The Effect of Weave Pattern on the Moisture Management Properties of 100% Cotton fabric

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Abstract

In this study, the effect of weave pattern on moisture management properties of 100% cotton differently woven fabrics have been assessed. The relation between fabric constructional parameters (such as fabric thickness, fabric weight, fabric bulk density, fabric cover factor, yarn count, yarn crimp and yarn twist per meter) and moisture management properties concerning the wetting time, spreading speed, demand absorbency capacity, maximum absorption rate, vertical wicking rate, air permeability and drying time were examined in accordance with different weave patterns (such as 1/1 plain, 3/1 satin and 2/1terry (both sided)). A general overview of the results showed that moisture management properties of cotton woven fabrics were affected by the weave patterns and constructional parameters.

Keywords

Cotton woven fabric, weave pattern, constructional parameters, moisture management

1.0 Introduction

Moisture transport properties of fabric in multi-dimensions are referred as moisture management properties. It significantly influences human perception of moisture sensation [1-5]. A new method and instrument called the moisture management tester (MMT) is developed to evaluate textile moisture management properties [4-5]. Moisture management of a fabric is its ability to absorb and transfer moisture through the fabric [6]. It is one of the key performance criteria in today's apparel industry which decides the comfort level of the fabric [5,7]. Comfort is a basic requirement in clothing selection in all conditions. However, the preference of people changes with the context: season, climate, age, type of work/activity and so on. Comfort can be defined as 'a pleasant state of psychological, physiological and physical harmony between a human being and the environment' [8,9]. The comfort properties of textiles are generally represented by its moisture transport and air permeability [10]. Wicking is the natural property of cotton fabric. It absorbs perspiration through capillary action from the body and evaporates the moisture from surface of fabric and keeps the body cool and dry [6]. Air permeability is the measurement of the ability to allow air flow through the fabric [6]. It is defined as the rate of air volume flowing through the fabric, when there is a pressure difference on both sides of the fabric. Air permeability is indirectly connected with moisture management, it provides the breathing and ventilation functions to the fabric. So it is also the main attribute of the moisture management performance. Drying time is also an important parameter. It is the length of time required to dry a garment. It is important to know the drying time during and after wear of garments, particularly for those engaged in outdoor activities such as tramping/hiking (e.g. a tramper may require a wet garment to dry overnight) [11]. Other fabrics such as upholstery items (curtains, covers, etc.), blankets and some highly absorbent fabrics such as towels, wipes and diapers are in a particular atmosphere.

The fabric should give comfort to wearer in terms of good perspiration absorbency and moisture management concerning parameters [6]. H. Özdemir concluded that both the fabric constructional parameter and the constituent fiber properties affect thermal comfort properties of fabrics [12].

This study aims at investigating the effect of weave pattern with constructional parameters on 100% cotton woven fabrics on the moisture management properties. Three types of cotton fabrics woven with different weaves

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such as 1/1 plain, 3/1satin and 2/1terry (both sided)were studied. The effect on moisture management properties were measured and analyzed as wetting time, spreading speed, demand absorbency capacity (DAC), maximum absorption rate (MAR), vertical wicking rate, air permeability and drying time test.

2.0 Materials and methods of measurement

2.1 Materials

100% cotton woven fabrics with three types of weave patterns such as 1/1 plain, 3/1satin and 2/1 terry (both sided) were selected and purchased from a local market of Mumbai (India).

2.2 Methods of measurement

2.2.1 Measurement of fabric thickness

The thickness of fabric samples was measured as the distance between the reference plate and parallel presser foot of the thickness tester under a load of 1KPa. Standard procedure using MI- milestone thickness tester as per IS-7702- 2012 was used.

2.2.2 Measurement of GSM

Standard procedure for measuring GSM as per ISO-3801-1977 was followed. A measuring balance (SHIMADZU AX-200) capable of weighing to an accuracy of 0.1 gm was used to weigh the samples of size 10x10 cm^2.

