1. Introduction

The textile industry is going through revolutionary changes aiming to meet unique needs of modern consumers. Textile products are more essential for human beings and now their development towards value added functions is on the rise. Value addition in clothing has changed the global textile scenario. Textiles and clothing should fulfill the function of comfort, aesthetic, safety and ecological requirements. These characteristics by and large defined the sensibility of the textile products. In addition social, psychological, physical, economical parameters play a vital role in the selection, wearing and purchase of textile products. The science of clothing has evolved drastically. Innovations in the field of textiles are now a day ahead. Today’s textile production is characterized by higher quality requirements, productivity and greater flexibility to meet the basic requirements of the global market. The contribution of the textile industry to the Indian economy is notable.

The definition and scope of technical textiles adopted by the authoritative textile terms and definitions, published by the Textile Institute is “Textile material and product manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics”, (Horrocks and Anand, 2004). Function is the primary criterion of technical textiles. The potential of technical textiles in India is still untapped. Technical textiles represent a multi disciplinary field with numerous end use applications. The production of different items of technical textiles industry has been slowly but steadily increasing in the country. Technical textiles have never been a single coherent industry sector and market segment. It is developing in many different directions with varying speeds and level of success.

Technical textiles can be classified into many categories, depending on their end use. The classifications are agrotech, buildtech, clothtech, geotech, hometech, industech, mobiltech, ecotech, packtech, protech, sporttech. Nowadays, technical textiles are widely used in filter clothing, furniture, hygiene medical, construction material, agro, automobile and geotech.

Sporttech segment comprises of technical textile products used in sports and leisure such as shoes, flying and sailing sports, climbing, angling, cycling, winter and summer sports and indoor sports. The technical textile products covered under
sporttech are sports composites, artificial turf, parachute fabrics, ballooning fabrics, sail cloth, sleeping bags, sport nets, sport shoes components, tents and swimwear.

Textile materials are used in all sports as sportswear, and in many games as sports equipment and sports footwear. The sports textiles’ sector includes specialist apparel for specific sports each with its own particular functions. The performance fiber, yarn, fabric and finishes developed for this specialist sector are increasing constantly. Typical garments include shorts, tracksuits, T-shirts, polo shirts and trainers. Specialized garments include wet suits and salopettes. It also includes some under wear, such as the jockstrap. Sportswear is also often worn as casual fashion clothing. From functional point of view, the active sportswear requires super lightweight, low fluid resistance, super-high tenacity and stretch ability. For those who are seeking comfort and healthy pursuit’s critical features include thermal regulation, UV resistance, sweat absorption and fast drying, vapour permeability and from aesthetic point softness, surface texture, handle, luster, colour and comfort are important factors, (Senthilkumar and Sundaresan, 2013).

Comfort is determined by the interaction of the body with its micro climate and its clothing. Consumer demand high level of comfort, design and easy care in all types of clothing. However, in sportswear, where thermo physiological comfort can significantly enhance the performance of the wearer, the uses of innovative textile products are commonly increasing in the recent years. Thermal comfort is depend upon both environmental and individual factors and is influenced by the core and skin temperature of the body. The thermo-neutral zone for naked resting subjects has been defined to lie between 28–30°C. In this comfort zone the human body is unaware of warmth or coolness. Outside this range the body feels discomfort. This means that the balance between the rates of heat loss and heat generated must be maintained, usually by putting on or taking off clothes. The sportswear required for modern athletics shall be both functional and fashionable. In recent years, more and more consumer pursuit for comfortable and elegant thin fabrics, usually such kind of fabrics are knitted or woven from two or more than two kinds of material.

The sporting goods industry occupies a major consumer market in a country’s economy. Market for performance sportswear is buoyant and will continue
to be as better performance garments are being introduced regularly. There has been a continued development of new and innovative technical fabrics to keep with the demand of the sports apparel market. Consumers are interested to staying dry and comfortable during workout. Moisture from the body passes through the clothing to keep dry and comfortable. Softness, shape retention, stretchability characteristics, comfort and easy care are other properties looked for in sportswear. As a consequence, many of the innovative textile developments have application of moisture management, anti-microbial treatment and UV protection in today’s performance fabrics.

Sportswear is a twentieth-century word. The merchandising definition of sportswear is “separate garments, priced individually that are worn for casual occasions or for participation in active sports”. Active sportswear is organized as separate and co-ordinate sportswear. Consumers are more and more conscious for the comfort of the garment that they are wearing. As a result new fibers and fabrics are emerging out for satisfying the needs. The latest textile materials are much more functioning specific for fulfilling specific needs in different sports activities. There are so many sports that people are involved in these days. No wonder sports gear becomes one of the top search items. The term “sports gear” implies a variety of sports related things from clothing and footwear to equipment and accessories. From individual to team sports, certain kinds of sports gear are designed specifically for each sport.

