Effect of material and applied finishes on the properties of single jersey knitted fabric

Nusrat Bibi*, M. Umar Abdullah Makhdoom**

* Department of Textile Design, University College of Art & Design, Facluty of Arts,
The Islamia University of Bahawalpur, Pakistan
** R&D product development, Masood Textile Mills, Pakistan

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Abstract- Knitted fabrics are widely used for clothing and apparels. The objective of this study was to investigate the mechanical and comfort properties of knitted fabrics produced with different raw materials and applied with different chemical finishes. Single jersey fabrics were produce from 100% cotton, 100% polyester, PV 80:20, PC 52:48 and CVC 60:40. These fabrics were pre-treated and then silicon softener, water repellent, resin and wicking finishes were applied to these samples. The performance was measured in terms of abrasion resistance, pilling resistance, areal density (grams per square meter), air permeability and overall moisture management capacity. The 100% polyester fabrics were found to have better properties.

Index Terms- Comfort, single jersey, knitted fabric, finish

I. INTRODUCTION

Clothing is one of the fundamental needs of human beings serving the means of protection from harsh climatic conditions. The clothing available in market may be categorized on the basis of fabric formation techniques, the most common of which are knitting, weaving and web bonding. According to International Trade Center statistics, the market share of knitted apparel and accessories was US$ 211.27 billion as compared to non-knitted apparels, which was US$ 193.87 billion in 2012 [1]. The knitted apparels are preferred due to their unmatched properties

[2] like shape retention, flexibility, crease resistance, low conversion cost (yarn to fabric), high production speed, etc. Additionally, the properties of apparel are also affected by the raw material, yarn parameters (count, twist, etc.), knitting factors (stitch density, stitch length, etc.) and application of finishes for particular end use.

Depending on the path followed by yarn in the structure of fabric, there are a number of knitted fabrics e.g. single jersey, interlock, rib, terry fleece, etc. All these fabrics are commonly used in our daily life as apparel, home furnishing, shoe panels, etc. Single jersey is an important type of knitted fabric commonly used for undergarments and T-shirts. It is very stretchy and light weight offering ease of motion to the wearer [3]. The structure of a single jersey fabric is shown in Figure 1. The length of yarn consumed in the loop formation is responsible for the flexibility and shape retention of knitted fabrics.

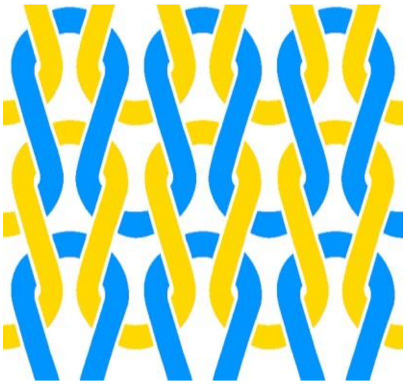


Figure 1. Structure of a single jersey knitted fabric

While designing an apparel, the most important point to be considered is the comfort of wearer. The comfort is broadly categorized into psychological, sensorial, body movement and thermal comfort [4]. It is agreed that the most important features of clothing comfort are transmission of heat, air and moisture from the clothing. Therefore, the fabrics worn very next must have better moisture management properties [5]. The transmission of moisture is driven by two phenomena namely diffusion and wicking. Diffusion is the movement molecules from area of high concentration to area of low concentration, while wicking is the spontaneous flow of a liquid in a porous substrate, driven by capillary forces. Hence the clothing will be comfortable if it absorbs moisture from the surface of body and transfers it to the atmosphere. The Figure 2 describes moisture management property of fabrics.

