# Investigation of the effect of cotton knitted fabric structure of babywear on moisture management properties

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## ABSTRACT – REZUMAT

**Investigation of the effect of cotton knitted fabric structure of babywear on moisture management properties**

*In recent years, baby clothing has become an important role in the garment sector. The increasing importance of baby clothing, along with the new designs, different fabric structures, accessories and clothing comfort is required to develop. Due to the increasing importance given to baby health in the world, babywears have to be manufactured from materials that are not harmful to health in accordance with the standards.*

*The purpose of this study is to investigate the effect of cotton knitted fabrics structure of babywear on moisture management properties. For this reason, moisture management properties (wetting time, absorption rate, spreading speed, accumulative one-way transport capability (OWTC) and overall moisture management capability (OMMC)) of cotton knitted fabrics of different structures which are widely used in babywear have been examined. Moisture management tester was used for liquid transport of the knitted fabric samples.*

*As a result of the study, it is observed that single jersey fabric had higher OMMC values than these of interlock and 1x1 rib knitted fabrics. Regarding the effect of yarn thickness, liquid transport increased with decreasing yarn thickness in general. Regarding the effect of fabric weight and fabric thickness, liquid transport decreased with increasing weight and thickness in general. Negative correlations were observed between fabric weight, fabric thickness and overall moisture management capability.*


***Keywords:*** *babywear, moisture management, cotton, knitted*


**Influența structurii tricoturilor de bumbac din îmbrăcămintea pentru bebeluși asupra proprietăților de control a umidității**

*În ultimii ani, îmbrăcămintea pentru bebeluși a înregistrat un rol din ce în ce mai important în sectorul articolelor de îmbrăcăminte. Această importanță, împreună cu noi modele, diferite structuri ale materialelor textile, accesoriile și confortul vestimentar necesită noi abordări. Datorită importanței acordate sănătății bebelușului, îmbrăcămintea trebuie să fie realizată din materiale care nu sunt dăunătoare sănătății, în conformitate cu standardele în vigoare.*

*Scopul acestui studiu este de a investiga influența structurii tricoturilor de bumbac din îmbrăcămintea pentru bebeluși asupra proprietăților de control a umidității. Din acest motiv, au fost studiate proprietăţile aferente controlului umidităţii (timpul de umectare, rata de absorbție, viteza de umezire, capacitatea acumulată de transport unidirecțional (OWTC) și capacitatea generală de control al umidității (OMMC)) din tricoturile de bumbac cu diferite structuri, care sunt utilizate pe scară largă în îmbrăcămintea pentru bebeluși. Testerul de control al umidității a fost utilizat pentru transportul lichidelor din probele de tricot.*

*Ca rezultat al studiului, se observă că tricoturile glat prezintă valori ale OMMC mai mari decât tricoturile interlock și tricoturile patent 1x1. În ceea ce privește influenţa fineții firelor, transportul lichidului a crescut odată cu creştere fineţii firelor. Din punctul de vedere al influenţei masei şi grosimii tricoturilor, transportul lichidului a scăzut odată cu creșterea masei şi grosimii. Au fost observate corelații negative între masa tricotului, grosimea tricotului și capacitatea totală de control al umidității.*


***Cuvinte-cheie:*** *îmbrăcăminte pentru bebeluși, controlul umidității, bumbac, tricot*

## INTRODUCTION

Babywear is a clothing product category for babies and infants up to 2 years old. In recent years, baby clothing has become an important place in the garment sector. The increasing importance of baby clothing, along with the new designs, different fabric structures, accessories and clothing comfort is required to develop. Due to the increasing importance given to baby health in the world, babywears have to be manufactured from materials that are not harmful to health in accordance with standards.

Today more than 50% of babywear is made of knitted fabric and most of them are used cotton. Choosing the right fabric is very important when producing babywear. The choice of the right fabric in the babywear increases the quality of the garment, the consumer's desire to buy the garment and the comfort of the baby in the garment.

Infant's clothing is sized according to their age: 3, 6, 12, 18, 24 months. During this age, the head does not correctly stand on their neck. So, garments should be selected with a full opening. According to the seasons, the material should be selected, thick or thin. Also, soft materials with the lightweight should be selected [1].

Fabrics of babywear must be durable to wear and tear. Babies prefer soft, absorbent fabrics that do not scratch their body. Cotton or polyester cotton blends provide comfort, durability, and easy care for fabrics of babywear.