Sports gear is particularly popular with teenagers. A T-shirt is a basic part of the entire workout ensemble allowing one to look awesome as one sweat away. Active wear is important when one push themselves to the limits. New developments in sports wear have always been about increasing functionality to improve performance. Material customization and versatility allow many creative design possibilities, breathable, flexible and light weight construction for comfort and freedom of movement and wash ability for easy care and maintenance.

In today’s world, naturally renewable resources are increasingly being required as a result of human dedication to protect environment. Bamboo fiber is a new regenerated cellulose fiber, obtained from the bamboo tree. Bamboo plant is an essential forest bio-mass resource. Bamboo does not require any pesticides or
chemicals and is also biodegradable. Bamboo fiber is a revolutionary one that has unparalleled advantages, including strength, versatility, softness and luxurious texture. In a very short time, clothing made from bamboo fiber has made it to the top ranks of eco-friendly choices, (Srivastava, 2013).

The well-known characteristics of bamboo material are its antibacterial property, incredible capability to breath and its intrinsic coolness, pleasant luster, better drape and tremendously comfortable soft feel. Bamboo naturally provides added protection against the sun’s harmful UV rays. The cross-section of bamboo fiber is mainly filled with numerous voids and micro-holes. It is as well extraordinarily hygroscopic and has more excellent moisture and temperature management properties. Currently, regenerated bamboo fibers have high demands in market and are being used in apparels including underwear, T-shirt, sports textiles, socks, towels, bathing suits, sanitary napkins, absorbing pads, bandages and surgical gowns, (Badr, 2013).

Cotton is the backbone of the world’s textile trade. It is also known as “King of fiber” and “White gold”. Due to its unique fiber structure it can absorb water up to 2.7 times of its own weight. Cotton is the most important apparel fiber. It’s combination of properties like pleasing appearance, comfort, easy care and durability makes cotton ideal for warm weather clothing, active wear, work clothes, upholstery, draperies, area rugs, towels and bedding. Cotton is good for use in hot and humid weather. The fiber absorbs moisture and feels good against the skin in high humidity. Moisture passes freely through the fabric, thus aiding evaporation and cooling, (Kadolph, 2011).

Bamboo, cotton, bamboo/cotton, tencel, nylon, acrylic, polypropylene, cotton lycra fibers can make ideal sportswear. The pre-requirement of ideal sportswear are odour control and skin friendly, since it has a close contact with skin and many of the sports persons face this problem. This can be achieved by introducing antimicrobial finish, anti allergic finish and odour adsorption finish and UV finish to the garments.

The material used for blending is also important because not all material can be mixed together. Wrong combinations can result in shrinkage or very weak structure of fabric. Improvement of existing properties and the creation of new
material properties are the most important reasons for the functionalization of textiles.

The common fabric formation techniques are weaving, knitting and non-woven. For sportswear knitting is very common and successful. Knitting is the art of using yarn to make fabric from interlocking loops. It is easier to process many high performance and high strength fiber yarns on knitting equipment as compared to weaving equipment. Knitting is a way of interlocking a series of loops that creates hand and machine knitting fabric. Knitted fabric has useful properties that make it suitable for a range of garments including tights, gloves, under wear and other close-fitting garments. The loop structure of knitted fabric stretches and moulds to fit body shapes. The major advantage of knitting technology is that the seamless garments can be produced on modern fully electronic and computerized equipment. This facility is not normally available in either weaving or non woven technologies. Also, it is easier to process many high performance and high strength fiber yarns on knitting equipment as compared to weaving equipment, due to lower abrasion and tensions, as well as shorter yarn paths involved during manufacture.

The art of making natural dye is one of the oldest methods of dyeing. Though the very earliest dyes were discovered by accident using berries and fruits, with experimentation and gradual development the vegetable dyes have resulted into a highly refined art. Some of the synthetic dyes were found to be associated with hazards affecting human life, creating skin diseases and lung problems. The natural and vegetable dyes are eco-friendly, bio-degradable and non-carcinogenic. Uses of natural dyes have increased several folds in the past few years due to the eco-friendly approach of the people. Dyeing is an ancient art, which predates written records. The widely and commercially used synthetic dyes impart strong colours, but causes carcinogenicity and inhibition of benthic photosynthesis, (Adeel et al., 2009). Germany was the first country to take initiative to put ban on numerous specific azo-dyes for their manufacturing and applications. Netherlands, India and some other countries also followed the ban, (Patel, 2011).

