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Comfort properties of some cellulosic fabrics

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Abstract : Thermal insulation, water vapour permeability, and air permeability were measured for three types of single jersey knitted fabrics, knitted at three different tightness factors on two single jersey knitting machines with two gauges. Fabrics were knitted from yarns with 30 Ne with the following fiber contents (100% cotton, 50% viscose / 50% cotton, 50% modal / 50% cotton). It was found that Modal/Cotton fabric gives higher air permeability, water vapour evaporation, and lower thermal resistance then comes 100% Cotton fabric then Viscose/Cotton fabric. Also it was found that fabric porosity is highly correlated with Thermal resistance, Air permeability, and Water vapour permeability for all fabrics under study. While fabric thickness affects significantly the properties under study for cotton, and modal/cotton fabrics. Also the loop length affects the comfort properties.
Keywords: Cellulosic fabrics, Modal Cotton blends, Viscose Cotton blends, Thermal resistance, Air permeability, Water vapour permeability
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Introduction

Comfort is multidimensional and complex. The psychological comfort has different aspects, thermo psychological comfort involving moisture and heat transfer through fabrics, sensorial comfort which contains different neural sensations when textiles comes into contact with skin, body movement comfort which relates to the textile ability that allows movement freedom, reduce body shaping and burden as required, aesthetic appeal which means subjective perception of clothing to the eye, hand, nose, and ear that contributes to the overall well-being of the wearer[1]. Pique structures were produced from 100% cotton and modal yarns from two different yarn counts (Ne 30, Ne 40) on 24 machine gauges and 30 inches diameter single jersey knitting machine. Fabrics with four different tightness were obtained. Thermal properties, air permeability, and thickness were measured. It was found that the finer the yarn the higher the air permeability. Cotton fabrics have lower thermal conductivity and higher thermal resistance than modal fabrics. Also modal fabrics have higher air permeability than cotton fabrics so they are preferred for warmer climates. There were no correlation between thermal resistance and fabric thickness for the investigated pique fabrics. Raw material properties highly affected the thermal performance[2]. 100% Egyptian cotton, 100% modal, and 100% micro modal yarns with Ne 30/1 were used to knit single jersey fabrics at constant stitch length 2.8 mm on knitting machine with gauge 24. It was found that 100% cotton fabric has less air permeability than 100% modal and micro modal fabrics. The lowest value of water vapor permeability was for the micro modal fabric then comes the modal fabrics and finally comes the cotton fabric. Cotton fabric had the highest thermal insulation, then comes the modal fabric, and then the micro modal fabric[3]. An artificial neural network model was constructed to predict the thermal conductivity of different knitted fabrics with different structures, different yarn counts, and different lycra proportion and count, made from cotton fabrics, viscose fabrics, and pleated knitted with lycra. Thermal conductivity was predicted from knitted structure, yarn composition, yarn count, machine gauge, lycra proportion, lycra yarn count, weight per unit area, and thickness. It was found that ANN can predict the thermal conductivity with average error 4%. This model was better than the linear model that cannot take into considerations the complex interaction, the nonlinear relationship that exists between operating parameters, properties of raw material and thermal conductivity[4]. The air permeability of pique knitted fabrics made from Ne 30, Ne 40 viscose and modal yarns with four stitch lengths and so four tightness factors was studied. It was found that the finer the yarn the higher the air permeability. The correlation between porosity and air permeability was higher in case of viscose fabrics. Tightness correlates negatively with air permeability. The modal pique structure has higher air permeability than viscose fabrics. Fabric thickness correlates negatively with air permeability[5]. The effect of linear density of the yarn, loop length on some comfort properties was studied. It was found that cotton/ polyester fabrics that have higher loop lengths have higher air permeability and water vapor permeability, and lower thermal conductivities [6].

Cotton and modal single jersey fabrics were knitted with two different yarn counts (Ne 30, Ne 40) on the same knitting machine with four different stitch lengths. It was found that tightness factor correlates more with air permeability than fabric thickness. A better correlation between porosity and air permeability was found in case of cotton fabrics (R 0.92 for Ne 40, 0.88 for Ne 30)than modal fabrics (R=0.69 for Ne 40, 0.58 for Ne 30) . Modal fabrics showed higher air permeability than cotton fabrics[7]. The effect of loop length has more influence on porosity than the stitch density and fabric thickness[5,7]. A theoretical model that can predict air permeability from porosity and other fabric parameters was established using 18 plain knitted fabrics with various knitting parameters. Two types of cotton yarns were used (ring and compact yarn) with three different yarn counts. The fabrics were knitted with three different tightness. It was found that fabric which had less courses per centimeter and finer yarn had the highest air permeability. According to some formulations the pore size decreased when stitch density, stitch length, or yarn diameter increased. Air permeability and fabric porosity found to be strongly correlated to each other[8]. The effect of loop length and different blend ratios of single jersey knitted fabrics on some comfort properties was investigated. Different blend ratios (polyester 50%/viscose 50%, polyester 50%/cotton 50%, polyester 60%/cotton 40% polyester, 70%/cotton 30% polyester) were used to produce fabric using 20 Tex yarn count with three tightness factors. The increase in loop length of fabric increased the air permeability and water vapor permeability. The best fabric that gives the highest comfort properties was polyester 50%/ viscose 50% with loose structure (less tightness factor)[9.] A positive correlation between fabric thickness and thermal insulation was found for textile fabrics [6,10].

