A COMPARATIVE STUDY ON THE PROPERTIES OF SELECTED KNITTED FABRICS

ROHINI.M
(16PTF007)

A Thesis Submitted to the

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

In partial fulfilment of the Requirement for the

Degree of
Master of Science in Textiles and Fashion Apparel

APRIL 2018

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Certified as bonafide project work

SIGNATURE OF HEAD OFTHE DEPARTMENT	**SIGNATURE OF THE GUIDE**

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I. INTRODUCTION

Knitting is considered to be the second most frequently used method of fabric construction, after weaving. It is one of the several ways to turn thread or yarn into cloth. It is similar to crochet as it consists of loops pulled through other loops. In other words, knitting is the process of construction of a fabric made of interlocking loops of yarn by means of needles. The loops may be eitherloosely or closely constructed according to the purpose of thefabric. The loops or stitches are interlocked using a needle, which hold the existing loop and a new loop is then brought over the new loop to form the knitted fabric. Knitting is different from weaving where in a single piece of yarn can be used to create fabric. The knitted fabric consists of horizontal rows known as courses and vertical columns of loops known as wales. Today, knitting is practiced manually, or with the help of the machines.(Parmar,2013). The term "Knitting" has been evolved from the saxon word 'cnyttan' which in turn was derived from the ancient Sanskrit word 'Nahyat'.(Chandra Roy, 2012).

Knitted fabrics respond to every movement of the body and return back to its original shape easily so they are widely used in apparel production. The most important properties required from the elastic knitted garments are wear comfort, fit, breathability and durability (Eryuruk, 2016). The knitted fabric is highly suitable for next to the skin wear.Its extensibility is very high which allows to fit snugly and without discomfort on any form. Therefore unique the knitted goods are mostly preferred than other fabrics. The sports garments and its protective accessories/wears manufactured from the knitted fabrics have higher functional properties (Kanakaraj and Ramachandran, 2015). Over last few years, there has been growing interest in knitted fabrics due to its simple production technique, low cost, high levels of clothing comfort and wide product range.

Knitting technology meets the rapidly-changing demands of fashion and usage. Knitted fabrics not only possess stretch and provide freedom of movement, but they also have good handle and easily transmit vapour from the body. Due to these properties the knitted fabrics, are commonly preferred for sports wear, casual wear and under wear (Marmarali, 2007). Among the various knitted fabric properties, comfort properties of clothing are equally important as aesthetic properties. The metabolic heat generated depending on the activity normally gets dissipated through clothing as perspiration. It is essential that the fabric should absorb perspiration quickly from the skin and transport to other area of fabric next to skin from where it gets transferred to the atmosphere. This makes the wearer feel comfortable (Goyal and Prabhu, 2013).

Moisture management can be defined as the controlled movement of water vapour and liquid water (perspiration) from the surface of the skin to the atmosphere through the fabric. This action prevents perspiration remaining next to the skin. Moisture management is one of the key performance criteria in today's apparel industry, which decides to allow the body's heat balance to be maintained under a wide range of environmental conditions and body activity. Apparel manufacturers have shifted their attention to the high performance end of the moisture management fabric market and consumers place increasing importance on the performance of garments. It should fulfil this temperature regulation of the body. All this phenomena come under one technical term, "moisture management" (Chinta *et al.,* 2013).

The human body produces moisture in the form of sweating, this perspiration should be taken away from the surface of skin to the attached clothing. The fabric should permit moisture to be transferred from the skin to the weather so as to refresh the body. The moisture transfer is a serious factor in regulation of body temperature. This action prevents perspiration from remaining next to the skin. Moisture management, thermal comfort and other comfort properties of knitted fabrics are considered to be the important performance criteria's. These factors are the most important attribute which depends on the use of raw materials. In addition knit structure also contribute to the fabric properties and end application of fabric (Nahrawy, 2016). Moisture transport properties of textiles have great influence on the thermal-physiological comfort of the human body, which is maintained by perspiring both in vapour and liquid form.

Therefore "A comparative study on the properties selected knitted fabrics was done to study the thermal comfort properties, moisture management and comfort properties of four different fabrics such as single jersey, honey comb, pique and warp knit with the following objectives;

- To study the physical properties of the selected knitted fabrics

- To study the mechanical, wettability and absorbency of the knitted fabrics
- To compare the properties of selected knit fabrics and evaluate the suitability of the selected knit fabrics for sportswear.

2. REVIEW OF LITERATURE

The review of literature for the present study on **""A Comparative Study on the Properties of Selected Knitted Fabrics"** are discussed under the following headings:

2.1 KNITTING:

Knitting is the second most popular technique of a fabric or garment formation by inter looping one or one set of yarns. Continuous length of yarn is converted into vertically intermeshed loops either by hand or by machine. The term "Knitting" has been evolved from the saxon word 'cnyttan' which in turn was derived from the ancient Sanskrit word 'Nahyat' (Chandra Roy, 2012).

Knitting is the process of fabric formation by producing series of intermeshed loops. Loops are the building blocks of knitted fabrics. The knitted fabrics are stretchable than the woven fabrics. The open structure of knitted fabrics also helps in moisture vapour transmission in sports garments. Besides, the knitted fabrics have more porosity than the woven fabrics. Therefore, knitted structures can trap more air resulting in lower thermal conductivity and higher thermal resistance. There are two principles of knitting namely warp knitting and weft knitting (nptel.ac.in/courses/116102005/2).

Knitted fabric is the most common fabric structure for base layer sportswear due to greater elasticity and stretchability compared to woven fabrics, which is very important for freedom of movement in sports. With the possibility of various combination of fabric constructions and yarns used, knitted fabric appears to be the most suitable for functionally adaptive sportswear. Knitted fabrics also mostly have uneven surfaces. A property that makes one feel more comfortable in the aspect of tactile sensations caused by the textile being in direct contact with the skin, when compared to smooth-surfaced woven fabrics of identical fibre compositions (Banu and Sevda, 2014)

2.1.1 HISTORY OF KNITTING:

Knitted fabrics are made from interlocking loops, formed from one or more yarns. The origins of hand knitting cannot be dated, but it is believed to be quite old. Hand knitting uses two needles or pin. One or more yarns may be used in a variety of stitches to produce weft knitted fabrics. The process requires time and skill. In machine knitting, loops of yarns are formed with the help of thin pointed needle. As new loops are formed they are drawn to the previous ones, thus producing a knitted fabrics (Blackberry, 1992)

The earliest known knitted fabric was a pair of socks found in an Egyptian tomb, which dates back to the 4th century B.C. The art of knitting seems to have perfected in Western Europe in the 14th century. It is said that in Europe hand knitting was an important industry which developed into an advanced craft by the 16th century. Hand knitting spread rapidly throughout Europe within a few generations. In 1589, William Lee, a clergyman invented the first knitting machine which knitted 8 loops to 1 inch of width. After the invention of the first knitting machine, the art of knitting was gradually taken over by guild-organized cottage industries in the 17th and 19th centuries. In 19th century, the industrial revolution which started in the late 18th century in Britain and spread throughout the world played key role in spreading wool spinning and cloth manufacture to factories. The full-fashioned knitting machine was invented in 1864 by William cotton of Leicestershire, England. This machine was a part of the original model of Lee. Also known as the lace market, the city of Nottingham, dominated the production of machine knitted lace in the 19th century. Power was applied to the knitting machines and subsequently, circular-knitting machines appeared on the scene. In 20th century, seamless stockings were knitted on circular machines. England became famous for its stockings. In fact, the word hosiery is derived from the old English word “hose” which means a covering for the leg. Initially cotton, wool, silk and later rayon yarn were used for making hosiery. The use of nylon improved the fit of hosiery due to its stretchable properties. Subsequently, the Great Britain, hosiery came to be associated with all types of machine-knit garments which is also known as knit wear. In United States, hosiery products are still known as stockings, socks, panty hose and tights. Knitwear was mainly associated with women’s fashion but later on, knitted pullovers, cardigans, shirts, men’s underwear, sportswear and swimwear also became popular (Neelima, 2009).

The 21st century has seen a resurgence of knitting. As another sign of the knitting’s popularity in the early 21st century, a large international online community and social networking site for knitters and crocheters, ravelry was founded by Casey and Jessica Forbes in May 2007. At first available by invitation only, the site connects knitting and crochet enthusiasts around the world.(Gosling and Lucinda, 2014).

2.1.2 KNITTED LOOP STRUCTURE:

The knitted loop structure may not be always noticeable because of the effect of structural fineness, fabric distortion, additional pattern threads or the masking effect of finishing processes. Unless however, the intermeshing of the loops is securely achieved by the needles receiving new loops before their old loops are cast off and the ground structure is not fractured during finishing to wear, a breakdown or separation of the structure will result. The properties of a knitted structure are largely determined by the interdependence of each stitch with its neighbours on either side and above and below it. Knitted loops are arranged in rows and columns roughly equivalent to the warp and weft of woven structures termed ‘courses’ and ‘wales’ respectively (Spencer, 2001).

2.1.3 TYPES OF KNITTING:

There are two major types of knit:

- Warp knitting
- Weft knitting

2.1.4 WEFT KNITTING:

There are three fundamental stitches in weft knitting - 1) plain-knit stitch, 2) purl stitch, 3) rib stitch. Novelty stitches are variations of these three stitches. The hand method of knitting is weft knitting. On a machine, the individual yarn is fed to one or more needles at a time. Weft knitted fabrics may also knit with multiple yarns, usually to produce interesting colour patterns. The two most common approaches are intarsia and standard colour work (Johnson, 2009).

In weft knitting, the wales are perpendicular to the course of the yarn; however in warp knitting, the wales and course run roughly parallel. In weft knitting, the entire fabric may be produced from a single yarn, by adding stitches to each wale in turn, moving across the fabric as in a raster scan. By contrast, in warp knitting one yarn is required for every wale. Since a typical piece of knitted fabric may have hundreds of wales, warp knitting is typically done by machine, whereas weft knitting is done by both hand and machine. Warp knitting fabrics such as tricot and Milanese are resistant to runs and are commonly used in lingerie. (Parmar,2012)

Weft knitting is the more diverse, widely spread and larger of the two sectors, and accounts for approximately one quarter of the total yardage of apparel fabric compared with about one sixth for warp knitting. Weft knitting machines, particularly of the garment length type, are attractive to small manufacturers because of their versatility, relatively low total capital costs, small floor space requirements, quick changing facilities, and the potential for short production runs and low stock-holding requirements of yarn and fabric (Spencer, 2001).

In this method loops are made by each weft yarn and loops are formed across the width of the fabric. Weft knitting machines are of two types;

- Flatbed machine
  - Single bed
  - Double bed or 'V' bed
- Circular bed knitting machine

In flat knitting machine, the needles do not perform any lateral movement. The axial movement of the needles, needed for loop formation, is actuated by a set of cams mounted on cam jacket which reciprocate laterally. In contrast, the cam jackets are generally stationary in circular knitting machine. The cylinder carrying the needle on its grooved surface rotates continuously to cause the upward and downward movement of needles. In many small diameter circular weft knitting machines, the cylinder may remain stationary while the cam jackets revolve. This is true for single feeder machines (nptel.ac.in/courses/116102005/2).

2.2 TYPE OF WEFT KNITTED STRUCTURES

2.2.1 PLAIN KNIT STITCH OR SINGLE JERSEY:

Jersey is the generic term applied to all types of weft knitted fabric. It was originally manufactured from wool, but now is made of wool, cotton and synthetic fibres. The term jersey is derived from the name of the channel Island that lies between Britain and France, where thick weft knitted fabrics were originally hand knitted for fisherman's sweaters (urbanara.co.uk/journal/buying-guide/jersey).

Jersey is a knit fabric used predominantly for clothing manufacture. The fabric can be very stretchy, single knitted, usually light-weight, jersey with one flat side and one piled side. When made with a lightweight yarn, the fabric is most often used to make T-shirts. Jersey is considered to be an excellent fabric for draped garments, such as dresses, and women's tops (Susna *et al*, 2002).

The plain knit is the basic form of knitting. It can be produced in flat form of knitting. It can be produced in flat-knit or tubular form. The flat knit is also called jersey stitch because the construction is like that of the turtleneck sweaters originally worn by the English sailors from the Isle of Jersey; it is sometimes called balbriggan stitch after the hosiery and underwear fabrics made in Balbriggan, Ireland (Hollen and Saddler,1952).

Plain flat knits may be shaped or full-fashioned. The knitting is done with a row of latch or beard needles arranged in a linear position on a needle plate or in a circular position on a cylinder. The plain knit produces a relatively lightweight fabric compared with a thicker fabrics produced by other stitches. Single or plied yarns may be employed. It has high rate of production, is inexpensive, and lends itself readily to variation in design by pattern devices. These variations include stripes, multi coloured patterns, textured surfaces produced by raised designs, and pile effects (Corbman,1982, Hollen and Saddler, 1952).
Knit fabric is the simplest and most economical weft knitted structure to produce, and has the maximum covering power. It normally has 40% potential recovery after stretching.(tikp.co.uk/knowledge/technology/knitting/principles).

The construction is formed by a matrix of similar loops. Hence on one face of the resultant fabric all loops exhibit technical back side and the other face would show technical front of all loops. This is the simplest of all weft knitted constructions produced with only one set of needles. Hence the construction is termed as plain jersey, simplest of all constructions (nptel.ac.in).

If a weft knitted fabric has one side consisting only of face stitches, and the opposite side consisting of back stitches, then it is described as a plain knitted fabric. It is also frequently referred to as a single jersey fabric. Technical face of single jersey fabric is smooth, with the side limbs of the needle loops having the appearance of columns of V's in the wales. These are useful as basic units of design when knitting with different coloured yarns. On the technical back, the heads of the needle loops and the basic of the sinker loops form columns of interlocking semi circles, whose appearance is sometimes emphasized by knitting alternate course in different coloured yarns (Cresswell *et al.*, 2002).

