CHAPTER II
REVIEW OF LITERATURE

For the present study, the review of literature is divided into the following subheadings:

2.1. Ecofriendly fabrics
2.1.1 Characteristics of ecofriendly fibers
2.1.2 Benefits of ecofriendly fabrics
2.1.3 Bamboo
2.1.4 Historical perspective of bamboo
2.1.5 Properties and benefits of bamboo
2.1.6 Modal
2.1.7 Historical perspective of modal
2.1.8 Properties of modal
2.1.9 Benefits of modal

2.2. Fabric Handle
2.2.1 Definition of fabric hand
2.2.2 Subjective Measurement of fabric hand
2.2.3 Kawabata Evaluation system of Fabrics
2.2.4 Nomenclature in hand
2.2.5 Factors affecting fabric hand
2.2.6 Benefits of objective measurement of low stress mechanical properties.
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2.3.1 Factors affecting comfort properties
2.3.2 Measurement of comfort properties

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2.4.2 Measurement of Performance Properties
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2.5.7 **Water repellent finish**- chemistry of water repellent finish
2.5.8 **Moisture Management finish**- definition, importance of moisture management finish

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2.6.2 History of body wear
2.6.3 Growth of body wear sector in India

2.7 **Beachwear**
2.7.1 Definition
2.7.2 History of swimwear
2.7.3 Types of beachwear

2.8 **Intimate wear**
2.8.1 Definition
2.8.2 History of lingerie
2.8.3 Types of intimate wear

2.9 **Designing of beachwear and intimate wear**
2.9.1 Factors to be considered for construction of beachwear and intimate wear
2.1 ECOFRIENDLY FABRICS

Ecofriendly, green, organic, sustainable are the variety of terms used today to tap the rapidly growing desire among the consumers to buy something that causes as little harm to the environment as possible. Calasibetta Charlotte (2005) defines eco-friendly apparels as “apparels made from natural fibers that were grown without pesticides and finished with non-polluting substance. They are also called as ‘green clothes’.

According to Reena Agarwal (2009), eco is a general term for fabrics and fashion made from sustainable production and less polluting manufacturing methods.

Parthiban M. et al (2009), defines green apparels as “clothing and other accessories that are designed to use organic and recycled materials, less packaging and more energy-efficient manufacturing”.

There are various ecofriendly fabrics that have been developed over the period of time and research is still being carried out to make these fabrics applicable in all spheres of clothing and apparels. Although the percent of the marketplace is small, the ecofriendly apparel market is definitely growing. There has been renewed interest in using plant fibers with previously little appeal for textile products. These include hemp, ramie and bamboo (bast fibers). Fiber performance properties, cost and availability are reasons for their limited usage, particularly in apparel. However the increased desire by the consumers for eco-fabrics has caused the textile industry to re-examine the potential use of these fibers derived from natural resources.

Ecofriendly fabrics are fabrics that are organic, bio degradable and not harmful to the environment. The use of ecofriendly fabrics leads to reduced carbon footprint. The use of various chemicals has led to carcinogenic effect on skin. Besides this the effluent produced during textile product manufacture causes considerable damage to the environment. Ecofriendly fabrics have natural characteristics that are user friendly, they are less harmful to the environment and hence the demand for it has increased as the consumer becomes eco conscious.
2.1.1 CHARACTERISTICS OF ECO FRIENDLY FIBRES

According to Megha C Karigar and Hanumanth Naik (2011), the characteristics of ecofriendly fibers are as follows:

- Eco friendly fibers are preferred in hot and humid climates because they keep the body cool.
- They are biodegradable and have no negative effect on the environment.
- They are resistant to mould and mildew and are disease free.
- They are grown without the use of pesticides and chemicals.
- Most of them are antibacterial, skin friendly and have certain healing properties.
- They help curb various skin ailments caused by synthetic and chemically treated fabrics.

2.1.2 BENEFITS OF ECO FRIENDLY FABRICS

According to Stone B (2010), ecofriendly fabrics benefit the environment and the wearer in the following ways-

- Reduced use of chemical fertilizers, pesticides and synthetics
- Less pollution to the soil and water
- Recyclable and sustainable
- Bio-degradable
- Non carcinogenic and non-allergic effect to skin
- Decreased carbon footprint and energy usage
- Give an economic boost to farmers and other producers who use environmentally friendly growing techniques

2.1.3 BAMBOO

Bamboo is the popular name for a tribe of grasses, Bambuseae, which are tree-like woody stems. Bamboo is a group of perennial grass and includes the largest members of the grass family. Bamboo are tapered cylindrically shaped grasses with mostly hallow forms (though some species are solid cylinders). It is an extremely fast growing plant, with some species obtaining growth surges of 100 cm per 24 hour period. (Hunter 2003).

Xiaobing Yu (2007) described the components of bamboo as cellulose, lignin and hemicellulose. Cellulose is \((C_6 H_{10} O_5)\) basically a carbohydrate and the most
important component of the bamboo for textile purpose. Lignin is another important
c constituent of bamboo. It is important in conducting water in culms. Hemi cellulose is
similar to cellulose but is less complex. The hemicellulose in bamboo has its main
component Xylan between that of the hardwood and softwood.

PLATE 2.1: BAMBOO FOREST

2.1.4 HISTORICAL PRESPECTIVE OF BAMBOO

According to Marilyn Waite (2009), “One of the earliest engineering practices
involved the use of scientific principles to extract and manufacture textiles for
practical applications. Between 1900 and 1950, total fiber production grew almost
three times as fast as world population. The earliest record of U.S Patents concerning
bamboo textiles was made by Philipp Lichtenstadt in 1864. This patent outlined the
invention of a “new process for disintegrating the fiber of bamboo, so that it may be
used in manufacturing cordage, cloth, mats or pulp for paper”. The process described
in the 1864 patent is quite similar to the process of 2009, in which one type of
bamboo fabric is made from regenerated bamboo cellulose. The process described is
roughly as follows: (Marilyn Waite, 2009)
1. Bamboo is cut out at joints.
2. Split up bamboo into pieces of slivers, of roughly half an inch in width
3. Pickle bamboo in a solution of clear lime water, nitrate of soda and oxalic acid.
4. Remove pickled bamboo after twelve to twenty four hours in order to boil in a solution of soda-ash
5. Crush and devil (comb, card or heckle) the material
6. Spin into cordage yarn or other forms for manufacturing.

2.1.5 PROPERTIES AND BENEFITS OF BAMBOO

Bamboo fabrics either pure bamboo, bamboo viscose or bamboo charcoal have some exceptional properties that makes it the most sought after fabrics today. According to Das (2007), the characteristics of bamboo include:

- Bamboo fabric has a natural sheen and softness that feels and drapes like silk but is less expensive and more durable.
- Hypo allergic and deodorant properties.
- High water absorption and fast drying caused by a high amount of micro cracks and grooves in the fiber surface. Bamboo is able to take up 3 times its weight in water.
- Bamboo wicks water away from the body 3 to 4 times faster than cotton, keeping the wearer drier, cooler and more comfortable.
- The structure of bamboo fibers make bamboo fabrics more breathable and thermal regulating than cotton, hemp, wool or synthetic fabrics.
- Bamboo fabrics do not need to be mercerized to improve their luster and dye-ability like cotton.
- Bamboo fibers and fabrics absorb dyes faster and more thoroughly than cotton, modal and viscose with better colour clarity.