Experimental

Preparation of samples

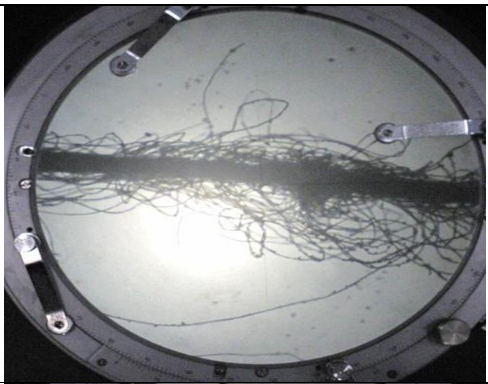
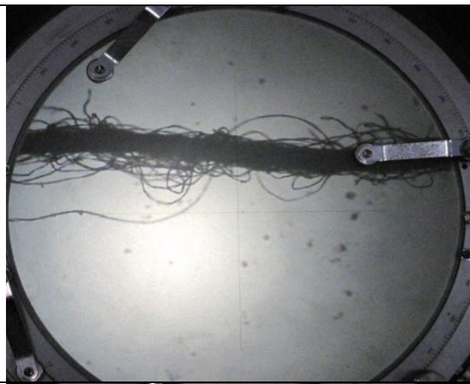
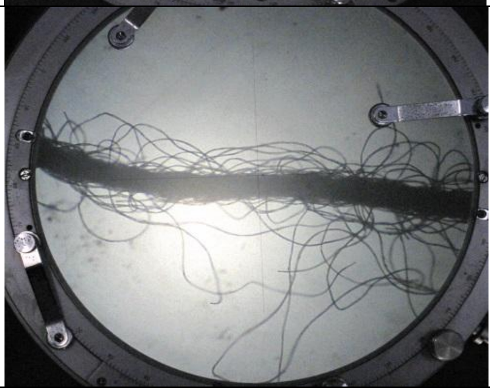
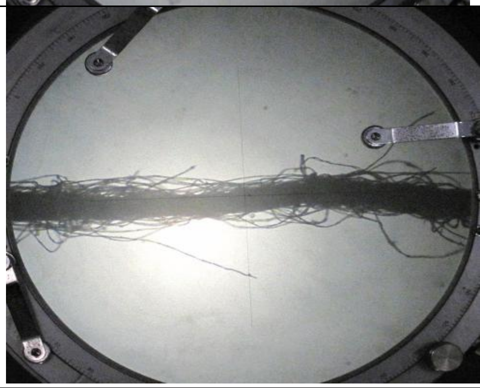
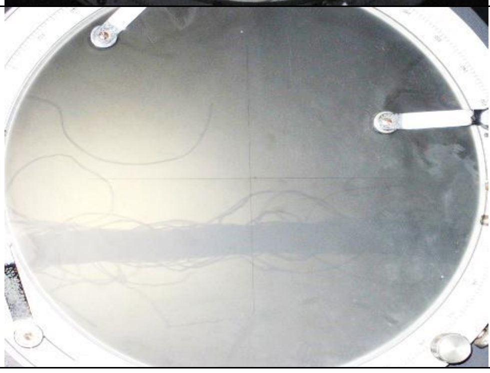
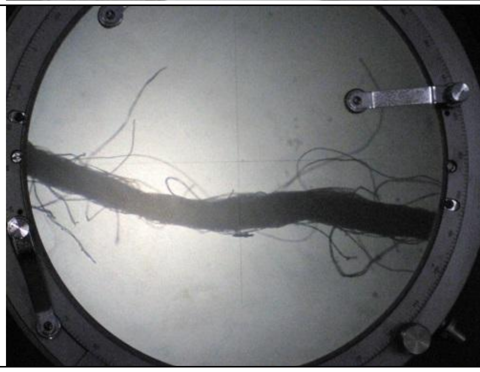
100% combed cotton yarn as well as 50% Viscose / 50% Cotton, and 50% Modal / 50% Cotton yarns were obtained from a spinning mill with the same count Ne30.

Three kinds of cellulosic knitted fabrics were produced from these three kinds of yarns on two knitting machines.17 inches diameter Single jersey circular knitting machine gauge 24, and 21 diameter Single jersey circular knitting machine gauge 28. The fabrics were produced from three different yarn types (100% Cotton, 50% Viscose / 50% Cotton, and 50% Modal / 50% Cotton) .The two knitting machines with the two gauges were adjusted to produce three different loop lengths (2.7, 2.9, 3.1 mm) which gives three different tightness factors for each kind of fabric.

