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Comfort and Mechanical Properties of Cotton and Cotton Blended Knitted *Khadi* Fabrics

Suman Pant[1*] and Rajkumari Jain[2]

Clothing and Textiles, Faculty of Home Science, Banasthali University, Banasthali304022, Rajasthan, India
Mobile: 09352141493, E-mail: suman.pant18@gmail.com

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ABSTRACT Main aim of present study was to develop hosiery material for *khadi* cottage industry. Hand spun cotton and cotton: polyester yarns were utilized to construct knit fabric in manually operated knitting machine. Plain knit and rib knit fabrics (1x1, 2x2) were developed in flat bed cotton hosiery machine of 14 gauge 40 inch. Comfort and mechanical properties of knitted fabrics constructed from hand spun cotton and cotton: polyester yarns were tested by standard procedure. It was found that cotton knitted *khadi* fabric is more comfortable than cotton: polyester *khadi* knit with less pilling tendency. On the other hand, strength and abrasion resistance of cotton:polyester *khadi* fabric is better than cotton knit fabric.

INTRODUCTION

Khadi is hand spun and hand woven cotton, silk and woolen cloth. There is also *khadi* cloth made of mixture of natural and manmade fibers called poly *khadi* viz. poly cotton, poly wool. Woollen knitted garments, especially sweaters, are also produced to some extent. *Khadi* can be considered the vocal representative of the Indian cottage industry. *Khadi* accounts for about two percent of total cloth produced in India. It coexists with most modern spinning and weaving mills and faces tough competition from mill sector. This is because of availability of mill made fabric in varying composition of fibers, yarns and structure.

Cotton *khadi* is a versatile fabric. It has the unique property of keeping the wearer warm in winter as well as cool in summer season. However, it gets easily crumpled therefore in order to keep it firm and smooth; starching and ironing is frequently required which increases maintenance cost.

In today's world of modernization and industrialization, tastes and preferences of consumers are changing rapidly, so there is a need to bring innovative changes and new designs in clothing. *Khadi* industry is also under continuous pressure to meet growing consumer's aspiration and demand through constant product innovation, improved quality and competition. Present study is toward product innovation for cottage *khadi* industry.

Today's consumer demands well-fitted, comfortable, and easy to care for garments, which can be washed and worn. This demand is easily met by knits. Cotton and its blends fabrics are more suitable to Indian climatic condition that is why the demand of these fabrics is increasing day-by-day.

An attempt has therefore been made in this study to utilize hand spun cotton and cotton blend yarns for development of knitted fabrics in manually operated knitting machine for *khadi* sector.

Clothing comfort is an extremely complex phenomenon and has drawn the attention of many textile research workers. It can be classified into three groups, namely psychological, tactile and thermal comfort. Thermal comfort is the factor governed by the movement of heat, moisture and air through the fabric. The thermal properties of cotton and polyester based single jersey of 1×1 rib and interlock structure were statistically investigated by Oglakcioglu and Marmarali (2007). The result indicated that each knitted structure tends to yield rather different thermal comfort properties. Interlock and 1×1 rib fabric had a remarkably high thermal conductiv-

Address for correspondence:
Dr. Suman Pant
Clothing and Textiles
Faculty of Home Science
Banasthali University,
Banasthali304022
Rajasthan, India
Mobile: 09352141493
E-mail: suman.pant18@gmail.com

ity and thermal resistance value. On the other hand, single jersey fabrics had higher relative water vapor permeability values than 1×1 rib and interlock fabrics, and gave a warmer feeling with lower thermal absorptivity values.

Su et al. (2007) studied moisture absorption and release of polyester and cotton composite knitted fabrics. Experimental results revealed that the diffusion rate and drying rate become better with decreasing cotton content. However, knitted fabrics made of profiled polyester alone showed the worst water absorption ability, which can be improved with the addition of cotton fiber.

