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Moisture transport in cotton woven fabrics of different weaves and linear density of weft yarn

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ABSTRACT

Cotton is the most common raw material of natural origin applied in clothing manufacturing. Clothing currently available on the market is usually made of plain weave fabrics. As part of this study, 3 pairs of cotton woven fabrics with different weaves (plain, twill 2/2 S, transverse rep 1/1) and different linear density of weft yarn (60 tex and 100 tex) were tested. The scope of research included determination of parameters characterizing the ability of fabrics to transport moisture in liquid form. The investigation was carried out on the Moisture Management Tester M290. The investigations allowed assessing the moisture transport of individual fabrics as well as the influence of both weave and linear density of weft yarn on the parameters characterizing the liquid moisture transport in the fabrics.

Keywords
cotton woven fabrics,
weave,
Moisture Management Tester,
moisture of liquid,
physiological comfort

1 Introduction

In the past, clothes were used by people primarily as a cover against the cold and other undesirable external factors. Currently, the role of clothing is not only to cover the body, but also to provide the user with comfort. Scientists around the world are concerned with the topic of physiological comfort. However, the interest in transporting moisture in liquid form (sweat) is relatively recent. Until now, there has not been such an accurate method or equipment to recreate the conditions for the spread of moisture through textiles. In Poland, this topic is still not very common. The transport of moisture in liquid form plays a very important role in shaping the physiological comfort, which is the basic feature of clothing usage. Ensuring the comfort of using clothing is currently one of the most important criteria for its production. From the point of view of physiological comfort, the ability to manage moisture by clothing fabrics is very important [1].

Comfort is a general condition that provides the user with comfort and satisfaction of clothing usage. It is defined as a state in which a person is in a state of harmony between the environment that surrounds them and psychophysical sensations, and their body is in a state of thermal equilibrium [2]. In the case of clothing, comfort of usage means no negative feelings caused by clothing being worn. Negative sensations can be affected by factors such as clothing mismatch, lack of freedom of movement, feeling cold or overheating, sweating, no sweat evaporation from the skin surface, etc. [1,3,4]. The transport of moisture in liquid form through the fabric is shown in Fig. 1.

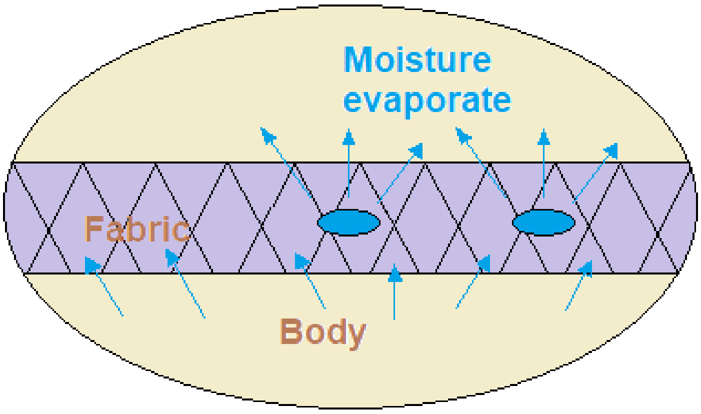


Fig. 1 Moisture management in clothing.

In addition to providing the user with comfort related to the use of clothing, the raw material from which the product is made is also important. The most commonly used raw material in the production of clothing is cotton, which is a natural fiber that has been known for a long time. Thanks to its hydrophilic properties, it is also suitable as a raw material in the production of clothing [5,6].

Cotton Incorporated has conducted research into the moisture management capacity of 100% cotton textiles. In their research, they used the entire spectrum of hydrophilic cotton properties. According to the conducted research, they stated that it is possible to produce 100% cotton fabrics with reduced absorbent capacity [7,8].

Woven fabrics are the most commonly used textile materials in the production of clothing. Garments made of woven fabrics are very often made of fabrics with plain weave. Plain weave belongs to the group of basic weaves, next to twill and satin [9].

