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Study on Single Jersey Knitted Fabrics Made from Cotton/ Polyester Core Spun Yarns. Part I: Thermal Comfort Properties

Vidhya M[1] *0000-0001-6036-6117

Parveen Banu K[1] 0000-0001-8497-2752

Vasanth Kumar D[2] 0000-0001-9449-2517

Prakash C[3] 0000-0003-2472-6765

Subramaniam V[4] 0000-0001-5192-9280

[1] Periyar University/ Department of Textiles and Apparel Design / Salem 636 011, Tamil Nadu, India

[2] VIT Fashion Institute of Technology (VFIT)/ Vellore Institute of Technology - Chennai/ Chennai 600 127, Tamil Nadu, India

[3] Indian Institute of Handloom Technology/Department of Handloom and Textiles/ Fulia, Ministry of Textiles, Govt. of India, Shantipur, Nadia 741 402, West Bengal, India

[4] Jaya Engineering College /Department of Textile Technology /Chennai 602 024, Tamil Nadu, India

Corresponding Author: Vidhya M, E-mail: vidhyaarumugam2604@gmail.com

ABSTRACT

This study, mainly focused on the effect of core-sheath ratio, twist and stitch length on the thermal comfort properties of single jersey knitted fabrics produced from various ratios (100:0, 80:20 and 60:40) of cotton/ polyester core spun yarns. The Box-Behnken design tool was used to study core-sheath ratio, twist and stitch length on the thermal comfort properties of single jersey knitted fabrics and response surface equations were derived and design variables were optimized. From this study, the findings reveal that the decrease in cotton ratio among the fabrics made from core spun yarns decreases the fabric thickness and hence a more porous structure that results in higher thermal conductivity, air permeability, water-vapour transmission and less thermal resistance. It is also evidenced that, increase in the yarn twist (high) and the stitch length (tight) in the fabric structure makes thicker and less porous fabric which results in higher thermal resistance and lesser thermal conductivity, air permeability and water-vapour transmission.

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KEYWORDS

Air permeability, thermal comfort, core spun yarn, thermal conductivity and resistance, water vapour permeability.

1. INTRODUCTION

Cotton fibres are soft, cool, breathable, absorbent and natural hollow fibres and able to hold 24–27 times of water of their weight [1]. They are strong, absorbent, dyeable, and have high abrasion resistance. In general, cotton is considered one of the well-known and comfortable fibres amongst all the fibres [2]. Cotton has poor wrinkle resistance properties, due to this cotton can be mixed with polyester or some permanent finish can be applied to give improved properties to cotton fabrics [3]. Hence to attain the best properties of the fibres, cotton fibres are often blended with polyester fibres [4-5].

Polyester fibre is one of the commonly used commercial fibres in the textile industry. These are strong synthetic fibres made by blending the alcohol and acid and initiating a sequence reaction [6-8]. Polyester filament yarns are commercially used interlocked fibres of continuous length

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majorly used for weaving and knitting [9]. The polyester filament yarn is one of the finest and synthetic yarns that are used for various purposes like embroidery, sewing, knitting, weaving and core yarn spinning [10-11]. Generally, core spun yams have two-component in their structure namely core and sheath [11]. Core spun yarns were used to improve strength, durability, comfort, aesthetics, and other functional properties [12]. Continuous filament yarn is used as a core and cotton staple fibres are used to spin the core spun yarns [13]. Filament-core yarns were produced to benefit both the filament and staple fibres properties by resulting in greater strength and good uniformity without sacrificing the surface characteristics of the staple fibre yarn. As the cotton was wrapped over the polyester filament, improvements were observed in yarn properties compared to synthetic yarns [14]. Various factors such as fibre type (natural, synthetic or blend), fabric type (woven or knitted) and fabric constructions (weave or knit structures) are considered as important properties and these properties affect the breathable and thermal properties of the fabrics. From a physiological perspective, comfort properties are majorly affected by the thermal insulation, breathability, moisture transmission properties of the fibres. Commonly polyester fibres have good wicking behaviour and moisture transmission properties and hence polyester fibres and their blends were most widely used in sports wears in recent years [15]. Consumers are more and more interested in knitted fabrics because of such advantages as good fit and softness. Still lot of researches are happening on the usage of core spun yarns for knitted fabric application [16-17].

Clothing comfort is one of the fundamental needs and universally required for the end-users. Such clothing comfort involves both the thermal and non-thermal components and depends on the wearer situation. Clothing comfort is considered as one of the fundamental properties when a textile product is valued. The comfort properties of the fabric are influenced by various parameters such as fibre type, fabric structure, areal density, moisture absorption, heat transmission and skin perception properties [18]. Textile materials can be valued by their comfort level. Such clothing comfort can be classified into two type’s namely sensorial comfort and non-sensorial comfort. Sensorial comfort deals with the fabric hand properties such as bending, shear, tensile, thickness and compression, drape, friction and roughness. Non-sensorial comfort deals with the thermal and moisture transmission properties which include air permeability and water-vapour transmission [19]. When a human mind expresses satisfaction when exposed to the thermal environment is defined as thermal comfort. In general, when the body temperature is about 37°C (98.6°F); this is achieved by balancing the amount of heat generated with the amount lost from the body. To maintain a stable body temperature, heat loss is needed to balance the heat production. If the body temperature is unstable, then the body core temperatures will change accordingly [20]. So the clothing and textile materials require the best thermal insulation properties accordingly for the cold and hot climates. Hence the thermal insulation depends on various factors such as fibre density, fabric thickness, drape and number of layers [21-22]. Mostly the thickness of the fabric is considered as one of the major factors because the fabric thickness encloses still air and restricts the external air movement. The thermal insulation of the fabric can be determined by the entrapped air and which is considered ad one of the most significant factors. Micro layers and macro layers of air enclosed within an assembly increase, the thermal insulation of the material increases. Hence the characteristics of fibre, type of fibre, yarn and fabric structure provide a key influence towards the thermal comfort properties [23-24].