2.2.2DOUBLE JERSEY:

Double jersey is weft knitted fabric which is formed by two sets of needles on a weft knitting machine with two needle beds. It is almost similar to the single jersey fabric but in double jersey, technical face and back side appearance is same (textilemerchandising.com/ fabric-double-jersey).

2.2.3 PURL STITCH:

This construction is also referred to as the links and links stitch. It is made on flat bed and circular machines by needles using hooks on both ends to alternatively draw loops to the front of the fabric in one course and to the back in the next course. It is a slower and more costly technique. The fabric looks the same on both sides and resembles the back of the plain knit. Like the plain knit, the purl knit will run up and down if a loop is broken. But a purl knit fabric will not curl at the edges. The use of double hook needles enables ready changeover during fabric construction to include flat and rib stitches, which makes it possible to duplicate virtually any hand-knitted structure. It lends itself to the heavy, jumbo stitch that produces a familiar bulky effect. Machine maintenance is expensive and production is slow, thus escalating the cost of the final effect. Because the purl stitch has crosswise stretch and excellent lengthwise stretch, it is widely used in infants and children's wear.(Corbman,1983).

In the simplest knitted fabrics, all of the stitches are knit or purl; these fabrics are denoted as stockinette and reverse stockinette, respectively. Vertical stripes are possible by having alternating wales of knit and purl stitches. Horizontal striping is also possible, by alternating rows of knit and purl stitches; the simplest of these is garter stitch. Check board patterns is also possible, the smallest of which is known as seed stitch; the stitches alternate between knit and purl in every wale and along every row, Fabrics in which the number of knit and purl stitches are not the same, such as stocknette, have a tendency to curl; by contrast ,those in which knit and purl stitches are arranged symmetrically tend to lie flat and drape well. Wales of purl stitches have a tendency to recede, whereas those of knit stitches tend to come forward (Kapoor, 2011).

2.2.4 RIB STITCH:

Rib knit fabrics have alternating lengthwise rows of plain and purl stitches constructed so that the face and back of the fabric appear alike. This may be produced either on a flat rib machine or a circular rib machine. In a flat rib machine, one set of needles is placed opposite the other set of needles in an inverted 'V' position of 45 degrees to the horizontally on a dial. In both machines, one set of needles pulls the loops to the front and the other set pulls the loops to the back of the fabric. Each set of needles alternatively draws loops in its own direction, depending upon the width of the rib desired. The rib construction will not curl at the edges. If a yarn breaks, it will cause a run downward only. The rib stitch has excellent width wise elasticity, particularly in the 2x2 rib structure. This characteristic has resulted in its extensive use in apparel where snugness of fit is essential, such as waistbands of sleeves and waistbands of garments. It is also widely used for underwear and socks for men and children (Thomas, 1972).

The full cardigan stitch is a bulky rib knit and is produced by one set of needles knitting and the other set of needles tucking on the first course. They reverse on the next course, with the plain needles tucking and the rib needles knitting. The fabric has the same appearance on both sides, looking like slightly stretched jersey fabric (Thomas, 1972).

The half cardigan stitch is a variation of the full cardigan stitch. It is produced by one set of needles alternately tucking and knitting on alternate courses. The construction on the back of the fabric is the reverse of the face. A variation of this stitch is the rack stitch, which has a herringbone pattern on the face (Corbman, 1983).

Rib knits have more elasticity crosswise than plain knits and are therefore used as wrist and neck bands on sweaters. Rib stitch is also used in making bulky knits. It is seldom used inyarn goods for outerwear garments but is used in underwear fabrics. Rib knit fabrics do not curl at the edges as do plain knits.(Hollen and Saddler, 1952).

Ribbed structures are more durable than plain knit so it is often used at the cuffs of a plain knit garment.(tikp.co.uk/knowledge/technology/knitting/principles)

2.2.5 INTERLOCK STITCH:

Interlock has the technical face of plain fabric on both sides, but its smooth surface cannot be stretched out to reveal the reverse meshed loop wales because the wales on each side are exactly opposite to each other and are locked together.(Spencer,2001).

These fabrics are a variation of rib knits made on the interlock machine. Interlock is an interlocking of two 1x1 rib structures in such a way that the face wale of fabric “1” is directly in front of the ‘reverse wale’ of the rib fabric “2”.Each interlock pattern row (often termed an ‘interlock course’) requires two feeder courses, each with a separate yarn that knits on separate alternate needles, producing two half gauge 1x1 rib courses whose sinker loops cross over each other. Thus old feeders will produce alternate wales of loops on each side and even feeders will produce the other wales (www.scribid.com/doc/66786475/Basics-of-knitting-Purl -and-Interlock-fabric).

2.2.6 PIQUE STRUCTURE:

Pique, or Marcella, refers to the weaving style, which is characterized by raised parallel cords or geometric designs of the fabric. Pique fabrics vary from semi-sheer dimity to heavy weight waffle cloth (Nielson and Karla, 2010). Pique fabrics are a type of dobby construction. This may be constructed in various patterns such as cord, waffle, honeycomb and birds eye piques. These fabrics require the addition of extra yarns, called stuffer yarns. These stuffer yarns are incorporated into the back of the fabric to give texture and added depth to the fabric design. Some piques may be made using the jacquard attachment to the loom.(Davis and Rebecca,1996).

2.2.7 HONEYCOMB STRUCTURE:

Polyester fabrics have so many advantages like excellent elasticity, wrinkle resistance and durability. They are widely used in the production of various types of clothing. However, in terms of moisture absorption, the clothing made from them is poor in comfort, and also easy to produce static electricity which brings about dust absorbing and clinging to body.

Honeycomb weaves derive their name from their partial resemblance to the hexagonal honeycomb cells of wax in which bees store their honey. These weaves form ridges and hollows which give a cell like appearance to the textures. Both warp and weft threads float somewhat on both sides, which coupled with the rough structure, renders this class of fabric readily absorbent of moisture.

End uses:

The fabrics constructed from honey comb weaves have a more rough structure. This renders more absorption of moisture. The weaves are, therefore suitable for towels and also in various forms for bed covers, quilt and sportswear.(textilelearner.blogspot.com/2011/03)

2.3 TYPES OF WEFT KNITTING:

2.3.1 BIAS KNITTING:

Bias knitting is a method by which the grain of a knitted fabric is skewed from the vertical, by decreasing on one side and decreasing on the other. The term "bias" derives from sewing, where bias refers to the diagonal between the weft and warp threads, where the elasticity of wovens is greatest. A classic use of bias knitting is in making a saw-toothed knitted hemline for a garment (Neelima, 2009).

2.3.2 CIRCULAR KNITTING:

Circular knitting is a form of knitting that creates a seamless tube. When knitting circularly, the knitting is cast on and the circle of stitches is joined. Knitting is worked in rounds in a spiral. Originally, circular knitting was done using a set of four or five double-pointed needles. Later, circular needles were invented, which can also be used to do circular knitting: the circular needle looks like two short knitting needles connected by a cable between them. Machines also do circular knitting; double bed machines can be set up to knit on the front bed in one direction then the back bed on the return, creating a knitted tube (Johnson, 2009).

2.3.3 CABLE KNITTING:

Cable knitting is a style of knitting in which the order of stitches are permuted. The stitches crossing behind are transferred to a small cable needle for storage while the stitches passing in front are knitted. The former stitches are then transferred back to the original needle or knitted from the cable needle itself (Neelima, 2009).

2.3.4 FLAT KNITTNG:

Flat knitting is a method for producing knitted fabrics in which the work is turned periodically, i.e., the fabric is knitted from alternating sides. The two sides of the fabric are usually designated as the right side(the side that faces outwards, towards the viewer and away from the wearer’s body) and the wrong side (the side that faces inwards, away from the viewer and towards the wearer’s body).In flat knitting, the fabric is usually turned after every row. However, in some versions of double knitting with two yarns and double-pointed knitting needles, the fabric may turned after every single row. A flat knitting machine is very flexible, allowing complex stitch designs, shaped knitting and precise width adjustment. It is, however relatively slow when compared to a circular machine. The two largest manufacturers of industrial flat knitting machines are stoll of Germany, and Shima Seiki of Japan.(Hiatt and Hemmons, 2012)

2.4 WARP KNITTING:

In warp knitting, one or more sets of warp yarns are wound on warp beams. Each individual yarn is drawn through a yarn guide to the hook of the knitting needle which is mounted on a guide bar that extends across the width of the machine. This bar moves to cause the yarn to be lapped around the needle. Next, the needle bar moves to form loops simultaneously through all needles, across the course. The guide bar then moves sideways to be positioned one or more needles away from the previous point. Thus each needle loops its own yarn, producing parallel rows of loops simultaneously that are interlooped in a zigzag pattern. More the guide bars, greater is the design flexibility (Brackenbury,1992).

Warp knitted fabrics have the very desirable characteristics lacking in the usual weft knitting. They are firm, do not sag, and their edges do not ravel when cut. Until recently warp-knit fabrics were used chiefly for underwear. By contrast, in warp knitting one yarn is required for every wale. Since a typical piece of knitted fabric may have hundreds of wales, warp knitting is typically done by machine. Warp knitting fabrics such as tricot and Milanese are resistant to runs, and are commonly used in lingerie.

2.5 TYPES OF WARP KNITTED STITCHES:

There are six fundamental stitches in warp knitting

- Tricot knit
- Milanese knit
- Simplex knit
- Raschel knit
- Crochet knit

2.5.1 TRICOT KNIT:

The machine has one or more warp beams mounted above it. Each set of yarns from a warp beam is fed to a row of needles arranged across the width of the machine and is controlled by yarn guides set in a guide bar that also laid across the machine. Since one guide bar is used for each set of warp yarns, the number of guide bars employed. The greater the number of bars, the greater the design flexibility. Tricot knits are used for a wide variety of fabric weights and designs. Typical uses of tricot fabrics are lingerie, lounge wear, sleepwear, blouses, shirts, dresses, slacks uniforms for nurses and waitresses, bonded fabric material, outwear and automobile upholstery (Corbman,1983).

2.5.2MILANESE KNIT:

The Milanese stitch produces a fabric very similar to tricot. The fine rib on the face and a diagonal pattern on the back can identify it.However,Milanese fabric is superior to tricot in smoothness, elasticity, regularity of structure, split and tear resistance.(Parmar,2013)

2.5.3 SIMPLEX KNIT:

Simplex fabric is made of fine yarn and is relatively dense and thick. It is a small part of warp knit production. Simplex fabric is used to make gloves, handbags, sportswear and slip covers. Eyelets and other open work can also be produced on the simplex machine (Parmar, 2013).

2.5.4 RASCHEL KNIT:

The raschel knit ranks in importance of production with tricot, but it surpasses it in a variety of products, which range from veilings and laces to powernets for foundation garments to such pile fabrics as carpets. The raschel knit is made with latched needles rather than the bearded type used for tricot, Milanese, and simplex. The raschel fabrics can usually be distinguished from tricot fabrics, in that raschel constructions are made with heavy yarns and usually have an intricate, lace like pattern, whereas tricot constructions are made with fine yarns and are either flat or have a simple geometric pattern. Raschel machines are extremely versatile. They can knit every type of yarn made of any kind of fibre, including metallic and glass and in any form, whether staple or filament standard or novelty. This versality naturally extends the possible characteristics and properties of the fabrics produced (Corbman, 1983).

2.5.5 CROCHET KNIT:

The basic stitch used in hand-crochet. This construction is used in a wide variety of fabrics ranging from nets and laces to bedspreads and carpets. In warp knitting, one yarn is required for every wale. Since a typical piece of knitted fabric may have hundreds of wales, warp knitting is typically done by machine, whereas both hand and machine do weft knitting. Warp-knitted fabrics such as tricot and Milanese are resistant to runs, and are commonly used in lingerie (Parmar, 2013).

2.6 JACQUARD KNITTING:

Both weft and warp knitting can incorporate the jacquard mechanism to produce multi-coloured designs. The Jacquard punched-card technique used in weaving can also be adapted to knitting. Cards control the selection or inhibition of the needles to produce the pattern.

Another technique for controlling the individual needles to produce the various types of knits and designs utilizes electronic or electromagnetic devices. A third means is the use of a strip of film encoded in a boxed fashion. The film is divided into successive opaque and transparent squares that act similarly to the holes in the jacquard card or paper tape. Lens directs light through the moving film to phototransistors to select the particular needle for each stitch. Jaquard knits are made on flat-bed and circular machines, and the fabric may be flat or ribbed. The fabrics are multi-coloured; each colour requires consecutively its own respective feed on each course of the design. The back of the fabric can be varied, as with a novel effect, striped pique, blister or solid back (Corbman, 1983).

Jacquard knitting is recognizable by its reversibility, either because the fabric is truly double-sided and back side does not show those floats A true double sided jacquard knit will have pattern on both sides and will be double thick. Jacquard knitting is most easily done on a machine (https://www.craftsy.com/knitting/article/jacquard-knittng-technique).

2.7 PILE KNITTING:

The production of pile knits has steadily grown in variety, importance and volume. They are constructed as fleece, high pile, terry and velour knits. Depending upon the type of construction, they are used for fur fabrics, rugs and fashion apparel fabrics.

2.8 PROPERTIES OF KNITS:

- Knits are known for their excellent drape, fit and comfort.
- They give warmth due to the insulative air pockets.
- Other positive features include high absorption, light weight and wrinkle resistance and recovery.
- The other side of the coin is that knits are costly and some fabrics tend to sag and loose shape.
- Some weft knits also face the problem of ladder formation.
- If one loop breaks, then a hole is made which starts to “run “or slip down the wale.(Brackenbury,1992)

2.9 USES AND CARE OF KNITS:

- Today, knits (especially warp knits) compete closely with products of the loom.
- Their properties make them the preferred choice for sportswear, casual wear, undergarments and socks.