2.1.6 MODAL

Cellulose is one of the most abundant natural resources on earth and for the majority of the last century, commercial routes to regenerated cellulose fibers have coped with the difficulties of making a good cellulose solution by using an easy to
dissolve derivative. Modal fiber is a second generation regenerated cellulosic fiber that has been defined by Phyllis G Tortora (1996) as “British generic fiber category for manufactured fibers of cellulose having a high breaking strength and high wet modulus”. Modal fibers were developed in Japan in 1951 and Lenzing started selling its version of them in 1964. Modal is also referred to as High Wet Modulus viscose fibers or polynosic rayon.

Modal fibers are defined in International Standard ISO 206: 999 (E) as high wet modulus, high breaking strength regenerated cellulose fibers produced by using particular viscose rayon, and regeneration bath compositions which allows greater molecular orientation during stretch and coagulation of the fibers.

PLATE 2.2: BEECH TREE
2.1.7 HISTORICAL PERSPECTIVE OF MODAL

The regenerated cellulosic fibers have come a long way. Cupro, acetate and Viscose fibers were developed more than 100 years ago. The use of high tenacity Viscose and Modal fibers has come a long way showing that these cellulosic regenerated fibers are well-established nowadays. The Historical development is given by Reinhard Kampl (1995).

TABLE 2.1: HISTORICAL DEVELOPMENT OF MODAL

**First generation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1894</td>
<td>Large scale production of the first cellulosic filaments according to the Viscose process (Viscose Synd. Ltd./London)</td>
</tr>
<tr>
<td>1916</td>
<td>First production of Viscose staple fibers (Glanzstoff AG)</td>
</tr>
<tr>
<td>1950</td>
<td>Considerable tenacity improvements of Viscose staple fibers particularly in the years between 1950 and 1970 resulted in an extended application range</td>
</tr>
</tbody>
</table>

**Second Generation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca. 1960</td>
<td>Development and production of Modal staple fiber types according to the Viscose process. Two different types: * High wet modulus - HWM * Polynosic Around 1970 the HWM type was prevailed on the European market - the US only produced HWM. The Far East produces Polynosic and Viscose.</td>
</tr>
<tr>
<td>Ca 1975/1980</td>
<td>Development of fine-denier Viscose fibers with higher tenacity</td>
</tr>
<tr>
<td>1986</td>
<td>Development of Micro-Modal (HWM)</td>
</tr>
</tbody>
</table>

**Third Generation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca. 1980</td>
<td>Pilot plant development of the “Newcell”-process (AM. ENKA)</td>
</tr>
<tr>
<td>1987</td>
<td>License agreement Lenzing/Akzo- Pilot production since 1990</td>
</tr>
<tr>
<td>1990</td>
<td>1990 License agreement Courtaulds/Akzo- Bulk production since 1992</td>
</tr>
</tbody>
</table>
2.1.8 PROPERTIES OF MODAL

Technical advancements in rayon processing have led to improved rayon fabrics such as high wet modulus (HWM) rayon. These technical advancements have created a rayon that is not only less prone to stretching when wet but more importantly they have a closed loop processing that allows 99.5% of the chemical solvents to be recycled and reused and any remaining emissions and pollutants can be decomposed in waste treatment plants.

The most outstanding feature of modal fabrics is its high wet modulus and alkali resistance. Modal possess lower elongation and higher wet modulus as it has high rate of polymerization. It has good dimensional stability even after repeated laundering. The strength and elasticity are comparable to that of cotton. This yarn is used for high quality woven fabrics and knitted materials. Modal is about 50% more water absorbent per unit volume than cotton. It’s designed to dye similar to cotton and is colour fast when washed. (S.P Mishra, 2000)

According to Ullmann’s (2008), “Modal has a rounder cross section, is more crystalline oriented structure so that the dry fiber is relatively strong. It has a breaking tenacity of 2.5 to 5.0 g/d, a breaking elongation of 9 to 18 percent when dry and 20% when wet and an elastic recovery greater than that of cotton. Modal possesses lower elongation and higher wet modulus as it has high rate of polymerization. It is lustrous and has a smoother surface than mercerized cotton. Modal fibers come in two varieties- polynosic and High Wet Modulus (HWM). Both are based on higher quality viscose than regular staple (6-8% cellulose, 6.5-8.5% sodium hydroxide, 40-50% carbon disulfide). Modal fibers are always cut into staple lengths and spun on conventional viscose spinning equipment”.

According to Sara J Kadolph (2009), “Modal has a more crystalline and oriented structure so that the dry fiber is relatively strong. It has greater durability, stability and strength when compared to cotton. They can be mercerized and finished to minimize shrinkage. They also wrinkle less than regular rayon in washing and drying”.

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2.1.9 BENEFITS OF MODAL

Michael (2008) states the advantages of modal as follows-

- Takes dye as well as cotton
- Light weight fabric
- Has the appearance of silk: luster/sheen/ gloss
- Holds colour when machine washed in warm water
- Fabric is not stiff, does not become rigid when machine washed
- Can be repeatedly washed and holds soft and smooth characteristic
- Soft and smooth against the skin
- Does not pile as much as cotton
- Resistant to fading and shrinkage
- Resistant to minimal build up when washed again and again
- Blends are more crease resistant
- Does not age like cotton

2.2 FABRIC HANDLE

The studies of fabric handle dates back to the early work reported by Pierce (1930). Considerable progress has been made over the last 72 years in the development of the theory of geometrical structure and mechanical properties.

2.2.1 DEFINITION OF FABRIC HAND

According to Sundaram (1993), the fabric handle is the terminology expressing the character and quality of a fabric as manifested by its performance in respect to fitting human body, the feel of the surface and comfort in wearing.

Kim and Slaten (1999), have defined fabric handle “as a perceived overall fabric aesthetic quality that reflects the fabrics mechanical and physical properties”.

The term fabric hand or handle has been defined by Loreta. V and Eugenija S (2006), as the quality of a fabric or yarn assessed by the reaction obtained from the sense of touch or the sum total of the sensations expressed when a textile fabric is handled by touching, flexing of the fingers and so on.
According to AATCC (2011), “Hand is the tactile sensations or impressions that arise when fabrics are touched, squeezed, rubbed or otherwise handled”.

2.2.2 SUBJECTIVE MEASUREMENT OF FABRIC HAND

According to Jiří Militký, Vladimír Bajzik (2001), “the subjectively evaluated hand is connected especially with surface, mechanical and thermal properties. The first attempts of hand evaluation of textiles were published in 1926. Two basic procedures of subjective hand evaluation are:

a) Direct method - is based on principle of sorting of individual textiles to defined subjective grade ordinal scale (e.g., 0 - very poor, 1 - sufficient, 5 - very good, 6 - excellent)

b) Comparative method - is based on sorting of textiles according to subjective criterion of evaluation (e.g., ordering from textiles with the most pleasant hand to textiles with the worst hand).

The wide range of word expressions is connected with term hand, e.g., smooth, full, bulky, stiff, warm, cool, sharp, etc. The expressions are used for denotation of primary hand. For prediction of hand using any subjective method it is necessary to solve following problems:

- Choice of respondents
- Choice of grade scale
- Definition of semantic.

According to O L Shanmugasundaram (2008), “subjective assessment is the traditional method of describing fabric handle based on the experience and variable sensitivity of human beings. Textiles are touched, squeezed, rubbed or otherwise handled to obtain information about physical parameters. The subjective assessment can also be described as a psychological reaction from the sense of touch, as the tactile sensitivity of people varies according to age, skin hydration, cultural aspects or gender of the test person. In the clothing industry professionally trained handle experts sort out the fabric qualities”. 

