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ORIGINAL PAPER

Influence of Cover Factor on the Physical Properties of Woven Fabrics

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***Abstract*- The aim of this paper is to explore the influence of cover factor on the physical properties of woven fabrics. 100% cotton woven fabrics of different thread count and width were used in this research for investigation. Nine types of fabric with different weaves like plain (1/1), twill (3/1) and 5 ends satin (4/1) were used while conducting the tests. The experiments were carried out in agreement with the test method provided by ASTM and AATCC as mentioend inside the paper. The cover factors of the samples were measured with an appropriate equation using weave factor values. It was seen from the research that, plain weave fabrics showed the maximum cover factor and weight (g/m²) values compared to twill and satin fabrics. It was because, plain weave contains maximum interlacement points compared to other weave structures. The fabrics of plain weave showed the maximum strength values, maximum air permeability values, and least shrinkage values. Fabrics with plain weave contain more interlacement, thus showed the maximum air permeability values. This research is practice-based and opens up possible ways for further study by technologists in this field of fabric cover factor and its influence on the physical properties of fabrics.**

***Keywords*: cover factor, strength, dimensional stability, air permeability, microscopic assessment**

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I. INTRODUCTION

There is a great importance of this research in the field of woven fabric manufacturing. Cover factor has some influence on the physical properties of woven fabrics. Cover factor specifies the range to which the part of a fabric is covered by the yarns [1]. Covering power discusses the capability to lodge space or to cover a range. It also expresses the weave ability of fabrics. A cloth with improved cover value would be more durable and substantial [2].

In woven fabrics there are mainly two cover factor values like warp cover factor and weft cover factor. Cover factor hangs on some issues like yarn count, thickness, density, and shape [3]. Cover factor increases with the increase of thread density in fabric. In case of cotton yarn, higher count expresses finer yarn [4]. Finer yarn expresses lower cover factor than coarser cotton yarn. Coarser cotton yarns are thicker in shape and show higher cover factor values in fabrics [5].

Usually, fabric balance is expressed as the proportion of the cover factors of warp to weft yarns in fabrics [6]. However, the quantity of crimp in the yarns is not engaged into attention in this description. Yarn crimp may not be disregarded in seeing cloth balance if the external texture of a material is significant [7]. So as to calculate the seeming area of interaction between the two descending fabrics, benefit is taken of the relation of warp and weft yarn exterior areas [8]. The percentage of the exterior area ended by warp and weft yarns inside a unit cell is defined by the subsequent Eq. (1) [9]:

$$\beta = \frac{l_{t.} d_{t.}}{l_{p.} d_{p.}}$$

$$\beta = \frac{l_{t.} \sqrt{T_T}}{l_{p.} \sqrt{T_P}} \quad (1)$$

Where, l expresses the modular length of yarns, and d expresses the diameter of yarns. Here, yarns are considered as circular in shape [10]. T is expressed as the yarn's linear density. If the crimp of the yarn is C, then the Eq. (2) can be developed as follows:

$$C_P = \frac{l_P}{P_T} - 1$$

$$C_T = \frac{l_T}{P_P} - 1 \tag{2}$$

Then, β can be further developed as follows for measuring fabric balance amount:

$$\beta = \frac{l_{t.}\sqrt{T_T}}{l_{p.}\sqrt{T_P}}$$

$$\beta = \frac{P_P.(1+C_T)\sqrt{T_T}}{P_T.(1+C_P)\sqrt{T_P}} \tag{3}$$

Where, P expresses yarn spacing that is 1/(yarn per cm) and subscripts P and T refer to warp and weft yarns of fabrics. Eq. (3) expresses the percentage of the external areas of the peak portions of the yarns that form the exterior of the clothes [11]. It can simply make a relationship between the outward evenness and abrasion. Consequently, the higher the exterior zone of reproduction yarns, the greater would be the clothes balance and, hence, the higher would be the frictional confrontation [12]. Equation of fabric balance (β) amount is shown in Eq. (3).