Finishing of fabric samples

The fabrics were finished according to the factory procedures. The produced fabrics were scoured to remove the noncellulosic materials according to their type. 100% Cotton and 50% modal/50% cotton fabrics were scoured at 95^{o} C for 30 minutes, while 50% viscose/50% cotton was scoured at 70^{o}C for 20 minutes followed by rinsing. Then the scoured fabrics were finished using wetting detergent, fatty acid, silicon hydrophilic, and polyethylene by pad-dry method followed by compactor and left for 24 hours for relaxation. Finally, finished fabric samples were taken to measure their physical and comfort properties. One yarn from each fabric type was raveled and put under Nikon Profile Projector Model V-12 (an apparatus which magnifies the yarn). Two photos of each yarn type were taken at two different lateral positions. Table 1 shows the three different yarn types used in this study with their photos.

Table 1 Yarn photos and specifications

Material	Count Ne	Twist factor	Photos of Yarn
100% Cotton	30	3.7	 
50% Viscose/ 50% Cotton	30	3.86	 
50% Modal/ 50% Cotton	30	3.76	 

From table 1 it is obvious that modal/cotton yarn has less hairiness than cotton and viscose /cotton fabrics.

Test methods

All the fabric samples were relaxed after fabric finishing for at least 48 hours.

Fabric weight per unit area

Standard procedures for measuring GSM for produced fabric samples as per (ASTM-D3776) [11] followed by using digital measuring balance.

Fabric thickness

Fabric samples thickness were measured according to standard (ASTM-D1777) [12].

Measuring stitch density

Stitch density obtained by counting the number of courses and the number of wales in one inch according to standard (ASTM - D3887) [13].

Measuring stitch length

Stitch length of each fabric sample was measured according to (ASTM - D3887) [13].

Air permeability

Air permeability of the samples were measured according to (ASTM - D 737) [14].

Water vapour permeability

Water vapour permeability of fabric samples were measured on Permetest at National Institute For Standard according to the standard ISO 11092 [15].

Thermal resistance

Thermal resistances of fabric samples were measured on Permetest according to the standard ISO 11092 [15]. The thermal resistance was measured in mk. m^2/w.

Calculating fabric porosity

Each fabric sample porosity was calculated according to the following equation

$P = 1 - (GSM*C*W/ h*1000*\rho)$

Where:

C: courses per centimeter W: wales per centimeter

h: sample thickness (mm) ρ: fiber density

Results and Discussion

Table 2 displays the loop length, weight, thickness, porosity, air permeability, thermal resistance, and water vapour permeability of cotton, viscose cotton, and modal cotton fabrics produced on knitting machine gauge 24, while table 3 displays the same properties for gauge 28.

Table 2 Fabric specifications of fabrics produced on gauge 24

Material	Loop length mm	Weight gm/m^2	Stitch density	Thickness mm	Porosity %	Thermal resistance mk.m^2/w	Water vapour Permeability %	Air permeability $cm^2/cm^3/s$
C	2.66	1.315	270	0.4	42.73	11.66	65.2	94
	2.87	1.227	248	0.4	50.92	12.7	65	102.8
	3.1	1.15	225	0.388	56.98	13.76	65	157.8
V.C	2.68	1.43	285	0.407	43.98	11.4	62.04	102
	2.87	1.32	238	0.407	49.88	8.58	65	113.4
	3.06	1.2	225	0.393	55.39	7.5	66	150
M.C	2.67	1.375	270	0.411	41.53	13.64	66.04	100
	2.9	1.25	229.5	0.394	52.87	11.2	67	148
	3.08	1.137	217.5	0.38	58.85	10.24	67	173.8

C: cotton fabric V.C: viscose/ cotton fabric M.C: modal/cotton fabric

Table 3 Fabric specifications of fabrics produced on gauge 28

Material	Loop length mm	Weight gm/m^2	Stitch density	Thickness mm	Porosity %	Thermal resistance mk.m^2/w	Water vapour Permeability %	Air permeability cm^2/cm^3/s
	2.67	1.428	270	0.41	39.03	11.66	56.9	65.2
	2.87	1.236	240	0.408	53.09	12.7	61.32	95
C	3.05	1.158	203	0.407	62.73	13.76	62.86	143
	2.67	1.426	277.5	0.406	36.71	11.4	59.79	83.4
	2.87	1.312	239.25	0.4	47.47	8.58	62.96	102
V.C	3.05	1.256	210	0.4	57.29	7.5	63	140
	2.66	1.37	272	0.389	37.99	13.64	56	117
	2.85	1.262	248	0.386	47.52	11.2	62.08	140
M.C	3.05	1.15	217.5	0.383	57.73	10.24	63.2	163

C: cotton fabric V.C: viscose/ cotton fabric M.C: modal/cotton fabric

Thermal properties

Figures 4 a, b represent the thermal resistance of cotton, viscose/cotton, and modal cotton fabrics produced on gauges 24 and 28 respectively.