As woven fabrics belong to the most widely used textiles in the production of clothing, in addition to knitted fabrics, the moisture management of these materials is also very important when choosing clothing.

Moisture management has the following function [10,11]:

- regulation of body temperature – sweat is produced when body temperature exceeds 37 °C. Suitable transport of moisture from the body surface to the environment reduces the body temperature;
- control of cloth weight increase;
- reduction of skin damage.

2 Materials and methods

2.1 Materials

Three pairs of cotton woven fabrics with different weaves (plain, twill 2/2 S, transverse rep 1/1) and different linear density of weft yarn (60 tex and 100 tex) were tested. Weaves report are presented in Fig. 2.
All fabric variants were manufactured on the basis of the same warp – 50 tex.

Pairs of woven fabrics:

- plain (100 tex) – plain (60 tex)
- twill 2/2 S (100 tex) – twill (60 tex)
- transverse rep (100 tex) – transverse rep (60 tex)

Linear densities of weft yarns are given in brackets.

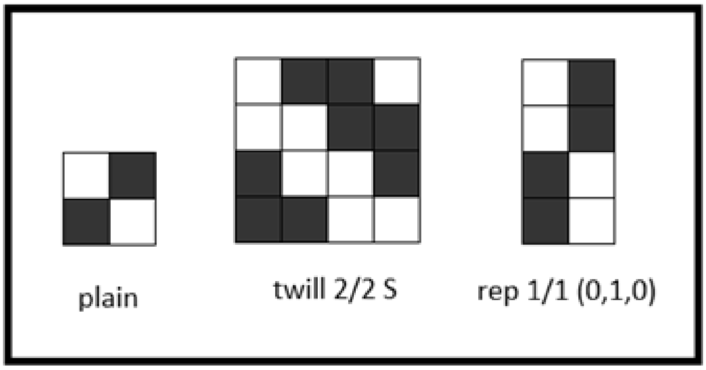


Fig. 2 Weaves applied in the manufactured fabric variants.

All fabrics have been finished in the same way. The finishing process included: desizing, washing, rinsing and drying. The basic parameters of the tested fabrics are shown in Table 1.

Table 1. Basic structural properties of investigated fabrics.

Parameter	**Unit**	**Value**					
		1	**2**	**3**	**4**	**5**	**6**
Weave	-	Plain	Plain	Twill 2/2 S	Twill 2/2 S	Rep 1/1 (0,1,0)	Rep 1/1 (0,1,0)
Weft density	**threads·dm^{-1}**	110					
Warp	-	50 tex					
Weft	-	100 tex	60 tex	100 tex	60 tex	100 tex	60 tex
Warp density	**cm^{-1}**	31.2	31.6	31.9	31.9	31.7	32
Weft density	**cm^{-1}**	11.5	11.7	11.6	11.8	11.9	11.8
Mass per unit area	**g·m^{-2}**	292	240	287	238	293	242
Warp crimp	**%**	14.2	8.8	7.0	5.9	9.8	6.8
Weft crimp	**%**	2.9	3.7	2.7	3.9	3.9	5.4
Thickness	**mm**	0.67	0.61	0.79	0.73	0.65	0.58

2.2 Methods

Fabrics have been tested for their ability to manage moisture in the form of liquid. The test was performed using the Moisture Management Tester M290 by SDL Atlas according to the device manual based on the AATCC Method 195-2011 [12].

Fig. 3 Moisture Management Tester M290

For more accurate results, 10 samples were tested for each type of fabric.

The device is controlled by a PC and special MMT290 software. The samples of 80 mm x 80 mm are cut from each tested fabric. The MMT is equipped with 2 sensors, upper and lower, each sensor is made of concentric rings of pins. During measurement, the sample is placed horizontally in the instrument between two sensors. The upper sensor examines the surface of fabric that is in direct contact with the skin, and the lower sensor the surface that is in contact with the environment. The measurement takes 2 minutes. For the first 20 seconds, synthetic sweat in the form of drops is dropped on the center of the top surface of fabric (Fig. 4). During the test, changes in electrical resistance are measured and recorded as the fluid passes through the sample.

