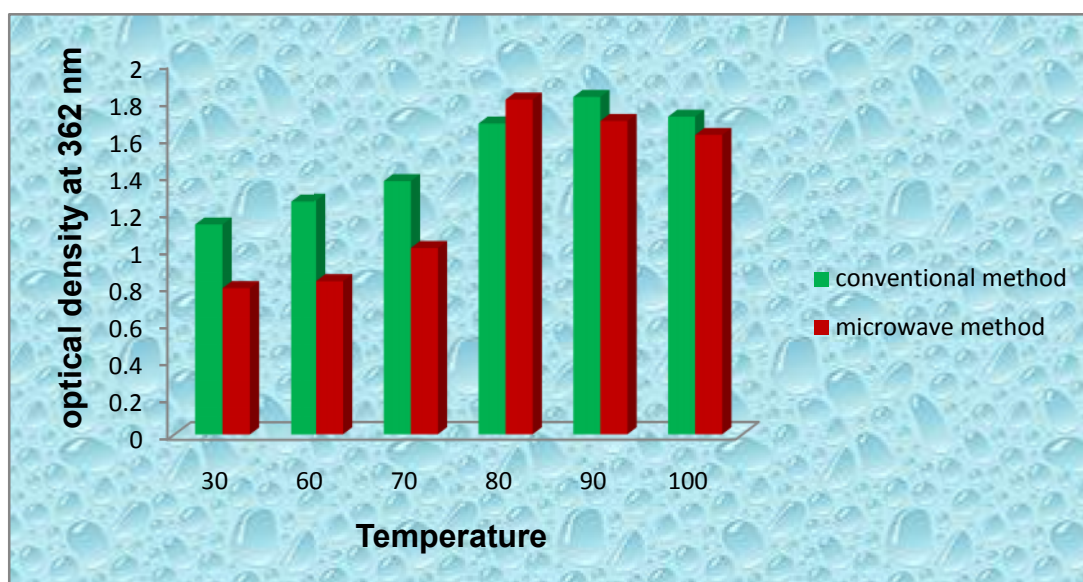


FIGURE 7
Optimization of temperature (°C)

From Table VII and Figure 7, it is evident that there was not much difference in optical density between 30, 60, 70, 80 and 90⁰c. Hence, the optimum temperature for extraction of dye was selected as 80 and 90⁰c for all the two extraction methods.

4.2 Evaluation of dyed fabric

4.2.1. Visual Inspection

The 25 post graduate students from textiles and clothing department were selected for evaluating the dyed fabric as given in Table VIII

Table VIII
Visual inspection

S.No	sample	Rating in percentage							
		General appearance			Texture			Evenness of dyeing	
		Good	Fair	Poor	Good	Fair	Poor	Even	Uneven
1.	CDS	91	9	-	86	14	-	95	5
2.	MDS	95	5	-	92	8	-	97	3

Majority of the judges (97%) ranked bamboo cotton dyed fabric samples as good in evenness in dyeing for microwave extraction method. Ninety two ranked good regarding texture of fabric whereas (92%) in microwave extraction method and (95%) ranked good for general appearance in microwave extraction method.

4.3 Objective evaluation

4.3.1. Physical and Mechanical Property Test

4.3.1.1. Fabric Weight

The fabric weight and analysis of variance of the samples OS, CDS and MDS are shown in Table IX and Figure 8.

Table IX
Fabric Weight (grams)

S. No.	Sample	Mean Value (grams)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	1.0404	-	-	21.951**
2.	CDS	1.1838	0.1434	7.52	
3.	MDS	1.123	0.0826	12.56	

** - significant at 1 per cent ($p < 0.01$)

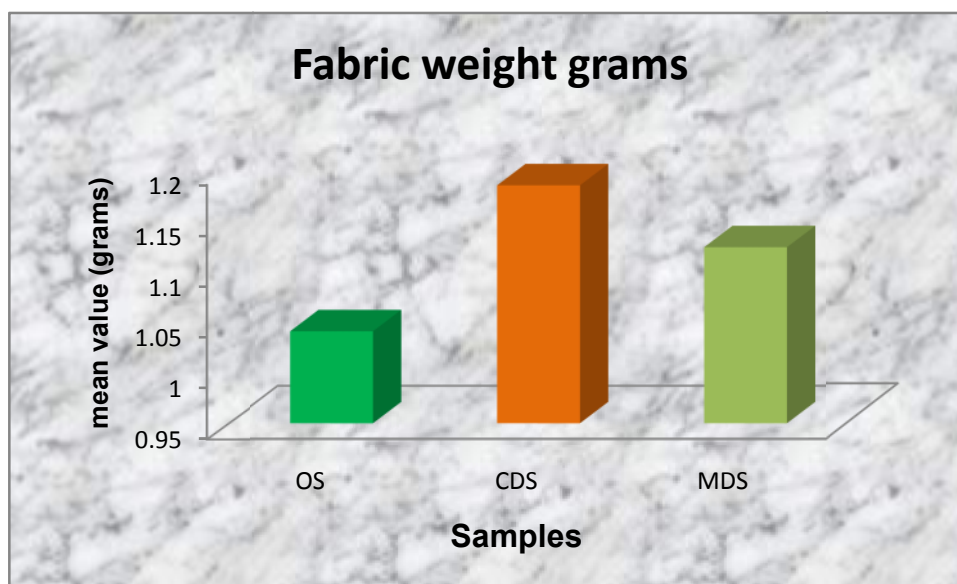


FIGURE 8

Fabric weight (grams)

From Table IX and Figure 8, it is clear that the fabric weight of all the samples increased when compared to original. The increase in fabric weight is maximum in conventional dyed samples. The increase in fabric weight when compared to the original was found to be significant difference at one per cent level.

4.3.1.2 Fabric Thickness

The fabric thickness and analysis of variance of the samples OS, CDS and MDS are shown in Table X and Figure 9.

Table X
Fabric Thickness (mm)

S.No.	Sample	Mean Value (mm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	0.296	-	-	25.177**
2.	CDS	0.364	0.068	4.29	
3.	MDS	0.414	0.118	4.84	

** - significant at 1 per cent ($p < 0.01$)

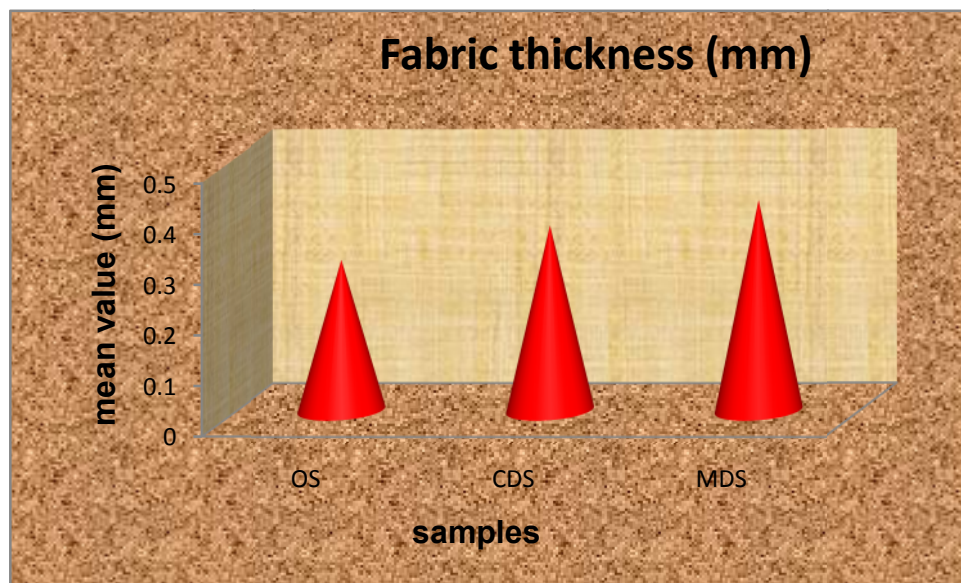


FIGURE 9

Fabric Thickness (mm)

From Table X and Figure 9, it is clear that the thickness of the samples CDS and MDS increased when compared to its original samples. The fabric thickness was increased of 4.29 per cent in CDS sample and 4.84 per cent in

MDS sample. The increase in fabric thickness is due to the absorbency of duestuff and adhere the fibres and also the microwave process made more absorbency the conventional method. The increase in fabric thickness when compared with the original was found to be significant at one per cent level.