In general, herbs are used for flavoring, food, medicine and perfume. Culinary use typically distinguishes herbs as referring to the leafy green parts of a plant, from a "spice," a product from another part of the plant, including seeds,
berries, bark, roots and fruits. Herbs are garden plants that are grown and harvested for culinary, aromatic, medicinal and fibrous uses. Plant herbs are placed in the garden for their unmistakable fragrance, attractive texture, appealing colours, and variety of home uses. Globally, as many countries have been enforcing a ban on textiles that have been colored using certain synthetic dyes, for example azo dyes, this was a body blow to the handloom industry. At the same time, textile dyes using natural vegetable dyes, especially medicinal plants, have been commanding a huge market due to their obvious advantages. The advantage of the dyes extracted from the medicinal plants origin from renewable resources, limited chemical reactions involved in their preparation, bio-degradable properties, health curing properties, and harmony with nature.

Neem tree (*Azadirachta indica*), abundantly found in the Indian subcontinent is a rich source of medicinal compounds. It has an excellent potential as an antimicrobial agent and its main constituents such as azadirachtin, salannin and meliantriol are proven insect growth regulator and antifeedent. Neem seed and bark extracts have been successfully integrated to the cellulosic substrate imparting a semi-durable antibacterial property against both Gram-positive and Gram-negative bacteria, (Hashmat *et al.*, 2012).

The British Pharmacopoeia describes eucalyptus oil as the oil distilled from the fresh leaves of *E.globulus* and other species. The medicinal value of eucalyptus oil is probably the most powerful antiseptic of its class, especially when it is old. It is good ointment for the skin, containing antiseptic and healing properties. It produces very satisfactory results in scurf, chapped hands, chafes, dandruff, tender feet, enlargements of the glands, spots on the chest, arms, back and legs, pains in the joints and muscles.

Recent developments in fabric and garment finishing technologies are spicing up commodity products. There are numerous reasons to added value to a product. The development of unique fabric and garment finishes comes with a host of challenges. Finishes must be durable during the fabric finishing process, stable in the presence of other chemicals, wash fast, evenly and consistently applied. Finishes also need to be financially feasible and environmentally friendly.
Finishing is the heart of textile processing. Finishing of textile fabric is carried out to increase attractiveness and serviceability of the fabric. Different finishing treatments are available to get various effects, which add value to the basic textile material. Processing is important to make it usable but finishing gives value addition and makes the garment attractive and comfortable. Finishing can incorporate desirable properties too. Fabric finishes are wet or dry treatments that complete a textile.

Fabric finishing is usually applied by ‘dip and squeeze’ process known as padding or impregnation, which is widely used in textile factories. Different finishing treatments are available to get various effects, which add value to the basic textile material. Antibacterial or anti septic finishes are typically applied in the form of bacteriostatic chemicals that suppress mold and mildew growth or prevent the rotting process. These finishes are important in health care settings.

Increasing the global competition in the world of textile and garment textile finishing is emerging globally. The rapid growth of novel finishing techniques has created many opportunities and challenges for the manufacturers. Customer requirements towards comfort, safety, aesthetics and functional performance have created a rapid increasing market for antimicrobial textiles, (Yas et al., 2010).

Odour is formed as a result of bacterial growth. An antimicrobial finish can be applied to the fabric to prevent bacterial growth and ultimately eliminates the it. Odour control is a hot topic in the apparel and hosiery arenas. It can be controlled by applying an antimicrobial finish removing the odour molecules as they are formed or covering up the odour with a fragrance.

Microbes cause many health problems because of the unhygienic clothes. Pathogenic microorganisms transfer infectious diseases, develop lung related disorders. Now, there is a big demand for the fabrics having functional finishes in general but antimicrobial finish in particular protecting human beings against microbes. The application of antimicrobial textile finishes include wide range of textile products for medical, technical, industrial, home furnishing, sports and apparel sectors.
Problems of hygiene are more and more to the force in textile finishing and it is now generally realized that antibacterial finish is very valuable in certain textiles for two reasons as a prophylactic measure to avoid infection and as a deodorant. Numerous types of bacteria exist on the earth. Most of the bacteria are beneficial to human kind but more number of them is harmful to human life. The battle against harmful germs has already begun in the sector of textile goods as well. Recently, consumers concern about sanitary properties of textile products and their safety towards human and environment.

In the recent years, consumers have become increasingly aware of the need for sun protection, which is related to the incidence of sun induced skin damage and its relationship with increased exposures to UV light. UV radiation can lead to acute and chronic reactions and damage, such as acceleration of skin ageing and sunburn. Protection of the skin against the action of solar radiation is a relatively new objective of textile finishing, since the textile does not always guarantee adequate protection. Thus, a special additional sun protection finish is applied in the form of UV stabilizers.

The presence of microcapsules has increased in the textile field. They have been applied as possible means of introducing new products to textiles such as fragrance, antibiotics and skin hydrants. In textiles the major interest in microencapsulation is currently in the application of durable finish. In microencapsulation, an active core material is encapsulated in a shell of limited permeability, so that the active core material is protected from the external environment till required or to affect the controlled release of the active core to achieve desired delay until the right stimulus is encountered. In addition, it can withstand for multiple wash.