- A whole range of fibres is being used for construction of knits for the gamut of end uses.
- These include wool, cotton, rayon, silk, metal yarns and textured synthetics like nylon and acrylic.
- Apparel uses of knits predominate other categories.
- Curtains, cushion covers, upholstery and carpets are the common applications of knits in the home.
- In India, Ludhiana produces a vast range of knitted home textile products (Brackenbury,1992).

2.10 ADVANTAGES OF KNITTING:

- Fabric can be produced with a minimum of only one yarn
- Loop size can be varied to a wide extent and that too very easily.
- During knitting, loops can be transferred from one needle to other.
- The extensibility and stability of the knitted fabric can be engineered.
- The desired porosity or compactness of the fabric can be achieved easily.
- Shaping can be done at the time of knitting on the resultant fabric.
- Yarns generally unsuitable for knitting can be introduced in the fabric as in lay.
- Loop structures are easily distorted under tension in application which imparts more freedom of movement and comfort to wearer.
- Fabric with single face, double face, open work and surface interest can be knitted according to requirement.
- The number of yarns to be knitted in the same fabric can be varied by selection.
- The total number of needles for loop formation can be varied from knitting cycle to cycle.
- Wastage of yarn during conversion of yarn into fabric by knitting is negligible.
- Knitting can produce fabrics which are very much suitable for intimate wears as well for technical applications.
- Design possibilities will be much higher (Chandra Ray, 2012).

2.11 DISADVANTAGES IN KNITTING:

- Dimensional stability will be lower than the woven fabric.

- Glass fabric is very crucial to knitting because bending rigidity will be higher. But in the weaving, we can produce glass fabric easily.
- Count range will be low in the knitting machine, but weaving is the versatile machine to produce any count of fabrics (https://textilestudycenter.com/knitting).

2.12 MOISTURE MANAGEMENT:

Moisture management is a kind of chemical treatment which can enhance the hydrophilic properties of fabric to absorb more moisture with a better hand or feel(such as soft, bulky, smooth), better rate of overall comfort and a better drape and pliability.(Kan,2007).The comfort is undoubtedly the most important human attribute depends upon the moisture transport is the transfer of liquid water capillary interstices of the yarn and fabric. Because of its good water absorption property, cotton is often used for next to skin wear such as t-shirts, underwear, socks. All these are known as “moisture management” which mean the ability of a textile fabric to transport moisture away from the skin to the garment’s outer surface in multi-dimensions and it is one of the key performance criteria in today’s apparel industry since it has a significant effect on the human perception of moisture sensation (Alina *et al.).*

2.12.1 NEED FOR MOISTURE MANAGEMENT

Comfort can be defined as a pleasant physical, physiological and psychological equilibrium state between the human being and the environment. For a person engaged in normal routine indoor activity, energy expended is 50 watts/square meter/hour. The metabolic heat generated is readily dissipated through the clothing as sweat. At rest, body will give off, about 60 ml of water vapour per hour at ambient conditions. During hard physical activity body sweats and in conventional clothing like cotton, the moisture traps out. The sports and leisure wear exert a barrier for efficient transfer of excess heat resulting in a rise in a core body temperature and skin temperature greater than 37 which increases sweating. The moisture locks out between clothing and body then it increases body temperature and perspiration even more. The excess heat moistens the fabric, which then reduces the body heat and makes the wearer becomes so tired. So, the fabric worn next to the skin should have two important properties. The initial and the foremost property is to evaporate the perspiration from the skin surface and the second property is to transfer the moisture in the atmosphere and make the wearer feel comfortable.

According to the researches, textiles which feel soft and supple do not cause any irritation on the skin such as scratching and itching. The textiles commonly worn, act as a barrier between the external environment and the human body. The behaviour of moisture in various fibres is different owing to their physical and chemical properties making it uncomfortable to the wearer unless the moisture is carried away by the natural drying process or aided by the apparel. Thus, moisture management in fabric is very useful if worn next to the skin at the time of exercising to keep the skin dry and make the wearer feel comfortable. For sportsmen and women being able to concentrate fully sporting activity, it is essential that their clothing is comfortable to wear (Chinta *et al*, 2013).

3. METHODOLOGY

The methodology adopted for the present investigation, **"A Comparative Study on the Properties of Selected Knitted Fabrics"** is discussed under the following headings:

3.2 Selection of Fabric

3.2. Identification of Fabric

3. 3 Objective Evaluation

3.3.1 Course and wale

3.3.2 Fabric count

3.3.3 Microscope Test

3.3.4 Fabric Thickness

3.3.5 Fabric Weight

3.3.6 Bursting Strength

3.3.7 Abrasion Resistance

3.3.8 Fabric Air Permeability

3.3.9 Fabric Water Permeability

3.3.10 Fabric Pilling

3.3.11 Thermal Conductivity

3.3.12 Flammability Test

3.3.13 Fabric Drape

3.4 Absorbency tests

3.4.1 Wicking Test

3.4.2 Immersion Test

3.4.3 Drop Test

3.4.4 Drying Rate

3.4.5 Spray Test

3.5 Statistical Analysis

3.1 SELECTION OF FABRIC:

The single jersey knit has a high stretchability and elasticity and it is soft and resilient too. Therefore, it is well suited for sportswear. The pique knits has low stretchability and the elastic recovery is more than weft knit single jersey. This fabric's cloth surface is hydrophobic, porous, such as honeycomb, more breathable than plain knitted fabric, moisture, dry and more resistant to washing. Due to its special texture, easy to recognize, so it is also called the pineapple rob. So, they are usually used for T- Shirts and sportswear. The honeycomb fabrics have good absorption and wicking property. Therefore these four fabrics were selected to study the properties and analyse their suitability for sportswear.

3.2 IDENTIFICATION OF FABRIC:

Every fibre has its unique structure. When fibres are viewed through the microscope, the cotton fibres resemble like ribbon like structure and polyester looked like a cylindrical like structure. While analysed through microscope, the fibres were noticed to be in cylindrical structure, therefore, it has been identified that the fibres are cent percent polyester.

3.3 OBJECTIVE EVALUATION

3.3.1 COURSE AND WALE:

A Course is a predominantly horizontal row of needle loops produced by adjacent needles during the same knitting cycle. A wale is a predominantly vertical column of intermeshed needle loops generally produced by the same needle knitting at successive cycles. The wales per inch and courses per inch of knitted fabrics are analogous to ends per inch and picks per inch of woven fabrics. For a knitted fabric, the wales per pinch and course per inch values are determined by the loop length. Smaller loop length leads to higher values of wales per inch and course per inch. As a result, the stitch density or loop density which is a product of wales per inch and course per inch also increases with the reduction in loop length.The ratio of course per inch and wales per inch is known as loop shape factor.

PROCEDURE

A course and wale is measured using a Pick Glass (Plate – I). The number of loops in the horizontal loops and the vertical loops were measured and recorded.

3.3.2 FABRIC COUNT:

Count is numerical expressions which express or indicate the fineness or coarseness of yarn used in textile. According to Textile Institution, count is a number indicating the mass per unit length or length per unit mass of yarn. Here, count has two systems indicate coarseness and fineness of yarn. Count is mainly two types namely Indirect System and Direct System.

INDIRECT SYSTEM:

The count of yarn expresses the number of length units in one weight unit. Thus higher the count, finer the yarn. The system is generally used for cotton, worsted and linen (wet spun) etc.

DIRECT SYSTEM:

The count of yarn expresses the number of weight units in one length unit. Thus higher the count, coarser the yarn. The system is generally used for synthetic fibre, jute, silk etc.

PROCEDURE

The yarns from the fabric are ravelled out to a certain level and it is aligned properly such that it should not have any breakage. Then the filament and staple yarns are identified and it is separated. For filament yarns, the yarn count is done using denier system method. The weight in milligrams of 9 metres of yarn is measured. So, 10 threads in 30 cm is taken and weighed using Electronic Weighing Balance (Plate – II). The average is be multiplied by 3 which will be the denier calculation.

For staple yarns, 12 threads of 12 inches are taken and weighed and measured. 1 yard is 36 inches. Here 4 yards of yarn is weighed in milligrams. To calculate the count, 2160 is divided by the average value and it is calculated.

3.3.3 MICROSCOPE TEST

Microscopes having magnification of at least 100 power, can be successfully employed for testing and identifying the fibre contents of a fabric. Microscope test is very effective for testing the natural fabrics. Difficulties can be faced while testing synthetic fabrics as many of them have similar appearance. However ,one must know, what the fibres look like under a microscope as many finishing processes like mercerizing and delustering, change the appearance of fibres under Electronic Microscope (Plate – III).Apart from it, dark coloured fabrics also cannot be tested with Microscope as light cannot pass through dark substances. For such fabrics, either the textile dyes have to be removed by stripping, bleaching or have to be chemically tested.

Thus the Single Jersey (Plate – IV), Honey comb (Plate – V), Pique (Plate – VI) and Warp Knit (Plate – VII) were viewed under the microscope.

3.3.4 FABRIC THICKNESS

The principle of measuring fabric thickness in BIS (2000) states that "essentially, the determination of the thickness of a compressible material such as a textile fabric consists of the precise measurement of a distance between two plane parallel plates as the pressure foot and the other as the anvil". The thickness gauge is maintained at a standard of ASTMD 1777.

Hungarian Thickness Gauge (Plate – VIII) was used to determine the thickness of the knitted samples. A clock type dial gauge built into a thickness tester. It should be rigidly mounted in a suitable frame after setting to zero. The gauge is also consists of a pressure foot and anvil. The sample is placed between the cleaned pressure foot and anvil. The sample is placed between the cleaned pressure and anvil without any pressure. The reading shown by the dial is noted down. Thickness was measured at different places away from 2” of the selvedge of the selected sample. The gauge is capable of measuring to an accuracy of one per cent for both of 5/1000 inch or more and to 0.00005 inches for thinner fabric. Based on this procedure, the thickness was determined for all the selected knitted samples.

Plate I

Pick Glass

Plate II

Electronic Weighing Balance

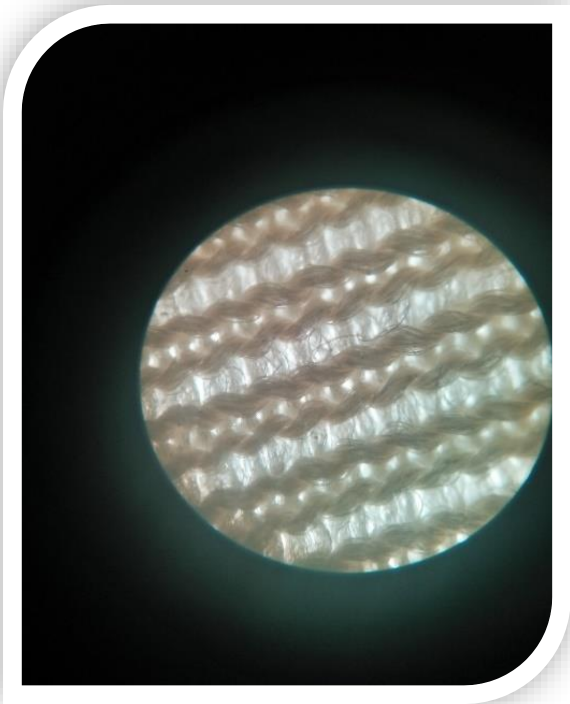
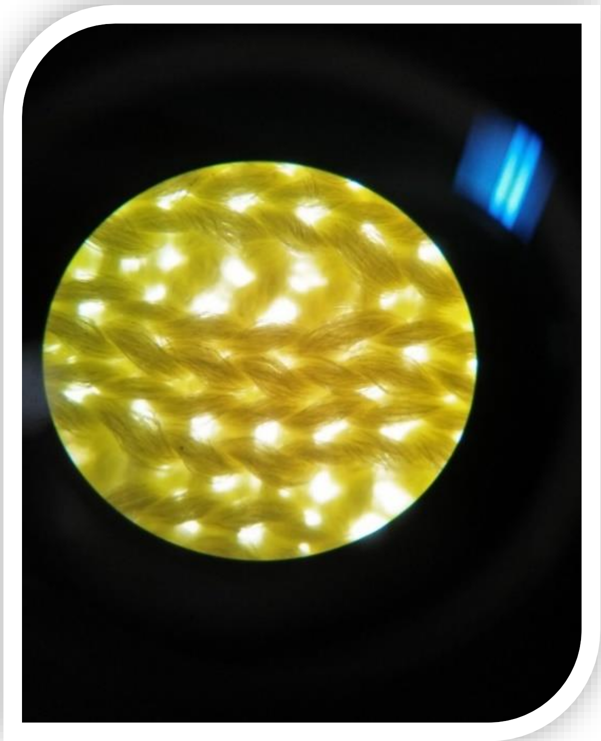