4.3.1.3. Fabric Stiffness (Warp)

Fabric stiffness and analysis of variance of the samples OS, CDS and MDS in warp direction were shown in Table XI and Figure 10

Table XI
Fabric Stiffness (Warp)

S. No.	Sample	Mean Value (cm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	1.68	-	-	11.414**
.	CDS	11.5	9.82	17.10	
3.	MDS	2.34	0.62	27.96	

** - significant at 1 per cent ($p < 0.01$)

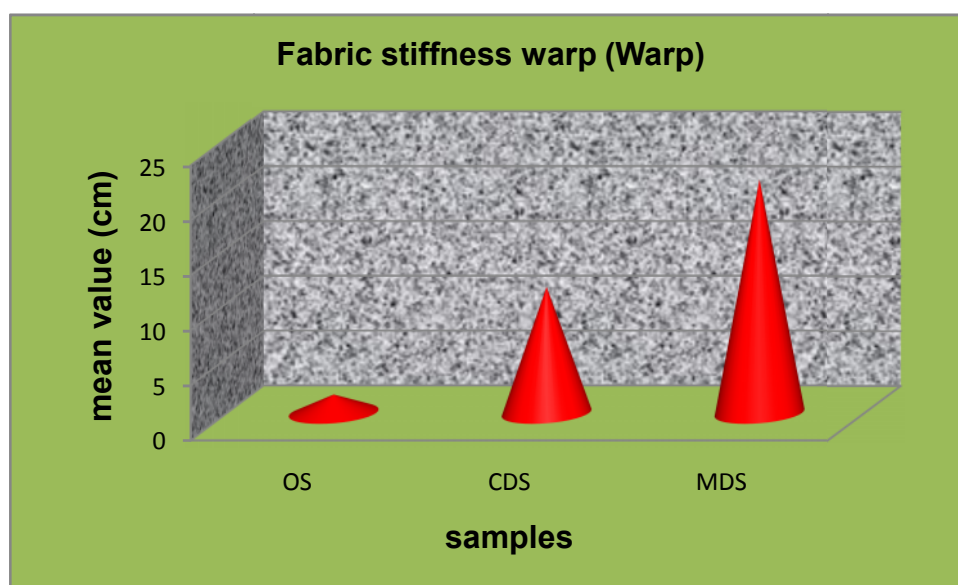


FIGURE 10

Fabric stiffness (Warp)

From Table XI and Figure 10, it is clear that the stiffness of the fabrics increased when compared with original. The increase in fabric stiffness was found to be 17.10 per cent in CDS and 27.96 per cent in MDS. The increase in the fabric stiffness when compared with the original was found to be significant at one per cent level.

Fabric stiffness (weft)

Fabric stiffness and the analysis of variance of the samples OS, CDS and MDS in weft direction were presented in Table XII and Figure 11.

Table XII
Fabric Stiffness (Weft)

S. No.	Sample	Mean Value (cm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	2.32	-	-	10.010**
2.	CDS	2.92	0.68	38.33	
3.	MDS	2.98	0.61	33.23	

** - significant at 1 per cent ($p < 0.01$)

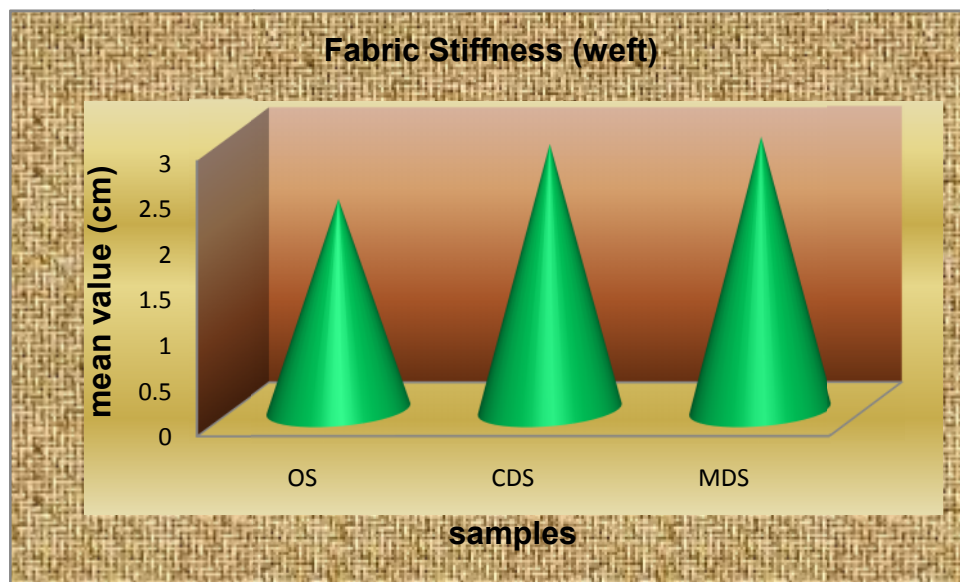


FIGURE 11

Fabric stiffness (Weft)

From Table XII and Figure 11, it is clear that the fabric stiffness of CDS and MDS was increased by 38.33 per cent and 33.23 per cent when compared with original fabric. The increase in stiffness was found to be maximum in CDS. The difference in fabric stiffness when compared with original was found to be significant at one per cent level.

4.3.1.4. Fabric Strength (warp)

Fabric strength and analysis of variance of the samples OS, CDS and MDS in warp direction is presented in Table XIII and Figure 12.

Table XIII
Fabric Strength (Warp)

S. No.	Sample	Mean Value (lbs)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	23.6	-	-	18.327**
2.	CDS	15.4	8.2	28.80	
3.	MDS	23.1	0.6	39.33	

** - significant at per cent ($p < 0.01$)

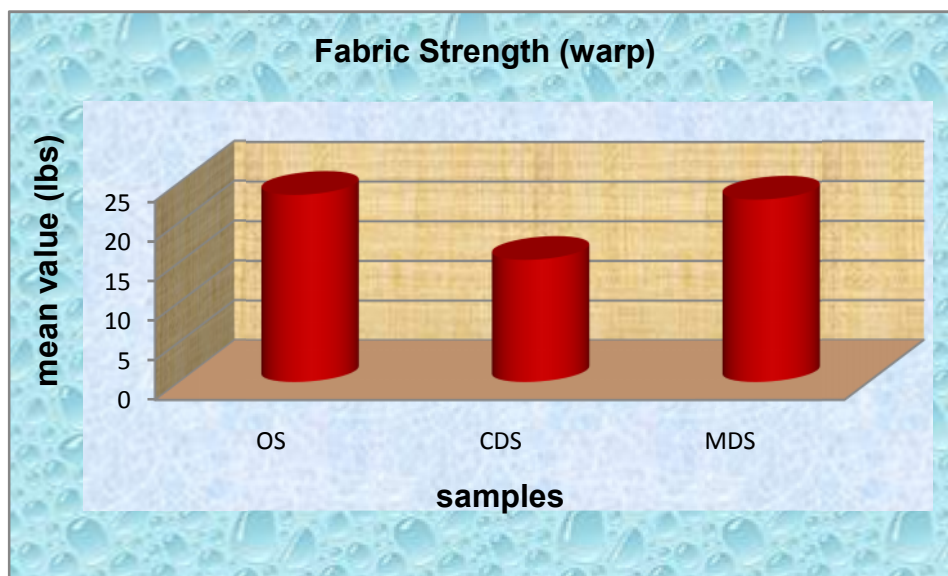


Figure 12

Fabric Strength (warp)

From Table XIII and Figure 12, it is clear that the strength of MDS fabric is increased by 39.33 per cent when compared with original fabric. The increase in fabric strength when compared to the original sample was found to be significant at one per cent level.

