Application of Antimicrobial Finish on Khadi Fabric Using *Acorus calamus*

By

Tharani, S

(13PTF016)

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

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Certified as Bonafide Research Work

27/3/15

Signature of the Head of the Department

Signature of the Guide

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1. INTRODUCTION

The textile industry is a diverse one, as much in the raw materials it uses as the technique it employs. At each stage of the textile industry, the negative impacts on the environment are as numerous as they are varied. The need for eco friendly textiles is being voiced soundly at present day times. So, the fibre, yarn, fabric, manufacturing process, finishes used, and treatment methods involved should not affect the environment, considering cradle to grave effect.

An attempt to apply antimicrobial finish on khadi cotton using a natural herb was intended as people are becoming more conscious about health and hygiene and Khadi cotton was selected for this as it has historical importance and deserves to be promoted and preferred by the mass. According to Thilagavathi *et al.,* (2005) the continuing environmental pollution makes it necessary to find new ways to enhance the health and hygiene qualities of consumer products. Textile consumers all over the world demand functionality in the products especially properties that relate to the protection of humans from the attack of microbes. The attitude of consumers towards hygiene and active lifestyle has created a high demand for antimicrobial treated textiles. At present, the trend is such that people keep commuting to various places in their day to day lives. They come in contact with microbes at their work places, public transports, vehicles, rest rooms and hospitals. Microbes are everywhere and they cannot be prevented from coming in contact with humans. They can only be restricted to a particular level.

Earlier people used herbs with medicinal properties to fight against microbes. Well known among them are neem and turmeric. It was applied directly on the skin on the affected areas to cure it. Later it was applied on bandages as such. As the technology developed, it was attempted to apply on textiles that are used in our daily life. At first the methods used for applying the finishes on fabric involved using chemicals which turned out to be harmful for the environment. And the search for environment friendly application methods started. Now at the present times, the sources used to give the antimicrobial property to the fabric and the method of application onto the fabric is entirely eco-friendly. Constituents from traditional herbs and plants are extracted to impart the property to fight against the microbes.

Microbial infestations pose danger to both the living and non-living beings. Obnoxious smell, spread of diseases, staining and degradation of textile materials are some of the detrimental effects of bad microbes. For these reasons, it is highly desirable that the growth of microorganisms on textiles be minimized during their storage and use. The antimicrobial finished textiles were desired to reduce the growth and transmission of microorganisms. The textiles can be treated with antimicrobial finishes to suppress or prevent the detrimental effects. At present, the application of antimicrobial finish is confined to specialty products in the medical, technical, industrial, home furnishing and apparel categories. Antimicrobial activity is inevitable to the fabrics that come in close contact to the body. In addition to apparel fabrics, industrial fabrics used for awnings screens, tents, tarpaulins, ropes and similar products need protection from rotting and mildew as they are exposed to weather.

In several instances, home furnishings such as carpets, shower curtains, mattress ticking and upholstery are treated with antimicrobial finishes (Paul, 2014). Also it is essential for fabrics used in hotels for the table linens, crowded public areas, nursing homes and hospitals as they are the places which are highly prone to microbial attack. An antimicrobial property present in clothing, healthcare fibrous product and home textile may come in contact with an individual’s skin or it may be affecting any living species found in the surrounding environment. Concern for this issue is growing and hence it is preferred that the antimicrobial finish is induced to the textiles from a natural source like an herb or plant (Uddin, 2014).

A number of Indian herbs and plants do have antimicrobial properties. Developing an eco-friendly natural antimicrobial finish from plant extracts for textile application will help to satisfy the needs of the ever demanding consumers. *Acorus calamus* is a tall perennial wetland monocot of the Acoraceae family. They have scented leaves and more strongly scented rhizomes that have traditionally been used medicinally and to make fragrances. It has been an item of trade in many cultures for thousands of years. It has been used medicinally for a wide variety of ailments. It has a very long history of medicinal use in Chinese and Indian herbal traditions. It is used in various Siddha and Ayurvedic medicines. The rhizome extract of the herb exhibits antimicrobial activity, says Pullaiah (2006). Hence the investigator has selected *Acorus calamus* possessing the antimicrobial property to apply on the fabric.

The increasing environmental concerns and demands for an environmentally friendly processing of textiles leads to the development of new technologies, the use of plasma being one of the suitable methods. The conventional wet treatments applied in textile processing for fibre surface modification and others are associated with many constraints. These treatments mainly concern with energy, cost and environmental issues. Application of plasma technology at low temperature in textile processing can prove to be the best alternative for these issues. Unlike conventional wet processes, which penetrate deeply into fibres, plasma only reacts with the fabric surface that will not affect the internal structure of the fibres. Plasma technology modifies the chemical structure as well as the surface properties of textile materials.

Khadi is a pure cotton material. Cotton is also known as the ‘King of fibres’. Among the textile materials known to man, cotton is the best for comfort and use. Cotton fabrics can withstand heavy wear and tear. They can be subjected to ironing processes without risks as they do not melt or pill. Also they can be easily washed using both hot and cold water thus making maintenance very easy. They have very good affinity to finishes hence it is the best suitable textile material for finishing processes.

Considering all the above facts, the investigator has taken up a study on “Application of Antimicrobial Finish on Khadi Fabric Using ***Acorus calamus***”, with the following objectives.

- to extract the essence from ***Acorus calamus*** rhizome
- to impart antimicrobial finish on khadi fabric
- to develop end products

2. REVIEW OF LITERATURE

The review of literature pertaining to the study entitled "Application of Antimicrobial Finish on Khadi Fabric Using ***Acorus calamus****"* is expressed under the following heads.

2.1 Natural fibres

2.2 Finishes in textiles

2.3 Medicinal plants/herbs

2.4 Home furnishings

2.1 NATURAL FIBRES

Natural fibres are advantageous as they are environmentally safe and non toxic. They do not cause any kind of skin irritations. They are fully biodegradable and hence are easy to dispose off. Being natural, the supply of raw materials is always renewable abundant and continuous. They are extremely easy to handle during various processes. The cost of the fibres is comparatively low (Salit, 2014).

As textiles have developed over many hundreds of years, the most suitable natural fibres have been selected and have become the basis of the textile industries of the world (Mohanty *et al.*, 2005). Today, as for many years past, cotton, wool, jute, flax and silk are the most important of our natural textile fibres, with a number of others doing relatively unimportant jobs (Shah, 2009).

Natural fibres can be divided as vegetable fibres, animal fibres and mineral fibres. Vegetable fibres include the most important of all textile fibres – cotton – together with hemp, flax, jute and other fibres produced by plants. They are based on cellulose, the material used by nature as a structural material in the plant world (Kaila *et al.*, 2011).

Among other natural fibres such as flax, hemp, wool and silk, cotton is widely used. It is considered to be quite versatile. It can be converted into fluffy as well as fine yarns. It is a fibre that breathes; consumers prefer cotton for its comfort, good heat and electrical conductivity, laundrability, absorbency, ease of finishing, dyeing, strength and cost (Singh, 2010).

Cotton fibres range in dimensions from 5 cm to 1.5 cm. It is hydrophilic and porous on immersion in water, it swells and its internal spaces fill with water (Kozlowski, 2012). Wool from sheep has been used as a textile fibre for years. It is a keratin protein fibre. The various breeds of modern sheep produce a wide range of wool types, which are classified according to fibre length and diameter. Early breeds of wild sheep were covered in a brownish coat that was shed annually.

2.1.1 Cotton and its importance

Cotton is purely a cellulose fibre that grows in the hair pod (boll) of cotton plants (Barker *et al.*, 2007). It is the product of a shrub of the Malvacea genus and Gossypium class. The fibre is short and fine usually about 1 inch long (Mahadevan, 2009). Cotton is the most important natural fibre in the world. They are the most traded of consumer goods during the industrialization age (Riello, 2013). It is grown and cultivated in warm climates. Wax, seed oil and natural colouring matter are the chief impurities found in the surface. Once these external impurities are removed, it is purely cellulose. Cellulose is the fibre forming material in these fibres (Clarke, 2004).

Cotton is usually white. It can also be yellowish white, bluish white, creamy white or grey. The wear life of the cotton fabric is high due to the strength of the fibre. The strength of the fibre is more when it is wet than when it is dry (Singh, 2007).

Cotton is always comfortable to touch and wear due to its high absorbancy. It absorbs and releases the perspiration quickly thus allowing the fabric to breathe (Thomas, 2006). It is a good conductor of heat. It draws the heat away from the skin to keep the wearer cool (Singh, 2007).

2.1.1a Properties of cotton

The properties of cotton fibre are such that it serves as nature's utility fibre. It combines attributes like durability and comfort in wearing. It is inherently strong because of the convolutions that create friction between the yarns and thus avoiding seam slippage. It has very little lustre and so is called "dead" fibre (Mahadevan, 2009). But the lustre of the fibre can be improved by mercerizing process. Cotton can be repeatedly washed or dry cleaned without the fear of damage (Rattan, 2007). Cotton fabrics shrink on washing but the fibre itself is stable dimensionally (Lewin, 2006). It is soft and hypoallergenic, meaning it does not irritate even sensitive skin. They are generally crisp and can hold their shape well. Cotton can be easily blended with other fibres be it synthetic or natural fibres. It is a relatively stiff fibre but on wetting, it becomes pliable and soft (Wilson, 2005).

Cotton fabrics are available in every conceivable quality, coarse and fine; in a huge variety of woven and knitted constructions; and it blends with both natural and synthetic fibres. The various types of woven coton fabrics are Diaper cloth, Dimity, Drill, Duck, Flannel, Flannelette, Gauze, Gingham, Lawn, Muslin, Organdie, Outing flannel, Percale, Pima Cotton, Polished cotton, Poplin, Oxford, Sail cloth, Seersucker, Swiss, Terry cloth, Velveteen, Whipcord (Thomas, 2006).

Cotton is only slowly attacked by sunlight, since cellulose lacks for the most part groups which absorb ultraviolet light between 300 and 400 nm. There is a gradual loss of strength when exposed to sunlight for long hours. The fabric starts to turn into yellow in colour. The damage caused will be due to the UV radiation than the heat (Mendelson, 2005).

Cotton does not stress easily. It has elongation at break of 5 to 10%. Elastic recovery of cotton is only 75% after 2% of elongation (Gordon *et al.*, 2006). Cotton withstands heat very well. They can withstand a hot iron. It has good resistance to degradation at heat. It begins to change yellow in colour after a long time at 120 ºC. Decomposition starts at 150ºC. Cotton exhibits a small loss in its strength when stored safely for a long period (Mendelson, 2009). The fibre itself does not shrink but the fabrics made of cotton shrink during washing as they are stretched during the various finishing processes (Parvathi, 2007).

Cotton is easily affected by bacteria and fungi. It is also attacked by mildew as it retains water and nutrients. Mildew will feed on the cellulose rotting and weakening the fabric. Mildew will flourish in cotton under hot and humid climate (http://textilefashionstudy.com/cotton-fiber-physical-and-chemical-properties-of-cotton/). Favorable preconditions for the growth of microorganisms are particularly created by the combination of heat and high atmospheric humidity during storage in still air. (Mahall, 2003). Microbial growth leads to odour development, discolouration and loss of functional properties. This calls for the need for antimicrobial finish on cotton materials for better durability and protection to the consumers while using the products (Duquesne *et al.,* 2007).

2.1.1b Applications of cotton

The principal use of cotton is in the clothing industry. The apparel industry produces well known products like denim blue jeans, chambray work shirts, seersucker corduroy and twill fabrics from cotton. Other products like trousers, blouses, shirts, T-shirts, socks, under garments are produced widely. The share of cotton consumed in home textiles accounts for 38% (Das, 2010). Another class of cotton products is the non wovens. They are usually produced from the cotton waste of the apparel industry. These products are bleached and do not have added chemicals (Gordon *et al.*, 2006). They are mainly applied for medical products. These non woven products have the absorbancy of cotton fibre as the main advantage. Surgical sponges, sanitary supplies and cosmetic applicators are made of non woven cottons. Personal care cotton products are finish free. Other cotton products are applied with a finish to change the surface qualities to suit the end use (Singh, 2010). Cotton is used universally for a variety of apparel (both inner wear and outer wear). It finds extensive usage in home textiles sector. Its softness makes it the most preferred fabric for under garments and other garments worn next to skin. The fibre also has innumerable uses in industrial applications including surgical, medical and sanitary supplies. It can be safely boiled and sterilized, thus making it valuable in the hygiene sector (Sekhri, 2012).

2.1.1c Finishes on cotton

Cotton fabrics are extremely receptive to chemical and mechanical finishes. At any stage, cotton fabrics can be subjected to a variety of finishes. Most cotton goods are improved in appearance or are rendered more slightly by adding filling or by smoothing down the size already present in the warp yarn (Barker, 2009). Some basic finishes on cotton are: scouring, bleaching, mercerizing, singeing, ammoniating, and shrinking. These are the preparatory processes used for preparing the cotton fabrics for manufacturing of consumer goods. Apart from these, aesthetic and functional finishes are applied to enhance the fabric. Of all the textile materials, cotton has the most affinity to finishes (Fletcher, 2008).

2.1.2 Khadi

Khadi has its roots in the freedom struggle of India. Khadi, was central to Gandhi’s vision of self-reliance and self-rule. Gandhi wanted Indians to spin their own cotton thread and to weave Khadi, by providing employment to many Indians and contributing to the country’s self-sufficiency. Hence, he was the first true Indian designer (Namrata and Naik, 2014)

For more than sixty years, khadi has been linked with India’s fight for freedom. However, designers do not just see the garment as being merely eco-friendly but luxurious-defining ‘haute couture’. Unlike other fabrics, khadi has stood as a testament of India’s past and is proof that ‘old is truly gold’ (Anjum, 2011). The material that symbolized self-reliance and emancipation during our freedom struggle has lost its sheen over the years. With many industrialists setting up textile mills, the mass production of fine cloth led to the availability of cloth at lower prices which in turn diminished the popularity of khadi (Mishra, 2014).

Khadi, the term indicates the village or cottage industries. khadi is typically a cotton fabric that is hand spun and hand woven with the help of charka, the spinning wheel (Ross, 2013). At first, khadi was available only in white colour which looked drab. But later coloured khadi came into existence and people started using khadi a little more than before (Trivedi, 2007). There is often an erroneous assumption that links khadi with other handloom products. What distinguishes khadi from handloom is that khadi is hand-spun, whereas handloom yarn, on the other hand, is processed in the mill (Namrata and Naik, 2014)

The making of khadi is eco-friendly since, it does not rely on electric units and the manufacturing processes do not generate any toxic waste products. In fact, in some states like Madhya Pradesh and Maharashtra, organic khadi is produced by avoiding all chemicals involved in the farming of cotton and during weaving and dyeing of fabric (Mishra, 2014). Khadi does not require as much capital as mills do and it does not require as much skill. The cost of production is very low as the consumption of space and power is less. Production of one metre of khadi consumes just three litres of water against 55 litres consumed in a conventional textile mill (Anjum, 2011).

2.1.2a Khadi production

The production of the fabric undergoes the following stages: yarn spinnig, yarn winding, warp separation, sizing, drawing and denting, weft preparation, weaving in the hand loom. The spinning process is done by hand using the traditional charkha with varying number of spindles. In the beginning, 2-spindle charkha was used later 4-spindle, 8-spindle, 10-spindle and 12-spindle charkhas came into existence. Farmers pick out cotton from fields. These cotton bolls are very coarse in nature and the fibres have to be separated from the seeds by hand using a sharp comb-like object (Sharma and Mishra, 2014). A process called ‘carding’ removes the final traces of waste from the cotton to produce what are called ‘slivers’. These are then spun into a yarn on a spinning wheel or a charkha, which turns out the slivers and twists them at the same time, thereby strengthening them. It is a completely manual process (Sahoo and Lodha, 2013). The khadi industry has a tradition of forming textiles using natural yarns like cotton, silk and wool. Most of the processes involved in the industry are carried out manually without the use of machineries (Trivedi, 2007).

2.1.2b Properties

In khadi production, since the spinning and the weaving are done by hand, high quality yarn cannot be expected (Ross, 2013). The yarn will not be so smooth and uniform as it is handspun. The aspect which makes khadi so unique and resilient is that it keeps the wearer warm in winter and cool in summer. It requires maintenance. Khadi looks good when it is starched but it does not remain the same after washing (Sahoo and Lodha, 2014). Khadi is expensive when compared to the mill fabrics as it involves laborious processes throughout the manufacturing process (Namrata and Naik, 2014).

2.2 FINISHES IN TEXTILES

Finishing is the term that encompasses a vast array of materials and activities. Unfinished textiles are virtually nonexistent (Jackman *et al.*, 2003). Finishes are surface treatments that are done to a fabric aiming to improve its aesthetic and functional performance. Some finishes are applied wet, some dry, some cold and some hot. Finishes given to the fabric will depend upon the end use (Clarkson *et al.*, 2002). Consumers have been using various chemical and mechanical finishes to improve the aesthetic and functional purposes. The two main categories which have become very famous and important in textile finishing are the comfort and protection functions (Gulrajani, 2013).

Special finishes are directly related to the end use of the product. They may improve the appearance of the fabric or give the fabric a functional ability or they may enable the fabric to perform a certain function effectively. Finishes affect the feel of the fabric. Customers who give priority to the performance of the products pay attention to the type of finishes given to the textile material to improve its functionality. Textiles that need to be stored for a long period like woolen blankets will require moth proof finishing and textiles that has to be used in hospital surroundings must have antimicrobial finishes (Fletcher, 2008).

2.2.1 Types

Finishes can be broadly classified as chemical and mechanical finishes. Mechanical finishes are carried out by machines that alter the surface of the fabric. Sometimes they are also called as physical finishes (Lawler *et al.*, 2002). In chemical finishes, water is used and then heat is used to drive off the excess water. Mechanical finishes do not make use of much water and chemicals to achieve the effect (Parmar, 2013). On the basis of durability finishes can be classified as temporary, semi durable, durable and permanent (Hargrave, 1997). Temporary finish may withstand just one wash or a few washes. Whereas permanent finishes withstand much number of washes, ironing and other fabric care activities. Some of the finishes that are frequently given to the fabrics are antibacterial or antiseptic finishes, antistatic finishes, care-free finishes, flame retardant finishes, insulative finishes, mothproofing, soil repellent and water repellent finishes (Nielson, 2007).

