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Effect of pretreatment on physical properties of cotton fabric

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Abstract
Cotton fiber is one of the most used materials among other natural fibers in the textile and clothing industry. The purpose of pretreatment is to remove added and natural impurities from the fabric. Pretreatment of cotton fabric prior to dyeing and finishing are mainly involves a combined process consisting of desizing and scouring. In this study main focus on to find out the effect of pretreatment on physical properties of grey, desized and scoured samples of cotton fabric. After desizing and scouring, physical properties of fabric were tested using standard test methods. The results of the study indicated that the gain in fabric count in warp and weft directions, weight, thickness and elongation both in warp and weft directions of fabric were found to be non-significant, while increase in bulk was found to be significant at 5% level of significance. It was also found the decrease in tensile strength both in warp and weft directions was found to be non-significant, whereas decrease in flexural rigidity was found to be significant at 1% level of significance. The change in bending length in both warp & weft directions and moisture regain was found to be non-significant.

Keywords: pretreatment, cotton, desizing, scouring, physical properties

Introduction

Cotton is the oldest and the most important of the textile fibers. It has been used in the East and Middle East for thousands of years and was found in use in America when the continent was discovered. In fact, Cotton is called King Cotton, because of its versatility of its use and certain of its properties. Everyday cotton is the work's predominant textile fiber accounting 50 million tons per year and will maintain the leading position into the next century. We are using more cotton fabrics for our daily life survives in the world (Nur *et. al.*, 2016) [10]. For using of cotton fabric we have design and colored with different processes. In finishing processes of textile materials, there are several modification methods to make some changes on fibers. It is possible to make these modifications in three ways; chemical, biochemical and physicochemical methods (Karahan *et. al.*, 2008; John and Anandjiwala, 2009) [3, 5]. Pretreatment is a process for prior fabric dyeing and finishing which involves desizing and scouring. The objective of desizing and scouring is to produce fabrics which are free from added and natural impurities. The nature of impurities depends on the nature of fibre from which the fabric has been made. The added impurities present on cotton fabric are dust, oil stains and size. (Karahan *et. al.*, 2008) [3]. One of the important steps is scouring, in which the complete or partial non-cellulosic compounds found in cotton are removed, as well as impurities such as machinery and size lubricants (Basra and Malik, 1984 [1]; Freytag and Donze, 1983) [2].

The noncellulosic components present in mature cotton fibers are found in the cuticle and the primary cell wall, the outermost layers of a concentric layered structure that makes up the cotton fiber. The surface layers, which contain lipids, waxes, pectins, organic acids, proteins/nitrogeneous substances, noncellulosic poly-saccharides, and other unidentified substances constitute approximately 10% of the total fiber weight (Heredia *et. al.*, 1993; Rollins, 1968) [4, 12] The surface layers protect the fibers against the environment during growth (Juniper and Jeffree, 1983 [6]; Meinert and Delmer, 1977) [8] and lubricate them during yam spinning and fabric construction. The layers also interfere with further aqueous chemical processing such as dyeing and finishing, and need to be removed before such aqueous processing (John and Anandjiwala, 2009) [5].

The aim of this research work was to investigate the influence of pretreatment of cotton fabric on physical properties. Physical properties of fabric are vital because these properties decide the functionality of the fabric. There were various physical properties such as geometrical, mechanical and comfort properties. The geometrical properties of the cotton fabric comprised of fabric count, weight and thickness etc. Mechanical properties includes tensile strength and elongation. Comfort properties includes bending length, flexural rigidity, moisture regain and air permeability of fabric.

Method and Material

Selection and procurement of materials: Different samples of cotton woven fabric were collected from local market of Hisar city (Haryana) on the basis of visual inspection. The collected samples were analyzed by physical, burning and solubility tests to ascertain that the samples collected are 100% pure cotton. Among the 100% pure cotton fabrics, medium weight grey cotton fabric was selected.

Pretreatment of the fabric: The fabric obtained after weaving is known as grey fabric. It contains both natural as well as added impurities. In order to make fabric suitable for different end uses, it is essential to remove impurities present in the fabric. The processes involved in removal of these impurities is known as preparatory processes which includes desizing and scouring.

Desizing of the fabric: Desizing was done to remove starch and any other sizing material present in the fabric. The cotton fabric was desized in a solution containing 1 percent sulphuric acid (H_2SO_4) at 50^0C with MLR 1:40 for 60 minutes. The fabric was rinsed thoroughly to remove loose starch and other residues, if left (Singh 2017) [14].