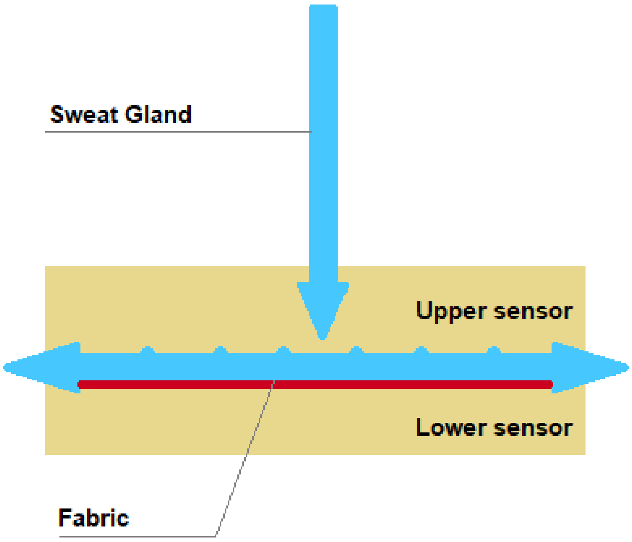


Fig. 4 Testing solution.

The test solution (synthetic sweat) is carried through the material in three directions [13]:

- spreading on the upper surface of the fabric,
- moisture transfer through the fabric from the top to the bottom surface,
- spreading on the lower surface of the fabric.

The MMT provides the values of the following parameters were determined:

- WT T – wetting time of top surface (s),
- WT B – wetting time of bottom surface (s),
- TAR – absorption rate of top surface (%/s),
- BAR – absorption rate of bottom surface (%/s),
- MWRtop – maximum wetted radius for top surface (mm),
- MWRbottom – maximum wetted radius for bottom surface (mm),
- TSS – spreading speed on top surface (mm/s),
- BSS – spreading speed on bottom surface (mm/s),
- R – accumulative one-way transport index (%),
- OMMC – Overall Moisture Management Capacity.

The MMT can identify 7 types of fabrics:

- waterproof fabric,
- water repellent fabric,
- slow absorbing and slow drying fabric,
- fast absorbing and slow drying fabric,
- fast absorbing and quick drying fabric,
- water penetration fabric,
- moisture management fabric.

The MMT device is used to examine woven and knitted fabrics as well as nonwovens. It can be also applied to examine textile packages.

The aim of the study was to examine pairs of cotton woven fabrics of different weaves and different linear density of weft yarn to characterize their ability to manage moisture in the form of liquid. The influence of the structural parameters – weave and linear density of the weft yarn – on the ability of the fabrics to transport the liquid moisture was also the aim of the investigations.

3 Results

Results from the Moisture Management Tester are presented in Tables 2 and 3, which present mean values from 10 measurements and the standard deviation of the results (in brackets).

Table 2. Results from Moisture Management Tester

Sample	**Weave**	**Weft**	**WT T (s)**	**WT B (s)**	**TAR (%/s)**	**BAR (%/s)**	**MWR_{top} (mm)**
1	Plain	100 tex	11.6 (6.3)	5.8 (3.1)	23.7 (4.2)	38 (16)	22.5 (2.6)
2		60 tex	4.9 (1.1)	5.3 (1.2)	90.2 (7.5)	70.1 (5.0)	27.0 (2.6)
3	Twill 2/2 S	100 tex	3.66 (0.19)	3.69 (0.29)	59.0 (1.2)	55.5 (0.9)	20 (-)
4		60 tex	3.14 (0.21)	3.30 (0.11)	55.1 (1.4)	52.1 (0.6)	20.5 (1.6)
5	Rep 1/1	100 tex	4.7 (0.7)	4.8 (0.5)	70.1 (7.7)	65.3 (3.0)	20 (-)
6		60 tex	4.3 (1.0)	4.3 (1.0)	61.9 (6.3)	62.1 (6.6)	20 (-)