2.2.2 Plasma treatment

Plasma technology is an environmentally friendly technology and a step towards creating solid surfaces with new and improved properties that cannot be achieved by conventional processes (Jahagirdar and Tiwari, 2007). Plasma is a gas of which a fraction of its constituents are no longer electrically neutral. Instead, the atoms / molecules are ionized, that is they lose or gain one or more electrons. These free electrons are also present in the plasma. Practically, plasma can be generated by applying an electrical field over two electrodes with a gas in between. This can be carried out at atmospheric pressure or in a closed vessel under reduced pressure (Buyle, 2009). Several types of plasma are known; however, non-equilibrium or cold plasma is used for the modification of physical and chemical properties of solid materials such as textiles. Plasma readily interacts with solid surfaces, causing reaction that would otherwise occur only at elevated temperature of the solid material (Navard, 2012).

Plasma is used for synthesis of nanostructures with interesting properties, removal of thin films of organic impurities, selective etching of composites, sterilization, passivation of metal, ashing of biological materials, etching of photoresists and functionalization of polymers (Ferreira *et al.,* 2009). The choice of discharge parameters is determined by the requirements of each particular application. For treatment of delicate organic materials, weak plasma performs better. Aggressive plasma destroys organic material in a fraction of a second. The advantages of using plasma are ecological and economical (Kan, 2015).

The textile subjected to the treatment is modified without an alteration of the bulk properties. Plasma produces no more than a surface reaction, the properties given to the material being limited to the surface layer of a few nanometers. The modification of the textile substrates using plasma enables different effects on the textile surface activation to a thin film deposition via plasma polymerization (Hossain, 2009). Due to low material and energy input, while avoiding wet – chemical process, the plasma technology provides the realization of environmentally sound processes (Hegemann, 2006).

2.2.3 Antimicrobial finish

Microbes are tiniest of creatures not visible to the naked eye. Microbes are found all around in the environment. They are likely to attack all the materials especially textile materials as they come in contact with the human body (Duquesne *et al.,* 2007). The climatic conditions also play a vital role in the growth of microbes. The inherent properties of the textile fibres allow for the growth of the microorganisms. Hot and humid climate aggravates their growth (Kumar, 2013). Infestation of microbes causes functional, aesthetic (staining) and hygienic difficulties (Alagirusamy *et al.*, 2010). The most trouble causing among the microbes are the bacteria and fungi. Fungi cause more damage to fabric than bacteria. Fungi cause discoloration of coloured fabrics, staining and fibre damage. Bacteria causes little damage to the fibre, develop a pungent odour and make the fabric feel slick and slimy (Kan, 2014). There are two aspects of protection given by the antimicrobial finishes. One is the protection of the wearer from pathogenic and odour causing microorganisms and the other is the protection of the textile material itself from the attack of microbes (Schindler *et al.*, 2004).

2.2.3a Need for antimicrobial finish

The needs for antimicrobial finish are

- to avoid cross infections by pathogens
- to control the infestation by microbes
- to arrest the metabolism in the microbes to hinder their growth

- to avoid the loss of performance properties of the fabric as a result of microbial fibre degradation
- to protect the wearer from infections
- to avoid the formation of odour due to microbial degradation of perspiration (Nadkarnim, 2007) (Hipler *et al.*, 2006)

Antimicrobial textiles should satisfy certain requirements for best results. They should selectively target specific microorganisms. The manufacturing and the application process of the textile material should be low hazard. There should be no deterioration of the quality of the material during the various cleaning and ironing processes (Kozlowski, 2012).

2.2.3b Applications

Antimicrobial textiles are in great demand in various sectors such as sport textiles, medical textiles, home textiles and hospital sector. This finish is applied to textiles used for awnings, screens, tents, tarpaulins and ropes that are used outdoors (Maheshwari, 2012). Home furnishings such as curtains, carpets, bath robes, bath mats, shower curtains, mattress ticking and upholstery are also given antimicrobial finish (Kumar, 2013). Bed linen and table linen used in hotels, nursing homes, schools and crowded public areas are more prone to the infestation of microbes; hence they are finished with antimicrobial finish (Anand *et al.*, 2010).

2.3 MEDICINAL PLANTS/HERBS

The use of medicinal plants for health reasons started thousands of years ago and is still being widely used in countries like Egypt, China and India (Thomas, 2000). Medicinal plants are gifts from nature to cure innumerable diseases among human beings and animals. Plants are rich sources of chemically diverse compounds, many with beneficial properties to human health (Sreeja *et al.,* 2013). The existance of these plants has inspired many to experiment on their medicinal properties. Investigations have proven that many of these medicinal plants possess antimicrobial activity (Banupriya and Maheshwari, 2014). Many of the modern medicines are indirectly made out of medicinal herbs. Plants and herbs are directly used as medicines in many cultures, especially in Indian culture (Kokwaro, 2009). A herb in general is a plant that does not have a woody stem. But in the term “medicinal herb”, it need not be strictly a plant without a wooden stem but any plant with a medicinal value. The medicinal substances found in these herbs are the products of natural metabolism in the plant or herb. Each species has its own genetic structure that governs the constituents and its properties (Bever, 1986).

2.3.1 *Acorus calamus*

The word ‘acorus’ is derived from the Greek word ‘acoron’. *Acorus calamus* also commonly known as sweet flag is known to possess medicinal properties and is being used in parts of Asia since long (Singh *et al.,* 2011). It is a smelly perennial herb with creeping rhizomes and sword shaped leaves. The leaves are long and slender rising from the rhizomes which lie horizontally (Kumar and Vandana, 2013). The rhizomes are round with approximately 8.636 cm in diameter, smooth, pinkish or pale green. Its leaf scars are white, brown and spongy (Rahamoz-Haghighi *et al.*, 2014). The taxonomical classification of *Acorus calamus* is that it belongs to Kingdom - Plantae; Subkingdom - Tracheobionta; Super division - Spermatophyta; Division - Magnoliophyta; Class - Liliopsida; Subclass - Arecida; Order - Acorales; Family - Acoraceae; Genus - Acorus; Species - calamus (Divya *et al.,* 2011).

2.3.1a Habitat and distribution

Sweet flag or *Acorus calamus* is a perennial herb that can be found in marshy land, shallow areas and at the edges of ponds. Propagation is through vegetative means as the herb produces seeds rather rarely (Ahmed *et al.*, 2010). With sufficient amount of moisture and irrigation, sweet flag can be cultivated in any desired region. Both tropical and sub tropical climates are suited (Imam *et al.*, 2013). *Acorus calamus* can be found wide spread in regions of Europe, Southern Russia, northern Asia Minor, southern Siberia, China and India (Warrier *et al.*, 1993).

2.3.1b Constituents and properties

The rhizome bark of *Acorus calamus* has 1.5%-3.5% volatile oil, including beta - asarone in variable proportions, eugenol, asarone, caffeine, camphor, camphene, alpha- asarone, alpha-terpineol, sitosterol, galangin (McIntyre, 2005). The smell of *Acorus calamus* is because of the constituent asarylaldehyde in roots and asarone in leaves (Raja *et al.*, 2009). The pale yellow to pale brown volatile calamus oil has an odour described as “woody-spicy with increasingly sweet after notes and great tenacity” (Motley, 1994).

There are four types of calamus that are used medicinally. Type I - *Acorus calamus* L. var. americanus, a diploid American var; type II - var. vulgaris L. (var. calamus), a European triploid; type III and type IV – var. agustatus Bess.and var.versus L., subtropical tetraploids (Khare, 2007). Alcoholic extract of *Acorus calamus* has sedative and analgesic properties. Also they have excellent anti inflammatory properties (Jayaraman *et al.*, 2010). Extractions of *Acorus calamus* exhibit repellent actions on variety of pests. It has been found effective in controlling ants, clothes moths, rats and pests (Haverkort *et al.*, 1996). The oil of sweet flag has some potential for protecting the stored food from insect and pests (Small *et al.*, 1999). It has been listed as an antibacterial, antifungal, insecticide and a fish poison (Devi *et al.*, 2009).

2.3.1c Application

Indian practitioners use *Acorus calamus* mostly externally. In the Ayurvedic system of medicine, the *Acorus calamus* rhizome is considered to have aromatic, stimulant, bitter tonic, emetic, expectorant, emmenagogue, aphrodisiac, laxative, diuretic, carminative and anthelmintic properties (Rajput *et al.,* 2014). Dried roots have long been used for flavoring of bitter liqueurs and appetizers. It is also employed in the production of alcoholic beverages and beer (Avadhani *et al.*, 2013).

A decoction of the root is given as a carminative for colic, flatulence and peptic ulcers. Apart from these therapeutic applications, the dried rhizome is used as a brain tonic for treatment in weak memory, psychoneurosis and epilepsy. In China the powder is blown into the nose of a coma patient to regain the consciousness. In India the powder is mixed with ghee and given to a new born baby on the seventh day from birth to increase its intelligence and memory power. Common health issues namely chronic diarrhoea, dysentery, intermittent fevers, cough and asthma are also treated with sweet flag (Pattanaik *et al.,* 2013). As a nerve stimulant it has been used for insomnia, mental fatigue, anxiety, depression and other nerve disorders. In western herbal medicine, sweet flag is used to treat digestive problems such as gas, bloating, colic, and poor digestive function. It also helps distended and uncomfortable stomachs and headaches associated with weak digestion (Balakumbahan *et al.*, 2010).

2.4 HOME FURNISHINGS

Furnishing is any article that decorates a house and makes it more comfortable. Home furnishing plays a very important role in the enhancement of any home décor. Items like draperies, linens, towels, carpets and soft floor coverings come under home furnishings. All these work well for the complete decoration of a house (Jefferys, 2006). They include bedcovers, spreads, pillow cases, throws, cushions, bolster covers, curtains, bath linen, carpets and rugs. Home furnishing is a growing industry. The entire range of home furnishing is increasingly becoming accessible to the growing middle class due to their rising income. (http://www.india-exports.com/home.html). Customers expect some functionality in the products in addition to design and quality. Many special finishes are being given to the furnishings according to their end use and the surroundings in which they will be used. Some of the finishes given to the furnishings commonly are anti microbial finish, fragrance finish, anti static finish, snit-mite finish and flame retardant finish (http://www.fibre2fashion.com/industry-article/paidArticles/4962.asp).

Home furnishings or soft furnishings are the most happening thing in the textile and fashion business today. Home furnishings include a wide range of products – carpets and rugs, curtains, table linen, mats and runners, kitchen linen and other kitchen accessories, bathroom furnishings, window treatments, hammocks, bed linen, bed spreads, blankets, pillows and pillow covers, cushion and cushion covers, duvets and duvet covers and many others (More and Barnett, 2004).The textile fabrics most commonly used for home furnishings may be listed as cotton, silk, jute, rayon, wool, nylon, polyester, satin, organza and organdy (Das, 2010).

Home furnishings find application in upholstery, window textiles, bed linen and other bed textiles, bathroom textiles, kitchen linen and accessories, table linen and other table cloths, rugs and carpets (Rowe, 2009).

Upholstery is used for covering cushions and furniture. Window textiles include curtains, drapes and blinds. Bed linen and other bed textiles include bed sheets and pillow cases, bed spreads, quilt covers, duvet covers, cushions, blankets, mattresses, bed throws, sofa throws and many other items. Bathroom textiles include shower curtains, bath robes, bath mats, bath rugs and towels. Table linen and other table cloths include table mats, napkins, placemats, chair covers, chair mats and pads, table runners and coasters. For table linen, cotton and linen are extensively used. Rugs and carpets are a part of the floor coverings. Kitchen linen includes aprons, mittens, dishcloths and kitchen towels (http://www.teonline.com/knowledge-centre/home-furnishing.html).

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3. METHODOLOGY

The Methodology adopted for the study entitled “Application of Antimicrobial Finish on Khadi Fabric Using ***Acorus calamus***” is discussed under the following headings.

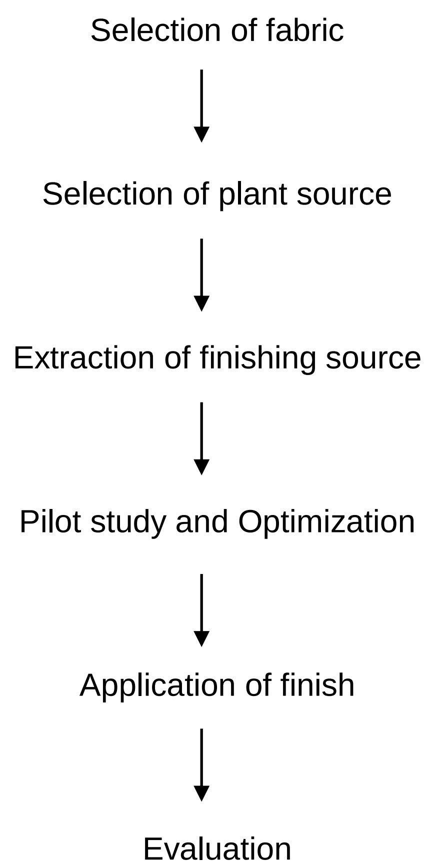


FIGURE – 1

FLOW CHART

3.1 SELECTION OF FABRIC

Cotton fabric is the most receptive fabric to finishes and is the fabric that is preferred universally (Mishra, 2014). So, Khadi cotton was selected for the application of the finish. Khadi with special finishes might be more desirable than the ordinary one. Khadi can be very well used for undergarments, fashion garments for infants and also for all age groups. It can also be used as furnishings namely table cloths, bath mats, curtains, pillow cases, bed covers, and napkins. It can be widely used in hospitals and hotels as well as at homes. Hence, khadi cotton was selected for applying the finish thus enhancing its status. (Appendix - I)

3.2 SELECTION OF FINISH

Antimicrobial finish can be applied to a fabric either by using chemicals or by using natural agents. Herbal antimicrobial finishes given to fabrics are gaining popularity and are proved to be effective and useful (Hooda *et al.*, 2013). Considering this fact, herbal source was selected for imparting antimicrobial property to the khadi material.

3.3 SELECTION OF PLANT SOURCE

The rhizome of the herb *Acorus calamus* contains active ingredients possessing antibacterial and antifungal properties (Avadhani *et al.,* 2013). So, this herb was selected for the study.

3.4 EXTRACTION OF *Acorus calamus*

Extracts of the rhizome was prepared using two solvents namely water and ethanol.

3.4.1 Ethanolic extraction

Ethanolic extraction was done in an orbital shaker (Plate I). An orbital shaker has a table board that shakes in a circular motion. The solutions to be stirred and extracted were taken in conical flasks. The board has holders to hold conical flasks. A protective ring is provided that has to be put around the holder and the flask together to secure it. The number of rotations per minute was set as 230 rpm and the temperature as 30ºC for a period of 24 hours following Behera *et al.,* (2014). After the extraction process was over, the solutions were filtered using filter paper to remove the residues in the extract. The filtered extract was collected in a sterilized beaker and stored in a refrigerator. The collected extracts were evaporated to remove the solvent. The evaporation process was done using a Soxhlet apparatus (Plate II). The extract amounting to 350 ml was taken in the round flask and the temperature was set as 35ºC. Thus the solvent was collected in the upper tubular flask. The collected solvent was stored in a container. This process was continued until all of the solvent was evaporated. The concentrated extract was collected and stored in a refrigerator.

3.4.2 Aqueous extraction

The aqueous extraction was carried out in a water bath (Plate III). About 10 grams of the herb was taken and soaked in 100 ml of distilled water. The mixture was allowed to boil in a beaker kept in a water bath. The temperature was set to 80ºC and the process was carried out for 30 minutes as explained by Johnson *et al.,* (2011). Then the solution was filtered and stored.

3.5 PILOT STUDY

A pilot study was conducted to check the antimicrobial activity of both extracts qualitatively by using the test method AATCC 147 (Agar plate test) It is a rapid qualitative method for determining antibacterial activity of treated textile materials against gram-positive and gram negative bacteria. The untreated (control fabric) and treated fabric samples were placed in nutrient agar that is streaked with test bacteria. Staphylococcus aurous for gram positive and E-coli for gram negative. Then they were incubated at 37ºC for 24 hrs to enable the bacteria growth as explained by Kumar *et al.,* (2009). After 24 hours, the bacterial growth was visually determined. For antifungal test AATCC method 30 was adopted. The untreated (control fabric) and treated fabric samples were exposed to Candida albicans in an agar plate streaked with the fungi. The petriplates were left to rest in room temperature for 3 days.

The zone of inhibition for both bacteria and fungi were measured using a metric scale. Ten readings were taken for each and the average was calculated. The average

PLATE – I

ORBITAL SHAKER

PLATE – II

SOXHLET

PLATE – III

WATER BATH

value was taken as the zone of inhibition. Then the zone of inhibitions formed for the aqueous extract and the ethanolic extract were compared. The extract with the larger zone of inhibition was chosen for further study. After the zones were measured, the decontamination process was carried out.

The zones of inhibition of the aqueous extract are exhibited in Plate IV and that of the ethanolic extract in Plate V.

3.6 OPTIMIZATION

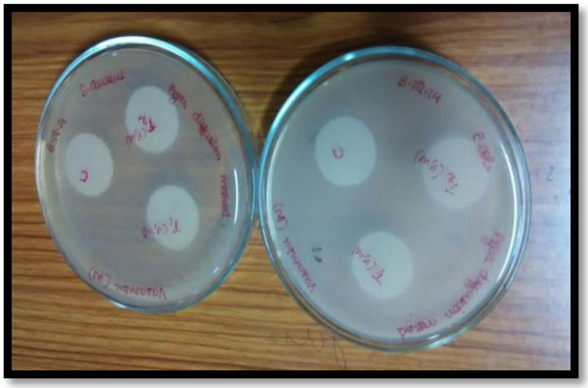
The concentration of the extract was optimized based on the antimicrobial activity. *Acorus calamus* was extracted using ethanol in five concentrations namely 2 percent (4 g in 200 ml), 4 percent (8 g in 200 ml), 6 percent (12 g in 200 ml), 8 percent (16 g in 200 ml) and 10 percent (20 g in 200 ml). The qualitative test for antimicrobial activity of the solutions was carried out. The AATCC agar diffusion method was adopted. The zone of inhibitions was recorded for each solution. The concentration that corresponds to the largest zone was decided as the optimized concentration. The zones of inhibition of the concentrations 2%, 4%, 6%, 8% and 10% are exhibited in Plate VI, Plate VII, Plate VIII, Plate IX and Plate X respectively.