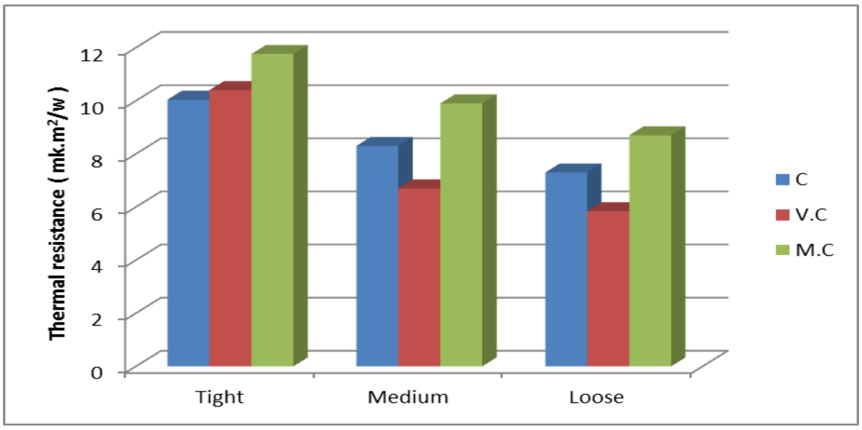


Figure (4-a) Thermal resistance of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 24

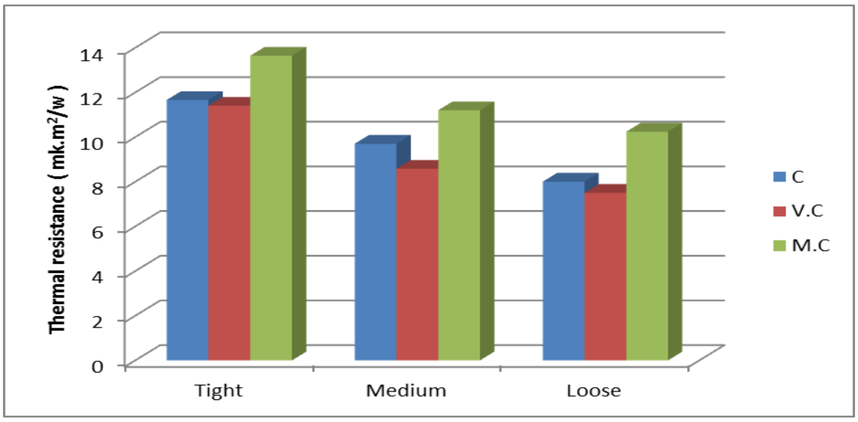


Figure (4-b) Thermal resistance of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 28

From both figures it is obvious that modal/ cotton fabric has higher thermal resistance than that of cotton and viscose/ cotton fabrics. Also the thermal resistance is the highest for tight structure (the lowest loop length) then it decreased while fabric tightness decreased. This is due to that fabric with biggest loop length or with looser structure contains more air and less fiber material so the thermal conductivity also decreased (thermal conductivity of fiber is higher than thermal conductivity of air). Since Rct = h/ λ while Rct is thermal resistance, h is fabric thickness, λ is thermal conductivity. The amount of decreasing in thickness may be more than the amount of decreasing in thermal conductivity so the thermal resistance decreased.

Figures (5-a,b), (6-a,b), (7-a,b) show the correlation between thermal resistance and porosity for cotton, viscose/cotton, and modal/cotton fabrics respectively.

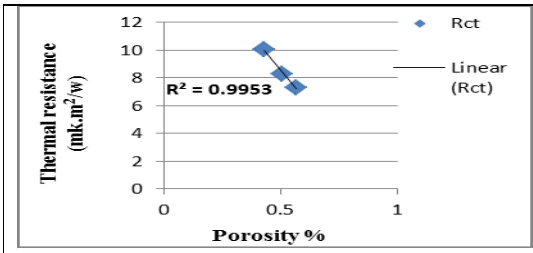


Fig.(5-a) Correlation between thermal resistance and fabric porosity for cotton fabrics produced on gauge 24

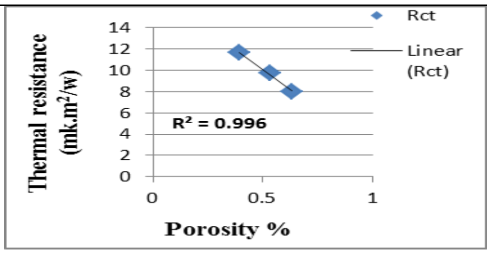


Fig.(5-b) Correlation between thermal resistance and fabric porosity for cotton fabrics produced on gauge 28

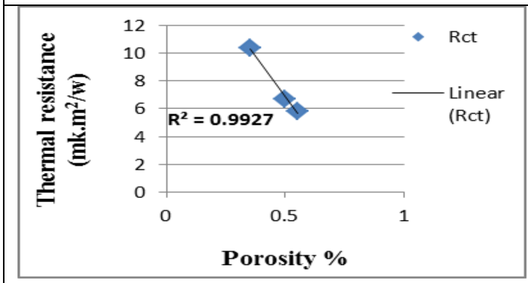


Fig.(6-a) Correlation between thermal resistance and fabric porosity for viscose/ cotton fabrics produced on gauge 24