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O.L. Shanmugasundaram (2008) further states that, “the need for tests to predict or assess subjective aspects of fabric aesthetics has increased in recent years for three main reasons:

- The trend towards light-weight clothing has resulted in the increased use of fabrics that are difficult to make-up and require new handling skills.

- The trend toward shorter seasons and the use of rapid systems have meant that the delivery of fabrics that are difficult to make-up will disrupt production schedules. For this reason it is even more important that the garment makers are able to predict fabric performance.

- The increased use of automation in garment manufacture removes the opportunity for skilled operators to correct for difficult or variable fabrics.

2.2.3 KAWABATA EVALUATION SYSTEM OF FABRICS (KESF)

The fundamental research on the mechanical properties of textiles showed that the mechanical properties have a profound influence on the handle characteristics of fabrics. In the late seventies, a major upsurge in the research on handle took place due to the pioneering efforts of Prof. Kawabata. With the help of hand evaluation and standardization committee (HESC), Kawabata identified primary hand values, which the Japanese experts consider important to the feel of fabrics. In collaboration with Kate Tec and Co. Kawabata developed the first series of Kawabata set of instruments. There are four instruments used for KES-F system and sixteen mechanical properties are utilized to compute the primary hand value (THV) and these in turn are used for computing total hand value (THV). The description of the instruments as explained by Hassan M Behery (2005) is given in figure 2.1.
2.2.4 NOMENCLATURE IN HAND

According to Saville B P (1999), the definition of primary hand is listed below.

**TABLE 2.2: DEFINITIONS OF PRIMARY AND SEMI- PRIMARY HAND**

<table>
<thead>
<tr>
<th>TERM</th>
<th>Japanese</th>
<th>English</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koshi</td>
<td>Koshi</td>
<td>Stiffness</td>
<td>A feeling related with bending stiffness. Springy property promotes this feeling. The fabric which have compact weaving density and woven by springy and elastic yarn makes this feeling strong.</td>
</tr>
<tr>
<td>Numeri</td>
<td>Numeri</td>
<td>Smoothness</td>
<td>A mixed feeling come from smooth, limber and soft feeling. The fabric woven from cashmere fiber gives this feeling strongly.</td>
</tr>
<tr>
<td>Fukurami</td>
<td>Fukurami</td>
<td>Fullness and Softness</td>
<td>A feeling come from bulky, rich and well-formed feeling. Springy property in compression and thickness accompanied with warm feeling are closely related with this feeling (Fukurami means swelling)</td>
</tr>
<tr>
<td>Kishimi</td>
<td>Kishimi</td>
<td>Scrooping feeling</td>
<td>Scrooping feeling. A kind of silk fabric possesses this feeling strongly</td>
</tr>
<tr>
<td>Shinayakasa*</td>
<td>Shinayakasa*</td>
<td>Flexibility with soft feeling</td>
<td>Soft, flexible and smooth feeling</td>
</tr>
<tr>
<td>Shari</td>
<td>Shari</td>
<td>Crispness</td>
<td>A feeling comes from crisp and rough surface of fabric. This feeling is brought by hard and strongly twisted yarn. This feeling brings us a cool feeling. (This word means a crisp, dry and sharp sound arising when a fabric is rubbed with itself)</td>
</tr>
<tr>
<td>Hari*</td>
<td>Hari*</td>
<td>Anti-drape stiffness</td>
<td>Anti-drape stiffness, no matter whether the fabric is springy or not. (This word means “spreading”)</td>
</tr>
</tbody>
</table>

*This is not a primary hand but semi- primary hand. This hand is added because of its importance in the evaluation of ladies thin fabrics.*
2.2.5 FACTORS AFFECTING FABRIC HAND

According to O L Shanmugasundaram (2008), “In textiles, the raw material, yarn structure, planar structure and finishing treatments affect the fabric hand. The basic elements that can fundamentally impacts fabric hand is as follows:

- Fiber characteristics: Fineness, length, friction property, resilience, compressibility
- Yarn type: Staple fiber, continuous filament, textured, count and twist
- Fabric construction: woven, knit, non-woven, weight, thickness, surface roughness
- Method and type of dyeing
- Finishing process

FIGURE 2.2: FACTORS AFFECTING FABRIC HAND
2.2.6 BENEFITS OF OBJECTIVE MEASUREMENT OF LOW STRESS MECHANICAL PROPERTIES

Sule and Bardhan (1999), give the benefits of objective measurement of low stress mechanical properties as:

✓ Better fabric engineering
✓ Predicting fabric performance during tailoring
✓ Predicting garment appearance during use
✓ Timely and effective process control
✓ Taking precautions during tailoring
✓ Evaluating modifiers

Sule and Bardhan (1999) further state that the subjective assessment is steadily becoming inadequate for modern textile and clothing applications due to these following reasons:

✓ Ever increasing diversity of fabric and clothing
✓ Non-replacement of experts with extensive experience in textiles and clothing
✓ Rapidly increasing automation in textiles and clothing manufacture
✓ Artificial need for quick response in the textile and clothing industries
✓ Increasing difficulties in precise language and communication in terms of subjective assessment of fabric quality attributes.

Against this background it has become more important than ever before to have knowledge of the objectively measured properties of the fabric being manufactured and made up into garments. However, although objective assessments are precise from a mechanical point of view, these methods have not been commonly used in the textile and clothing industry. Even today, many companies still use subjective evaluation to assess fabric properties. The main reason for this situation is the repetitive and lengthy process of measurement and the lack of knowledge for a good interpretation of the test results.
### 2.2.7. Research Findings on Bamboo and Modal Textiles in Terms of Handle and Mechanical Properties