Durability of fabric is one of the very important criteria for consumers. Durability is affected mainly by strength, abrasion resistance and other related mechanical parameters. Sawhney et al. (1991) did the comparison of fabrics made with cotton covered polyester staple-core yarn and 100% cotton yarn. Cotton covered/polyester staple-core yams and conventional 100% cotton yarns of equivalent size were woven and knitted into various fabrics for evaluation. The woven fabrics were tested for abrasion resistance and tear and tensile strengths. The knitted fabrics were tested for bursting strength, abrasion and pilling resistance. The staple- core yams, which were only modestly stronger than equivalent 100% cotton yams, produced fabrics remarkably improved in all the important properties when compared to the fabrics made with conventional 100% cotton yams.

It is on the basis of above the context that the present study has been planned.

Objectives of the Study

1) To construct cotton and cotton: polyester knitted *khadi* fabrics.
2) To study the effect of type of yarn on comfort and mechanical properties of knitted *khadi* fabric.
3) To study the effect of type of stitch on comfort and mechanical properties of knitted *khadi* fabric.

MATERIAL AND METHODS

Material

Cotton and Cotton: Polyester (60: 40) blended hand spun yarns of 20s count were used for the study. These yarns were purchased from the *Khadi Gramodhyog* of Kaladera, Jaipur, Rajasthan. Yarns, which are being spun by *khadi* village cottage industry for weaving, were used for knitting in the study.

Methods

Determination of Properties of Selected Yarns

Following properties of yarns were tested-

Yarn evenness-Cutting and weighing method was used to determine yarn evenness (Booth 1996). Percent irregularity was calculated.

Lea strength (IS: 1671-1977) and Count strength product

Yarn count (IS: 1671-1977) -Yarn count in Cotton English system was determined.

Construction of Knitted Fabric

Knitted fabrics were prepared on manually operated flatbed cotton hosiery machine of 14 gauge 40 inch. Two types of stitches were used for the construction of knitted fabric-

(a) Single jersey
(b) Rib - 1x1rib and 2x2 rib

Determination of Physical Properties of Developed Fabrics

Following physical properties of knitted fabrics were determined as per the established standards-

Weight (IS: 1964-1970), thickness (IS: 7702-1975), and stitch density(Joseph 1986)

Mechanical Properties

Bursting strength (IS: 1966–1975 RA 2006), Abrasion resistance (IS: 12763-1989 RA 05), Pilling (IS: 10971-1984 RA06)

Comfort Properties

Thermal conductivity- Thermolabo II – (Heat flow method) method was used to test thermal conductivity of knitted fabrics.

Air Permeability

Air permeability of knitted fabric was determined by constant air flow method using KES-F8-AP1 instrument. The resolution of pressure measurement is 2 Pa, assuring high precision.

Wicking Ability

The ability of a fabric to absorb water, especially by a wicking or capillary action, may be observed by timing the rate at which water climbs up a narrow strip of fabric suspended vertically

with its lower end dipping into the water. Rate of wetting was calculated.

RESULT AND DISCUSSION

Table 1 shows properties of yarns selected for the study.Although yarns of 20s count were purchased, analysis of yarn count in laboratory revealed that there is difference in yarn count of cotton and cotton: polyester yarns. Cotton yarn was found to be finer than cotton: polyester yarn (Indirect system of yarn count). This may be due to hand spinning system used by *khadi* cottage industry. Variation in hand spun yarn is bound to be there.

Table1: Physical properties of yarns

S. No.	*Name of property*	*Type of yarn*	
		Cotton	*Cotton: Polyester*
1.	Yarn Count (Ne)	19.35	15.53
	CV% of yarn count	3.6	2.9
2.	Lea strength (lbs)	96.59	266.52
	CV % of lea strength	3.33	2.93
3.	Count Strength Product	1772.42	3606.01
4.	Yarn evenness (% irregularity)	17.63	12.14

Lea strength of cotton yarn was less than that of cotton polyester blended yarn. Count strength product of cotton polyester blended yarn also showed its strength higher than cotton yarn. It is obvious that blending of polyester fiber with cotton fiber provides more strength to the yarn. CV percent shows higher variation in cotton yarn than in cotton: polyester yarn.It is apparent from table that cotton yarn was more uneven than cotton polyester blended yarn because of higher percent irregularity.

