Chapter 2
Review of Literature

The present study titled “A comparative study of three varieties of Cotton / banana Mixture Fabrics Treated with Enzymes and Natural Dyes” was proposed, based on the following literature survey. This chapter 2, covers the topics literature on Textile Industry, varieties of banana natural Fibers, environmental issues, enzymes, handloom, and naturally extracted dyes, and testing parameters.

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2.1 Status of Indian Textile Industry

The Indian textile industry has the capacity to manufacture a wide variety of products suitable to different market segments, both within India and across the world. The industry is the second-largest employer after agriculture, providing employment to 45 million people directly and 60 million people indirectly, and contributes approximately 5% to India’s Gross Domestic Product (GDP), and 14% to overall Index of Industrial Production (IIP). The textile sector has witnessed a spurt in the investments during the last 5 years. The Govt. of India has started a promotion of its 'India Handloom' initiative on social media like Facebook, Twitter, and Instagram, with a view to connect with customers, especially youth to promote high-quality handloom products with Natural Fibers. (http://www.ibef.org) May, 2017.

In the recent years, the fashion industry, educational institutions, media, and consequently the beneficiaries have become more perspective of the environmental and ecological movement, so as the terms green, sustainable, ethical, recycled, organic, cross-fertilization and global fashion design, are readily confused (Thomas, 2015).

2.2 Eco Green Textiles: Krishnaveni and Amsamani, 2012, have stated that eco-textiles have gained importance as one of the most promising resources that helps to promote new innovations in an eco-friendly manner. According to Joshi et.al., 2009, says that these agents reduces the ill-effects of the microbial growth on textile materials, but also comply with the statutory norms imposed by the regulatory agencies.
2.3 Potential of Banana in India

Around the world banana and plantains are produced in developing countries and developed countries which are the required by banana importers and consumers. Though, banana is produced in 123 countries around the world, only 10 major banana producing countries account for 75% of total banana production. India, Brazil, China, and Ecuador alone produce half the total volume of world bananas.

India is the largest producer of Banana in the world with an annual production of 16.81 million tons from an area of 4.90 lakh hectares. The average productivity of the country is 34.30 tons per hectare. Among the different states, Tamilnadu ranks first in area and production with 92000 hectares and 4.856 million tons respectively. The productivity is highest in Maharashtra with an average of 60 tons per hectare.

India is a pioneer country in the world that effectively enacted “suigeneris” plant variety protection and farmers’ rights system in 2001. Plant breeders in public and private sector in India have introduced several new varieties in crops that have increased productivity and farm income considerably. Protection of Plant Varieties and Farmers Rights Act, 2001 provides for legal protection of varieties of crop plants of economic importance, and it is expected that the revenue earned through commercial exploitation of these varieties will be ploughed back to strengthen the research and development system. (S.Uma.M.S.Saraswathi et.al., Bulletin 21. NRCB.Trichy.)

Banana fiber needle punched non-woven can used as thermal insulation medium effectively. Thick and porous banana fiber needle punched non-woven contains evenly disbursed void which are responsible for thermal insulation. Needle punched non-woven technology is the most suitable for banana fibers. Composite fabrics to be used in geo textiles, automobile textiles, can be produced with the recyclable and bio-degradable banana fiber. (N.Shanmugam, P.G.Patel, Indian Journal for Applied Research, April,2015.)

Properties of banana fiber are superior among the natural fibers. Combination of two different materials along with low manufacturing cost, makes them useful in various fields of engineering and sports goods. The future of banana seems to be bright with the low- cost and environmentally superior to other synthetic fibers. (Ravi Batnagar, Gaurav Guptha et.al. Indian Journal of Scientific Research, May 2015).
2.3.1 Varieties of Banana

More than 20 varieties are commercially grown in different parts of India. However, Indian banana trade mainly depends on “Cavendish Clones” of banana, which are called by different names in different areas. The important Cavendish clones are: Basrai (Dwarf Cavendish), Robusta, Harichal, Grand Naine, Shrimanthi, Bhusaval and Pedda Pachi Aranti. There are other locations specific varieties are grown in large quantity in different regions throughout the country. The important varieties are: Rasthali (Silk), Poovan (Mysore), Karpuravalli (Pisang Awak), Nendran (French Plantain), Hill Banana and Monthan (cooking). (C.K. Narayana., M.M. Musthafa., Tech.Bulletin 15. NRCB. Trichy).

Banana trade is dominated by Grand Naine, one of the most popular Cavendish Clones (AAA). This is mainly because of its amenability to tissue culture, hi-tech cultivation practices like high density planting, fertigation etc. This has led to the enhanced production and productivity. However, in some southern parts of India, polyclonal system of cultivation is still in vogue with varied seasons of cultivation ultimately leading to the year around availability of one or the other varieties of banana. (S.Uma., M.S.Saraswathi et.al., Tech. Bulletin21.NRCB.Trichy).

The banana plant is a relatively large perennial herb with leaf sheaths that form trunk-like pseudo stems. When fully grown the stem attains a height of 6.1 to 9.1 meters and surmounted with large oval leaves. The plant has 8-12 leaves, that are up to 4.2 meters long and 0.94 meters wide with a strong footstalk and midrib. The flower: spring in great spikes from the center at crown of leaves. At first, it forms a large, long-oval, tapering, purple-clad bud. As it opens, the slim, nectar, tubular, toothed, white flowers appear. They are arranged in a whorl like cluster along the floral spike; the fruits vary in length from 10cms to 30 cms (http://www.ptri.dost.gov.ph/databases/indi_fibers/banana.htm.

Plant fibers are cellulosic materials and have potential applications, in paper and packaging industries. The fibrous material from plant is renewable material and hence environmental friendly, because of its degradability in nature. Fibers may occur on any part of the plant, such as root, stem, fruit and even in the seed. Usually, plant fibers are classified as xylem and phloem fibers, the latter one can be obtained from the outer cortical region of the stem. Banana plant is rich in phloem fiber, also called as cortical or pericyclic fibers. The fiber from banana plant is an agricultural waste and an abundantly
available renewable resource, and has been used as good reinforcement in thermosets as well as thermoplastics. The banana plant exists in different varieties, and the few varieties selected for our study are Red Banana, Nendran and Robusta. (V.A.Kiruthika and K.Veluraja. 2009).

Banana Abaca fibers come from the banana variety of mesa textiles, which is commonly known as abaca, abaca banana, tree whose leaves are held on a pseudo trunk with extremely long fiber-reinforced and inter woven leaf stems. They have a high textile strength and resist not. Historically, they have been used to make rope. They are environmentally friendly.

2.3.1.1 Red Banana: Red Banana, also known as Red Dacca bananas in Australia, is a famous variety with a reddish-purple skin and are bigger, when compared with other varieties and similar to Nendran or Plantain types. Due to its color, it is often called by different names like Chenkadali, Raktha Kadali, Kappa Vazhai., etc. upon ripening, the fruit attains sweet taste with an orange-yellow color and a pleasant aroma. They are best eaten in their soft and unbruised state. It contains more beta-carotene and vitamin C than the usual yellow bananas. Red bananas get ripe in a few days at room temperature, best suited for storage outside refrigeration. (http://healthyliving.natureloc.com/common-banana-types-available-kerala).