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Research Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodings</td>
<td>2001</td>
<td>Comparison of properties among different cellulosic fibers which showed that viscose has lower wet strength as compared to modal.</td>
</tr>
<tr>
<td>Tatjana Kreze and Sonja Malej</td>
<td>2003</td>
<td>Carried out comparative investigations of the new Lyocell and conventional viscose and modal fibers to identify the differences in the molecular and fine structure of these fibers.</td>
</tr>
<tr>
<td>Xu, et al</td>
<td>2007</td>
<td>Investigated the thermal and structural differences among chemical bamboo fiber, Tencel and conventional viscose fibers. The findings of the study were that chemical bamboo fibers indicate good water retention power due to the many voids in their cross section and chemical bamboo fibers and conventional viscose fiber possess better ability of absorbing and releasing water than Tencel.</td>
</tr>
<tr>
<td>Chen et al</td>
<td>2007</td>
<td>Compared the antibacterial properties of bamboo viscose (jersey knit) and common wood- viscose (jersey knit) and found that the antibacterial properties of bamboo fabrics were significantly higher than those of common wood viscose fabric. This was due to the fact that bamboo fabric rapidly absorbs and evaporates water due to its structure and that bacterium cannot survive in such a dry environment.</td>
</tr>
<tr>
<td>Grineviciute et al</td>
<td>2007</td>
<td>Analyzed the fabric handle properties of bamboo, cotton and cotton/ bamboo fabrics. Bamboo fiber provided better hand properties than cotton fabrics. The researchers concluded that by changing the bamboo mixture ratios, fabrics with differing characteristics could be manufactured.</td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>Research work</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Nazan Erdumlu and Bulent Ozipek</td>
<td>2008</td>
<td>Carried out an investigation of regenerated bamboo fiber and yarn characteristics of bamboo fiber are quite similar to those of viscose rayon fiber. On the other hand, its natural antimicrobial characteristics, high air and moisture permeability, ensuring breathability in particular knitted goods are distinctive characteristics of bamboo. They also concluded that although the price of bamboo fiber is high compared to viscose rayon or other cellulosic fibers, it is expected that bamboo fiber will have a large share of the market in a short period of time due to its distinctive characteristics.</td>
</tr>
<tr>
<td>Sarkar and Appidi</td>
<td>2009</td>
<td>Analyzed the ultraviolet protection and antimicrobial effect of bamboo viscose fabric and concluded that untreated fabric had low as well as insufficient protection and antimicrobial effects.</td>
</tr>
<tr>
<td>Hasani, H</td>
<td>2009</td>
<td>An objective approach to assess the handle of various knitted fabrics has been made by analyzing the force-displacement curves.</td>
</tr>
<tr>
<td>Marilyn Waite</td>
<td>2010</td>
<td>Studied the differences in textile properties between two different species of bamboo (Phyllostachys edulis and Bambusa emeiensis). The main conclusions drawn from the results were that the species of bamboo is not trivial for bamboo textile application and there are fundamental differences between the type and function of bamboo textiles that are manufactured chemically versus those that are manufactured mechanically with the aid of enzymes. The experiment test showed that mechanical bamboo fibers are much stronger than those chemically manufactured displaying better moisture wicking properties.</td>
</tr>
<tr>
<td>Gericke and Jani</td>
<td>2010</td>
<td>Carried out a comparative study of regenerated bamboo, cotton and viscose rayon fabrics. The results showed that regenerated bamboo fibers can be made in fabrics that are very comfortable and have excellent moisture and temperature management properties.</td>
</tr>
<tr>
<td>Senem Kursun, Gulay Ozcan</td>
<td>2010</td>
<td>Investigated the effects of UV radiation especially for swimwear fabrics exposed to sunlight during the summer days.</td>
</tr>
<tr>
<td>Author</td>
<td>Year</td>
<td>Research work</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Wang Yueping et al</td>
<td>2010</td>
<td>Studied the structure of bamboo fiber for textiles. Results showed that the chemical composition of bamboo fiber is the same as all bast fibers, that is, cellulose constitutes the majority and lignin needs to be reduced further for textile application.</td>
</tr>
<tr>
<td>Shanmugasundaram. O L, Gowda, R V Mahendra</td>
<td>2010</td>
<td>Paper reports study on the development and characterization of baby diapers made from four different fibrous compositions, namely pure bamboo, pure organic cotton, bamboo/organic cotton (70/30), and bamboo/organic cotton (50/50). Antibacterial activity tests have been carried out on baby diapers against <em>S. aureus</em> and <em>E. coli</em>.</td>
</tr>
<tr>
<td>Lipp-Symonowicz et al</td>
<td>2011</td>
<td>Compared bamboo and viscose fibers and they stated that so called bamboo fibers are in reality man made viscose fibers made from bamboo cellulose and bamboo fibers are comparable to viscose fibers in their morphological structure and properties.</td>
</tr>
<tr>
<td>Filiz Sekerden</td>
<td>2011</td>
<td>Carried out an investigation on the unevenness, tenacity and elongation properties of bamboo/cotton blended yarns and the results indicated that the ratio of bamboo fiber in the blend had an effect on the properties of yarn. As the ratio of bamboo increased, the yarn unevenness decreased. But there was no apparent significant effect of the ratio of bamboo on the yarn tenacity and elongation.</td>
</tr>
<tr>
<td>Adine Geriche and Jani Van du Pol</td>
<td>2011</td>
<td>A comparative study of anti-microbial properties of cotton and other regenerated cellulosic fabrics showed that both regenerated bamboo and regenerated cellulosic fabric showed significantly higher anti-microbial activity that of cotton.</td>
</tr>
<tr>
<td>Ajay Rathod and Dr. Avinash Kolhatkar</td>
<td>2012</td>
<td>Studied the physical and UV protection properties of single jersey and rib fabric produced from bamboo fibers.</td>
</tr>
<tr>
<td>Sudipta S Mahish et al</td>
<td>2012</td>
<td>Analyzed the functional properties of bamboo/polyester blended knitted apparel fabrics.</td>
</tr>
</tbody>
</table>
2.3 COMFORT PROPERTIES


- Psychological comfort- consumer prejudice, colour and prevalent fashion.
- Sensorial comfort- involves the tactile sensation of a garment on the human body.
- Thermophysiological comfort- entails both thermoregulation and moisture management”.

According to Parthiban M (2006), “comfort in clothing is defined as a state of satisfaction indicating physiological, psychological and physical balance among the person, his/her clothing, and his/her environment”.

2.3.1 FACTORS AFFECTING CLOTHING COMFORT

According to S M Ishtiaque (2000), “clothing comfort is affected by functional, aesthetic and influencing factors. The factors are enumerated below:

- **Functional factors**-
  Functionally clothing needs to meet the following requirements-
  1. Maintain a comfortable microclimate in terms of temperature and humidity in the skin sensory zone
  2. Good absorption of moisture and ability to transmit moisture vapour.
  3. Absence of unpleasant odour (perspiration)
  4. Compatibility with the skin
  5. Good extensibility without restricting mobility.
  6. Good fit stability
  7. Low intrinsic weight (not impairing physical performance)
  8. Fabric substantially water- repellent and dirt- repellent

- **Aesthetic factors**-
  Aesthetic factors include higher softness, higher drapability, and graceful luster.
Influencing factors-
1. The thermal insulation and moisture resistance of a clothing system are governed both by the fit of the individual garments and by the characteristics of the textile material.
2. Good air permeability”

2.3.2 MEASUREMENT OF COMFORT PROPERTIES

The factors effecting the measurement of comfort are described elaborately by S. M Ishtiaque (2000) which is as follows:
1. Thermal insulation- measures the resistance of dry or damp fabrics.
2. Moisture vapour permeability- determines the resistance of fabrics to the transfer of insensible perspiration emanating from the body.
3. Water absorption- determines the capacity and rate of fabrics to mop up the liquid sweat generated by the body.
4. Wicking- determines the capacity and rate of the fabrics to transport absorbed sweat away from the point of absorption that is away from the skin.
5. Surface coefficient of friction- of fabrics contributes to the sensorial comfort of fabrics. The coefficient can increase significantly in a wet fabric leading to rubbing or chafing of the skin.
6. Handle of a garment describes its tactile qualities and include softness, compressibility, pliability and drape.

2.4 PERFORMANCE PROPERTIES

2.4.1 FACTORS AFFECTING THE PERFORMANCE PROPERTIES OF FABRICS

According to Ozge T et al., (2010), “the performance characteristics of fabrics are related to its mechanical properties in a low stress region as well as its surface and dimensional properties. These properties are tensile, shear, bending, compression, surface friction, hygral expansion and relaxation.

The factors affecting the performance properties are:
- Fiber Quality
- Yarn formation
According to Gonca, et al (2010), a study conducted on the performance properties of regenerated fabrics, the structural properties of viscose, modal and lyocell fibers and yarns were investigated. Besides, the influence of structural characteristics of the fibers on the performance properties of knitted fabrics such as pilling, bursting strength, color efficiency and thermo physiological properties were determined. It was determined that due to the fiber structure; pilling tendency of viscose fabric is higher compared to lyocell and modal grey fabrics. Since the tensile strength of lyocell fiber is higher, fabric bursting strength of lyocell fabric is higher than the modal and viscose fabrics. As the thermal conductivity of lyocell fabric is higher, it gives cool feeling compared to viscose and modal fabrics. The highest colour efficiency is obtained from lyocell fabrics”.