It is clear from Table 2 that weight of hand knitted fabrics composed of hand spun cotton yarn was higher than that of cotton polyester fabrics. The reason may be difference in density of cotton and polyester fibers. Density of polyester fiber is less than that of cotton that is why presence of polyester in blends has made cotton: polyester blend lighter in weight. Plain knits were lighter in weight than rib fabrics. 2x2 rib was heaviest and thickest fabric. This is due to difference in their structure (Spencer 2001).

Thickness of cotton knitted fabrics was more than that of cotton polyester blend fabrics though cotton yarn is finer than cotton: polyester yarn. The reason is that due to higher unevenness in cotton yarn, it was breaking frequently during knitting therefore, two yarns were used together. That is why cotton knits were thicker than cotton: polyester knits. Thickness of plain knit fabric was less than rib fabrics. Among rib fabrics, 2x2 rib was thicker than 1x1 rib in both cotton and cotton: polyester knitted fabrics. This variation in thickness of knitted fabrics may be due to the difference in structure of the stitch type.Relaxed rib fabrics are thicker than plain knit fabrics.

In general stitch density of cotton knit was higher than that of cotton: polyester fabrics, only exception being 1x1 rib. As knitted fabrics were made of hand spun yarns on manually operated machines, there are bound to be some variation.

Mechanical Properties

Bursting Strength

Bursting strength is one of the important mechanical characteristics of knitted fabric. Table 3 reveals that in general bursting strength of cotton knit fabric was less than that of cotton polyester blend knit fabric. Bursting strength of a fabric depends upon many factors. Yarn strength is one of the factors affecting bursting strength of knitted fabric (Bahl and Arora 2010). This may be one of the reasons for high bursting strength of cotton polyester blend fabric as cotton: polyester yarn is stronger than pure cotton yarn.

Table 2: Weight, thickness and stitch density of knitted fabrics

	Weight (ounce/sq yard)			*Thickness (mm)*			*Stitch density*		
	Plain knit	*1x1 rib*	*2x2 rib*	*Plain knit*	*1x1 rib*	*2x2 rib*	*Plain knit*	*1x1 rib*	*2x2 rib*
Cotton	6.7	10.06	15.22	1.42	1.61	1.94	2025	1369	2500
Cotton: Polyester	4.96	8.89	11.55	1.29	1.43	1.64	1521	2025	3364

Table 3: Bursting strength and abrasion resistance of knitted fabrics

Fabric	*Bursting strength (kg/cm²)*			*Number of cycles to break yarn*		
	Plain Knit	*1x1 Rib*	*2x2 Rib*	*Plain knit*	*1x1 Rib*	*2x2 Rib*
Cotton	5.22	5.50	8.15	83	161	211
Cotton : Polyester	6.67	7.72	7.67	105	354	343

It is also observed from Table 3 that in case of cotton knitted fabric; plain knit and 1×1rib knit fabrics showed almost similar bursting strength whereas 2×2 rib knit fabric showed highest bursting strength. Highest bursting strength of 2×2 rib may be the result of compact structure of this stitch.In case of cotton polyester blend fabric; both 1×1 rib knit and 2×2 rib knit have almost similar bursting strength which is higher than that of plain knit.

ANOVA calculated shows effect of fabric and stitch type on bursting strength of knitted fabric (F=96, P>0.01; F=70.02, P>0.01). Interaction between these two factors is also found significant (F= 29.55, P>0.01).

Abrasion Resistance

Knit structures tend to be abraded more quickly than woven fabrics because ofinterloping which tend to give textured surface. Abrasion resistance of knitted fabrics has been assessed by counting the number of rubbing cycles required to break the yarn. Higher the rubbing cycles, greater the abrasion resistance. It is evident fromTable 3 that the cotton knitted fabrics showed less abrasion resistance than cotton polyester blended fabrics. It is also clear that rib fabrics showed better abrasion resistance than plain knit fabrics, which is two to three times more than plain knit fabrics.