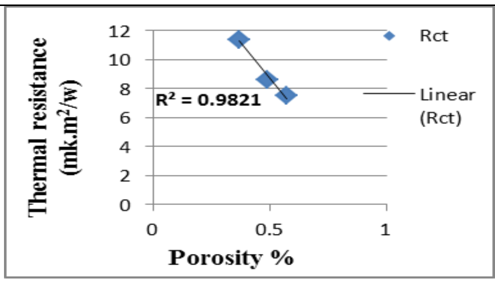


Fig.(6-b) Correlation between thermal resistance and fabric porosity for viscose/ cotton fabrics produced on gauge 28

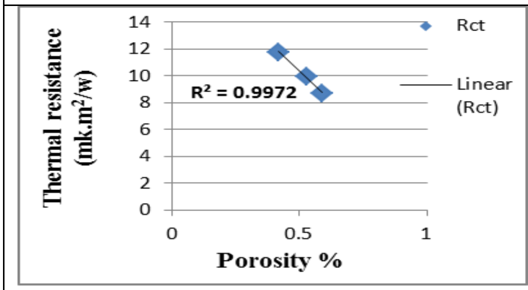


Fig.(7-a) Correlation between thermal resistance and fabric porosity for modal/ cotton fabrics produced on gauge 24

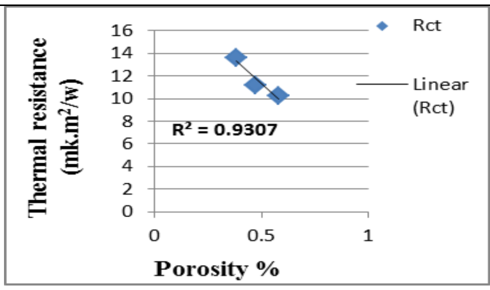


Fig.(7-b) Correlation between thermal resistance and fabric porosity for modal/ cotton fabrics produced on gauge 28

Rct: thermal resistance

There is high negative correlation between thermal resistance and porosity for the three kinds of fabrics. The higher the porosity the lower the thermal resistance. This emphasizes what concluded from figures (4-a, b), because as the stitch length increased the porosity increased and also the thermal resistance decreased

Air permeability

Figures (8 a, b) show the air permeability of cotton, viscose/cotton, and modal cotton fabrics produced on gauges 24 and 28 respectively

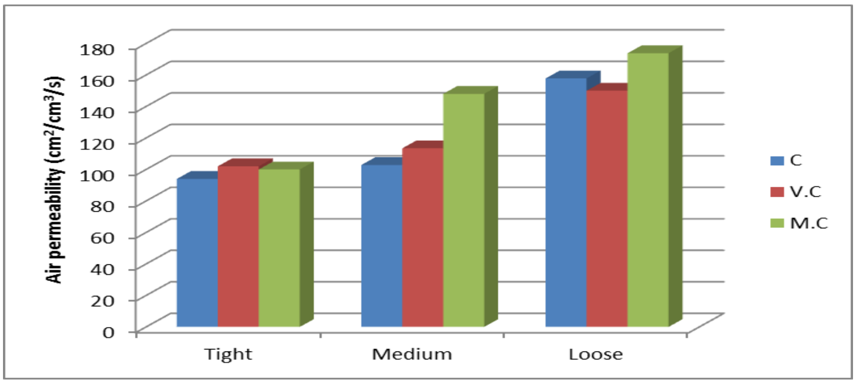


Figure (8-a) Air permeability of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 24

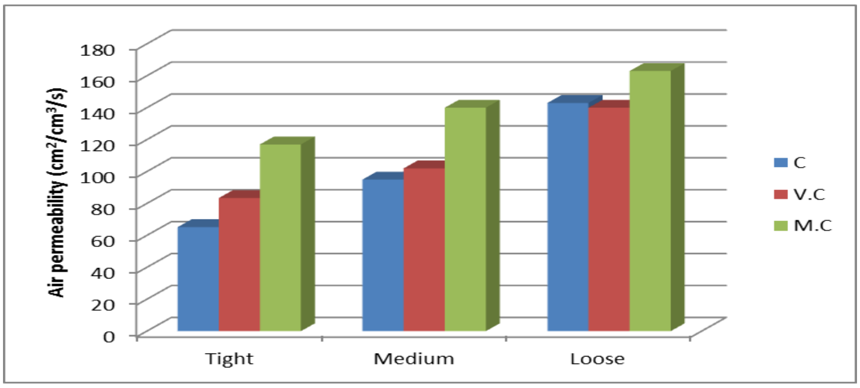


Figure (8-b) Air permeability of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 28

From both figures (8-a, b) It can be noticed that modal/ cotton fabrics have the highest air permeability then comes cotton and viscose/cotton fabrics (agrees with5, 7). This may be due to the lower hairiness of modal/cotton yarn than cotton and viscose/cotton yarn (see table1). The bigger the loop length (looser structure) the higher the air permeability (agrees with 6). Figures (9-a,b), (10-a,b), (11-a,b) show the correlation between air permeability and porosity for cotton, viscose/cotton, and modal/cotton fabrics respectively.