During any sports activity, the physiological and psychological comfort of the clothing can be comprehensively balanced by the environment, clothing performance and human body. The comfort properties of the sportswear play a vital role and mainly concentrate on the performance and wearer comfort of the sportswear [25]. The significance of functional clothing used for various activities such as sports, outdoor and other protective garments has got increased in the last decades. Hence thermal properties, moisture transmission and air permeability properties of the clothing should be improved to meet the requirements of sportsperson and athletes [26]. In general, during any sports activity, a human body can able to generate more than 1000W of heat and the generated heat has to be transferred to the environment so that makes the wear comfortable by staying in the thermal equilibrium. For transferring such heat to the environment clothing is necessary for sports for identification, ethical reasons and also to protect our body against impact [27]. Gokarneshan [2019] investigated the thermal comfort properties of single jersey knitted fabrics made from the intimate blends of recycled polyester and cotton fibres. It is also reported that, increase in the ratio of recycled polyester fibres among the blends the fabric becomes thin, porous and lightweight and results in lesser thermal resistance and higher thermal conductivity, relative water-vapour permeability and air permeability properties [28-29]. Jhanji et al [2015] examined the thermo-physiological properties of polyester-cotton plaited fabrics by varying the fibre linear density and yarn type and reported that the plaited fabrics made from carded yarns of polyester fibres have higher linear density and resulted in higher thermal resistance and lower thermal absorptivity which in line makes the wearer feel comfortable [30]. Similarly, the fabrics made from the core yarn result in higher moisture transmission and air permeability properties with the combination of combed cotton yarn in the sheath and coarser polyester yarn in the core.

Aytac and Unal [2017] investigated the comfort properties of plain knitted fabrics made of core spun yarns, by blending the cotton, viscose and PES fibres in the sheath and different ratios of PVA within the core. The researchers concluded that the permeability properties of the knitted fabrics produced with cotton, viscose, and PES fibres in the sheath and PVA in the core were positively affected [31]. Khalil et al [2020] studied the thermal comfort properties of 100% cotton, cotton with full-platted Lycra, Core, and Dual Core spun yarns (DCS). It is concluded that the core spun and DCS show the highest elongation 27% increased thermal conductivity 18% decreased water-vapour permeability which gives extensibility and comfort at the same strength compared to 100% cotton samples [32]. Prakash and Ramakrishnan [2013] reported that, as the loop length increases, the thermal conductivity also increases due to the fabric packing density and also an increase in the loop length decreases the flow rate of water-vapour [33]. Atalie et al [2019] proved that an increase in the yarn twist increases the fabric permeability due to more air gaps in the fabric structure thus enhancing the overall sensorial comfort [34]. Although many researchers investigated the comfort properties of fabrics with different blend compositions, linear density, fabric structure and few researchers only investigated the comfort properties of knitted fabrics made from core spun yarns. Hence, this study is mainly intended to study the thermal comfort properties of single jersey knitted fabrics made from cotton/ polyester core spun yarns.

Latif et al [2018] examined the comfort properties of fabrics made from cotton fibres blended with various regenerated fibres such as viscose, Tencel, modal, bamboo and proved that when cotton blended with any regenerated fibres could replace the usage of 100% cotton in the clothing applications to meet the requirements of growing demands of the clothing [35]. Likewise, Medar and Mahale [2018] reported that the comfort properties of union knitted fabrics made from cotton and bamboo/ tencel fibre blends were analyzed. This study reveals that the comfort properties of the union knitted fabrics made from bamboo and tencel fibres blended with cotton fibres resulted in superior comfort properties by enhancing the wearer's physiological needs this further enhances their personality and their working efficiency [36]. Oglakcioglu and Marmarali [2007] investigated the thermal comfort properties of knitted fabrics made of various structures and evidenced that the relative water vapour permeability of the single jersey structure is higher than 1 X 1 rib and interlock structure and keeps the wearer warmer and comfortable due to the lower thermal absorptivity properties. Due to the structural nature, single jersey fabrics remarkably results in lower thermal conductivity and higher relative water vapour permeability of 1 X1 rib and interlock fabrics [37]. Khalil et al [2017] reported that the thermal comfort properties of single jersey knitted fabric produced from different lycra states and proved that the knitted fabrics are characterized by comfort when compared to woven fabrics due to their higher extensibility, air permeability and heat retention properties which consequences in dimensional instability after repeated cycles of washing [38]. Hence to maintain the dimensional stability of the knitted fabrics, additional lycra yarns (spandex) are either half or fully plaited with 100% cotton yarns. It is also suggested that, instead of full plaited fabrics, knitted fabrics made from lycra (in core) and cotton in the sheath can also be used. Vadicherla and Saravanan [2017] examined the thermal comfort properties of single jersey knitted fabrics made from different blend ratios, linear density and loop lengths of recycled polyester and cotton blended yarns and proved that increase in the recycled polyester ratio and loop length among the blends the fabric becomes thin, porous and lightweight results in higher thermal resistance, air permeability, relative water-vapour permeability and lesser thermal conductivity [39]. Similarly when the recycled polyester ratio decreases and the cotton ratio increases the fabric becomes thick, heavier and less porous fabric with higher thermal conductivity, lesser air permeability and thermal resistance and high relative water-vapour permeability at medium linear densities.

