ANALYSIS OF COMFORT PROPERTIES OF MULBERRY SILK AND VISCOSE BLENDED KNITTED FABRICS FOR SUITABILITY IN CLOTHING IN TEMPERATE REGIONS

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Abstract

This study reports on the impact of textile properties of knitted fabrics blended in three unlike proportions of mulberry silk and viscose fibre, on desired comfort for temperate regions. Attempt was made on four knitted fabrics, blended in proportions of 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose, each in two unequal counts. Objective assessment of the fabrics has been carried out in order to obtain the scores on various aspects of comfort. Parameters like thermal conductivity, air permeability and water permeability were chosen for experimental design. The influence of fabric weight, thickness, weight, stitch length and tightness factors have been statistically analyzed and discussed. Also, thermal conductivity has been correlated with air permeability and water permeability. It has been exercised to bring about a knitted fabric with desired properties in temperate climates. Results suggest that knitted fabrics blended in 60% mulberry silk: 40% viscose in both yarn counts 15 and 20 Nm, were found most suitable for apparel use in temperate regions. These fabrics held a good mix of warmth and coolness by having a thermal conductivity of 1.140 and 1.145 Clo, air permeability of 439.2 and 435.7 CFM and water permeability of grades 3 for both fabrics. A worthy influence of constructional properties was observed on comfort characteristics. A feeble negative correlation of thermal conductivity with air permeability and water perm was noticed.

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Commented [SA3]: The significance of this research is evident in these sentences.

Commented [SA4]: Here's an example I provided for you. "An experiment was conducted with four knitted textiles with uneven counts, each of which was mixed with 50% mulberry silk and 50% viscose, or 40% mulberry silk and 60% viscose. As part of the objective evaluation, we evaluated the fabrics on different comfort variables. To achieve the experimental design, thermal conductivity, air permeability, and water repellency were taken into account."

Keywords: *Comfort, Insulation, Permeability, Property, Thermal*

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1. Introduction

Commented [SA6]: After reviewing the introduction of your manuscript, I have confidence that it is well-written and provides valuable information. However, it would be helpful to provide a clearer identification of the specific research gap. Clearly expressing this gap is essential to highlight the importance of your study. Although the properties and benefits of mulberry silk and viscose, as well as their applications in textiles, have been thoroughly discussed, the specific gap in the current literature has not been clearly emphasized. It would be beneficial to include a paragraph that clearly outlines the gaps in previous research and explains how your study intends to address these gaps.

Human comfort is manifold, mostly subjective and is influenced psychologically by clothing (Song 2011). The term comfort is associated with the absence of unpleasantness or discomfort or a neutral state compared to the more active state of contentment. Comfort can be interpreted as an amiable state of physiological, psychological, and physical conformity between a human and its environment (Marulleau et al 2017). It banks the wearer's activity, clothing type, climatic environment (humidity, temperature, and wind velocity) and the sensibility of each subject. The understanding of heat and moisture transfers through clothing is a major concern for scientific researchers, designers, developers and manufacturers. Worn apparel works as a barrier for heat and vapour transport between the skin and the environment. It is composed of fibers materials, air enclosed between skin and garment, and still air bounded to the outer surface of it (Havenith 2005). Different clothing properties affect the thermal comfort for various climates.

Of the all the climates, temperate climates are temperatures can change greatly here, between summer and winter. So, most places with a temperate climate have four seasons *viz.* summer, autumn, winter and spring. Other areas with a temperate climate can have very unpredictable weather. One day it may be sunny, the next may be rainy, and after that it may be cloudy. This is normal in summer as well as in winter (Pandey 2018). Therefore, apparel for such climates should be not so warm and not so cool at the same time. The fabrics used should allow the air to pass and should trap it as well to provide certain amount of thermal insulation insulation. It was understood that the heat and moisture transmission through apparel was doubtlessly the most significant factor in clothing comfort (Dhinakaran *et al* 2007). Data reveals that wear comfort is a highly demanded characteristic in clothing (Hipler and Elsner 2006). The comfort of a swaddled body ~~in relation to~~concerning warmth largely banks on the nature of the equilibrium established between the properties held by the fabric. Although mostly discussed subjectively, objective measurement of the same has been attempted in the present paper by analyzing the desired properties.

2. Objectives

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The goal of this study is to analyze the influence of parameters related to comfort for blended knitted fabrics by using mulberry silk and viscose fibre, for suitability in temperate regions. Also, the research aims to bring out the fabrics with appropriate mix of properties to be used in temperate climates for apparel use.