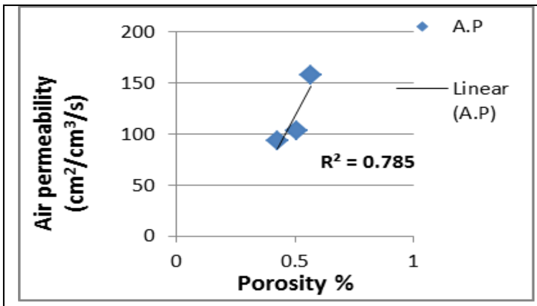


Fig.(9-a) Correlation between air permeability and fabric porosity for cotton fabrics produced on gauge 24

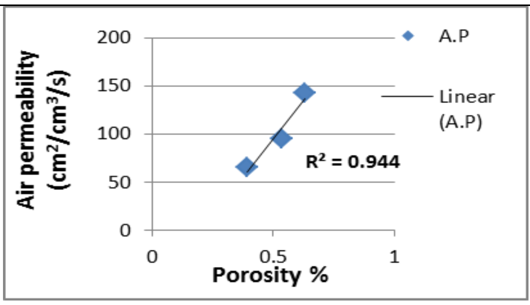


Fig.(9-b) Correlation between air permeability and fabric porosity for cotton fabrics produced on gauge 28

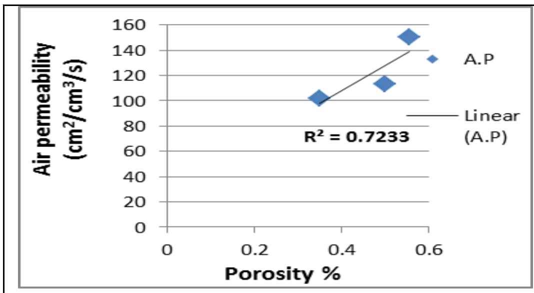


Fig.(10-a) Correlation between air permeability and fabric porosity for viscose/cotton fabrics produced on gauge 24

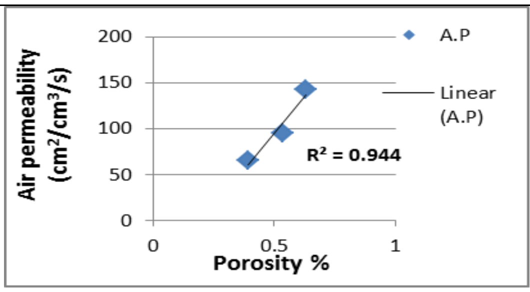


Fig.(10-b) Correlation between air permeability and fabric porosity for viscose/cotton fabrics produced on gauge 28

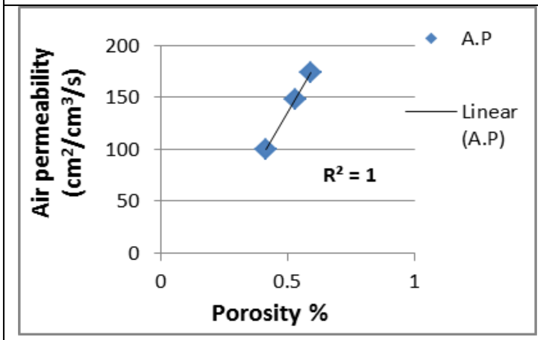


Fig.(11-a) Correlation between air permeability and fabric porosity for modal/cotton fabrics produced on gauge 24

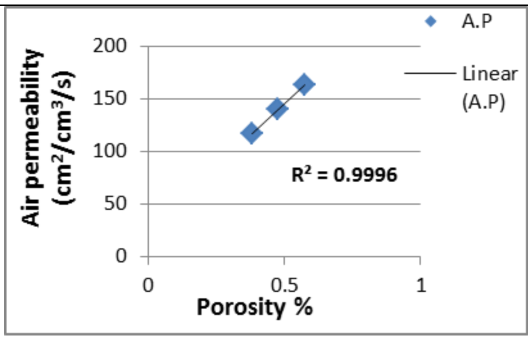


Fig.(11-b) Correlation between air permeability and fabric porosity for modal/cotton fabrics produced on gauge 28

A.P : Air permeability

The high correlation between air permeability and porosity for the three kinds of fabrics could be noticed (agreed with 8). The higher the fabric porosity the higher its air permeability. The best correlation between porosity and air permeability was noticed in case of cotton/ modal fabrics. This could be due to the lower yarn hairiness of these fabrics.

Water vapour evaporation

Figures (12 a, b) show the water vapour evaporation of cotton, viscose/cotton, and modal cotton fabrics produced on gauges 24 and 28 respectively.