The selection of suitable cloth for the babies allows them to move comfortably. The cloth should not irritate the delicate skin of the baby. When selecting babywear, there are a few things needed to be aware of in order to keep baby safe and comfortable. So, the patterns of the babywear should be simple and comfortable [1]. For babies, comfort and safety are very important. The fabric should not be sticky, slippery or thick, but also breathable. The fabric also has to withstand of washing. Fabrics of babywear should transfer the sweat outside quickly to provide tactile and sensorial comfort for babies [2].

The ideal babywear should be soft, comfortable, easy to put and take off, ligthweight, non-irritating and allow quick transmission of sweat from skin to environment.

Moisture management transmission is one of the most important performance properties, which determine the comfort level of the fabric, in the clothing industry. When any liquid is dropped on the surface of a fabric, it moves into multiple directions and its movement depends upon the structure of the fabric. The properties of the fabric regarding the liquid and moisture transport into multiple dimensions are called the moisture management transmission properties [3–4].

The primary cooling mechanism of the body is evaporation of perspiration. The behavior of the moisture absorbed at the fabric inner surface and evaporated at the outer surface significantly influences the babies comfort. Therefore, it is necessary to determine the fabric structural properties before the design of babywear. Babywear needs the ability to transfer sweat from skin's surface to the outer side of the garment to evaporate and then to maintain the dry sensation during sleeping or playing with a heavy sweating rate [5–6].

To improve the comfort of the babywears, it is important to know the liquid moisture management properties of the fabrics [7–8]. In fabric structures, for high moisture management properties generally, cotton fibers are used in order to maximize transport moisture properties.

The purpose of this study is to investigate the effect of the babywear cotton knitted fabrics structure on moisture management properties. For this reason, moisture management properties (wetting time, absorption rate, spreading speed, accumulative one-way transport capability (OWTC) and overall moisture management capability (OMMC)) of cotton knitted fabrics of different structures which are widely used in baby clothing have been examined.

## MATERIALS AND METHODS

### Materials

In this study, moisture management properties of six types of cotton knitted fabrics at two groups with different structural properties which are widely used for baby wears were examined. Fabric samples at the first group have same weave type (interlock) but different yarn counts. Fabric samples at the second group have different weave types but nearly same yarn count. At this study, effect of yarn counts, weave types, fabric thickness and fabric weight of 100% cotton knitted fabrics was investigated and trying to find best fabric structure for moisture management properties for babywears. Basic properties of fabric samples for this study are shown in table 1.

### Methods

In this study, moisture management properties tests were made to the fabric samples. The ASTM D 3776-09a standard was used to measure the mass per unit area [9]. The ASTM D1777-96 (2007) standard was used to measure the thickness values of fabric samples [10].

Moisture management properties were measured by SDL Atlas M 290 Moisture Management Tester (MMT) instrument (figure 1) according to AATCC 195 standard [11]. Fabric sample is placed horizontally in the instrument between the upper and lower sensors (figure 2). Wetting time of the top and bottom surface, absorption rate of top and bottom surface, spreading speed of the top and bottom surface, accumulative one-way transport capability and overall moisture management capability of the fabric samples were examined to determine the proper babywear knitted fabric structure for moisture transfer.

Table 1

STRUCTURAL PARAMETERS OF FABRIC USED

| Fabric groups | Fabric code | Weave type | Yarn count (Ne) | Material | Thickness (mm) | Weight (g/m$^2$) | Wales per cm | Courses per cm |
|---|---|---|---|---|---|---|---|---|
| 1st group | A1 | Interlock | 24/1 | 100% Cotton | 0.82 | 265 | 12 | 14 |
| | A2 | Interlock | 36/1 | 100% Cotton | 0.75 | 210 | 15 | 14 |
| | A3 | Interlock | 50/1 | 100% Cotton | 0.69 | 160 | 18 | 14 |
| | A4 | Interlock | 60/1 | 100% Cotton | 0.59 | 155 | 18 | 17 |
| 2nd group | A1 | Interlock | 24/1 | 100% Cotton | 0.82 | 265 | 12 | 14 |
| | A5 | 1x1 rib | 30/1 | 100% Cotton | 0.72 | 205 | 12 | 19 |
| | A6 | Single Jersey | 30/1 | 100% Cotton | 0.40 | 155 | 16 | 20 |