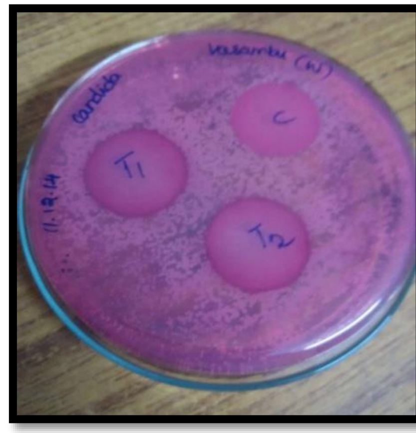
3.7 PREPARATION OF FABRIC

The size is a protective coating applied to the warp yarns. The desizing step is designed to remove the warp size. It is preparatory process carried out before applying any kind of finish to the fabric (Behery, 2005). So, the sized khadi cotton fabric was subjected to desizing to remove the size matter from the fabric. For desizing, the fabric was immersed in detergent solution prepared using soft water which was boiled for for half an hour. Then the fabric was taken out, rinsed thoroughly and dried in shade. Thus the desized khadi fabric was obtained. (Appendix - I)

3.8 APPLICATION OF FINISH

The application of the finish on the fabric was carried out using the following steps.





BACTERIA **FUNGUS**

PLATE – IV

ANTIMICROBIAL ACTIVITY OF AQUEOUS EXTRACT

BACTERIA

FUNGUS

PLATE - V

ANTIMICROBIAL ACTIVITY OF ETHANOLIC EXTRACT

GRAM +VE BACTERIA

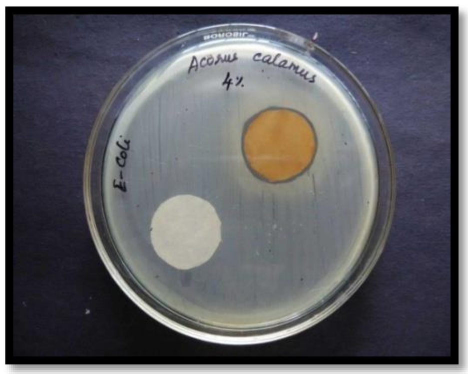
GRAM -VE BACTERIA

FUNGUS

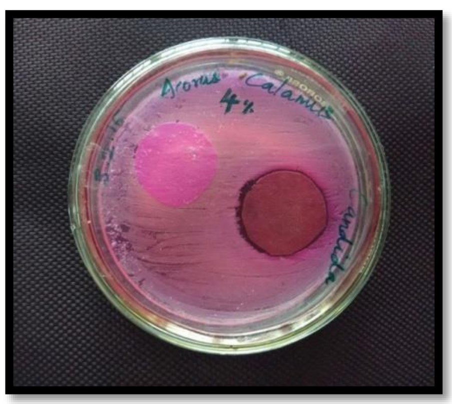
PLATE – VI

ANTIMICROBIAL ACTIVITY OF 2% CONCENTRATION

GRAM +VE BACTERIA



GRAM -VE BACTERIA

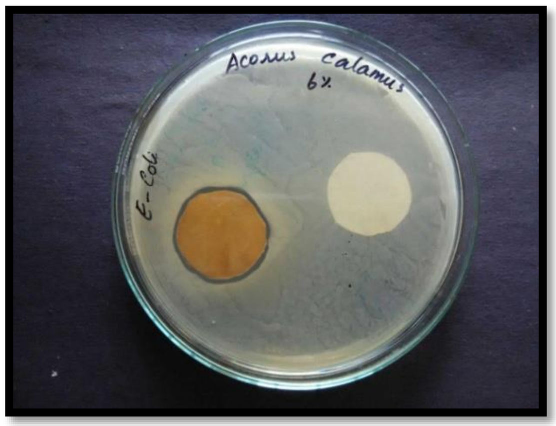


FUNGUS

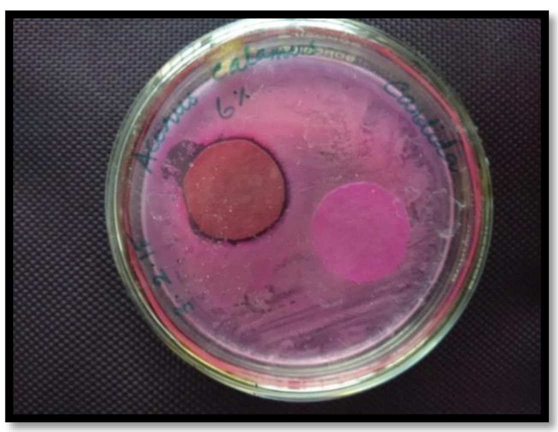
PLATE – VII

ANTIMICROBIAL ACTIVITY OF 4% CONCENTRATION

GRAM +VE BACTERIA



GRAM -VE BACTERIA



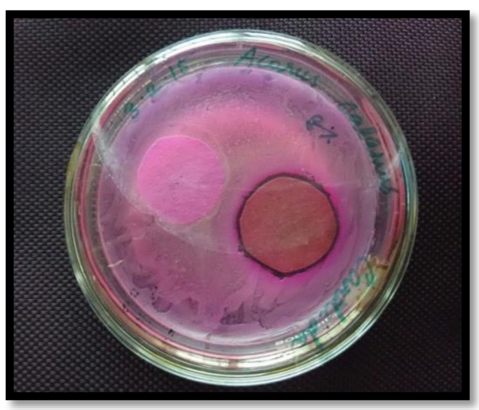
FUNGUS

PLATE – VIII

ANTIMICROBIAL ACTIVITY OF 6% CONCENTRATION

GRAM +VE BACTERIA

GRAM -VE BACTERIA

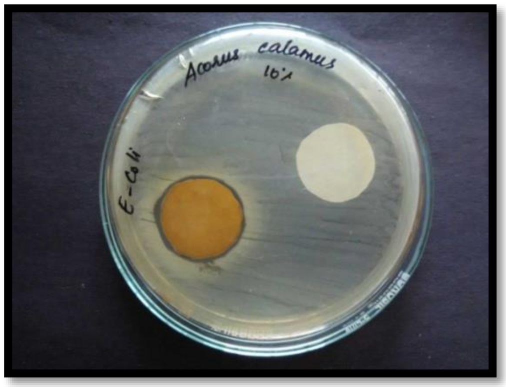


FUNGUS

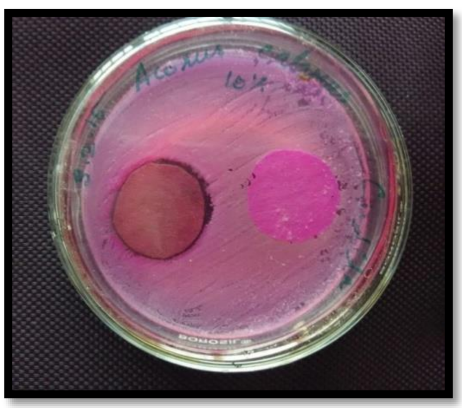
PLATE – IX

ANTIMICROBIAL ACTIVITY OF 8% CONCENTRATION

GRAM +VE BACTERIA



GRAM -VE BACTERIA



FUNGUS

PLATE – X

ANTIMICROBIAL ACTIVITY OF 10% CONCENTRATION

3.8.1 Exhaustion method

For exhaustion method (Plate XI), the material liquor ratio was taken as 1:40. The fabric was immersed in the selected rhizome extracted solution and heated at 50ºC - 55ºC for 45 minutes. The parameters for application such as the M:L ratio, time and temperature was followed as stated by Mahesh (2011). After treatment, the fabric was left to dry in shade. A water bath was utilized for the application process. (Appendix - I)

3.8.2 Pad – dry – cure method

Pad – dry – cure method (Plate XII) was executed using a padding mangle. The objective of this process is to mechanically impregnate the fabric with the extract. The M:L ratio for the process was taken as 1:5 as stated by Karolia and Mendapara (2007). A padding mangle offers continuous processing of the fabric in the concerned liquor. During padding, the fabric was made free from creases and the selvedges were opened out before feeding the fabric into the guide rollers. The fabric was passed into the solution of *Acorus calamus*, under a submerged roller and out of the bath. The fabric was then squeezed to remove excess solution. The padding mangle was made to run at a speed of 15ml/min. After padding, the fabric was air dried and then cured for 3 minutes at 140ºC as stated by *Yadav et al.,* (2006). (Appendix - I)

3.8.3 Plasma treatment

Plasma treatment was done using the plasma chamber (Plate XIII) which was operated in a vacuum. Vacuum evaporation is a physical vapor deposition (PVD) process and are of the most commonly used methods for deposition of functional films on different substrates. The process allows vapor particles to deposit directly on the substrate where vapor particles condense back to a solid state, forming a functional coating. Vacuum is used to prevent the collision of the evaporated particles with unwanted particles (Vihodceva and Kukle, 2013).

PLATE – XI

EXHAUSTION METHOD

PLATE - XII

PAD-DRY-CURE METHOD

PLATE – XIII

PLASMA CHAMBER

The sample was cut to the size of the square frame. The sample was pinned to the frame and the frame was placed inside the chamber. To create the vacuum, all the valves were closed and the rotary compressor was switched on. Once the vacuum was created, plasma discharge with power of 400 W for 5 seconds was applied as suggested by Kale *et al.,* (2011). After 5 seconds, the rotary compressor and the plasma discharge was switched off and the valves were opened to release the vacuum. Samples were immediately dipped in the *Acorus calamus* solution after plasma treatment. (Appendix - I)

3.9 EVALUATION OF THE FINISHED FABRIC

The original, desized and all the treated samples were subjected to evaluation. The various evaluation methods (subjective and objective) used for the study are explained under the following heads.

3.9.1 Subjective evaluation

The subjective evaluation was carried out for both visual and sensory parameters. The Performa used for the subjective evaluation is exhibited in Appendix II.

3.9.1a Visual inspection

The treated samples were displayed before a panel of members which consisted of 30 judges comprising post graduate students specialized in textiles and clothing. An evaluation sheet was prepared and given to the judge. The criteria considered for the evaluation were general appearance, evenness and luster.

3.9.1b Sensory evaluation

The treated samples were given to the panel of members and they were asked to feel the fabric and evaluate them. The fabric samples were to be evaluated as coarse, smooth or very smooth. Also the fragrance was evaluated as strong, moderate or subtle.

The results obtained were consolidated and recorded.

3.9.2 Objective evaluation

The objective evaluation was carried out for the fabric samples using respective standard tests.

3.9.2a Physical property tests

The physical property tests carried out were fabric count, fabric weight and fabric thickness.

3.9.2a1 Fabric Count

The count of the fabric was determined by counting the number of warp yarns and weft yarns in one inch of the fabric. To determine the count, a Pick glass (Plate XIV) was used. Ten readings were taken, recorded and the mean value was calculated.

3.9.2a2 Fabric weight

Fabric weight is the weight per square metre of the fabric. It may be expressed as grams per square metre. Fabric weight is the relative weight of the fabric, describes Saini (2004). Electronic weighing balance was used to determine the fabric weight which was multiplied by 100 for obtaining GSM. The samples for weighing were cut using a GSM cutter. Ten readings were observed and the mean weight was calculated and recorded. The electronic weighing balance and the GSM cutter are exhibited in Plate XV.

3.9.2a3 Fabric thickness

The thickness of a textile material is the distance between the two plane parallel as the pressure foot and the other as the anvil (Jewel, 2005). Thickness is measured to an accuracy of at least 0.01mm under the prescribed pressure ranging from 0.005 psi depending on the type of fabric under test.

The Hungarian thickness tester (Plate XVI) was used to measure the thickness. The tester was operated by hand. It has a broad anvil upon which a pressure foot is pressed by a spring. The dial has calibrations that indicate the thickness of the fabric in thousands of an inch between the avail and the pressure foot. Each division of the dial reads 0.01mm.

The fabric to be tested is placed on the anvil and the pressure foot is lowered onto it without excess pressure. The reading pointed in the dial was recorded. The readings were taken at ten different placed on the same fabric and recorded.

3.9.2b Mechanical property tests

For analyzing the mechanical properties of the fabric samples, the tests namely tensile strength, elongation and pilling were done.

3.9.2b1 Tensile Strength and elongation

Tensile strength is the force required to break a fabric when it is under tension (Vaishnav and Joshi, 2000). It is the resistance of the fabric to a tensile load or stress in either the warp or filling direction. Elongation is the extent to which the fabric under tension extends until it cuts off. The percentage of strength and elongation is determined by testing the fabric using a tensile strength tester.

The Eureka Pendulum Tensile strength tester (Plate XVII) was used to conduct the study. The rate of speed and capacity of the machine is 48 cm / min and 90 kg respectively. The gauge length was taken as 25 cm. The dial of the tester is calibrated in pounds and kg. There is a scale marked in inches that can be used to measure the elongation. There are to jaws; one fixed and the other one movable. The fabric sample is fixed between the two jaws. The pointer of the dial should point at zero when the test is started. The length and width of the samples were taken as 12” and 2.5” respectively. The load was applied on the fabric until the sample was torn. The reading on the dial was noted to determine the strength and the reading on the scale was noted as the elongation. The samples were taken both in the warp and weft directions of the fabric. Ten such observations were made and recorded.

3.9.2b2 Pilling

Pilling is the formation of little circular clusters of fibre on the surface of the fabric, produced as a result of the fabric being rubbed against itself or some other material (Fung, 2002).

Fabric samples were tested for pilling using a pill box (Plate XIX) which consists of twin wooden cubic boxes, each with sides about 25 cm long, the inside walls of which

PLATE – XIV

PICK GLASS

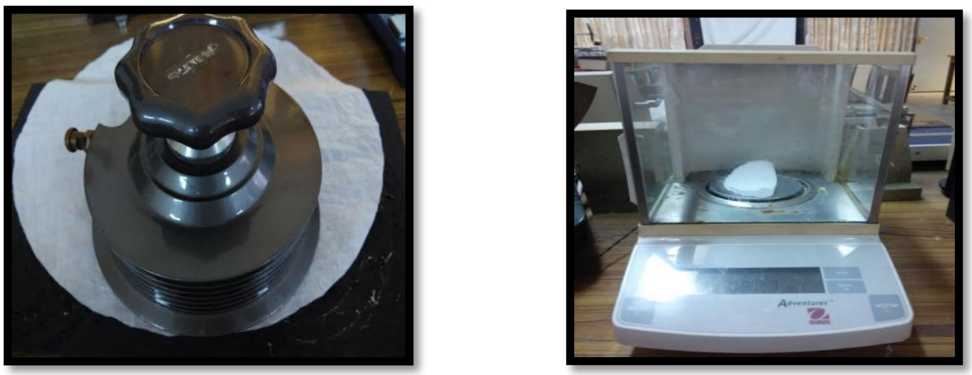


PLATE – XV

GSM CUTTER AND ELECTRONIC WEIGHING BALANCE

PLATE – XVI

THICKNESS TESTER

PLATE – XVII

TENSILE STRENGTH TESTER

are lined with cork. Fabric samples were wrapped around rubber formers and placed inside the boxes, which were then rotated around a common axis for 30 minutes. The samples were then assessed on a scale of 1 to 5. The higher the rating, the lesser the pilling.

3.9.2c Comfort property tests

To assess the comfort properties of the fabric samples, tests such as fabric stiffness, crease recovery and drape were conducted.

3.9.2c1 Fabric Stiffness

Fabric stiffness is defined as the resistance of a fabric to bending under its own weight (Song, 2011).

The Shirley fabric stiffness tester (Plate XX) was used to measure the stiffness of the sample. The samples were cut to the size of the template. Samples were taken in both warp and weft directions of the sample. Four ends on two sides, face and back of the fabric with two ends on each side were marked as A, B, C and D. The readings were recorded for all four sides. Ten samples in each direction were taken. The tester was set on a table so that the horizontal platform and the index lines are at eye level.

The specimen was placed on the platform with the template on top of it, so that the leading edges coincide. The specimen and the template were slowly pushed forwarded until the leading edges of the specimen touch the index line. The bending length was measured. This was carried out for all the fabric samples and the mean value was calculated.

3.9.2c2 Crease recovery

A crease is a line or mark produced in anything by folding. It is the deformation in a fabric intentionally formed by pressing (Operath, 2006). Crease recovery is the ability of a fabric to recover from unwanted creases. It is the property of the material to resist wrinkling and to restore the initial state after the force causing its crease is removed. Creasing of textile material is a complex effect involving tensile, flexing, compressive and other stresses. The ability of the fabric to resist creasing depends on the fibre it is made of (Fan and Hunter, 2009).

Shirley crease recovery tester (Plate XXI) was used for the test. The instrument has a circular dial calibrated in degrees. It has a clamp for holding the sample. A knife edge and an index line can see at the bottom centre of the dial to measure the recovery angle. The fabric samples each of 5 cm x 2.5 cm size were cut both in warp and weft directions. The samples were folded and creased under a load of 20 N and atmospheric conditions for a predetermined period (5 minutes). After that, the load was removed and one leg of the sample was mounted on the clamp in the tester. The fabric recovers from the crease. The dial was rotated so that the sample coincides with the knife edge. The reading that the index line points was recorded as the crease recovery angle. Ten samples were taken from each direction of the fabric. The mean value was calculated for all the samples and recorded.

3.9.2c3 Drape

Drape is the ability of bending behaviour of fabric under its own weight to assume a graceful appearance in use (Hu, 2004).

Eureka Drape meter (Plate XXII) was used to determine the drapability of the fabric samples. Specimens were cut using the template. A brown paper was also cut to the same size and weighed using an electronic weighing balance. The test specimens were placed on the circular disc in the drape meter and operated. The image of the draped sample was traced on the brown paper and it was cut on the outline and weighed. Then the brown paper was cut to the size of the supporting disc in the meter and again weighed. The drape coefficient for each sample was calculated using the recorded readings by applying the following formula.

$$\text{Drape coefficient} = \frac{A_S - A_d}{A_D - A_d} \times 100$$

A_S – Mass of shaded area; A_D – Mass of total paper ring; A_d – Mass of supporting area

PLATE – XVIII

PILLING BOX

PLATE – XIX

STIFFNESS TESTER

PLATE – XX

CREASE RECOVERY TESTER

PLATE – XXI

DRAPE METRE

3.9.2d Absorbency tests

Various absorbency tests carried out for the treated and untreated samples were drop test, sinking and wicking.

3.9.2d1 Drop test

The drop test (Plate XXIII) is the time required for a single drop of water to penetrate through to the underside of the fabric, describes Jewel (2005). The ability of a fibre to take up moisture is determined as absorbency.