It is noticed from the literature that although core spun yarns have been produced and studied for their various properties, their exploitation in knitted fabrics is obscure. The influence of core-sheath ratio, twist and stitch length on the thermal comfort properties of the single jersey knitted fabrics produced from core spun yarns have not been studied yet. The novelty of this study is to produce a cost-effective core spun yarn by using a unique core spin attachment on the ring-spinning machine. A very few researches were carried out in this area, hence based on the literature which inspired the researchers to take up this study on the effect of core-sheath ratio, yarn twists and the stitch length on the thermal comfort properties of the single jersey knitted fabrics.

2. MATERIAL AND METHOD

2.1 Material

For this study, MCU 5 cotton fibres with 31mm fibre length, 4.1 µg/in fibre fineness, 22.5 g/tex fibre strength, the linear density of 0.17 tex, 8.5% moisture regain and 6% elongation were used in the sheath (cotton staple fibres) and for the core polyester monofilaments with 50 and 65 deniers were used during the core-yarn spinning process. Core sheath proportions of 100:0, 80:20 and 60:40 of cotton/ polyester core spun yarns were produced by varying different levels of the yarn twists (low, medium and high). Single jersey knitted fabrics were produced by varying the stitch length (loose, medium and tight) in the fabric structures and the thermal comfort properties were studied.

2.2 Method

2.2.1 Yarn production

As shown in Figure 1, the yarn production process starts with fibre mixing, lap production, carding, drawing, rove-preparation and ring spinning. This study is aimed to optimize and produce three different yarns (100% cotton, 80:20 and 60:40 cotton/polyester core spun yarns) with a linear density of 14.76 tex by varying three different twist levels (940, 1020, 1100). For producing 100% cotton yarns, a ring frame machine was used, similarly, for producing core spun yarns Trytex Core Lycra ring frame with a core spin attachment above the drafting unit was used (as shown in Figure 2). In the core spin attachment, a polyester monofilament was passed through the front drafting roller and the core spun yarns were produced with the blend ratio of 80:20 (50 denier polyester monofilament was used in the core) and similarly for 60:40 (65 denier polyester monofilament was used in the core).

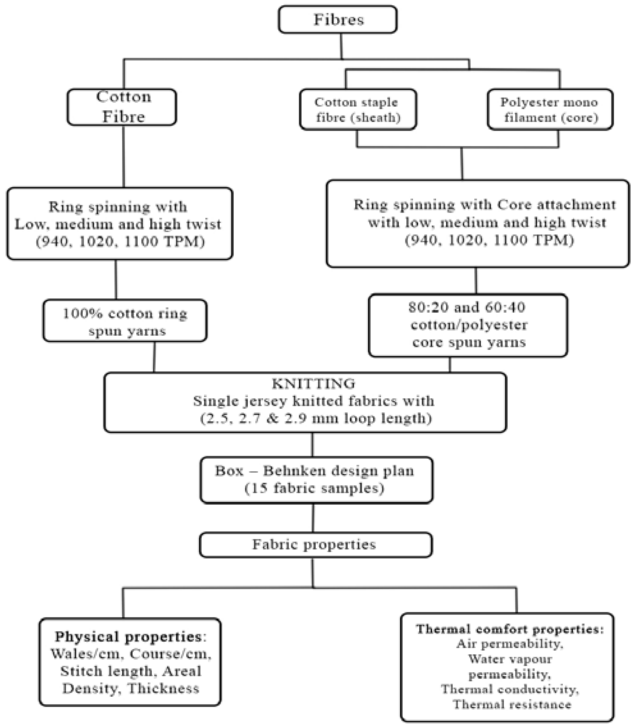

Figure 1. Experimental plan

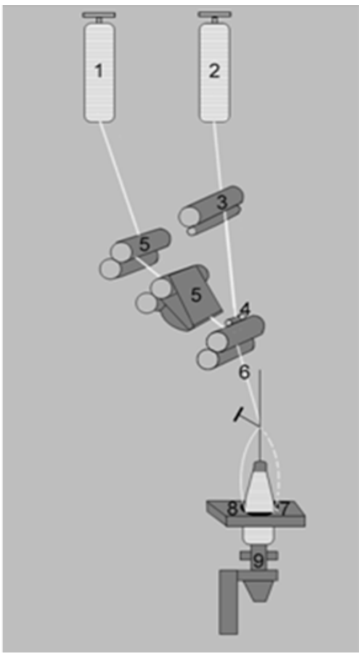

Figure 2. Core spinning process diagram 1. Cotton roving, 2. Polyester filament, 3. Positive feed roller 4. Feeding roller, 5. Drafting roller, 6. Core spun yarn 7. Traveller, 8. Ring, 9. Drive

2.2.2 Fabric production

Box-Behnken, (three-level - three variable factorials) design tool was used in this study. The input parameters under study were the core-sheath ratio of cotton and polyester (100%, 80:20, and 60:40), twists per metre (940, 1020, and 1100) and loop length (2.5, 2.7, 2.9 mm). The knitted fabric samples were shown in Figure 3. The coded factors were calculated using the following Equation (1),

$$x_c = \frac{(x-\ddot{x})}{\Delta x} \qquad \text{Equation (1)}$$

where x is the actual value of the factor, (low or centre or high level, $\ddot{x}$ is the mean value of all levels of the factor, and Δx is the difference between the levels of the factor.

Fifteen single jersey knitted fabric samples with a yarn linear density of 14.76 tex were knitted as per the combination as shown in Tables1 and 2. The fabrics were knitted using a smart machinery knitting machine with the following specifications; gauge- 32inch, 24-inch dia, 4 feeders/inch, 35 rpm speed and 1800 needles. Single jersey knitted fabric samples (as mentioned in Figure 3.) were subjected to the dry, wet and full relaxation treatments as per the procedure set out by the 'Starfish' recommendations. The fabrics were then subjected to scouring and then conditioned in the standard atmospheric conditions of 27ºC ± 2 ºC at a relative humidity of 65% ± 2% prior to testing.