2.4.2 MEASUREMENT OF PERFORMANCE PROPERTIES

According to Wendy Zhu (2010), “The performance specification requirements for fabrics, meant for various end uses, are usually guided by the internationally approved 'Standard performance specifications'. Generally, the main performance characteristics which, are tested on fabrics are:

- **Drapability:**

  B. K Behera along with Kaushal Raj Sharma (2004) and Rajesh Mishra (2007) discussed the importance of Drapability. Fabric drape is one of the most important properties of flexible materials and significantly contributes to graceful appearance of the fabrics. It describes the way in which fabric falls itself in a specific shape. This is strongly related to the low stress mechanical properties of the fabrics, like bending rigidity. Bending and shear properties are thought to be main factors influencing drape and fabric handle.”
• Wickability:

U J Patil et.al (2009) described wicking and the significance of wicking property. Wicking is the spontaneous flow of liquid in a porous substance, driven by capillary forces. Wicking is an important moisture property in which the moisture is transferred to the atmosphere. This is essentially important for fabric worn next to the skin so as to absorb the perspiration from the skin surface and transfer the moisture to the atmosphere making the wearer feel comfortable.

• Air permeability:

According to Subrata Das (2008), “air permeability describes the property of fabric to let air through it. This is important for outdoor clothing because it should function as a wind protection. The air permeability of the fabric can influence its comfort behaviour. A fabric that is permeable to air will be permeable to water and the thermal resistance of a fabric is as well strongly dependent on the enclosed still air”.

• Bending Rigidity:

Mehmet E Y et al (2008) described stiffness as one of the most widely used parameters to judge bending rigidity and fabric handling. The degree of fabric stiffness is related to its properties such as fiber material, yarn and fabric structure. Fabric stiffness influences the fabric deformation.

• Breaking strength (in both directions), Bursting strength (in both directions)
• Colourfastness to burnt gas fumes, crocking, chlorinated pool water, dry-cleaning, frosting (flat abrasion), laundering, light, ozone, perspiration and sea water, Colourfastness to water, Dimensional change to dry-cleaning, laundering and pressing, Distortion of yarn, Durability of back coating
• Fabric appearance rating, Flammability, Laundered appearance, Light degradation, Non-fibrous material, Pilling resistance
• Retention of hand, character and appearance, Soil release, Surface abrasion, Tear strength (in both directions), Thermal transmittance
• Water repellence, Water resistance, Yarn distortion and yarn slippage resistance.
2.5 WET PROCESSING AND FINISHING

2.5.1 DYEING

According to Wikipedia (2010) dyeing is defined as- “the process of imparting colours to a textile material in loose fibre, yarn, cloth or garment form by treatment with a dye”.

2.5.2 SIGNIFICANCE AND USE OF REACTIVE DYES

According to Muhammad Naeem and Muhammad Javidaid Mughal (2009), “reactive dyes differ from other class of dyes in term of that the molecule of a reactive dyes contains one or more reactive groups capable of forming a covalent bond with a compatible fibre group. The main step in the dyeing procedure with a dye of such type comprise adsorption on the fibre, diffusion into the fibre and react with the specific group of fibre, by means of nucleophilic addition or nucleophilic substitution. Reactive dyes containing sulphatoethylsulphone give addition reaction, while the dyes containing Cyanuric chloride give substitution reaction in presence of alkali. Reactive dyes have been very popular due to their high wet fastness, brilliance and range of hues. Continuous dyeing with reactive dyes is now important due to its high productivity and consistency of shades over runs”.

“Easy application and choice of different kinds of application techniques like exhaust, semi- continuous and continuous, suitability to dye on any conventional and modern machine, presence of wide range of shades from dull to bright and pastel to dark, compatibility, possibility of getting acceptable all round fastness properties and cost effectiveness are the major key factors listed by R.H Deshpande and Y M Indi (2010) which are responsible for the growth of reactive dyes.”

Further enumerating the advantages of reactive dyes C. Paravathi and T. Maruthavanan (2010) emphasized that “reactive dyes have been increasingly used for dyeing and printing of both natural and regenerated cellulosic fibers due to the advantages of colouring and dyed fabric durability.”
2.5.3 FINISHING

According to Wikipedia “Finishing refers to any process performed on yarn or fabrics after weaving or knitting to improve the look, performance or hand of the finished textiles or clothing.”

“Finishing is a process which the woven fabrics undergo before sale to give it a desired feel, shine, freshness, body and general ‘shop look’. There are many types of finishes including physical, chemical and mechanical. The modern trend is towards the production of durable and lasting finishes” explains Raul Jewel (2005),

The objective of finishing is to add attractiveness or desirability to fabrics. There are also specialized finishes whose functions are to make the fabrics especially suitable for a particular purpose. Finishing is a branch of textile technology which has made great strides recently and new finishes are coming into existence almost daily.

2.5.4 CLASSIFICATION OF FINISHES

Textile finishes can be classified in several ways. According to Allen C Cohen (1997), “they can be categorized according to aesthetics (i.e., modifying appearance and/or hand) or to function. They can be grouped as to whether they are either a chemical or mechanical finish. Finishes can also be categorized as to their degree of permanence- permanent, durable, semi durable and temporary.” Further finishes are classified as:

a. Renewable and Durable
b. Routine (Basic) and Special

Routine finishes are applied to almost all fabrics with an aim to improve their appearance. Special finishes are applied with a specific purpose or end use in mind.” Special finishes are applied to improve and enhance the performance and functionality of the textiles. Some of the special finishes based on the end use include:
2.5.5 UV PROTECTION FINISH

2.5.5.A. NEED AND SIGNIFICANCE OF UV FINISH

Sunlight is important for human health. The body needs it to form vitamin D, which is important for bone structure. At the same time, ultraviolet rays contained in sunlight pose a major stress and risk potential for the skin. The UV protection factor states how long someone wearing UV protective clothing can stay out in the sun without suffering damage to their health (skin damage). The Ultraviolet Protection Factor (UPF) is comparable to the sun protection factor of sunscreen (SPF). In both cases, the basis for calculations is what is known as the intrinsic protection time of the skin, which can vary considerably depending on the individual skin type.

According to W. D Schindler and P J Hauser (2004), long term exposure to UV light can result in acceleration of skin ageing, photo dermatosis (acne), phototoxic reaction to drugs, erythema (skin reddening), sunburn, increased risk of melanoma (skin cancer), eye damage and DNA damage. Textiles are intrinsically suited for UV protection application. To quantify the protective effect of textiles, the solar protection factor (SPF) is determined. The SPF is the ratio of the protection erythemal effect to the actual erythemal effect transmitted through the fabric by the radiation and can be measured by spectroscopic measurements. The SPF is also referred to as UPF (Ultraviolet Protection factor).

Scientific methods of evaluating the UPF of fabrics have been developed and specified according to Australia/New Zealand (AS/NZ) standard 4399:19961; other nations and regions have produced their own standards modeled after this original work, e.g. AATCC 183:20042 with ASTM D6544 and ASTM D6603 in the United States and EN 13758-1 in Europe.

S B Ghosh et al (2003) investigated the effect of dyes and finishes on UV protection of jute/cotton fabrics, which showed that the treatment of jute/cotton fabric with titanium dioxide provides satisfactory protection against UV rays. They also state that on the basis of wavelength, the ultraviolet radiation falls into three categories: UV-C (<280 nm), UV-B (=280-320nm) and UV-A (320-400 nm).
According to Deepti Gupta et al (2005), “fabrics, specially dyed can absorb significant amount of UV radiation and have a protective effect. Further they have studied the anti UV and anti-microbial properties of some natural dyes on cotton and concluded that all dyes showed high absorption in the UV region. The UV activity of the fabrics increased with the increase in concentration of the dyes.

