AUTEX Research Journal, DOI: 10.1515/aut-2018-0030 © AUTEX

LIQUID MOISTURE TRANSPORTATION PROPERTIES OF FUNCTIONAL UNDERWEARS: PART 1

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Abstract:

This study investigates the effect of material composition on moisture management properties. Fiber type has significant influence on the moisture management properties of knitted fabrics. In this article, single jerseys knitted fabric samples with different yarn compositions were prepared. Liquid moisture transportation properties including wetting time, absorption rate, spreading speed, one-way transportation capability, and OMMC were evaluated by Moisture Management Tester (MMT) and vertical wicking was evaluated using thermography system and image analysis. Knitted sample having fine cotton yarns with coolmax and micro denier multifilament polypropylene showed best liquid transportation properties. There is a strong co-relation between OMMC and accumulative one-way transport index with vertical wicking of knitted samples.

Keywords:

Moisture Transportation, breathability, Moisture Management Tester, wicking.

Introduction

Moisture transportation through textile materials influences greatly on the thermo-physiological comfort properties of the human body maintained by perspiration in vapor and liquid states. Clothing assembly should have the ability to transfer this perspiration to the atmosphere so that the thermal balance of the body should be maintained [1]. If human sweat does not dissipate quickly, the humidity of the air between the skin and the textile assembly that contacts with the skin rises. This increment in humidity does not allow rapid evaporation of liquid water on the skin. Similarly, in response, the body increases sweating to disperse excessive thermal energy. If a fabric cannot remove liquid water through fabric, it causes uncomfortability for a wearer [2]. Sweat should also be transported away from the skin in order to keep the skin dry. This ability of a garment that transports moisture away from skin to the garment's outer surface is called as moisture management [3].

Human body heat and moisture loss can be prevented by wearing clothes. It is necessary to wear such fabrics that support the body in order to achieve thermal and moisture equilibrium with its environment so that a comfortable microclimate can be generated next to the skin [4]. This is crucial in order to increase the wearer's performance in sports and active wear, because clothes with undesirable thermal and moisture properties decrease the wearer's comfort level and also affect the body performance [5]. Clothes having excellent moisture management properties are widely used for different types of applications. These fabrics have excellent comfort and performance properties because of their quick dry ability and effective movement of liquid moisture away from the skin with superb breathability [6][7].

Moisture Management Tester (MMT) investigates horizontal spreading of liquid drops on the surface of fabric samples and evaluates liquid transmission from the fabric's inner surface to the outer surface [8]. The disadvantage of this tester is the lack of determination of real spreading direction of liquid moisture. In order to overcome this disadvantage, researches use image analysis system to capture both area and real spreading direction of liquid in horizontal wetting [9][10] and vertical wicking [11].

In a study carried out by Hu et al, eight sets of sportswear fabrics were tested using MMT and the results revealed that liquid moisture management properties for these fabric samples were significant. The objective measurements were compared with the subjective measurements of moisture sensations during exercise. It was concluded that the ratings of both moisture sensations had increased with the increase in running time [8].

In a study carried out by Oner et al., samples having three different materials and three different knit structures were prepared. Cotton, viscose, and polyester were used as materials, and knit structures prepared were Single Jersey, single Pique, and 1×1 rib. In this study, it was concluded that the highest OMMC values have been observed in polyester fabrics. This result indicated that the polyester fabrics had good moisture management property and quick water transfer ability as compared to other fibers. The lowest OMMC values had been observed in cotton fabrics. It means that the cotton fabrics become wet than that of others [12].

Chen et al. developed a new double jersey knitted structure and compared its properties with 1×1 rib structure. Double jersey structure was knitted with different yarns as face and back loops. They analyzed and concluded better initial water absorption rate and accumulative one-way transport properties in double jersey knit structure compared with conventional knitted structures [13].

Wicking methods are used for the capillary phenomenon to analyze the liquid transport properties of fabrics. Wicking phenomena takes place when sweat travels along the surface of the fiber but is not absorbed inside the fiber. Wicking is the flow of a liquid in a porous substrate driven by capillary forces. The type of flow is caused by capillary action based on properties of the liquid, liquid-medium surface interactions, and geometric configurations of the pore structure in the medium [14][15].

The rate at which liquid travels along and through a fabric sample is observed according to a standardized wicking method and manually timed and recorded at specific intervals of times. There are different wicking test methods.