Fabric strength (weft)

Fabric strength and the analysis of the variance of the samples OS, CDS and MDS in the weft direction are shown in Table XIV and Figure 13.

Table XIV

Fabric strength (weft)

S. No.	Sample	Mean Value (lbs)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	15.6	-	-	9.22**
2.	CDS	22	6.4	24.75	
3.	MDS	24	8.4	18.71	

** - significant at 1 per cent ($p < 0.01$)

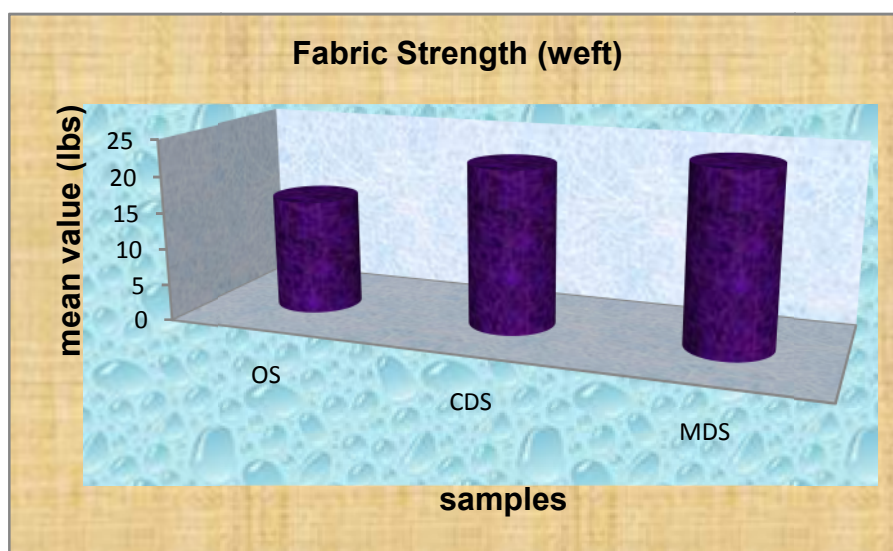


Figure 13

Fabric Strength (weft)

From Table XIV and Figure 13, it is evident that the fabric strength increased in all the samples. The increase was found to be maximum in CDS (24.75) followed by MDS (18.71). the fabric strength was maximum in CDS and MDS dyed fabric in both warp and weft direction. The increase in fabric strength when compared with the original was found to be significant at one per cent level.

4.3.1.5. Fabric Elongation (Warp)

Fabric elongation and analysis of variance of the samples OS, CDS and MDS in warp direction are shown in Table XV and Figure 14.

Table XV
Fabric Elongation (Warp)

S. No.	Sample	Mean Value (inches)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	2.34	-	-	19.991**
2.	CDS	1.38	0.96	24.75	
3.	MDS	2.86	0.52	45.05	

** - significant at 1 per cent ($p < 0.01$)

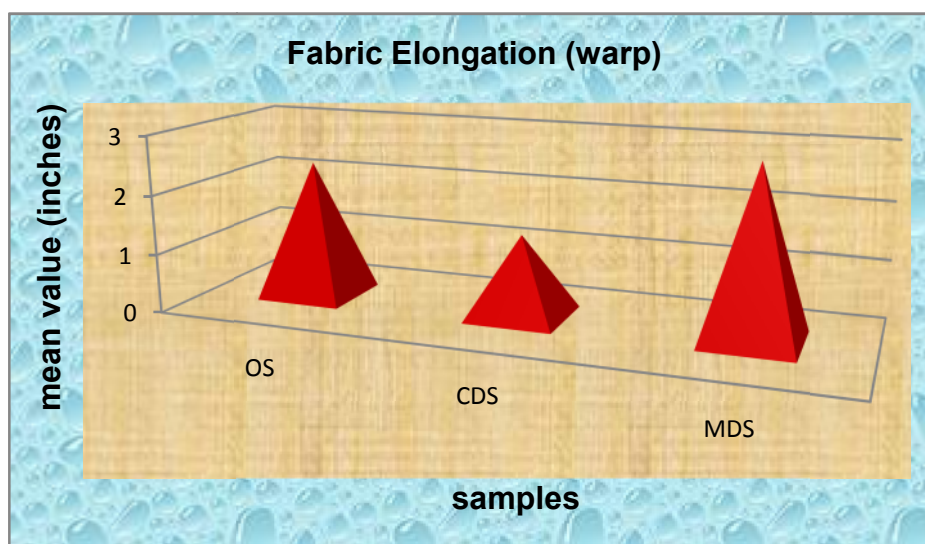


FIGURE 14

Fabric Elongation (Warp)

From Table XV and Figure 14, it is clear that the elongation of CDS and MDS sample increased by 24.75 per cent and 45 per cent respectively. The elongation of CDS was decreased by 24.75 per cent, when compared to its original fabric.

Fabric elongation (weft)

Fabric elongation and analysis of variance of the samples OS, CDS and MDS in weft direction are shown in Table XVI and Figure 15.

Table XVI
Fabric Elongation (Weft)

S.No	Sample	Mean Value (inches)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	1.74	-	-	3.216**
2.	CDS	2.16	0.42	41.28	
3.	MDS	2.44	0.14	24.57	

** - significant at 1 per cent ($p < 0.01$)

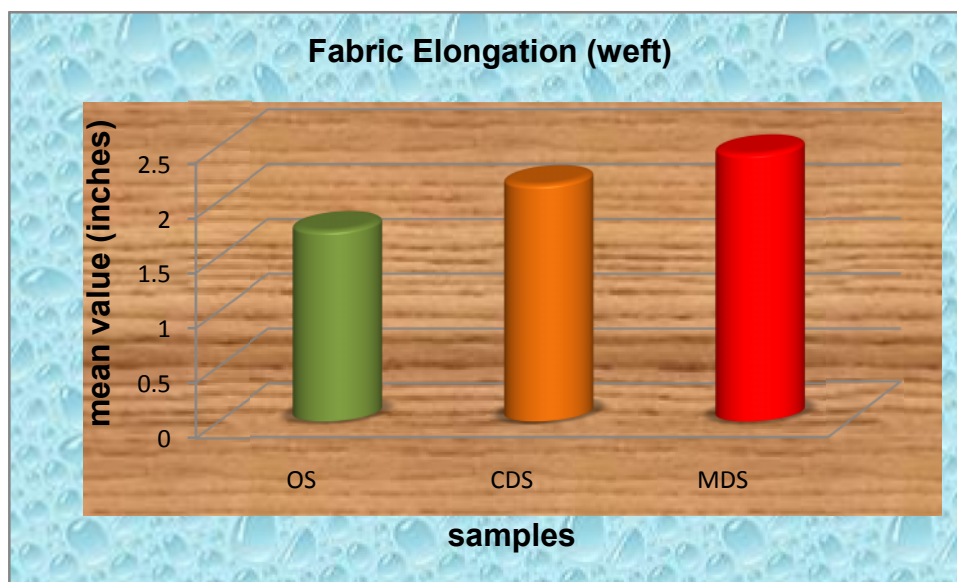


FIGURE 15
Fabric Elongation (Weft)

From Table XVI and Figure 15, it is clear that the Fabric Elongation in weft direction was increased by 41.28 per cent and 24.57 per cent for CDs and MDS respectively. The elongation of weft fabric is decreased by per cent when compared to original fabric. The difference in fabric elongation when compared with original was found to be significant at one per cent level.