Red banana is the most relished and highly prized variety of Kerala and Tamil Nadu. Its commercial cultivation is prominent in Kanyakumari and Tirunelveli districts of Tamil Nadu. It is also popular in Karnataka, Andhra Pradesh and to some extent, in Western and Central India. In Bihar and other regions, it is popular as Lal Velchi while in Karnataka as Chandra Bale. The color of the pseudo-stem, petiole, midrib and fruit rind is purplish red. It is a robust plant with bunches weighing 20-30 kg under good management practices. Fruits are sweet, orange- yellow coloured and with a pleasant aroma. It is highly susceptible to bunchy top, fusarium wilt and nematodes. (National Horticultural Board). nhb.gov.in/pdf/fruits/banana/ban013.pdf

2.3.1.2 Nendran: This belongs to Plantain AAB. This variety is also known as French plantain and Rajeli. It is a popular variety of Kerala where it is used as fresh fruit as well as for making chips. Nendran plant, is a slender, medium statured plant reaching a height of 2.5 meters. The bunches have 4-6 hands each with 8-10 fruits weighing 10-14 kgs. The fruits have a distinct neck with thick green skin turning, buff yellow on ripening.
Skin turns yellow upon full ripening. It is starchy, pink fleshed and highly suitable for making chips and powder. (NRCB., Trichy)

Bananas are deeply linked with the traditional culture of Kerala. In Kerala, Banana is referred as ‘Pazham’. “Ethapazham or Nendran pazham is the lengthiest and biggest banana variety commonly available across Kerala. (http://healthyiving.natureloc.com/ common-banana-types-available-kerala).

It is a popular variety in Kerala where it is relished as a fruit as well as used for processing. Commercial cultivation of Nendran has picked up rapidly in Tamil Nadu in the recent past. Nendran is known to display considerable diversity in plant stature, pseudo stem color, presence or absence of male axis, bunch size, etc. Bunch has 5-6 hands weighing about 12-15 kg. Fruits have a distinct neck with thick green skin turning buff yellow on ripening. Fruits remain as starchy even on ripening. Nendran is highly susceptible to Banana Bract Mosaic Virus (BBMV), nematodes and borers.(National Horticultural Board). nhb.gov.in/pdf/fruits/banana/ban013.pdf

2.3.1.3 Robusta: This belongs to AAA Cavendish sub-group and is also known as Bombay green, Harichal and Pedda Pachi Aranti. It is mostly grown in Karnataka, Andhra Pradesh, Maharashtra and Tamilnadu. The plant is medium-tall with a strong pseudo stem. It has uneven black blotches all along its length. The bunch weighs about 25-30 kgs with 10 hands, and each hand has about 16 – 20 fruits. The fruits are dark-green color and turn to bright yellow if ripened between 22-25 deg.C. The fruit is very sweet with a good aroma.(NRCB. Trichy).

It is a semi-tall variety, grown mostly in Tamil Nadu and some parts of Karnataka for table purpose. It is a high yielding and produces a bunch of large size with well developed fruits. Dark green fruits turn bright yellow upon ripening depending on ripening conditions. Fruit is very sweet with a good aroma. Bunch weighs about 25-30 kg and it requires propping. Fruit has a poor keeping quality leading to a quick breakdown of pulp after ripening, hence not suited for long distance transportation. Robusta is highly susceptible to Sigatoka leaf spot disease in humid tropics. (National Horticultural Board) nhb.gov.in/pdf/fruits/banana/ban013.pdf

Banana is one of the tallest of the herbaceous plant with pseudo stem. Its robust tree- like soft stem is composed of sheeting spiral leaf-bases, which contains fibers of sufficient strength to keep the tree erect.
2.4 Banana Cultivation: Basic soil characteristics

- Banana can grow from the poorest to the richest type of soil with varying success.
- The soil should be tested before cultivation.
- The soil should have good drainage, adequate fertility, and moisture.
- Deep, rich, loamy, salty clay loam soil with pH between 6-7.5 is the most preferred for banana cultivation.
- Poorly aerated and nutritionally deficient soil, which is not drained properly is not suitable for banana.
- Extreme clayey, sandy soil, Saline soil, and Calcareous soil is not suitable for Banana cultivation.
- Avoid soil of low-lying areas, very sandy and heavy black cotton with ill drainage.
- A balanced soil with proper acidic and not too alkaline, rich in organic material with high nitrogen content, adequate phosphorous level and plenty of potash are good for banana.

Banana crop cannot, tolerate a wind speed of even 30 km/h. Banana being a shallow rooted crop requires proper propping with bamboo or casuarina poles to avoid lodging during windy seasons. The supporting poles should be tied against the peduncle of developing bunches, so that it protects the plant from lodging and bears the whole weight of the developing bunch. (http://www.agritech.tnau.ac.in/expert_system/banana/cultivation.html)

Reports reveal that Kulkarni et.al.,(1983), were the first to report on fiber yield, structure and properties of banana fibers gathered from a few commercially cultivated varieties and observed that variations existed in both across the thickness of the Pseudo stem. They also reported differences in the tensile and structural properties among fibers belonging to varieties and showed that the matrix in which the cells are embedded in the fiber had a role in deciding the strength of the fiber.

2.5 Cotton Fiber

Cook confines that, cotton is the oldest and the most important of the textile fibers. India is believed to be the first country to grow this fibre. The concept of producing textile fibers from these seed-hairs was known to Ancient Egyptians and by the earliest Chinese. There is some evidence that this fibre was used in Egypt as early as 3000 B.C. But there is no doubt that India transformed the production into an industry, the fabric being
manufactured as early as 1500 B.C. This concept is believed to be known to ancient Egyptians and Chinese as early as 3000 B.C.

India today enjoys a unique position in global cotton and is surpassed only by China as a consumer of cotton. It is also one of the significant exporters of cotton yarn and garments (Daga, 2012).

Cotton, genus Gossypium, one of the world’s most important crops, produces white fibrous balls that are manufactured into highly versatile textiles. The world’s leading producers of cotton are Pakistan, China, the United States, India, Uzbekistan, Brazil, Turkey, Australia, and Egypt, (Mahadevan, 2010).

Cotton is a natural fiber popular for its comfort and durability (Shanthi and Krishnabai, 2010). Cotton is the backbone of the world’s textile trade. It is also known as “King of Fiber” and “White Gold.” Cotton is a soft white fibrous substance covering seeds of certain plants. Cotton grows in a form known as a ball around the seeds of cotton plant, a shrub native to tropical and sub-tropical regions around the world, including America, India and Africa. The English name, which began to be used circa 1400, derives from the Arabic ‘qutun’ meaning Cotton, (Rastogi, 2009).

### 2.5.1 Qualities of Cotton Fiber

Cotton is a non-allergenic natural fiber that doesn’t irritate sensitive skin. Softness makes it a preferred fabric for underwear and other garments worn close to the skin, adaptability allows it to blend easily with most of the other fibers. Cotton is one of the absorbency rate and holds up to 27 times its own weight in water and becomes stronger when wet. Its strength and absorbency make it an ideal fabric for medical and personal hygiene products. (mytextiles.blogspot.in).

The explanations given by Anne Barnett, give the required characteristics to the end product (e.g. blending of man-made fibers with natural fibers produces the desired easy-care characteristics); compensate for variations in characteristics of the raw materials (even cotton of a single origin exhibits variability and must be blended); hold down raw material costs (blending-in of raw material at low price level); influence favorably the behavior of the material during processing (improve the running characteristics of short staple material by admixture of carrier fibers); and achieve effects by varying color, fiber characteristics and so on.