3. Materials and methods

3.1 Test fabrics

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Six types of fabrics were knitted by using blended yarns of two different yarn counts, each in three different blending proportions *viz.* 60% mulberry silk: 40% viscose, 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose. Blended knitted fabrics were utilized for the present course of experimentation.

3.1.1 Fibre characteristics

Table 1 Physical parameters of mulberry silk waste and viscose fibre

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Physical parameters	Mulberry silk waste	Viscose
Fibre length (cm)	130.667	139.789
Fineness (denier)	1.87 ± 0.045	3.96 ± 0.119
Fibre diameter (microns)	12.73 ± 0.226	27.46 ± 0.364

Fibres were washed in soft water and dried at room temperature for 48 hours. Mulberry silk waste fiber with linear density 1.87 denier and cut length 130.667 was blended with viscose tops exhibiting a linear density 3.96 denier and cut length 139.789 mm (Table 1).

3.1.2 Development of blended yarns

A worsted spinning system was used to blend mulberry silk waste and viscose fibre. Yarns were developed in two different counts. Mulberry silk waste was opened properly by hand and then fed into a carding machine. Further to this, the fibres were blended using gillbox. At this step, fibres were blended in three different ratios of 60: 40, 50:50 and 40:60. After this, the drawing procedure was carried out. Sheikhi et al (2010) also used gill box machinery for blending acrylic fibres with varying fineness. Since, twist per inch is a parameter that influences output behavior of yarns, it was viewed as being held constant. Variables are viewed as changing while parameters typically either don't change or change more slowly (Nykamp 2012), therefore, all the yarns were incorporated with same amount of twist (10 twists per inch).The developed yarn cones weighed 50 g each. Yarn characteristics are depicted in table 2.

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Table 2 Physical properties of blended yarns

Yarn density (Nm)	Blended ratio	Twist per inch (TPI)	Unevenness percentage (U %)
15	60% mulberry silk: 40% viscose	10	28.30
15	50% mulberry silk: 50% viscose	10	25.10
15	40% mulberry silk: 60% viscose	10	23.78
20	60% mulberry silk: 40% viscose	10	29.50
20	50% mulberry silk: 50% viscose	10	28.12
20	40% mulberry silk: 60% viscose	10	24.94

3.1.3 Construction of knitted fabrics

Developed knitted fabrics were assigned codes for ease of discussion and understanding (Table 3). Fabric knitted in 60% mulberry silk: 40% viscose yarn and 15 Nm count was called M_1, fabric made in 50% mulberry silk: 50% viscose in the same count was assigned code M_3, whereas fabric knitted in 40% mulberry silk: 60% viscose yarn in 15 Nm count was called M_5. In the similar pattern, fabric knitted in 60% mulberry silk: 40% viscose yarn and 20 Nm count was called M_2, fabric made in 50% mulberry silk: 50% viscose in the same count was assigned code M_4 and fabric knitted in 40% mulberry silk: 60% viscose yarn in 20 Nm count was called M_6.

Table 3 Coding of developed fabric proportions

Blending proportion	Yarn count (Nm)	Code assigned
60% mulberry silk: 40% viscose	15	M_1
60% mulberry silk: 40% viscose	20	M_2
50% mulberry silk: 50% viscose	15	M_3
50% mulberry silk: 50% viscose	20	M_4
40% mulberry silk: 60% viscose	15	M_5
40% mulberry silk: 60% viscose	20	M_6

Table 4 elucidates structural parameters of blended knitted fabrics. Yarn densities, tightness factor and fabric thickness for blended knitted fabrics have been determined. It is apparent from the results depicted that thickness of fabric $M_{1,}$ M_2, M_3 and M_5 was more than that of fabric M_4 and M_6. Also, weight of fabrics M_1, M_2 and M_3 was more than fabrics M_4, M_5 and M_6. The reason for this difference was the difference in yarn counts of yarns used for knitting the fabrics. Fabrics M_1, M_3 and M_5 were knitted by using a thicker yarn (15 Nm) as compared to M_2, M_4 and M_6 (20 Nm) thus carry more thickness and weight. Maximum tightness factor was calculated for fabric M_3 and M_5, however, there was no significant difference found among the values for all the fabrics.

Table 4 Physical properties of knitted fabrics made by blending different proportions of mulberry silk and viscose fibres.