4.3.1.6. Fabric Count (Warp)

Fabric count and analysis of variance of the samples OS, CDS and MDS in warp direction are shown in Table XVII and Figure 16.

Table XVII
Fabric Count (Warp)

S.No	Sample	Mean Value (mm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	115	-	-	32.71**
2.	CDS	127	9	8.07	
3.	MDS	129	11	9.84	

** - significant at 1 per cent ($p < 0.01$)

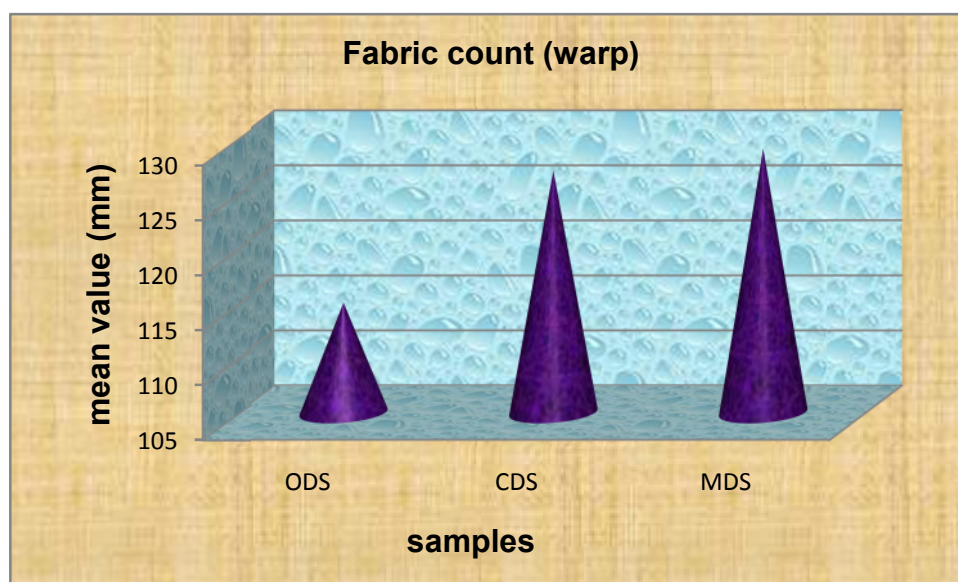


FIGURE 16

Fabric Count (Warp)

Fabric Count (Weft)

Fabric count and analysis of variance of the samples OS, CDS and MDS in warp direction are shown in Table XVIII and Figure 17.

Table XVIII
Fabric Count (Weft)

S.No	Sample	Mean Value (mm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	96	-	-	25.08**
2.	CDS	93	7	6.81	
3.	MDS	95	9	7.97	

** - significant at 1 per cent ($p < 0.01$)

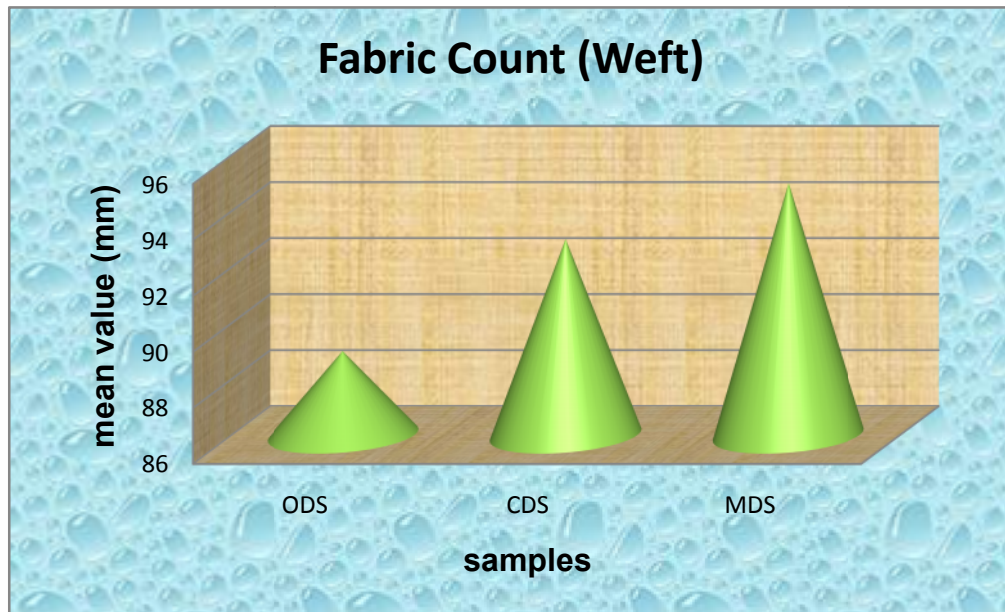


FIGURE 17

Fabric Count (Weft)

4.3.2 Absorbency Test

4.3.2.1. Sinking Test

The sinking level of OS, CDS and MDS bamboo cotton fabric and analysis of variance are shown in Table XIX and Figure 18.

Table XIX
Sinking Test

S. No.	Test Sample	Mean Value (sec)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	13.6	-	-	10.956**
2.	CDS	12.6	1.00	13.00	
3.	MDS	18.2	5.4	25.85	

** - significant at per cent ($p < 0.01$)

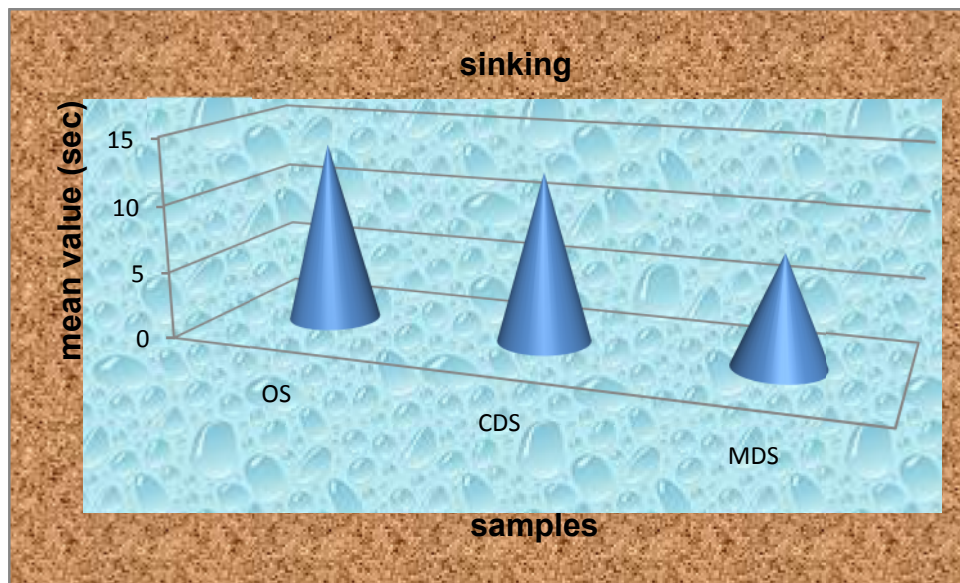


FIGURE 18
Sinking test

From the Table XIX and Figure 18 it is evident that the sinking level of CDS (13.00 per cent) and MDS (25.85 per cent) increased when compared to its original fabric.

