(REFEREED RESEARCH)

IMPROVEMENT OF LIQUID MOISTURE MANAGEMENT IN PLAITED KNITTED FABRICS

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ABSTRACT

The main purpose of this study is to investigate the effect of knitted fabric structures and material composition on moisture management properties. Fiber type and fabric structure have significant influence on moisture management properties of knitted fabrics. In this article, single jersey, plaited jersey and hybrid plaited jersey knitted fabric samples with different yarn compositions were prepared. Air permeability and liquid moisture management properties including wetting time, max wetted radius, absorption rate, one-way transportation capability and OMMC were evaluated. Plaited jersey and hybrid plaited jersey structures have better moisture management properties than that of single jersey knitted structures. In comparison with plaited jersey and hybrid plaited jersey structures, air permeability of single jersey knitted structures is better.

Keywords: Single jersey, Plaited jersey, Thermo physiological comfort, Moisture management

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1. INTRODUCTION

Clothing designed for leisure sports is worn not only for aesthetic reasons but also for special control functions of the human body. Clothing comfort includes three main considerations: thermo-physiological, sensorial and psychological comfort (1).

Human thermal comfort depends on a combination of garment, climate, and physical activity. Main factors which affect thermo-physiological comfort are fiber type, yarn properties, fabric composition, fabric structure and chemical finishing (2).

Sweat shirts are widely used in sports, army and personal wears. Mostly knitted sweat shirts are manufactured according to the requirement of the wearer. Sweat shirts like hoodie are used in cold environment.The main function of sweat shirt is to make wearer dry, cool, fresh and comfortable. Mainly cotton fiber is used for manufacturing of sweat shirts. Synthetic fibers are also used for this purpose. Many research works are carried out to study the functional properties of double layered fabric such as heat and moisture transport properties (3).

When human body temperature goes beyond from normal range due to hot and humid weather or heat generated during physical activity due to metabolic activities. In this case human body acts a cooling system and starts sweating. To increase the comfort level clothing must ensure transmission and evaporation of moisture. Sweat must be transferred or removed from the surface of the skin towards the fabric that is next to the skin. After absorbing moisture, fabric should wick out moisture to the atmosphere in order to reduce the humidity (1). There is a general agreement that the transfer of heat, moisture and air through the fabric are major factors for thermal comfort (4).

Sweat should be transported away from the skin in the form of moisture or liquid in order to keep the skin dry. The ability of a garment to transport moisture away from skin to the garments outer surface is called as moisture management (5).

Thermal diffusivity, air and water vapor permeability are influenced by raw material type and knitted fabric structure. Wicking and drying of a fabric is greatly influenced by the selection of raw material and knit structure.

Natural fibers such as cotton having hydrophilic nature have bonding sites for water molecules and water tends to remain in the fibers. Cotton has poor tendency of moisture transportation. Synthetic fibers such as polyester are hydrophobic and have few bonding sites for water molecules. Hence, they tend to remain dry and have good moisture transportation and release properties (6).

Sweat shirts made of 100% cotton fiber absorb lot of moisture but wicking rate is poor that is why it causes irritation and discomfort to the wearer because of getting wet. Shirt made of 100% polyester has low moisture absorbency and causes irritation in hot conditions.

Double layer fabrics are used to ensure better clothing comfort in sports and active wears. High moisture transfer properties of these fabrics affect their comfort properties and make them more functional. Commonly, a simple double-layer construction is used in which the inner face is made of a synthetic filament yarn that is hydrophobic in nature and has a good capillary action; the outer face is made of a hydrophilic yarn that absorbs the wicked moisture and allows it to evaporate (7).

Most important component of the clothing comfort is thermo-physiological comfort. It is of great significance because of tremendous support to the active leisure. It is also preferred to balance the human body's core and skin temperature at varying environmental conditions and extent to normalize the micro-climate between the wearer's skin and the garment. Numerous factors that influence the thermo-physiological comfort properties of a wearer are heat exchange within clothing, air permeability, transfer and evaporation of moisture. Wetting, wicking and moisture management are critical characteristics that affect thermophysiological comfort of a garment (8).