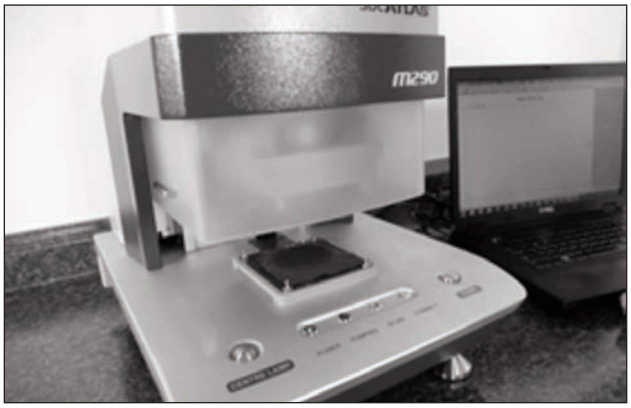


Fig. 1. Moisture management tester (MMT) [7]

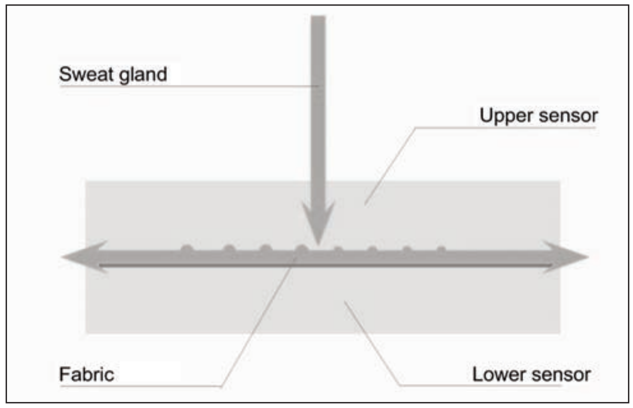


Fig. 2. Sketch of moisture management tester sensors [7]

MMT test results were evaluated using the grading scale, which is a 5-point scale, given according to AATCC Test Method 195 (2012). For each fabric, five repetitions were made, and the arithmetic mean was calculated from the individual measurement results.

At grading scales of AATCC Test Method 195, the excellent value for wetting time is (< 3) = very fast, for absorption rate is (>100) = very fast, for spreading speed is (>4) = very fast, for accumulative one-way transport capability is (>400) = excellent and for overall moisture management capability (0MMC) is (>0.8) = excellent, so that a fabric which has these values is excellent for liquid transmission.

Prior to the tests, all fabric samples were conditioned for 24 hours in standard atmospheric conditions (at a temperature of 20±2°C and relative humidities of 65 ±2%).

The results were evaluated statistically by using SPSS 14.0 program. Completely randomized single-factor (one way) multivariate analysis of variance (ANOVA) as a fixed model was applied to data. Student-Newman-Keuls (SNK) tests were used to compares the means. The treatment levels were marked in accordance with the mean values, and levels were marked with the different letter (a, b, c and d) to show that they were significantly different.

The correlation coefficients were calculated to determine the relationships between fabric structural properties (weight, thickness and yarn count) and fabric moisture management properties (wetting time, absorption rate, spreading speed, accumulative one-way transport capability and overall moisture management capability).

## RESULTS AND DISCUSSION

Wetting time (top and bottom), absorption rate (top and bottom), spreading speed (top and bottom), accumulative one-way transport capability (OWTC) and overall moisture management capability (OMMC) test results of the fabric samples are presented in figures 3–7. Analysis of variance and Student-Newman-Keuls test results are given in tables 2 and 3.

The correlation coefficient values between the fabric structural properties (weight, thickness and yarn count) and moisture management properties of fabrics are presented in table 4. Positive correlations were observed between weight, thickness and wetting time. In other words, the wetting time values increased when the fabric weight and thickness increased. The negative correlations were observed between weight, thickness and absorption rate, spreading speed, OWTC and OMMC values, as shown in