4.3.2.2 Capillary Rise Test

The capillary rise level of OS, CDS and MDS bamboo cotton fabric and analysis of variance were shown in Table XX and Figure 19.

Table XX
Capillary Rise Test

S. No.	Test Sample	Mean Value (cm)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	1.86	-	-	51.642**
2.	CDS	2.46	0.6	31.01	
3.	MDS	3.76	1.9	35.89	

** - significant at 1 per cent ($p < 0.01$)

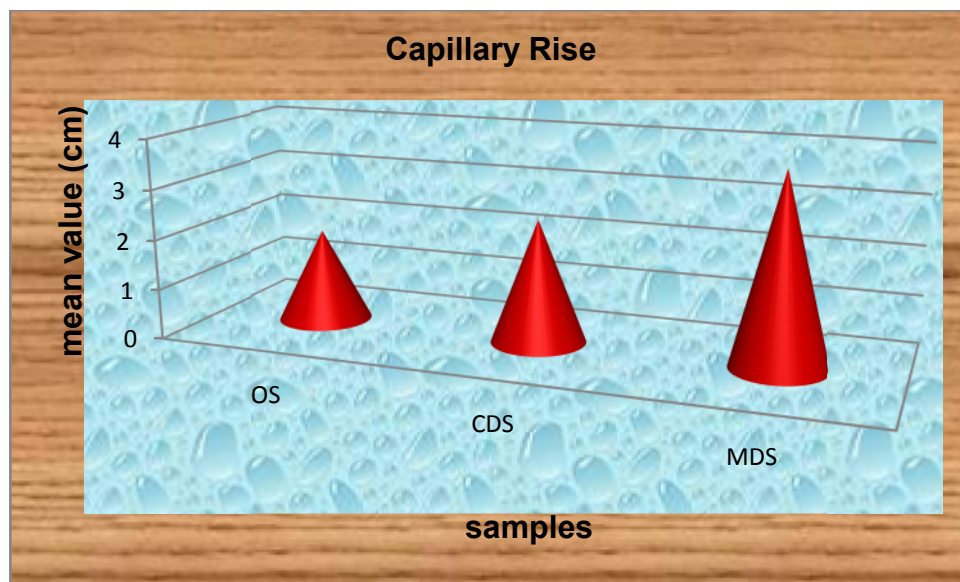


FIGURE 19
Capillary Rise Test

From the Table XX and Figure 19 it is evident that the capillary level of CDS (31.1 per cent) and MDS (35.89) increased when compared to the original fabric. The difference in fabric elongation when compared with original was found to be significant at one per cent level.

4.3.2.3 Drop Test

The Drop level of OS, CDS and MDS bamboo cotton fabric and analysis of variance are shown in Table XXI and Figure 20.

Table XXI
Drop Test

S. No.	Test Sample	Mean Value (sec)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	8.82	-	-	9.318**
2.	CDS	9.89	0.352	29.22	
3.	MDS	10.24	1.422	35.39	

** - significant at 1 per cent ($p < 0.01$)

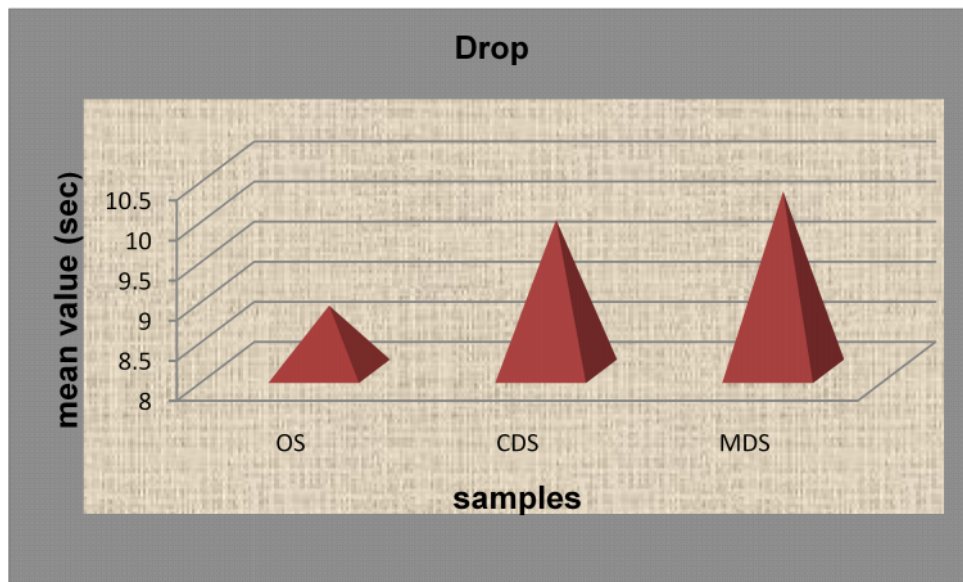


FIGURE 20
Drop Test

From the Table XXI and Figure 20 it is evident that the Drop level of CDS (29.22 per cent) and MDS (35.39 per cent) increased when compared to the

original fabric. The dyed bamboo cotton fabric shows better absorbency. The difference in fabric elongation when compared with original was found to be significant at one per cent level.

4.3.3. Comfort Property

4.3.3.1. Drapability

The fabric drapability of OS, CDS and MDS bamboo cotton fabric and analysis of variance are shown in Table XXII and Figure 21.

Table XXII

Drapability Test

S. No.	Test Sample	Mean Value (percent)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	61.51	-	-	73.611**
2.	CDS	71.70	10.18	60.18	
3.	MDS	67.01	5.49	20.13	

** - significant at 1 per cent ($p < 0.01$)

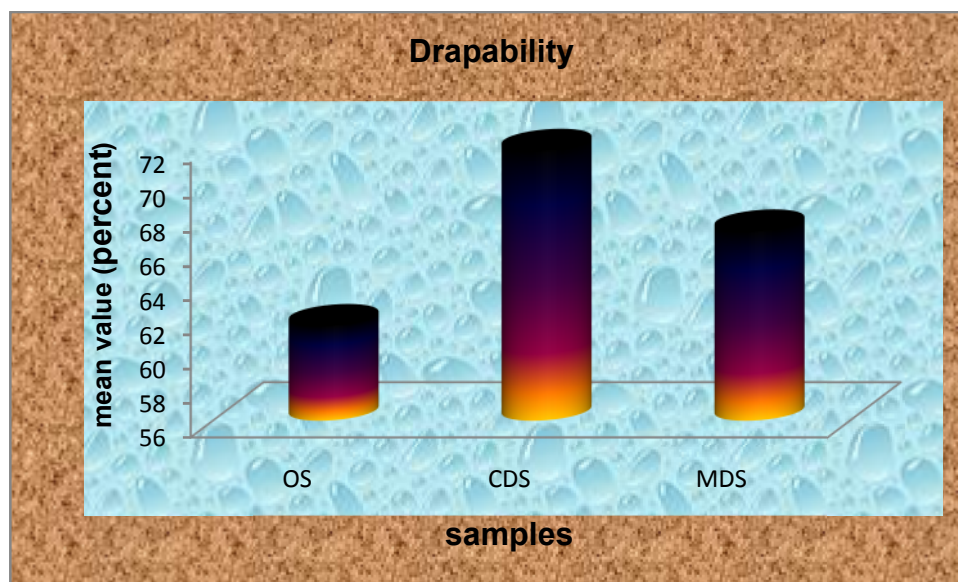


FIGURE 21

Fabric Drapability Test

From the table XXII and figure 21 it is evident that the drapability CDS (60.18 per cent) and MDS (20.13 per cent) increased when compared to OS and MDS fabric. The difference in fabric elongation when compared with original was found to be significant at one per cent level.