Plate III

Electronic Microscope

Plate IV
Microscopic view of
Single Jersey



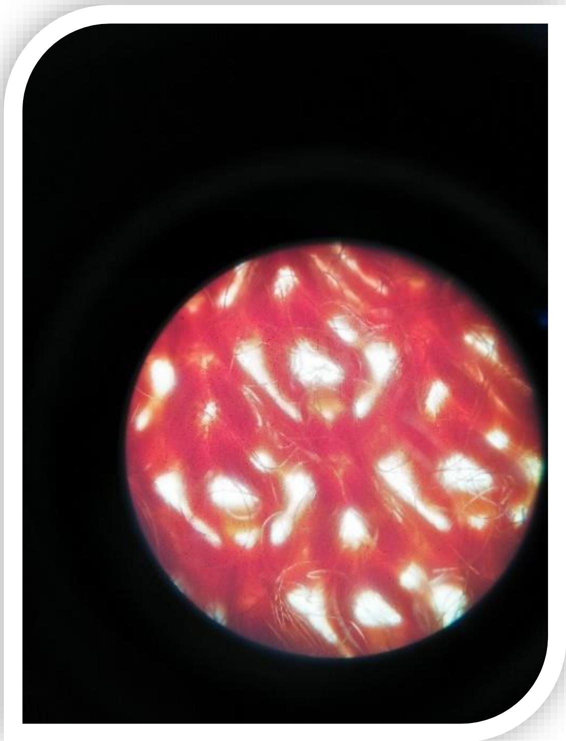


Plate V
Microscopic view of
Honey Comb

Plate VI
Microscopic view of
Pique

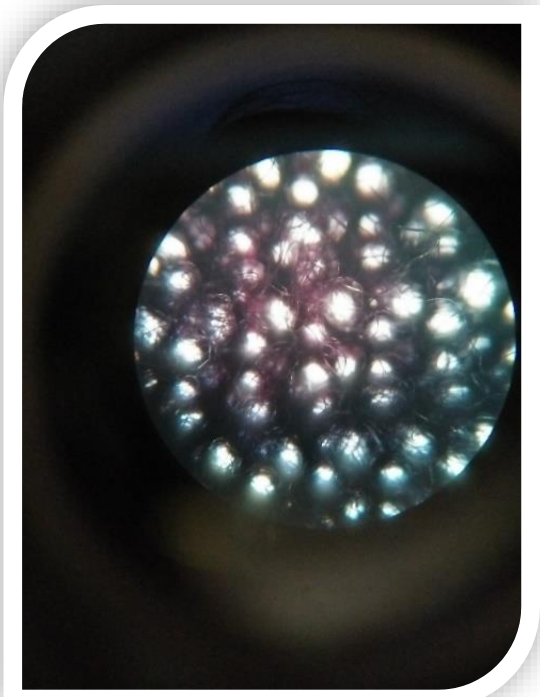


Plate VII
Microscopic view of
Warp Knit

Plate VIII
Thickness Gauge

Plate IX
GSM Cutter

Plate X
ırsting Strength Tester


AIR PERMEABILITY TESTER

Plate XI
Abrasion Resistance Tester

Plate XII
Air Permeability Tester

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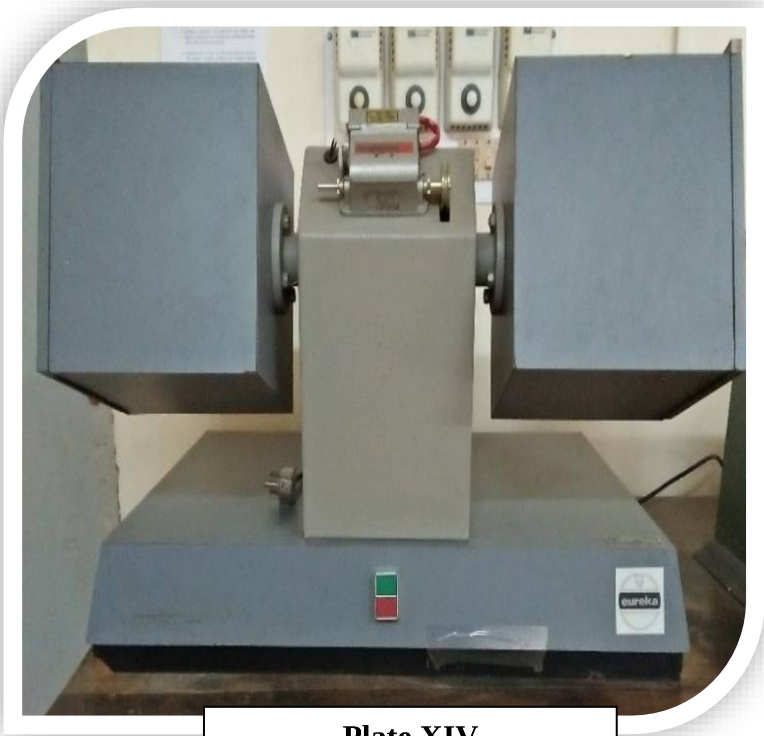

Plate XIV
Pilling Tester

Plate XV
Thermal Conductivity Tester

Plate XIII
Water Permeability Tester

Plate XVI
Auto Flame V

Plate XVII
Drape Meter

Plate XIX Wicking Test	Plate XX Immersion Test

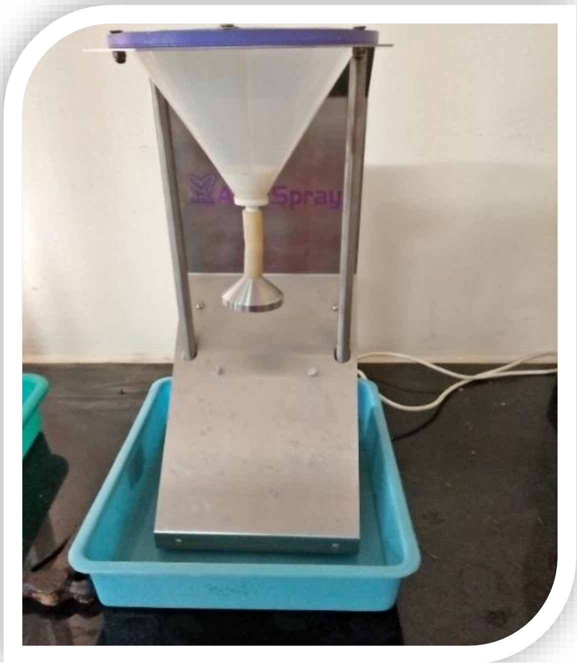

Plate XXI
Drop Test

Plate XXII
Spray Test

FABRIC WEIGHT:

Fabric weight is the relative weight of the fabric and expressed as the weight of the particular size of a size of a piece as grams per square meter or ounces per square yard

(Angappan and Gopalakrishnan, 2006). GSM means "Gram per square meter" that is the weight of fabric in gram per one square meter. By this we can compare the fabrics in unit area which is heavier and which is lighter. The fabric weight is maintained at a standard of ASTMD 2646.

Fabric weight of the knitted samples was determined using Electronic Weighing Balance GSM Cutter (Plate – IX) is a derive used to cut circular specimen of 100 square centimetres of a fabric very accurately. It has 4 blades that cut the fabric when the hand wheel is rotated by applying light pressure. The samples were cut and weighed accurately using a digital balance having 0.01 sensitivity. The value in grams is multiplied by 100 and that gives grams per square metre of the fabric. The sample used weighed for four times and the mean value was calculated and recorded. Based on this following procedure, the weight of all the knitted fabric was found.

3.3.6 BURSTING STRENGTH:

Bursting strength is a method of measuring strength in which the material is stressed in all directions at the same time and therefore more suitable materials such as knitted fabrics, lace or non woven.

The EUREKA Bursting strength Tester (Plate – X) type EC-61 serves for the determination of the bursting ability of flexible samples, such as fabrics, knitted fabrics, boned fibre fabrics, felts, card boards, paper foils, polythene sheets etc.

The bursting test which applied stresses to the samples complex by bulging whereby both directions (warp and weft) interact not only in their force, but also their elongation components, which reduces the difficulties normally occur during the tensile strength tests. Further more the bursting stress compiles in many cases by or those of the practice and that the bursting strength gives more informative characteristics than the tensile test, when the load is applied only in one direction, as in the case of warp or weft way strip test. The bursting strength test is the only test that is of use with knitted fabrics to determine its strength.

The determination of the bursting strength is more important for fabrics like filter cloths, parachute, cloths, sacks, nets, fabric containers, when the fabrics are stressed in all directions. The test may also be used to test the bursting strength of the fabrics without well defined directions such as felts, bonded fibre fabrics and similar textile structures.

PROCEDURE:

The instrument is used for testing bursting strength should have a constant rate of speed and must be capable of giving a uniform displacement of 6±0.25 cubic inches per minute. The clamp ring should have an internal diameter of 1.20 inches. For proper operation, the machine must be stopped at the instant of rupture in order to avoid additional application of pressure and load on the specimen.

Briefly, the specimen is clamped by a ring over a thin flexible rubber diaphragm which itself is clamped over a circular hole in the upper face of the reservoir. The liquid used may be water or glycerine. The pressure in the liquid is increased, by valves or screw-driven piston. Due to increase in pressure, the diaphragm bulges taking with it the specimen. At some point the fabric bursts, and the pressure at that point is indicated by the pressure gauge. Based on this procedure, the bursting strength of the knitted fabrics were determined.

3.3.7 ABRASION RESISTANCE:

The ability of material to resist the action of abrasive force is clearly one of the major criteria to take into account when assessing durability. Abrasion is one aspect of weave and is the rubbing away of the component fibres and yarns of the fabric(Booth,1996).

The Eureka Martindale Abrasion Resistance Tester (Plate – XI) is designed to give controlled amount of abrasion between fabric surfaces at comparatively low pressure in continuously changing directions. The severity of abrasion varies with the nature of the abradant. Five samples were cut at specimens and assess the pilling standard of the face of each individual specimen. Repeat the above for the remaining specimen. Based on this procedure, the abrasion resistance of the fabrics are determined.

3.3.8 AIR PERMEABLITY:

Air Permeability Tester (Plate – XII) is defined as the volume of air in millimetres which is passed in one second through 1008 mm^2 of the fabric at a pressure difference of 10 mm head of water (Jewel, 2005).In the British standard test, the air flow through a given area of fabric is measured at a constant pressure drop across the fabric of 10 mm head of water. The specimen is clamped over the air inlet of the apparatus with the use of rubber gaskets and air is then sucked through it by means of a pump. The air value is adjusted to give a pressure drop across the fabric of 10 mm head of water and the air flow is then measured during a flow metre.

Five specimens for each of the knitted sample were used with a test area of 508 mm and the mean air flow in ml per second is calculated from the five results. From this, the air permeability can be calculated in ml per 100 mm per second.

PROCEDURE:

- Test the conditioned specimens in the standard atmosphere for testing textiles, which is 21 ± 1℃(70 ±2ºF) and 65 ±2% relative humidity, unless otherwise specified in a material specification or contact order.
- Handle the test specimens carefully to avoid altering the natural state of the material.
- Place each test specimens onto the test head of the test head of the test instrument, and perform the test as specified and perform the test as specified in the manufacturer's operating instructions
- Place coated test specimens with the coated side down(towards low pressure side) to minimize edge leakage.
- Make tests at the water pressure differential specified in a material specification or contract order. In the absence of a material specification or contract order,use a water pressure differential of125 Pa (12.7 mm or 0..5 in.of water).
- Read and record the individual test results in SI units as $cm^3/s/cm^2$ and in inch-pound units as $ft^3/min/ft^2$ rounded to three significant digits.
- For special applications, the total edge leakage underneath and through the test specimen may be measured in a separate test, with the test specimen covered by an airtight cover, and subtracted from the original test result to obtain the effective air permeability.
- When a 955 confidence level for results has been agreed upon in a material specification or contract order, fewer test specimens may be sufficient. In any event, the number of tests should be at least four.
- Following the procedure, the selected knit fabrics were tested for air permeability.

3.3.9 WATER PERMEABILITY:

Water vapour permeability is the ability to transmit vapour from the body. The sweat from the body is to be removed from the surface of the skin in the atmosphere via clothing (next to skin).Surrounding temperature, humidity and moisture resistance of garment are the leading factors that determine the evaporation rate of sweat from the body surface. If the moisture resistance is excessively high, because of the worse rate of evaporation ,the stored heat in the body could not go out which causes an uncomfortable feeling (Nahraway,2016).

The merit of a fabric intended for usages like rain coat, waggon covers or tent cloth is judged only by its ability to keep water out. Conversely when intended for hose pipes or canvas buckets, to keep water in .In another but quite different occasion, fabrics are expected to exhibit the ability to absorb moisture and water rapidly e.g. towelling fabric. Therefore, a study on the subject of water fabric relations becomes important.

PROCEDURE

The water permeability test is also called as the water pressure head test. A circular piece of fabric is taken which is of 200 in diameter and then it is subjected to a constant head of water for one hour in water permeability test (Plate - XIII) and the readings were recorded.

3.3.10 FABRIC PILLING:

A garment is considered to be serviceable when it is fit for its particular end use. It is a fabric surface fault characterized by little pills of entangled fibre clinging to the cloth surface and giving an unsighty appearance. It is formed by rubbing action on loose fibres that are present on the fabric surface. Stronger component in the blend aggravated its seriousness. While the fabric has higher breaking strength and lower bending stiffness results more pill. The low twist factor, higher hairiness, and loose fabric structure results easy and large pills.

The formation of small balls of entangled fibre on the fabric a hearing to the surface is called pilling. Fabric specimens mounted around rubber tubes are tumbled in a rotating cork-linked cubical box. The rubbing on the box liner accelerates the pilling process of the fabric. The degree of the pilling of the specimen is accessed visually against photographs of standard pilled fabrics by counting the pills on the specimens.

Pilling Tester (Plate – XIV) consists of two numbers of cubical wooden boxes constructed in 13 mm thick wood with internal sides of 235 mm prior to lining. Each box in lined with 3.2 m thick buff-finished cork joining material. By means of an electric driving unit, each box is rotated at constant 60± 2 rpm about a horizontal axis passing through the centres of two opposite faces. An automatic switch is fitted which will stop the machine after the predetermined number of revolutions.