2.2.3 Calculation of Fabric Bulk Density

Fabric bulk density (FBD) was calculated according to Equation (1) : [13,14]

FBD (g/cm^3) = Fabric unit weight (g/cm^2) / Fabric thickness (cm)………………………… (1)

2.2.4 Measurement of yarn count in fabric

The standard procedure IS- 3442-1980 RA 2014 was followed to measure the length and weight of yarns in fabrics and calculate the yarn count (Ne). A Torsion balance (50 mg) capable of weighing to an accuracy of 0.01 mg and a measuring balance (SHIMADZU AX-200) capable of weighing to an accuracy of 0.1 gm was used to weigh the yarns.

2.2.5 Measurement of thread density

Thread density (number of warp and weft threads per inch in woven fabric) in fabrics was calculated by the standard procedures IS-1963-2004 RA2014 and ASTM D 3775-2012.

2.2.6 Calculation of Fabric Cover Factor

For any fabric, there are two cover factors: warp cover factor (K_1) and weft cover factor (K_2). Calculations of the warp (K_1), weft (K_2) and fabric (Kf) cover factor are presented in Equations (2), (3) and (4), respectively [14,15]:

$K_1 = EPI/\sqrt{Ne_1}$………………………… (2)

$K_2 = PPI/\sqrt{Ne_2}$………….………………… (3)

$Kf = K_1 + K_2 - (K_1K_2/28)$……….…..………..(4)

Where; EPI stands for number of warp threads per inch, PPI stands for the number of weft threads per inch of fabric. Ne_1 and Ne_2 are the warp and weft yarn count in Ne (English count) respectively.

2.2.7 Measurement of crimp % of yarns in fabrics

The crimp% of yarns in fabrics was measured and calculated by the standard procedure IS 3442-1980. The SASMIRA crimp tester was used to straighten the yarns and then measure the average length of yarns when straightened.

2.2.8 Measurement of twist in yarn

Twist per unit length was measured and calculated by the standard procedure using TPI analyzer- digital twist tester as per ASTM D 1422 M-13 and ASTM D 1423 M-16 was followed. However, the twist per unit length of the satin fabric air jet spun yarns (false twist) could not be measured.

2.2.9 *Moisture management (liquid absorbance and transport) properties*

Greenwood absorbency test system, model 3100, was used to measure the dynamic liquid absorbance and transport properties such as wetting time, spreading speed, demand absorbency capacity (DAC) and maximum absorption rate (MAR) in fabric samples. Total wetting time of 5.5 cm samples was recorded, then the DAC and MAR was calculated by standard test method ISO 9073-12: 2002 (E). Five tests on each sample were done and the mean value is reported.

2.2.10 Vertical wicking

Vertical wicking was measured by the standard test method AATCC-197-2013. The sample size was 15 ×2.5 cm used to measure the vertical wicking height (mm) and the relative wicking rates (mm/min) of woven fabrics obtained, for the 30min test period. Ten tests of the warp and weft side of each sample were carried out and the mean value was calculated.

2.2.11 Air permeability

Frazier® Air permeability tester was used to measure the air permeability by the test method IS-11056-2013.The opening area was 1-$inch^2$ and water column was 0.79 cm. Ten tests on each sample were carried out and the mean value was calculated.

2.2.12 Drying time

Drying time of samples was calculated by the standard test method AATCC TM 199. The samples were preconditioned at temperature25±2˚C and 65±5% relative humidity, for 30 min before the testing was carried out. 100% wet pickup of fabric samples was recorded at the starting drying point. The samples were dried at temperature 25±2˚C and 65±5 % relative humidity. However, this temperature is a nonstandard testing condition for drying samples. Ten tests on each sample were carried out and the mean value of moisture retention % after drying is reported.

Moisture retention (%) = $(W_2 - W_1 / W_2) \times 100$………. (5)

Where, W_2 is the weight of saturated fabric sample in grams and W_1 stands for the weight of dry fabric sample in grams.