Yarn of cotton plain knitted fabrics broke after 83 cycles followed by 1×1 rib and 2×2 rib knit, which broke after 161 and 211 rubbing cycles respectively. Like cotton fabric, the plain knit cotton polyester blended fabric showed less abrasion resistance than 2×2rib and 1×1 rib fabrics. Highest abrasion resistance property was exhibited by 1×1 rib cotton polyester blend fabric followed closely by 2×2 rib cotton polyester knit.

The difference in abrasion resistance of cotton and cotton polyester fabric is due to thepresence of polyester fibers in blended yarn. Fibers which are inherently tough have better abrasion resistance than do the others (Booth 1996). Polyester fiber is tougher than cotton fiber. Higher abrasion resistance of rib fabrics may be ascribed to theirgreater thickness compared to plain knit. Thick fabrics are more resistant to friction than thin fabric (Joseph 1986).

Effect of type of yarn has been found significant (F=24.69, P>.01). Similarly effect of stitch type is also found significant (F=11.65, P>0.01).

Pilling

Pill formation is a serious problem in knitted fabrics from both natural and manmade fibers and blends. This gives the garment an unsightly appearance, affects handle and brings down the quality. The pills are formed during wear and washing by the entanglement of loose fibers which protrude from the knitted fabric. Pilling tendency of knitted *khadi* fabrics has been evaluated in terms of pilling grade and presented in Table 4.

Table 4: Pilling grade of knitted fabrics

	Pilling grade		
Fabric	*Plain Knit*	*1x1 Rib*	*2x2 Rib*
Cotton	2.5	2.5	2
Cotton : Polyester	3	3	2.5

It can be seen that the knitted fabric samples were rated 2 to 3, which indicates moderate to severe pilling. Pilling tendency was higher in cotton: polyester blend than in pure cotton knit.

Various factors affect the pilling behavior of textile fabrics such as physical and mechanical properties of fibers and yarns, the construction and surface characteristics of fabric. Knits exhibit pilling problems because of their loose construction. Excessive pilling may occur on the knitted cotton fabrics due to the improper binding of fibers. In this study hand spun yarns have been used which are unevenly twisted (Jasinka 2009).

Knits of synthetic: natural staple fiber blend contain numerous eligible free fiber ends that begin the pilling very fast. In addition, polyester

fiber has high mechanical strength. Yarn spun from cotton polyester blends is stronger than cotton yarn. Fabrics of strong fibers show pilling more quickly and more severally than fabrics of weaker fibers, as the strong fibers tend to ball up into pills and remain on the fabric surface, while the weaker fibers ball up and break away easily.

Comfort Property of Knitted Fabrics

Thermal Conductivity

Thermal conductivity is one of the factors affecting thermal comfort. It is the abilityof a fabric to transfer heat from body to environment and vice versa depending uponwhether temperature of body is more or less than that of environment.It is evident from Table 5 that cotton knitted fabrics showed lower thermal conductivity as compared to cotton: polyester knitted fabric. This can be explained by high weight per unit area and thickness of cotton knitted fabrics; and therefore more still air in these fabrics. Still air inside the fabric geometry has the least thermal conductivity rate as compared to conductivity of fibers. So air conveys a low quantityof energy via conduction and therefore, thermal conductivity of fabric decreases (Badr 2013).

Among the cotton knitted fabrics, 1×1 rib knit fabric showed highest thermal conductivity followed by 2×2 rib and plain knit fabric. Similar trend was observed incotton polyester blended knitted fabric, that is, 1×1 rib knit fabric showed highest thermalconductivity value followed by 2×2 rib and plain knit fabric.

The correlation coefficient was determined between fabric thickness and fabric thermal conductivity value. It is found that negative correlation (r= -0.035) significant at five percent level exists between these two properties.

Effect of yarn type on thermal conductivity is found to be significant (F=50, P>0.01).Effect of type of stitch is also found to be significant (F= 725, P>0.01). Thus both the factors affect thermal conductivity of knitted fabrics.

Air Permeability

Air permeability is closely related to thermal property and is frequently a major factor in body comfort. Fabrics with good air permeability encourage body heat loss. Air resistance of the fabric is the time in seconds for specific volume of air to pass through specific volume of fabric. Lower the value of air resistance, higher will be theair permeability of fabric. Air resistance of fabrics has been measured in kpa s/m.