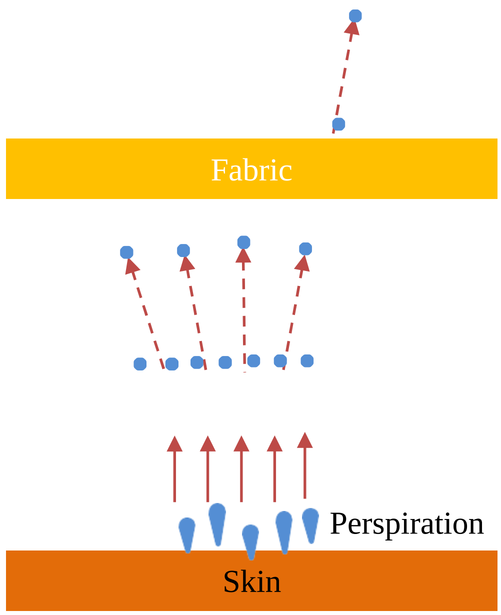


Figure 2. Moisture management in fabrics

Researchers have worked to determine the thermal comfort and moisture management properties of textile materials specially knitted fabrics. Ucar et al [6] determined the thermal properties of 1x1, 2x2 and 3x3 rib fabrics. They demonstrated that the heat loss in the fabric is decreasing by decreasing in rib number, i.e.in the order of 3×3, 2×2 and 1×1. Because of their structural properties, single jersey fabrics have remarkably lower thermal conductivity and thermal resistance values as well as higher relative water vapour permeability values than 1×1 rib and interlock fabrics [7]. The heat and water vapour transfer through fabrics is highly related to its capillary structure and surface characteristics of yarns, as well as air volume distribution within the fabrics. This is a complex phenomenon, depending on a number of parameter like fabric geometry, fabric thickness [8], fabric density, yarn and fabric structure [9], etc. The thermal resistance offered by the fabric decreases as the twist in yarn increases; also the slacker structure of fabrics produced from finer yarns results in lower thermal conductivity and higher water vapour permeability [10].

Supuren et al. [11] investigated the comfort properties of double face knitted fabrics and concluded that polypropylene-cotton (inner-outer) fabrics have better moisture management properties. Majumadar [12] concluded that the water vapour permeability and air permeability of knitted fabrics depends on the raw material, and is better for regenerated bamboo as compared to the cotton. Ensuring a smooth fabric surface improves the comfort properties of fabric along with its air permeability, heat transmittance [13]. Cil et al. showed that the diffusion and wicking abilities of fabrics increase with the use of coarse yarns while the drying rates increase with the use of comparatively finer yarns [14]. Researchers have also worked to predict the comfort properties of single jersey knitted fabrics, considering the properties of yarn along with its cover factor and knitting gauge [15].

To improve the properties of knitted fabrics or impart functional properties, certain chemical finishes are applied. Some common functional properties include water repellency, wicking, durable press, softness, water repellency, soil release, wrinkle resistance, antimicrobial activity, UV protection, etc. These finishes are applied to the fabric after scouring, which involves the removal of added impurities like waxes, protein substances, pectin and others. The objective of this study is to investigate the mechanical and comfort properties of knitted properties developed from different materials and treated with different chemical finishes.

II. Materials and Methods

As the study was aimed to investigate the effect of raw materials and applied finishes on performance properties of single jersey knitted fabrics, different materials and finishes were used for this purpose. The yarn count used for this study was 20 tex, while five different materials were used. Similarly, five different finishes were applied to the produced fabrics. The details of raw material and finishes is given in Table 1.

Table 1. Variables of the study

Sr. #	Material	Fabric treatment
1	100% cotton	Pre-Treatment
2	100% polyester	Water repellent Finish
3	PV 80/20	Resin Finish
4	PC 52/48	Softeners (silicon)
5	CVC 60/40	Wicking finishes

Using different raw materials, five different single jersey knitted samples were produced on circular knitting machine. The knitting parameters were kept constant for all the samples, i.e. stitched length was 0.29 mm and the fabrics areal density was 150 grams per square meter. Each of these fabrics was performed with five different treatments given in Table 1, resulting in twenty-five different samples (Table 2).