Table 3. Results from Moisture Management Tester (continued)

Sample	Weave	Weft	MWR_{bottom} (mm)	TSS (mm/s)	BSS (mm/s)	R (%)	OMMC -
1	Plain	100 tex	24.0 (3.2)	1.57 (0.52)	1.83 (0.44)	89 (28)	0.30 (0.05)
2		60 tex	28.0 (2.6)	5.50 (0.52)	5.71 (0.56)	-82 (18)	0.42 (0.01)
3	Twill 2/2 S	100 tex	20 (-)	3.87 (0.20)	3.64 (0.16)	15 (12)	0.42 (0.02)
4		60 tex	20.5 (1.6)	4.36 (0.20)	4.22 (0.15)	19.0 (9.8)	0.44 (0.01)
5	Rep 1/1	100 tex	20 (-)	3.39 (0.15)	3.22 (0.16)	24 (12)	0.42 (0.02)
6		60 tex	20 (-)	3.89 (0.18)	3.87 (0.13)	33 (11)	0.48 (0.02)

On the basis of the obtained results, it was found that the tested samples differ in terms of the values of the indicators characterizing the moisture transport.

Fig. 5 and 6 show the test results for individual pairs of fabrics.

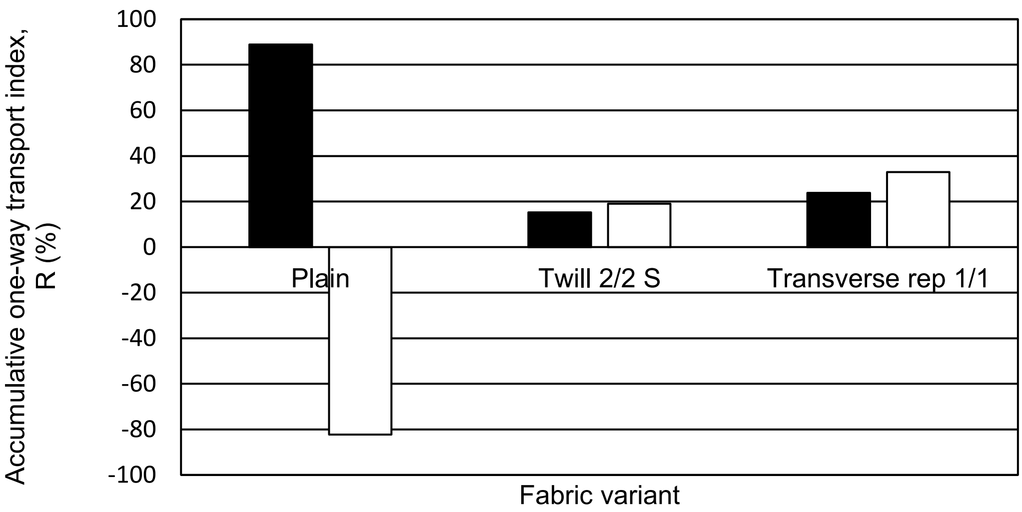


Fig. 5 Accumulative one-way transport index, R for individual pairs of fabrics.

The classification of fabrics according to the value of the accumulative one-way transport index is as follows [12]:

- < -50 – very poor,
- -50 - 100 – poor,
- 100 - 200 – good,
- 200 - 400 – very good,
- > 400 – excellent.