4.3.3.2. Crease Recovery Test

The fabric crease recovery test of OS, CDS and MDS bamboo cotton fabric and analysis of variance were shown in XXIII and Figure 22.

Table XXIII

Crease Recovery Test

S. No.	Test Sample	Mean Value (angle)	Gain or Loss over Original	Percentage of gain or loss over original	'F' Value
1.	OS	73.60	-	-	.658 ^{ns}
2.	CDS	75.20	1.6	41.38	
3.	MDS	78.80	5.2	46.00	

ns - Not Significant

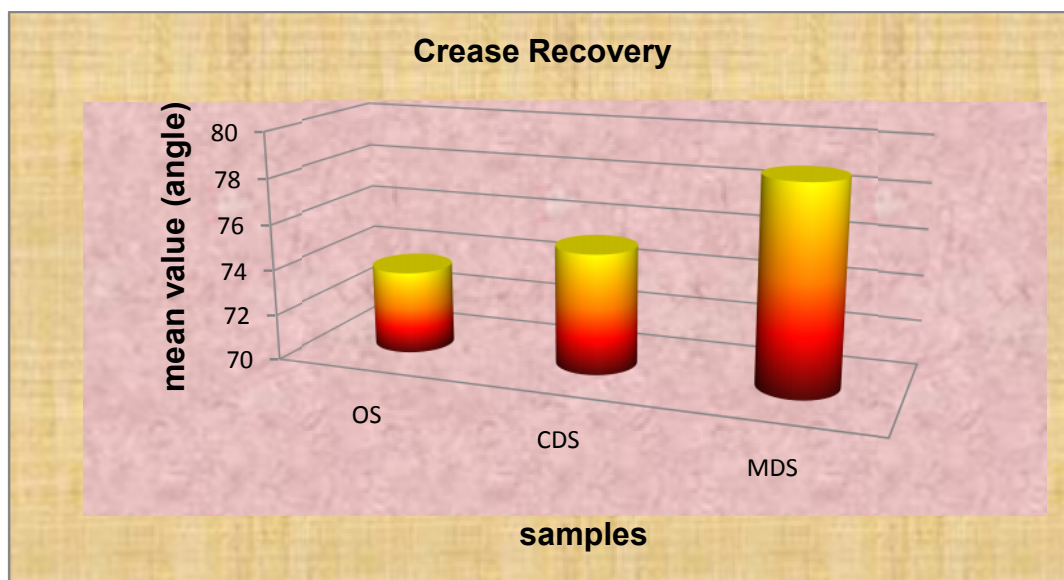


FIGURE 22

Fabric Crease Recovery Test

From the Table XXIII and Figure 22 it is marked that the crease recovery of CDS (41.38 per cent) and MDS (46.00 per cent) increased when compared to the original fabric. The processing of bamboo cotton fabric has improved its crease recovery. The difference in fabric elongation when compared with original was found to be significant at one per cent level.

4.3.4. Colour Fastness Test

Colour fastness to sunlight, crocking and washing was determined and the results are presented in Table XXIV.

Table XXIV
Colour fastness to sunlight, crocking and washing

S.No.	Sample	Sunlight		washing		Crocking			
		Colour change	Staining	Colour change	Staining	Dry		Wet	
						Colour change	staining	Colour change	Staining
1.	CDS	4	4	4	4	5	4	4	5
2.	MDS	5	5	5	5	5	5	5	5

5- Excellent; 4-very Good

From the table XXII, it is marked that all the dyed samples showed good fastness to sunlight with regard to washing and crocking all the samples showed good fastness when compared to CDS and MDS has excellent colour fastness to all the colour fastness tests.

4.3.5. Colour Strength

The samples treated with microwave dye extraction method and conventional dye extraction method was further given for testing its colour strength value (K/S value). The sample were compared for its K/S value using spectrophotometer with 10⁰ observer under D 65 illuminant. The difference in extraction methods has not only caused differences in hue colour but also significant changes in the K/S value. From the results, its is identified that the sample treated with microwave dye extraction method showed good K/S value by

1.2998, with its Δa range as -2.236 and Δb value as 9.084. Thus it could be determined that the sample treated with microwave dye extraction method show good colour strength value.

5. SUMMARY AND CONCLUSION

India has a rich biodiversity and harbours wealth of useful resources and there is no doubt that the plant kingdom is a treasure-house of diverse natural products. One such product from nature is the dye. Dyes are one of the most important uses of the plants. The majority of natural dyes are vegetable dyes from plant sources roots, berries, bark, leaves, and wood and other organic sources such as fungi and lichens (Resonance, *et al.*, 2010).

The globalization of markets and increasing demand for products has created a deep interest in the use of raw materials from natural resources. Organic awareness and environmental consciousness of consumers have revived the interest on natural dyed textiles. The major advantages of natural dyes are that they are biodegradable, non-carcinogenic, non-mutagenic and colour soothing to human eyes. Dyeing with natural dyes can be a way of value addition to the textile products, (Flint, 2008).

Bamboo Cotton is the most beautiful of all textile fibres is acclaimed cotton is the king of fibres. Bamboo cotton is a natural cellulosic fibre. Bamboo fabric is very soft and can be worn directly next to the skin. Bamboo is highly water absorbent and able to take up three times its weight in water. It is soft and absorbent in nature, which was appropriate for apparels. It is also a very strong. It is cool to wear in the summer season. In the present study, colourants extracted from the wood of the *Caesalpinia sappan* tree have been chosen for its dye ability. The coloured constituents of *Caesalpinia sappan*, commonly known as padhimugam, possess properties which find good application in textile industry, (Fung, 2002).

The properties of padhimugam colourants include their instability to oxidation, non-toxicity and flexibility. Traditionally *Caesalpinia sappan* have been used in medicines to cure wounds, ulcers and useful in rheumatism. *Caesalpinia sappan* are also used for the colouration of wool and silk. The bamboo cotton fabric dyed with *Caesalpinia sappan* imparts beautiful shades and fastness properties to bamboo cotton fabric. There is a growing demand for developing suitable extraction techniques for more efficient and effective of available active

matters from the plant materials. The main objective of the present study is to determine the suitable method for the extraction of dye from padhimugam. Microwave is one of the upcoming method of textile industries. It is used for natural dyeing. Extraction through microwave takes few minutes to extract dye from source.

Hence the present study “**Application of *Caesalpinia sappan* by Microwave Extraction Method on Bamboo Cotton Woven Fabric**” was carried out with the following objectives to:

- Selection of the material or fabric
- Select the extraction method and natural sources
- Optimization of dyeing method
- Select suitable mordant and mordanting technique
- Dyeing the selected fabric with the extracted solution
- Evaluate the finished fabric with standard testing method

Methodology Adopted

- Dye from *Caesalpinia sappan* wood were extracted by two different methods conventional, microwave extraction.