Table 1. Variables and levels used in Box-Behnken design

Variables	Levels		
	- 1	**0**	**1**
Core sheath ratio % (**A**)	100	80:20	60:40
TPM (**B**)	940	1020	1100
Loop length in mm (**C**)	2.5	2.7	2.9

Table 2. Box-Behnken design sample plan

Std.	Run	Factor 1 A: Core sheath ratio	Factor 2 B: TPM	Factor 3 C: Loop length
8	1	1	0	1
7	2	-1	0	1
9	3	0	-1	-1
13	4	0	0	0
15	5	0	0	0
3	6	-1	1	0
5	7	-1	0	-1
1	8	-1	-1	0
4	9	1	1	0
2	10	1	-1	0
10	11	0	1	-1
14	12	0	0	0
12	13	0	1	1
11	14	0	-1	1
6	15	1	0	-1

2.2.3 Test Methods

Single jersey knitted fabrics produced from the cotton/ polyester core spun yarns were tested for areal density (ASTM D 3776), thickness (ASTM D 1777-96) under the standards respectively. Air permeability (ASTM D737-96) of the single jersey knitted fabric samples were investigated using Textest FX 3300 tester at a pressure of 100 Pa and measurements of the samples were carried out ten times and the average and standard deviation of the values were reported. Water-vapour transmission of single jersey knitted fabrics was determined using the Permetest instrument (ISO 11092). The Permetest instrument works on the principle of heat flux sensing and it measures the heat flow caused by the evaporation of water passing through the tested sample and the average values of five readings were reported. Alambeta testing instrument was used to measure the thermal conductivity and thermal resistance of the fabrics. The thermal resistance of the textile materials depends on the thickness and porosity of the particular layer of fabrics. The sample is kept between two plates (one is hot and another is cold) provided in the instrument, according to ISO 11092 standards and measurements of the samples are carried out five times and the average values were reported

3. RESULTS AND DISCUSSION

3.1 Physical properties

Table 3 exhibits the physical properties of single jersey knitted fabrics made from 100% cotton and cotton/polyester core spun yarns. As per the standards, wales/ cm, course/ cm, stitch length, areal density and thickness of the single jersey knitted fabrics were tested. Optimized values of A = 78:22, B= 1080, C = 2.8.

Figures 4 to 9 represents, 3-D graphs indicating the interactive effects of (a) Core ratio and TPM (b) Core ratio and Loop length; and (c) TPM and Loop length on the air permeability of cotton/polyester core spun knitted fabrics.

From Figures 4 and 5, it was observed that the increase in polyester content decreases the thickness and fabric weight. Table 4 reveals the statistical significance with high F-value and low *p*-values. From statistical analysis, the response surface equation derived for areal density and thickness was found to be

$$\text{Areal density} = 107+1.5*A+2.625*B-0.875*C+0.0000*AB+0.0000*AC+0.25*BC-1.125*A^2-0.375*B^2-0.375*C^2$$

$$\text{Thickness} = 0.5600+0.0125*A+0.0212*B-0.0087*C-0.0075*AB+0.0025*AC+0.0000*BC+0.0075*A^2-0.0050*B^2-0.0050*C^2$$

100% cotton knitted fabrics with a high twist and low loop length show the highest areal density and thickness values. As per the studies [39-41], polyester is a finer fibre that has low bending rigidity, enhances packing fraction which enhances the compressibility of knit loops and makes thinner and lighter fabrics. Low twist and increased loop length in fabrics show lower GSM and thickness which agrees with the findings of the researchers [42-47].

3.2 Thermal comfort properties of knitted fabrics produced from cotton/polyester core spun yarns

Thermal comfort properties of cotton/polyester core spun knitted fabrics were shown in Table 5. “Design Expert” software was used to perform the experimental study and the interactive effects of these variables and their response surface equations were derived. ANOVA quadric model was used for statistical analysis and results are summarized in Table 6, which reveals the statistical significance with high F-value and low *p*-values.

Table 3. Physical properties of knitted fabrics produced from cotton/polyester core spun yarns

Sample code [Core sheath ratio (Cotton: Polyester) – TPM – Loop length]	Wales/cm	Course/cm	Stitch length	Areal density (g/m²)	Thickness (mm)
100:0 - 940 - 2.7	17	21	0.149	104	0.56
100:0 - 1020 - 2.9	16	22	0.133	106	0.57
100:0 - 1020 - 2.5	18	23	0.149	108	0.58
100:0 - 1100 - 2.7	17	22	0.148	109	0.59
80:20 - 940 - 2.9	17	21	0.137	103	0.53
80:20 - 940 - 2.5	19	23	0.145	105	0.54
80:20 - 1020 - 2.7	18	22	0.138	106	0.53
80:20 - 1020 - 2.7	18	22	0.138	106	0.53
80:20 - 1020 - 2.7	18	22	0.138	106	0.53
80:20 - 1100 - 2.9	17	21	0.133	107	0.54
80:20 - 1100 - 2.5	18	23	0.145	108	0.55
60:40 - 940 - 2.7	18	22	0.137	102	0.52
60:40 - 1020 - 2.9	17	21	0.130	103	0.51
60:40 - 1020 - 2.5	19	23	0.138	104	0.53
60:40 - 1100 - 2.7	18	22	0.141	105	0.52

Table 4. Analysis of variance

	Degrees of freedom	F-value	*p*-value
Areal density	9	37.67	0.0005
Thickness	9	136.63	< 0.0001