The transport of liquid within a fabric can take place through the available inter yarn spacing and through the inter fiber space in its constituent element. Such transmission takes place primarily by capillary action. So, the generation of inter and intra yarn spaces in fabric is expected to influence transportation of liquid (9).

The human body produces heat continuously inside his/her body during all his/her activities because of metabolic activities. Due to excessive physical exertion and greater level of heat generated by the body itself, heat transfer through clothing is insufficient to compensate for the body's energy balance. In this case, body begins to sweat and due to evaporation of this sweat, human body feels cooling effect. Human body remains dry in order to avoid discomfort and other skin related diseases (3).

The transfer of moisture through fabrics takes place via two main processes; wicking and absorption. Good wick ability of fabric can help efficient transport of liquid from skin surface to the outer surface of the fabric. Similarly, moisture absorption refers to the uptake of moisture byindividual fibers from the surface of skin. Natural fibers like cotton and regenerated cellulose fibers show much higher absorption abilities in comparison with synthetic fibers (10).

Dryness of body plays vital role to keep it free of perspiration and bacteria that causes variety of problems like blisters and athletic deceases. These problems can be resolved if we are able to develop a garment in which the wearer feels comfortable. In order to develop such type of garment, we will have to emphasis over the bio-physical aspects of the garments in the form of liquid/moisture transportation and permeation of air through the fabric.The sweat transportation in the form of liquid or vapor consequently through the fabric touching the skin causes dryness (11).

Pernick et al., studied the moisture absorption and wicking properties of multi-layer weft knitted fabrics. This multi layering is comprised as a first layer of hydrophobic yarns and a second layer of hydrophilic yarns. These layers being secured together by series of courses forming spacer yarns. The hydrophobic layer comprised polyester yarns while the hydrophilic layer comprised cotton and rayon yarns (12).

Chen et al., designed a new double jersey knitted structure and compared it with 1×1 rib structure and a double jersey structure knitted with different yarns as face and back loops. He analyzed and concluded the significantly better initial water absorption rate and accumulative one-way transport properties as compared to conventional knitted structures. Continued to his work, plant-based design which contains two tucking courses sandwiched between two knitting courses has shown the best results in fabric comfort properties (13).

Supuren et al., has developed double-face knitted fabrics comprised of only two type of fiber incorporated as yarns in four different options like (i.e. cotton-cotton, polypropylene-cotton, cotton-polypropylene, polypropylene-polypropylene) on face and back of the fabric have been compared for moisture management properties. Established results of the fabric samples with cotton as (outer-side) and fabric with polypropylene (inner-side) showed the best moisture management properties (7).

In a previous study., Only effect of fabric physical property and knitting parameter on comfort-related properties of commercial sportswear fabric was investigated (14).

In a study it was observed that slack forms of rib, interlock and single jersey structures have higher transfer wicking ratios as compared to their tight forms. All tight knitted structures had higher contact angles than their slack forms due to higher compactness of the surface. The test results revealed that the parameters of comfort are significantly affected by knitted structure (15).

In a study carried out by Ozdil et al., cotton yarns with different yarn counts (Ne 20, Ne 30, Ne 40) and different twist values (α_e = 3.2, 3.6, 4.0) were knitted as single jersey structure in the same production conditions. The moisture management properties of the fabrics were measured. Overall moisture management capacity (OMMC) values of all the cotton fabrics were found in the same category even the yarn counts and yarn twist coefficients were different (16).

In this study, plated knitted fabrics produced with functional fiber yarns in the back of the knit (close to the body); combined with polypropylene or polyester in the face (outer surface) were tested in terms of their wicking behavior and drying rate capacity. The wicking behavior of fabrics is mainly determined by the effective capillary pore distribution and pathways as well as surface tension. The drying capability is related to the macromolecular structure of the fiber. Viscose Outlast® demonstrated the best wicking ability in both horizontal and vertical wicking, but showed low drying capability. Coolmax® showed a good wicking ability and the best drying capability (17).