Optimization of dye extraction

- Various parameters such as solvent, dye concentration, pH, time and temperature were optimized for the extraction of dye.

Optimization of dyeing

- Dyeing parameters such as time, dye concentration, mordanting techniques were optimized for effective dyeing of the fabric.
- The dyed fabric were evaluated both subjectively and objectively.

Findings of the Study

Evaluation of Samples

Caesalpinia sappan dyed samples of silk were evaluated by subjective and objective methods, such as mechanical, physical and comfort properties. The laboratory test was analyzed statistically.

Objective Evaluation- Physical and Mechanical Property

- Fabric weight of CDS and MDS is (72.52 per cent), (12.56 per cent) respectively when compared with original fabric. It is statistically proved that the significant difference at one per cent level.
- Fabric thickness CDS and MDS increased (43.29 per cent) and (25.84 per cent) when compared with original fabric. It is statistically proved that the significant difference at one per cent level.
- The tensile strength warp direction of CDS (28.80 per cent) and MDS (39.33 per cent) increased when compared to the original fabric. Significant at one per cent level.
- The tensile strength weft direction of CDS (24.75 per cent) and MDS (18.71 per cent) increased when compared to the original fabric. It is statistically proved that the significant difference at one per cent level.
- The elongation warp direction of CDS (24.75 per cent) and MDS (45 per cent) increased when compared to the original fabric. They were significant at one per cent level.
- The elongation weft direction of CDS (41.28 per cent) and MDS (24.57 per cent) increased when compared to the original fabric. It is statistically proved that the significant difference at one per cent level.
- The stiffness warp direction of CDS (17.10 per cent) and MDS (27.96 per cent) increased when compared to the original fabric. They were significant at one per cent level.
- The stiffness weft direction of CDS (33.23 per cent) and MDS (38.33 per cent) increased when compared to the original fabric. It is significant at one per cent level.
- The sinking test result shows the absorbency of the CDS (13.00 per cent) and MDS (25.85 per cent) increased when compared to the original fabric. They were significant at one per cent level.
- The drop test results shows the absorbency of the CDS (29.22 per cent) and MDS (70.39 per cent) increased when compared to the original fabric. They were significant at one per cent level.

- The capillary rise tests results showed CDS (31.01 per cent) and MDS (35.89 per cent) increased when compared to the original fabric.
- The colour fastness test showed excellent result because *Caesalpinia sappan* as a colouring substance has good fastness.

Conclusion

Microwave extraction were found effective way of extraction and dye uptake is higher than conventional method other additional features about microwave method cheaper and also economical. Natural dye extracts natural colours from medicinally rich herbs, plants, flowers, fruits, stems, barks and minerals making the whole production cycle devoid of any chemical use with almost no carbon footprint. Natural dyes are not only biodegradable, but also have medicinal properties like anti-bacterial, anti-inflammatory and anti-allergic which are beneficial for the skin of the person using it. It ensure that the discharge of the dyeing unit is devoid of any toxic chemicals and heavy metals protecting the precious water sources, (Flint, 2008).

Caesalpinia sappan is an eco-friendly, natural dye. It will not cause any side effect and it has anti-viral and anti-oxidant property. Leaves are a component of Jamu, a traditional herbal medicine in java. The leaves, flowers and wood are applied in the treatment of wood is very bitter, stops bleeding from the chest and lungs, heals wounds, ulcers, improves complexion and useful in rheumatism, (Muthu and Subramanian, 2014).

The small core of heartwood produces a dark red solution in water and is being used as herbal drinking water in kerala, since time immemorial for its antithirst, blood purifying, antidiabetic, complexion enhancer and several other properties. Since *Caesalpinia sappan* has enormous medicinal properties, the dye can be commercialized and used widely for treating many diseases the advantages of using natural dyeing, health risk free and there is no need to toxic chemicals, which are hard to dispose off, (Clark, 2011).

Further Study

Due to time constraints, testing the efficacy of dyeing using various other mordants weren't possible so myrobolan was the only mordant taken in the current study, though myrobolan had proved good efficiency in dye fixation, in further studies could also be carried out using other mordants, herbs, extraction method and type of materials.

BIBLIOGRAPHY

Books

- Annis. (2012). Understanding and improving the durability of textiles. Elsevier. (P>34).
- Au, K.F. (2011). Advances in knitting technology. Woodhead limited. (p.42)
- Behery, H. (2005). Effect of mechanical and physical properties on fabric hand. Elsevier. (P.290).
- Bernard . (2007). Fiber to fabric. (p.170)
- Bhat, P. (2000). Natural dyes and eco-friendly. Industrial and technical consultancy. (p.1-2).
- Bhattacharyya, N. (2010). Natural dyes for textile and their eco-friendly applications. IAFC. (Pp.3-4)
- Buchtold, T., & Mussak, R. (2009). Hand book of natural colourants. John Wiley and sons. (P.3)
- Chenz , Z., Kimura, M., Suzuki, M., Konda, Y., Hanabusa, K., shirai, H. (2013). Synthesis and characterization of new acrylic polymer containing silk protein fibre. (Pp. 168-172).
- Choudhury, R., R.k. (2006). Textile preparation and dyeing. Science publishers. (p.232).
- Clark, M. (2011). Hand book of textile and industrial dyeing. Elsevier. (p.25)
- Collins, H. (2010). The theory and practice of research for the creative industries. AVA. (p.164)
- Darwekar, M., Ghorpade, B., padma., Vankar., S. (1999). Convention on natural dyes. (Pp.131-132).
- Ericlichtfouse, schwarzbauer, J., Robert, D. (2013). Green materials for energy products and Depollution. (p.10).

- Flint. (2008). Eco-colour: botanical dyes for beautiful textiles. Murdoch books. (P.87).
- Fung, W. (2002). Coated and laminated textiles. CRC press. (P.283).
- Gulrajani, M.c., & gupta,D. (2001). Introduction to natural dyes. Govt of india publishers. (Pp. 9-10)
- Hansen, V. (2012). The silk Road. Oxford university press. (P.283).
- Herbst, W., & Hunger, K. (2006). Industrial organic pigments. John wiley & sons. (P.144).
- Horrocks, R., Anand, S., & Anand, S. (2000). Hand book of technical textiles. CRC press. (P.218).
- Hu, J. (2008). Fabric testing. Woodhead limited. (p.108)
- Hunger, K. (2007). Industrial dyes chemistry properties. John wiley and sons. (P.348).
- Jain, H. (2010). Techniques of dyeing and printing. Ane books pvt.ltd. (Pp.4-5)
- Katia, L. & Werner, B. (2004). Textile chemical environmental data and facts. Springer. (P.309).
- Kozlowski, R. (2012). Handbook of natural fibres. Elsevier . (P. 148).
- Lakshmi, K., & purushothaman, V. (2007). Improving the efficiency of selected natural dyes on cotton fabrics. (p.53)
- Macdonald, E.F. (2008). The construction of preference in engineering design and implications for green products. (P.64).
- Meenakshi, & Rastogi,. (2009). Fibres and yarn. Sonali. (p.69).
- Muthu, S., & Subramanian. (2014). Eco-friendly raw materials. SGS limited. (Pp.1-20)
- Panda, H. (2010). Hand book on paint testing methods. INC. (p.413)

- Raja, D., prakash, c., Ramakrishnan, G., Koushik., C.V. (2013). The textile institute. (p.843).
- Resonance, Vinod, R. & Kanetkar. (2010). History and Advancements. (P.794).
- Sanad, S.H., Mohamed, A.S., Ramadan, A. (2005). Polym-plast technology eng. (Pp.1269-1279).
- Saxena.s., & Raja, A.S.M. (2014). Natural dyes and textile science and clothing technology. (Pp.37-38)
- Sekhri, S. (2012). Text book of fabric science. PHL learning pvt.Ltd. (P.46).
- Song, G. (2011). Improving comfort in clothing. Elsevier .
- Sung , W.P., Jimney, C.M., Ranchen. (2013). Environment energy and sustainable development. CRC press. (p.472).
- Vainker, S.J. (2004). A cultural history. British Museum press. (P.8).
- Vankar, p.s., & Shankar, R., wijayapala, s. (2009). Dyeing cotton silk and wool yarn with extract of garnicia mangostana pericarp. JTATM. (p.6).