Table 2. The list of samples produced

Sr. #	Material	Fabric Treatment
1	100% cotton	Pre-Treatment, PT
2	100% cotton	Water repellent Finish, WR
3	100% cotton	Resin Finish, RF
4	100% cotton	Softeners (silicon), SS
5	100% cotton	Wicking finishes, WF
6	100% polyester	Pre-Treatment, PT
7	100% polyester	Water repellent Finish, WR
8	100% polyester	Resin Finish, RF
9	100% polyester	Softeners (silicon), SS
10	100% polyester	Wicking finishes, WF
11	PV 80/20	Pre-Treatment, PT
12	PV 80/20	Water repellent Finish, WR
13	PV 80/20	Resin Finish, RF
14	PV 80/20	Softeners (silicon), SS
15	PV 80/20	Wicking finishes, WF
16	PC 52/48	Pre-Treatment, PT

17	PC 52/48	Water repellent Finish, WR
18	PC 52/48	Resin Finish, RF
19	PC 52/48	Softeners (silicon), SS
20	PC 52/48	Wicking finishes, WF
21	CVC 60/40	Pre-Treatment, PT
22	CVC 60/40	Water repellent Finish, WR
23	CVC 60/40	Resin Finish, RF
24	CVC 60/40	Softeners (silicon), SS
25	CVC 60/40	Wicking finishes, WF

Pre-treatment of knitted fabrics

The knitted fabrics were first semi-bleached to remove impurities. The bleaching was performed at 98°C for 30 minutes using below recipe. The fabric was then rinsed and neutralized using acetic acid.

Wetting agent: 0.5 g/liter Anti-creasing agent: 3 g/liter

Detergent: 1 g/liter Scouring agent: 1.3 g/liter Bleaching agent: 5.9 g/liter

After pre-treatment, different finishes and softeners were applied to the knitted fabrics including softeners, resin finishes, water repellent finishes and the finishes for wicking. The detail of finishing recipe for different application is given in Table 3.

Table 3. Recipe for different finishes applied to fabrics

RESIN FINISH		**SILICON FINISH**	
Acetic acid	0.11%	Acetic acid	0.11%
Texsoft-PE	3%	Texsoft-PE	1.65%
Magasil MT	1.50%	Magasil MT	1%
Cerafin SMT	2.50%	Cerafin SMT	3.30%
Fixapret ECO	3.50%		
Magnesium chloride	2%		

WATER REPELLENT FINISH		**WICKING EFFECT FINISH**	
Citric acid	0.40%	Acetic acid	0.11%

Biogaurd X19	8.00%	Rucofin SIQ	2.00%
Rucogaurd WEB	2.50%		

III. Testing and Evaluation

The treated knitted fabrics were characterized for different parameters including air permeability, areal density, shrinkage, torque, bursting strength, pilling, OMMC and wicking. The testing standards for each property are mentioned in Table 4. The length and width wise shrinkage and fabric torque were checked using shrinkage checking instrument named as Quick view plus. Fabric was given 3 washes and then dried in relax state on perforated plate shelf having 21 °C temperature and 65 % RH. The fabric durability was checked in terms of pilling and bursting strength.

Table 4. Standard test methods followed to evaluate the fabric performance

Property	Instrument	Standard test method
Air permeability	Air permeability tester	ISO-9237
GSM	GSM Cutter	ASTM-D3776
Bursting strength	Molan tester	ASTM-D3786
Pilling	Random Tumble Pilling Tester	ASTM-D3512
Comfort	MMT tester	AATCC-195