2.5.6 ANTI-MICROBIAL FINISH

2.5.6.A. DEFINITION

Antimicrobial finishes on fabrics can protect human beings against microbes. According to Srikanth (2010), “the word antimicrobial is a general term for any product that kills or controls microbes. Microbes are small organisms that cannot be seen by the naked eye, they include a variety of micro-organisms like bacteria, algae, fungi”. The finish inhibits the growth of microbes on the surface of the fabrics, maintains hygiene and freshness, stops bad odour and improves the life of the article.

Based on the durability of antimicrobial properties of textile material, antimicrobial finish can be grouped under 2 categories, namely, temporary and durable finish. Incorporation of antimicrobial (AM) finishes may be done by exhaust or pad-dry-cure methods, depending on the chemistry involved.

2.5.6.B. EFFECT OF MICROBIAL GROWTH ON TEXTILES AND BENEFITS OF ANTIMICROBIAL FINISH

Deepti Gupta and Somes Bhaumik (2007) say that the effects of microbial growth on textiles are as follows:

1. Generation of body odour
2. Effect on human health
3. Degradation or staining of textiles
4. Reduces the life of the articles
Antimicrobial finishes add value to textiles and garments by providing protection in different ways such as-

i. Prevent the growth of bacteria and fungi, thus protecting textiles against unpleasant odours, mildew spots and the premature loss of functional properties.

ii. Protect the wearer or user of a textile against bacteria, yeast, dermatophytic fungi, and other related microorganisms for aesthetic, hygienic or medical purposes.

iii. Protect the textile itself against bio-deterioration caused by mould, mildew and rot producing fungi.

iv. Protect the textile from insects and other pests for preservation of the fiber and/or protection of persons wearing clothing from insects and pests.

According to S. Mahesh et al (2011), “Several challenges have been created for apparel researchers due to increasing global demand in textiles. Therefore, textile finishes with added value particularly for medical cloths are greatly appreciated and there is an increasing demand on global scale. The consumers are aware of hygienic life style and there is a necessity of textile product with antimicrobial properties. Several antimicrobial agents’ viz., triclosan, quarternay ammonium compounds and recently nanosilver are available for textile finishing”.

In the last few years, the market for antimicrobial textiles has recorded a double digit growth. There are various agents used for antimicrobial finishing. Thilagavathi G (2005) developed ecofriendly antimicrobial textiles, Anjali K and Snehal M (2007) conducted a study on imparting antimicrobial finish on cotton using chitosan and it was observed that the finish provided better functionality, good performance and improvement in physical properties, Joshi m, et al (2009) and Sathianarayanan et al (2010) used herbal products to develop ecofriendly antimicrobial textile finishes.

Some commercial antimicrobial products and their composition is given by Deepti Gupta and Somes Bhaumik (2007)
### TABLE 2.3: LIST OF COMMERCIAL ANTI-MICROBIAL PRODUCTS

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Chemical Composition</th>
<th>Company</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanitized- AG</td>
<td>Halogenated phenoxy-compound and isothiazolinone derivatives</td>
<td>Sanitized AG, Switzerland</td>
<td>Socks and apparels</td>
</tr>
<tr>
<td>Reputex 20</td>
<td>PHMB</td>
<td>Zeneca biocides</td>
<td>Durable for cotton</td>
</tr>
<tr>
<td>Sensil 555</td>
<td>-</td>
<td>Senka Corp., Japan</td>
<td>Antimicrobial and deodorant finish for cellulusic</td>
</tr>
<tr>
<td>Ultrafresh Range</td>
<td>5-chloro-2 (2,4-dichlorophenoxy) phenol</td>
<td>Thomson Research Associates, Canada</td>
<td>Nonionic odour protection and anti-staining</td>
</tr>
<tr>
<td>Steri-septic range</td>
<td>Triclosan</td>
<td>Thomson Research Associates, Canada</td>
<td>Cationic, anionic and nonionic are available for cotton and polyvinyl fibers</td>
</tr>
<tr>
<td>Bioden/ Amolden range</td>
<td>Cationics/ Phenylamides</td>
<td>Daiwa, Japan</td>
<td>Bedding, garments, nonwovens for deodorizing</td>
</tr>
<tr>
<td>Biosil</td>
<td>Quarternary ammonium compounds</td>
<td>Toyobo, Japan</td>
<td>Bedding, towels, socks, undergarments</td>
</tr>
<tr>
<td>Peach fresh</td>
<td>Tertiary ammonium compounds</td>
<td>Nisshinbo, Japan</td>
<td>For PET fibers and fabrics</td>
</tr>
<tr>
<td>Aegis Microbe shield</td>
<td>3- (trimethoxysilyl) propyl dimethyl octadecyl ammonium chloride</td>
<td>PPT, UK</td>
<td>Combat growth of candida and yeast that cause thrush</td>
</tr>
<tr>
<td>Sanitan</td>
<td>Tertiary ammonium compounds</td>
<td>Kuray, Japan</td>
<td>For PET fibers and fabrics</td>
</tr>
<tr>
<td>Tinosan Range</td>
<td>Triclosan based on 2,4,4’- trichloro-2’- hydroxy- diphenyl ether</td>
<td>Ciba specialist chemicals, Switzerland</td>
<td>Durable treatment for cotton, polyester, polyamide, acrylic and their blends with cotton</td>
</tr>
</tbody>
</table>
2.5.7 WATER REPELLENT FINISH

Karla J Nielson (1997) defines “Water repellent finishes as something added to the soil-repellent finish and can be either durable or non-durable. These finishes make the textile less hydrophilic, or water-absorbing, in order to protect it against moisture damage. Outdoor furniture fabric, drapery fabrics and some nonresidential textiles benefit from water repellent finishes”.

Water repellent finishes are chemical finishes that resist the penetration of water into or through the fabric but permit the passage of moisture or air through the fabrics (J J Pizzuto, 2010).

2.5.7 A CHEMISTRY OF WATER REPELLENT FINISH

A K Prasad (2007) describe that, “water repellent finish gives hydrophobic features to the substrate. There are three main product groups for this finish-

- Metal salt paraffin dispersion
- Polysiloxanes
- Fluorocarbon polymers

When finishing with these products, the surface of the goods must be covered with molecules in such a way that their hydrophobic radicals are ideally positioned as parallel as possible facing outwards. Aluminum salt paraffin dispersions are positively charged products due to the tri-valent aluminum salt. This produces a counter polar charge on the fibre surface which is significant for the adsorption of the product. After drying, the fat radicals form a so-called "brush" perpendicular to the fibre surface which prevents water drops from penetrating into the fibre. Polysiloxanes form a fibre-encircling silicone film with methyl group’s perpendicular to the surface. The oxygen atoms are facing towards the fibre. The film formation and direction of the methyl groups are responsible for the hydrophobic properties of the finish. Fluorocarbon polymers also form a film where the fluorocarbon radicals are perpendicular to the fibre axis thus prevent wetting of the fibre surface. Their high hydrophobic and oleophobic action is explained by the extremely low interfacial
tension of the fluorocarbon chain towards all chemical compounds. When finishing with these products, the surface of the goods must be covered with molecules in such a way that their hydrophobic radicals are ideally parallel and facing outwards. While paraffin dispersions and polysiloxanes only provide hydrophobic effects, the fluorocarbon products also exhibit oleophobic action. On synthetic fibres in particular, the hydrophobic and oleophobic action of fluorocarbons is excellent. Fluorocarbons are distinctly superior to the other products with regard to washing and cleaning durability”.