The fraction of a part of a fabric covered by the yarns per unit area is known as the 'fractional coverage'. Fractional coverage is donated as FK and Eq. (4) is developed:

$$FK = wd_1 + fd_2 - wfd_1d_2 \tag{4}$$

Here, w and f are the warp and weft yarn per cm, and d_1 and d_2 are the warp and weft yarn diameter. Here, ρ is the fiber density in g/cm^3. For the other weave like twill and satin, w and f can be reformed with weave factor, M, average yarn spacing and yarn diameter, conferring to the yarn bunching decoration, therefore Eq. (5) could be developed [13]:

$$\frac{1}{w} = M_{\rho_{a1}} - (M-1)d_1 \tag{5}$$

Here, M expresses weave factor as shown in Eq. (5), ρ_{a1} is the normal warp yarn spacing, and d_1 is the non-compacted warp yarn diameter. Clothes thickness, softness, stiffness, rigidity or firmness or texture all are important fabric parameters [14]. These properties depend on the other properties of fabrics like shrinkage, weight per unit area, strength, elasticity, absorbency, etc. [15].

The fractional cover factor of fabric (K) can be achieved with below Eqs. (6) and (7) where, ā is the major diameter, entire space engaged by warp as a total is P_{r1}, entire space engaged by weft as a total is P_{r2}, N is the number, therefore the fractional cover factor K is determined by Eqs. (6) and (7):

$$K = \frac{\sum_1^{Nr1} \tilde{a}_1}{P_{r1}} \tag{6}$$

$$K = \frac{\sum_1^{Nr2} \tilde{a}_2}{P_{r2}} \tag{7}$$

The structural properties of fabrics depend on various properties such as yarn's diameter, yarn's shape or roundness, etc. Hamilton applied a model by which fabric's tightness values could be obtained. Here, s_1 is the warp thread spacing, s_2 is the weft thread spacing, and b is the minor diameter of trampled thread [16]. Eqs. (8) and (9) are for measuring the warp and weft thread spacing:

$$Kp_1 = \frac{b_1}{s_1} \tag{8}$$

Further, weft thread spacing could be achieved with the below equation:

$$Kp_2 = \frac{b_2}{s_2} \tag{9}$$

Thread spacing for the partial geometry is given by Eq. (10):

$$S = p_1 - (a - b) \tag{10}$$

Combining the equations, we can build the following Eq. (11):

$$a_{ip} = \frac{Kp_1}{Kp_2} \tag{11}$$

From these equations we obtain Eq. (12):

$$a_{ip} = \frac{b_1 s_1}{b_2 s_2} \tag{12}$$

If the yarn diameter is β, then the ratio of major and minor diameter is expressed with the below Eq. (13):

$$\beta = \frac{b_2}{b_1} \tag{13}$$

For non-plain weave, the value of pi is obtained by Eq. (14) to measure the space occupied by weave repeat. Here, n_i is the intersection number, n_f is the number of float, p_f is the thread spacing for float unit:

$$pi = \frac{1}{n_i}\left(p_r - \sum\nolimits_1^{n_f} p_f\right) \tag{14}$$

The yarn diameter can be measured by Eq. (15):

$$d = K_3\sqrt{Tex} \tag{15}$$

With the Brierley's formula for the theoretical maximum square fabric sett, the Eq. (16) is developed:

$$N = \frac{K_4F^m}{\sqrt{Tex}} \tag{16}$$

Eq. (17) shows the warp sett:

$$N_1 = NW^u \tag{17}$$

If, $w=N_1/N_2$ and $u=1/(1-g)$ then the Eq. (17) can be developed to find out the average yarn count by Eq. (18):

$$Tex = \frac{nTex_1 \times Tex_2}{n_1Tex_2 + n_2Tex_1} \tag{18}$$

Here, Tex is the average yarn count, n is the total number of thread in a weave repeat, F is the average warp or weft float, m is the 1st weave coefficient and g is the 2nd weave coefficient. The value of N_a is further developed with the following Eq. (19):

$$N_a = \frac{N_1}{w^u} \tag{19}$$

The equation can be further developed as Eq. (20):

$$N_a = N_1^{\frac{8}{8-1}} N_2^{\frac{1}{1-8}} \tag{20}$$

Combining all, the tightness value t is expressed with the following Eq. (21):

$$t = \frac{N_a}{N} \tag{21}$$

Clothes looseness, tightness or compactness, etc., may have the highest impact on drape ability owing to its consequence on fiber's and yarn's sovereignty of crusade [17]. Consequently, any issue that upsurges the fiber and yarn liberty of movement inside the cloth, for example fabric's construction, weave structure or fabric slackening, reduces the cloth pliable and shear toughness and the cloth drape constant [18]. At a relentless mass, the cloth drape constant would decline as the float length rises that is in the number of yarns interlacement [19]. Therefore, the cloth of twill weave would have lower drape constant compared to plain weave of the same weight per unit zone.