Table 2

STATISTICAL ANALYSIS (ANALYSIS OF VARIANCE AND SNK TEST) RESULTS FOR MOISTURE MANAGEMENT PROPERTIES (WETTING TIME AND ABSORPTION RATE)

| Parameters | | Wetting Time Top (sec) | | Wetting Time Bottom (sec) | | Absorption Rate Top (%/sec) | | Absorption Rate Bottom (%/sec) | |
|---|---|---|---|---|---|---|---|---|---|
| | | P/Sig. | SNK | P/Sig. | SNK | P/Sig. | SNK | P/Sig. | SNK |
| Yarn Count (Ne) | A1 (24/1) | 0.000* | 4.46 d | 0.000* | 4.37 d | 0.000* | 35.74 a | 0.190 | 50.35 a |
| | A2 (36/1) | | 4.11 c | | 4.30 d | | 49.17 c | | 56.95 a |
| | A3 (50/1) | | 3.44 a | | 3.38 a | | 45.73 b | | 52.20 a |
| | A4 (60/1) | | 3.67 b | | 3.75 b | | 45.89 b | | 55.04 a |
| Fabric Type | A1 (interlock) | 0.000* | 4.46 c | 0.000* | 4.37 c | 0.000* | 35.74 a | 0.000* | 50.35 a |
| | A5 (rib) | | 3.59 b | | 3.57 b | | 44.86 b | | 56.07 b |
| | A6 (jersey) | | 3.06 a | | 3.15 a | | 50.76 a | | 75.25 c |

* statistically significant (P < 0.05).
a, b, c and d represent statistically difference ranges according to SNK test.

Table 3

| STATISTICAL ANALYSIS (ANALYSIS OF VARIANCE AND SNK TEST) RESULTS FOR MOISTURE MANAGEMENT PROPERTIES (SPREADING SPEED, OWTC AND OMMC) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | | **Spreading Speed (Top) (mm/sec)** | | **Spreading Speed (Bottom) (mm/sec)** | | **OWTC (%)** | | **OMMC** | |
| | | **P/Sig.** | **SNK** | **P/Sig.** | **SNK** | **P/Sig.** | **SNK** | **P/Sig.** | **SNK** |
| Yarn Count (Ne) | A1 (24/1) | 0.000* | 2.43 a | 0.000* | 2.60 a | 0.000* | 222.47 b | 0.190 | 0.548 a |
| | A2 (36/1) | | 2.88 b | | 2.86 b | | 157.68 a | | 0.516 a |
| | A3 (50/1) | | 3.66 c | | 3.95 d | | 317.35 c | | 0.769 b |
| | A4 (60/1) | | 3.52 c | | 3.65 c | | 312.47 d | | 0.749 b |
| Fabric Type | A1 (interlock) | 0.000* | 2.43 a | 0.000* | 2.60 a | 0.000* | 222.47 a | 0.000* | 0.548 a |
| | A5 (rib) | | 3.32 b | | 3.48 b | | 240.45 a | | 0.658 b |
| | A6 (jersey) | | 4.22 c | | 4.53 c | | 309.35 b | | 0.830 c |

* statistically significant (P < 0.05).
a, b, c and d represent statistically difference ranges according to SNK test.

Table 4

| CORRELATION COEFFICIENT BETWEEN STRUCTURAL AND MOISTURE MANAGEMENT PROPERTIES OF FABRICS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Wetting Time** | | **Absorption Rate** | | **Spreading Speed** | | **OWTC** | **OMMC** |
| | **Top** | **Bottom** | **Top** | **Bottom** | **Top** | **Bottom** | | |
| Weight | 0.870 | 0.804 | –0.760 | –0.481 | –0.910 | –0.841 | –0.740 | –0.860 |
| Thickness | 0.845 | 0.770 | –0.681 | –0.881 | –0.904 | –0.866 | –0.650 | –0.832 |
| Yarn Count | –0.270 | –0.234 | 0.287 | –0.237 | 0.337 | 0.286 | 0.524 | 0.428 |

table 4. In other words, the absorption rate, spreading speed, OWTC and OMMC values increased when the the fabric weight and thickness decreased.

## Wetting Time (WT) test results

WT top and bottom range values were compared using the grading scale, which is a 5-point scale, according to AATCC Test Method 195. The grades of the indexes are: 1 (≥ 120) = non-wetting, 2 (20–119) = slow, 3 (5–19) = medium, 4 (3–5) = fast, 5 (<3) = very fast.