Murugesh Babu (2007) explained that, “the recent trend in this finish is to develop self-cleaning smart fabrics based on the self-cleaning concept of the leaves of lotus plant. Hydrophobic coatings cause water to form almost spherical droplets that readily roll away carrying dust and dirt with them. The self-cleaning fabrics work using photocatalytic properties of titanium dioxide”.

2.5.8 MOISTURE MANAGEMENT FINISH

2.5.8.A DEFINITION

Kannappan K and Geeta M (2011) define “moisture management as an important aspect which decides the comfort level of the fabric. Every human being sweats during different kinds of activities. An important feature of any fabric is how it transports this water out of the body surface so as to make the wearer feel comfortable. So moisture management is referred to its ability to transport, store and dispose liquid water and moisture from the surface of the skin to the atmosphere through the fabric”.

2.5.8.B. IMPORTANCE OF MOISTURE MANAGEMENT FINISH

Liquid transporting and drying rate of fabrics are the two vital factors affecting the physiological comfort of the garments. The moisture transfer and quick drying behaviour of textiles depends mainly on the capillary capability and moisture absorbency of their fibers according to Raul Fangueiro et al (2009). These textiles are especially used in sport garments next to the skin or in hot climates.
According to A K Prasad (2007), “the area of textile finishing where improving the absorbency is still one of the main considerations are sportswear, some of which is also made with functional jersey with hydrophobic synthetic fibers on the inside and hydrophilic cellulosic fibers on the outside. The mode of action consists of the finest fibrilled microfibers (PES, PA or PP) transporting the moisture rapidly from the skin through the capillary interstices to the absorbent outer layer. In this way the textile layer of synthetic fibers next to the skin remains dry”.

Sharabaty T et al (2008) carried out an investigation on moisture transport through polyester/cotton fabrics which showed that the wicking coefficients in multi layered fabrics are found to be much better than other fabrics of 100% cotton. Vasant Kumar et al (2011) studied the comfort properties of knitted fabrics with hydrophilic finishes.

2.6 BODYWEAR

2.6.1 DEFINITION

According to a market survey conducted by CBI (2008) “Bodywear includes the following product groups:

- Underwear for women/girls: pants, knickers, briefs, vests, petticoats, underskirts or slips, teddies and French knickers for women.
- Underwear for men/boys: pants or briefs, boxer shorts, vests
- Foundation wear: bras, corselets, corsets, girdles and suspender belts.
- Night and home-wear: nightwear includes nightdresses, pyjamas and negligees for women and nightshirts and pyjamas for men. Home or loungewear covers dressing gowns, housecoats and bathrobes.
- Swim and beachwear: one and two piece (bikinis), swimsuits for women and swimming trunks and bermudas for men.
- Hosiery: pantyhose, tights, stockings and ankle and knee length socks.”
2.6.2 HISTORY OF DEVELOPMENT OF BODYWEAR

According to Elaine Stone (2008), “The physical fitness boom of the 1980s and 1990s, which lured millions of Americans into aerobics classes and body building activities, also was responsible for producing a new fashion category ‘bodywear’. It encompasses coordinated leotards, tights, unitards, wrap skirts, sweatsuits, leg warmers, shorts, T-shirts and crop tops. The line between bodywear and active wear is constantly shifting—especially as stretch fabrics find their way into more and more active wear. Originally bodywear was sold in hosiery departments. Many manufacturers capitalized on this market by creating new exciting leotards with coordinating tights, cover ups and other workout apparel necessities.”.

2.6.3 GROWTH OF BODYWEAR SECTOR IN INDIA

Bodywear sector seems to be growing rapidly with the trend of innerwear being worn as outer wear. A classic example of this is the growth and development of corsets from foundation wear to designer outer wear. According to a report by Global Industry Analysts (2008), the world market for knit underwear and nightwear is predicted to reach 78.5% billion by 2012. The industry is expected to grow by 34.5% during the period of 2011-2015 with Asia-Pacific representing the fastest growing market.

According to Noopur Anand (2008), “the Indian lingerie industry seems to have slowly gained foothold in the global market providing huge opportunity for branded players to exploit this unorganized sector. Various factors such as increase in disposable income, emergence of new Indian women, awareness among the Indian women that lingerie is more than a utility product and effect of globalization have led to this sudden surge in this industry. Intimate wear and beachwear are two categories that have garnered most attention in recent years in terms of research and development. Apparently women are spending around 15 times more on lingerie than they used to some years ago”.

According to Sharma R (2008), “an investigation of the reasons behind the growth of bodywear sector was due to the following trends:
- The outerwear for women has undergone tremendous change, from salwar kameez and Saris to denims and t-shirts, especially in the urban areas.

- Increasing number of female demography entering professional life’s where they need different outerwear for office, parties, recreation resulting in innerwear to compliment the outerwear.

- Increased awareness of health and physique – a phenomenon witnessed by springing in of neighborhood gymnasiums. It is fitness factor that has resulted in the increased sales of intimate wear for sports activity.

- Special occasions like marriage or social gathering which call for special outerwear and matching inner wear”.

2.7 BEACHWEAR

2.7.1 DEFINITION OF BEACHWEAR

Beachwear or swimwear is designed to be worn at the beach or for swimming. Sportswear designed to be worn at the beach, the swimming pool, for sunbathing or swimming is defined as beachwear by Charlotte Mankey Calasibetta (2002). According to Mary N (2002), “swimwear is defined as clothing worn for swimming”. Formerly called as bathing suits, beachwear comes in one piece or two piece designs.

An article by Apparel search (2004) has defined “beachwear also referred to as swimsuit as an item of clothing designed to be worn for swimming”.

2.7.2 HISTORY OF SWIMWEAR

According to Phyllis G Tortora (2010), “bathing suits in the early 1920s was fairly voluminous with tunic and knickers carried over from 1910s. Bathing suits show marked evolution in the period from 1920 to 1947. By the end of the 1920s, the modern concept of costumes in which women could really “swim” rather than “bathe”
had been established. In the 1930s, bathing suits with halter tops became popular. With the introduction of latex the bathing suits became more fitted and wrinkle free. Two-piece bathing suits first made their appearance in 1930 and became popular during the 1950s.

During the 1960s considerable variety was evident in bathing suit styles. These ranged from two piece bathing suits of relatively conservative cut to scantier bikinis”.

### 2.7.3 TYPES OF BEACHWEAR

Kori Ellis (2010), explain the type of beachwear as follows:

- **One piece** - One piece swimwear is derived from the shape of a leotard.

- **Maillot** - In designer's terms, a maillot is your traditional one-piece swimming suit. It normally features a scoop neck and two tank straps. The straps vary in thickness from a couple inches wide to thin spaghetti straps.

- **Bandeau Swimwear** - Both one piece and two piece suits can be bandeau style. Bandeau is a strapless style in which the fabric can is pleated and gathered in the middle. Oftentimes, bandeau swimsuits offer detachable straps that you can attach in different manners - spaghetti, halter or criss-cross style.

- **Monokini** - When the monokini was originally created, it was a swimsuit that left the breasts completely exposed. It wasn't popular at all and evolved into a very revealing version of the one-piece suit. Basically the monokini is a one piece suit where the sides are nearly completely cut out, giving the appearance of a bikini that are connected with a thin strip of material.
- **Classic Bikini**- A classic bikini top is shaped very similar to a traditional bra. It features two cups (which can have underwire support) and straps that go over the shoulders and connect to the band across the back. The classic bikini bottom offers complete coverage of the groin and buttocks. The legs are cut high. This swimsuit style is similar to a high-cut panty.