Parameter	Fabric M_1	Fabric M_2	Fabric M_3	Fabric M_4	Fabric M_5	Fabric M_6
Yarn count (Ne)	15	20	15	20	15	20
Wales/ inch (WPI)	13	12	14	15	14	16
Courses/ inch (CPI)	19	18	19	20	20	18
Fabric thickness (mm)	0.883	0.840	0.763	0.663	0.883	0.703
Fabric weight, GSM	204.000	200.000	203.667	175.333	180.667	134.333
Stitch length (inch)	0.077	0.083	0.071	0.066	0.071	0.0625
Tightness factor	4.093	3.367	4.529	4.219	4.529	4.456

3.2 Method

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3.2.1 Thermal insulation

KES-F 7 THERMO LABO II, Thermal insulation tester was used for the measurement of thermal insulation in knitted fabric samples. The sample to be tested was placed over a heat plate and a constant temperature (room temperature plus another 10℃) was maintained. It was then kept in contact with the air. After this, a constant wind was then applied continuously to the sample surface. The amount of heat lost through the sample was then measured by the instrument for calculating the heat retention rate (%). There are two methods of measurement in general. One is a dry method that measures direct values for the condition when contact is made between dry skin and textile material. The other one is the wet method which takes values for conditions when contact is made between sweaty skins. The test was therefore conducted by using the dry contact method. For each specimen, the procedure was repeated three times and the final calculation was made by taking the mean of all three readings.

3.2.2 Air permeability

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The air permeability values of the blended knitted fabrics were measured by using an automatic air permeability tester. A circle of fabric (5cm^2) was clamped into the tester and through the use of a vacuum, the 125 Pa of air pressure was made different on one side of the fabric. Airflow happened from the side with higher air pressure, through the fabric, to the side with the lower air pressure. From this rate of airflow, the air permeability of the fabric was determined. For each specimen, the procedure was repeated three times and the final calculation was made by taking the mean of all three readings.

3.2.3 Water permeability

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Water permeability was tested by using spray tester TF160 (AATCC 22). Spray tester is ~~such~~ an instrument ~~which~~ that measures the water repellency of a fabric. In this test 50 ml of water was poured through a spray nozzle. The water fell onto the specimen which was mounted over a 6 inches diameter embroidery hoop and fixed at an angle of 45 degrees. When the water was used up, it was observed and a grade was given to the specimen. For each specimen, the procedure was repeated three times and the final calculation was made by taking the mean of all three readings.

Fig 1 Water permeability tester

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Spray rating:

Grade 1: All of the surface is wet.

Grade 2: Half of the surface is wet. It usually means the sum of small and disconnected areas of wet.

Grade3: Only small and disconnected areas of wet on the surface.

Grade4: The surface appears water drop but not wet.

Grade5: The surface is neither wet nor water drop

4. Results and Discussion

4.1 Thermal insulation

The thermal insulation characteristics of various knitted fabrics (blended in 3 different proportions) were analyzed (Table 5). It was observed that fabrics with a higher content of silk fibre *viz.* fabric M_1 and M_2 showed higher values for thermal insulation (Fig 2). The outcome reveals that fabrics M_1 and M_2 hold significantly higher ($p \leq .05$) insulating character than other fabrics. This may be understood by considering figures for fabric thickness and weight for blended knitted fabrics.

This is because of higher fabric thickness, lesser air permeability and higher tightness factor. Also, it was observed that the thermal insulation value of the knitted fabrics depends on the stitch/loop length (Ramchandran et al 2010), the knitted fabric having higher stitch length shows lower thermal insulation behavior. With a higher density of fibres, thermal insulation value tends to increase (Marolleau et al 2007). In the present case also, fabrics with higher tightness factor exhibit higher thermal insulation values. In temperature ~~region~~regions, where there is never too hot and never too cold, insulating character of fabric should be more than 1 Clo, however, a higher the 2 Clo may produce unnecessary heat for the climate. Fabric M_1 and M_2 seem appropriate for usage in this case.