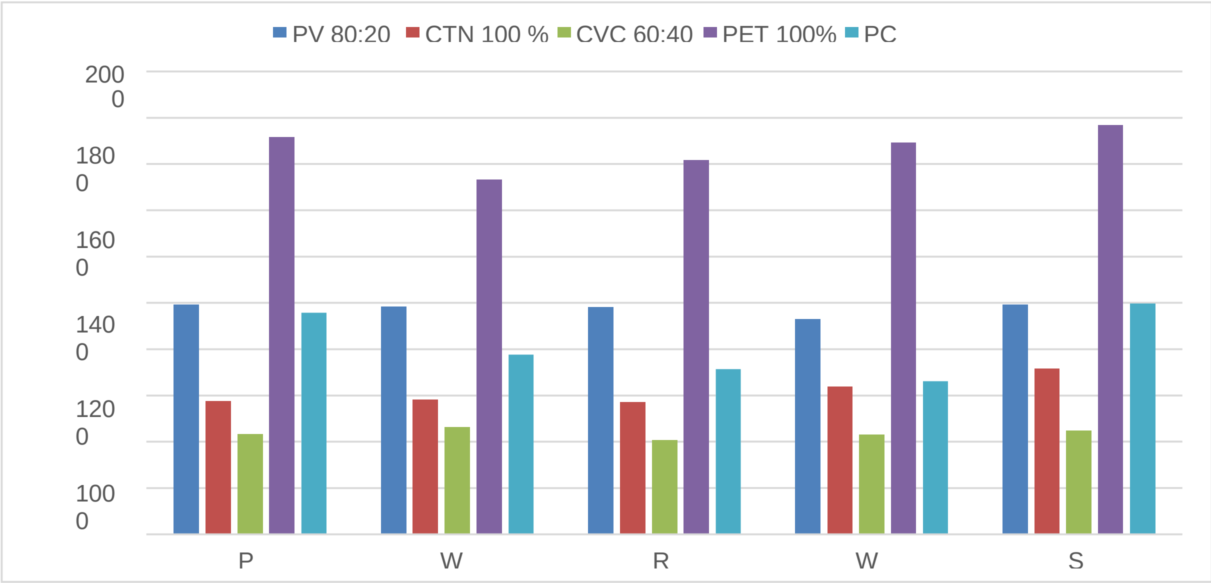
IV. Results and Discussion

The air permeability results of all the fabric samples are shown in Figure 3. It is clear from the results that 100 % polyester single jersey has highest air permeability (AP) value as compared to the other materials in all the finishes. The reason is that the polyester fibers are highly aligned, with no protruding fibers on the yarn surface. Thus it offers least hurdle for air to pass through it, giving highest value of air permeability.

Further to that the least value of air permeability is exhibited by the fabrics knitted from CVC 60:40 yarn. The knitted fabrics from PV 80:20 yarn and PC 52:48 have almost same value of air permeability, with PV 80:20 on slightly lower side. The random fiber orientation and hairiness in the 100 % cotton, PC, PV and CVC yarn fabrics does not allow air to pass through properly and therefore air permeability reduces as compared to 100 % polyester fibers. The results exhibit that as the percentage of polyester is decreasing, the air permeability of the fabric is also decreasing.

The effect of chemical finish is not so prominent for all the knitted fabrics, as there is only small variation. This is perhaps due to the fact that finishes have been applied uniformly to all the fabrics and therefore reduction in air permeability is almost same. It is evident from the results that the air permeability has increased slightly after the application of silicon softener, while decreased after the application of water repellent finish. The effect is more prominent in case of 100% polyester yarn. The result shows that raw material has more effect on the air permeability of knitted fabrics, as compared to the application of finishes. Finishes are suitable for minor change in performance properties while raw material is a major source for this change.

Figure 3. Air permeability results of all fabric samples



The bursting strength results of knitted fabrics are shown in Figure 4. The highest value of bursting strength is achieved for the knitted fabrics produced from 100% polyester yarn. It is also evident that the bursting strength of knitted fabrics is decreasing with decrease in polyester fiber content in the yarn, exhibiting lowest value for 100% cotton fabric. When a fabric fails during a bursting strength test, it does so across the direction which has the lowest breaking extension. The cotton fiber has lower elongation (5-8%) as compared to polyester (15-20%) and viscose (12-16%), therefore, it shows lowest value of bursting strength. On the other hand, PV 80:20 is a blend of 80% polyester and 20% viscose and it shows lower bursting strength than 100% polyester fabric.
Studying the effect of finish on the bursting strength of knitted fabrics, it is evident that the bursting strength of all types of materials is decreasing after application of finish as compared to pre-treated knitted fabrics. The decrease may be attributed to the fact that when finish is applied to the knitted fabrics, it makes the fabric stiff, decreasing is extensibility, which results in bursting strength reduction. Study on the finishes and their effect on bursting strength proves that rate of decrease in the bursting strength does not seem to be entirely dependent on the cross-linking but also on other factors such as fiber embrittlement, fabric stiffening or cellulosic damage during finishing conditions. It may also be said that these finishes impart the functional properties at the cost of mechanical properties.