For this test burette filled with distilled water was clamped in a stand. The fabric sample was mounted in a conical flask, covering the mouth of the flask and secured with a rubber band and was placed at the base of the stand. The distance between the sample and burette nozzle was kept constant. The nozzle of the burette was opened 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 samples of the same material and the mean value was calculated and recorded.

3.9.2d2 Sinking test

Sinking test (Plate XXIV) is a test for wet ability of the fabric. Samples were prepared in sizes of about 5cm x 5cm. Distilled water was taken in a glass beaker. The samples were dropped on the water one by one. The stop watch was started when the fabric struck the surface of the water and stopped when the last corner sank below the water surface. The time taken by each sample to sink was noted. The mean value was calculated for all the ten samples and recorded in seconds.

3.9.2d3 Wicking test

Wicking test (Plate XXV) is a test that helps to measure the rapidity of absorption, says Paul (2005). The samples were prepared with a dimension of 15 cm length and 2.5 cm width. A mark was made at 1cm from one end of the sample. The other end of the sample strip was hoisted with a glass rod which was placed across the beaker. The sample was left to dip in the wafer such that the surface of the water was in line with the 1 cm mark made on the fabric. The rise of the water level on the sample

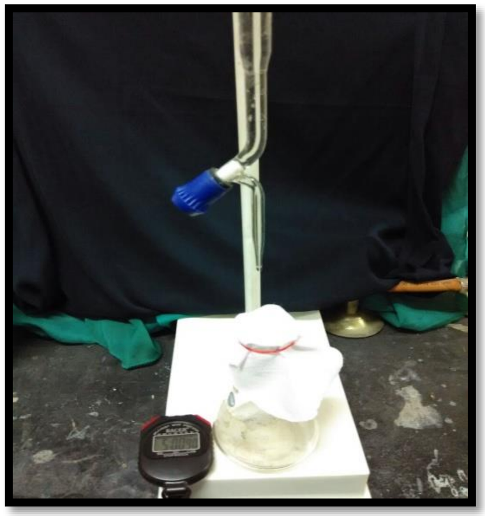


PLATE – XXII

DROP TEST

PLATE – XXIII

SINKING TEST

PLATE – XXIV

WICKING TEST

was noted after 30 minutes keeping the time constant. The measurement was made starting from the 1cm mark to the extent up to which the sample was wet. The readings were recorded and the mean value was calculated. A total of ten samples were tested, recorded and expressed in centimetres.

3.9.3 Analysis of antimicrobial property

The treated samples E, P and PL were tested for the antimicrobial property using the AATCC agar diffusion method. The zones of inhibition for all the samples were measured and recorded.

3.9.4 Special tests

A special test to check the treated samples for repellency against ants was conducted.

3.9.4a Ant repellent test

The treated sample which gave the best results in absorbency was utilized for further study. For testing ant repellency, the selected treated sample (PL) and untreated sample were cut in squares measuring 20 cm X 20 cm. Then a small piece of plastic sheet was cut and placed on top of both the samples. One table spoon of honey was put on both the plastic sheets to attract the ants. The fabric samples were placed in a location where there was ant activity. It was noted after 30 minutes, the number of ants on each fabric, feeding on the honey. The method adopted for this test was referred from (https://www.usc.edu/CSSF/History/2010/Projects/J2310.pdf).

3.9.4b Performance study

The treated sample used for the product preparation was tested for the ant repellent property after wash. The sample was washed using detergent powder in cold soft water and dried in shade. Then ant repellent test was carried out and the number of ants feeding on the honey kept over the fabric was noted. This was repeated again after the second and third washes. The number of ants was counted and recorded after every wash.

3.10 SEM ANALYSIS

The Scanning Electron Microscope is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition (Reed, 2005). Scanning Electron Microscope provides a means of better visual understanding of textile fibres and fabrics and has improved concepts of the role of unit interactions in fibrous matrices. So, the Scanning Electron Microscopic appearance was studied for the samples D, E, P and PL. It was observed at various magnifications namely x 500, x1500, x3000 and x7500.

3.11 PRODUCT PREPARATION

The product prepared from the selected treated material was a covering for fruits. This was evaluated visually.

3.11.1 Stitching

Two layers of fabric were used in stitching the fruit cover; an untreated inner layer and a treated outer layer. Two semicircular pieces were cut for the sides and a rectangular piece for the centre. The circular sides of the semicircular pieces were attached to the opposite sides of the rectangular piece. The lower edge and the seams of the fruit cover were then adorned with a lace. A metal wire was attached to both the inner seams to hold the shape of the cover.

3.11.2 Performance study

The prepared fruit cover was used to cover the fruits kept in one end of the dining table. Some fruits were kept uncovered at the other end of the table. It was observed for the attack of ants and flies.

3.12 NOMENCLATURE

The nomenclature used for various samples are given in Table I.

TABLE – I

NOMENCLATURE

S. No	Nomenclature	Sample
1	O	Original sample
2	D	Desized sample
3	E	Sample treated by exhaustion method
4	P	Sample treated by pad-dry-cure method
5	PL	Sample treated by plasma treatment method
6	PLW1	1 time washed plasma treated sample
7	PLW2	2 times washed plasma treated sample
8	PLW3	3 times washed plasma treated sample

The original, desized and treated samples were evaluated subjectively and objectively. The results of the desized sample were compared with the original sample and all the treated samples were compared with the desized sample, considering it to be the untreated sample.

4. RESULTS AND DISCUSSION

The findings of the study are discussed under the following heads.

4.1 Pilot study

4.2 Optimization

4.3 Subjective evaluation

4.4 Objective evaluation

4.5 Antimicrobial test

4.6 Special tests

4.7 SEM Analysis

4.8 Product performance study

4.9 Product cost estimation

4.1 PILOT STUDY

The zone of inhibitions formed for bacteria and fungus in aqueous extract and ethanolic extract are tabulated below.

TABLE – II

PILOT STUDY

S. No	Extract	Zone of Inhibition - Bacteria (mm)		Zone of Inhibition - Fungus (mm)
		Gram +ve	Gram -ve	
1	Aqueous	-	-	-
2	Ethanolic	1.2	1.7	2

From the Table II, it is obvious that in the ethanolic extraction of *Acorus calamus*, there was 1.2 mm of zone of inhibition in the gram +ve bacteria and 1.7 mm in the gram –ve bacteria and 2 mm of zone in the fungus. There was no antimicrobial activity in the aqueous medium.

Hence, it could be concluded that there was antimicrobial activity in the ethanolic extraction of *Acorus calamus* from the pilot study.

4.2 OPTIMIZATION

The zones of inhibitions for the five different concentrations of the ethanolic extract are tabulated below.

TABLE - III

OPTIMIZATION

S. No	Concentration	Zone of Inhibition (Bacteria) (mm)		Zone of Inhibition (Fungus) (mm)
		Gram +ve	Gram –ve	
1	2%	1	1.5	1.9
2	4%	1.5	1.5	2.1
3	6%	1.7	1.9	2.3
4	8%	2	2.2	2.5
5	10%	1.5	1.7	2.1

From the Table III, it is clear that the highest zone of inhibition of gram +ve bacteria was observed in the concentration of 8 percent with 2 mm followed by 6 percent (1.7 mm), 4 percent and 10 percent (1.5 mm) and 2 percent (1 mm).

As for the gram -ve bacteria, the highest zone of inhibition was observed at 8 percent concentration with 2.2 mm followed by 6 percent (1.9 mm), 10 percent (1.7 mm) and 2 and 4 percentages (1.5 mm)

As far as fungus is concerned, the highest zone of inhibition was observed at 8 percent concentration with 2.5 mm followed by 6 percent (2.3 mm), 4 and 10 percentages (2.1 mm) and 2 percent (1.9 mm).

Hence, it could be concluded that 8 percent concentration of the ethanolic extract of *Acorus calamus* rhizome has the best antimicrobial activity.

4.3 SUBJECTIVE EVALUATION

The treated samples were subjectively evaluated by a panel of 30 members and the findings are given in Table IV and Table V.

TABLE - IV

VISUAL INSPECTION

Properties	Sample E	Sample P	Sample PL
General Appearance			
Very good	20 (67%)	21 (70%)	28 (93%)
Good	4 (13%)	5 (17%)	2 (7%)
Moderate	6 (20%)	4 (13%)	-
Evenness			
High	2 (7%)	27 (90%)	29 (97%)
Medium	25 (83%)	3 (10%)	1 (3%)
Low	3 (10%)	-	-
Lustre			
Very good	-	-	-
Good	20 (67%)	26 (87%)	27 (90%)
Moderate	10 (33%)	4 (13%)	3 (10%)

General appearance

From the Table IV, it is evident that the maximum number of judges feels that the samples had a very good general appearance of which it was highest in sample PL with 93 percent, followed by the samples P and E with 70 and 67 percentages respectively.

Evenness

From the table IV, it is clear that the samples P and PL were rated high in evenness of which it was highest in sample PL with 97 percent followed by sample P with 90 percent ratings. Sample E was rated to have medium evenness with 83 percent ratings.

Lustre

From the Table IV, it is obvious that the maximum number of judges feels that the samples had a good lustre of which it was highest in sample PL with 90 percent, followed by samples P and E with 87 and 67 percentages respectively.

Hence, it could be concluded that all the treated fabric samples exhibited very good general appearance and good lustre through visual inspection.

TABLE - V

SENSORY EVALUATION

Properties	Sample E	Sample P	Sample PL
Texture			
Coarse	5 (17%)	30 (100%)	-
Smooth	25 (83%)	-	26 (87%)
Very Smooth	-	-	4 (13%)
Fragrance			
Strong	-	3 (10%)	-
Moderate	23 (77%)	25 (83%)	27 (90%)
Subtle	7 (23%)	2 (7%)	3 (10%)

Texture

From the Table V, it is evident that all the judges feel that the sample P has a coarse texture. Samples E and PL were rated smooth in texture with 83 and 87 percentages of ratings.

Fragrance

From the Table V, it is clear that maximum number of the judges feel that the samples have a moderate fragrance of which it is highest in sample PL with 90 percent ratings followed by samples P and E with 83 and 77 percentages respectively.

Hence, it could be concluded that the texture was smooth in sample PL, and in all the three treated samples there was moderate fragrance observed.

4.4 OBJECTIVE EVALUATION

The results obtained for the treated and untreated samples when evaluated objectively are expressed in the following tables.

4.4.1 Fabric Count

The results obtained for the fabric count is expressed in Tables VI & VII and Figures 2 & 3.

TABLE - VI

FABRIC COUNT (WARP)

S. No	Sample	Fabric count	Loss or gain value	Loss or gain percent	F Value
1	O	77	-	-	156.28**
2	D	86	9	12	
3	E	97	11	13	
4	P	99	13	15	
5	PL	85	-1	1	

** - Significant at 1% level

From the Table VI and Figure 2, it is clear that the fabric count increased in the desized sample to about 12 percent. The increase in the count was observed in all the treated samples over the desized sample of which it was the maximum in sample P of 15 percent followed by the samples E and PL of 13 and 1 percentage respectively.

From statistical analysis also it is proved that there is 1% significance.

Hence it could be concluded that the treated samples showed an increase in fabric count of which it was the highest in sample P.

TABLE – VII

FABRIC COUNT (WEFT)

S. No	Sample	Fabric count	Loss or gain value	Loss or gain percent	F Value
1	O	67	-		649.072**
2	D	78	11	16	
3	E	83	5	6	
4	P	84	6	8	
5	PL	78	-	-	

** - Significant at 1% level

From the Table VII and Figure 3, it is clear that the weft count increased to the maximum in sample P to 8 percent followed by the sample E with 6 percent. Neither loss nor gain was observed in sample PL.

It is also proved that there is 1%significance while considering the F value.

Hence it could be concluded that in weft direction the fabric count increased on desizing which further increased on finishing treatment and the increase was higher in sample P.

4.4.2 Fabric Weight

The results obtained for fabric weight is presented in Table VIII and Figure 4.

TABLE - VIII

FABRIC WEIGHT

S. No	Sample	Weight (GSM)	Loss or gain value	Loss or gain percent	F Value
1	O	102	-	-	1854.285**
2	D	95	-0.07	7	
3	E	82	-13	14	
4	P	153	58	61	
5	PL	96	1	1	

** - Significant at 1% level

From the Table VIII and Figure 4, it is clear that the weight of the fabric reduced on designing in sample D to 7 Percent over original sample O.

The treated samples namely P & PL showed an increased in weight of which it was higher in sample P with 61 percent and in sample PL with 1 percent over sample D. A loss in weight was observed in sample E of 14 percent over the sample D. The increase in weight in sample P may be due to the increase in thickness.

The F value also proves that there is 1%significance.

Hence it could be concluded that the weight increased drastically in sample P where as only slight increase was observed in sample PL.

4.4.3 Fabric Thickness

The results obtained for fabric thickness are presented in Table IX and Figure 5.

TABLE - IX

FABRIC THICKNESS

S. No	Sample	Thickness (mm)	Loss or gain value	Loss or gain percent	F Value
1	O	0.33	-	-	0.945^{ns}
2	D	0.32	-0.01	3	
3	E	0.34	0.02	6	
4	P	0.38	0.06	19	
5	PL	0.32	-	-	

^{ns} – Not significant

From the Table IX Figure 5, it is clear that the fabric had reduced in thickness of 3 percent in the desized sample over the original sample O. Both the treated samples P and E Showed increased in thickness of 19 percent and 6 percent respectively over desized sample. The sample PL showed neither loss nor gain in thickness over desized sample D.

It is also clear that the F value is insignificant with regards to thickness of the samples.

Hence it could be concluded that the increase in thickness was higher in sample P and no change was observed in sample PL.

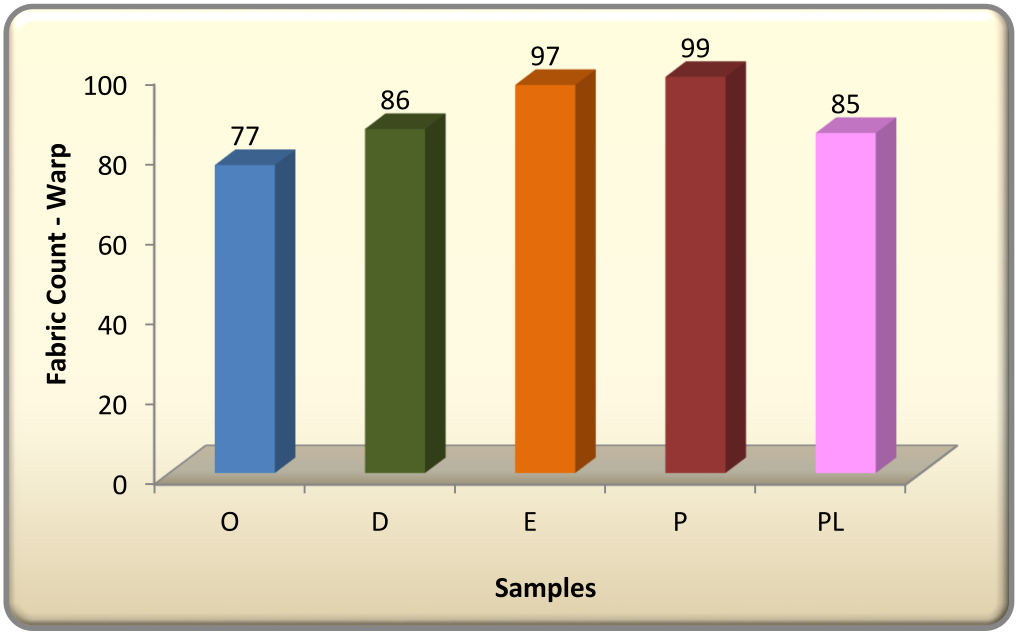


FIGURE – 2

FABRIC COUNT (WARP)

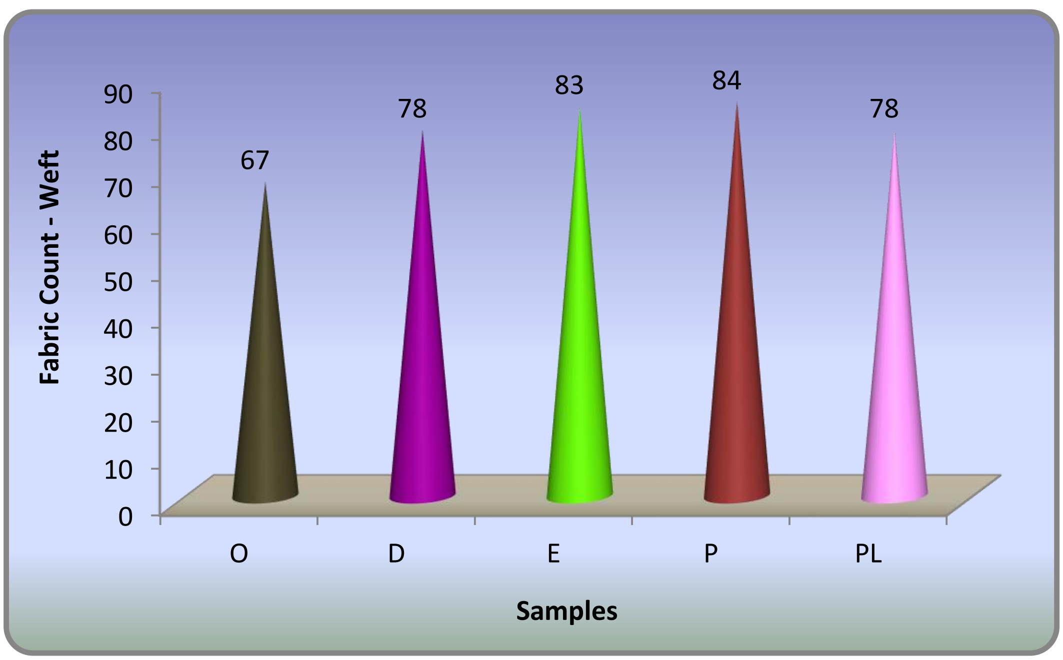


FIGURE – 3

FABRIC COUNT (WEFT)