The wetting time values of the fabric samples are shown in figure 3. In figure 3, it was observed that all fabric samples had "fast" WT values. At the first group, fabric sample (A1) with highest thickness and weight had the highest wetting time. At the second group, single jersey fabric sample (A6) had the lowest WT values because it has lowest fabric thickness. The face and back side of fabric samples were named "the top surface" (inner) and "the bottom surface" (outer). The top surface of the fabric is designed to be in touch with the human skin. The top and bottom surfaces of the fabric samples gave almost similar results to each other for wetting time results. The fabric samples aren't thick. So that the wetting time values at the top and bottom surfaces were similar. Cotton fiber has a hydrophilic property. Cotton fabric has a high moisture absorption property; the test liquid penetrates into the cotton fibers.

According to the statistical analysis in table 2, the yarn count (Ne) and fabric type have a significant effect on top and bottom wetting time values of the fabric samples.

Positive correlations were observed between fabric weight, fabric thickness and wetting time, as shown in table 4.

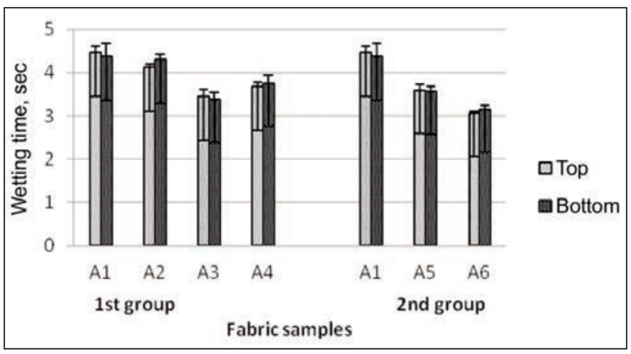


Fig. 3. Wetting time of top and bottom surface of fabric sample

## Absorption Rate (AR) test results

Absorbency is used to describe the ability of a fabric in moisture. AR top and bottom range values were compared using the grading scale, which is a 5-point scale, according to AATCC Test Method 195.

The grades of the indexes are: 1 (0–9) = very slow, 2 (10–29) = slow, 3 (30–49) = medium, 4 (50–100) = fast, 5 (> 100) = very fast.

Absorption rates on the top and bottom surfaces (%/sec) are the average moisture absorption ability of the specimen, in the pump time [12].
The absorption rate values of the fabric samples are shown in figure 4. At the first group, it was observed that (A2), (A3) and (A4) fabric samples AR values higher than (A1). At the second group, it was observed that single jersey fabric sample (A6), AR values higher than 1×1 rib (A5) and interlock (A1) fabric samples. At these fabric samples when the fabric thickness and fabric weight decrease, AR values increase. The top and bottom surfaces of the fabric samples gave different results to each other. Absorption rate value of bottom surface was higher than top surface. The total water content of the top and bottom surfaces seems to be lower for cotton fabric. The wetted areas on both surfaces are not large, since the water molecules are absorbed by the fibers.

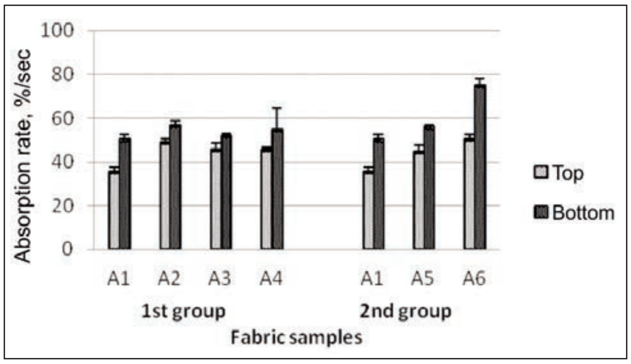


Fig. 4. Absorption of top and bottom surface of fabric samples

According to the statistical analysis in table 2, the yarn count (Ne) and fabric type have a significant effect on absorption rate values of the top surface of the fabric samples but the yarn count (Ne) doesn't have a significant effect on absorption rate values of the bottom surface of the fabric samples.
Negative correlations were observed between fabric weight, fabric thickness and absorption rate, as shown in table 4.