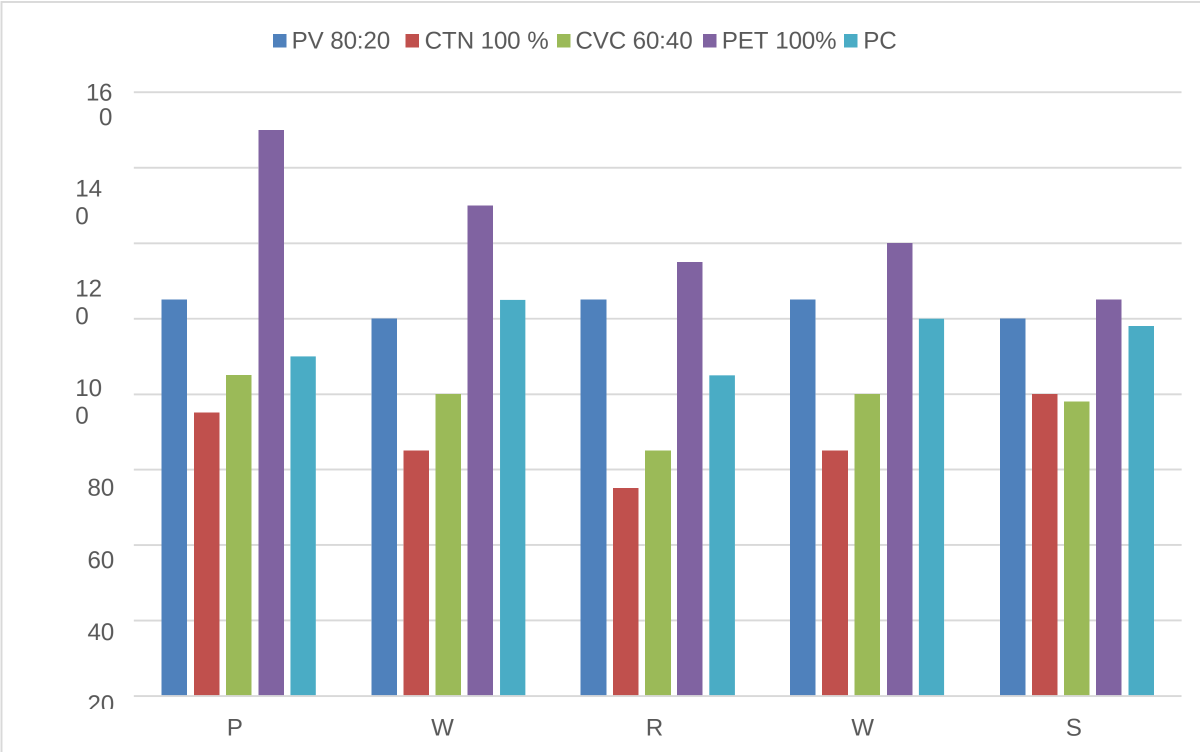


Figure 4. Bursting strength of all fabric samples

Pilling is a major problem with the knitted fabrics, resulting in the development of small fuzz balls on the fabric surface. It results due to the abrasion on the surface of fabric, which causes either brushing up of free fibre ends not enclosed in yarn structure and the conversion of fibre loops into free fibre ends by the pulling out. The pilling results of all the knitted fabric samples are given in Figure 5, where 5 is no pilling, 4 is slight pilling, 3 is moderate pilling, 2 is severe pilling and 1 is very severe pilling.