II. EXPERIMENTAL

A. Materials and Methods

A.1. Materials Used

Different types of plain, twill and satin weave fabrics were used in this research for investigation. All the fabrics were 100% cotton cellulosic fabrics as stated in Table I. These fabrics have nearly similar density for easy assessment and experimentation process.

These sample fabrics were collected from fabric mill. It is seen from the table that these fabrics have different widths. It is also seen that the warp yarn count is 20 Ne and weft yarn count is 16 Ne for all the fabrics. The end per inch (EPI) was 100, 105, and 110 yarns where pick per inch (PPI) was 50, 55, and 60 yarns. The weave of the fabric was plain (1/1), twill (3/1) and satin 5 ends (4/1). Fig. 1 shows plain, twill and satin fabric used in this research for experimentation.

A.2. Structural Diagram of Fabrics

It is seen from Fig. 2 that, plain weave fabrics have the structural interlacement arrangement of 1 up and 1 down order. The coloured boxes indicate warp yarn up and white boxes indicate warp yarn down in the fabric. Twill weave fabrics have the structural interlacement arrangement of 3

TABLE I
100% COTTON CELLULOSİC FABRİCS

S.N	Composition and type	Construction	Weave	Width (″)
A	100% Cotton canvas	20×16/100×50	Plain (1/1)	58.90
B	100% Cotton canvas	20×16/105×55	Plain (1/1)	59.00
C	100% Cotton canvas	20×16/110×60	Plain (1/1)	58.10
D	100% Cotton twill	20×16/100×50	Twill (3/1)	58.11
E	100% Cotton twill	20×16/105×55	Twill (3/1)	58.90
F	100% Cotton twill	20×16/110×60	Twill (3/1)	58.10
G	100% Cotton satin	20×16/100×50	5 ends satin (4/1)	59.00
H	100% Cotton satin	20×16/105×55	5 ends satin (4/1)	59.10
I	100% Cotton satin	20×16/110×60	5 ends satin (4/1)	58.11

Fig. 1. Plain, twill and satin fabric used in this research.

up and 1 down order. Three warp yarns go to the upward position and then 1 warp yarn goes to the downward position [20]. There is a 5 ends satin weave in this structural diagram of fabrics. Satin weave is formed by move number. The distance between two adjacent interlacing points is called move number. Three move number is used in this 5 ends satin fabrics. In satin weave, there is only one binding point in each end or pick of fabrics. It has less binding points and more float lengths compared to plain and twill weave fabrics.

A.3. Methods

The experiments were carried out in accordance with the test method provided by American Society for Testing and Materials (ASTM) and American Association of Textile Chemists and Colorists (AATCC) as mentioend undernenth the paper. The weight of the clothes was measured in agreement with the test method provided by ASTM D 3776. Tear and tensile strength were measured in accordance with the test method provided by ASTM D 1424 and ASTM D 5034. Shrinkage was measured in agreement with the test method provided by AATCC 135 standard. Air permeability was measured in accordance with the test method provided by ASTM D 737.

B. Experimentation

B.1. Cover Factor Measurement

Cover factor specifies the extent to which the area of a cloth is covered by the yarns. It is the percentage of the area covered by the yarns to the total area of fabric. Cover factor also describes the compactness, solidity and density of fabric. The higher the cover factor, the lower the penetration of dye particles, so cover factor has a direct relationship with the colour properties of fabrics. Weave factors are obtained from the weave matrix and have outstanding connection with the experimental aspect. They cover most of the weaves but cannot be executed for calculating the factors of weaves those are not balanced. We know the weave factor for plain weave is 0.98, weave factor for twill (3/1) weave is 0.78 and weave factor for satin weave is 0.68 [19]. These weave factors are practically used in industries. Cover factor was calculated by Eq. (22) and the data are positioned in Table II:

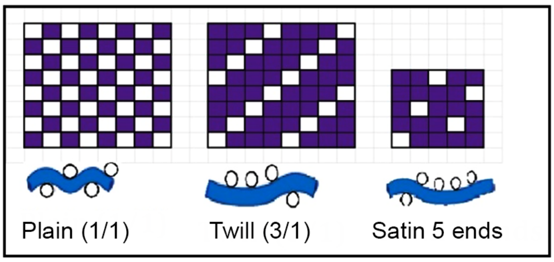

Fig. 2. Structural diagram of plain, twill, and satin weave.

$$\text{Fabric cover factor} = \left[\left\{\left(\frac{\text{EPI}}{\sqrt{\text{warp count}}}\right)+\left(\frac{\text{PPI}}{\sqrt{\text{weft count}}}\right)\right\} - \left[\frac{\left\{\left(\frac{\text{EPI}}{\sqrt{\text{warp count}}}\right)\times\left(\frac{\text{PPI}}{\sqrt{\text{weft count}}}\right)\right\}}{28}\right]\right]\times \text{weave factor} \tag{22}$$

B.1.1. Cover Factor Measurement of Sample A

It is seen from Table I that, the construction of the fabric A is 20×16/100×50. Here, warp yarn count is 20 Ne, weft yarn count is 16 Ne, EPI is 100 and PPI is 50. Weave factor for plain weave is 0.98. Therefore, the cover factor of the fabric was measured with Eq. (22) as shown below:

$$\left[\left\{\left(\frac{\text{EPI}}{\sqrt{\text{warp count}}}\right)+\left(\frac{\text{PPI}}{\sqrt{\text{weft count}}}\right)\right\} - \left[\frac{\left\{\left(\frac{\text{EPI}}{\sqrt{\text{warp count}}}\right)\times\left(\frac{\text{PPI}}{\sqrt{\text{weft count}}}\right)\right\}}{28}\right]\right]\times \text{weave factor}$$

$$\left[\left\{\left(\frac{100}{\sqrt{20\ \text{Ne}}}\right)+\left(\frac{50}{\sqrt{16\ \text{Ne}}}\right)\right\} - \left[\frac{\left\{\left(\frac{100}{\sqrt{20\ \text{Ne}}}\right)+\left(\frac{50}{\sqrt{16\ \text{Ne}}}\right)\right\}}{28}\right]\right]\times 0.98$$

$$\left[\left\{\left(\frac{100}{\sqrt{20}}\right)+\left(\frac{50}{\sqrt{16}}\right)\right\} - \left[\frac{\left\{\left(\frac{100}{\sqrt{20}}\right)+\left(\frac{50}{\sqrt{16}}\right)\right\}}{28}\right]\right]\times 0.98$$

$$\left[\left\{\left(\frac{100}{4.4721}\right)+\left(\frac{50}{4}\right)\right\} - \left[\frac{\left\{\left(\frac{100}{4.4721}\right)+\left(\frac{50}{4}\right)\right\}}{28}\right]\right]\times 0.98$$

$$\left[\{22.3609+12.5\} - \left[\frac{22.3609\times 12.5}{28}\right]\right]\times 0.98$$

$$\left[34.8609 - \left[\frac{279.5113}{28}\right]\right]\times 0.98$$

$$[34.8609 - 9.9825]\times 0.98$$

$$24.8784\times 0.98$$

$$24.3808$$

Hence, the cover factor for sample A is 24.3808.

Following the same technique, the calculation for

TABLE II
PHYSICAL PROPERTİES OF FABRICS

S.N	Construction	Weave	Cover factor			Weight (g/m^2)	Tear strength (g)		Tensile strength (g)		Shrinkage (%)		Air permeability ($cm^3/s.cm^2$)
			Warp	Weft	Total		Warp	Weft	Warp	Weft	Warp	Weft	
A	20×16/100×50	Plain (1/1)	22.36	12.50	24.38	208	1235	844	34019.4	24040.4	-1.5	-2.0	59 465.38
B	20×16/105×55	Plain (1/1)	23.47	13.75	25.18	223	1249	859	36741	26308.4	-1.5	-1.5	57 577.59
C	20×16/110×60	Plain (1/1)	24.59	15.00	25.89	237	1265	877	38555.4	28122.7	-0.5	-1.0	56 161.75
D	20×16/100×50	Twill (3/1)	22.36	12.50	19.40	205	1224	832	32205.1	21772.4	-2.0	-2.5	44 363.06
E	20×16/105×55	Twill (3/1)	23.47	13.75	20.04	219	1235	846	34473	23586.8	-1.25	-2.0	42 947.22
F	20×16/110×60	Twill (3/1)	24.59	15.00	20.60	234	1253	866	35833.8	25401.2	-1.0	-1.5	42 003.32
G	20×16/100×50	5 ends satin (4/1)	22.36	12.50	16.91	203	1210	819	29483.5	19504.5	-2.5	-3.0	35 396.06
H	20×16/105×55	5 ends satin (4/1)	23.47	13.75	17.47	216	1222	833	31751.5	20865.2	-2.25	-2.5	33 980.22
I	20×16/110×60	5 ends satin (4/1)	24.59	15.00	17.96	231	1239	852	34019.4	22679.6	-1.0	-1.5	33 036.32