Perwuelz et al. [16] used an image analysis method in order to investigate the wicking process of colored liquid in yarns structure. There is another method that deals with measuring water transport along textile fibers by an electrical capacitance that consists of the construction of an apparatus with a specially designed electrical amplifier circuit and condenser electrodes, between which sample fibres are placed [17][18]. Furthermore, there exist wicking methods based on electrical resistance [19][20].

Nemcokova et al. [21] applied technique based on the combination of thermography system and image analysis system for the evaluation of both vertical wicking of fabrics and horizontal wetting of fabrics. Thermography system took the advantage of a physical rule: during water evaporation heat arises.

Method and Materials

Materials

Six yarn samples were selected for the development of four fabric samples. Micro denier multifilament polypropylene yarn was arranged by Chemosvit Fibrochem, Slovakia, and all other yarn samples were arranged by Masood Textile Mills, Faisalabad, Pakistan. All fabric samples were produced on circular weft knitting machine (Mayer & Cie, Germany) with machine gauge of 24″ and 30″ diameter using constant machine settings. All fabric samples have the same design, that is, single jersey. All fabric specifications are mentioned in Table 1 along with their compositions. In all knitted samples, 20 Denier spandex was used.

Methods

Moisture Management Test

The testing of fabric samples was performed using five replicates of each sample. Fabric mass per square meter was determined according to the ASTM D3776. Moisture management properties of fabric samples were tested using MMT (SDL Atlas) according to the AATCC Test Method 195-2009. The overall moisture management capacity determines the overall ability of the fabric to manage the moisture and is calculated from moisture absorption rate, spreading speed of bottom surface, and cumulative one-way transport index. To determine the moisture management capability of a fabric, the fabric specimens were placed between top and bottom concentric sets of moisture sensors of the MMT. A predefined amount of test water (representing synthetic sweat) was introduced at the top side of the fabric by a pump, and the test water was then transferred to the fabric specimens in three directions: spreading outwards on the top layer of the fabric, transferring from the top fabric side to the bottom fabric side, and spreading outwards on the bottom side of the fabric. The change in water content in the top and bottom layer was

Table 1: Details of Single Jersey knitted samples

First Component	Second Component	Third Component	Fabric Thickness (mm)	Fabric Weight (GSM)	Sample Codes
50% Cotton Linear density: 36/1 Ne	25% Coolmax Linear density: 36/1 Ne	25 % Micro denier Multifilament Polypropylene Linear density: 100 Denier	0.74	288	A
50% Modal Linear density: 36/1 Ne	25% Coolmax Linear density: 36/1 Ne	25 % Micro denier Multifilament Polypropylene Linear density: 100 Denier	0.74	285	B
50% Viscose Linear density: 36/1 Ne	25% Coolmax Linear density: 36/1 Ne	25 % Micro denier Multifilament Polypropylene Linear density: 100 Denier	0.74	292	C
50% Cotton Linear density: 60/1 Ne	25% Coolmax Linear density: 36/1 Ne	25 % Micro denier Multifilament Polypropylene Linear density: 100 Denier	0.73	250	D

then detected by the moisture sensors and recorded by the connected computer [22].

Vertical Wicking by Thermography System

Thermography system takes the advantage of a physical rule: during water evaporation heat arises. This process is possible to be captured on a thermograph using a thermography system. Obtained thermographs are evaluated using an image analysis system to find moisture management parameters of weft knitted structures. The rate of water transport is measured according to a vertical strip wicking test. One end of a fabric strip is secured vertically, whereas the opposite end dangles in a dish containing distilled water. The height to which the water was transported along the strip is measured at intervals of 10, 20, 30, 40, 50, and 60 s and then at 10 min, and the readings are reported in millimeters (mm). Higher wicking values show greater capability for transporting liquid water. Thermal imaging is used to monitor moisture transport when wicking cannot be easily detected with the naked eye. Obtained thermograms are evaluated using image analysis system to find moisture management parameters of textile materials [21].

Results and Discussions

Moisture management Test by MMT

All moisture management parameters such as wetting time, absorption rate (%), spreading speed, accumulative one-way transport index, and OMMC were measured and the results are given in Table 2.