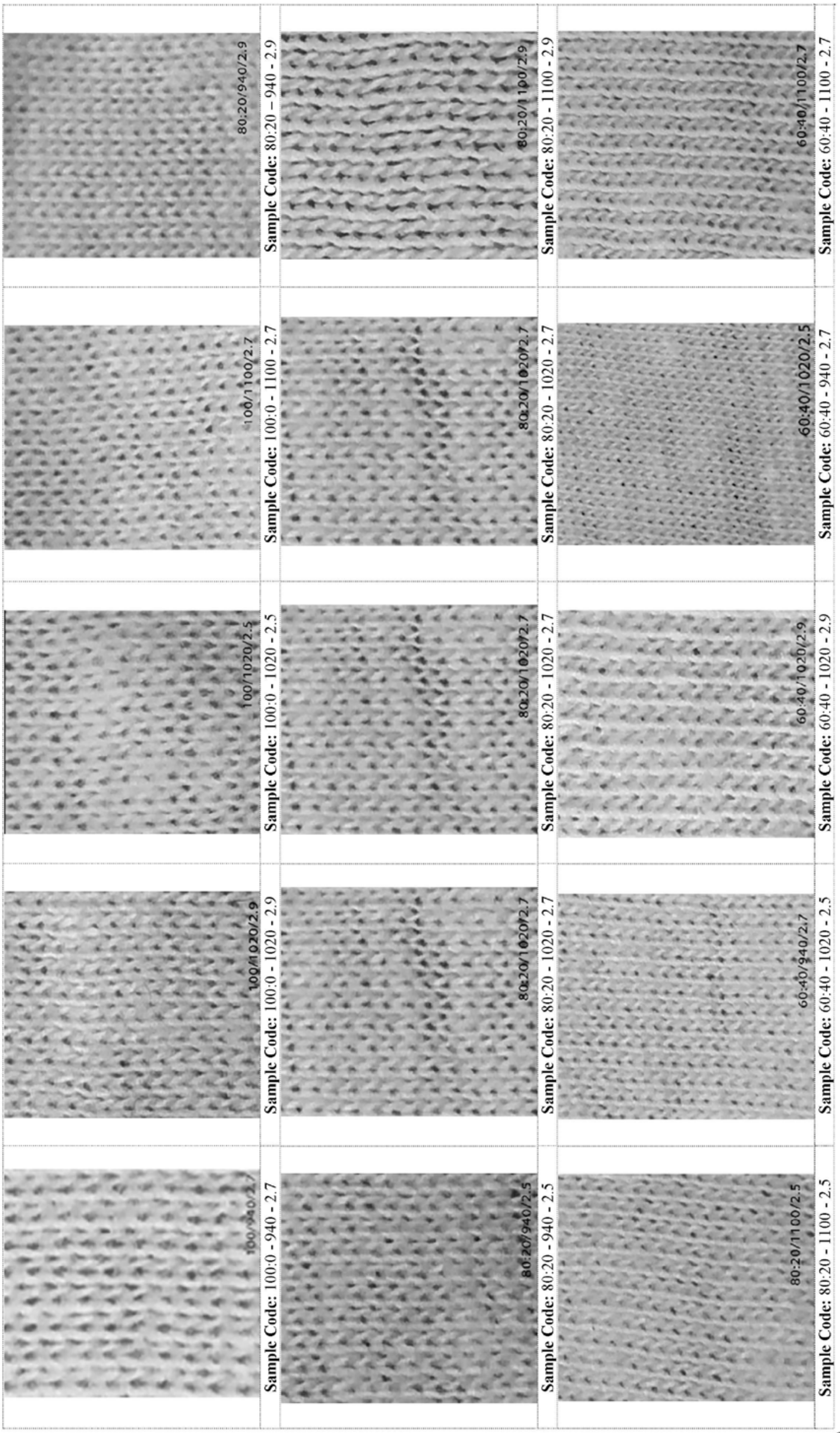

Figure 3. Cotton and Cotton/ Polyester core spun knitted fabric samples

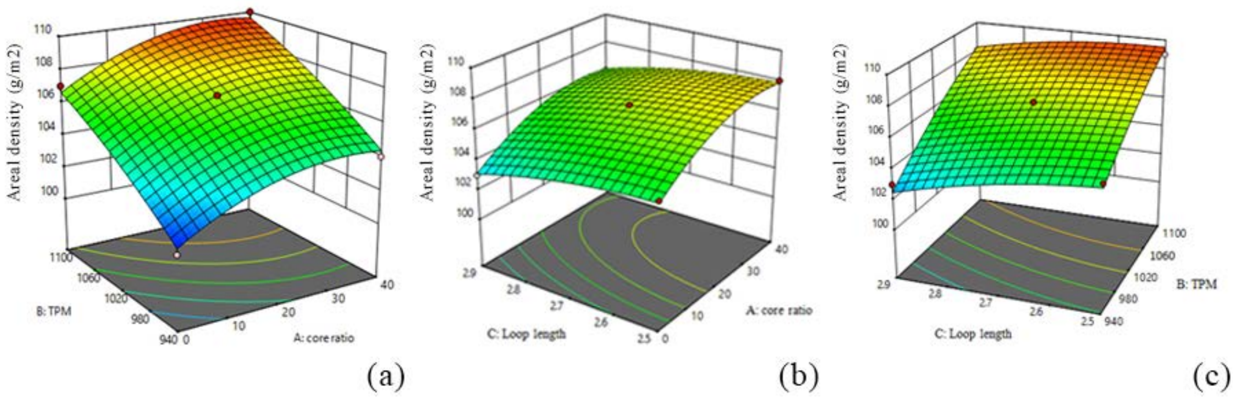

Figure 4. Areal density of knitted fabrics produced from cotton/polyester core spun yarns