All samples are conditioned and all tests carried out in the standard atmosphere for testing. A relative humidity of 65 ± 2 percent and a temperature of 20± 2 for testing remove any fibres or fluff from the empty boxes of text machines by light brushing or vaccum cleaning and inspected the cork linings. Mounted the specimen into each box and closed the lids. Set the machine to run. After the test time, the machine is stopped to remove the specimens and access the pilling standard of the face of each individual specimen. Repeat the above for the remaining specimen. Based on this procedure, the pilling nature of the knitted fabrics were determined.

3.3.11 THERMAL CONDUCTIVITY

TF 130 Flat – Plate Thermal Conductivity Tester (XV), was used to determine the thermal insulation properties insulation properties of various, quilting products, and other heat insulation materials. The thermal conductivity should be done with the standard of ASTM D1518.The performance of equipment conforms to GB 11048- 1989 (Textile Insulation Test Method) standard. Microcomputer control and data processors are used, to determine and calculate the various performance of sample directly. The test results (insulation rate, heat transfer coefficient, CLO value) can be displayed on the LCD display and printed out. Without artificial calculation, easy to operate and the test speed is fast.

Make the sample covered on the testing plate. The testing plate, base and the date to the microcomputer by temperature sensor to maintain a constant temperature. Make the heat of testing plate can only be distributed in the direction of sample. The insulation rate, heat transfer coefficient, CLO value and heating time of testing plate that needs to keep constant temperature in a certain time are calculated by microcomputer. Insulation rate: Q1 is heat dissipating capacity without sample,Q2 is heat dissipating capacity with sample. heat transfer coefficient: U_{bp} is test plate heat transfer coefficient without sample.U1 is test plate heat transfer coefficient with sample .CLO value under the condition that the room temperature is 21℃, relative humidity ≤50% and air flow is 10cm/s(calm).

Date setup: Turn on the power, the main menu is displayed, chose “set” by the direction key, as shown:

Press ‘yes” key to enter the setting page, select items by “▲ and ▼ “ keys, press “▶“ key to enter set state, press numeric keys to set the flash date and over, press “ “key to exit set up and press “yes” key again to save the settings

The temperature setting is 35°C.Start testing until the temperature of testing plate, protection plate and base plate reach 35°Cin the same time.

"Heat cycle" is five cycles commonly, test is over after 5 thermal cycles. The heat cycle depends on the thickness of sample.

Preheating time is from 30 min to 60 min, preheating is to make the equipment reach the standard temperature at normal temperature.

Following the procedure, the thermal conductivity of all the selected knit fabrics were determined.

TEST:

BLANK TEST:

Choose "Test" in the main menu by the direction key. Press "yes" key to enter test page, select test items by " ▲ and ▼ " keys and press "yes" key again to test. At this time, three working indicating lamps will light to show the heating state. The heating plates of equipment will be heated to the required temperature and keep in the range of 0.5. The test will be stared automatically when the above requirements are achieved. The display will show the current test date and can be checked by " ▲ and ▼ ". After the test, the display will return to the previous menu automatically.Buzzer alarm and ring 20 times continuously.

SPECIMEN TEST:

Open the organic glass door, put the sample on the test plate flat and close the glass door. Choose "Specimen Test" by " ▲ and ▼ " keys and press "yes" key to start. The display will show the current test date and can be checked by " ▲ and ▼ After the test , the display will return to the previous menu automatically. Buzzer alarm and ring 20 times continuously. The equipment stops automatically. After all test items finished, press "yes" key return main menu. The test results can be checked and printed out.

3.3.12 FLAMMABILITY :

MAG Auto Flame V (Plate – XVI) helps to determine flammability of textile fabrics by observing and measuring the case of ignition, limited flame speed of vertically oriented test specimen when subjected to a small igniting flame applied to the face or bottom edge. Instrument can be tested a single fabric or any combination of materials.

TESTING PROCEDURE:

The flammability test is done with the standard of ASTMD 6413.Inert the burner1 in the burner holding area. Then adjust the pilot flame using the needle valve of the pilot light to a flame height of approximately 3 mm when measured from it's lowest point. Also adjust the burner flame using the needle valve of the burner to achieve a flame height gauge(40±2mm).The burner is positioned so that the middle of the lower edge of the specimen holder centered 19 mm above the burner. The timer is adjusted to provide a 12 second flame to the fabric. Mount the fabric and each specimen is exposed to the flame with in 4 minute of removal from the conditioning area of storage. The test fabric is clamped between two halves of the holder, with the bottom of the fabric even with bottom of the holder. With the holder held vertically secure the fabric in the holder within a minimum of 4 cups. he two clips are positioned near the top of the holder one on each side to stabilize the fabric. Similarly, two clips are positioned near the top of the holder one on each side. Then turn off the hood ventilation by using a top plate. Start the timer and expose the fabric for 12 seconds. Observe the specimen for melting or dripping during the flame exposure. Record any observations. Immediately after the flame is removed start a stop watch for measurement of the after flame and after glow time.

Observe how long the specimen continuous to flame after the 12 seconds exposure time. Record after flame time within 0.2 seconds. Observe how long the specimen continuous to glow after the after flame ceases or after removal of the flame if there is no after flame. Record this after glow time to the nearest 0.2 seconds. Then remove the fabric holder from the test cabinet turn on the hood ventilation to clear the test cabinet of fumes and smoke. Based on this procedure, the flammability of the knit fabrics were determined.

3.3.13 FABRIC DRAPE

Drape is the term used to describe the way the fabric hangs under its own weight. It has an important bearing on how good a garment look in use(Brade,2003).To determine drapability Eureka Drape meter(Plate – XVII) was used. Five samples were cut according to the size of the templates. A brown paper was also cut to the same size of the fabric. Each sample was placed between two small circular plates so that its free edges drape down under their own weight. Image of the drape samples found on the brown paper was traced and cut along the outline. It was weighed using an electronic balance. A drape co-efficient was calculated for each sample using the formula.

Drape coefficient = $W_s – W_d$ /$W_{D –}$ W_d

$W_{S ==}$Weight of the paper whose area is equal to the projected area of the specimen

W_d= Weight of the paper whose area is equal to the area of the supporting disc

W_D = Weight of the paper whose area is equal to the area of the specimen

Based on the procedure, the drap coeeficient ability of the fabrics were determined.

3.4 ABSORBENCY TESTS:

METHODS OF TESTING

The following are the methods used for measuring water resistance of a fabric:

3.4.1 Wicking Test

3.4.2 Immersion Test

3.4.3 Drop Test

3.4.4 Drying Rate

3.4.5. Spray Test

3.4.1 WICKING TEST:

Wicking is when the fabric is totally wetted and the liquid is transported into the fabric without any external forces.The 100ml beaker was taken and filled with distilled water. Five fabrics were cut into sizes of 15cm length and 2.5 cm width from the knitted fabrics.

Place the rod over the opening of a glass bowl, so the specimen hangs in the bowl without touching the bottom. Leave the specimen for 1 minute. After 1 minute measure how high the water has moved, starting 20mm from the edge. The speed and amount of a liquid that wicks into a fabric depends on the capillary spaces distribution and sizes.The same procedure was done for five times and then mean value was calculated.

3.4.2 IMMERSION TEST:

Immersion Test (Plate – XIX) is a simple test for wettability of fabric. In this test, a small square specimen about 1”x1” was cut and dropped it to the surface of water in a beaker. The time taken for the specimen to sink below the surface is observed. The shorter the time the greater the wettability.

3.4.3 DROP TEST:

In the initial stages of wetting, the drops of water pearl of the fabric and after some time the pearling stops, the water enters the pores of the fabric and becomes wet. Therefore, the drop peneteration test is to count the number of drops required to penetrate the fabric to the inner side when all the drops fall to the same spot.

Drop test (XX) is a count of the number of drops required to penetrate through the underside of the fabric when all the drops fall onto the same spot (Grover and Hambey, 2002). The samples were fixed onto the embroidery frame and burette was used to drop water in the centre of the fabric. Time and number of drops were noted down for all the samples.

3.4.4 DRYING RATE:

For the drying time test (XXI), the knitted fabrics were first cut into 10 cm x 10 cm and then wetted with 1 ml of distilled water dropped into it using a accurate dropper. Then the drying time of fabrics were evaluated. For measuring the drying rate ,the samples were weighed in the dry state(dry weight-W_f) using an Electronic Balance and instantly after wetting (wet weight at the initial stage-W_O).The change in weight (W_i) was recorded at 10 min intervals and the remaining water ratio (%) was then calculated, for each interval using the following equation:

Remaining water ratio (RWR%) = $(W_i - W_f) \times 100/(W_O - W_f)$.

The remaining water ratios were used to express the drying ability of the fabrics as wetted by sweat.(Arafa Badr and El-Nahrawy, 2016)

3.4.5 SPRAY TEST:

Accu Spray (Plate – XXI) is an instrument used to any textile fabric, which may or may not have been given a water-repellent finish. It measures the resistance of fabric to wetting by water. It is especially suitable for measuring the water repellent efficacy of finishes applied to fabrics. This spray test is done with the standard ASTM D176 – 90.

TESTING PROCEDURE:

Fasten the test specimen securely in the 125m metal hoops so that it presents a smooth wrinkle free surface. Place the hoop on the stand of the tester with the fabric uppermost in such a position that the center of the spray pattern coincided with the centre of the hoop. In the case of twills, gabardines, piques or fabrics of similar ribbed construction. Place the hoop on the stand in such a way that the ribs are diagonal to the flow of water running off the fabric specimen.

Pour 250 ml of distilled water at 27±1°C(80±2ºF) into the funnel of the tester and allow it to spray onto the test specimen in 25-30 seconds. Avoid touching the funnel with the beaker while pouring the distilled water. The spray time must be between 25-30 seconds, otherwise the nozzle should be checked to see if the holes are enlarged or blocked. Take the hoop by one edge and tap the opposite edge smartly once against a solid object, with the fabric facing the object, then rotate the hoop 180º and tap once more on the point previously held. Selected knitted fabrics were tested for their resistance to wetting following the procedure.

3.5 STATISTICAL ANALYSIS:

Statistical is used for presenting the facts in a definite form, statistics simplifies mass of figures facilities compression and also help in prediction and formulating hypothesis. ANOVA is essentially a procedure for testing the difference among different group of data for homogeneity. ANOVA is commonly used to test difference among the means of several independent group. Analysis was carried out mainly to see whether the best results vary due to the difference in the dyes, mordants and techniques.

4. RESULT AND DISCUSSION

RESULTS AND DISCUSSION:

4.1 Identification Test

4.1.1 Wales and Course

4.1.2 Fabric Count

4.2 Assessment of Physical Properties

4.2.1 Fabric Thickness

4.2.2 Fabric Weight

4.3 Assessment of Mechanical Properties

4.3.1 Bursting Strength

4.3.2 Abrasion Resistance

4.3.3 Fabric Pilling Test

4.3.4 Thermal Conductivity

4.3.5 Flammability Test

4.4 Assessment of Comfort Properties

4.4.1 Fabric Drape

4.4.2 Air Permeability

4.4.3 Water Permeability

4.5 Wettability and Absorbency Tests

4.5.1 Wicking Test

4.5.2 Immersion Time Test

4..5.3 Drop Test

4.5.4 Drying Time Test

4.5.5 Spray Test

4. RESULTS AND DISCUSSION:

4.1 Identification Test

4.1.1 Wales and Course

The results of single jersey fabric and analysis of variance is presented in the Table- I and Figure - 1

TABLE – I

Wales and Course of Single Jersey

Samples	Mean	SD	T Value
No. of Wales	32.20	1.483	24.508**
No. of Course	62.30	1.788	

Values are mean of five samples in each group

** - significant at 1% level

From the Table –I and Figure – 1, it is clear that the wales of the sample Single Jersey is 32.2 WPI and course of the sample Single Jersey is 62.30 CPI respectively. However, there is 1% significant was found.

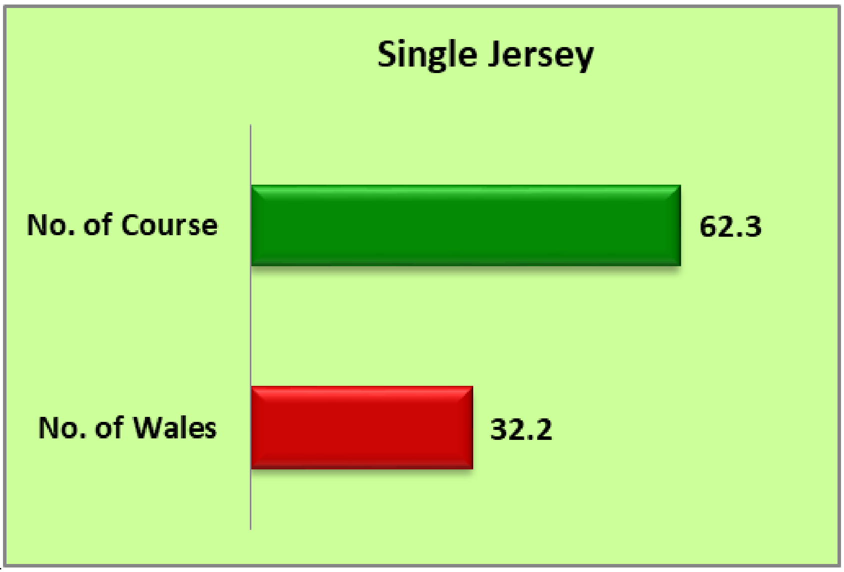

FIGURE – 1

WALES AND COURSE OF SINGLE JERSEY

The results of honeycomb fabric and analysis of variance is presented in the Table- II and Figure - 2

TABLE - II

Wales and Course of Honey Comb

Samples	Mean	SD	T Value
No. of Wales	42.80	0.836	2.058*
No. of Course	41.60	1.140	

Values are mean of five samples in each group

* - significant at 5% level

From the Table –II and Figure – 2,it is clear that the wales of the sample Honeycomb is 42.80 WPI and course of the sample Honeycomb is 41.60 CPI respectively.However,there is 5% significant was found.