Some blends are made with a mix of natural fibers and manufactured fibers, where the desired properties one counteracts the disadvantages of the other. For e.g., A good all round performance is achieved when the comfort and insulating properties of
natural fibers and their properties of high strength, good abrasion resistance and easy care characteristics.

The percentage of each fiber in the blend gives an indication of the properties of the fiber, for e.g. there must be enough of each fiber to give the blend the beautiful qualities of each. Blending is a compromise between the properties of two different fibers which has an idle set of properties, combining these fibers produces a fabric which process the best properties. (Anne Barnett.,)

It is said that Polyester and cotton blended yarn is capable of obtaining a polyester and cotton blended fabric having a superior bulkiness and a soft touch, and a polyester staple fiber stock which is useful to obtain the blended yarn as a yarn having superior properties with regard to neps and a yarn evenness. To obtain the above mentioned polyester cotton blended yarn, a coarse denier staple fiber having a pre-determined range of fineness are used, and a suitable number of fibres constituting the blended yarn and fiber lengths of the staple fibers are defined. (http://www.cottonblends html).

Other major cotton blends are, Cotton/Acrylic blends, Silk/Cotton blends, Cotton/Jute blends, Cotton/Wool blends, Linen/Cotton blends (M.L.Gulrajani (blended textiles).

2.6 Opportunities for Banana Fiber in Khadi Industry

The story of khadi in contemporary India is a story of India’s resurgence as a nation, vital part of our national revival. What began with Mahatma Gandhi got a recent fillip when Prime Minister Narendra Modi gave the fabric a fresh push, up to the fashion ladder by wearing the fabric even during his visits abroad Gandhi chose khadi as a symbol of his dreams for India when he returned from South Africa. The charkha was selected by him as a sign of non-violence and self-sufficiency and the material woven from it – Khadi – epitomized the nation’s feelings of patriotism and nationalism. The revival of the charkha was symbolic of the nation’s quest for freedom and self-reliance. In 1921, Gandhi thought of a strategy and came up with the charkha as an icon of the struggle for Indian’s freedom (Abishek Mangala., 2002 ).

Khadi is the only Indian feel good fabric as it gives employment to thousands as well as a boost to the economy and sustains indigenous artisans. Supporting khadi is one way of encouraging the talented artisan to live in his ancestral village rather than give
up in despair and flock to an urban slum for an alternative employment. But khadi is far from fading away, thank for the lift given to the fabric by the Prime Minister himself. Meher Castelino wrote about the state of khadi affairs and how some designers are moulding it a new fabric (http://www.khaiindia.com).

The name may have changed over the centuries but the the warp, and the weft have not. Khadi, as we call the hand-woven fabric made legendary by Mahatma Gandhi, has been around since times immemorial. Its timeline is its own hurrah: Among the greatest achievements of the Harappa and Mohenjo-Daro civilizations were the mastery over hand-spinning and hand-weaving. Every pre-Aryan home had its own Charkha or spinning wheel. Invaders came and went, but Khadi wove its way through the Vedic period, the Mughal and Medieval period. The expertise was so much part of everyday life that it became a traditional cottage industry. In Andhra Pradesh, a bride was gifted a one-spindle Khada Charkha as a wedding gift (http://www.khaiindia.com).

Khadi is an Indian fabric. Khadi is also known by another name Khadder. It is made by spinning the threads on an instrument known as Charkha. During pre-Independence era of India, the movement of khadi manufacturing gained momentum under the guidance of father of nation Mahatma Gandhiji. This movement of khadi manufacturing and wearing started as to discourage the Indians from wearing of foreign clothes.

Khadi before independence, was considered as the fabric for the potential leaders and the rural people. In contrast, has found its way into the wardrobe of fashion conscious people. The current situation is that the demand is more than supply. Earlier, the type of khadi available was khadi cotton, which had very coarse texture and feel. However, many varieties of khadi like khadi using fibers like, silk, wool, and cotton are freely attainable now, which makes it fashionable fabric and likeable by the masses (www.khadiculture.com).

Khadi is a versatile fabric. It has the unique property of keeping the wearer warm in winter as well as cool in summer season. This fabric has coarse texture and gets easily crumpled and therefore, in order to keep it firm and stiff, starch is to be added. The more the fabric is being washed; it gets an enhanced better look. Khadi is not easily worn out for years together, at least 4-5 years. Very attractive and designer apparels are made by doing handwork on the garments made from it. Khadi spinning is generally done by girls and women and weaving mostly by men. During spinning of khadi the threads are
interwoven in such a manner that it provides passage of air circulation in the fabric. Apart from this unique property, it also provides warmth in winter season, which is a quite surprising factor. (www.Komilakhadi.com).

After other natural fibers, it is the now the turn of the banana fiber. A group of weavers in Anakaputhur, southern suburb of Chennai, have been weaving attractive pieces of cloth from the humble ‘Vazhai Naaru’ it means the Banana Fiber. Anakaputhur, was once an important handloom centre, known for its Madras handkerchiefs. Over the years, the vocation fell upon hard days and is now restricted to a few families. Some of them own pit looms to weave dress materials from natural fibers, with some government support. Self- help groups and members of Anakaputhur Jute Weavers Association., are these days busy trying to meet the deadlines for bulk orders placed by Central Government, Agencies and Private firms. According to C.Sekhar, President of the Association, dresses woven out of natural fibers were in great demand inside and outside India. Raw fiber is purchased from growers in Kundrathur area and Koyambedu wholesale market in Chennai. The fibers are cleaned in a simple bleaching process and the fat content removed. After a very delicate process of removing single strands of fiber, they are woven into fabrics like any other materials. These materials have great affinity for colors, and attractive designs could be woven. There is plenty of scope for weavers, to make sufficient money if they take up weaving of natural fibers with help and encouragement from the Government. (Article from “THE HINDU”).

2.6.1 HANDLOOM

The growth and all round developments of handloom industry had a direct influence on the improvement of the economy of the nation. The Indian textiles industry is extremely varied, with the hand-spun and hand-woven sector at other end of the spectrum, and the capital intensive, sophisticated mill sector at the other. The decentralized power looms /hosiery and knitting sector from the largest section of the Textiles Sector (Sharma and Kukreti, 2016).

The widest employment opportunities are given by the handloom cottage industry. Lot of thrust has been given to implementation of schemes for promotion and development of handloom and Khadi sectors, after agricultural sector.

Patra points out that some of the areas that need attention in the handloom industry are reduction in prices, increased availability, improvement to the quality /colour, durability, innovative design, more varieties, latest fashion and trends, more awareness,
special market survey for handloom products, customization, reduction in intermediaries, etc. to improve the satisfaction level of handloom customers (Patra and Dey, 2015).

Some of the problems faced by the handloom weavers’ improper supply of raw material, price hike in yarn, lack of proper marketing facilities, lack of market awareness and promotion, lack of proper financial resources, involvement of middlemen, competition from mill and power looms products, lack of modern technology, lack of prompt and timely support from the government and other allied agencies and so on. It is a well-known fact that the handloom weavers in some parts of the state are starving to death and even commit suicides, due to lack of facilities as well as disproportionate earnings corresponding to their labour, in the weaving activity. The standard of living of the weavers is significantly low, and they are leading miserable and pitiable life due to unemployment and underemployment. The handloom industry gives large opportunities to the rural people but at the same time each and every product did not give equal profits and equal demand. So, the master weaver/independent weaver has to analyze the profit and demand of the particular products and invest in the market potential (Kudri and Thakur, 2014).