Fabric structure seems to be much more important for effective achievement of moisture management properties. Major consideration in the knitted fabric structure is that which layer we are using next-to skin and are mostly more hydrophobic and better wicking yarns which absorb less amount of moisture, and the outer fabric layer of knitted structure has yarns which pull the moisture outwards and facilitate quicker evaporation. Selection of all these parameters can be important for making a knit structure of best moisture management properties (18).

Foshee et al. has patented his work by developing dual layer knitted fabric. This fabric contains water-absorbent yarns on the outer side and water-wicking yarns on the inner next-to-skin side. Water-absorbent yarns used are cotton, viscose, blend of polyester and cotton with about 85% cotton and 15% polyester. The wicking yarn used is profiled fibers such as Coolmax® polyester (19).

There are numerous studies in fabric liquid management properties that depend on the fiber properties, yarn properties, fabric structure (single jersey, plaited jersey, double faced). But it is first time we developed a blend of samples having single and plaited jersey knit structures. The objective of preparation of single jersey and plaited jersey structures was to compare the liquid transport properties of structures. Development of plaited knit structures with micro denier polyester and trans- dry fabrics is a new work which differentiate liquid transport properties than that of single jersey trans dry fabrics. Fabrics especially use as under garments requires the immediate transport of sweat. But second layer should be absorbent so that the wicked moisture should be absorbed by second layer. But spread ability and drying of liquid moisture is very important phenomena for knitted fabrics specially used as under garments and active wears. That is why we used outer layer as trans- dry fabric because spread ability and dry ability of trans- dry fabrics is better than that of other fabrics prepared by natural and synthetic materials. So development of hybrid structures is a new work which showed better liquid transport results as compared to single jersey structures. Similarly hybrid knit structures showed better moisture transportation results than that of the plaited jersey knit structures that are prepared by natural and synthetic yarns.

This study investigates the comparison of liquid transportation and air permeability of single jersey, plaited jersey and hybrid plaited jersey knit structures.

2. MATERIALS AND METHODS

2.1 Materials

Total eight yarn samples (30/1 Ne) were selected and used in combinations to prepare nine weft knitted fabrics. All samples were produced on circular weft knitting machine (Mayer & Cie, Germany) with machine gauge of 24 and 34" diameter using constant setting values. Testing results of yarns used are given below in Table 1. Out of 9 samples, 3 were single jersey (SJ1, SJ2 and SJ3), 3 were plaited jersey (PJ1, PJ2 and PJ3) fabrics with different blend ratios and 3 were hybrid plaited jersey (HPJ1, HPJ2 and HPJ3) fabrics in which different yarns were used in 1:1 ratio on front side of the fabric. Figure 1 shows the construction of plaited jersey. All fabric specifications are mentioned in Table 2 along with their compositions. Inner layer of the fabric was composed of micro polyester filament yarn 100% (45denier) for only plaited jersey fabrics.