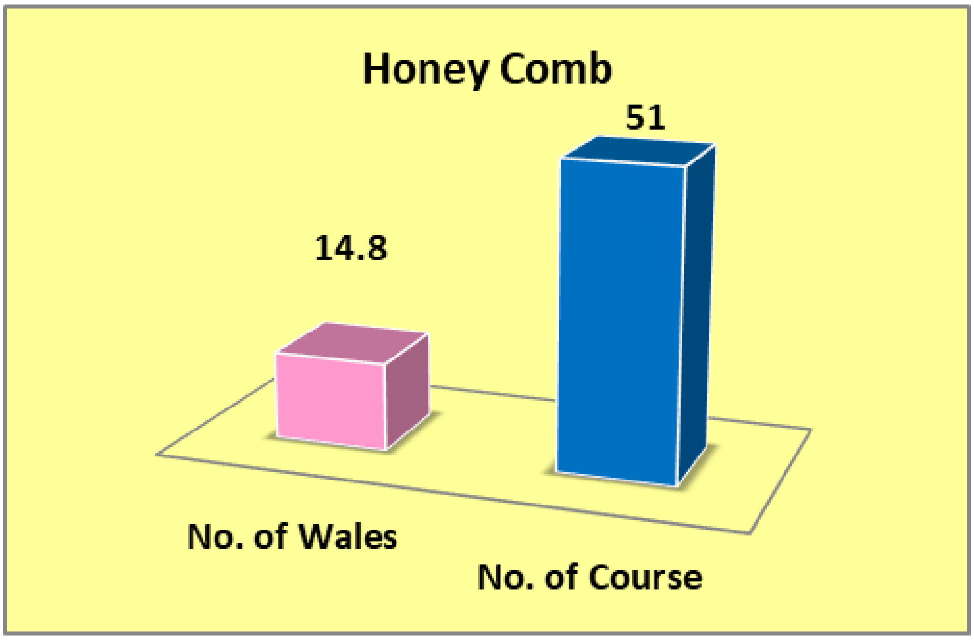

FIGURE - 2

WALES AND COURSE OF HONEYCOMB

The results of Pique fabric and analysis of variance is presented in the Table- III and Figure - 3

Table III

Wales and Course of Pique

Samples	Mean	SD	T Value
No. of Wales	27.80	0.836	13.880**
No. of Course	31.20	0.836	

Values are mean of five samples in each group

** - significant at 1% level

From the Table –III and Figure – 3, it is clear that the wales of the sample Pique is 27.80 WPI and course of the sample Pique is 31.20 CPI respectively. However, there is 1% significant was found.

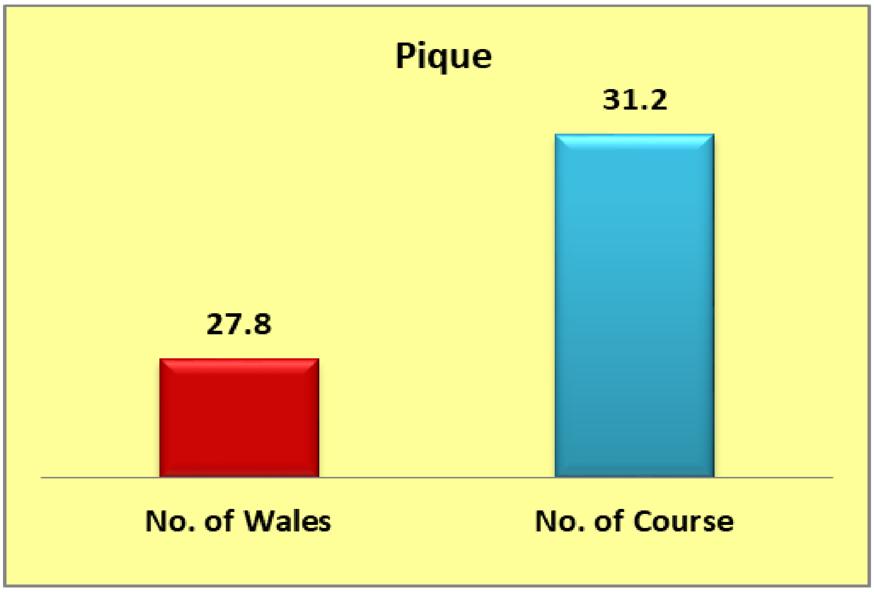

FIGURE – 3

WALES AND COURSE OF PIQUE

WARP KNIT

The results of Warp Knit fabric and analysis of variance is presented in the Table- IV and Figure - 4

TABLE IV

Wales and Course of Warp Knit

Samples	Mean	SD	T Value
No. of Wales	14.80	0.447	73.893**
No. of Course	51.00	1.000	

Values are mean of five samples in each group

** - significant at 1% level

From the Table –IV and Figure – 4,it is clear that the wales of the sample Warp Knit is 14.80 WPI and course of the sample Warp Knit is 51.00 CPI respectively.However,there is 1% significant was found.

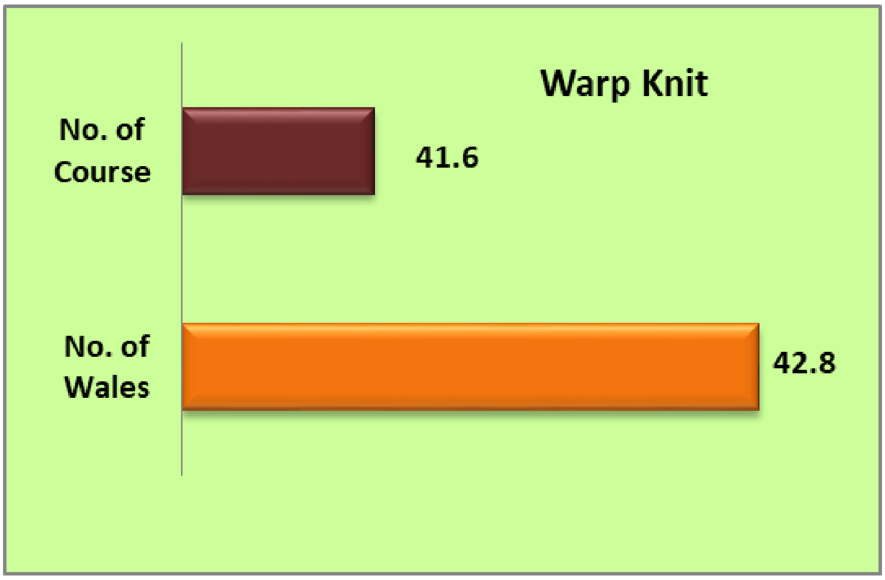

FIGURE – 4

WALES AND COURSE OF WARP KNIT

4.1.2 Fabric Count

TABLE - V

S.No	Samples	Mean		Count	
		Staple yarns	Filament yarns	Staple Yarns(s Ne)	Filament yarns(Denier)
1.	Single Jersey	26.98	-	-	80.94
2.	Honey Comb	-	35.5	-	106.5
3.	Pique	121.96	36.2	17.71	108.6

From the above Table - V , the count of the single jersey fabric is noted to be 26.98 and the count of the Honeycomb(35.5) and Pique fabric(121.96 and 36.2) respectively with staple and filament yarns.

4.2 Assessment of Physical Properties

The physical properties of the fabric such as thickness and weight were analysed.

4.2.1 Fabric Thickness

The results of fabric thickness of the knitted fabric end analysis of variance for all the samples are presented in the Table – VI

Table - V

Fabric Thickness

Samples	Mean thickness(mm)	SD	F Value
Single Jessy	0.47	0.02	4.7221**
Honey Comb	0.62	0.05	
Pique	1.30	0.55	
Warp Knit	1.73	0.02	

Values are mean of five samples in each group

** - significant at 1% level

From the Table – V and Figure -5,it is clear that the fabric thickness of the sample Single Jersey and Honeycomb is 0.47 and 0.62 mm whereas mean thickness of Pique and Warp Knit is 1.30 and 1.73 mm respectively. However,the statistical analysis shows 1% significant was found between the knitted fabrics.

Honeycomb weft knitted fabrics will have minimum of thickness.The smaller their thickness is,the better their moisture absorption and liberation will be.

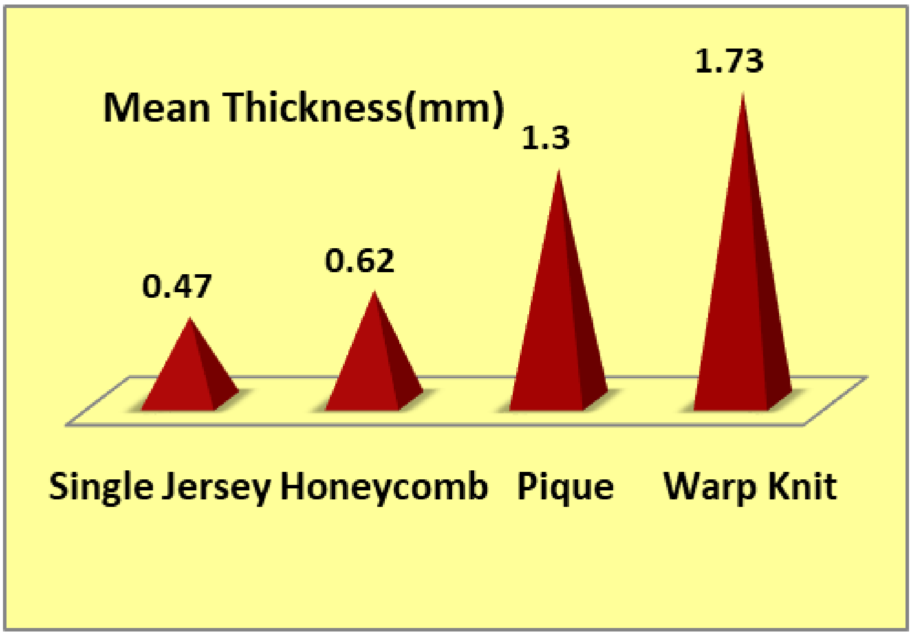

FIGURE – 5

FABRIC THICKNESS

4.2.2 Fabric Weight

The fabric weight of the knitted fabrics and analysis of variance for all the samples are presented in Table VI and Figure – 6.

TABLE - VI

FABRIC WEIGHT

Samples	Mean Weight(gsm)	SD	F Value
Single Jessy	1.24	0.01	137.67**
Honey Comb	1.73	0.14	
Pique	1.96	0.03	
Warp Knit	2.15	0.04	

Values are mean of five samples in each group

** - significant at 1% level

It is evident from the Table – VI and Figure – 6,that the fabric weight of the samples Single Jersey and Honey Comb was found to be 1.24 and 1.73 gsm followed by Pique and Warp Knit(1.96 and 2.15 gsm) respectively and the statistical analysis show one percent significant between the weight of the knitted fabrics.

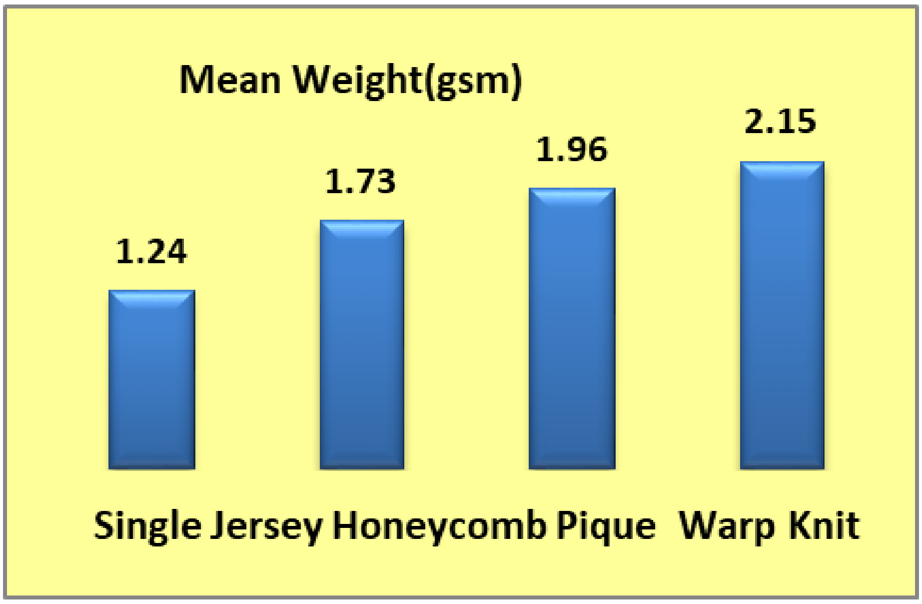

FIGURE – 6

FABRIC WEIGHT

4.3 Assessment of Mechanical Properties

The salient mechanical properties of the knitted fabrics were analysed.

4.3.1 Bursting Strength

The evaluation of bursting strength of the fabrics are discussed in the Table – VII and

Figure – 7

TABLE – VII

Samples	Mean Bursting strength(kg/cm^2)	SD	F Value
Single Jersey	13.2	0.84	0.040**
Honey Comb	14.80	1.64	
Pique	10.00	0.71	
Warp Knit	17.40	2.07	

Values are mean of five samples in each group

** - significant at 1% level

From the Table – VII and Figure – 7, it is clear that the fabrics Warp Knit and Honey Comb fabrics have higher bursting strength (17.80 and 14.80 Kg/cm^2) respectively and the statistical analysis shows one percent significant between the knitted fabrics.