It can be observed from the Table 5 that air permeability of cotton knitted fabrics was found to be better than cotton polyester knitted fabric, as their air resistance is less than cotton: polyester fabric. The reason might be longer loop lengthof cotton knits resulting in higher porosity in these fabrics which causes air to pass easily and rapidly. High negative correlation (r= -.92) is found between loop lengthand air resistance. Positive correlation exists between tightness and air resistance. This shows that tighter the construction of knitted fabrics higher will be air resistance.

It can also be seen that plain knits exhibited better air permeability property than rib fabrics. 2×2 rib knit fabric showed highest air resistance followed by 1×1 rib fabric and plain knit respectively in both cotton and cotton polyester blended knitted fabrics. Stitch density of 2×2 cotton and 2×2 cotton:polyester rib; and 1×1cotton: polyester rib fabrics are higher than plain knit exhibiting more compact construction than plain knit. This aspect might have caused variation inair permeability of fabrics of different stitch type.

Difference in air permeability of cotton and cotton: polyester blend was not significant (F=3.63, P=0.01). But significant difference at one percent level was found between air permeability of fabrics of different type of stitches (F= 10.87,P>0.01). Interaction between these two factors is also significant (F= 10.50, P>0.01).

Table 5: Thermal conductivity and air permeability of knitted fabrics

	Thermal conductivity (W/cm.deg C)			*Air resistance (k pa s/m)*		
Fabric	*Plain knit*	*1x1 Rib*	*2x2 Rib*	*Plain knit*	*1x1 Rib*	*2x2 Rib*
Cotton	4.59	5.17	5.04	0.0357	0.0607	0.0928
Cotton: Polyester	4.97	5.94	5.51	0.0544	0.1124	0.1366

Moisture Absorption

It is very important for the textile material to have the ability to absorb moisture vapor from the skin. Whenever fibers absorb liquid water or moisture vapor, heat is released. Therefore, water absorbency of fabrics is an important factor affecting wearer's thermal comfort. Moisture absorption of knitted fabrics has been measured by measuring wicking time (rate of wetting).

It can be observed from Table 6 that rate of wetting was higher in cotton knitted fabrics than in cotton polyester knitted fabrics. This is due to the fact that cotton is a natural fiber and it has good moisture absorbency. On the other hand cotton: polyester knitted fabric contains polyester fiber which is hydrophobic in nature, though polyester has good wicking ability.

Table 6: Wicking time of knitted fabrics

	Rate of wetting (inches per minute)		
Fabric	*Plain Knit*	*1x1 Rib*	*2x2 Rib*
Cotton	0.35	0.38	0.16
Cotton : Polyester	0.33	0.06	0.075

No particular trend was observed with respect to effect of type of stitch on rate of wetting of fabrics. In case of cotton knitted fabric, 1x1 rib knit fabric showed highest wicking ability followed by plain knit and 2x2 rib respectively. Very little difference was found between wicking ability of 1x1 rib and plain knit. It may be on account of constructional and dimensional differences. 2x2 rib is more compact and thicker so moisture absorption and movement is not as fast as in plain knit fabric.

In cotton polyester knitted fabric, plain knit exhibited highest wicking ability followed by 1x1 rib knit and 2x2 rib respectively though difference was very marginal between wicking ability of 1x1 and 2x2 ribs.

Two way ANOVA showed that there was significant difference in wicking ability of fabric composed of cotton and cotton polyester blended yarns at 0.01 level of significance. Significant difference was also found in wicking ability of fabrics of different types of stitches.

CONCLUSION

It can be concluded that cotton *khadi* knit is more comfortable due to higher moisture absorption, air permeability and thermal conductivity than cotton: polyester knit with less pilling tendency. On the other hand cotton: polyester is more durable. Stitch type also affects these properties of knitted fabrics.

RECOMMENDATION

Present study was towards product innovation. It explored the possibility of creating knitted fabric for *khadi* sector. Result showed that knitted fabric can be constructed in *khadi* industry and variety can be provided to consumers of *khadi* products.

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