### Spreading Speed (SS) test results

SS top and bottom range values were compared using the grading scale, which is a 5-point scale, according to AATCC Test Method 195. The grades of the indexes are: 1 (0.0–0.9) = very slow, 2 (1.0–1.9) = slow, 3 (2–2.9) = medium, 4 (3–4) = fast, 5 (>4) = very fast.
The spreading speed values of the fabric samples are shown in figure 5. At the first group, it was observed that (A1) and (A2) fabric samples had "medium" and (A3), (A4) fabric samples had "fast" SS values. At the second group (A5) fabric sample had "fast" and (A6) fabric sample had "very fast" SS values. At these fabric samples when the fabric thickness and fabric weight decrease, SS values increase. The top and the bottom surfaces of the fabric samples gave different results to each other. Spreading speed value of bottom surface was higher than top surface. This is because the absorption rate value of bottom surface was higher than top surface.

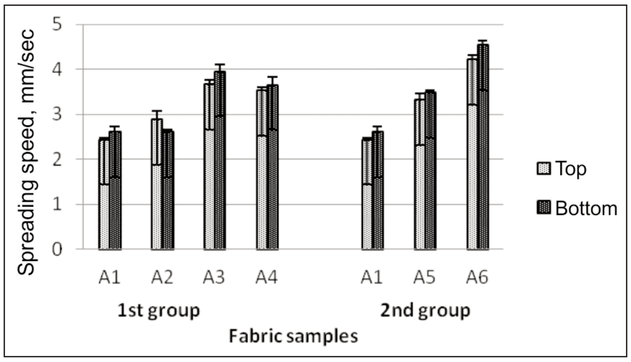


Fig. 5. Spreading speed of top and bottom surface of fabric samples

According to the statistical analysis in table 3, the yarn count (Ne) and fabric type have a significant effect on spreading speed values of the top and the bottom surfaces of the fabric samples.
Negative correlations were observed between fabric weight, fabric thickness and spreading speed, as shown in table 4.

### Accumulative One-Way Transport Capability (OWTC) test results

OWTC means, the difference of the cumulative moisture content between the two surfaces of the fabric. OWTC value gives the difference between the area of the liquid moisture content curves of the top and the bottom surfaces of a specimen with respect to time.
OWTC range values were compared using the grading scale, which is a 5-point scale, according to AATCC Test Method 195. The grades of the indexes are: 1 (<–50) = very poor, 2 (–50–99) = slow, 3 (100–199) = good, 4 (200–400) = very good, 5 (>400) = excellent.
The OWTC values of the fabric samples are shown in figure 6. At the first and the second groups, it was observed that all fabric samples except A2 had "very good" OWTC values. A2 had "good" OWTC value. The reason for this explains with the denser structure of fabric sample A2 than A1. In these fabric samples,

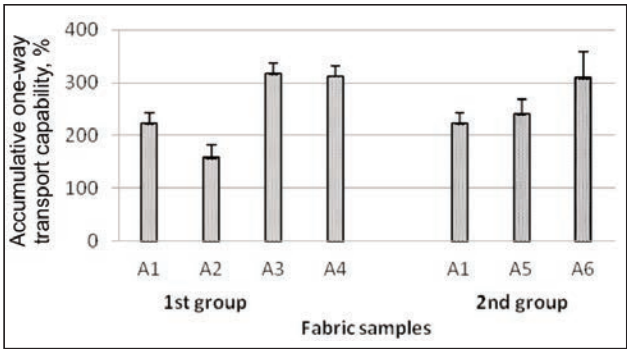


Fig. 6. Accumulative one-way transport capability of top and bottom surface of fabric samples

when the fabric thickness and fabric weight decrease, OWTC values increase.

According to the statistical analysis in table 3, the yarn count (Ne) and fabric type have a significant effect on OWTC values of the fabric samples.

Negative correlations were observed between fabric weight, fabric thickness and accumulative one-way transport capability, as shown in table 4.

### Overall Moisture Management Capability (OMMC) test results

OMMC is an index that determines the total transfer capacity of the liquid moisture in a fabric. Overall moisture management capability indicates the overall ability of the fabric to manage the transport of liquid moisture, which includes three aspects of performance; moisture absorption rate of the bottom side, one-way liquid transport ability and maximum spreading speed of the bottom side [13–16]. The overall moisture management capacitiy (OMMC) was calculated using equation 1.

$$OMMC = C_1\, AR_B + C_2\, OWTC + C_3\, SS_B \qquad (1)$$

Where $C_1$, $C_2$ and $C_3$ are the weights of the indexes of the absorption rate of the bottom surface ($AR_B$), the one-way transport capability (OWTC) and the spreading speed of the bottom surface ($SS_B$). Here $C_1$ = 0.25, $C_2$ = 0.5 and $C_3$ = 0.25, and they are adjustable in practice according to end-of-use purposes.