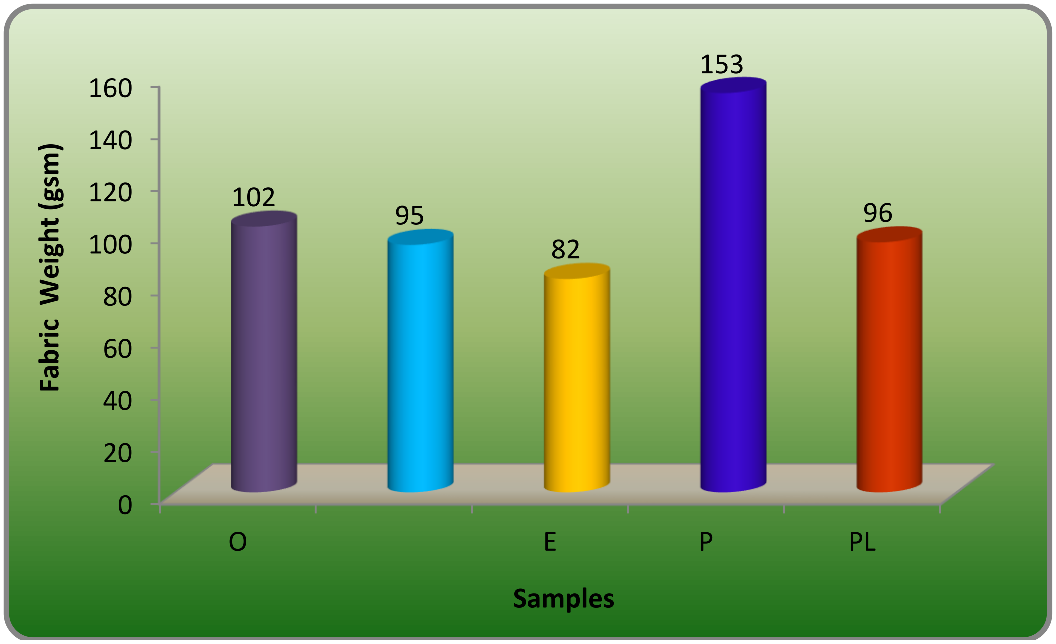


FIGURE – 4

FABRIC WEIGHT

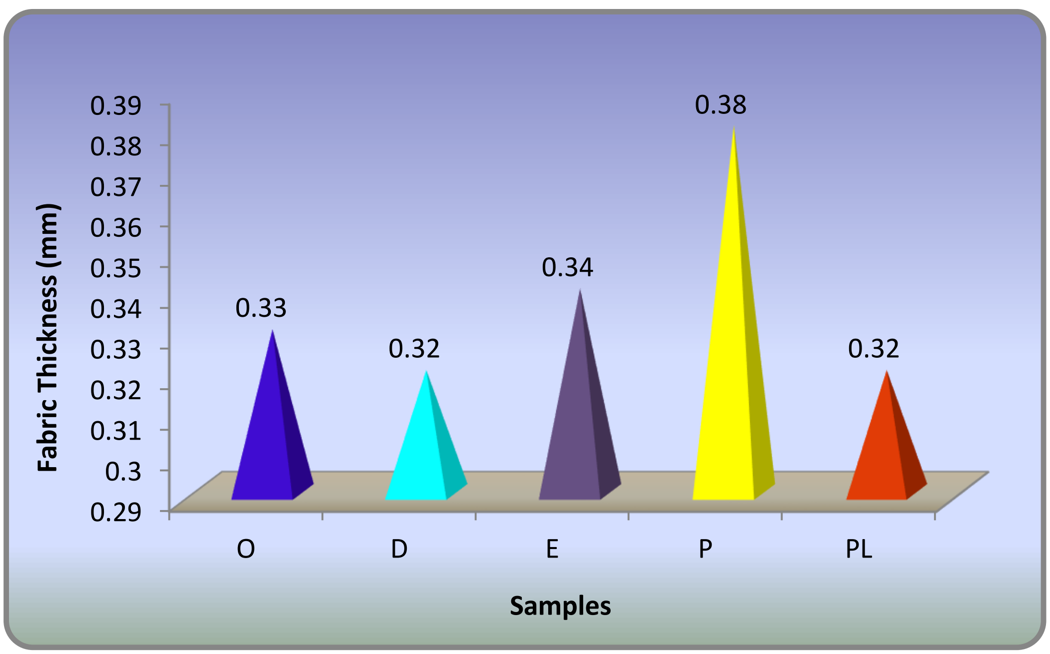


FIGURE – 5

FABRIC THICKNESS

4.4.4 Tensile Strength

The results obtained for tensile strength are presented in Tables X & XI and Figures 6 & 7.

TABLE - X

TENSILE STRENGTH (WARP)

S. No	Sample	Strength (Kg)	Loss or gain value	Loss or gain percent	F Value
1	O	27	-	-	900.87**
2	D	28	1	4	
3	E	26	-2	7	
4	P	22	-6	21	
5	PL	24	-4	14	

** - Significant at 1% level

From the Table X and Figure 6, it is obvious that in warp direction the strength of the fabric increased by 4 percent in the desized sample D over the original sample O. Strength loss was the highest in sample P of 21 percent followed by the samples PL of 14 percent and E of 7 percent over the desized sample.

It can be seen clearly that there is 1% significance as per the F value.

Hence it could be concluded that the strength loss was highest in sample P in warp direction.

TABLE - XI

TENSILE STRENGTH (WEFT)

S. No	Sample	Strength (Kg)	Loss or gain value	Loss or gain percent	F Value
1	O	26	-	-	281.371**
2	D	27.5	1.5	6	
3	E	21	-6.5	24	
4	P	19	-8.5	31	
5	PL	20	-7.5	27	

** - Significant at 1% level

From the Table XI and Figure 7, it is clear that is weft direction the fabric showed increase in strength of 6 percent over original sample. Among the treated samples, the maximum loss in strength was noted in sample P of 31 percent followed by the samples PL and E with 27 and 24 percentages respectively over the desized sample.

From the statistical analysis also it is proved that there is 1% significance.

Hence it could be concluded that the greatest loss in strength was observed in the sample P over the desized sample.

4.4.5 Elongation

The results obtained for elongation are presented in Tables XII & XIII and Figures 8 & 9.

TABLE - XII

ELONGATION (WARP)

S. No	Sample	Elongation (%)	Loss or gain value	Loss or gain percent	F Value
1	O	8	-	-	160.714**
2	D	11	3	38	
3	E	7	-4	36	
4	P	4	-7	64	
5	PL	5	-6	55	

** - Significant at 1% level

From the Table XII and Figure 8, it is clear that the desized fabric sample D in warp direction showed on increase in elongation of 38 percent over original sample O. All the treated samples showed a decrease in elongation over desized samples of which reduction was the highest in sample P of 64 percent followed by sample PL and E with 55 and 36 Percentages respectively.

It is also proved that there is 1% significance while considering the F value.

Hence it could be concluded that the elongation of the fabrics reduced on the application of finishing treatments.

TABLE - XIII

ELONGATION (WEFT)

S. No	Sample	Elongation (%)	Loss or gain value	Loss or gain percent	F Value
1	O	5	-	-	243.18**
2	D	9	4	80	
3	E	2	7	78	
4	P	1	8	89	
5	PL	2	7	78	

** - Significant at 1% level

From the table XIII and Figure 9, it is clear that the deiszed fabric sample D in weft direction showed an increased in elongation of 80 percent over original sample O.

All the treated samples showed a decreased in elongation over the desized sample of which reduction was highest in sample P of 89 percent followed by both the sample E and PL with78 Percent.

The F value also proves that there is 1% significance.

Hence it could be concluded that the elongation of the fabrics reduced on the application of finishing treatments.

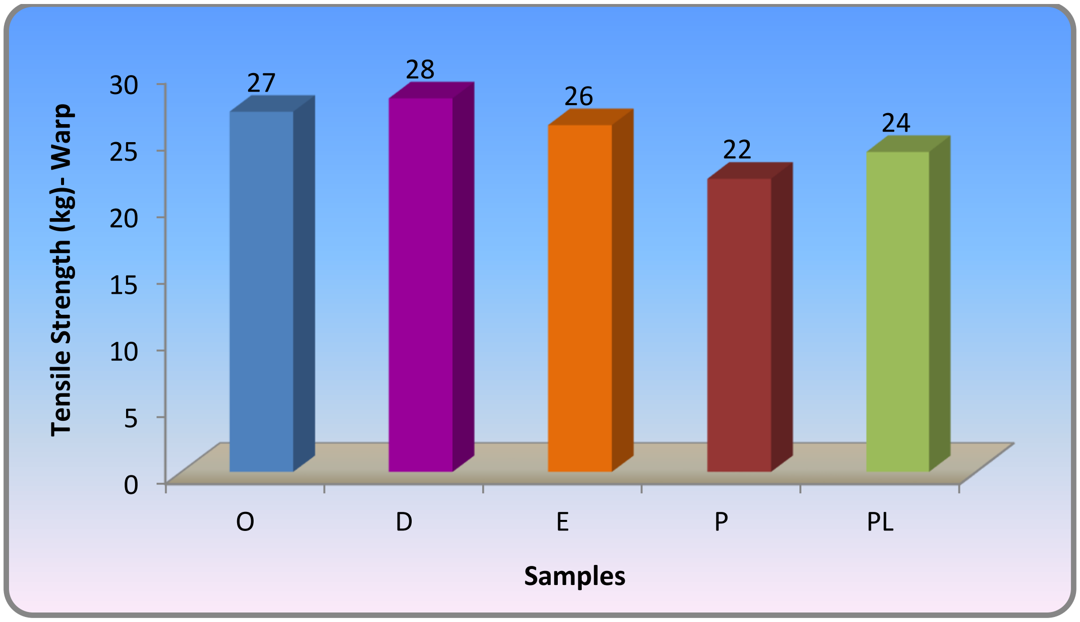


FIGURE – 6

TENSILE STRENGTH (WARP)

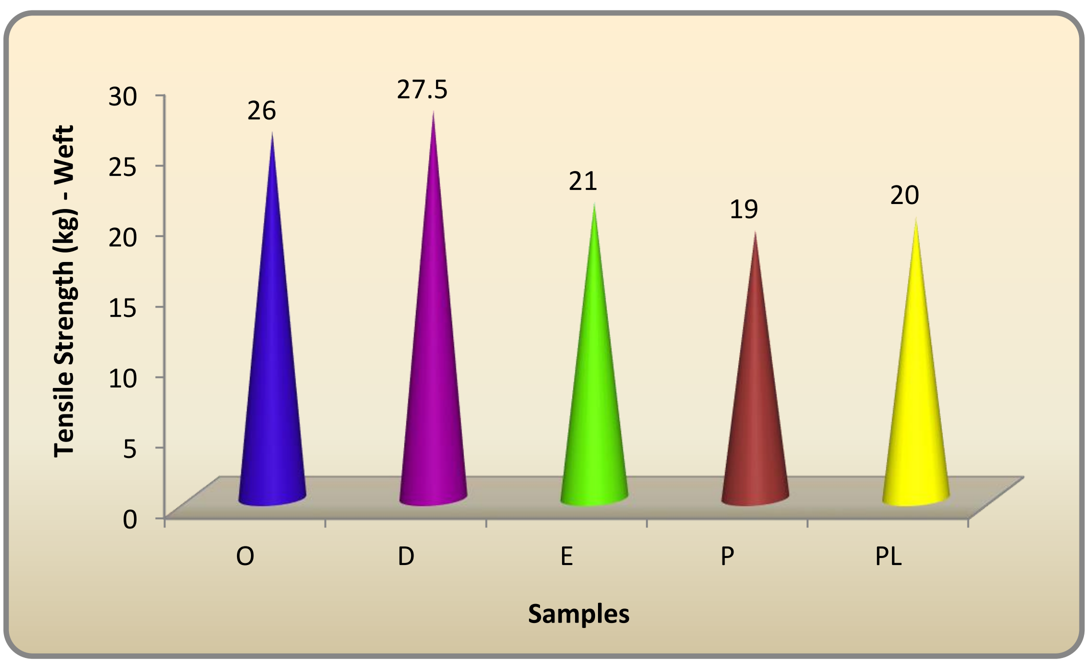


FIGURE – 7

TENSILE STRENGTH (WEFT)

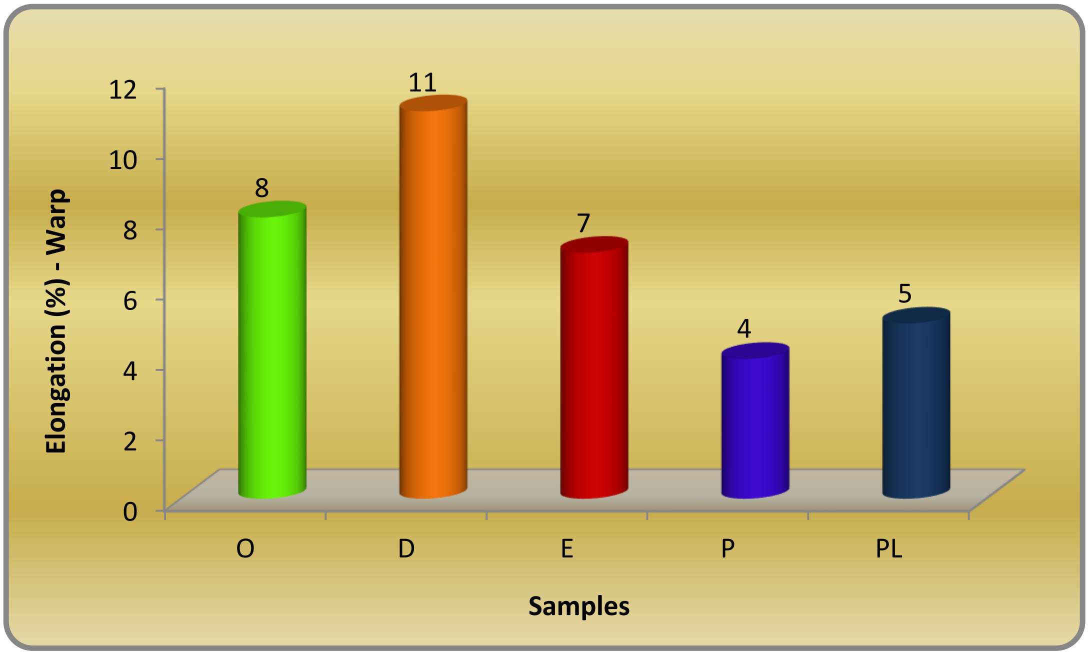


FIGURE – 8

ELONGATION (WARP)

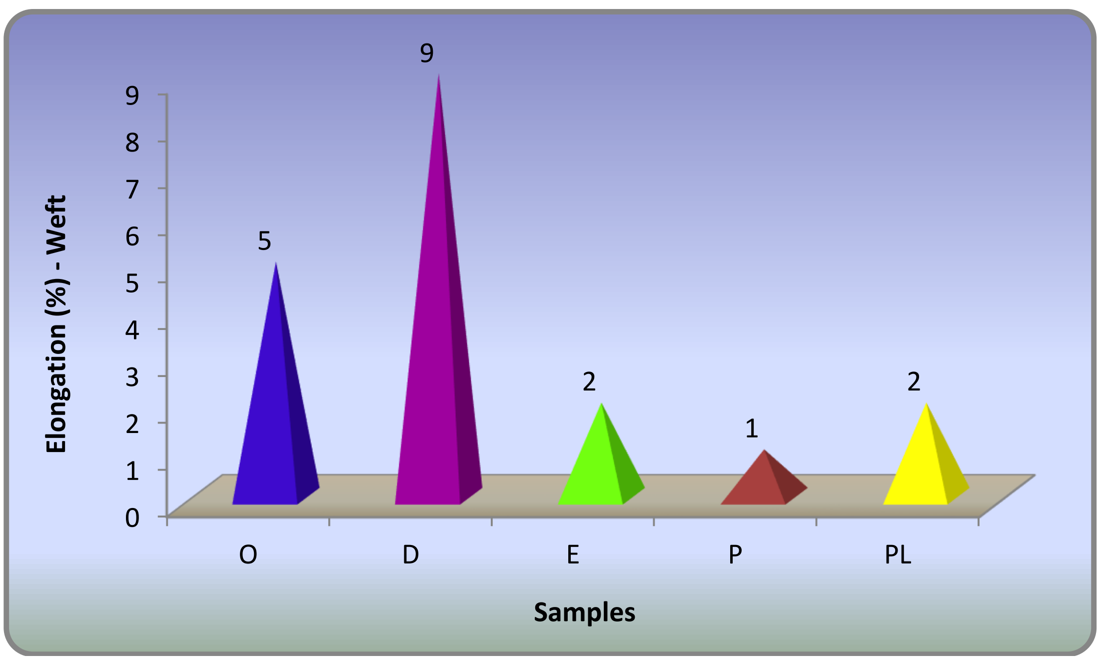


FIGURE – 9

ELONGATION (WEFT)

4.4.6 Pilling

The results obtained for pilling are presented in Table XIV.

TABLE - XIV

PILLING

S. No	Sample	Grade
1	O	1
2	D	1
3	E	2
4	P	2
5	PL	2

From the Table XIV, it is obvious that the grading for the untreated samples O and D was 1 but in the case of treated samples it was rated to be 2.

Hence, it could be concluded that slight pilling was observed in all the treated samples.

4.4.7 Fabric Stiffness

The results obtained for fabric stiffness are presented in Table XV & XVI and Figures 10 & 11.

TABLE - XV

FABRIC STIFFNESS (WARP)

S. No	Sample	Stiffness (cm)	Loss or gain value	Loss or gain percent	F Value
1	O	2.9	-	-	36.81**
2	D	2.7	-0.2	7	
3	E	2.3	0.4	15	
4	P	5	2.4	89	
5	PL	2.1	0.6	22	

** - Significant at 1% level

From the Table XV and Figure 10, it is obvious that the stiffness in the fabric reduced in sample D of 7 percent over the sample O. The treated samples E and PL showed decreased stiffness of 15 and 2 percentages respectively over desized sample, but the sample P showed an increase in stiffness of 89 percent.

It can be seen clearly that there is 1% significance as per the F value.

Hence it could be concluded that the stiffness of the fabric in warp direction reduced in samples E and PL but increased in sample P.

TABLE – XVI

FABRIC STIFFNESS (WEFT)

S. No	Sample	Stiffness (cm)	Loss or gain value	Loss or gain percent	F Value
1	O	2.8	-	-	107.58**
2	D	2.2	-0.6	21	
3	E	1.9	-0.3	14	
4	P	4.9	2.7	123	
5	PL	1.55	-0.65	29	

** - Significant at 1% level

From the Table XVI and Figure 11, it is obvious that the stiffness in the fabric reduced in sample D of 21 percent over the sample O. The treated sample E and PL showed decrease in stiffness of 14 and 29 percentages respectively over the desized sample D .But the sample P showed an increased in stiffness of 123 percent.