samples B, C, D, E, F, G, H, and I were done with using Eq. (22) as stated above and the consequences are shown in Table II.

B.2. Weight Measurement

Using ASTM D 3776 the weight of the fabrics was measured. This test method is used to measure the mass per unit area (weight) of clothes. The fabric is cut in a round shape using a rotary knife cutter by placing the fabric on a rubber sheet. Fabrics are cut at least at three different positions to get the accurate weight values. Using an electronic measurement scale, the weight of the cloth was measured in g/m^2 unit and the values are listed in Table II.

B.3. Tear Strength Measurement

Tear strength was measured in accordance with the test method provided by ASTM D 1424. It is the standard test method for measuring the tearing strength of fabrics by falling a pendulum apparatus. It helped to determine the force requisite to promulgate a single-rip tear beginning from a cut in a cloth and applying a falling pendulum device. By the pendulum in its original location prepared for a test, the two clamps were detached by a distance and were associated in such a way that the clamped samples stayed in a plane parallel to the axis of the pendulum. The device had an indicator straddling on the similar axis as the pendulum to record the tearing force. And it was relieved by means of calculating and exhibiting the essential results deprived to the use of an indicator. This device is equipped to afford substitutable full scale force choices. The samples were taken for assessment to the machine direction with the lengthier measurement parallel to the axis. While cutting the fabric samples, carefully supported the yarns running in the parallel direction in such a way that, once the split was cut, the consequent tear would happen amid these yarns. Reading from the device was taken cautiously and the tear strength was obtained and is shown in Table II.

B.4. Tensile Strength Measurement

Tensile strength of the samples was measured in agreement with the test method provided by ASTM D 5034. It is a grab test system for the measurement of breaking force and elongation of the woven fabric samples. The fabric samples were cut in a size of 4 in^2 shape. Then the samples were mounted with its clamp and a force was applied to break the specimen. The upper part and lower part of the samples were clamped at the jaw. By the use of computer, a signal was given to start the machine until the fabric is destroyed due to up and down force from the device. Then the data for the breaking force of the materials were achieved from the computer interface and are presented in Table II.

B.5. Shrinkage Measurement

The dimensional stability or the shrinkage of the fabric was measured following by AATCC 135 standard. This test is measured with the increase or decrease of length and width of the fabrics after washing. The fabric was cut in 40 in^2 shape and interlock stitched was given to the edge of the fabric so that yarns could not be removed from fabric due to laundry in washing machine. The fabric was marked by 36 in^2 shape with permanent marker so that marking was not removed due to washing. The sample was loaded on the machine and its washing was started at 60 °C temperature for 5 min. After that the sample was rinsed in normal room temperature of 30 °C. Subsequently, the sample was dried in the machine for 3 min with air blow. Then the samples were pulled out and dimension was taken by measurement tape and shrinkage values were detected and positioned in Table II.

B.6. Air Permeability Measurement

The air permeability of the sample was measured following

ASTM D 737 test method. With this process the rate of air flow passing vertically through a fabric is achieved between the two surfaces of fabric. The rate of air flow is measured in $cm^3/s.cm^2$. Air permeability is the competence of a material to permit air to pass through the clothes. The assessment of air permeability is less where the clothes are stiffer. Air permeability principle was complex where the fabrics were slackly woven. The air pressure kept for this test was 125 Pa across the samples. During the experiment, the room temperature was maintained at 20 °C with a relative humidity of 65%. Air permeability of the samples was tested and their values are listed in Table II.