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Table 5 Analysis of fabrics blended knitted fabrics for comfort properties

Comfort parameter	Fabric M_1	Fabric M_2	Fabric M_3	Fabric M_4	Fabric M_5	Fabric M_6	Critical difference
Thermal insulation (Clo)	1.140^a	1.145^a	0.980^{bc}	1.028^b	0.972^b	1.034^b	0.095
Air permeability (CFM)	439.2^a	435.7^b	687.4^c	571.8^a	715.7^d	505.8^e	14.642
Water permeability (Grade)	3^a	3^a	3.5^b	2^d	2.5^c	2^d	0.057

^{a,b,c} Significant at 5 % level of significance, same alphabet= no significant difference, different alphabet= significant difference, CD= Critical difference, NS= Not significant

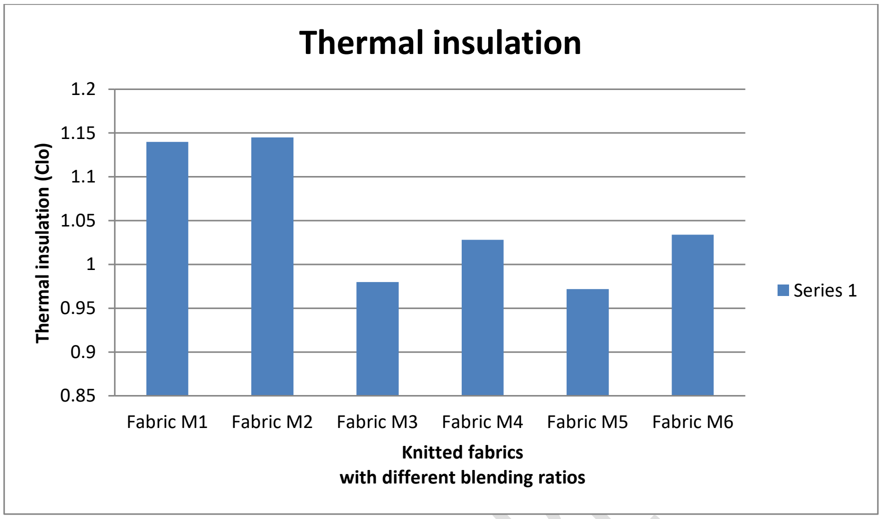

Fig2 Thermal insulation behaviour of knitted fabrics blended in three different proportions

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4.1.1 Effect of Fabric thickness, Fabric weight, Stitch length and Tightness factor on Thermal insulation.

Table 5 shows statistical analysis of results at a 5 % level of significance. The thermal insulation values of the knitted fabrics show significant differences (critical difference 0.095) at 95% degree of freedom. Table 6 elucidates the findings of regression analysis of thermal insulation with four independent variables *viz.* Fabric thickness, fabric weight, stitch length and tightness factor. Regression coefficient shows a positive impact of fabric thickness and fabric weight on thermal insulation, which clearly means that thermal insulation also rises with the ~~rise~~increase in the value of fabric thickness and weight, however, the effect was not found to be significant in both cases. As regards to stitch length, a negative coefficient reveals a non-significant negative relationship. Tightness factor, again positively influences the insulating character of the fabric. The relationship was also found to be significant in this case. Frydrych et al (2002) also concluded in their study that higher insulating properties can be achieved by the right choice of fabric thickness and fabric cover factor. Other than this, the type of content of the fabric greatly affects the thermal insulation character of the fabric. In the present study, fabrics M_1 and M_2 were knitted by using 60% mulberry silk: 40% viscose and therefore silk content is more than the other fabrics. Silk composition shows higher insulating properties in comparison to cellulosic fabrics.

Table 6 Effect of fabric thickness, fabric weight, stitch length and tightness factor on thermal insulation of blended knitted fabrics

Thermal Insulation	Independent parameters				
		Coefficient	**Standard error**	**t-value**	**p value**
	Constant	1.995	0.593	3.364	0.005
	X1	0.141	0.218	0.646	0.530
	X2	0.001	0.001	0.613	0.550
	X3	-5.507	5.061	-1.088	0.296
	X4	0.180	0.065	-2.754	0.016
	R^2 (%)	0.724			

t-value= t statistic value, p= probability value, *Significant at 5 percent level of significance

X1= Fabric thickness

X2= Fabric weight

X3= Stitch length

X4=Tightness factor

4.2 Air permeability

Air permeability was found to be the highest for fabric M$_5$ followed by fabric M$_3$.Ogulata (2006) stated that air permeability is mainly dependent upon the fabric's weight and construction (thickness and porosity). It can be clearly seen in table 7 that fabrics with lower thickness and weight have scored higher figures for air permeability. Air permeability is a significant measure of comfort as it can influence the body in more than one way. When fabrics allow the air to pass in a momentous quantity, the human body cools itself by sweat production and evaporation during periods of high activity. Also, the thermal resistance of a fabric is strongly dependent on the enclosed still air, and this factor is in turn influenced by the fabric structure (Dhinakaran 2007). However, too much allowance to air can hinder the convenience of the body in temperate regions. It will cause too much passage of air which is not suitable for a region of temperature 18°C or around (The Environment Literary council 2017).