The R indicator characterizes the transport of liquid from the inside of the fabric to the outside. Positive and high values of the R parameter show that sweat can be easily and quickly drained from the body surface. According to the above classification and the results presented in Fig. 5, it can be concluded that all fabrics according to the program classification achieved a poor result, only a plain weave fabric with linear density of weft yarn of 60 tex achieved a very poor result. These results are not satisfactory. The diagram above shows that moisture is not easily and quickly removed to the environment

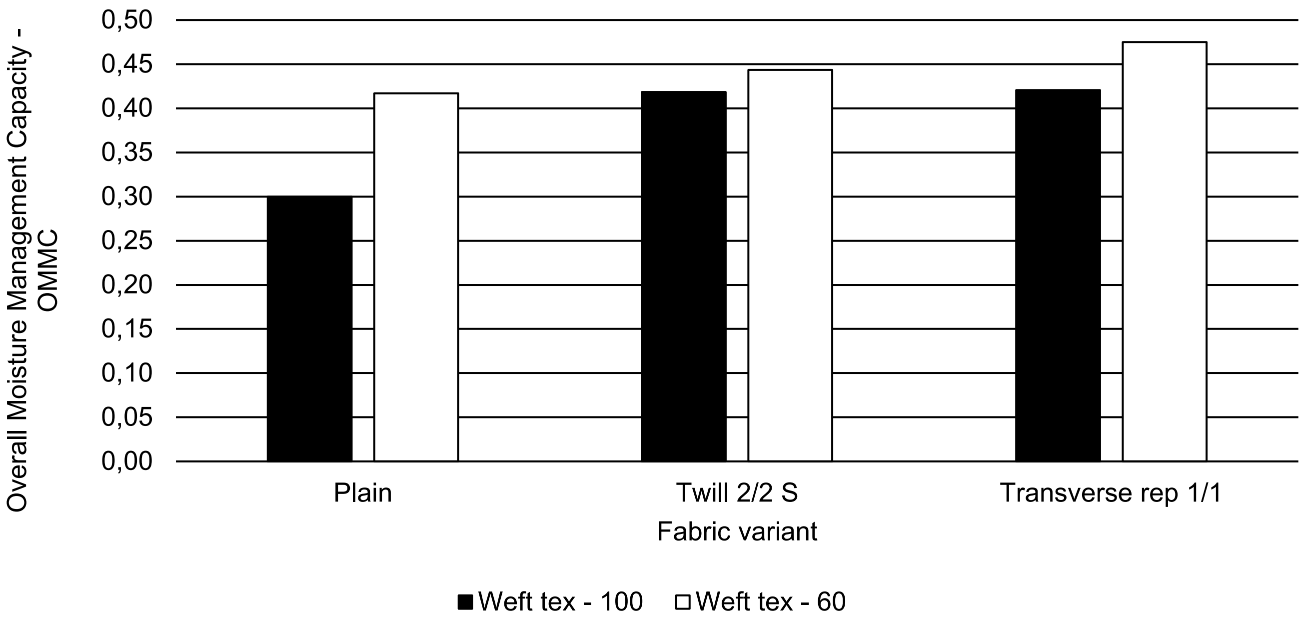


Fig. 6 Overall Moisture Management Capacity, OMMC, for individual pairs of fabrics.

The OMMC indicator (Overall Moisture Management Capacity) is calculated by the software using 3 parameters:

- absorption rate of bottom surface,
- moisture spreading speed for the bottom surface of the sample,
- accumulated one – transport index.