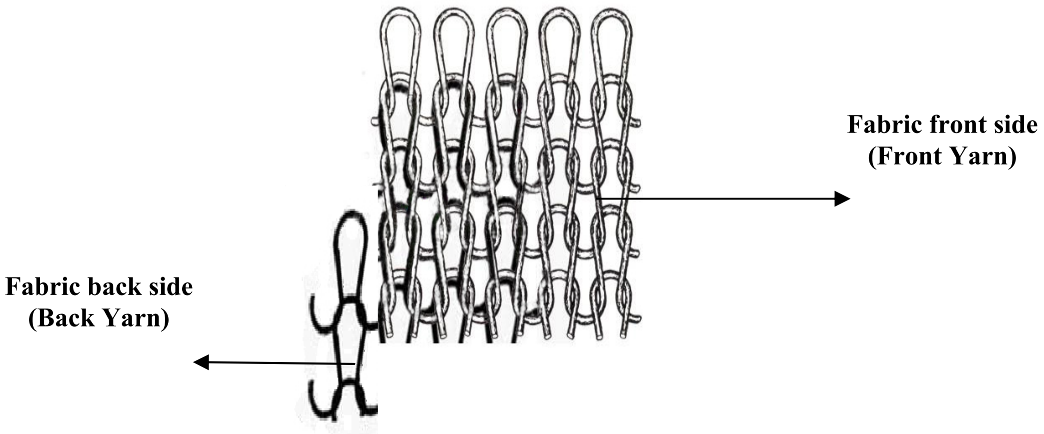

Figure 1. Construction of plaited knitted fabric

Table 1. Test results of yarns used

Type of yarns	Count (Nec)-CV%	Strength (lbs)	CLSP	U %	IPI	Hairiness
30/1 Ne CMB Treated cotton 100%	30/1-0.77	78.3	2485	10.65	147	4.9
30/1 Ne CMB cotton 100%	30/1-0.97	72.1	2157	10.42	97	5.84
30/1 Ne Spun Polyester 100%	30/1-0.93	190	5653			
30/1 Ne CVC 60/40	30/1-0.59	85.6	2533	11.99	430	5.97
30/1 Ne Cotton/ Polyester/ Rayon (50:38:12)	30/1-0.68	82.5	2464	13.36	1185	6.09
30/1 Ne PC 50:50	30/1-1.05	194	5808			
30/1 Ne Cotton/ Coolmax® 60:40	30/1-0.62	87.6	2585	12.05	445	5.99

Table 2. Details of fabric samples and compositions

Sample Code	Front yarn (FY1)	Front yarn (FY2)	Back yarn (BY)	Composition Results
SJ1	30/1 Ne. CMB cotton 100%			100% cotton
SJ2	30/1 Ne. Cotton/ Polyester/ Rayon			50% cotton, 38% polyester, 12% rayon
SJ3	30/1 Ne PC 50:50			Polyester/Cotton 50:50
PJ1	30/1 Ne Cotton /Polyester/Rayon (50:38:12)	……………	45 Denier Micro Polyester Filament 100%	Cotton /Polyester /rayon 44: 52:4
PJ2	30/1 Ne Cotton/ Coolmax® (60:40)	……………	45 Denier Micro Polyester Filament 100%	Polyester/Cotton 55:45
PJ3	30/1 Ne CMB cotton 100%	……………	45 Denier Micro Polyester Filament 100%	CVC 80: 20
HPJ1	30/1 Ne CMB cotton 100%	30/1 Ne Spun Polyester 100%	45 Denier Micro Polyester Filament 100%	PC 60:40
HPJ2	30/1 Ne CMB cotton 100%	30/1 Ne CVC 60/40	45 Denier Micro Polyester Filament 100%	CVC 60:40
HPJ3	30/1 Ne CMB cotton 100%	30/1 Ne CMB Treated cotton (Water repellent)	45 Denier Micro Polyester Filament 100%	CVC special 80:20

Table 3. Test results of knitted fabrics

Sample Code	Mass (g/m^2)	Fabric PH (After bleach)	Loop length (mm)
SJ1	165	6.97	3
SJ2	160	7.15	3.2
SJ3	163	6.93	3.3
PJ1	175	6.99	3
PJ2	173	6.91	3.2
PJ3	176	6.95	3.1
HPJ1	176	7.01	3.2
HPJ2	177	6.98	3
HPJ3	176	7.12	3.1

2.2. Applied Treatment

All of the fabric samples were half bleached to remove the natural extracts. For half bleaching, exhaust dyeing machine (Fong) was used and bleaching was done for 25min at 85°C. Recipe used: Hydrogen peroxide 4g/l, caustic soda 3g/l, stabilizer and wetting agent. After half bleaching samples were dried, conditioned and tested in the standard atmosphere conditions. No chemical or mechanical finish is applied. The pH value of the half bleached fabric was tested to test the acid and alkali contents remained in fabric. The pH value will not make the skin itchy if controlled between weak acid and neutrality. The test method AATCC 81-2006 was used to measure pH of the water extract from half bleached fabric. This test method determines the pH of wet processed textiles. 10 g specimen was cut into small pieces and immersed into boiling distilled water (250 ml) for 10 minutes. Finally the water cooled down to room temperature and pH of the extract was determined using a pH meter. The pH values are given in Table 3.