According to the results, samples A, B, C, and D showed excellent wetting and absorption of liquid in minimum time. Sample D having finer cotton showed very fast wetting, whereas samples A, B, and C took slightly more wetting time. In case of absorption rate, sample D showed less percentage of absorption of liquid as compared to samples A, B, and C.

According to the results, samples A, B, C, and D showed excellent spreading of liquid in minimum time. Samples C and D showed very fast spread ability because of less absorption rate. Sample D showed fast liquid spread ability because of finer cotton yarns also, whereas samples A and B showed less liquid spread ability because of course count of cotton and Modal and because of more absorption rate. In case of OMMC, sample D showed higher percentage value of one-way transport index because of more wick ability of liquid through fabric sample, whereas samples A, B, and C having more absorption rate showed less one-way transportation of liquid.

Sample D showed excellent OMMC value. Samples A, B, and C showed very good OMMC value according to grading specifications. Sample D showed higher values of OMMC because of the involvement of multifilament polypropylene, Coolmax, and finer imported cotton yarns in fabric samples.

Vertical Wicking:

Vertical wicking results of all samples are given in Tables 3 and 4.

Table 2: MMT results of knitted samples.

Samples	Top Wetting Time (s)	Bottom Wetting Time (s)	Top Absorption Rate (%/s)	Bottom Absorption Rate (%/s)	Top Spreading Speed (mm/s)	Bottom Spreading Speed (mm/s)	Accumulative One-Way Transport Index (%)	OMMC
A	2.34	2.47	59.79	68.02	9.52	8.80	125.10	0.60
B	2.26	2.36	58.60	65.96	9.63	9.37	112.29	0.59
C	2.32	2.39	60.01	68.48	11.75	11.37	136.20	0.62
D	1.97	2.06	38.50	58.30	11.33	9.71	387.00	0.84

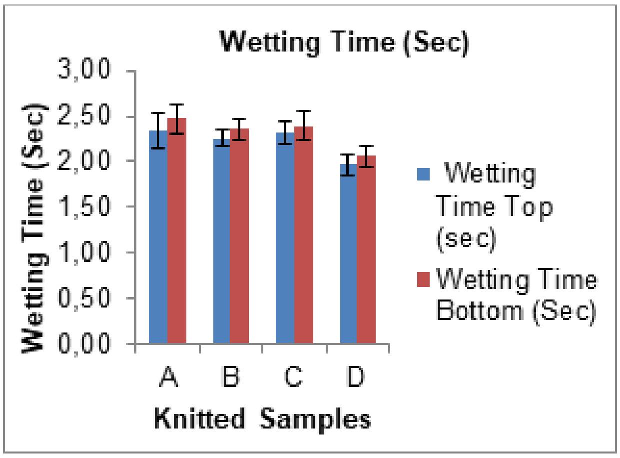


Figure 1. Wetting time (s)

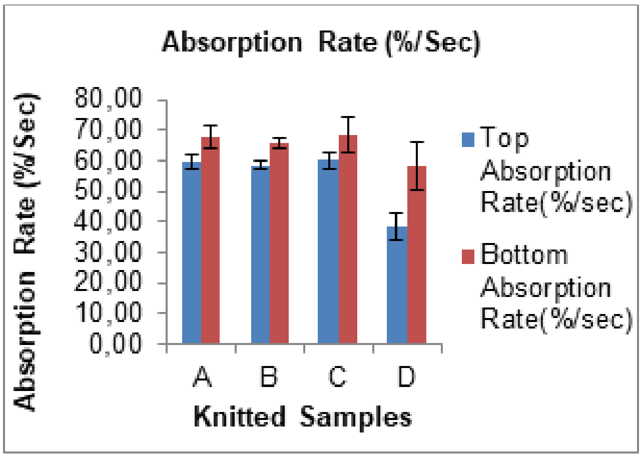
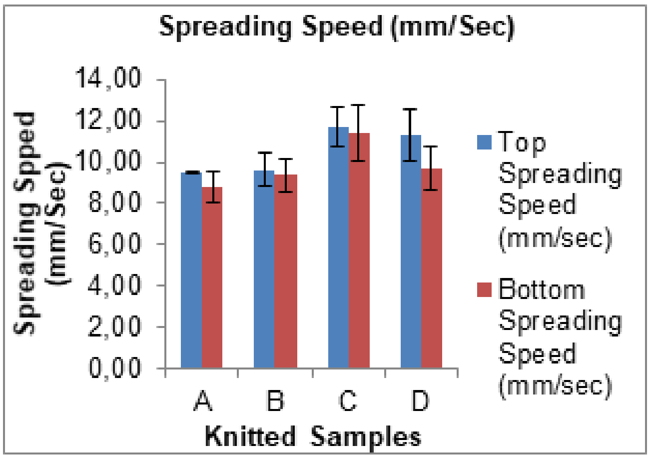