2.7 Enzymes the Natural Catalyst

2.7.1 Introduction and Importance of Enzymes

Enzymes are biological catalysts that mediate virtually all the biochemical reactions that constitute metabolism in living systems. They accelerate the rate of chemical reaction without themselves undergoing any permanent chemical change. i.e. they are true catalysts. In 1878 German physiologist Wilhelm Kühne (1837-1900) coined the term enzyme, which comes from Greek In 1897, Eduard Buchner reported extraction of functional enzymes from cells. All known enzymes are proteins. Enzymes differ from chemical catalysts in several important ways:

1. Enzyme-catalyzed reactions are at least several orders of magnitude faster than chemically-catalyzed reactions. When compared to the corresponding unanalyzed reactions, enzymes typically enhance the rates by 10^6 to 10^13 times.
2. Enzymes have far greater reaction specificity than chemically-catalyzed reactions and they rarely form byproducts.
3. Enzymes catalyze reactions under comparatively mild reaction conditions, such as temperatures below 100^0 C., atmospheric pressure and pH conditions around
neutral. Conversely, high temperatures and pressures and extremes of pH are often necessary in chemical catalysts.

2.7.2 Enzymes in the Textile Industry

Enzymes are principally classified and named according to the chemical reaction they catalyze, as this is the specific property that distinguishes one enzyme from another.

Enzymes are gaining an increasingly important role as a tool in various wet textile pre-treatment and finishing processes (Stanescu, 2002; Thiry, 2001; Cavaco-Paulo, et al. 1998; Heine and Hocker, 1995). Conventional wet textile pretreatment and finishing procedures applied throughout the textile industry are often characterized by high concentrations of chemicals, alkaline or acidic pH, and high temperatures with consequent high consumption of energy. Enzymes are very specific catalysts; they operate best at ambient pressures, mild temperatures and often at a neutral pH. It is to be expected that, within 5 to 10 years, wet textile production processing will be shifted substantially towards sustainable restrictions and the decreasing availability of fresh water. Biocatalysts has proven to be a flexible and reliable tool in wet textile processing and a promising technology for fulfilling expected future requirements.

Processes for natural fiber-based fabrics have been developed using enzyme technology for the degradation of starch after weaving, the scouring and the removal of excess hydrogen peroxide, before dyeing, modification of cotton fabric (finishing or bio-polishing), production of Lyocell fabric, ageing of denim, modification of wool, degumming of silk and for the treatment of water effluent from textile production mills.

The application of enzyme technology is very specifically targeted to a component (substrate) present on the fiber. Besides its effectiveness, enzyme technology is also preferred for its environmentally friendly character since no hazardous chemicals are used, unlike the situation in chemical processes, and the enzyme itself is fully biodegradable. Owing to the ongoing integration of enzyme technology in an already large and still increasing number of partial processes, the textile production industry is shifting from a notoriously polluting industry to a less polluting one. Additionally, the textile area has been recognized as innovative.

Enzyme application increases tensile energy, extensibility, and improves the surface characteristics of the cotton/banana union fabric. (Tholkappian.E.2016. Enzymes can be applied in several steps of textile wet processing and in formulation of detergent powders. Preparation for coloration steps generally involves the removal of impurities,
natural colored pigments, sizes and lubricants. Preparation of synthetic fibers also involves thermal treatments for uniform dyeing. After coloration, processes include chemical and mechanical processes. Industrial laundering and home washing of garments can be also included in the post-coloration processes. To give an overview of enzymatic applications in textiles a brief characterization of major wet processing steps before, during and after dyeing will be presented.

Dyeing processes aims to prepare the textile materials to receive dyes or pigments with high fastness properties. In preparation, all impurities and natural colored pigments have to be removed. Generally, preparation for coloration is similar for all colors, but is more stringent for whites and lighter shades. Major processes during preparation are singeing, desizing, scouring, washing-off, bleaching, mercerizing, carbonization and thermal treatments.

Dyeing is an important process, which deals with the application of dyes and pigments on textile materials to impart color with high fastness. The dyes and pigments are applied to textile materials in acidic, neutral and alkaline conditions, depending on the chemical structure of the dye or pigment. In the case of cellulosic fibres, mainly, direct, vat, and reactive dyes are used. All dyes for cellulosic fibres are applied under neutral to alkaline conditions, since only at high pH values are cellulosic fibers charged.

2.7.3 Use of Enzymes for Bast Fibers

Bast fibers (flax, hemp, jute, kenaf and others) are composed of cellulose (over 50%), hemicellulose, lignin, pectin, fats, waxes and other substances. Bast fibers are extracted from the plant stem by a process called ‘retting’ as mentioned before. The purpose of retting is the partial degradation of the fiber materials, in such a way that fibers can be obtained from the plant stems. Former retting processes of flax were based on incubation with bacteria and moisture (the stem in an open grass field) or in water (immersing the stem in slow rivers); nowadays, retting is more often carried out in tanks of water at 30°C. Despite being an old, much attention has been given to retting. The use of enzymes like hemicellulases and Pectinases for retting allows a more controlled degradation of the fibers and a reduction of effluents. Upgrading is the process of replacing a product with a newer version of the same product.

However, in retting or further softening treatments, care should be taken since the removal of fibrous material may yield unacceptable levels of strength loss (Cavaco-Paulo 1998).
2.8 Application of Enzymes

2.8.1 Desizing

The use of amylases for desizing starch and their derivatives from woven fabrics was introduced almost 100 years ago. The enzymes used are mainly of bacterial origin such as *Bacillus subtilis*. Owing to advances in biotechnology a range of amylases acting at different temperatures from 20°C to 115°C is available today. The optimum pH of the treatment lies between 5 and 7, depending on the enzymes used. All kinds of techniques can be used in the treatment ranging from padding to exhaustion methods. Amylases are used to de-size fabrics made or dyed yarns, where oxidative desizing agents cannot be applied. Enzymatic desizing is the method of choice in wetting processing routes prior to dyeing when high levels of dye fastness are demanded, owing to the fast and very efficient removal of starch. Incomplete removal of starch might cause friction fastness problems. (GEORG GUBITZ 2003)

Enzyme application increases tensile energy, extensibility and improves the surface characteristics of the cotton-banana union fabric. Detailed study was undertaken to explore the sew ability of cotton-banana blended fabrics and it is concluded that they give better/higher seam pucker but higher bending rigidity than 100% cotton (Behara et.al., 2000,2001). Several products were made from banana fibers in Philippines, which were reported to be elegant and highly versatile.

Desizing with amylases is one of the oldest enzymatic processes used in textile industry. A comprehensive description of the process can be found in Uhlig (1998).

Cellulase are the most successful enzymes used in textile processing. They can be used to obtain an aged or renewed look for cotton fabric and these include the individual enzymes endoglucanases (EGs) and cellobiohydrolases. For the generation of ageing effects EGs or EG – rich mixtures are used, while for renewal and depilling effects complete mixtures can be applied. Commercially produced cellulases are produced from the fungi *Humicola insolens* (optimum activity at pH 7) and *Trichoderma reesei* (optimum activity at pH 5). Although mono component EGs and EG- enriched products have been made available recently and have proven to be successful in many applications, for economic reasons mainly Cellulase mixtures are still used (Cavaco-Paulo, 1998).
Fabric or garment de-pilling is usually carried out after heavy processing where pills are raised. Cellulase are used for pilling removal from fabric surfaces in machinery with high levels of mechanical agitation like jets, winches or drum washing machines. The most likely mechanism of enzymatic de-pilling/cleaning is the action of the enzyme (absorption/hydrolysis) on easily accessible pills (or fibrils) at the surface of a fabric. The pills become weaker after partial hydrolysis by Cellulase and they are removed from the fabric by mechanical action. This mechanism is supported by the fact that de-pilling effects only take place at higher levels of mechanical agitation.