JOURNALS

- Afrin, T., Rupinder, K., Xungai, Wang, Tsuzuki, T., & Kanwar, K. (2013-2014). (Vol. 105, No.12, Pp.1292-1293). The journal of the textile institute.
- Ammayappan, L., Jose, S., & chakraborty, S. (2013). (Pp.32-33). Colouration of textiles by natural dyes.
- Anitha, R. (2011). International Journal of Multidisciplinary management studies. (Vol.1, Issue 3, P.101).
- Badami, S., Moorkoth, S., & Suresh, B. (2004). Natural product Radiance. (Vol.312, Pp. 76-77).
- Bhat, V. (2012). Modern dyeing technique for eco-friendly environment. (Vol.59, Pp. 43-48). Colourage.

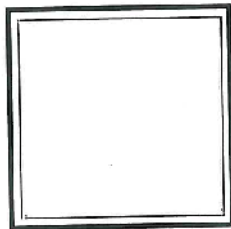
- Chandraprabha, P., Ravi., P.K., & Sarma, U.S. (2012). Dyeing of coir using caesalpinia sappan. (Pp.2-3).
- Dayal, R., P.C., Kumar, D.R., onial, P., & Rawat, D.R. (2006). Natural dye from lantana camara leaves. (Vol.1 II. No:12, P.153). Colourage.
- Jayalakshmi, I., & Soundanyaa, D. (2014). Effect of natural dyeing in bamboo material. (Vol-11. No.2, Pp.37-38). Colourage.
- Jun, H., Yanxiaoling., WangWei., WuHao., Hualel, & Dulijun. (2008). (Vol.13, P.474).
- Kalpana, S., Subramanian, M., & Nithyanandan, R. (2005). Salt and alkali free reactive dyeing on cotton fabric. (Vol.114, P.3). The Indian textile journal.
- Karolia, A., & Mendapara, S. (2007). Imparting antimicrobial and fragrance finish on cotton using chitosan with silicon softener. (Vol.32, P.99). Indian journal of fibre and textile research.
- Mahesh, G., & Anitha, D. (2014). The Indian textile journal. (P.69).
- Mehta, S., & Jahan, S. (2014). Colourage. (P.45) .
- Poornima, A., & Devi, S.B.S. (2014). Natural dyeing. (Pp. 36-37). Colourage.
- Prabhu, K.H., Teli, M.D., Nilesh, & Waghmare, G. (2011). Fibres and polymers. (Vol.12, No.6, Pp. 753-759).
- Prusti, A.K., purohit, A., Nayak., A. & Das., N.B. (2010). Colourage. (Vol.1, p.55).
- Raja, D., Prakash, C., Ramakrishnan, G., & Koushi, C.V. (2013). (Vol.105, No.8, Pp.842-846).
- Ramani, S., & Raja, V. (2013). International journal of current research. (Vol.5, Issue, 09, P. 2478).
- Rathod, A., Kolhatkar, A. (2014). The Indian textile Journal. (P.50).
- Samanta, A.K., & Agarwal, P. (2009). Application of natural dyes on textiles. (Pp. 384-399). Indian journal of fibre and textile research.

Shah, T.R., & Sabale. (2010). Dyeing of Nylon with Natural colourants. (Vol.3, No.3, P.96). Colourage.

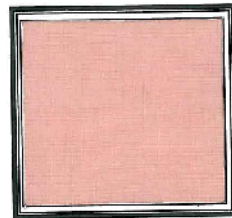
Siva, R. (2007). Current science. (Pp.916-919).

APPENDIX – 1

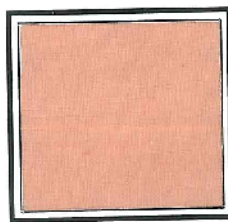
100% BAMBOO COTTON FABRIC



Original Fabric



Conventional Dyed Fabric






Microwave Dyed Fabric

APPENDIX – II
Visual inspection

S.No	Sample	Rating in percentage							
		General appearance			Texture			Evenness of dyeing	
		Good	Fair	Poor	Good	Fair	Poor	Even	Uneven
1.	CDS								
2.	MDS								

APPENDIX – III

Natural dye – Color strength

		क्षेत्रीय प्रयोगशाला वरुन समिति वरुन मंगलम, भास्कर संस्कार राज चेंबरस, 978-A, थडागम रोड कोयंबटूर - ६४१ ००२ Tel : 2473094, 2473758 Fax : 2472689 E-mail : tccbe@dataone.in	REGIONAL LABORATORY TEXTILES COMMITTEE (Ministry of Textiles, Govt. of India) Raj Chambers 978-A, Thadagam Road, Coimbatore - 641 002.	
8393 /2014-15		TEST REPORT	18.03.2015 Format No.05/32/01	
Test report No Name and address of Customer		: UMA A.S. (II.M.Sc TEXTILES & FASHION APPAREL), : AVINASHILINGAM UNIVERSITY, COIMBATORE		
Sample forwarding letter No. & date Date of receipt of Sample		: 11.03.2015 : 11.03.2015		
Buyers Name & address (Optional)		:		
Customer sample Ref.		: MICROWAVE DYED SAMPLE		Sample swatch
Sample description Lab Sample No. Sample colour Date/s of Testing		: WOVEN FABRIC : CT - 8393 : : 12 TO 17 03 2015		
TEST RESULTS				
I	COMPARISION BETWEEN CONVENTIONAL & MICROWAVE DYED SAMPLE COLOUR STRENGTH BY SPECTROPHOTOMETER WITH 10° OBSERVER, D65 ILLUMINANT		CCO-9187	
a	ΔE Value	9.657		
b	ΔL Value	2.395		
c	Δa Value	-2.236		
d	Δb Value	9.084		
e	Strength in (%)	257.359		
II	VALUES:			
a	X	82.126		
b	Y	84.697		
c	Z	77.417		
d	L	93.752		
e	C	10.521		
f	H	69.945		
III	K / S VALUE:		1.2998	
<ul style="list-style-type: none"> • Colour difference on strength adjusted to 100%. • Tested at R.O.TC, Tirupur. 				
K. GOWRISANKAR 18/03/15 गुणवत्ता आश्वासन अधिकारी (प्रयोगशाला) Quality Assurance Officer (LABS)				
Sample is not drawn by Textiles Committee. Results relate only to the sample tested. This test report is not to be published in any form without the explicit written consent of the Textiles Committee. Please quote Test Report No. and date for all future correspondence. Remarks on the backside of the report. Sample is conditioned and tested at a temp. of 27±2°C (instead of 21±2°C) and 65±2% RH wherever ASTM D 1997-04 test methods are adopted. Complaints, if any, are to be received within 45 days of date of issue of the test report.				

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