Figure 2. Absorption rate (%/s)



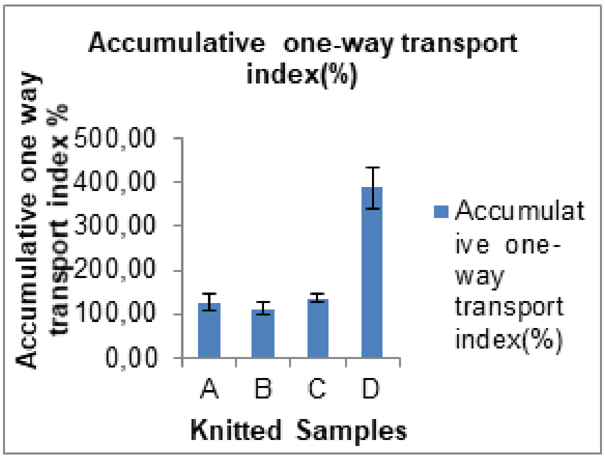


Figure 3. Spreading speed (mm/s)

Figure 4. Accumulative one-way transport index (%)

Table 3. Vertical Wicking of samples (Course wise)

Samples	10 Sec	20 Sec	30 Sec	40 Sec	50 Sec	60 Sec	600 Sec
A	24.8	31.9	39.7	45	48.6	51.4	104.2
B	27.6	34.2	39.9	46.3	49.8	52.4	109.5
C	27.9	34.4	41.1	47.5	50.7	53.3	111.5
D	30.6	41.6	49.1	52.7	57.8	61.3	122.2

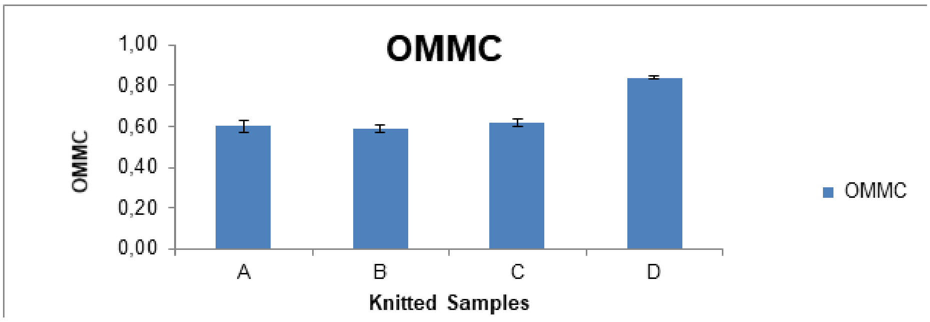


Figure 5. OMMC values

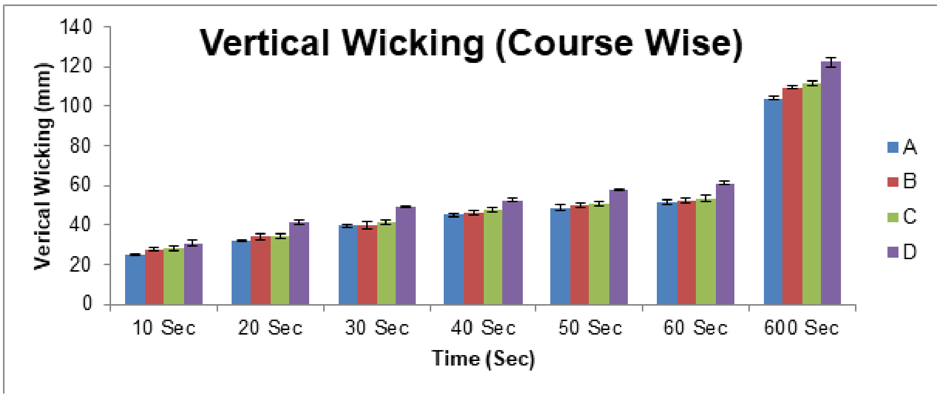


Figure 6: Vertical wicking of knitted samples (course wise)

All samples have wick ability. Sample D showed maximum uptake of water. Samples A, B, C showed less uptake of water vertically. In all samples, composition of polypropylene and coolmax is similar to that of other cellulosic materials. In sample D, there is an involvement of fine cotton, so this sample showed highest level of wicking as compared to other samples in which cellulosic material is used as course.