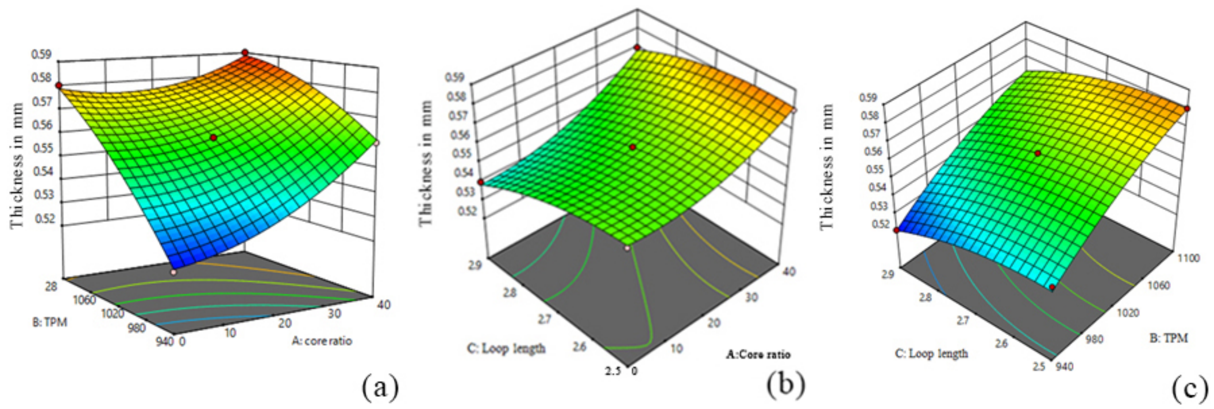

Figure 5. Thickness of knitted fabrics produced from cotton/polyester core spun yarns

Table 5. Thermal comfort properties of knitted fabrics produced from cotton/polyester core spun yarns

Sample code [Core sheath ratio (Cotton: Polyester) – TPM – Loop length]	Response 1 Air permeability in c.c/cm.sq/sec (ASTM D 737-04) (2016)	Response 2 Water vapour transmission (Breathability) ($g/m^2/24h$)	Response 3 Thermal conductivity (W/mK)	Response 4 Thermal resistance ($m^2K/W\times10^{-3}$)
100:0 - 940 - 2.7	92.5	2098.46	0.0322	17.08
100:0 - 1020 - 2.9	115	1809.73	0.0317	17.67
100:0 - 1020 - 2.5	102	1732.39	0.0319	17.24
100:0 - 1100 - 2.7	121	2037.62	0.0315	18.1
80:20 - 940 - 2.9	115	2103.19	0.0328	16.15
80:20 - 940 - 2.5	102	1732.39	0.0319	17.24
80:20 - 1020 - 2.7	118	1821.5	0.0325	16.31
80:20 - 1020 - 2.7	118	1821.5	0.0325	16.31
80:20 - 1020 - 2.7	118	1821.5	0.0325	16.31
80:20 - 1100 - 2.9	141	1887.07	0.0321	18.69
80:20 - 1100 - 2.5	108	1726.98	0.0387	13.71
60:40 - 940 - 2.7	93.1	1843.25	0.0408	12.75
60:40 - 1020 - 2.9	115	2103.19	0.0328	16.15
60:40 - 1020 - 2.5	108	1726.98	0.0387	13.71
60:40 - 1100 - 2.7	130	1675.96	0.0374	15.78

Table 6. Analysis of variance

	Degrees of freedom	F-value	*p*-value
Air permeability	9	26.06	0.0011
Water-vapour transmission	9	23.71	0.0014
Thermal conductivity	9	62.32	0.0001
Thermal resistance	9	426.91	<0.0001

3.2.1 Air Permeability

Table 5 shows the air permeability result and the 3-D graphs (Figure 6.) indicates the effect of variables on the air permeability of single jersey knitted fabrics produced from core spun yarns. The response surface equation obtained for air permeability is mentioned as follows,

$$\text{Air permeability} = 118 - 3.45{*}A + 14.3625{*}B - 9.4375{*}C + 2.1{*}AB - 1.5{*}AC - 0.625{*}BC - 6.4875{*}A^2 - 2.3625{*}B^2 + 1.4875{*}C^2$$

From Figure 6 it was observed that the fabrics with a higher twist and higher loop length show higher air permeability values. When the twist increases, fibres are bound compactly to the yarn body that reducing the hairiness brings high air permeability. The lower hairiness of the yarn contributes towards higher air permeability. Air will flow primarily through the inter-yarn pores because of the high twist in the yarn and the compression of the yarn near the binding points [25-26]. When the loop length increases, the fabric porosity and the air permeability also increase. With the increase in the loop length, the looser the structure leads to higher air permeability. The highest air permeability value of 141 c.c/cm.sq/sec was obtained in 80:20 cotton/polyester core spun knitted fabrics with a high twist and high loop length. An increase in polyester core ratio decreases the fabric thickness and it becomes lighter and more porous with high air permeability which agrees with the study [39]. The lower thickness accompanied by weight per square meter and facilitate the passage of air through the fabric and thus correlates with the earlier studies [42-44].