2.3. Moisture management

To measure moisture and liquid transportation of sportswear, moisture management tester (MMT) was established as shown in Figure 2. This tester is very unique in its construction and it fulfills all the aspects of sweat management for fabric's top and bottom sides (20).

Figure 2. Moisture Management Tester

The liquid management trend is in the form of 'wetting time', 'absorption rate', 'one way transport capability', 'spreading/drying rate' and 'overall moisture management capacity'. Wetting time is actually the time in which tested fabric is wetted. Absorption rate is the speed at which the mean quantity of generated sweat is absorbed during the initial water content in textile material. Spreading speed is the accumulated rate of surface wetness to a maximum radius from the point at which the water droplet falls. The maximum wetted radius is the greatest water ring radius measured on the surface of fabric. Accumulative one-way transport capability is the difference between the areas of the liquid moisture content curves of a fabric with respect to time (21, 22, 23).

Overall (liquid) moisture management capability (OMMC) is overall ability of the fabric to manage the transport of liquid moisture. OMMC is calculated by using following equation (1).

$$OWTC = C1MARb + C2OWTC + C3SSb \qquad (1)$$

Here, C1, C2, and C3 are the weights of the index of the absorption rate.

Moisture management properties of the conditioned samples were measured by moisture management tester (MMT). Moisture management test was performed according to the AATCC Test Method 195-2009. The moisture management tester is designed to measure, sense and record the liquid moisture transport characteristics of the fabric in multiple directions (24). An average of five readings was taken for each sample.

2.4. Air permeability

Textest FX instrument was used to measure air permeability of different knitted samples and measurement was done according to standard ASTM D2986 test method. Measurement was done at the range of 3 and pressure 200 Pa. Principle of this instrument depends on the measurement of air flow passing through the fabric at a certain pressure gradient ΔP.

3. RESULTS AND DISCUSSION

3.1. Moisture management

Wetting time was investigated for all samples having different material composition and knitted structures. Single jersey samples showed almost same wetting time as compared to the plaited jersey samples and some of hybrid plaited jersey samples. It can be seen in Figure 3 that PJ and HPJ samples took less time to absorb water drop except HPJ3 sample. HPJ3 took more time because it has one water repellent front yarn.

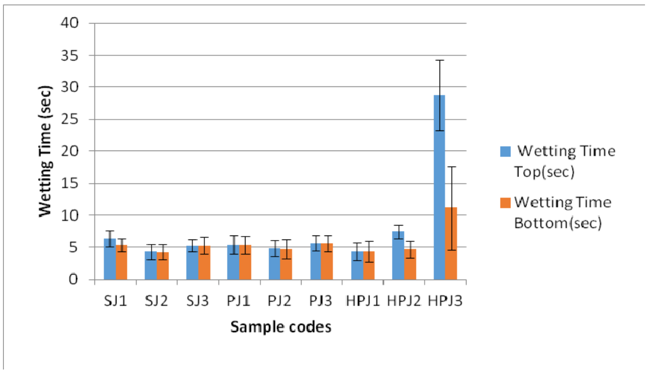

Figure 3. Comparison of wetting time between different knitted structures

All fabric samples' wetted radius has observed within specific time frame. Higher values of wetted radius have observed in PJ and HPJ samples as shown in Figure 4. HPJ2 showed highest wetted radius for top (23mm) and bottom (26mm). The microcirculatory environment imparting the property of higher rate of sweat transportation through the fabric depends on the construction and thickness of fabric. It also causes capillary action and provides a media of prompt spreading of sweat on inner side and outer side of fabric. It can be concluded that samples having micro polyester on inner side of the fabric enhance the moisture transportation by capillary action.