III. RESULTS AND DISCUSSION

A. Cover Factor

Cover factor is a number that specifies the degree to which the part of a cloth is enclosed by the yarns. It is the percentage of the area covered by the yarns to the total area of fabric. It is seen from Table II that, sample C or plain weave fabric has the highest cover factor of 25.89. On the other hand, sample G or satin weave fabric has the lowest cover factor of 16.91.

B. Weight

The weight of a fabric has a slight relationship with the cover factor of fabric. It is seen from the experimentation that, if the cover factor of the fabric increases, then the weight of the fabric also increases. Followed by ASTM D 3776 the weight of the fabrics was measured and the results are presented in Table II. It is seen from Table II that, the weight of the fabric increases with the increased value of cover factor. It is also seen from the experimentation that, plain weave has the best weight values compared to twill and satin weave fabrics. Satin weave fabrics showed the least amount of weight values.

C. Tear Strength

Followed by ASTM D 1424, the tear strength of the specimen was measured. Tear strength was investigated in both warp and weft way of the samples. It is also noticed that, tear strength has a relationship with the cover factor of fabrics. Tear strength was increased with the increased amount of cover factor values. It is also seen from Table II that, plain weave fabrics exhibit the best strength values of 1265 g compared to twill and satin weave fabrics. Satin weave fabrics expressed the least values of tear strength of 1210 g.

D. Tensile Strength

Followed by ASTM D 5034, the tensile strength of the fabric was conducted. Tensile strength was measured in equally warp and weft way of the fabrics. It is observed that, tensile strength has a through connection with the cover factor of cloths. When the cover factor value of the fabric improved, the tensile strength of the cloth also improved. Table II expresses that, plain weave fabric shows the greatest strength values of 38555.4 g compared to twill and satin weave fabrics. Satin weave fabric showed the smallest value of tensile strength of 29483.5 g.

E. Shrinkage

Shrinkage or dimensional stability of cotton fabric is observed while washing in hot/cold water. Cotton fabric has a tendency to shrink while washing in normal water at home or at industry. It was also observed that, cotton fabrics shrink less when they are more rigid/compact with more value of cover factor. If the cover factor value is less, yarns get sufficient space to shrink more. That’s why, fabric with lesser cover factor exposed the more amount of shrinkage value. Shrinkage assessment was carried out in accordance with the test method provided by AATCC 135 standard. Table II shows the value of shrinkage, where it is noticed that, satin weave fabric exposed the maximum number of shrinkage value of -3% in compared to plain and twill weave, where plain weave fabric showed the least shrinkage values of -0.5%.

F. Air Permeability

Air permeability is the proportion of airflow passing vertically through an identified zone under a suggested air pressure discrepancy between the two surfaces of a substantial. ASTM D 737 declares air permeability as the percentage of air flow passing upright through a notorious area under an agreed air pressure variance between the two surfaces of a substance; the unit is expressed in $ft^3/min.ft^2$. The values of air permeability of the clothes are shown in Table II. It is seen from the table that, plain weave fabrics have the highest air permeability values of 59 465.38 $cm^3/s.cm^2$, since they have more interlacement than twill and satin fabrics. On the other hand, satin weave fabrics have the least amount of interlacement points, which allow less air or water vapour to pass through the fabrics. Due to less interlacement points, satin weave fabrics have the less air permeability values of 33 036.32 $cm^3/s.cm^2$. Twill weave fabrics represent the intermediate position for the air permeability values compared to plain and satin weave fabrics.

IV. CONCLUSION

It was seen from the research that the influence of cover factor was discussed on the physical properties of woven fabrics. Due to the higher interlacement ratio, plain weave fabrics showed the maximum cover factor values. Rigidity or compactness was less in the twill and stain weave compared to plain woven fabrics. More thread count like EPI and PPI showed more cover factor values. Extra crimp from plain weave fabrics due to more interlacement ratio has a greater advantage for more weight (g/m^2) values. Tear and tenslie strenght were also more for plain weave fabrics in both warp and weft way. Plain weave fabircs shrink less in water due to more compactness from the more interlacement points. More interlacement points ensure more air permeability values of the fabrics. Therefore, plain weave fabrics showed the maximum air permeability values. All the physical properties of the woven fabrics were investigated in this research. The findings of this study are useful for textile workers who are responsible for the production of cotton woven fabrics and to control their physical properties.

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