From the statistical analysis also it is proved that there is 1% significance.

Hence it could be concluded that the stiffness of the fabric in weft direction reduced in samples E and PL but increased in sample P.

4.4.8 Crease recovery

The results obtained for crease recovery are presented in Table XVII & XVIII and Figures 12 & 13.

TABLE - XVII

CREASE RECOVERY (WARP)

S. No	Sample	Crease recovery angle	Loss or gain value	Loss or gain percent	F Value
1	O	52	-	-	41.57**
2	D	62	10	19	
3	E	72	10	16	
4	P	71	9	15	
5	PL	75	13	21	

** - Significant at 1% level

From Table XVII and Figure 12, it is obvious that the crease recovery angle of the sample D has increased over O by 19 percent.

As of the treated samples, the crease recovery angle has increased over sample D to 72º (sample E), 71º (sample P) and 75º (sample PL).

It is also proved that there is 1% significance while considering the F value.

Hence, it can be concluded that the sample PL has the highest crease recovery angle in the warp direction.

TABLE - XVIII

CREASE RECOVERY (WEFT)

S. No	Sample	Crease recovery angle	Loss or gain value	Loss or gain percent	F Value
1	O	71	-	-	1143.58**
2	D	108	37	52	
3	E	100	-8	7	
4	P	88.5	-19.5	18	
5	PL	102.5	-5.5	8	

** - Significant at 1% level

From the Table XVIII and Figure 13, it is clear that the crease recovery angle of the sample D has increased by 7 percent over the sample O.

All the treated samples have a decreased creased recovery angle with 100º (sample E), 88.5º (sample P) and 102.5º (sample PL) respectively.

The F value also proves that there is 1% significance.

Hence, it could be concluded that the treated samples have a decrease in crease recovery angle over the desized sample D.

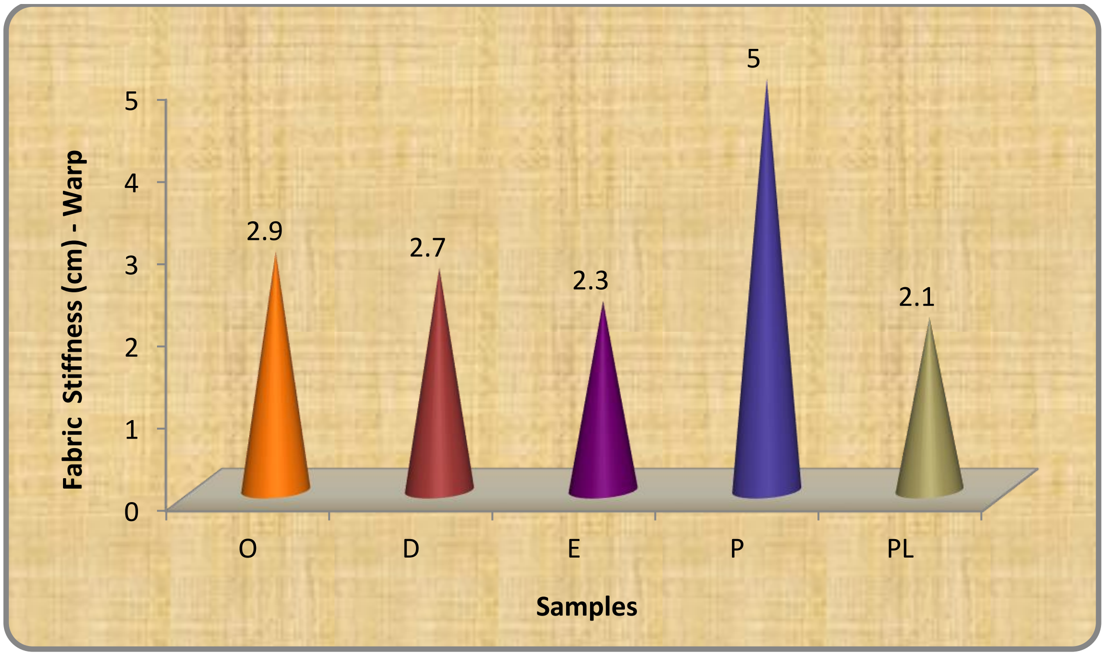


FIGURE – 10

FABRIC STIFFNESS (WARP)

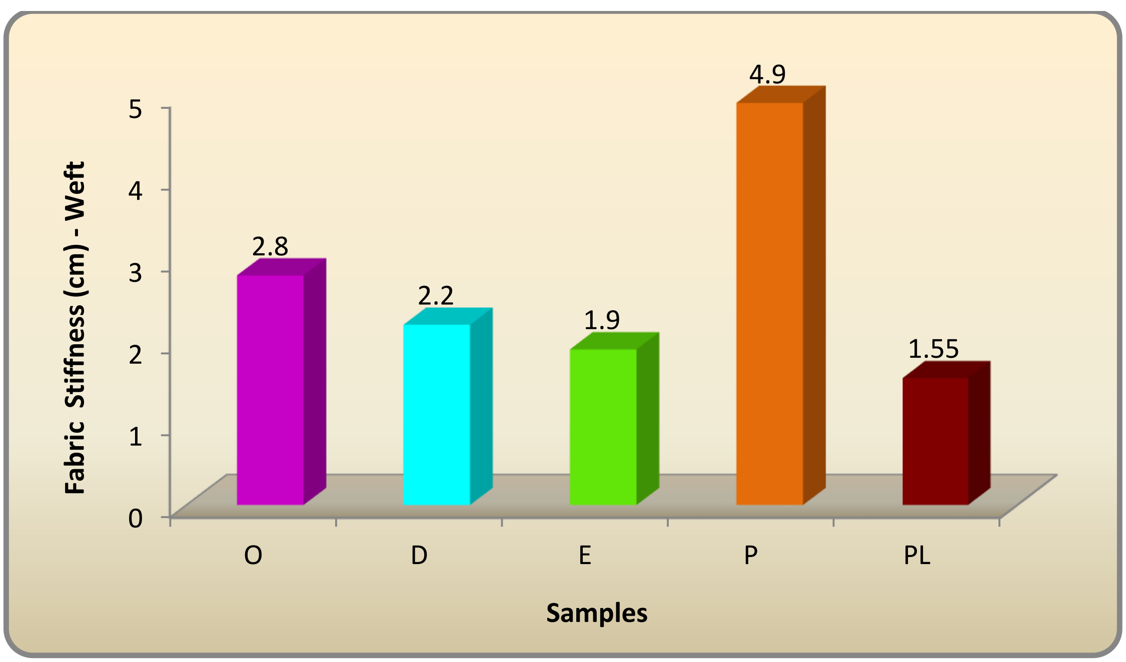


FIGURE – 11

FABRIC STIFFNESS (WEFT)

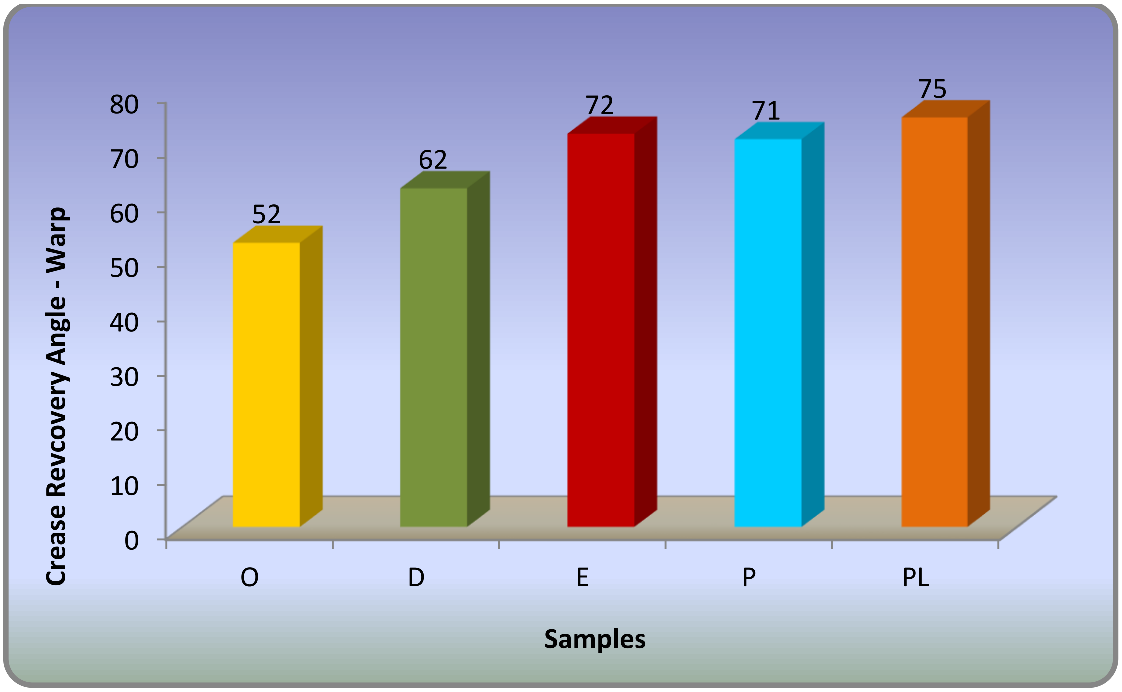


FIGURE – 12

CREASE RECOVERY (WARP)

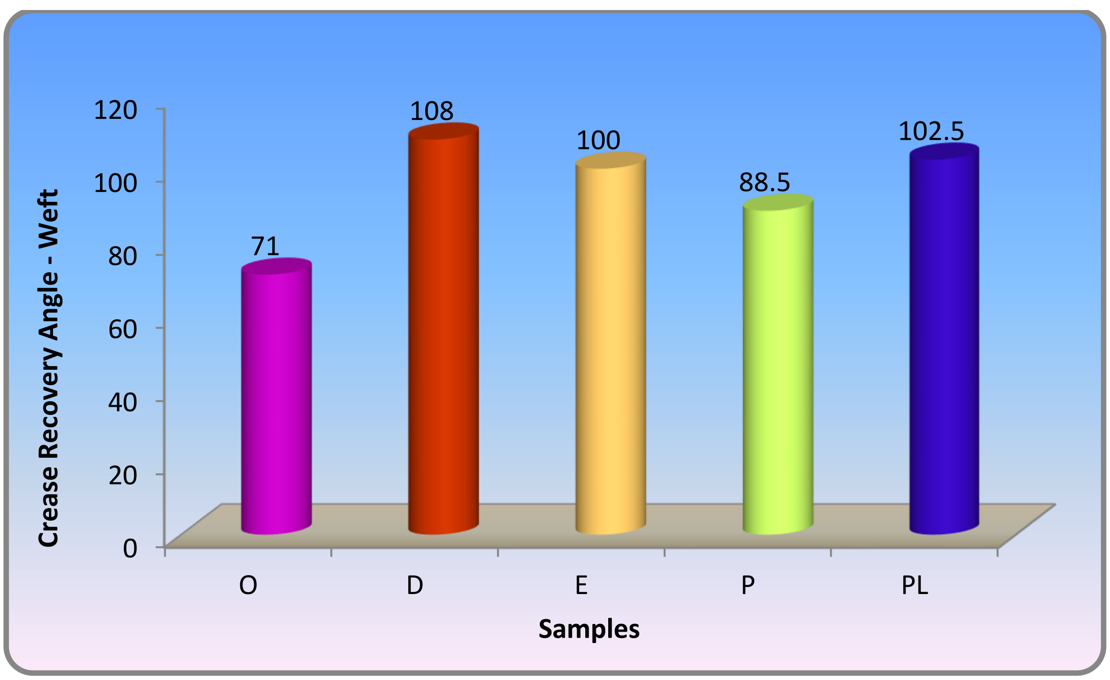


FIGURE – 13

CREASE RECOVERY (WEFT)

4.4.9 Drape

The results obtained for drape is presented in Table XIX and Figure 14.

TABLE – XIX

FABRIC DRAPE

S. No	Sample	Drape coefficient	Loss or gain value	Loss or gain percent	F Value
1	O	66.66	-	-	771.74**
2	D	63.58	-3.08	5	
3	E	46.96	-16.62	26	
4	P	95.37	31.79	50	
5	PL	47.06	-16.52	26	

** - Significant at 1% level

From the Table XIX and Figure 14, it is clear that the drape of the sample D has increased by 5 percent over the sample O.

Among the treated samples, samples E and PL have increased drape of 26 percent over sample D. As for sample P, it has a drastic decrease in drape of 50 percent when compared with sample D.

From the F value it is obvious that there is 1% significance.

Hence it could be concluded that the sample P has the lowest drape while sample samples E and PL have an increase in drape after treatment.

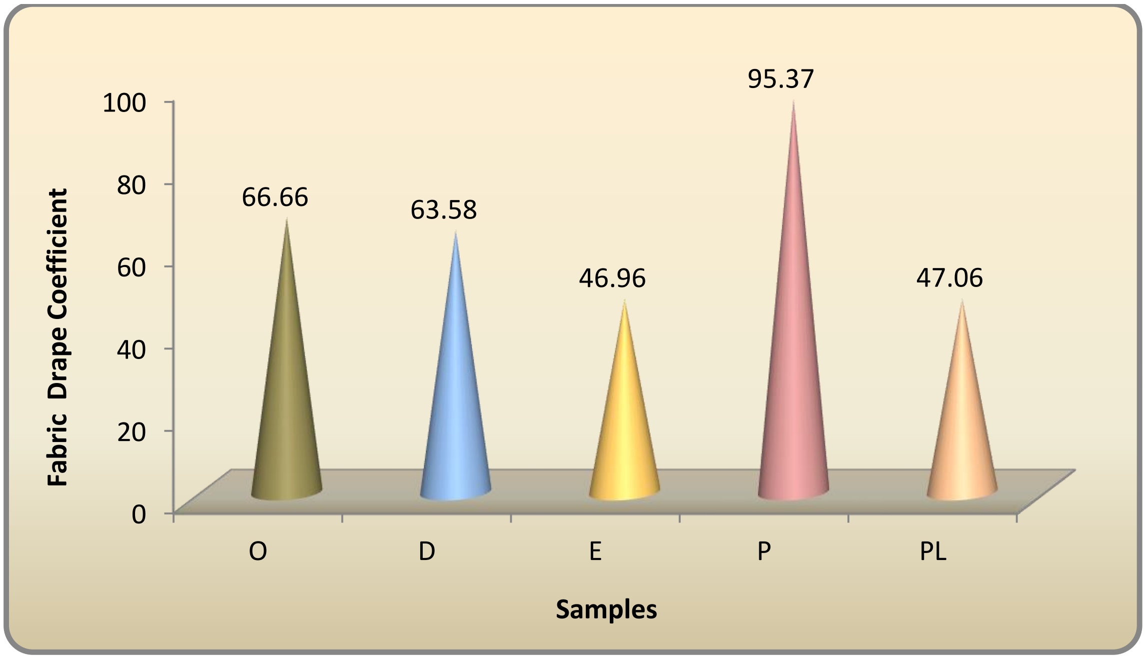


FIGURE – 14

FABRIC DRAPE

4.4.10 Drop test

The results obtained for drop test are presented in Table XX and Figure 15.

TABLE - XX

DROP TEST

S. No	Sample	Time (sec)	Loss or gain value	Loss or gain percent	F Value
1	O	25	-	-	1317.76**
2	D	2	-23	92	
3	E	2	-	-	
4	P	3	1	50	
5	PL	1	-1	50	

** - Significant at 1% level

From the Table XX and Figure 15, it is clear that the time taken for the drop to penetrate into original sample O was 25 seconds which drastically reduced in the sample D by 92 percent.

The treated sample E took the same amount of time (2 seconds) as the desized sample D to allow the drop to pass through. The sample P shows increase in time (3 seconds) and the sample PL shoes decrease in time (1 second) to allow the drop to pass through them.

Shishoo (2007) says plasma treatments are increasingly used for improving hydrophilicity, water transfer and drying rate properties of fabric. This may be the reason for the increased absorbency.

It can be seen clearly that there is 1% significance as per the F value.

Hence, it could be concluded that the sample PL has the highest absorbency over the desized sample D after treatement.

4.4.11 Sinking

The results obtained for sinking are presented in Table XXI and Figure 16.

TABLE - XXI

SINKING

S. No	Sample	Time (sec)	Loss or gain value	Loss or gain percent	F Value
1	O	42	-	-	5511.69**
2	D	3	-39	93	
3	E	2	-1	33	
4	P	3	-	-	
5	PL	1	-2	67	

** - Significant at 1% level

Form the Table XXI and Figure 16, it is obvious that the desized sample D took very less time (3 seconds), to sink when compared to the original fabric O which took 42 seconds.

Among the treated samples, the sample P took the same time (3 seconds) as the desized sample to sink. Samples E and PL took 2 seconds and 1 second respectively to sink under the water surface. It is clear that the samples E and PL took less time than the sample P.

From the statistical analysis also it is proved that there is 1% significance.

Hence, it could be concluded that samples E and PL had increased in absorbency property after treatment.

4.4.12 Wicking

The results obtained for wicking are presented in Table XXII and Figure 17.

TABLE - XXII

WICKING

S. No	Sample	Wicking (cm)	Loss or gain value	Loss or gain percent	F Value
1	O	0.4	-	-	317.64**
2	D	5.7	5.3	1325	
3	E	4.35	-3.95	69	
4	P	2.6	-3.1	54	
5	PL	6.8	1.1	19	

** - Significant at 1% level

From the Table XXII and Figure 17, it is clear that the wicking ability of the desized sample D has drastically increased over the original sample O.

Among the treated samples, sample PL has the most wicking ability of 6.8 cm followed by sample E of 4.35 cm and sample P of 2.6 cm.

In the first stage of the treatment, plasma reacts with the substrate surface where active species and new functional groups are created, which can completely change the reactivity of the substrate says Hegemann (2006). This may be the reason for the increased wicking ability in the plasma treated sample.

It is also proved that there is 1% significance while considering the F value.

Hence, it could be concluded that the treated samples have an increase in wicking ability than the original and the desized samples.