The principal requirement of all garments, whether they are worn for protection for sports activity or for work is comfort in all its interpretations, physical and psychological. A garment should be light in weight, flexible without restricting body movements, the correct size for the person wearing it, in a design and colour appropriate for the activity and acceptable to the wearer, and breathable with minimum restriction on the passage of perspiration. Finally it should possess all the properties needed to give the type and degree of protection required.
Sportswears are engineered to maximize comfort through moisture management and temperature regulation to enhance the performance level of sports persons and at the same time make them more competitive. To achieve these desirable properties the right choice is the textiles using specialized fibers, yarns, fabric and finishing techniques. The use of such textile materials has created a demand and a high scope for the innovative suppliers of technical textiles and functional sportswear and active wear. Although many studies have been carried out to enhance the comfort of sportswear, the investigator decided to do research on to improve certain qualities of sportswear through appropriate finishing treatments. T-shirts as a sportswear have been chosen for this study, because it is universally used by all sports personnel.

Now and in future, consumers would be attracted towards special textile materials that differentiate among other products, multi-functional, technologically perfect and available at a reasonable price. Nowadays, customers are more and more aware of problems caused by microbes. Exposure to sunrays is leading to possibility incidence of skin cancer. Therefore claims for protection are increasing. Researchers are now looking for natural products, which do not have any ill-effects on the general population and are easily degradable. Consequently, there is increased research activity to find solutions based on natural products for most protective finishes. Protective clothing is used to protect the human body from the impacts of sun, wind, rain, chemicals, heat and fire, biological agents and microbes.

Hence the present study “Eco-friendly Dyeing and Finishing on Bamboo/Cotton Knitted Fabric for Sportswear” is taken up with the following objectives:

Phase I - Objectives

- To conduct preliminary interview for market and consumer survey.
- To conduct market survey to elicit information regarding types of yarn, fabric, garment, size, colour, natural dye and finishes for sportswear.
- To conduct consumer survey to elicit information regarding types of sports activity involved, time spent, preferable type of yarn, fabric, garment, size, colour for sportswear, skin problem faced, knowledge about natural dye and herbal finishes and preference regarding special finishes.
• To study the characteristics of the selected yarns such as yarn count, Lea strength, single yarn strength, elongation, yarn evenness, twist per inch, yarn appearance, yarn imperfection and yarn hairiness.
• To develop raw fabric and preparatory processed fabric.

Phase II- Objectives

• To select Natural dye sources and Bio-mordants, for the development of sportswear.
• To apply the selected Natural dye at different concentration and to conduct the visual inspection and quantitative assessment of dyed fabrics.
• To apply the selected Bio-mordants at different concentration and to evaluate the Bio-mordants finishes fabrics using quantitative assessment.
• To select the suitable mordanting technique from pre-mordanting, meta-mordanting and post-mordanting.
• To apply the selected Natural dye with suitable mordanting technique for the developed Bio-scoured single jersey knitted fabrics.

Phase III-Objectives

• To select herbs for antibacterial finish, UV finish and fragrance finish.
• To extract the selected herbs and finishing the selected material using dip dry method.
• To evaluate the antibacterial finished fabrics by quantitative assessment of antibacterial activity and selection of 3 herbs for further study.
• To evaluate the UV finished fabrics by UV protection/penetration measurement tester and selection of 3 herbs for further study.
• To evaluate the fragrance finished fabrics by sensorial evaluation of fragrance intensity and selection of 3 herbs for further study.

Phase IV - Objectives

• To develop microcapsules from the selected three herbs for each finishes namely, antibacterial finish and UV finish.
• To apply the developed microcapsules to import the antibacterial and UV finishes on developed fabrics namely, 100% cotton, 100% bamboo and 50:50 bamboo/cotton blend.
• To assess the microencapsulated antibacterial finished fabrics, quantitatively, qualitatively and antifungal test, and to select best one among three.
• To assess the microencapsulated UV finished fabrics, using UV protection/penetration measurement tester and to select best one among three.
• To optimize the concentration of antibacterial and UV finishing extracts.
• To optimize the antibacterial and UV finishing extract composition and materials such as 100% cotton, 100% bamboo and 50:50 bamboo/cotton blend.

Phase V - Objectives

• To study the characteristics of the selected fabric namely, 50:50 bamboo/cotton single jersey knitted fabrics imported with selected finishes of optimized composition/concentration, such as SEM analysis, FTIR analysis, washing test has been carried at three levels at 10, 20 and 30 washes, visual inspection, general physical properties and comfort properties.
• To develop sportswear using the selected fabrics finished with optimized concentration/ composition.
• To conduct wear study of the above developed sportswear with the selected sports personnels.