All samples have wick ability. Sample D showed maximum uptake of water. Other samples A, B, C showed less uptake of water vertically. In all samples, composition of Polypropylene and coolmax is same with other cellulosic materials. In sample D, there is an involvement of fine cotton, so this sample showed highest level of wicking as compared to other samples in which cellulosic material used is course.

Table 4. Vertical wicking of samples (wale wise)

Samples	10 Sec	20 Sec	30 Sec	40 Sec	50 Sec	60 Sec	600 Seconds
A	13.2	14.1	15.6	15.8	16.5	17.2	75.8
B	14.9	15.7	17.9	19.4	20.7	21.9	92.9
C	13.8	14.4	15	15.8	16.5	17.2	86.2
D	15.7	16.2	18.5	21.9	22.3	24.5	97.6

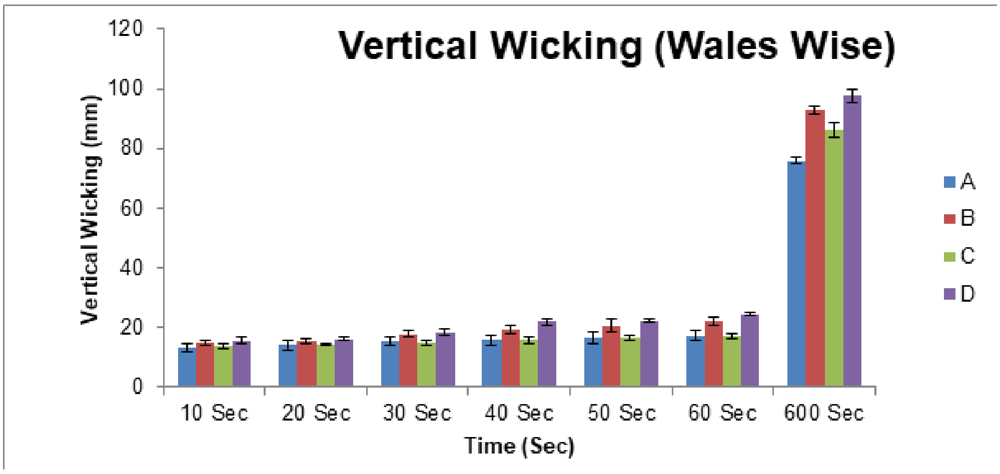
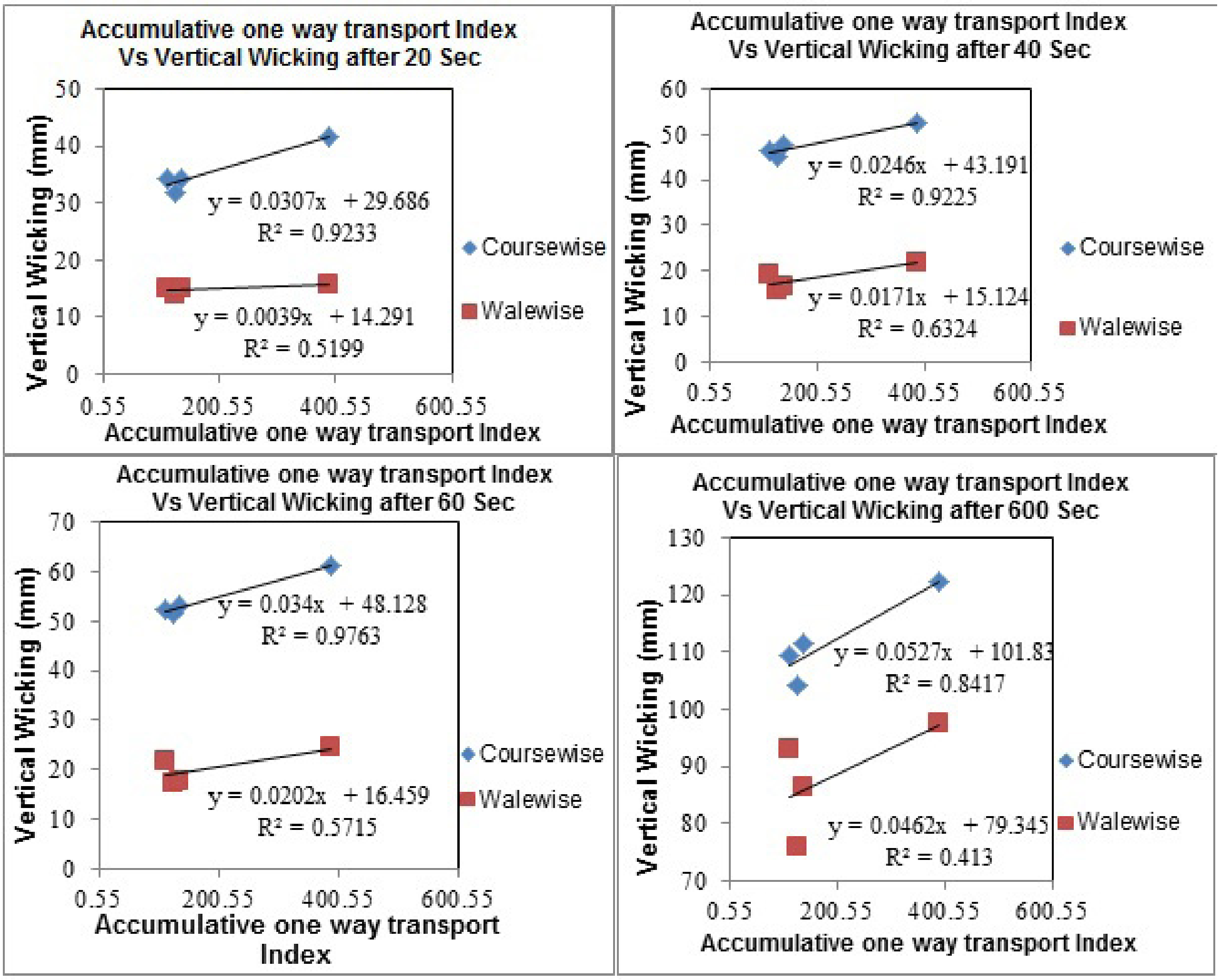