4.2.1 Effect of Fabric thickness, Fabric weight, Stitch length and Tightness factor on air permeability

Table 7 reveals impact of various constructional parameters on the air permeability of the fabric. Regression coefficient shows a negative impact of fabric thickness and fabric weight on air permeability, which means that the air permeability of blended knitted fabrics will decrease with a rise in the value of fabric thickness and weight, however, the effect was not found to be significant in both the cases. Air permeability decreases with fabric weight and has a significant negative correlation (Debnath and Madhusoothanan 2010). As regards stitch length, a positive coefficient reveals a significant negative

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relationship. Tightness factor, again negatively influences air permeability of the fabric. The relationship was also found to be significant in this case. Herath (2013) concluded in his study that there was a correlation between fabric tightness, air permeability and fabric thickness as knitted fabrics became tighter, their weight and thickness were higher, while their air permeability was found to be lower.

Table 7 Effect of fabric thickness, fabric weight, stitch length and tightness factor on air permeability of blended knitted fabrics

Air permeability	Independent parameters	Coefficient	Standard error	t-value	p value
	Constant	81.419	1432.088	0.57	0.956
	X1	-531.377	527.399	-1.008	0.332
	X2	-1.168	2.325	-0.502	0.624
	X3	13960.610	123.827	1.143	0.274
	X4	-23.234	157.650	0.147	0.885
	R^2 (%)	0.339			

t-value= t statistic value, p= probability value, *Significant at 5 percent level of significance

X1= Fabric thickness

X2= Fabric weight

X3= Stitch length

X4=Tightness factor

4.3 Water permeability

Highest score was obtained by fabric M_3 (3.5), followed by similar grade of 3 by fabrics M_1 and M_2 (Table 5). Results reveal that water permeability of most fabrics was not so high. For a temperate region, fabrics with an average level of permeability to water will work well Hyun-Ah Kim (2021), however, the fabrics under study, fabrics M_1, M_2 and M_3 show average levels of water permeability, while fabrics M_4, M_5 and M_6 may be called poor performers on this scale. Fabrics M_1 and M_2 however, carry lesser amount of hydrophilic fibre (viscose rayon), still exhibited higher grades of water permeability. The reason for this may understood by considering the influence of fabric thickness, fabric weight, stitch length and tightness factor on fabric performance.

4.3.1 Effect of Fabric thickness, Fabric weight, Stitch length and Tightness factor on water permeability

Table 8 reveals impact of various constructional parameters on water permeability of the fabric. Regression coefficient shows negative impact on fabric thickness water permeability, which means that water permeability of blended knitted fabrics will witness a fall with a rise in the value of fabric thickness, however, the relationship was found to be non-significant. Wilbik-Hałgas et al (2005) concluded in their study that water vapour permeability does not correlate with thickness in knitted fabrics. Fabric weight, however, will negatively affect the amount of water entering into fabric surface. As regards to stitch length, again a negative coefficient is a sign of significant negative relationship. Also, in a study by Chidambaram et al (2011), the anticipated increase in air permeability and relative ~~water-vapour~~water-vapor permeability with a decrease in yarn linear density and an increase in loop length was observed. In the present study, if densities of yarns used for knitting were analyzed, it was observed that fabrics knitted with yarn of lower densities have exhibited higher permeability to water. Tightness factor, on the other hand, also negatively influences water permeability of the fabric. The relationship was also found to be significant in this case. Tightly constructed fabrics transmit water vapour predominantly by a diffusion-controlled mechanism similar to air permeability (Lomax 1985).

Table 8 Effect of fabric thickness, fabric weight, stitch length and tightness factor on water permeability of blended knitted fabrics

Water permeability	Independent parameters	Coefficient	Standard error	t-value	p value
	Constant	3.302	4.227	0.781	0.449
	X1	-2.646	1.557	-1.700	0.113
	X2	0.004	0.007	0.639	0.534
	X3	-9.860	36.066	-0.273	0.789
	X4	-0.131	0.465	0.281	0.783
	R^2 (%)				

t-value= t statistic value, p= probability value, *Significant at 5 percent level of significance

X1= Fabric thickness

X2= Fabric weight

X3= Stitch length

X4=Tightness factor

4.4 Relationship of Air permeability with Thermal insulation

It has been observed that quality of air permeability also has great impact on insulating power of the fabrics. Ramachandran et al (2010) mentioned that thermal conduct values increase with rise in air permeability of knitted fabrics. In other words, thermal insulation values decrease with increase in fabric air permeability. During testing, it was viewed that both the properties were seen to have inverse association.