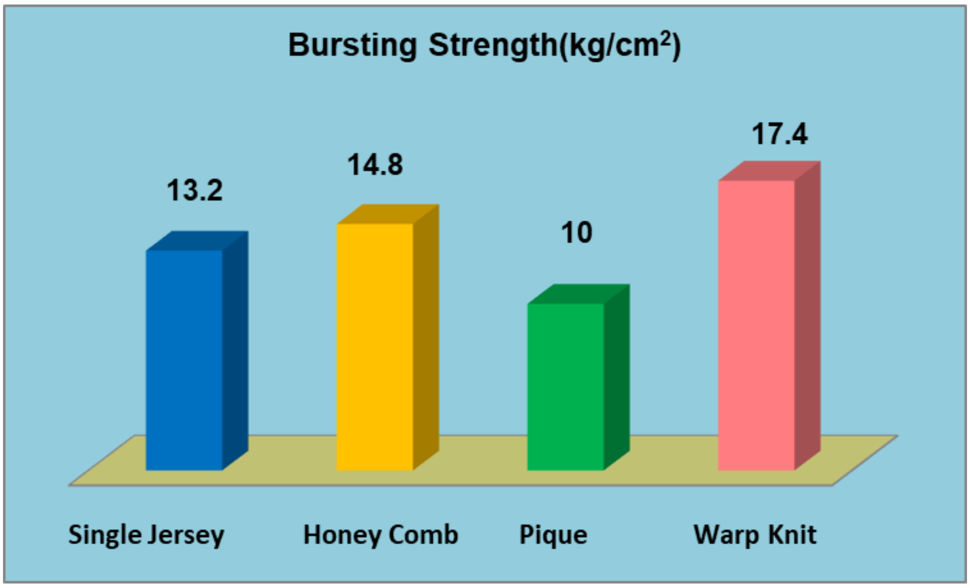

FIGURE -7

BURSTING STRENGTH

4.3.2 Abrasion Resistance

The abrasion resistance of the knitted fabrics and the analysis variance of all the samples are presented in Table -VIII

TABLE - VIII

S.No	**Samples**	**Mean resistance(gm)**
1.	Single Jersey	0.182
2.	Honey Comb	0.266
3.	Pique	0.268
4.	Warp Knit	0.292

From the Table – VIII , it is clear that all the fabrics has good resistance towards abrasion and thus there was no weight loss.

4.3.3 Pilling Test

The results obtained in the pilling tests carried for the knitted fabric samples are presented in the Table – IX

TABLE – IX

PILLING OF FABRIC

Samples	**Pilling**
Single Jersey	5
Honey Comb	5
Pique	4
Warp Knit	4

4 – Slight pilling,5 – No pilling

From the Table – IX, it is observed that the slight pilling was occurred in sample Pique and Warp Knit whereas pilling was not noticed among Single Jersey and Honey Comb.

4.3.4Thermal Conductivity

The results of the thermal conductivity of the samples are discussed below in the Table – X and Figure - 9

TABLE – X

S.No	**Samples**	**Insulation Rate T.R**	**Heat Transfer Coefficient (HTC)**	**Clo Value**
1.	Single Jersey	-13.54	-78.35	-0.08 clo

2.	Honey comb	-12.64	-82.51	-0.08 clo
3.	Pique	-24.98	-37.18	-0.18 clo
4.	Warp Knit	-16.80	-56.80	-0.12 clo

Thermal Conductivity

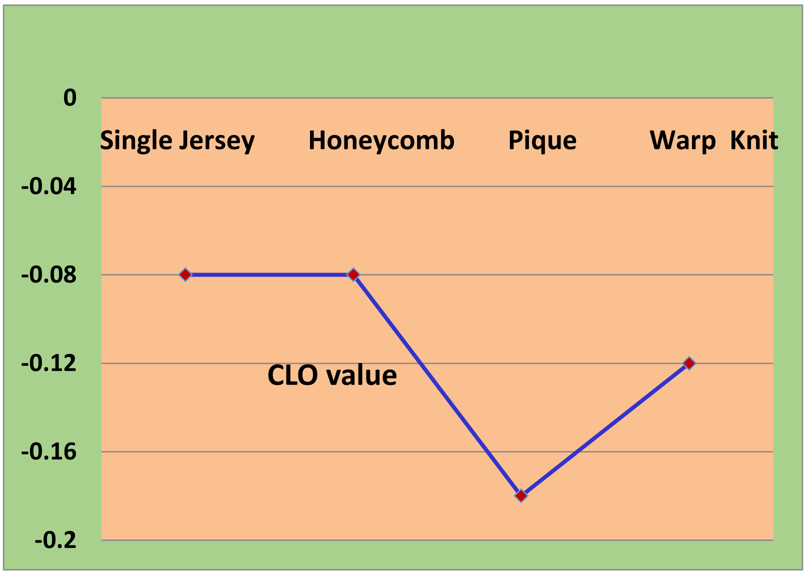

FIGURE – 11

CLO VALUE

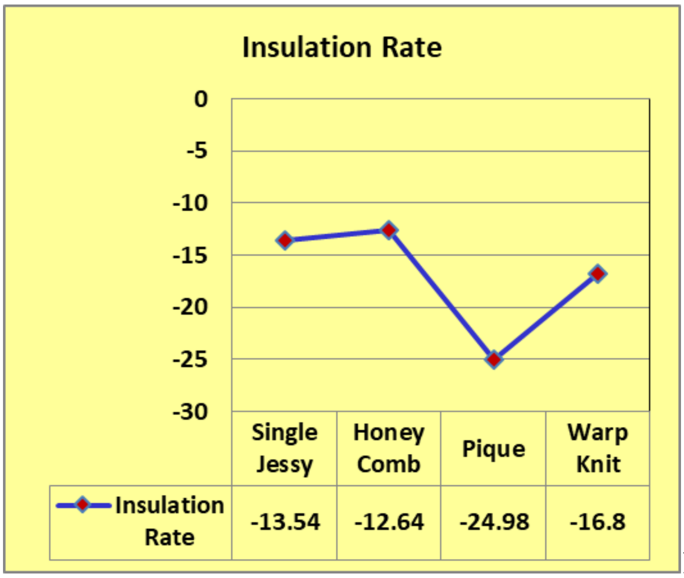

FIGURE – 9 INSULATION RATE

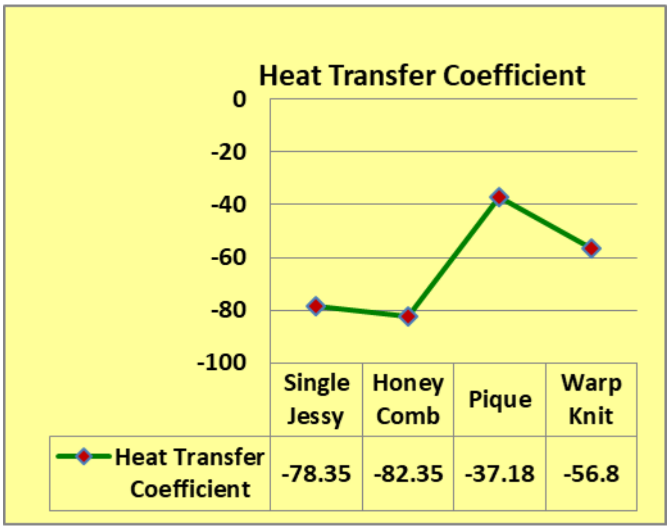

FIGURE – 10

HEAT TRANSFER COEFFICIENT

4.3.4 Flammability

The results of the flammability of the fabric is discussed below in the Table – XI

TABLE - XI

S.No	Sample	After Flame Time	After Glow Time	Occurrence of melting or dripping if any
1.	Single Jersey	-	Nil	Nil
2.	Honey Comb	-	Nil	Yes
3.	Pique	2 sec	Nil	Yes
4.	Warp Knit	5 sec	Nil	Yes

From the Table – XI , is clear that the samples pique and warp knit has after flame time of (2 and 4 seconds) respectively and none of the fabrics have after glow time.The fabrics such as honeycomb, pique and warp knit fabrics has melting and dripping.

4.4 Assessment of Comfort Properties

The comfort properties of the fabrics were analysed

4.4.1 Fabric Drape

The results of the drape coefficient of fabric and analysis of variance of all the samples are expressed in Table – XII and Figure – 12

TABLE – XII

Fabric Drape

Samples	**Mean drape coefficient(g)**	**SD**	**F value**
Single Jersey	15.32	0.41	1651.9545**
Honey comb	23.12	0.65	
Pique	41.40	0.65	
Warp knit	31.17	0.70	

Values are mean of five samples in each group

** - significant at 1% level

From the Table – XII, it is clear that the drape coefficient is maximum in the samples Pique and Warp Knit of 41.40 g and 31.17 g followed by samples Honey comb and single jersey of 23.12 g and 15.32 g respectively.More the coefficient lesser will be the drapability of the fabric and the statistical analysis shows one percent difference was found between the samples.

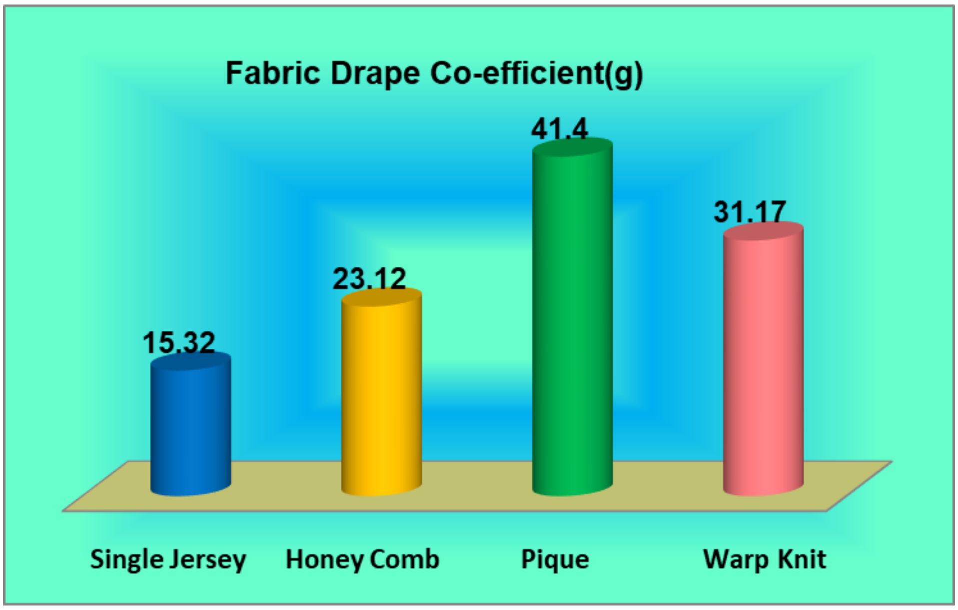

FIGURE – 1

FABRIC DRAPE

4.4.2Air Permeability

The results of the air permeability of knitted samples and analysis of variance of all samples are presented in Table – XIII and Figure - 13

TABLE – XIII

Fabric Air Permeability

S.No	Samples	Mean
1.	Single Jersey	94.3
2.	Honeycomb	186.4
3.	Pique	121.6
4.	Warp knit	123.6

From the Table – XI, it is evident that the air permeability is higher in the samples honeycomb and warp knit (186.4 and 123.6) and the samples pique and warp knit were noted to be (121.6 and 94.3) respectively.

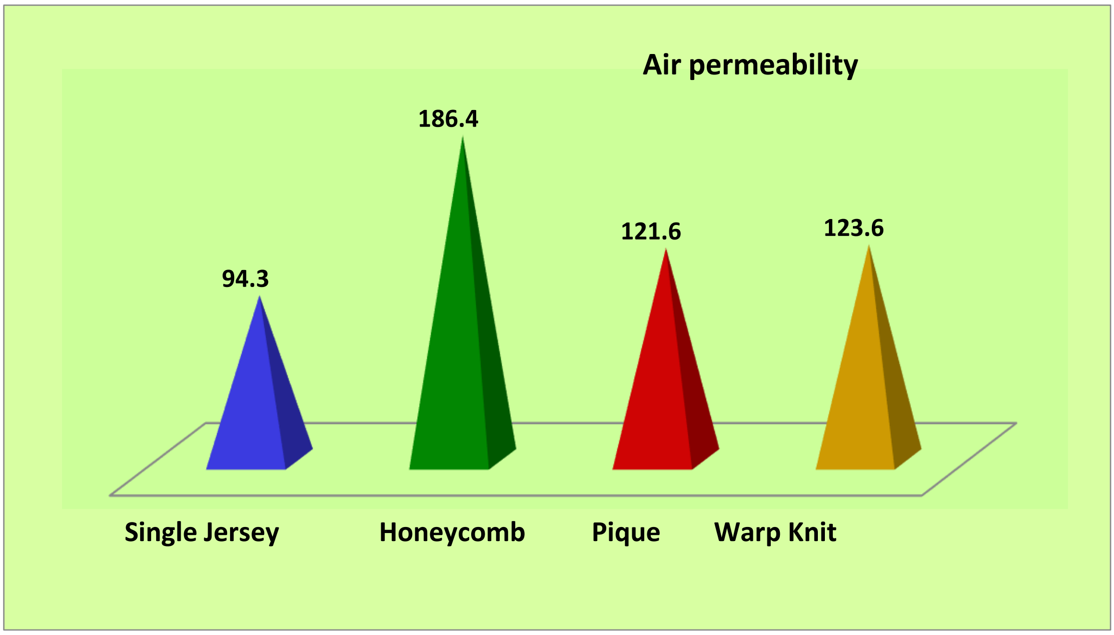

FIGURE – 12

AIR PERMEABILITY

4.4.3 Water Permeability

The results show that the fabrics are unable to hold the water in machine when the pressure is increased. Therefore all the samples have good water permeability.