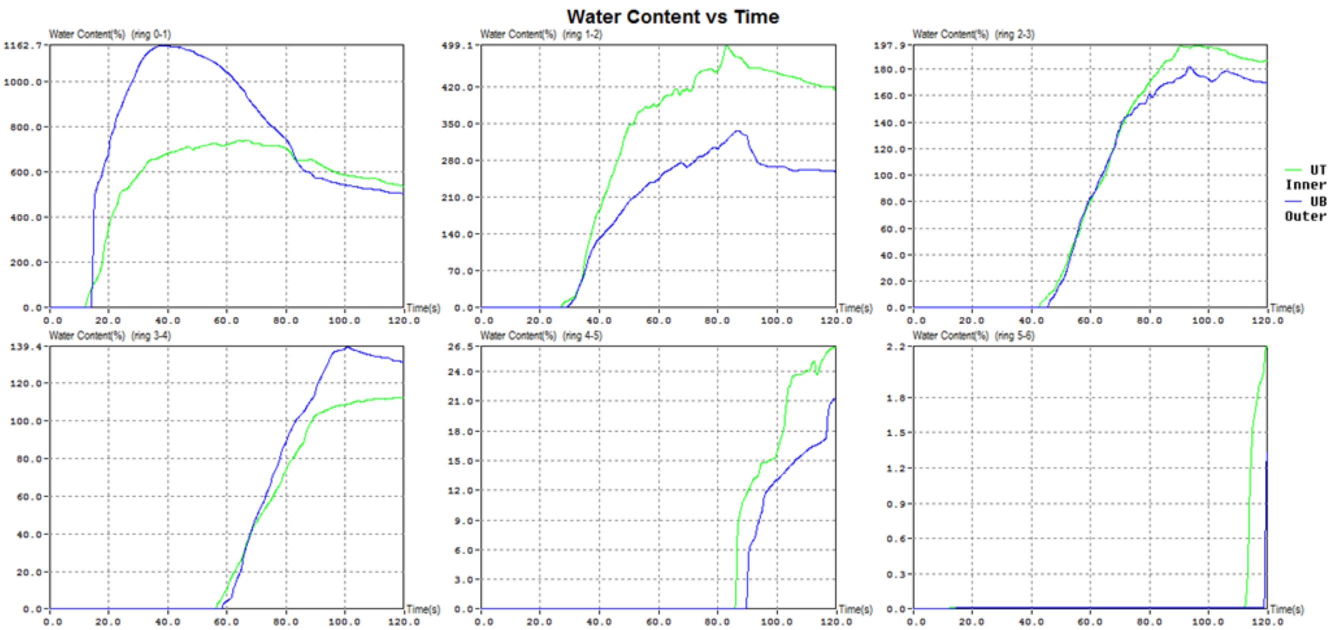
The classification of fabrics according to the value of the Overall Moisture Management Capacity is as follow [12]:

- 0 - 0.2 – very poor,
- 0.2 - 0.4 – poor,
- 0.4 - 0.6 – good,
- 0.6 - 0.8 – very good,
- 0.8 - 1 – excellent.

Overall Moisture Management Capacity for all fabrics except plain weave woven fabric with a linear density of weft yarn with 100 tex are classified as good from the moisture management point of view. A plain weave fabric has the most weft and warp interlacing points and a more compact structure compared to other fabrics. The linear density of the weft yarn, which is 100 tex, probably also had a significant influence on the result. Due to the higher linear weight, more moisture can be absorbed by the fabric and kept inside the fabric structure. It limits the liquid evaporation.

By analyzing the pairs of woven fabrics, it can be concluded that better results were achieved for the woven fabrics with a linear density of weft yarn of 60 tex.

Fig. 7 and 8 present graphic interpretations of the measurements that were downloaded from the software cooperating with the MMT 290 device.



	Top Surface	Bottom Surface
Wetting Time	11.419	13.197
Absorption rate(%/s)	21.1022	31.5964
Max wetted radius(mm)	25.0	25.0
Spreading Speed(mm/s)	1.5692	1.4781
One Way Transport Capability	68.6937	
Test Description	Praca dyplomowa	

Fig. 7 Top and bottom moisture content for plain weave woven fabric (weft 100 tex) for individual sensor rings.