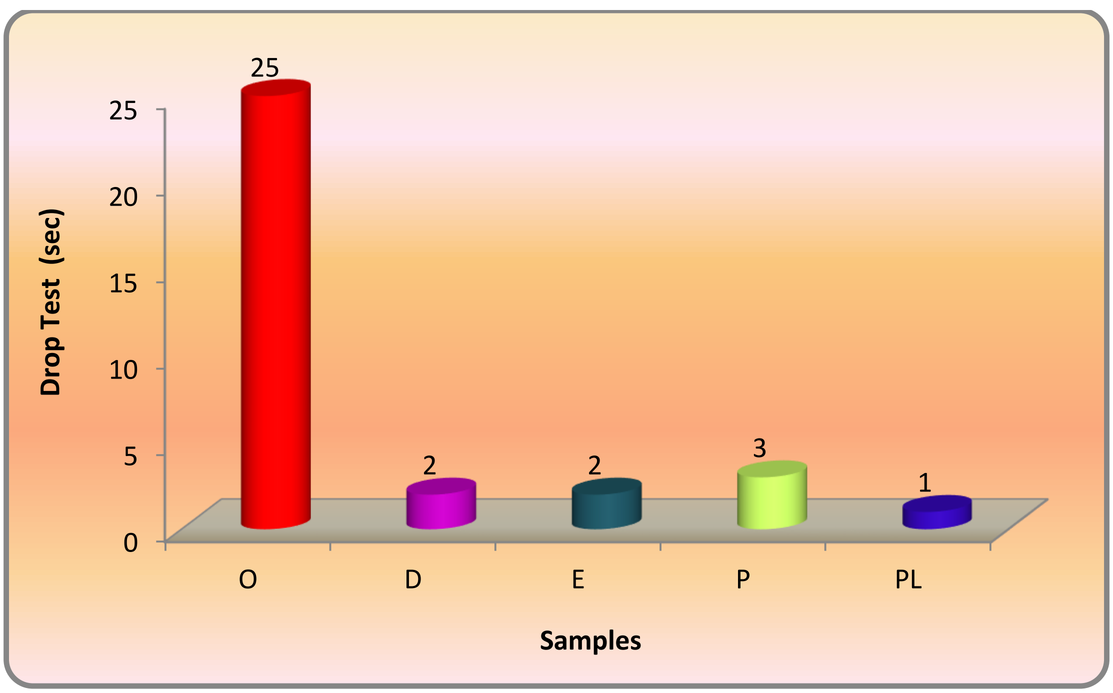


FIGURE – 15

DROP TEST

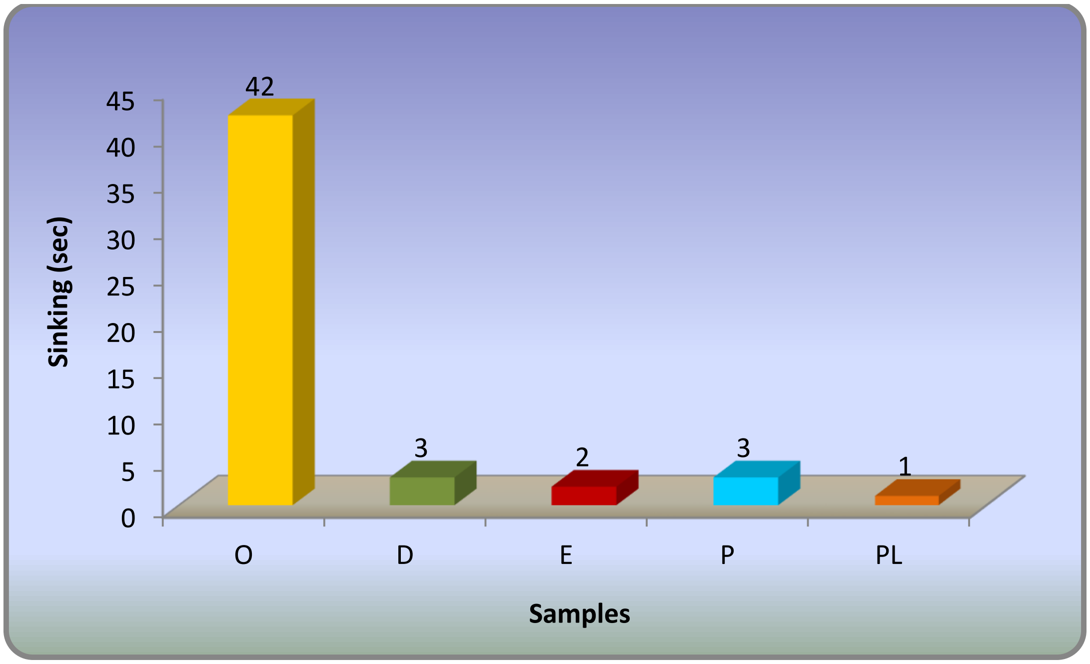


FIGURE – 16

SINKING

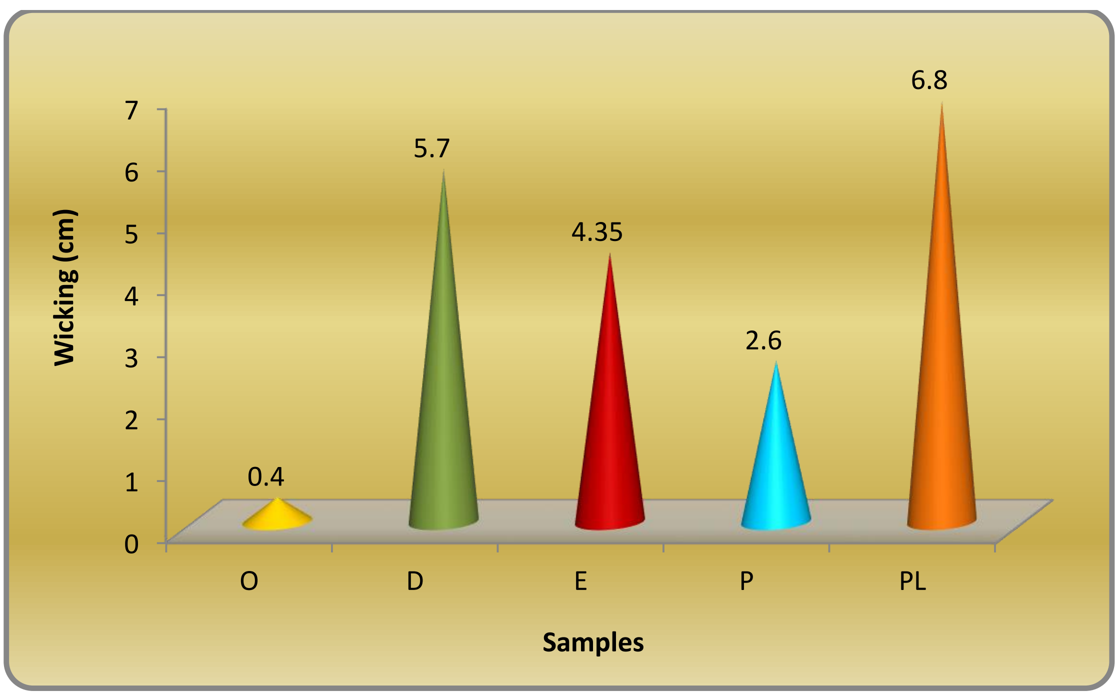


FIGURE – 17

WICKING

4.5 ANTIMICROBIAL TEST

The antimicrobial activities of the treated samples are discussed below in Table XXIII. The zones of inhibition of samples E, P and PL are exhibited in Plate XXV, Plate XXVI and Plate XXVII respectively.

TABLE - XXIII

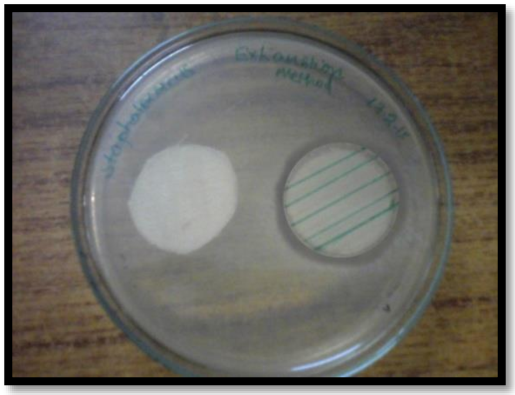
ANTIMICROBIAL TEST

S. No	Sample	Zone of Inhibition (Bacteria) (mm)		Zone of inhibition (fungus) (mm)
		Gram +ve	Gram -ve	
1	E	2.2	2.1	2.3
2	P	2.2	2.3	2.5
3	PL	2.3	2.3	2.5

From the Table XXIII, it is evident that the highest zone of inhibition of gram +ve bacteria was observed in sample PL with 2.3 mm followed by samples E and P with 2.2 mm.

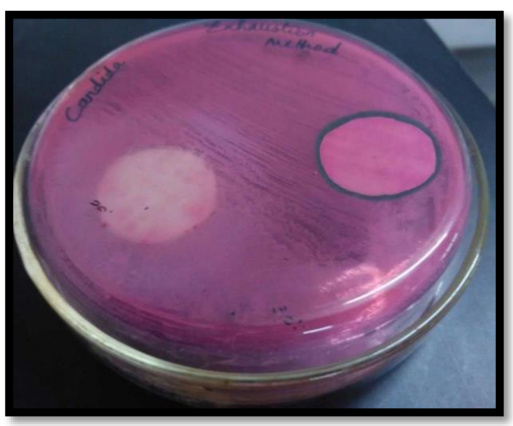
As for the gram –ve bacteria, the highest zone of inhibition was observed in samples P and PL with 2.3 mm followed by sample E with 2.1 mm.

As far as fungus is concerned, the highest zone of inhibition was observed in samples P and PL with 2.5 mm followed by sample E with 2.3 mm.



GRAM +VE BACTERIA

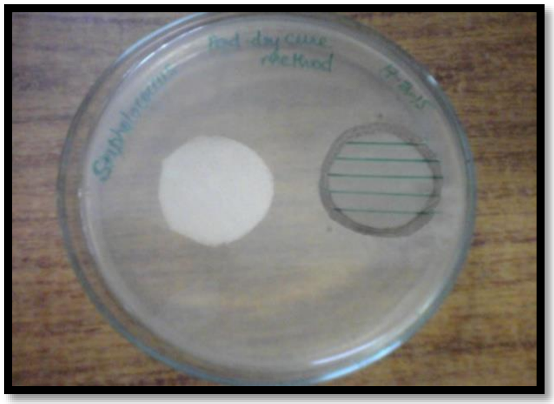
GRAM -VE BACTERIA



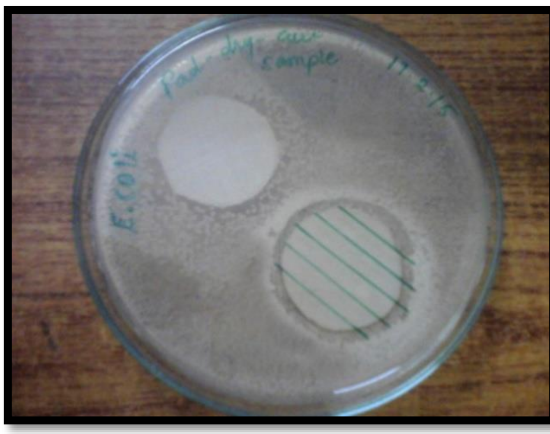
FUNGUS

PLATE – XXV

ANTIMICROBIAL ACTIVITY OF SAMPLE E



GRAM +VE BACTERIA



GRAM -VE BACTERIA

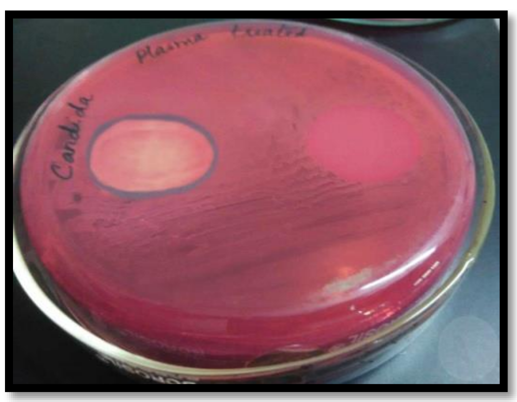
FUNGUS

PLATE – XXVI

ANTIMICROBIAL ACTIVITY OF SAMPLE P

GRAM+VE BACTERIA

GRAM -VE BACTERIA



FUNGUS

PLATE – XXVII

ANTIMICROBIAL ACTIVITY OF SAMPLE PL

4.6 SPECIAL TESTS

The results of special tests carried out are tabulated and discussed under.

4.6.1 Ant repellent test

The results of ant repellent test are presented in Table XXIV and Plate XXVIII.

TABLE - XXIV

ANT REPELLENT TEST

S. No	Sample	No. of ants
1	Untreated	44
2	Treated	0

From the Table XXIV and Plate XXVIII, it is clear that there were 44 ants on the untreated sample and no ants on the treated sample.

Hence, it could be concluded that the treated fabric had good repellency against ants.

Untreated sample

Treated sample

PLATE – XXVIII

ANT REPELLENT TEST

4.6.2 Performance study

The performance study of the selected treated sample PL is presented in Table XXV and Plate XXIX.

TABLE – XXV

PERFORMANCE STUDY

S.No.	Samples	No. of ants
1	PL	-
2	PLW1	6
3	PLW2	33
4	PLW3	72

From the Table XXV and Plate XXIX, it is clear that the treated sample PL was noted to have no attack of ants. After the first wash, in the sample PLW1, it was noted to have 6 ants on the fabric. After the second and third washes, the number of ants attacking the fabric increased with 33 ants after the second wash in sample PLW2 and 72 ants after the third wash in sample PLW3. This is vividly shown in the Plate XXIX

PLW 1

PLW 2

PLW 3

PLATE XXIX

PERFORMANCE STUDY

4.7 SEM ANALYSIS

From the Scanning Electron Microscopic appearance at various magnifications, it is obvious that the appearance of sample P exhibited the adherence of *Acorus calamus* on the surface of the fibres. This adherence was noted to be more in the sample PL. This may be due to the treatment methods adopted for the study. (Plate XXX, Plate XXXI, Plate XXXII and Plate XXXIII)