The high overall moisture management capacity value means that the moisture transfer is high [12].

OMMC range values were compared using the grading scale, which is a 5-point scale, according to AATCC Test Method 195. The grades of the indexes are: 1 (0.0–0.19) = very poor, 2 (0.2–0.39) = poor, 3 (0.4–0.59) = good, 4 (0.60–0.80) = very good, 5 (> 0.80) = excellent.

The OMMC values of the fabric samples are shown in figure 7. At the first group, it was observed that (A1), (A2) had “good” and (A3), (A4) had “very good”. At the second group, (A1), (A5) had “good” and (A6) had “excellent” OMMC values. At these fabric samples when the fabric thickness and fabric weight decrease, OMMC values increase.

According to the statistical analysis in table 3, the fabric type has a significant effect on the OMMC values of the fabric samples.

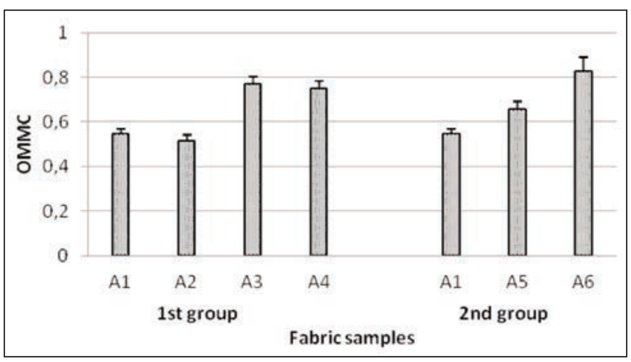


Fig. 7. Overall moisture management capability of top and bottom surface of fabric samples

Negative correlations were observed between fabric weight, fabric thickness and overall moisture management capability, as shown in table 4.

## CONCLUSION

In recent years, baby clothing has become an important role in the garment sector. The increasing importance of baby clothing, along with the new designs, different fabric structures, accessories and clothing comfort is required to develop.

Today more than 50% of babywear is made of knitted fabric and most of them are used cotton. Choosing the right fabric is very important when producing babywear. The choice of the right fabric in the babywear increases the quality of the garment, the consumer’s desire to buy the garment and the comfort of the baby in the garment.

The primary cooling mechanism of the body is evaporation of perspiration. The behavior of the moisture absorbed at the fabric inner surface and evaporated at the outer surface significantly influences the babies comfort. Therefore, it is necessary to determine the fabric structural properties of moisture transfer before design of babywear. Babywear needs the ability to transfer sweat from skin’s surface to the outer side of the garment to evaporate and then to maintain the dry sensation during sleeping or playing with a heavy sweating rate.

Fabrics of babywear must be durable to wear and tear. Babies prefer soft, absorbent fabrics that do not scratch their body. Cotton or polyester cotton blends provide comfort, durability, and easy care for fabrics of babywear.

Moisture management properties of the fabrics are among the most important parameters that determine the wearer’s comfort perception. Sweat transmission and absorption properties of garment are affected by fiber properties, yarn and fabric structural parameters, chemical processing and clothing design properties.

In this study, the effect of cotton knitted fabrics structure fabric weight, fabric thickness, weave type and yarn count of babywear on moisture management properties was investigated.

It has been tested that different knitted structures have different comfort properties. The fabric structure properties influence moisture transfer properties.

In this study single jersey fabric sample (A6) had an “excellent” accumulative one-way transport capability (OWTC) and overall moisture management capability (OMMC) values. Also single jersey fabric wetting time, absorption rate and spreading speed were very fast.

On the other hand, single jersey fabric should be chosen for babywears for better moisture management properties.

Interlock fabric samples (A3) and (A4) had “very good” accumulative one-way transport capability (OWTC) overall moisture management capability (OMMC) values.

Statistical analysis showed that yarn count and knitted fabric type had an effect on moisture management properties. It was seen that the spreading speed, OWTC and OMMC values increased as yarn thickness, fabric weight and fabric thickness decreased. A positive correlation was observed between fabric weight, fabric thickness and wetting time. But at the same time negative correlations were observed between fabric weight, fabric thickness and absorption rate, spreading speed, OWTC and OMMC values.


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