The pilling results show that 100 % polyester fabrics have slight pilling as compared to the other fabrics. The 100 % cotton fabrics also show a better pilling resistance, but inferior to that of 100% polyester. The other three materials show almost same pilling behavior. This is due to the reason that fibre with low breaking strength and high bending stiffness tend to break before being pulled fully out of the structure leading to shorter protruding fibres, which cause pilling. The application of finish has improved the pilling rating of the knitted fabrics slightly. The reason is that, when finish is applied on fabric, it makes a protective layer on the yarn surface which reduces the short fibers from this yarn, thus pilling is reduced.

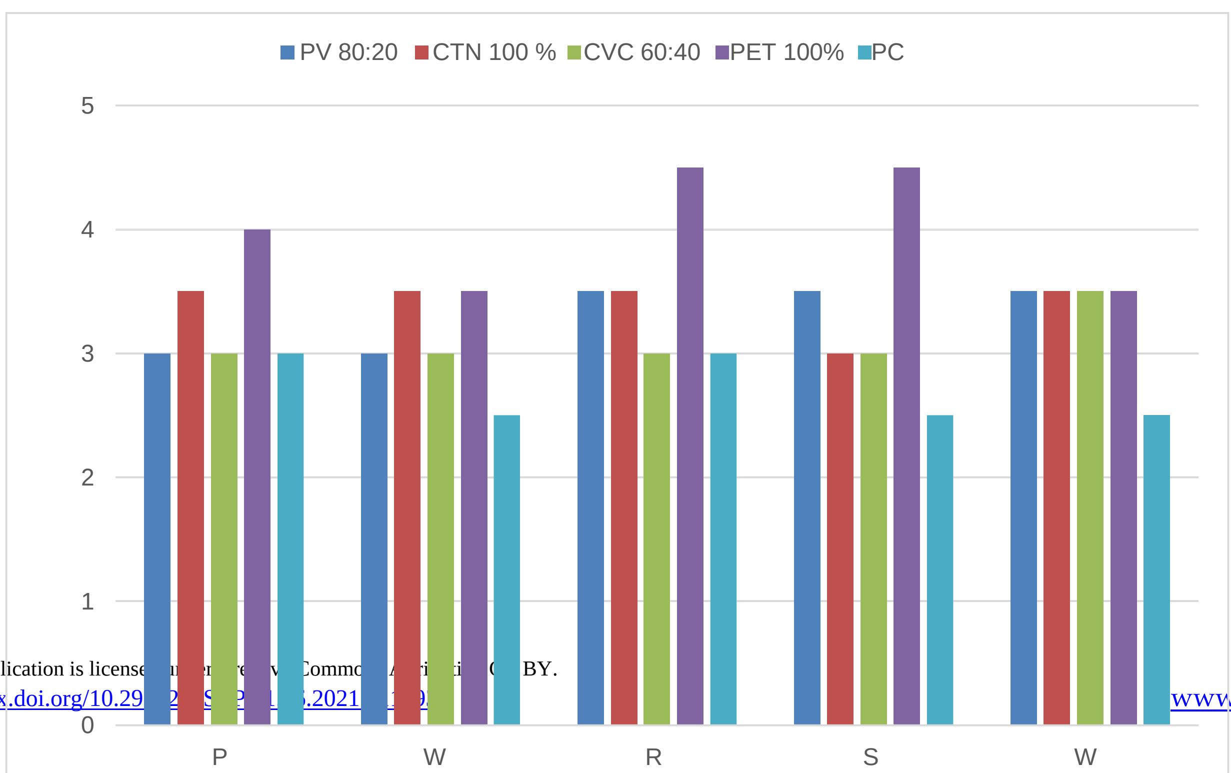


Figure 6 shows the areal density (GSM or gram/m^2) of fabrics has increased after the application of finish. The reason for higher GSM of PV is that, viscose fiber has high moisture regain and good absorbency as compared to cotton and polyester.