3.0 Result and Discussion

Table 1. Constructional parameters of different weave patterns of fabric

Constructional parameters of fabric	Plain woven fabric	Satin woven fabric	Terry woven fabric
Fabric weight (gm/m²)	95.5	147.65	486.45
Thickness (mm)	0.38	0.39	2.5
Fabric bulk density (gm/cm³)	0.25	0.378	0.194
Yarn count Warp count (Ne 1) Weft count (Ne2)	31.636 30.545	61.09 84.36	12.30 12.43
Thread density Ends per inch (EPI) Picks per inch(PPI)	69 53	205 210	54 88
Warp cover factor Weft cover factor	12.267 9.589	26.228 22.864	15.39 24.96
Fabric cover factor	17.655	27.676	26.631
Yarn crimp% Warp yarn crimp% Weft yarn crimp%	0.7 17.1	1.7 8.1	0.7 15.2
Warp yarn TPM Ply Type of twist Weft yarn TPM Ply Type of twist	881 1 Z 719 1 Z	- 1 False twist - 1 False twist	401 2 S 692 1 Z

3.1 Effect of weave pattern on moisture management (liquid absorbance and transport) properties of cotton fabrics

The dynamic liquid transport and absorbance properties are categorised under moisture management properties [3]. The relation of different woven fabrics between absorbency (a) and time (t), demand absorbency capacity and maximum absorption rate of different woven fabrics is shown in Figure A, B and C respectively. The fabric bulk density (Table 1) of differently woven fabrics showed the inverse relation with demand absorbency capacity and maximum absorption rate. It was also observed that the absorbency capacity had an inverse relation to the spreading speed (Table 2). While wetting time (total absorption time) was increased with the absorbency capacity of fabrics.

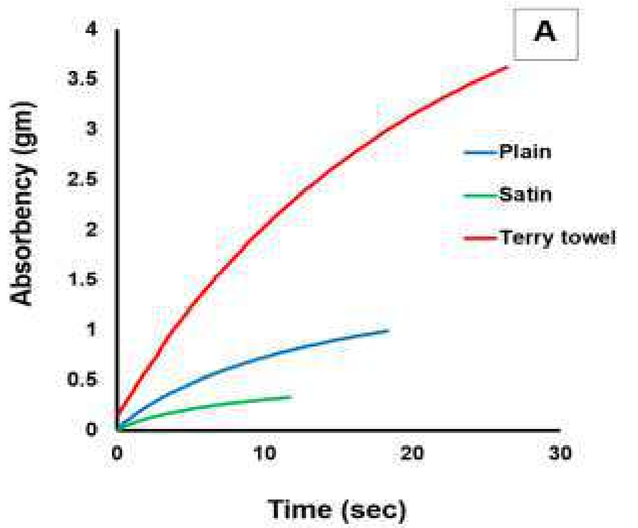

Figure A. Effect of weave pattern on wetting time (a/t curve)

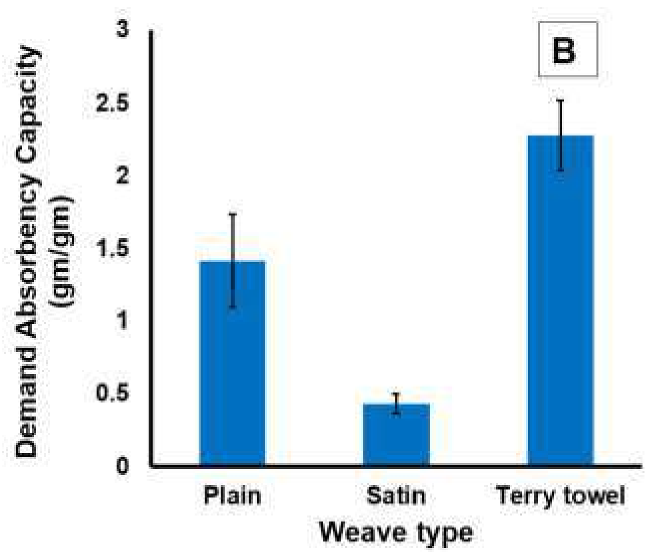

Figure B. Effect of weave pattern on demand absorbency capacity (DAC)