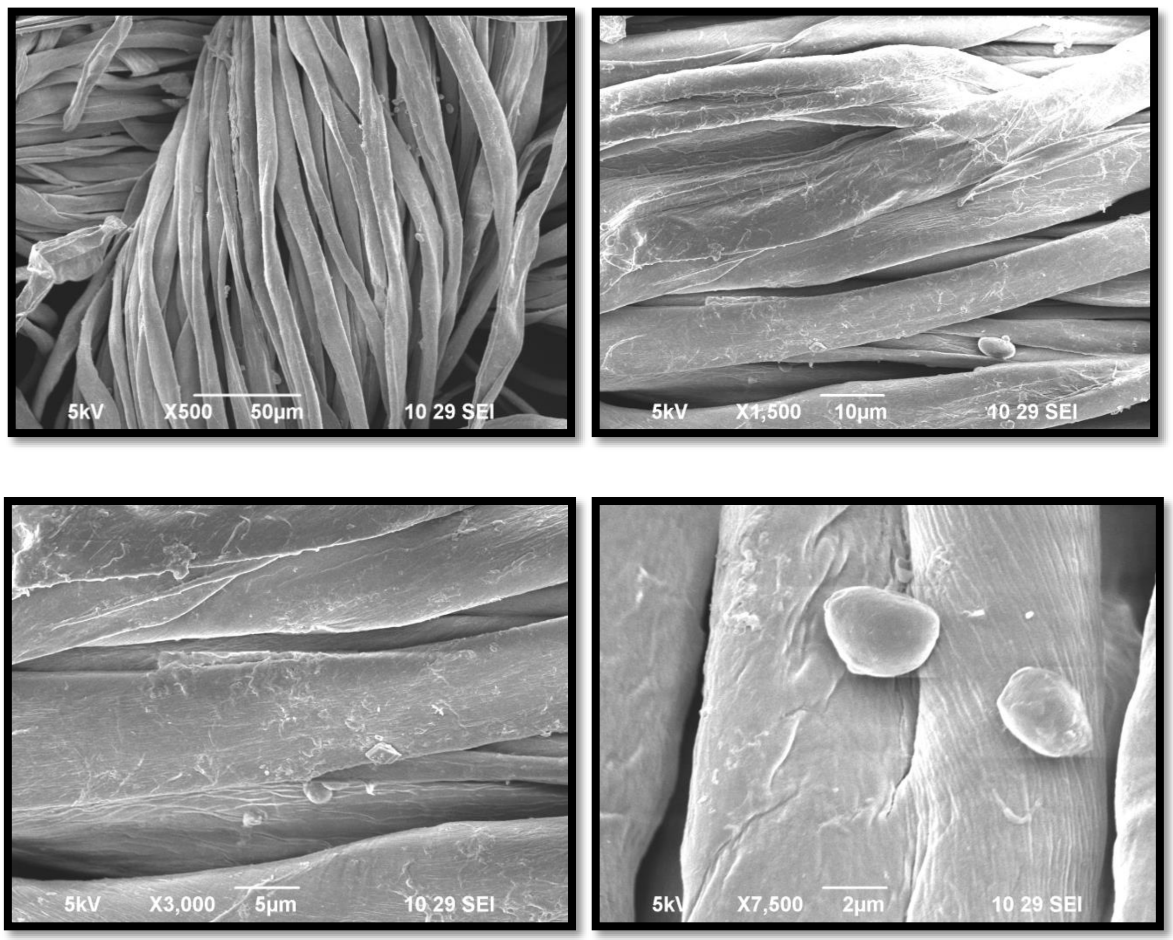


PLATE XXX

SEM APPEARANCE OF SAMPLE D

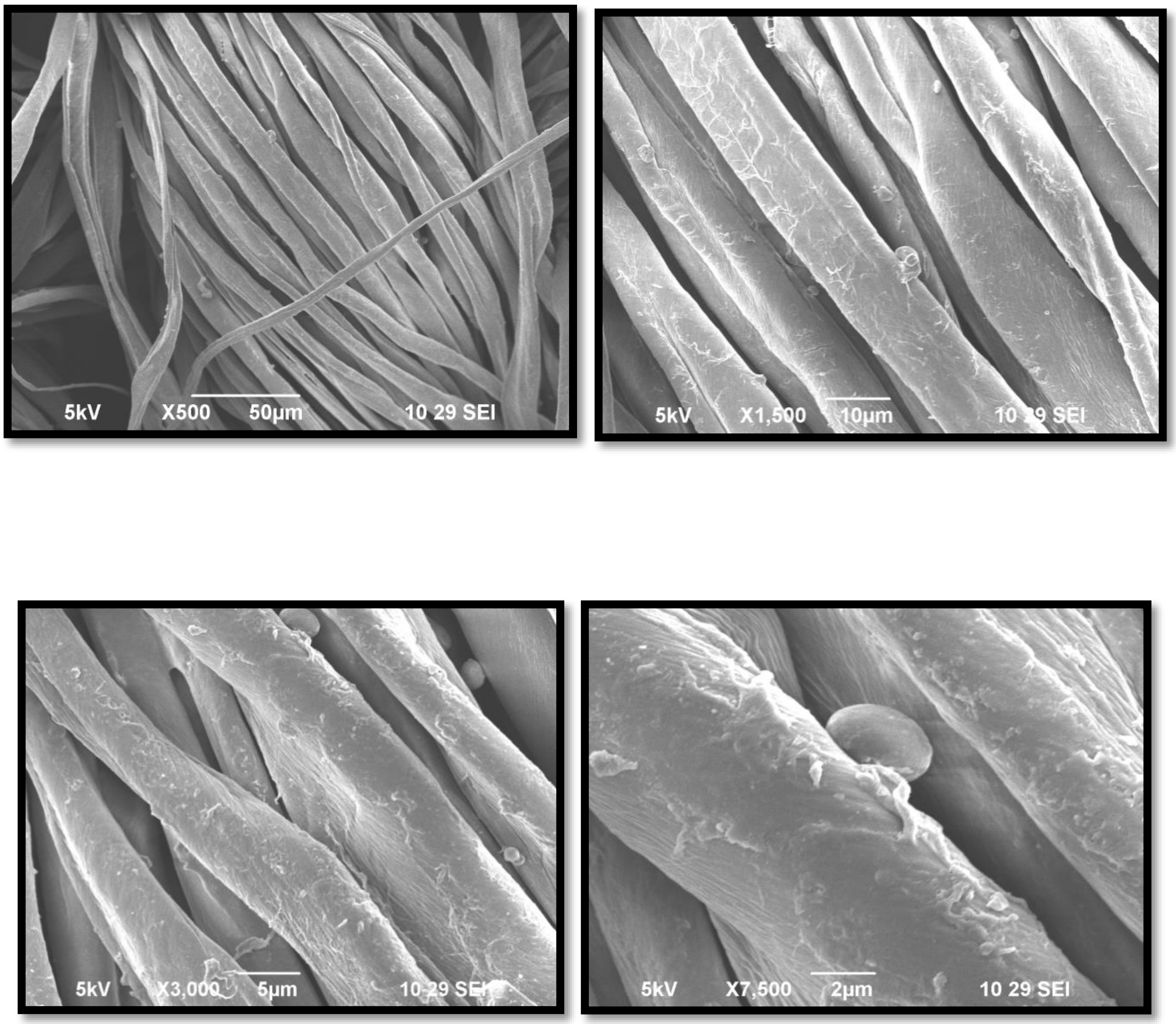


PLATE XXXI

SEM APPEARANCE OF SAMPLE E

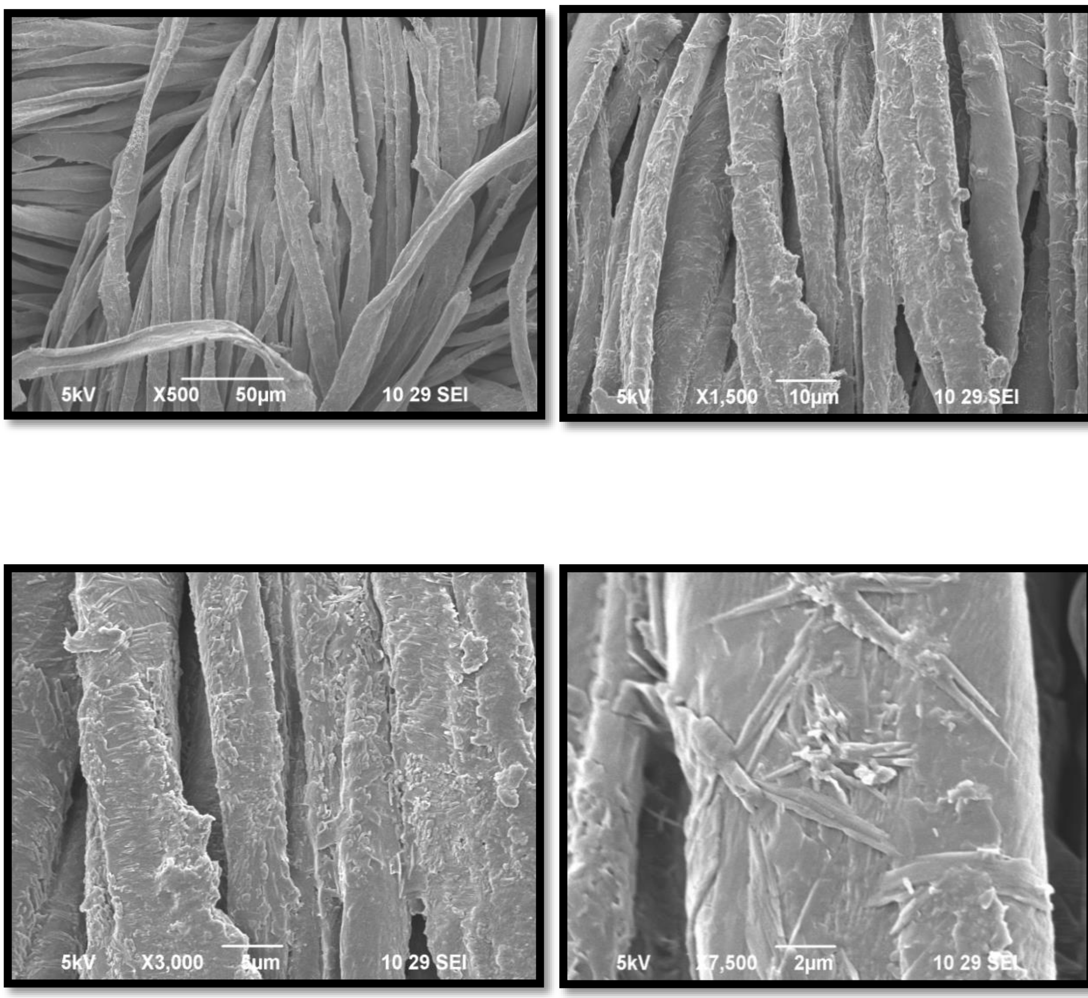


PLATE XXXII

SEM APPEARANCE OF SAMPLE P

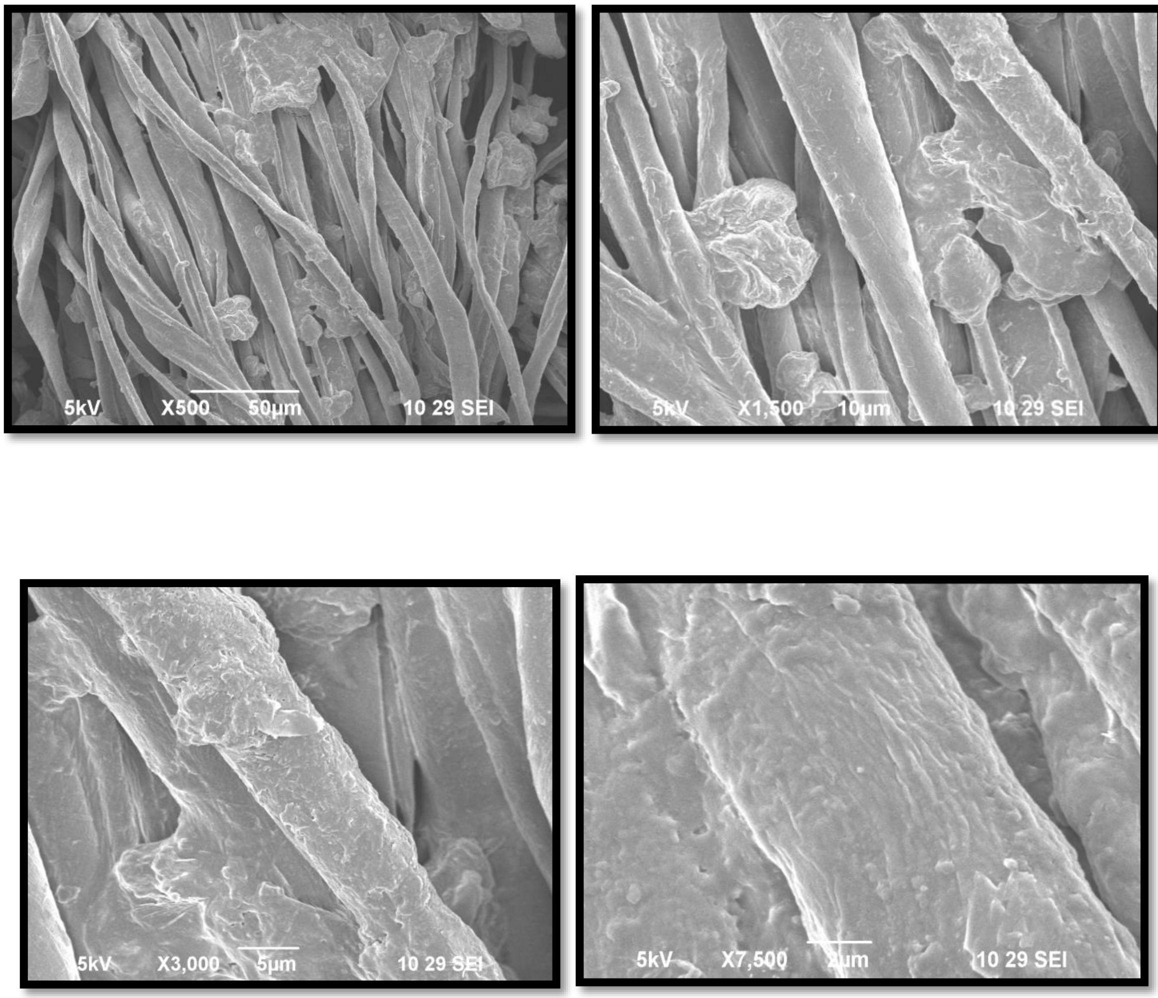


PLATE XXXIII

SEM APPEARANCE OF SAMPLE PL

4.8 PRODUCT PERFORMANCE STUDY

The performance study of the product has been discussed under. (Plate XXXIV)

PLATE XXXIV

PERFORMANCE STUDY OF FRUIT COVER

From Plate XXXIV, it can be seen clearly that there was no attack of flies or ants on the fruit basket which was covered with the treated fruit cover. Hence, it could be concluded that the treated fabric effectively repels ants and flies.

4.9 PRODUCT COST ESTIMATION

The estimated cost of the product is presented in Table XXVI.

TABLE – XXVI

COST ESTIMATION

Particulars	Cost (Rs.)
Fabric	80
Finishing	165
Stitching	10
Materials used for stitching	7
Grand total	**Rs. 262**

Thus the cost of the fruit cover was estimated to be Rs.262/- only.

5. SUMMARY AND CONCLUSION

The textile industry is a diverse one, as much in the raw materials it uses as the technique it employs. At each of the stage of the textile industry, the negative impacts on the environment are as numerous as they are varied. The need for eco friendly textiles is being voiced soundly now a day. So, the antimicrobial source, the treatment methods and the fabric used were selected so as to not affect the environment.

An attempt to apply antimicrobial finish on khadi cotton using a natural herb was intended as people are becoming more conscious about health and hygiene and Khadi cotton was selected for this as it has historical importance and deserves to be promoted and preferred by the mass. The environmental pollution makes it necessary to find new ways to enhance the health and hygiene qualities of consumer products. Textile consumers all over the world demand functionality in the products especially properties that relate to the protection of humans from the attack of microbes. Microbes are everywhere and they cannot be prevented from coming in contact with humans.

Microbial infestations pose danger to both the living and non-living. The textiles can be treated with antimicrobial finishes to suppress or prevent the detrimental effects. Antimicrobial activity is inevitable to the fabrics that come in close contact to the body. An antimicrobial property present in clothing, healthcare fibrous product and home textile may come in contact with an individual's skin or it may be affecting any living species found in the surrounding environment.

The increasing environmental concerns and demands for an environmentally friendly processing of textiles leads to the development of new technologies, the use of plasma being one of the suitable methods.

Considering the above facts, the investigator has taken up an experiment on "Application of Antimicrobial Finish on Khadi Fabric Using ***Acorus calamus***", with the following objectives.

- to extract the essence from ***Acorus calamus*** rhizome
- to impart antimicrobial finish on khadi fabric
- to develop end products

METHODOLOGY

The methodology pertaining to the study "Application of Antimicrobial Finish on Khadi Fabric Using ***Acorus calamus***" is presented in the following steps.

- Khadi cotton fabric was selected so as to promote khadi and because cotton is the most receptive to finishes.
- Antimicrobial finish was selected to be applied on the fabric.
- *Acorus calamus* was chosen as the natural source as herbal antimicrobial finishes are gaining popularity.
- Ethanolic extraction of *Acorus calamus* was done in an Orbital shaker.
- Aqueous extraction of *Acorus calamus* was done in a water bath.
- A pilot study was done to test the antimicrobial activity of both the extracts.
- The extract which showed good antimicrobial activity was chosen for further study.
- Optimization for the concentration of the selected extract was carried out.
- Five concentrations namely 2%, 4%, 6%, 8%, 10% were tested for antimicrobial activity using the AATCC agar diffusion method.
- The concentration which showed the best results was chosen for applying the finish on the fabric.
- The fabric was desized using commercial detergent and dried before application of the finish.
- The finish was applied on the fabric using three methods namely exhaustion method, pad-dry-cure method and plasma treatment.
- Exhaustion method was carried out by dipping the desized sample into the *Acorus calamus* solution at 50ºC to 55ºC for 45 minutes.
- Pad-dry-cure method was executed using a Padding mangle.
- For plasma treatment, the fabric was treated with plasma in a plasma chamber operated in vacuum. Then the fabric was immediately dipped in *the Acorus calamus* extract.
- The treated fabrics were evaluated subjectively and objectively.

- Ant repellent test was conducted for the treated fabric which was evaluated for its performance.
- The samples were analyzed using Scanning Electron Microscope.
- The product prepared was a fruit cover that can be used in dining tables to prevent the attack on ants and flies.
- The performance of the fruit cover was assessed by covering some fruits and observing it visually.
- The cost of the prepared product was estimated.

FINDINGS OF THE STUDY

- The ethanolic extract showed activity against bacteria and fungus.
- The concentration of 8 percent of ethanolic extract showed the highest zone of inhibitions for bacteria and fungus.
- All the treated samples had very good general appearance. Sample PL had highest evenness and good lustre.
- Sample P was very coarse and had moderate fragrance.
- The fabric count had increased in both the warp and weft directions for all the treated samples.
- The weight of the treated samples had increased after treatment except for the sample treated using exhaustion method.
- The fabric samples have become thicker after treatment, except for the sample PL which had no change in thickness.
- All the treated samples showed a decrease in strength in both the warp and weft directions.
- The elongation also had reduced in all the samples after treatment.
- The abrasion resistance had decreased in all the samples after treatment.
- Slight pilling was found in all the treated samples.
- The fabric stiffness in both the warp and weft directions had reduced in samples E and PL after treatment while it increased tremendously in sample P.

- The samples show an increased crease recovery angle in the warp direction and a decreased crease recovery angle in the weft direction after treatment.
- The treated samples E and PL showed an increased drape and sample P had a reduced drape.
- All the absorbency tests (drop test, sinking tet and wicking test) showed improvement in absorbency after treatment with the highest rate of absorbency in sample PL.
- The treated samples P and PL showed highest zone of inhibitions for fungus, and gram –ve bacteria while sample PL had the highest zone of inhibition for gram +ve bacteria.
- The ant repellent test showed that the treated samples had a very good repellency against ants.
- SEM analysis also showed the adherence of the *Acorus calamus* particles on the fibres.
- Product also gave a satisfactory result as it prevented the attack of flies.
- The cost of the fruit cover was estimated to be Rs.262/-

CONCLUSION

The application of *Acorus calamus* using plasma treatment for inducing antimicrobial property on khadi material proved to be effective in imparting antimicrobial property as well as ant repellent property. Plasma treatment gave the best results in absorbency of the finish applied.

RECOMMENDATIONS

- *Acorus calamus* can be used to give fragrance finish.
- It could be applied in baby garments.
- It could be used for mosquito repellency.
- Sustainability of the finish on the surface of the fabric may be improved by giving a suitable treatment.

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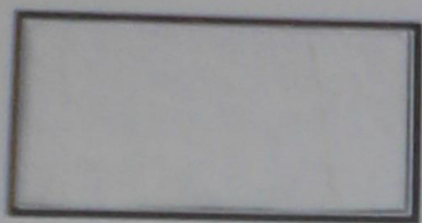
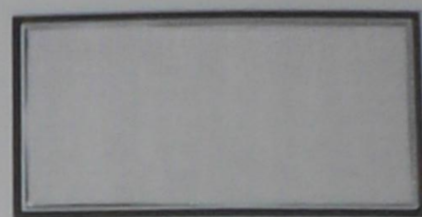
APPENDIX I

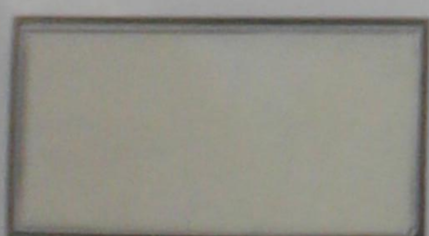
FABRIC SAMPLES



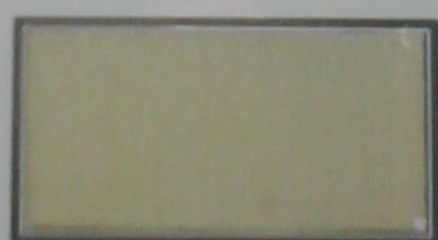
Sample O



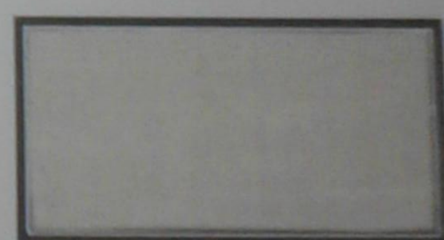
Sample D



Sample E



Sample P



Sample PL

APPENDIX II

SUBJECTIVE EVALUATION PERFORMA

S. No	Samples	General appearance			Texture			Evenness			Lustre			Fragrance		
		Very Good	Good	Moderate	Coarse	Smooth	Very smooth	High	Medium	Low	Very Good	Good	Moderate	Strong	Moderate	Subtle
1	E															
2	P															
3	PL															