4.5 Wettability and Absorbency Tests

The results of the absorbency tests carried out for the selected knitted fabrics are expressed below.

4.5.1 Wicking Test

The result of the wicking test is presented in the Table – XV and Figure - 13

TABLE - XIV

Wicking

Samples	Mean wicking(cm)	SD	F Value
Single Jessy	5.86	0.59	20.85**
Honey Comb	5.62	0.41	
Pique	5.74	0.40	
Warp Knit	3.94	0.54	

Values are mean and SD of five samples in each group

** - Significant at 1% level

From the Table – XII and Figure – 10, it is observed that the wickability was highest in the sample Single Jersey and Pique(5.86 cm and 5.74 cm).It was lowest in the samples Honey Comb and Warp Knit (5.62 cm and 3.94 cm).The statistical analysis also proved a significant difference at one percent level.

The single Jersey,pique and honeycomb have very good moisture wicking performance.The Honeycomb fabrics will have excellent moisture absorption and liberation

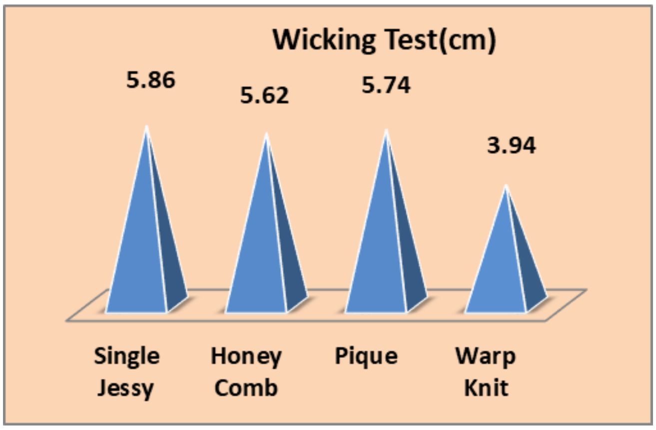

FIGURE – 13

WICKING

4.5.2 Immersion Test

The result of the immersion test of the knitted fabrics are presented in the Table – XV and Figure – 14.

TABLE - XV

Immersion Test

Samples	**Mean immersion(seconds)**	**SD**	**F Value**
Single Jessy	15.41	1.12	56.4910**
Honey Comb	33.50	5.70	
Pique	9.30	1.92	
Warp Knit	11.72	2.28	

Values are mean and SD of five samples in each group

** - Significant at 1% level

From the Table – XIII and Figure – 12,it is clear that the immersion time was maximum for the sample Honey Comb (33.50 seconds), whereas the samples Single Jersey, Pique and Warp Knit took(15.41,9.30 and 11.72 seconds) respectively. As per the statistical analysis, the difference was noted to be significant at one percent level.

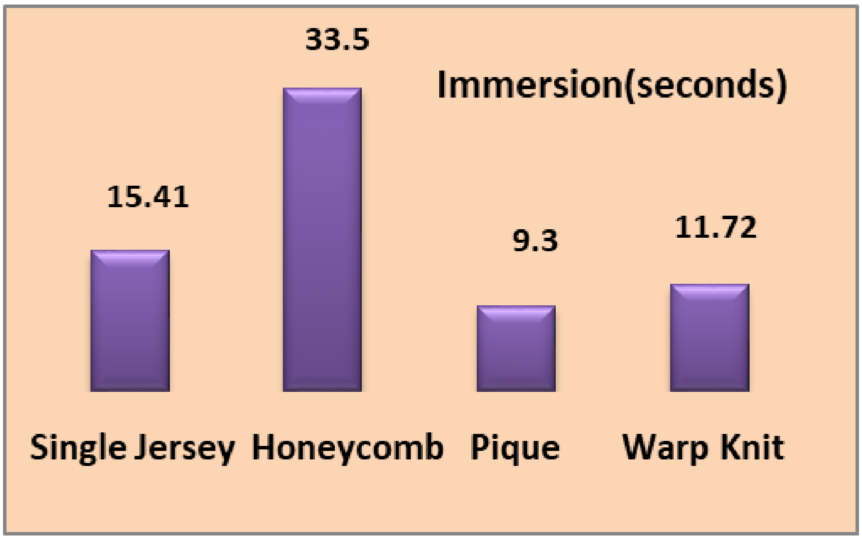

FIGURE -14

IMMERSION TIME

4.5.3 Drop Test

The result of drop test of the knitted fabric is presented in the Table – XVI and Figure – 15.

TABLE - XVI

Drop test

Samples	Mean Drop (seconds)	SD	F value
Single Jersey	3.53	1.40	6.8434**
Honey comb	5.50	0.44	
Pique	4.08	0.06	
Warp knit	3.74	0.39	

Values are mean and SD of five samples in each group

** - Significant at 1% level

From the Table – XIX and Figure – 13, it is obvious that the time taken by the water droplet to penetrate into the fabric was maximum is noted to be maximum in the samples honey comb and pique (5.50 and 4.08 seconds) whereas samples warp knit jersey warp knit single jersey could absorb water within (3.74 and 3.53 seconds) respectively.As per the statistical analysis shows one percent significant between the samples.

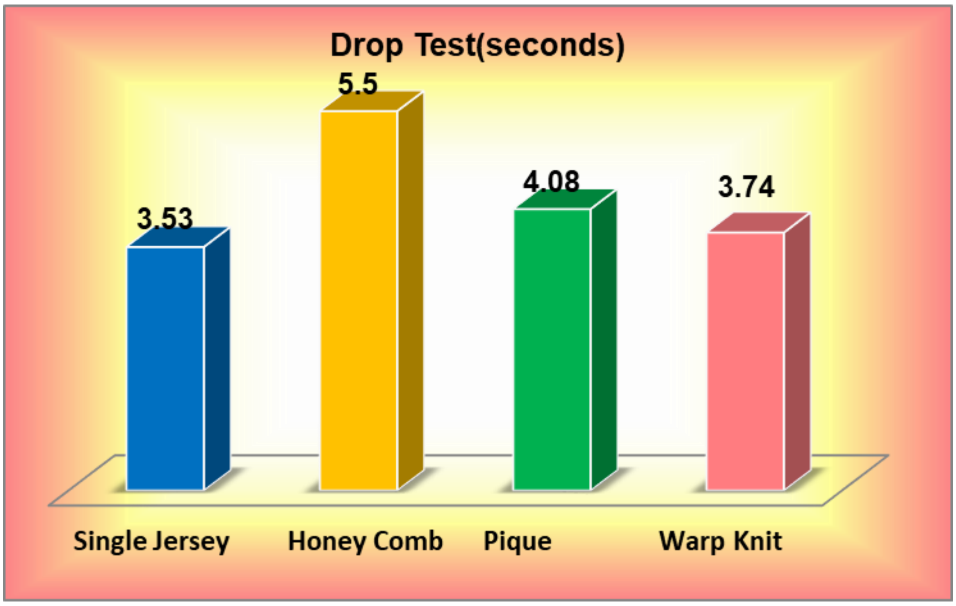

FIGURE - 15

DROP TEST

4.5.4 Drying Time Test

The result of drying time test of the knitted fabric is presented in the Table – XVII and Figure – 14.

TABLE – XVII

Drying Test

Samples	Mean drying rate	SD	F value
Single Jersey	57.09	4.98	26.7997**
Honey comb	70.36	2.59	
Pique	68.22	4.24	

Warp knit	52.31	2.62	

From the Table – XX and Figure – 14, it is clear that the time taken by the fabric to dry was maximum in the samples honeycomb and pique(70.36 and 68.22) whereas the samples single jersey and warp knit took (57.09 and 52.31) respectively. As per the statistical analysis

Generally,the fabrics which has higher drying ability corresponds to lower fabric thickness

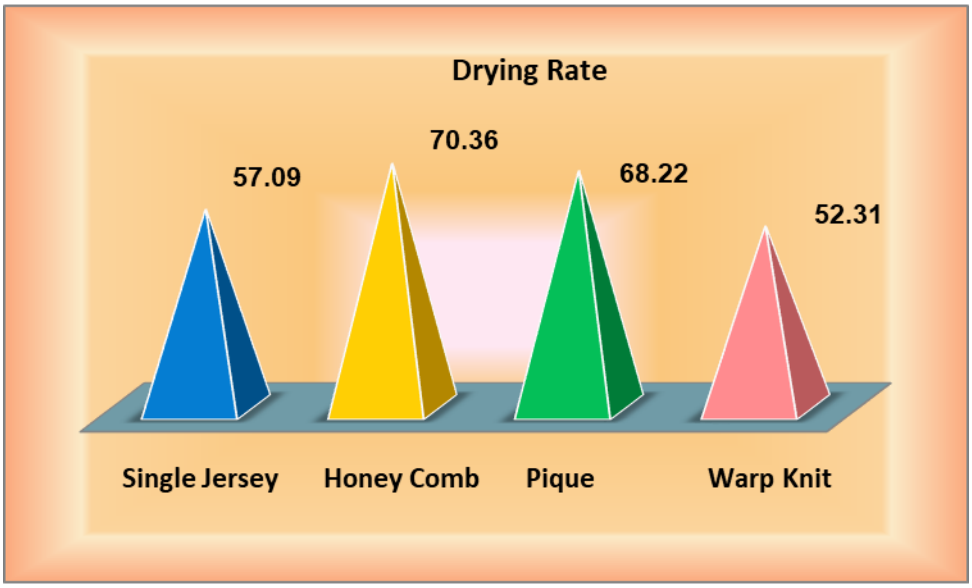

FIGURE – 16

DRYING TIME

4.5.5 Spray Test

The result of the spray test is presented below in the Table – XVIII

TABLE - XVIII

S.No	**Samples**	**Standard**
1.	Single Jersey	0
2.	Honey Comb	0
3.	Pique	0
4.	Warp Knit	50

50 – Complete wetting of whole of upper surface

0 – Complete wetting of whole upper and lower surface

From the Table –XVIII, it is obvious that the samples Single Jersey, Honey Comb and Pique has complete wetting of whole of upper and lower surface whereas the sample Warp Knit has complete wetting of whole of upper surface.

5. SUMMARY AND CONCLUSION

Knitting is the second most popular technique of a fabric or garment formation by interloping one or one set of yarns. Continuous length of yarn is converted into vertically intermeshed loops either by hand or by machine. The term “Knitting” has been evolved from the saxon word ‘cnyttan’ which in turn was derived from the ancient Sanskrit word ‘Nahyat’(Chandra Roy,2012).

Knitted fabrics respond to every movement of the body and return back to its original shape easily so they are widely used in apparel production. The most important properties required from the elastic knitted garments are wear comfort, fit, breathability and durability.(Eryuruk,2016).

The knitted fabric is highly suitable for next to the skin wear. Its extensibility is very high which allows to fit snugly and without discomfort on any form. Therefore the knitted goods are mostly preferred than other fabrics. The sports garments and its protective accessories/wears manufactured from the knitted fabrics have higher functional properties (Kanakaraj and Ramachandran,2015)

Considering the above facts the investigator selected the research work on the topic **“A Comparative study on the properties of selected knitted fabrics”** with the following objectives;

- To study the physical properties of the selected knitted fabrics
- To study the mechanical, wettability and absorbency of the knitted fabrics
- To compare the properties of selected knit fabrics and evaluate the suitabilityof the selected knit fabricsfor sportswear

EXPERIMENTAL PROCEDURE

Selection of the Fabric:

The four knitted fabrics such as single jersey, honey comb, pique and warp knit were selected for the study. The knitted fabrics were objectively analysed for the following test parameters

- Fabric Thickness
- Fabric Weight
- Bursting strength

- ❖ Abrasion resistance
- ❖ Pilling
- ❖ Air permeability
- ❖ Water permeability
- ❖ Thermal conductivity
- ❖ Flammability
- ❖ Wicking
- ❖ Immersion test
- ❖ Drop test
- ❖ Accu spray test

SALIENT FINDINGS

- Fabric thickness was found to be maximum for the warp knit of 1.73 mm.
- Fabric weight is gradually increased in warp knit of 2.15gsm.
- Bursting Strength is increased in warp knit with 17.46 kg/cm^2
- All the fabrics has good resistance towards abrasion.
- Slight pilling was found in single jersey and warp Knit.
- Fabric drapability were found to be maximum in pique fabrics of 41.40.
- The immersion time was found to be maximum in single jersey of 3.50.
- The Insulation rate is maximum for pique fabrics which is -24.98%.
- Heat Transfer Coefficient is maximum for honeycomb of fabrics of -82.51.
- The clo value is maximum for pique fabrics of -0.18 clo.
- The wickability of the fabric was found to be maximum for Single Jersey fabrics of 5.86 cm
- The drop test was found to be maximum for pique fabrics of 5.50 seconds.
- The drying rate was found to be maximum for the honeycomb fabrics of 70.36 %
- The spray test was found to be maximum for the samples Single Jersey, Honey Comb and Pique fabrics.

CONCLUSION

Knitted fabrics are best suitable for sportswear due to its comfort. Pique is used in sportswear and formal cotton shirt fabrics, demonstrating its versatility. It is commonly used for polo shirts which is worn for fashion purposes or in golfing as well as white tie events. The fabrics constructed from honey comb weaves have more thread floats on both sides and have a rough structure. This renders more absorption of moisture. The weaves are, therefore, suitable for towels and also in various forms for sportswear, bed covers and quilts. Single jersey fabrics are generally made with a lightweight yarn, this is the fabric most often used to make T-Shirts and sportswear. Comparing the properties of all the selected knit structures, Single Jersey, Honey Comb and Pique could be very well used for wearable garments whereas Warp knit coated fabric is suitable for outer wear garments and accessories.

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