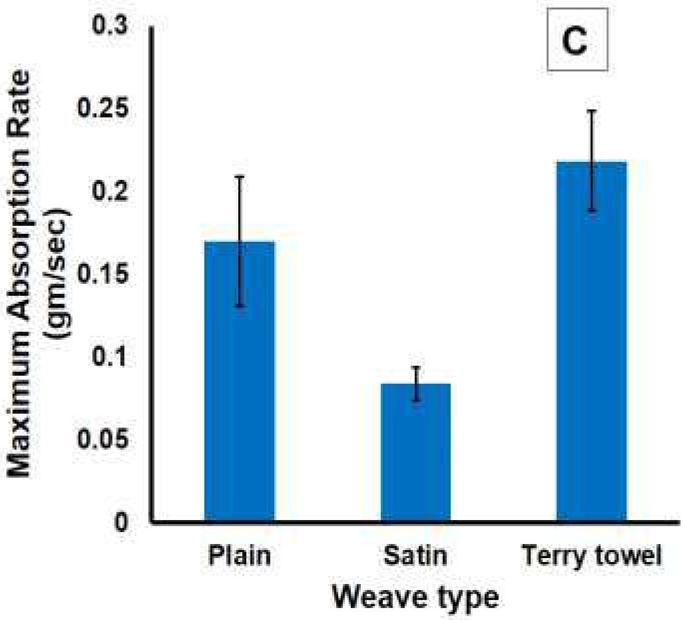

Figure C. Effect of weave pattern on maximum absorption rate (MAR)

Table 2. Moisture management performance properties such as demand absorbency capacity (DAC), maximum absorption rate (MAR) of differently woven fabrics

Parameters of moisture management	Plain woven fabric	Satin woven fabric	Terry woven fabric
Wetting time (sec)	18.3	11.7	26.4
Spreading speed (mm/sec)	3	4.7	2
DAC (gm/gm)	1.415	0.432	2.28
MAR (gm/sec)	0.17	0.084	0.218

In satin woven fabric, it was observed that the fabric had low wetting time (Table 2), less absorbency and high-water spreading speed due to the lengthier floats and fewer interlacing in its construction with its smooth surface. This fabric could absorb only 0.432 times its own weight. The lowest absorbency capacity (gm/gm) in the satin woven fabric may be due to fine yarns (high Ne), false twist (air jet spun) yarns and its high thread density and bulk density of the fabric. Fine yarns and high thread density would have small gaps (low pore size) and high surface area (highest cover factor shown in (Table 1) in its structure and more yarns would be on the surface of fabric due to fewer interlacements. So, water could rapidly move with the finest yarns with a less absorbency capacity of the fabric.

Plain woven fabric showed lower fabric bulk density and higher absorption rates than the satin woven fabric, but higher bulk density and lower absorption rates than the terry woven fabric. The plain-woven fabric had the lowest weight, thickness and thread density (Table 1). The water spreading speed on the surface with the yarns of plain-woven fabric was lower than satin woven fabric due to slightly rough surface, but it could absorb 1.415 times its own weight. The better absorbency capacity may be attributed due to interlacements of successive warp and weft yarns and lower thread density of better twisted yarns, as they can create the pores (spaces) in its structure. Those spaces can accommodate and transfer water. Hence the absorption capacity and the absorption rate of plain-woven fabric were higher than the satin woven fabric.

In terry woven fabric, demand absorbency capacity and maximum absorption rates were the highest and fabric bulk density was lowest. It could absorb 2.28 times of its own weight. This fabric had coarser yarns with low twist and highest thickness. So, it had the highest absorbency capacity, but there was the lowest water spreading speed with the low twist yarns. Coarser yarns and piles may provide more spaces to accommodate water in the fabric structure. This was due to the presence of capillary space and the availability of capillary pressure, that it could absorb and transfer water. But the spreading speed was lowest due to its highest absorbency capacity and lowest bulk density.

3.2 Effect of weave pattern on vertical wicking properties of cotton fabrics

Capillary transport of liquid water through fabrics was assessed and shown in Figure D as the vertical wicking of different woven fabrics in warp and weft directions. In vertical wicking, water transfer depends upon the capillary spaces with fibers, yarns and capillary pressure availability. This statement is in agreement with the work reported by Kissa that the wicking is a spontaneous flow of a liquid into porous substrate driven by capillary forces [16].