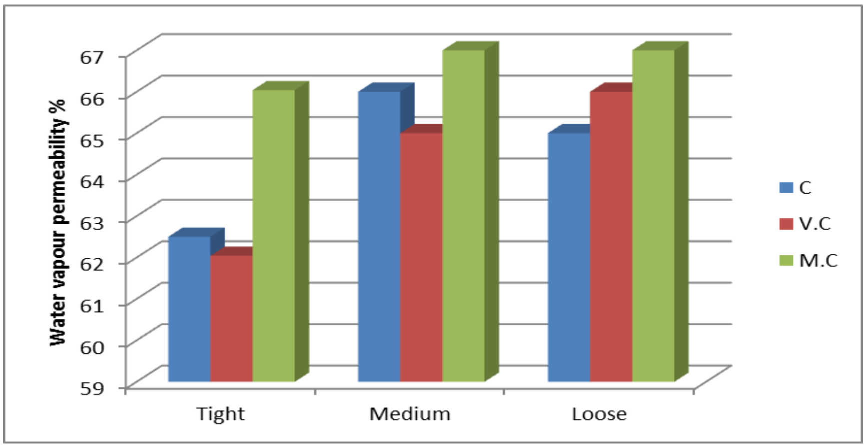


Figure (12-a) Water vapour evaporation of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 24

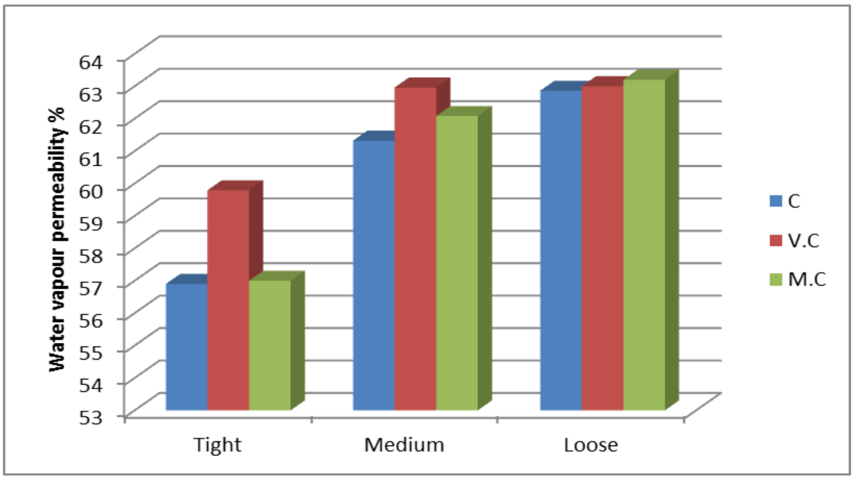


Figure (12-b) Water vapour evaporation of cotton, viscose/cotton, and modal cotton fabrics produced on gauge 28

The results obtained from these two figures do not show a certain result. Modal /cotton fabric have the highest water vapour evaporation because this is the case only for fabrics produced on gauge 24. It is obvious that the higher the loop length (more open structure) the higher the water vapour permeability (agrees with 6).

Figures (13-a,b), (14-a,b), (15-a,b) show the correlation between water vapour permeability and porosity for cotton, viscose/cotton, and modal/cotton fabrics respectively.

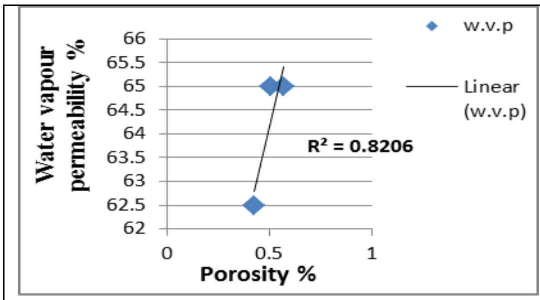


Fig.(13-a) Correlation between water vapour permeability and fabric porosity for cotton fabrics produced on gauge 24

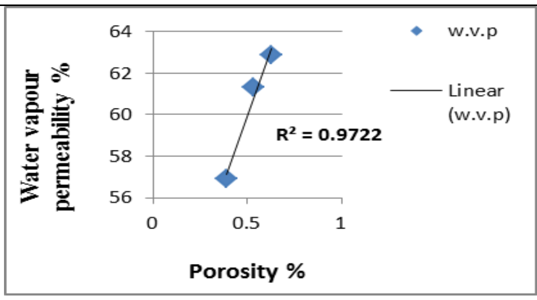


Fig.(13-b) Correlation between water vapour permeability and fabric porosity for cotton fabrics produced on gauge 28

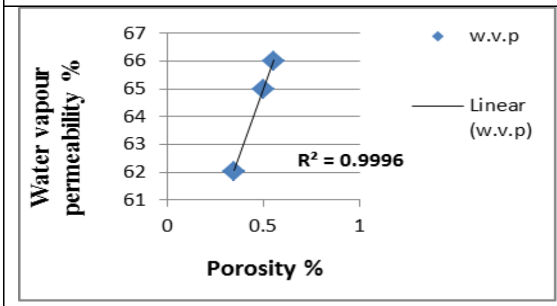


Fig.(14-a) Correlation between water vapour permeability and fabric porosity for viscose/cotton fabrics produced on gauge 24