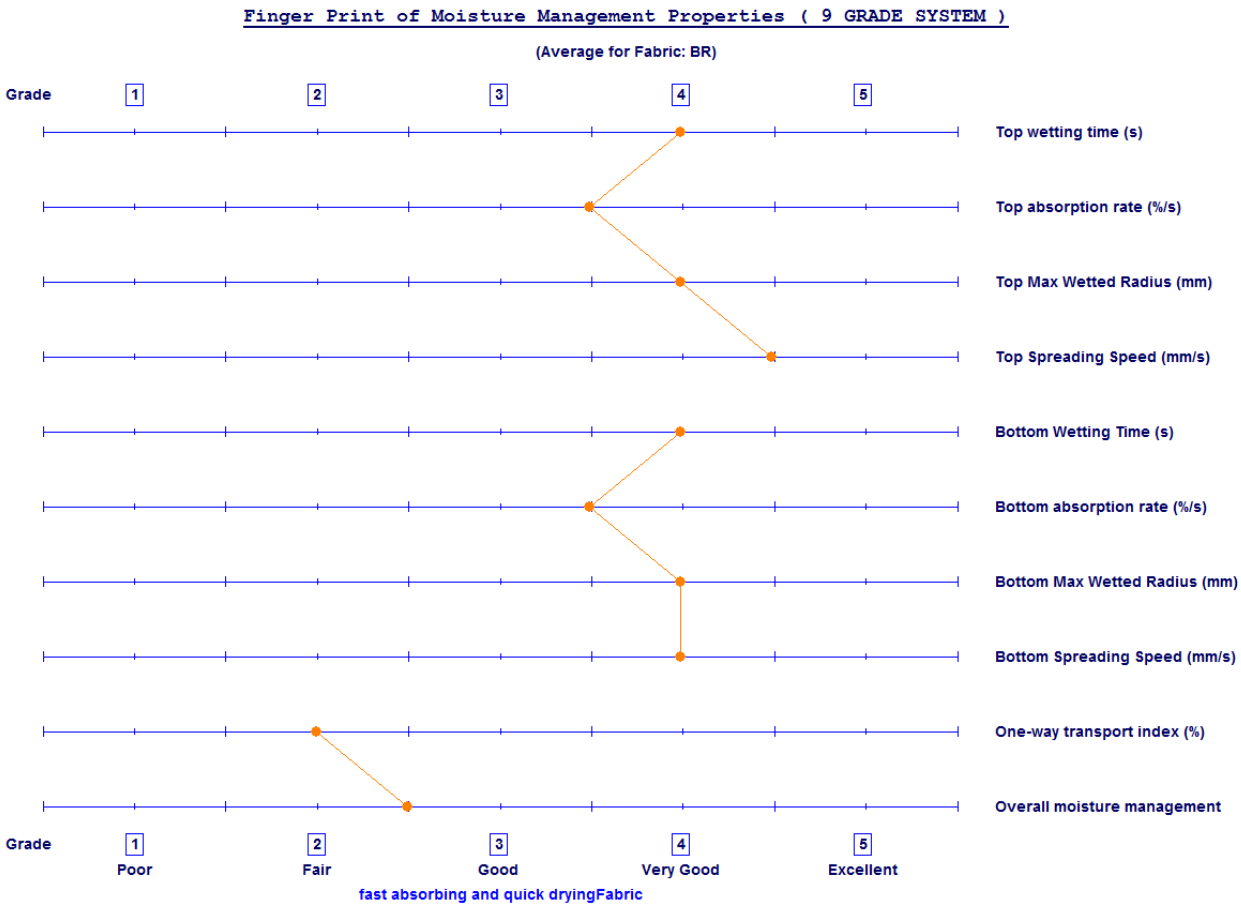


Fig. 8 The ability of twill 2/2 S weave woven fabric (weft 100 tex) to manage liquid moisture.

4 Conclusions

After analyzing the test results, it can be concluded that better results were achieved by the fabric with the linear density of weft yarn 60 tex than by the woven fabric which linear density of weft yarn 30 tex. This may be because woven fabrics made of higher linear density retain moisture in the fiber structure for a long time. Due to the fact that cotton has hydrophilic properties, this moisture can be retained for a longer time in the structure of woven fabrics than in the case of fabrics that contain fibers other than cotton.

Woven fabrics made of cotton yarns are not the best choice for clothing due to their properties. However, by appropriate modification of, i.e., the linear density of the yarn or the weave, the moisture transport properties of the woven fabrics can be improved to make them better in terms of moisture management.

Author Contributions

D. Kamińska: investigation, data curation, writing – original draft preparation; M. Matusiak: methodology, supervision, writing – review and editing, funding acquisition, data curation, resources. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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