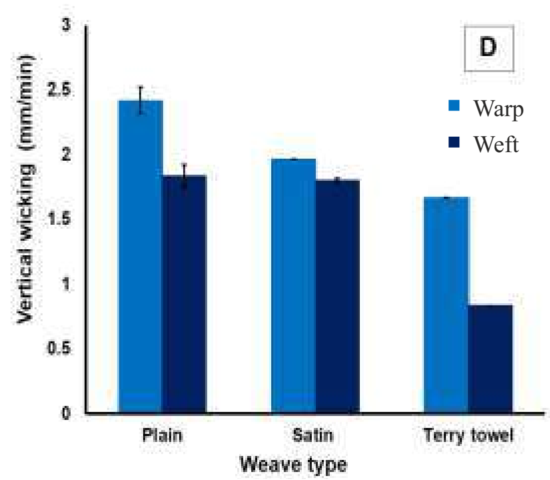

Figure D. Effect of weave pattern on vertical wicking rate

In this study, it is apparent that the wicking rates of plain woven fabric and satin woven fabric were higher than the terry woven fabric. Fabric weight per unit area and thickness showed the inverse relation with vertical wicking rates.

Satin woven fabric showed lower vertical wicking rates (mm/min) than the plain woven fabric because of its lower capillary flow due to its highest thread density, bulk density, weight per unit area and thickness (Table 1). While in plain woven fabric weight per unit area and thread density were lower than satin woven fabric but the twist in the yarn was higher. This fabric contained more spaces to absorb and transfer water therefore it showed highest vertical wicking rates.

In terry woven fabric, high thickness of low twist yarn and pile structure may attenuate the wicking process due to the formation of air pockets in low twist yarn. So the vertical wicking rates (mm/min) were low due to low capillary flow availability.

In all fabric samples vertical wicking rates were higher in warp direction than the weft direction. Because in these fabric structures warp yarns were straighter (low crimp shown in Table 1), so the overall length of yarn would be shorter in warp direction. The straighter yarns were found in the longitudinal direction of the test strips of warp. Therefore, in the warp direction less resistance of water would occur in the vertical wicking. Hence vertical wicking rates were higher in warp direction.

3.3 Effect of weave pattern on air permeability of cotton fabrics

Air permeability is the free passage of air in the fabric. The effect of air permeability in fabric samples was assessed in Figure E.

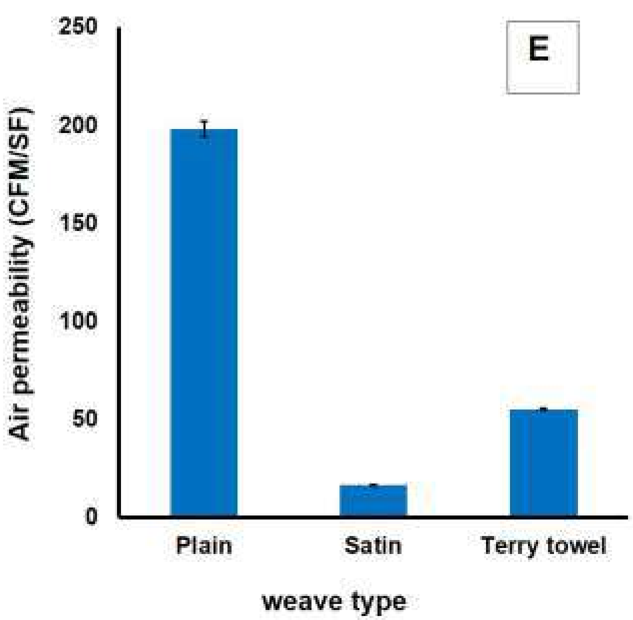

Figure E. Effect of weave pattern on air permeability

In this study, the satin fabric construction was compact (highest thread density) and contained finest yarns (high count) that may be woven tightly so the free spaces get reduced. Air permeability decreases as the weft density increases. Therefore, cover factor has a significant effect on air permeability. Air permeability of fabric samples decreased with an increase in fabric cover factor (Table 1).

Here the plain-woven fabric had very loose structure (lowest thread density), cover factor of fabric and weight of fabric was very low. Large pores could be seen in the structure. So air permeability was highest in plain woven fabric with lowest cover factor.