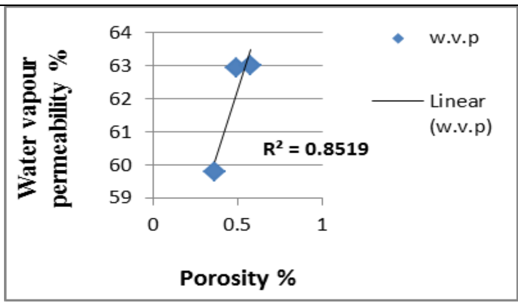


Fig.(14-b) Correlation between water vapour permeability and fabric porosity for viscose/cotton fabrics produced on gauge 28

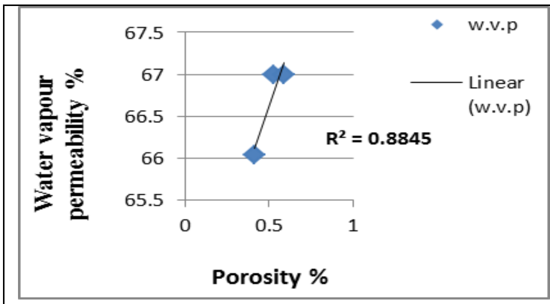


Fig.(15-a) Correlation between water vapour permeability and fabric porosity for modal/cotton fabrics produced on gauge 24

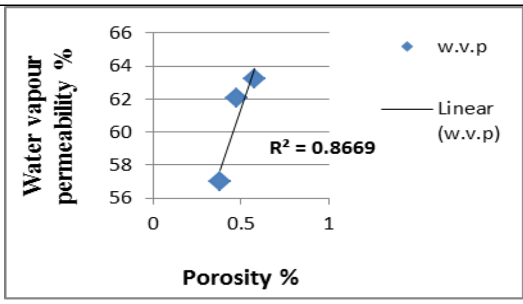


Fig.(15-b) Correlation between water vapour permeability and fabric porosity for modal/cotton fabrics produced on gauge 28

w.v.p: water vapour permeability

The water vapour permeability has a good correlation with fabric porosity for the three kinds of fabrics.

A multiple linear regression analysis was done to predict the tendency of thermal resistance, air permeability, and water vapour permeability from fabric properties for each fabric type. Tables 4,5, and 6 show the best regression equation for each property for cotton, viscose/cotton, and modal/cotton fabrics.

Table 4 Regression equations for cotton fabrics

Property	**Regression equation**
Thermal resistance	Rct=-22.4-13.4 P+ 95.63 h R^2= 0.951
Air permeability	A.P= 748.1+ 293.6 P-1959.6 h R^2= 0.944

P : fabric porosity **h: fabric thickness**

Table 5 Regression equations for viscose/cotton fabrics

Property	**Regression equation**
Thermal resistance	Rct=181.4- 20.6 P R^2= 0.80
Air permeability	A.P =7.24 + 228.6 P R^2= 0.716
Water vapour permeability	w.v.p=-54.99 + 17.2 P R^2= 0.932

P : fabric porosity

Table 6 Regression equations for modal/cotton fabrics

Property	**Regression equation**
Thermal resistance	Rct=24.16-21.5 P-52.6 h R^2= 0.946
Air permeability	A.P=390.2+ 252.4 P-995.6 h R^2= 0.972
Water vapour permeability	w.v.p=-100+ 49.8 P+ 356.5 h R^2= 0.932

P : fabric porosity **h: fabric thickness**

From tables 4, 5, 6 it is obvious that thermal resistance, air permeability are function of fabric porosity for the three fabric types (agrees with 7). Fabric thickness found to be significant factor with porosity that affects air permeability. Fabric thickness correlates negatively with air permeability in case of cotton and modal /cotton fabrics (agrees with 5). While it correlates with thermal resistance positively for cotton fabric, and negatively for modal /cotton fabrics. In case of viscose/ cotton fabrics the thickness found to be nonsignificant factor affecting thermal resistance, air permeability, and water vapour permeability (may be a larger number of samples needed to ascertain this result). This may be due to finishing process which affects viscose fibers. See table 1-a high hairiness of viscose /cotton yarn was noticed after finishing process.

Conclusion

This study is a comparative study that determines the difference in some comfort properties for some cellulosic fabrics. Fiber type is a main factor that affect the comfort properties of the fabric. Modal/cotton fabrics gives the highest air permeability, highest thermal resistance than that of cotton, and viscose/cotton fabrics. This means that modal/cotton fibers are good to be used in summer clothes especially that they also have higher values of water vapour permeability. Fabric porosity is the key factor that affects thermal resistance, air permeability, and water vapour permeability of the fabric. Also the effect of loop length on thermal resistance, air permeability, and water vapour permeability is obvious. The best relation could be obtained between comfort properties and fabric porosity and thickness was in case of modal /cotton fabrics (this may be due to their lower yarn hairiness after finishing process) see table 1. Also a good relation obtained for cotton fabrics in case of thermal resistance, and air permeability. The higher the loop length the higher the air permeability, and water vapour evaporation and the lower the thermal resistance of the fabric for the three kinds of fabrics used.

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