Figure 7: Vertical wicking of knitted samples (wale wise)



Co-relation of Vertical Wicking with Accumulative One-Way Transport Index and OMMC

There is a positive co-relation between vertical wicking and accumulative one-way transport index of samples A, B, C, and D. This co-relation is very strong in case of results taken in course-wise direction as compared to those taken in wale-wise direction. The co-relation of accumulative one way transport index was taken with vertical wicking after 20, 40, 60, and 600 s. This co-relation is shown in Figure 8.

There is a positive co-relation between vertical wicking and OMMC of samples A, B, C, and D. This co-relation is very strong in case of the results taken in course-wise direction as compared to the results taken in wale-wise direction. The co-relation of OMMC was taken with vertical wicking after 20, 40, 60, and 600 s. This co-relation is shown in Figure 9.

CONCLUSIONS

This study mainly focuses on the involvement of synthetic and natural yarn materials in single jersey knitted fabrics. Four knitted fabric samples having 50% courser cotton, 50% modal, 50% viscose, and 50% fine cotton, respectively, were developed with 25% coolmax and 25% multifilament polypropylene. According to the results, it was concluded that sample D showed fast wetting, less absorption, very fast spread ability of liquid moisture, and higher values of accumulative one-way transportation index and OMMC as compared to samples A, B, and C. Similarly, in case of vertical wicking results, it was concluded that sample D showed maximum uptake of liquid moisture at every segment of time from start to 10 min of time. Sample D comprises 50% finer cotton, whereas the other three samples composed of course counts of cotton, modal, and viscose. So from this study, it can also be concluded that if finer counts are used for these materials, best results can be achieved. There is a strong positive co-relation of accumulative one-way transport index and OMMC with vertical wicking especially in course-wise direction. Second part of this study will be the investigation of 3D porosity of functional underwear by means of micro tomography system.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Education, Youth and Sports of Czech Republic and the European Union's