2.8.2 Bio-Scouring

Enzymatic scouring has generated a great deal of interest in the light of cost saving and growing environmental concerns. Pectinases, Cellulase, proteases and lipases have all been investigated with respect to their effectiveness in removing non-cellulosic impurities and increasing the wettability of the textile material (Roessner, 1995; Buschle-Diller et al., 1998; Takagishi et al., 2001; Traore and Buschle-Diller 2000; Waddell, 2002). More recently, efforts to include enzymatic bleaching with glucose oxidizes and peroxides have also been reported (Buschle-Diller et al., 2001; Tzanov et al., 2002) with the glucose oxides in free or immobilized on a support material. (Cavaco-Paulo, Gubitz 2003)

Cellulosic fibers are currently the only ‘synthetic’ fibers treated with enzymes. Cellulase dosages applied to regenerated cellulose fibers are lower than for cotton as the former fibres are more susceptible to enzyme attack. This is mainly due to the fact that regenerated cellulose is present as cellulose II. In the area of synthetic fibers, cellulases are mainly used for the treatment of Lyocell fabrics having a high pilling tendency after processes with strong mechanical agitation. Cellulases are essential finishing agents when used in a processing route to obtain a peach-skin feeling. When lyocell fabrics are subjected to a process with strong mechanical action, so-called primary fibrillation is produced (with raised longer fibers and fibrils). Cellulases can be used to clean fabric and fiber surfaces; thereafter, another treatment with higher agitation action is applied and a secondary and uniform fibrillation is produced with very short fibrils, giving the peach-skin feeling. (Georg, Gubitz, 2003).

2.8.3 Bio-Polishing

Biopolishing is a biological process (Mojsov 2014a; Mojsov 2014b;), which employs the same cellulase action on the surface of the cellulosic materials, and can be
carried out at any stage of wet processing but most conveniently performed after bleaching.

The removal of surface fibers or fibrils and an increase in the pilling resistance values are directly related. (Uddin, 2015). The creasing characteristic of fabrics is affected by many factors like yarn twist, fabric density, fabric constructions, fabric thickness apart from the fiber type. (Altas and Yilmaz).

Finishing agents can be used to alter fabric hand and to change the draping quality. Starching gives body weight, smoothness, and stiffness to fabric. Resins can modify hand of fabric and produce a variety of effects. Polyethylene emulsion, silicone, ionic and non-ionic softners impart softness. (Pant, 2010).

**2.9 Advantage of Enzymes**

Before grey cotton fabric can be dyed and finished it has to be treated in order to make it hydrophilic and to remove the primary cell wall. In conventional cotton scouring processes high temperatures (90-100°C) and high concentrations of NaOH (approx. 1mol/L) are used to remove the impurities from the primary cell wall (pectin, protein, organic acids) and hydrophobic components from the cuticle (waxes and fats) in a non-specific way to make the fiber hydrophilic. Owing to the higher concentration of NaOH, extensive washing and rinsing is required, causing increased water consumption. The use of high concentration of NaOH also requires the neutralization of the effluent, which requires additional chemicals. It is obvious that this process needs to be improved considerably to meet today's energy and environmental demands. Much research has been directed to replace this process with an enzymatic one (Agarwal et al., 2002; Buchert et al., 2000; Buschle-Diller et al., 1998; Csiszar et al., 2001; Etters, 1999; Hartzell and Hsieh, 1998; Lenting et al., 2002; Li and Hardin, 1998; Tzanov et al., 2001; Yachmenev et al., 2001). The potential to degrade and remove the undesired components from the cotton fibers of different enzymes, such as pectinases, cellulases, and lipases, as well as different process conditions, have been investigated. (Nierstrasz and Warmoeskerken, 2003).

There is a wide range of applications and a multitude of prospects for the use of enzymes in textile processing, leading to a positive impact on the environment (Mojsov, 2014) as enzymes are readily biodegradable (Doshi and Shelke, 2001).
Cellulase is the most popular and versatile enzyme used in textile wet processing for bio-preparation, bio-polishing, and softening of cellulosic fibers (Hebeish et al. 2013; El-Sayed et al., 2010).

2.10 Origin of Natural Dyes

The dyeing of textiles is mentioned in the “Vedas,” red, yellow, blue, black, and white were the main colors. In fact, in the 7th Century India had a virtual monopoly in the production of dyed, painted and printed textiles with natural colors, expresses Bhuyan and Saika (2004).

Archaeological proof shows that dyeing was a widespread industrial enterprise in Egypt, India, and Mesapotamia about 3rd B.C., reveals Sharma (2007). The first colorants were the natural extracts of plant, animal and mineral origin, explains Shukla (2005).

Natural dyes have been an integral part of men’s life since time immemorial. Relics from excavation at Mohenjo-Daro and Harappa, Egyptian mummies, Ajanta cave paintings and Mughal paintings show the use of natural dyes states Srivasthava (2005).

Evidence of use of natural dyes during Pre-Muslim and Muslim period of Indian history is much better conserved in the form of dresses, manuscripts and paintings. Some of the records of the court historians (biographers like Firdusi) are written and illustrated with natural dyes. The palace decoration and the ceiling of the temples of Halebid and Belur (Karnataka) widely testify to the mastery of the Indian craftsmen in the use of natural dyes. The colored exquisite silk and muslin fabrics of India have been found belonging to the period of 16th and 17th centuries. Thus, the use of natural dyes is an ancient history since pre/historic periods. A fragment of coarse madder dyed cotton fabric in a plain weave found during the excavation of the ancient Harappan sites indicates that even people of Mohanjo-Daro (c.3000 B.C.) used natural dyes. Several historical examples found during excavation show that natural dyes were used since ancient time, (Khan, M. 2005).

Only after 1856, the development of synthetic dyes came into prominence and still dominates the entire dyestuff industry and had ben well received due to their ease in reproducibility and cost factors. However, in the late 1994, Germany struck a severe blow to dye-stuff industries, and subsequently other European countries also executed ban on import of textiles and garments colored with a series of azo dyes made from aromatic compounds, which are carcinogenic, allergic and poisonous. (Jayaprakasam, 1997).
Customer’s interest and demand for ecofriendly textiles and eco-friendly textiles and dyes led to the revival of natural dyes for textiles, with the newer energy-efficient dyeing process and more reproducible shade developing processes. (Ashis Kumar Samanta et.al. 2009).

In recent years few enterprising people keen on exporting textiles and garments are venturing to revive the processes of dyeing with natural dyes, mainly due to the interest shown in export markets in the sophisticated fabric in which natural dyes are used. At a time when natural dyeing process are gradually being discarded even in a few places where they have been kept alive for so long and when it seems clear that this knowledge will also be lost to the country in course of time the enthusiasm of these few people to revive the processes commercially is commendable (Premi.1996).