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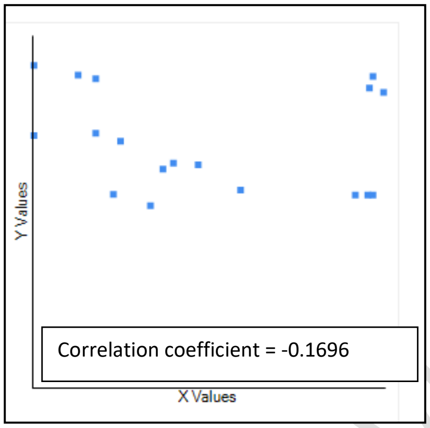

Fig 3 Correlation between Thermal insulation and Air permeability

(X values= Thermal insulation, Y values= Air permeability)

Correlation coefficient was calculated and a technically negative, but non-significant, correlation between both variables was noticed. Air layers trapped within a clothing microenvironment contribute to the thermal insulation afforded by the ensemble. Any exchange of air between the external environment and these trapped air layers results in a change in the ensemble's thermal insulation (Bouskill 2002). Therefore, the harmony between the two parameters can only bring about an appropriate fabric for temperate regions.

4.5 Relationship of water permeability with Thermal insulation

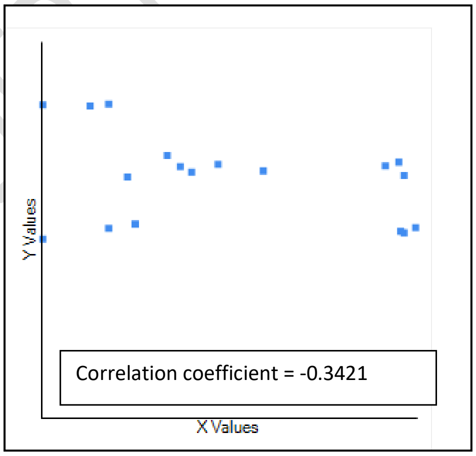

Fig 4 Correlation between Thermal insulation and Water permeability

(X values= Thermal insulation, Y values= Water permeability)

Heat transfer through clothing is an important topic related to thermal comfort in environmental engineering and functional clothing design. The total heat transmitted through clothing is commonly considered as the sum of the dry heat transfer and the evaporative heat transfer (Chen et al 2003). Hence, permission for moisture to enter the fabric surface is an important parameter ~~which~~ that will affect the insulating power of the material to large extent. When tested statistically for the present test samples, a negative correlation was found between the two variables; however, the relationship was not significant.

5. Conclusion

Comfort is mostly a subjective expression and has not been judged much in objective manner so far. It can be expressed by the experience of a person, however, objective computation of the same by considering factors and properties influencing comfort. In case of apparel, properties *viz.* thermal insulation, air permeability and water permeability were judged and findings were analyzed for suitability to temperate regions. Figures for thermal insulation of fabrics knitted with 60% mulberry silk: 40% viscose, in both yarn counts, 15 and 20 Nm were 1.140 and 1.145 Clo respectively which appropriately suit general climate of temperate regions. Higher silken content ~~alongwith~~along with constructional parameters of fabric thickness, weight, stitch length and tightness factor has played vital role in giving values above 1 Clo. Air permeability on the other hand is much higher for fabrics knitted with a composition of 50% mulberry silk: 50% viscose and 40% mulberry silk: 60% viscose in yarn count 15 and 20 Nm. But too much airflow can cause feeling of uneasiness and cold in temperatures of 18°C or below. Figures for fabrics knitted with 60% mulberry silk: 40% viscose in both yarn counts 15 and 20 Nm were found to be 439.2 and 435.7 CFM, which were not too high, but ~~will~~ would allow a good amount of air to pass through it. An average score for water permeability was also scored by both these fabrics making them suitable to be used in temperate climates for apparel use. A mix and balance of available figures assert on having evenness in warm and cool ~~feeling~~feelings. Study agrees with past reviews that constructional parameters hugely affect the performance of fabrics in terms of comfort. Changes in thickness, weight, tightness factor and stitch length has affected the final properties of blended knitted fabrics. Also, higher silk content in fabrics knitted with 60% mulberry silk: 40% viscose in both the counts was responsible for convenient insulating aspect and water permeability.

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References

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