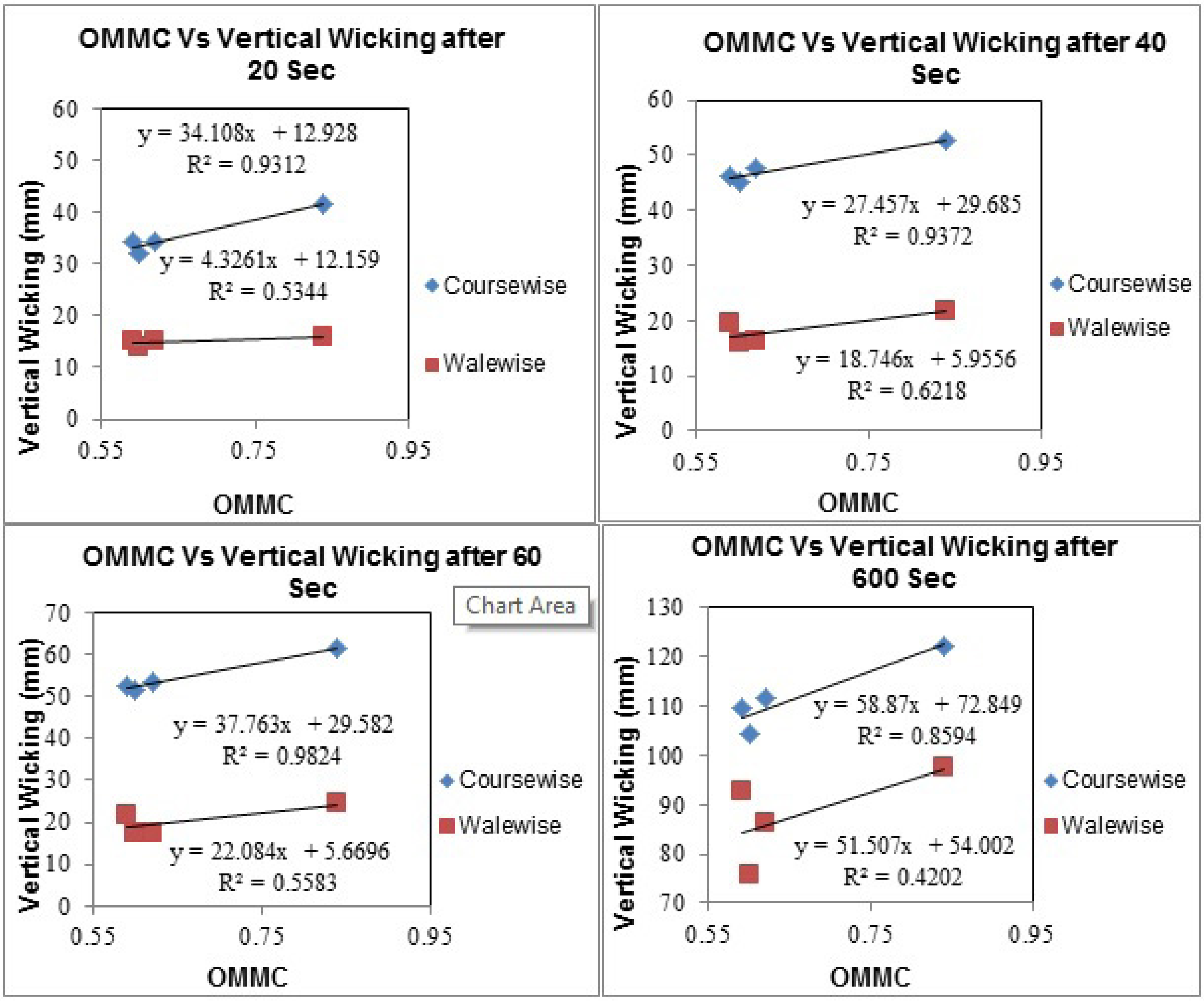


Figure 9: Co-relation of OMMC and vertical wicking

European Structural and Investment Funds in the frames of operational program, Research, Development and Education—Project Hybrid materials for Hierarchical structures (HyHi, Reg. No. CZ.02.1.01/0.0/16_019/0000843). The authors thank Masood Textile Mills, Faisalabad, Pakistan, for its full technical assistance for the preparation of knitted samples.

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