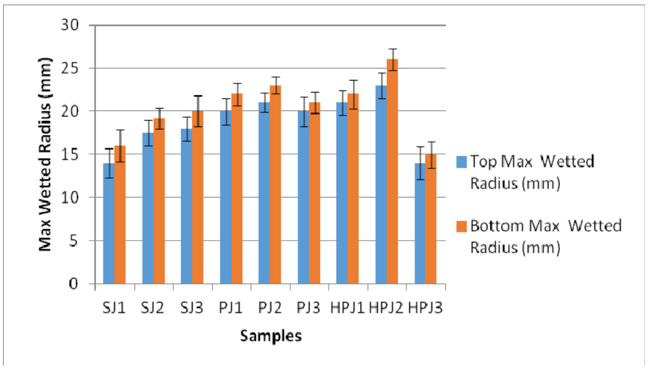

Figure 4. Comparison of wetted radius between different knitted structures

Over all the maximum absorption rate value has been observed at inner side of samples which is in direct contact with skin. Inner side of PJ and HPJ samples are composed of micro polyester. PJ and HPJ samples exhibit high absorption rates as compared to single jersey samples as shown in Figure 5. Absorption rate depends upon the fiber composition of fabric. Synthetic fibers like polyester and polypropylene are used for manufacturing of different variety of fabrics. Natural cotton fibers tend to absorb and retain body moisture, whereas synthetic fibers tend to improve wicking away from the body leading to evaporation of the moisture.

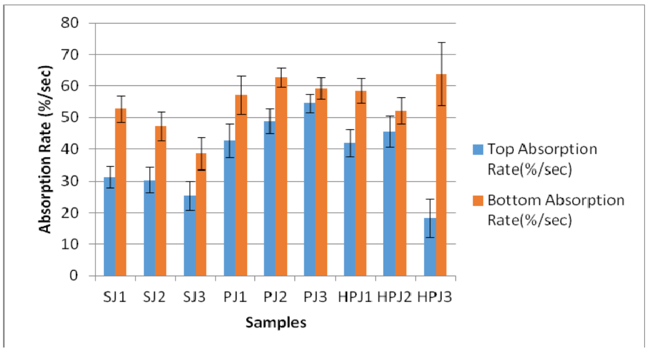

Figure 5. Comparison of absorption rate between different knitted structures

The evaluation of one way transportation capacity value with respect to different type of sample, PJ and HPJ samples exhibit highest value of one way transportation capacity of sweat generated inside the fabric as compared to the single jersey samples as given in Figure 6. HPJ3 had highest value due to the presence of water repellent yarn on the front side of the fabric. This higher side trend in micro polyester fiber containing yarn is due to existence of microcirculatory environment produced inside the yarn construction and fabric as well. This micro circulatory environment is due to implementation of capillary action which may help the sweat to transport from the skin of human body to outer lay while well contributing to provide maximum comfort and ease of higher sweat release within minimum span of time.

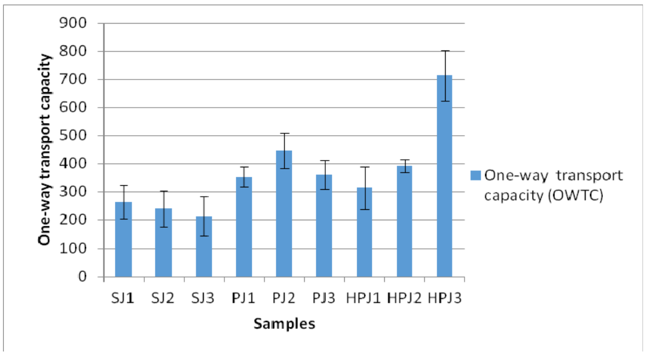

Figure 6. Mean comparison of one-way transportation capacity of samples

Moisture Management phenomena depends on wetting and wicking ability of fabric. We have compared the overall moisture management capacity of all samples as shown in Figure 7. Overall moisture management capacity (OMMC) is actually the quantitative analysis of transportation of sweat generated inside the fabric. Normally it is the combination of one way transportation of liquid, moisture absorption and spreading rate inside the fabric. Out of all samples plaited jersey and hybrid plaited jersey samples shown best results for OMMC. Sample PJ2 has greater overall moisture management capacity than all other samples. But sample HPJ3 has lowest OMMC value which is due to the presence of cotton yarn treated with hydrophobic finish. PJ2 and HPJ2 samples have excellent OMMC values and falls in grade 5 of OMMC grading system. All other samples (SJ1, SJ2, SJ3, PJ1, PJ3 and HPJ1) have very good OMMC values and falls in grade 4 categories except HPJ3 sample which has 3 grading points.