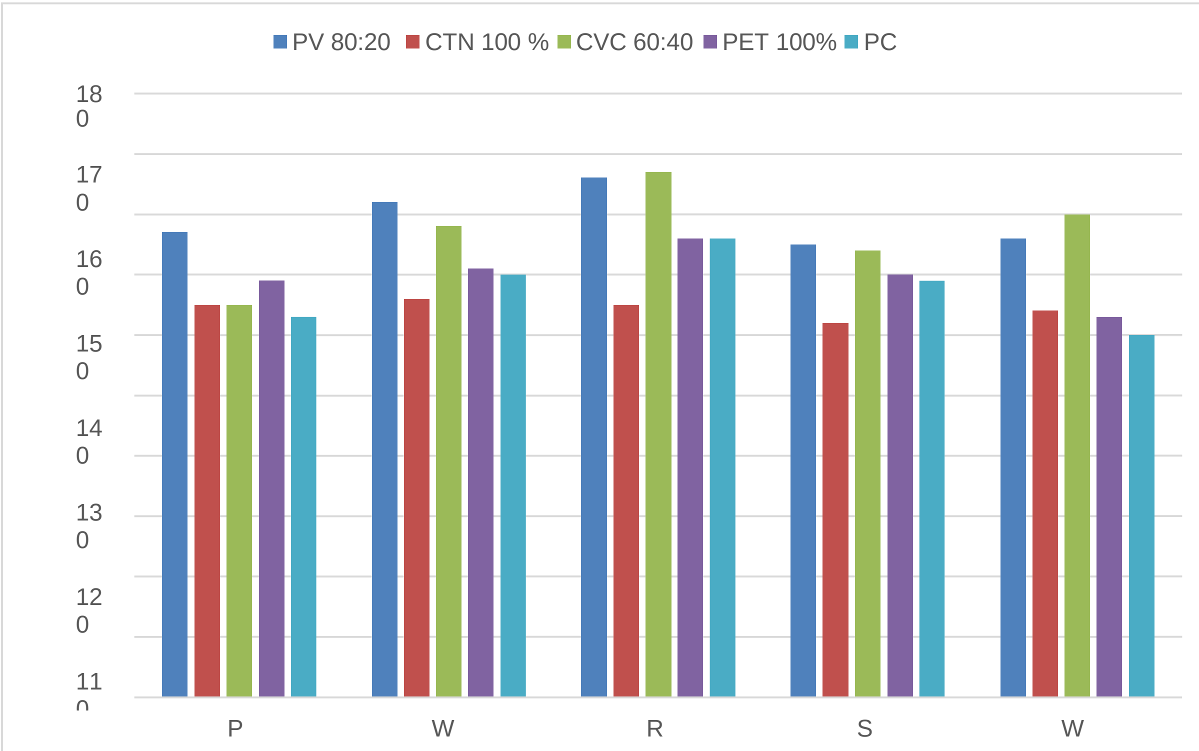


Figure 6. Areal density of knitted fabrics

The OMMC indicates the overall ability of fabric to manage liquid moisture transfer, and is determined by bottom absorption rate, one-way transport, and bottom spreading speed. Figure 7 shows the OMMC results of single jersey knitted fabrics. The results show that PC 52:48 has high OMMC value followed by 100% polyester, PV 80:20, 100% cotton 100 % and CVC 60:40. The better OMMC of PC fabrics may be attributed to the quick moisture absorption by constituent cotton fibers and wicking by the polyester fibers. These fibers in combination result in better comfort properties of the knitted fabric. Although CVC knitted fabric also contains both cotton and polyester, but the low polyester content resulted in negative one way transport index, and OMMC reduced.