A list of dye yielding plants of India given by Perkin and Everest was reproduced by Gulati, who also gave equivalent common Indian names for easy identification of the plants. In the remarkably produced treatise Natural Dyeing Processes of India has given in the appendices the list taken from Liotard and also that from Perkin and Everest. Mohanty et.al. have also compiled from existing literature on an alphabetical list of botanical names in regional languages together with a number of illustrations of plants used as dyes and/or auxiliaries in India (Mehta, 2006).

2.10.1 Scope and Importance of Natural Dyes:

The office of the Development Commissioner for Handlooms Ministry of Textiles (Govt. of India) with the assistance of its branch offices like Weavers Service Centre, Indian Institute of Handloom Technology (IIHT’s) and Natural Handloom Development Corporation (N.H.D.C.) have been contributing a lot since last few years. But in recent times serious efforts have been made to enhance the use of natural dyes by implementing projects, research work and seminars. It was also felt in seminars that the extracts of vegetable dyes should be chemically analyzed and trials shall be made to standardize them after extracting the dyes in a solution form that would be able to be sold in the market. (Pellew C.E. 1998).

Since mostly the locally available natural products were utilized only for coloring textiles, therefore depending upon local weather conditions, stages of growth of the vegetable products, their storing conditions and even quality of local water available for processing affected the final shades. The difference in tones of the leaves or flower petals or fruits one sees in one and same plant species is the weakness of these
products. Such a possibility of variation in final shades is one of the major issues considered in textile coloring. (Wells, 2000).

The problem of pollution is the main stimulus behind the resurge of natural dyeing materials. Though after the advent of chemical colors, people have got used to very bright and very fast range of shades which is still impossible for materials available for dye extraction until today. However, it is always not necessary or desirable to have only very bright or fast shades on the cost of nature damage. The pleasant effect of natural shades may at times win over in aesthetic aspects over the chemical dyestuffs. (Dean.J.2001)

These limitations of the natural dyes can be coped by making the efforts to streamline the supply channels of natural products and to enhance their dyeing quality. If sufficient research time is allotted to this subject, recipes could be developed, which bring any of the desired colors at par with their competing synthetic colors (Seker, 1999).

Use of vegetable products for textile coloring at the commercial level is to an extent a virgin area nearly seven years ago. The pastel color effect of natural dyes, on fashion fabrics, and being eco-friendly, have brought the attention from all over the world and surge for its use in growing faster everyday. The usage of natural dye is surging all over the world every year. Up until now, more than 500 natural dye sources are known. A very favourable crop could be expected in this field if due efforts are put in for its growth and promotion. Exploration of plant parts for dye extraction, which is otherwise wasted like bark leaves and flowers etc. need to be exploited (Smanta, 2003).

Natural dyes are mordant dyes. The mordant is the life for the vegetable colors except in the case of Indigo. Without mordant no color adheres in vegetable dyeing. It acts as an agent between the fiber and the color by helping the color and penetrates into the fiber permanently and makes it fast. Most of the natural dyestuffs will not by themselves adhere to yarn or cloth except as a surface stain which is easily washed away. A mordant generally of metallic origin introduced upon the prepared cloth unites with the dyestuff during the process of dyeing in the vat usually under heat to form an insoluble lake (Basu, 2006).

Source-wise, the natural dyes have variable chemical compositions with physical and chemical characterisics, besides the compositions of vegetable part of the plant from where the natural dyes are extracted. This again depends on conditions and place of growing, harvesting period, extraction methods and conditions, application, and
technological process followed. Many workers have reported some of the most noteworthy experimental techniques and attainable best parameters on extraction and application of natural dyes, which are temperature, time, media / type of solvent, vegetal material and liquor ratio, and on the observations of varying mordanting agents and techniques as well as dyeing parameter (Gupta and Gulrajani, 1999).

2.10.2 Butea monosperma – The Sacred Tree

It is a sacred tree, referred to as a treasurer of the gods, and used in sacrifice related rituals. From its wood, holy utensils are made. The flowers are offered as in place of blood in sacrifice rituals to the goddess Kali. The dried barks of the tree and the dry sticks are used to make sacred fire. It is an anthropogenic tree of several castes. 'Chakradatta' mentions the use of its gum in external astringent application. The leaves are believed to have astringent, depurate, diuretic and aphrodisiac properties. It promotes diuretic and menstrual flow. The seed is anthelmintic. The bark is also used in snakebite. When seeds are pounded with lemon juice and applied to the skin the act as a rubefacient. Arab horse dealers put one seed into each feed of corn to keep their horses in condition. (Murthy 1941 Journal)

Butea (Palash) is native to India and is found throughout the country. Palash tree is also known as ‘flame of the forest’ because of its red coloured flowers. It is also found in Sri Lanka, India, Myanmar and other countries of Indian subcontinent. Palash or Dhak is found throughout India up to 1300-1400 m except in very arid parts.

A moderate sized, deciduous tree; bark fibrous, bluish grey or light brown outside; Leaves compound, with three leaflets, rachis 12-22.5 cm long, leaflets hard, rigidly curvaceous, glabrescent above and silky tomentose beneath; Flowers terminal, red in colour, appear on leafless tree giving an appearance of fire flame; Calyx dark brown, hairy outside and fleshy, grey-silky inside; Petals are bright orange-red; stamens, 2-adelphou;ovary shortly stalked; Pod 10-15 cm, bearing single seed at the end of the pod: (Anupama 2013)

The Butea monosperma is famously known as the “flame of the forest” and the reason behind the tree getting accorded this name is that it bears very bright flowers which are either orange or scarlet in color. When the tree is in full bloom, the flowers grow in a number of clusters and the appearance of the tree is then such that it looks as if it has been set aflame, hence, the name. The tree Palash is of medium height and has compound leaves. The leaves of the tree fall off in the winter season and the flowers then
bloom in the months of February and March. The flowers grow in huge clusters and on leaf-less branches. The fruits that the plant bears are in the shape of flat pods and each fruit contains a single seed within itself.

2.10.3 Medicinal Value of Palash

The tree *Butea monosperma* was discovered in India and its therapeutic properties were first discovered here as well. Its parts have been used ever since for various medicinal purposes.

It is a medicinal tree and its different parts are used to cure various clinical disorders. Palash is used as tonic and anthelmintic in Ayurveda. In Ayurvedic treatise Acharya Charak and Sushruta mentioned the medicinal use of seeds and bark. Chakradatta described its gum as astringent and seeds as anti-parasitic. Palash is considered anti-inflammatory, antimicrobial, anthelmintic, anti-diabetic, diuretic, analgesic, antitumor and astringent. Its leaves are astringent, diuretic and anti-ovulatory properties. Its flowers are tonic and nutritive. Its roots are used to treat night blindness (Book: Anupama, 2013)

Literature Himalayan Drug co. have used this flower for their products for chemotherapy related and skin related diseases.

2.10.4 Characteristics of *Butea monosperma*

It is an erect, medium sized tree of 12-15 m high, with a crooked trunk and irregular branches. The shoots are clothed with gray or brown silky pubescence. The bark is ash colored. The leaves 3 foliate, large and stipulate. Petiole is 10-15 cm long. Leaflets are obtuse, glabrous above, finely silky and conspicuously reticulate veined beneath with connate or deltoid base. From January to March, the plant is bald.