3.2.2 Water-vapor transmission

Water-vapour transmission is the ability of a fabric to permit the water vapour to pass through the body and to prevent the entry of water. It highly depends upon the macro-porous structure of the fibres in the yarn [30]. From statistical analysis, the response surface equation derived for water vapour transmission is

$$\text{Moisture Vapour Transmission} = 1821.50 + 83.52{*}A - 112.35{*}B + 32.23{*}C + 49.70{*}AB - 66.19{*}AC - 97.21{*}BC - 23.68{*}A^2 + 39.70{*}B^2 + 36.72{*}C^2$$

The lowest water-vapour transmission rate of 1675.96g/m^2 for 24hours was obtained in a 60:40 cotton/polyester blend with the TPM and loop length of 1020 and 2.7mm respectively as shown in Figure 7. When the TPM and loop length of 80:20 cotton/polyester core spun knitted fabrics were 940 and 2.9, the water vapour transmission rate was highest as 2103.19 g/m^2 for 24 hours. An increase in polyester in the core reduces the yarn diameter, better packing fraction, increases the pores that contribute to the higher water vapour transmission rate. The low twist and the high loop length, makes the fabric more porous and thinner which results in an increased water vapour transmission rate. Polyester fibres transport the water vapour from the body at a higher rate than cotton fibres [46]. They attributed these differences to the fact that hydrophilic fibres retained water molecules and could even swell to reduce the porosity of the fabrics [47-48]. 100% cotton fabrics show 2098.46 g/m^2/24h at low twist with 2.7mm loop length. Water-vapour transmission rate was strongly correlated with the cross-section of the fibre, fabric thickness and moisture-absorbing properties did not play a significant role [49]. From the literature, it is proved that air permeability has a close relationship with the water-vapour transmission.

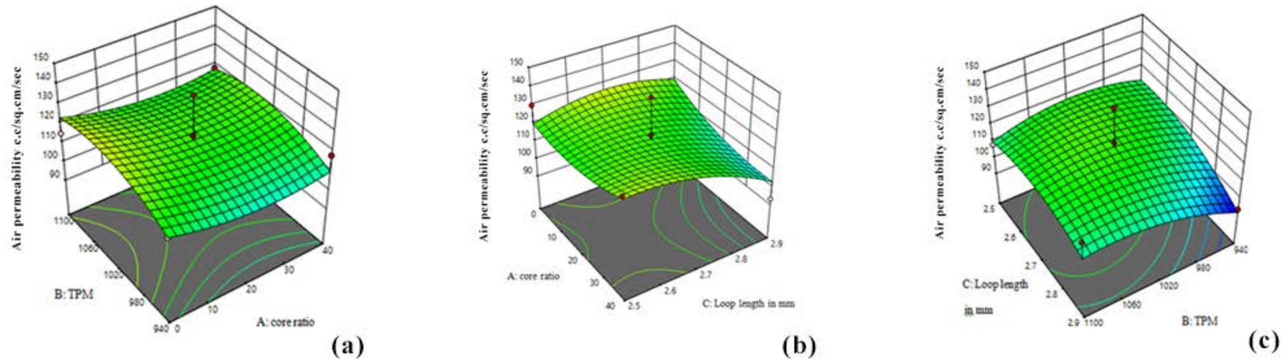

Figure 6. Air permeability of knitted fabrics produced from cotton/polyester core spun yarns

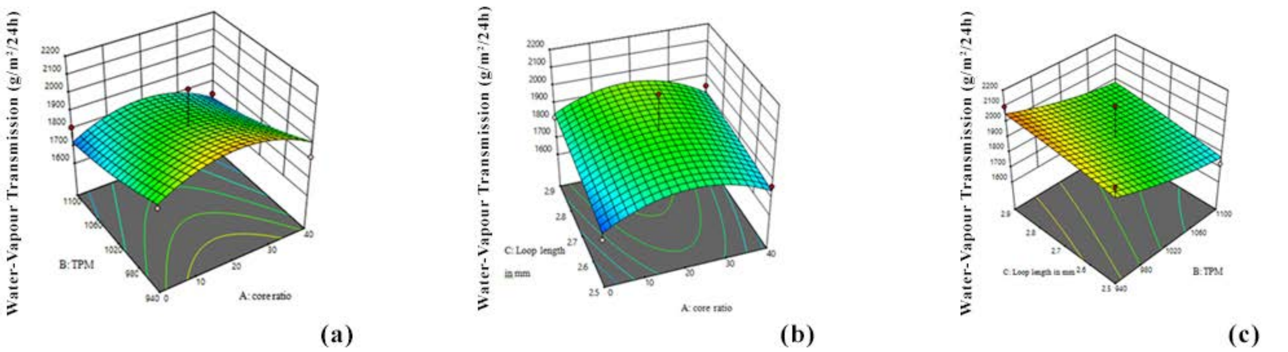

Figure 7. Water-vapour transmission of knitted fabrics produced from cotton/polyester core spun yarns

3.2.3 Thermal conductivity

The ability of a fabric to conduct heat is referred to as thermal conductivity. The thermal conductivity of the fabric depends on the air entrapped within it than on the fibre conductivity. Response surface equation for thermal conductivity as

$$\text{Thermal conductivity} = 0.0325+0.0325*A - 0.0007*B + 0.0001*C - 0.0007*AB + 0.0001*AC + 0.0000*BC + 0.0028*A^2 + 0.0002*B^2 - 0.0002*C^2$$

It is apparent from Figure 8, 60:40 cotton/polyester core spun fabrics show a higher thermal conductivity value of 0.0408 W/mK at low twist and medium loop length. 100% cotton fabrics with a high twist and medium loop length show the lowest value of 0.315 W/mK. The thermal conductivity of the knitted fabrics can be influenced by the increased twist and stitch length of the fabrics. An increase in the cotton fibre content on the fabric leads to a decrease in the thermal conductivity of the fabrics. This is attributed to the lower fabric cover that allows more air gaps in the fabric structure, thus improving the resultant thermal conductivity through the fabric [50]. This study shows a well-known fact that thermal conductivity is inversely proportional to the thermal resistance of the fabrics. This is in substantial agreement with the findings of previous works [51- 52].