- **String Bikini**- The traditional string bikini features a two triangle shaped pieces of fabric that cover the breasts. The triangles are connected with three strings. One string runs through the bottom of each triangle with the ends tying in the back to create the band. The other two strings come out of the top of each triangle and tie at the back of the neck. On the string bikini bottom, the triangle front and triangle back are connected with a strip of fabric at the crotch. The bottom is tied at the hips with strings.

### 2.8 INTIMATE WEAR

#### 2.8.1 DEFINITION OF INTIMATE WEAR

Lingerie is quintessentially feminine. As foundation wear, lingerie is the basis upon which a woman creates her silhouette and builds her sense of identity. According to Karoline N and Karen B (1997), it was in 1922 that the term ‘lingerie’ appears for the first time. The earliest known pieces of underwear can be traced back to the ancient civilization of Egypt and Greece, when it seems their use was purely functional. Throughout century undergarments have gone through dramatic changes. Lingerie has always been a very personal matter. Especially today, women are able to choose between varieties of style options designed to accomplish the same purpose.

According to Karen Morris (2001) the term lingerie “includes any garment that is worn as a first layer beneath other clothing”. Undergarments include panties and bra. Bra is a shaped undergarment worn by women to mold and support the breasts whereas panties are garments worn under outer clothing covering torso below the waist.
2.8.2 HISTORY OF LINGERIE

A brief survey in intimate wear by Yahoo (2008) describes the history of intimate wear from 1900s. During the Victorian Age (1837-1901), intimate apparel, especially for women, was much more complicated and therefore cumbersome to wear than it is today. Popular intimate apparel of the era included whalebone corsets, bustles, bodices, and bloomers. While clothes relaxed during the Edwardian Era (1901-1910) with the introduction of bloomers and gradual acceptance of bras, it was not until the 1920s that Western women began openly rejecting constricting intimate apparel. The 1930s, which encompassed the Great Depression, saw more relaxed clothing, meaning that intimate apparel became less structured, as well. In the 1960s, women's intimate apparel continued to appear feminine until the end of the decade when the hippie era began.

2.8.3 TYPES OF INTIMATE WEAR

According to www.wikipedia.com “Panties are divided into various types based on such criteria as amount of rear coverage, width at the sides, and height at which they are worn. These categories are not necessarily distinct and usage may vary somewhat among brands.

- **Briefs** rise to the waist or just below the navel and have full coverage in the rear. In the classic (or full) brief, the sides extend below the hip. In the high-cut (French cut) brief, they are somewhat narrower.

- **Boyleg** briefs (or boy shorts) are styled after men's briefs and may have short legs extending below the crotch.

- **Control panties** (or control briefs) are a special type of briefs designed to offer support and give a slimmer appearance; these usually contain a stretch material such as spandex and may extend above the waist.

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PLATE 2.5: TYPES OF UNDER GARMENTS
• **Hipsters** are similar to briefs, but are worn lower with the waistband around the hips.

• **Bikinis** are also worn at the hips, but the fabric at the sides is narrower. In the **string bikini**, it disappears altogether to leave the waistband as a "string". The rear coverage of the bikini is not as full as with the brief.

• **Tangas/String bikinis** have full rear coverage, but the waistband is reduced to a narrow strip at the sides.

• **Thongs** have a waistband similar to tangas, but the rear coverage is not as full.

• The **G-string** is a thong with virtually no rear coverage, the narrow strip in the back extending from the crotch all the way to the waistband.

According to Karoline Newman and Karen Bressler (1997), “Types of bra include-

• **Convertible**- a bra with removable straps that can be worn in different ways.

• **Cookie**- a removable padded insert made of fiberfill.

• **Demi bra**- a low cut style that covers lower half of breast.

• **Foam cup**- a cup that is padded with foam to give a smooth silhouette and prevent nipples from showing.

• **Front closure**- a bra that closes in the center front

• **Halter**- a bra with straps that fasten behind the neck.

• **Lined cup**- a cup that offers additional support.

• **Longline**- a style that reaches to the waist and offers shaping for the upper torso.

• **Minimizer**- a bra designed to reduce projection by 1.5 to 1.75 inches.

• **Molded cup**- a sculpted, seamless bra cup that provides smoothness.

• **Padded**- a bra with a fiberfill padded cup that makes breasts appear larger.

• **Push up**- a bra with padding at the bottom outside portion of the cup. These bras lift the breasts up and/or push them together to create cleavage.
• **Racer back**- a bra with straps that makes a ‘v’ shape between the shoulder blades.
• **Seamed**- any bra that has seams running through the cup.
• **Seamless**- cups that are made without seams give a smoother look.
• **Shelf bra**- similar to a demi bra only slightly less coverage.
• **Soft-cup**- a bra without structure, underwire, padding or molded cups.
• **Strapless**- an underwire style with wide sides and no straps.
• **Underwire**- a bra with a flexible wire sewn under the bottom of each cup.
• **Wide away**- a bra with widely set shoulder straps.

According to Karoline Newman and Karen Bressler (1997), “fabrics play an important role in providing support to the bras. The more Lycra a brassiere contains, the more supportive it will be. But you should consider various fabrics for their ability to wick away moisture. Pure cotton simply absorbs moisture; but an inside layer made from moisture managing fabric can serve better”.

### 2.9. DESIGNING OF BEACHWEAR AND INTIMATE WEAR

According to Ann Haggard (2004), “Lingerie, beach wear and leisure wear are extremely diversified in their degree of fit. They range from the skin tight corsets, swimsuits and leotards to the loose and casual French knickers, bathrobes and beach pyjamas. Construction of bodywear is complex and requires special trims, machines and pattern making techniques to make them. Fit, structural details and functionality are the three main factors to be considered for designing bodywear. Commonly used fabrics include tricot, nylon knits, Lycra blends, and some cotton knits. Knits is most popular fabric in market today primarily for its structure, versatility and stretchability.”

“There are three aspects that need to be considered when designing a garment. They are functional, structural and decorative aspects. Functionality is how the garment works physically on the body. This is important factor for intimate wear and beachwear as these are specialized garments worn for specific functions. The function of the garment influences the fabric selection. The second aspect is the structural design. These refer to all seamlines that are stitched to hold the garment together. The
third aspect is decorative design as with functionality the consumer also looks for aesthetic appeal, says Julie Cole and Sharon C (2008).

### 2.9.1 FACTORS TO BE CONSIDERED FOR THE CONSTRUCTION OF BEACHWEAR AND INTIMATE WEAR

Ann Haggar (2004) emphasizes on two reasons to be kept in mind while adapting pattern to knit fabrics- the shrinkage factor and the stretch factor. The shrinkage factor requires the size of the pattern to be enlarged and the stretch factor requires the size of pattern to be reduced. To reduce the stretch for better fit the length and width has to be reduced.

According to Helen Joseph Armstrong (2007), “a combination of accurate measurement and a thorough understanding of the difference between body and pattern size is essential. Bra which is the most fitted garment requires actual body measurement without ease to get proper shape and provide correct degree of fit.”

Ann Haggar (2004) has described the successful factors to be considered for construction of swimsuit which need careful consideration during the design and pattern making processes.

1. Choice of fabrics and its suitability for the design: stretch & non stretch. The designs and patterns for each are necessarily quite different.
2. Appropriate choice of blocks as a base from which to start. As swimsuits nearly always fit the body closely, choose blocks that do the same.
3. Body truck length, correctly measured and applied to the flat pattern, the lengthwise fit of a swimsuit is just as important as the fit around the body especially as it is more difficult to alter once the garment is cut.