While terry woven fabric showed moderate air permeability, it may be due to its moderate fabric cover factor. The low tension warp is woven to form loops therefore it may increase fabric thickness and weight per unit area in the terry woven fabric. On the other hand, the fabric structure had a moderate thread density, coarser yarns (low Ne) and low fiber compactness in the yarns (low twist). So it may not be a compact structure but this fabric had the highest thickness and weight.

3.4 Effect of weave pattern on drying time of cotton fabrics

The length of time required to dry the samples was shown in Figure F. This study showed 100% moisture retention after drying in all samples. Highly twisted yarns in the fabric make the fabric dry easily. While low twist yarns in the fabric have better absorbency capacity and hence retard drying. The plain woven fabric showed the lowest drying time. This was due to its lowest weight per unit area and the maximum twist in its yarns. While the absorbency capacity of plain woven fabric was higher than the satin woven fabric, but here the wet pick up % was same for all fabric samples. The satin woven fabric dried slower than the plain woven fabric due its compact structure.

Drying time did not show a significant effect with the absorbency capacity of fabrics at 100% wet pickup. At this pick up %, plain woven fabric seemed slightly dry due to its low weight and high absorbency capacity. Satin woven fabric seemed saturated due to its high weight and low absorbency capacity. Hence drying time increased with increase in fabric weight.

In case of terry woven fabric, it was heavy, weight per unit area and thickness was highest in this fabric. Its structure had piles of low twisted yarns. This fabric showed good absorbency at same pickup % and took too long to dry due to its highest weight. It had low air permeability and lowest water spreading speed (inner and outer surface of the fabric). This may be the reason of its slowest drying capacity.

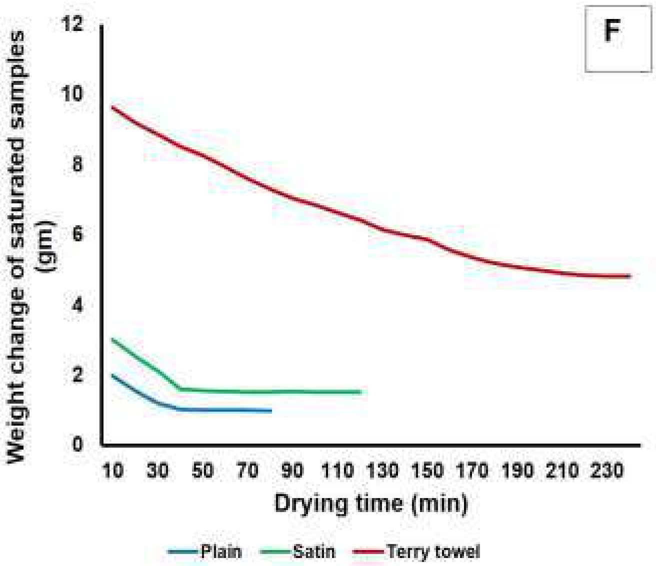

Figure F. Effect of weave pattern on drying time

4.0 Conclusions

The end use of fabrics can be rationalized according to their moisture management performance properties. In this study, different woven fabric structures have been found to show significant effect on moisture management performance properties such as wetting time, spreading speed, demand absorbency capacity, maximum absorption rate, vertical wicking rate, air permeability and drying time, particularly when the constructional parameters were different such as fabric weight, thickness, fabric bulk density, fabric cover factor, yarn count and yarn twist. The significant effects were found as, the absorbency capacity had an inverse relation to the spreading speed. The demand absorbency capacity of woven fabrics and the maximum absorption rate of woven fabrics were found to increase when the fabric bulk density decreased. The vertical wicking rate increased with decrease in fabric weight per unit area and thickness. The air permeability decreased with an increase in the fabric cover factor. The drying time had an inverse relation to the yarn twist (fiber compactness in the yarn) of fabric but it had increased with fabric weight per unit area. Therefore it can be concluded from this study that moisture management behavior of textile fabrics is dependent on variety of fabric constructional parameters and weave patterns. Each fabric can be recommended for different end uses. Textile manufacturers can make the right choice according to the performance and functionality of cotton fabrics.

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