PJ2 sample whose front side is made of 30/1 Ne. 60% cotton, 40% Coolmax yarn and back side made of 45 denier 100% micro polyester exhibits highest moisture management properties among all the samples as shown in Figure 7. Blending has an important role in moisture-related comfort properties of clothing. Plaited jersey samples showed good moisture management properties due to the presence of hydrophobic inner side and hydrophilic outer side, inner side helps to transport sweat from skin to outer side of the fabric and enhance the moisture transportation due to capillary action. Presence of hydrophobic fibers such as polyester helps to increase the wicking property of the fabric.

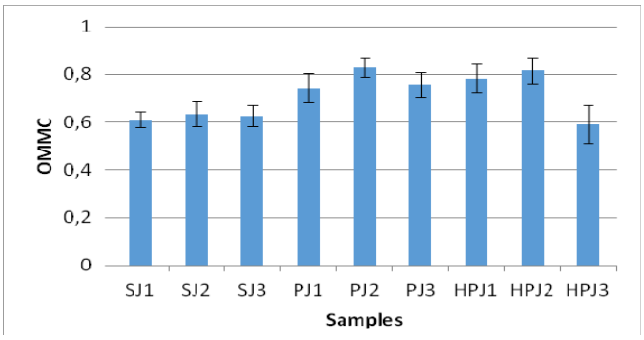

Figure 7. Mean comparison of Overall moisture management capacity (OMMC) of samples

3.2. Relation of OMMC to Air permeability

Figure 8 shows the relation between OMMC and AP. It can be seen that as AP is increasing the OMMC is decreasing. Sample PJ1, PJ2, PJ3, HPJ1 and HPJ2 showing high OMMC values but low AP values. Moreover, single jersey samples exhibited high AP than plaited and hybrid jersey fabric. It can be seen that OMMC is increasing with decrease in AP. Thus, it can be concluded that fabric structures have a great effect on air permeability. Permeability and porosity is strongly related to each other. If a fabric has very high porosity so it is more permeable (1, 25, 26). It can be assumed that there is no significant relation between OMMC and air permeability.

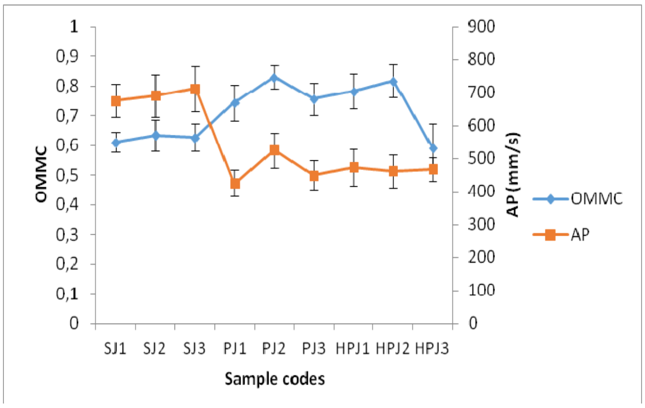

Figure 8. Comparison between OMMC and air permeability of samples

4. CONCLUSIONS

This study mainly focuses on the effect of structure and material composition of single and plaited jersey fabrics on the moisture management and air permeability properties. Double face structure is used with different composition of yarn on front side of the fabric and only one yarn is used on back side of the fabric which is 45 denier 100% micro polyester. PJ2 sample whose front side is made of 30/1 Ne. 60% cotton, 40% Coolmax® yarn and back side made of 45denier 100% micro polyester exhibits highest moisture management properties among all the samples. Sample HPJ2 is also in ‘excellent’ category in term of moisture manage properties. PJ2 and HPJ2 also have good air permeability. Both fabrics can be used as high performance active wear. A double-face structure with micro polyester yarn for the inner surface and cotton/coolmax® blend yarn for the outer surface; can easily transfers the generated sweat while keeping a dry feeling. So it can be recommended for summer, active and sportswear, due to the high moisture management property and high level of comfort in the wet state.

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