2.10.5 Flowers – The Natural Dye

Flowers in rigid racemes of 15 cm long, densely brown velvety on bare branches. Calyx is dark, olive green to brown in colour and densely velvety outside. The corolla is long with silky silvery hairs outside and bright orange red. Stamens are diadelphes, anthers uniform. Ovary 2 ovule, style filiform, curved and stigma capitate. Pods argenteo-canescent, narrowed, thickened at the sutures, splitting round the single apical seed, lowest part indehiscent. The seeds are flat, reniform, curved. (La-Meddica Journal, Seshadri et.al., 1971).
The main constituent of the flower is butrin (1.5%) besides butein (0.37%) and butin (0.04%). Also contains flavonoids and steroids. Later studies proves that isobutrin slowly change to butrin on drying.

The flowers form a gorgeous canopy on the upper portion of the tree wears a kind of exquisite orange and red color. Flowers start appearing in February and stay on till the end of April. The flowers yield an orange dye, which is used to prepare traditional Holi colour. (Divya Fagaria and Rao, 2015). (www.ijsrp.org)

2.11 MORDANTS

The word ‘mordant’ comes from the Latin word ‘mordere’ meaning ‘to bite’ as in ‘to fast onto’. Mordants are substances that are used to fix a dye to the fibers. They improve the dye take-up and fix it permanently into the fibers, enhancing light – and wash – fastness, states Dean, (2001).

Naik et al. (2006) observed that mordants form insoluble aggregates with the dye molecules, by which they help in absorption and fixation of the dye and trapping within the dye and trapping within the fibre structure, thus offering high fastness properties. (http://www.dainet.org/livelihoods/1297d.htm).

There are three types of mordants, metallic, tannic, and oil. Metallic mordants are alum, potassium dichromate, ferrous sulphate, copper sulphate, and stannous chloride. The type of mordant used will affect the color produced by the dye stuff, and as a result a variety of shades can be produced from a single dye bath by treating with different mordants, explains Nadiger et al. (1997).

Tannic acid mordant is considered as a natural mordant. The word tannin derived from the early French word ‘Tan’ which means bark of an oak. Tannins are naturally occurring coloring compounds of high molecular weight, revealed Gill and Singh (2005). The term tannins was introduced by Seguin in 1796 to describe the substance present in the number of vegetable extracts, expresses Gulrajani (1999).

In dyeing of turkey red color using madder, oil mordants are mostly used. Which form a complex with the metal salts present to give turkey red color of superior fastness and hue, says Nadiger et al. (2004).

Mordants are considered as a significant part of the natural dyes or to be more precise the natural dyeing process by the dyers of natural dyes. This is an anomaly
which continues to be perpetuated by different authors and practitioners of natural dyeing. (Chattopadhyay et al. 1997).

There are different mordants like Alum stannic chloride, stannous chloride, ferrous sulphate, oxalic acid and zincoxide, which are used in the dyeing and printing of colors extracted from vegetables. Of the above mordants, alum is the major mordant which was used from the beginning in the vegetable colors in India, particularly in Machilipatnam and the Coromandel coast. The dyers and printers of this area have been using alum as the main mordant to obtain different colors, and some dyestuffs would yield a variety of colors with different mordants and different concentrations.

Alum has been used for centuries in Europe and it damages the fiber least and gives a great sparkle to the hue and hence it is the most sought after mordant. For best results, yarn or fabric samples mordanted with Alum will be left overnight in cool, dark place before dyeing. (Anderson 1971).

2.11.1 Aluminium Sulphate (Alum)

Alum is the most commonly used mordant and is in the market has been in use since ancient times. Alum, helps to reduce the amount of mordants needed for fixation and brightens and evens the final color of cloth, remarks Wells (2000). True “Alums” by historical definition are double salts of aluminium, for quality control and as a performance test, elongation is increase in the length of the specimen, tells Kothari (1999).

In dyeing of most vegetable colors, mordanting and coloration are the two known processes. The mordanting prepares the material to be dyed to receive the dye. Mordant should not affect the physical characteristics of the fiber. A mordant must not flatten i.e. dull or deaden the luster of the fiber. But if anything is raised or brightened it for penetrate into the fiber thoroughly. Different mordants give varying colors with the same dyestuff. Alum, Iron, Tin, Chrome and Copper mordants are used commonly. (Singh.K.2004).

2.11.2 Myrobalan:

Chebulic myrobalan is a moderate or large deciduous tree with a darkbrown bark exfoliating in wooden scales. It is also known as Haritak in Sanskrit, Harda in Hindi, and Kadukkai in Tamil. The fruit is the most useful part of the tree, since it is rich in tannin. Depending upon the geographical source, they vary in tannin contents. Myrobalan has been used as a medicine as well.
2.11.3 Methods of Mordanting

The percentage of chemicals and the weight of the material to be dyed are very important. The details of chemicals to be used for various mordants with their quantity, fixed temperature has to be maintained. Duration of time and the procedure to be followed after mordanting and before dyeing have to be followed strictly. There are three ways of mordanting. Mordant and dyes may be applied in three ways. They are as follows:

- **Pre-Mordanting** – where the mordant is applied first, followed by dyeing.
- **Post Mordanting** – where the dyeing is done first, and then mordanting is carried out.
- **Simultaneous mordanting** - where mordant and dye are mixed together and applied.

Mordants are commercially available commonly in the form of salts from metals, such as chrome, copper, tin, iron and aluminium. These mordants are listed in descending order of relative toxicity. Other types of mordants which are not metal mordants are tannins, cream of tartar, baking soda and vinegar. The latter two serve to change the alkalinity and acidity respectively of the dye, another property that influences the final color. Besides metallic salts, tannins and other inorganic compounds sometimes oils, such as oil of turkey and its type are also used as mordants. It is often remarked that the addition of a mordant to an appropriate dye solution results in a very sudden dramatic change in color. This is due to the incorporation of the metal atom into the delocalized system of the dye. Metals have relatively low energy levels, so their incorporation into a delocalized system results in lowering of the overall energy. The absorbance of the hue and thus its color is related to this phenomenon (Rao, 2006).

2.12 Textile Testing:

Bharathi (2004) expressed the different structural properties were considered for different types of fabric, depending on the end use, special properties in the fabrics and tests may be performed to assess these properties. Testing of fabric is very important to ensure the quality of garments.

- **Influence of Fibre Properties on Fabrics**

  The fibre properties and the method of spinning influence the yarn properties, while the fabric properties are also influenced by warp and weft density of the woven fabrics and weave, weaving conditions, e.g. speed of weaving, warp insertion rate, weft beat-up.
force, the way of shed opening, warp preparation for weaving, warp and weft tension
number of threads in reed dent, construction and technological parameters and finally the
treatments that are given to them Dubrovski (2010).

The anisotropy of the fabrics causes considerable fabric deformation even at low
loads, and this deformation is important for tailoring, as well as fitting a garment(Pavlinic
and Gersak, 2009).

The main factors that reduce service life of the garment are heavily dependent
upon its end use. Certain parts of apparel, such as collar, cuffs and pockets, are
subjected to serious wear. In home textiles like carpets and upholstery fabrics, socks and
technical textiles also abrasion is a serious problem. Yarn abrasion is also important
factor that should be considered during processing (Özdil et.al.,2012).