3.2.4 Thermal resistance

The thermal resistance properties of cotton/polyester knitted fabrics were shown in Table 5 and Figure 9. Response surface equation derived for thermal resistance is

$$\text{Thermal resistance} = 16.31-1.64*A+0.9837*B -0.4225*C + 0.5025*AB - 0.1400*AC - 0.3150*BC - 0.7412*A^2 +0.3588*B^2 + 0.2612*C^2$$

An increase in the stitch length of the fabric increases the thermal resistance properties and this is due to an increase in the air gaps in the fabric structure. Air is considered a good thermal insulator and hence the air gaps increases result in enhanced thermal resistance of the knitted fabrics. The increase in thermal resistance at the same time by an increase in loop length is explained due to a decrease in fabric thickness proportionally and a change in pore structure [53-54]. The thermal resistance of the knitted fabric decreases with the decrease in the fabric density. Due to the decrease in the fabric density, the air trapped in the holes of the knitted fabrics will be higher. The higher the thermal resistance value of the air compared to the textile fibres, the lower the total heat transfer in the fabric and the higher the thermal resistance [55-56].

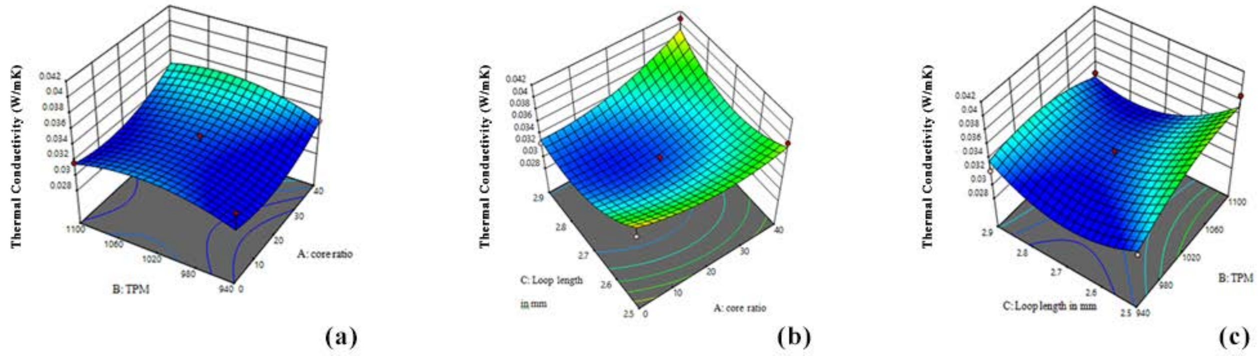

Figure 8. Thermal conductivity of knitted fabrics produced from cotton/polyester core spun yarns

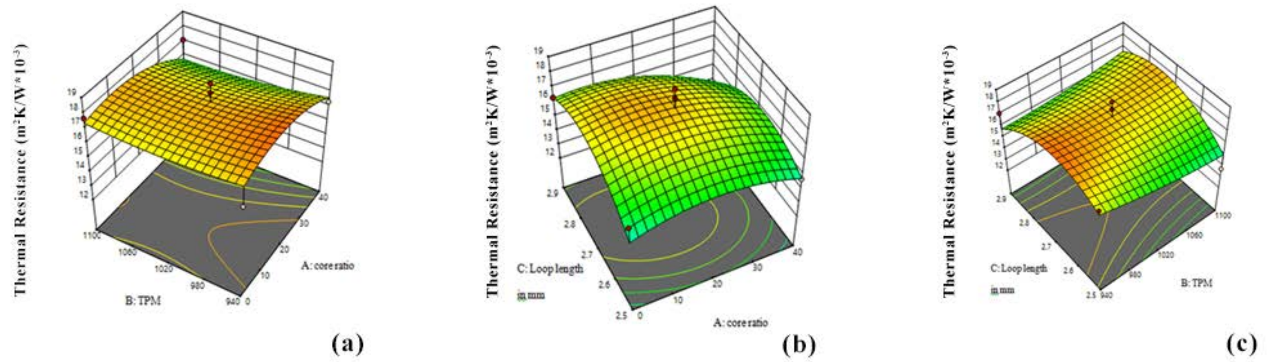

Figure 9. Thermal resistance of knitted fabrics produced from cotton/polyester core spun yarns

4. CONCLUSION

The thermal comfort properties of 100% cotton, 80:20 and 60:40 knitted fabrics produced from cotton/polyester core spun yarns were investigated in this study. It was found that the core-sheath ratio, twist and stitch length have a significant influence on the thermal comfort properties of the knitted fabrics. It is also noticed that the decrease in cotton ratio decreases the fabric thickness and results in lighter and more porous fabric structure leads to higher thermal conductivity, thermal resistance, air permeability and lower water-vapour transmission properties [39]. An increased twist in the yarn and tight loop structure in the fabric makes the fabric thicker and less porous with higher thermal resistance and lower thermal conductivity, air permeability and water-vapour transmission rate [44-45]. This is a fragmented part of our research work and this paper (Part I) mainly focused on the thermal comfort properties of knitted fabrics produced from cotton/polyester core spun yarns. In continuation to this research work, the next paper (Part II) is mainly focused on the moisture management properties of knitted fabrics produced from cotton/polyester core spun yarns. Compared to the knitted fabrics made from 100% cotton yarn, loose structured 80:20 cotton/polyester core spun knitted fabrics shows higher thermal resistance, air permeability, water-vapour transmission and lesser thermal conductivity and are more suitable for various end uses with enhanced thermal comfort properties.

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