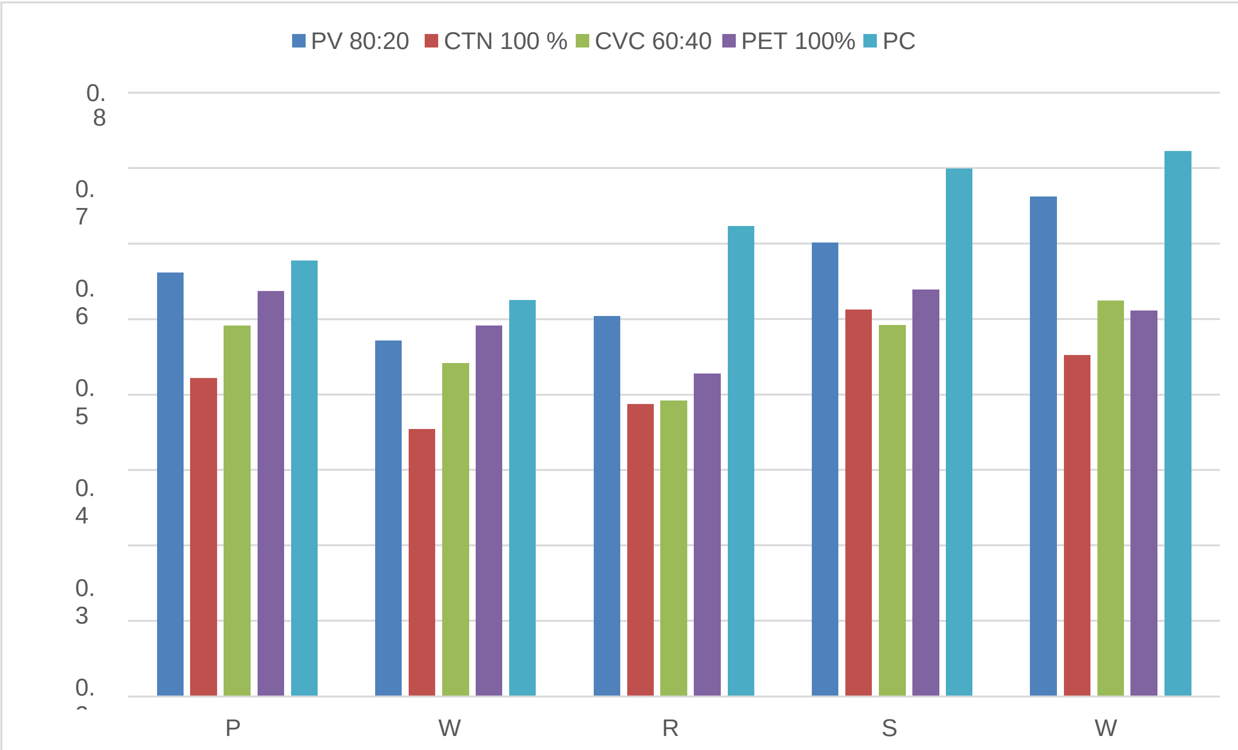


Figure 7. Overall Moisture Management Capacity of knitted fabrics

The wicking finish has significantly improved the OMMC properties of all types of knitted fabrics. Moisture wicking finish makes synthetic fabric absorb sweat. It thus pulls moisture away from the skin and transfers it to the surface of fabric. A slight decrease is observed in case of water repellent finish and the resin finish. This may be attributed to the reduction in the pore size due to accumulation of finish material in the pore. On the other hand, there is also a decrease in the OMMC of knitted fabrics treated with silicon softeners. The silicone softener has the ability to lubricate fibers, which in addition to imparting softness also improves the wicking and ultimately the OMMC of fabric.

V. Conclusions

The current study was focused to study the effect of raw material and finishes on fabric bursting strength, Fabric GSM, pilling resistance, OMMC and air permeability. Single jersey fabrics were produce from five different materials. All the fabric samples were pre-treated and four different types of finishes were applied on these samples and performance properties were checked. It was concluded that, Overall 100 % polyester fiber has good performance properties with low pilling, high bursting strength, and better OMMC values with a drawback of little moisture transportation followed by PV 80/20, PC 52/48, CVC 60/40 and Cotton 100 %.

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AUTHORS

First Author – Nusrat Bibi (Assistant Professor), Department of Textile Design, University College of Art & Design, Facluty of Arts, The Islamia University of Bahawalpur, Pakistan, Mail Id: nusratbibi1987@gmail.com, Cell# 03008667684

Second Author – M. Umar Abdullah Makhdum, R&D product development, Masood Textile Mills, Pakistan, Mail Id: umar.makhdoom@masoodtextile.com, Cell# 03000702974