The uniaxial or biaxial tensile properties of fabrics, compression, shearing ,
bending rigidity, bursting and tear resistance are influenced by the mechanical properties
of woven fabrics like fibre properties, and their molecular properties and structure.
The mechanical properties of fibres depend on their molecular structure, where
macromolecules can be arranged in crystalline (unique arrangements of molecules) or
amorphous (coincidental arrangements of molecules) structure. The macromolecules are
orientated mostly along the fibre axis and are connected to each other with intermolecular
bonds. When a force is applied, the supra molecular structure starts changing (Geršak,
2006).

Fibres in use are subjected to a variety of different forces, which are repeated
many times (Hearle and Morton, 2008).

The mechanical properties and dimensions of the fibres such as fibre type, fibre
fineness and fibre length are the main parameters that affect abrasion. Fibres with high
elongation, elastic recovery and work of rupture have a good ability to withstand repeated
distortion and hence a good degree of abrasion resistance (Hu, 2008).The removal of the
fibres from yarn structure is one of the reasons of the abrasion. Therefore, factors that
affect the cohesion of yarns will influence the abrasion resistance of fabrics as well.
• **Abrasion**

Abraison is the physical destruction of fibres, yarns, and fabrics, resulting from the rubbing of a textile surface over another surface (Abdullah et al., 2006). Abrasion resistance and durability are frequently related, and the relationship varies depending on different end uses, and different factors may be necessary in any calculation of predicted durability from specific abrasion data (ASTM; D 4966).

• **Creasing**

Creasing is a very complex phenomenon dealing with combined action of several forces like bending, flexing, tensile, etc. It an aesthetic property and has direct bearing with the constituent yarnfibers of which it is composed of and finishes applied. The crease recovery angle is an important fabric property and can be associated with the aesthetic property of fabric. Fabrics are available in different weights measured per unit area (Kanade and Koranne, 2015). Flexural rigidity may be converted into quantity called the bending modulus that takes account of thickness. Flexural rigidity itself is highly dependent on thickness; in fact, doubling the thickness increases the flexural rigidity eightfold. The bending modulus, on the other hand, is in a sense a measure of the intrinsic stiffness of the material. Generally speaking, it reflects the degree of compactness or of the adhesion between fibres and threads—the difference between what is described as a “full” handle and “papery” (Peirce, 2008).

Crease recovery angle increases in the warp and weft after the enzyme treatment, and this is a positive attribute to the consumers. Statistical values indicate that there is a high significant trend after the treatments. (P.Aparna and Saradha Devi, 2013, Asian Journal of Home Science).

**Thickness of the Fabric**

• **Stiffness**

Fabric weight is the mass per unit area of a fabric. Stiffness is resistance to bending (ASTM, 2005). Basu (2006) states that stiffness is an important characteristic of a fabric. The importance of stiffness depends on the end use of the fabric.

Stiffness was influenced by yarn count, where higher the count, the stiffer it would become. (P.Aparna and Saradha Devi 2013, Asian Journal of Home Science).
• **Weibull distribution**

Weibull distribution is used for characterizing the variability in the mechanical properties of the fibers. This has become a well established and predicts the inherent dispersion in strength of brittle materials. Weibull modulus has been widely used in estimating chance of failure.

The Weibull modulus parameters determine the shape and location of the cumulative distribution function. The Weibull modulus which is the shape factor has a value between 1 to 5 for natural fibers. On a normalized scale, a higher m leads to a steeper function and thus a lower dispersion of strength. Once a set of experimentally measured strength value are obtained, it is desirable to fit the Weibull equation to determine the two parameters, knowledge of which leads to complete characterization of the fibers.

**Overall Moisture Management Capacity (OMMC) :**

Hu et.al (2005) have developed a new moisture management test for characterizing liquid moisture management properties. Ten indices are used to characterize the overall moisture management properties. It was demonstrated that eight sets of sports wear, which were tested, showed significantly different values. The fabric that gave a higher value of OMMC (Overall Moisture Management Capacity) was regarded as the best fabric. It was found that OMMC was significantly correlated with both moisture sensations at 15 and 20 minutes but not at 0 and 5 minutes during the trial running.

Wardiningsih and Troynikov (2012) were the first research workers to report on the influence of cover factor on liquid moisture transport performance of bamboo knitted fabrics. Tanveer Hussain (2015) et al., have reviewed the factors that affect moisture management control. This subject has attracted the attention of many research workers. Wang et al., (2007), have reported on the effect of moisture management on functional performance of cold protective clothing. It was reported that mesh polyester had exhibited higher OMMC. Two kinds of clothing system were tested and both had the same four layer structure (underwear, vest, coat and outer jacket), but with use of different functional fabrics. A climatic chamber in which a temperature of -15°C, could be employed was used. Eleven young male subjects participated. They were dressed in clothing ‘A’ and ‘B’, and walked on a tread mill. The humidity and temperature at the skin surface and at different layers of the clothing system were measured together with
measurements of thermal and moisture sensation. That the moisture management property of fabrics significantly affected the moisture difference on and a temperature distribution in the cold protective clothing systems has been shown.

**Color Fastness Tests**

- **Introduction**
  
  Color is one of the most important factors in consumer acceptance of textiles. Retention of color is equally important to consumers and is often a determining factor in the serviceability of a textile item. Color fastness depends on the dye; the fiber and the method by which the dye is applied, described Collier and Epps. Color fastness is the property of a dye or print that enables it to retain its depth and shade throughout the wear life of a product indicates Kothari.

  Color fastness to Sunlight
  Color fastness to Washing
  Color fastness to Dry and Wet Pressing
  Color fastness to Dry and Wet Crocking
  Color fastness to Perspiration

  In all the above color fastness evaluation of the fabrics, a change in the original color (shade) and / or staining or color transfer on the standard test fabric was evaluation by visually comparing the test specimen to the AATCC grey scale for color change, staining and chromatic transference scale.

  Fastness to washing is of great importance to the consumer and there are several washing tests which are applied according to the purpose for which the material is intended, express Raul (2005). Light fastness refers to a fabrics’ ability to maintain its original color when it is subjected to light up to a prescribed exposure level, says Yates (2002).

  **Grey Scale**

  - **Color Fastness to Sun Light**

    Light has a deteriorating influence on all regenerated cellulosic products, and degradation takes place on the surface exposed to sunlight states Mishra. Color fastness of light depended on the number, nature and position of constituent groups on the dye chromosperes denotes Guptha.
• **Color Fastness to Perspiration (Acidic and Alkaline) Perspirometer**

The color fastness to perspiration test method is intended for use in determining color fastness of colored textiles to the effects of perspiration. It is applicable to dyed, printed or otherwise colored textile fibers, yarns and fabrics of all kinds and to the testing of dyestuffs as applied to textiles states AATCC. **Prayag** denotes that human perspiration is of two kinds, acidic and alkaline, therefore the test is carried out using acidic and alkaline liquors separately.

**Hall** expresses that artificial perspiration tests have been devised in which colored material is treated successively with special and alkaline liquor whose effect closely resembles those of human perspiration.

The samples were evaluated for color change and staining using respective grey scales.

Yates (2002), tells that the grey scale is a pre-established, printed gradation showing various shades of grey from lightest to black. The fabric is evaluated on a scale from 1 to 5 according to how many values on the grey scale separates the two. 5, indicates no color loss, and 1, indicates severe color loss. These classes may be described in qualitative term as follows:

- Class 5    Excellent
- Class 4    Very Good
- Class 3    Good (Average)
- Class 2    Fair
- Class 1    Poor

Generally, those items exhibiting color fastness equivalent to class 2 or 1 are considered unacceptable from the consumer's point of view.