Scouring of the fabric: Scouring of the cotton fabric was done for the removal of natural and added impurities like oils, fats, waxes and other extraneous dirt that may have been added to the fabric during manufacturing process. The fabric was weighed and soaked before immersion in the scouring bath. The fabric was squeezed thoroughly and was treated in a water solution containing 1 percent soap, 3 percent soda ash and 0.5 percent sodium sulphite at boiling temperature (100^0C) with MLR 1:40 for 60 minutes. After that the fabric was rinsed thoroughly to remove any residues, if left and dried on a flat surface (Poonia, 2018) [11].

Determination of the physical properties of the cotton fabric after pretreatment

The fabric samples were conditioned prior to determination of fabric dimensions under standard test conditions i.e. relative humidity of 65 ± 2 percent and a temperature of 27 ± 2^0C.

Geometrical properties

Geometrical properties i.e. fabric count, weight, thickness and bulk of cotton fabric were studied as per the standard test methods described below.

Fabric count: Fabric count is the number of warp yarns (ends) and weft yarns (picks) per square inch in the cotton fabric. Paramount pick glass with pointer was used to determine the fabric count of the cotton fabric using ASTM–D123 test method. An average of five readings was taken as the fabric count.

Fabric weight: Samples were cut at random from all the three selected fabrics with the help of round cutter of GSM. The individual samples were suspended on the clamp of the pointer beam of the Paramount Precision Scale for GSM using ASTM D3776-90 test method. The movement of the pointer beam was controlled with the help of break knob provided at the centre of the unit. The weight per unit area was read directly from the Quadrant scale from 0-250 GSM. An average of five readings was calculated as fabric weight.

Fabric thickness: Fabric thickness is defined as the distance between two parallel surfaces while exerting a specific pressure on the material by the pressure foot of the tester. Paramount Fabric Thickness Gauge was used to determine the thickness of the samples using BS 2544: 1967 test method. An average of five readings was calculated as the fabric thickness.

Bulk: Fabric bulk (cm^3 /gm) expresses the specific volume of a material. Bulk is the inverse of density. Bulk was calculated by dividing the thickness of a fabric by its basic weight.

$$\text{Fabric bulk (cm3 /gm)} = \frac{\text{Thickness (cm)}}{\text{weight (gm /sq. cm)}}$$

Mechanical properties

Mechanical properties i.e. tensile strength and elongation were tested to analyze the effect of pretreatment on mechanical properties of cotton fabric. The mechanical properties of fabrics were studied as per the standard test methods described below.

Tensile strength: Tensile strength is the ability of the fabric to withstand the load of force usually expressed as kilogram weight or pound weight. Tensile strength of fabric was determined on Paramount Tensile Tester using IS 4169 test method. Averages of five readings of the specimen from both directions (warp and weft) were taken.

Elongation: Elongation of fabric corresponding to tensile strength is the original length of the sample at breaking point. Elongation of fabric was determined on Paramount Tensile Tester using IS 4169 test method. The per cent elongation at breaking point was calculated from the following formula:

$$\text{Elongation at break (\%)} = \text{Lf} - \frac{\text{Li}}{\text{Li}} \text{x100}$$

Where,
L_i= initial reading
L_f= Final reading

Comfort properties: Comfort properties, i.e. moisture regain, bending length, flexural rigidity and air permeability were studied as per the standard test methods described below.

Moisture regain: Moisture regain is defined as the weight of water in a material expressed as a percentage of the oven dry weight. The 'oven dry weight' is defined as 'the constant weight' obtained by drying at a temperature of 105±3 °C. Moisture regain was determined using BS 1051:1964 test method. The samples were weighed and an average mean was calculated. The percentage of moisture regain was calculated using the following formula:

$$\text{Moisture regain (\%)} = \frac{\text{Original weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

Fabric bending length: The Stiffness Tester determines the bending length of the fabrics by cantilever method in which the fabric specimen are allowed to bend under its own weight as the length of the overhanging portion of the specimen is gradually increased. The bending length of the fabric samples was determined by Paramount Stiffness Tester using BS 3356: 1961 test method. An average of 20 readings in warp and 20 in weft direction was calculated.

Flexural rigidity: Flexural rigidity is defined as the force couple required to bend a non-rigid structure in one unit of curvature or it can be defined as the resistance offered by a structure while undergoing bending.

The area and weight was determined for calculating the flexural rigidity.

$$\text{Flexural rigidity (G)} = \text{W} \times \left(\frac{\text{L}}{2}\right)_3 \text{mg} - \text{cm}$$

Where,
W= weight per unit area of fabric in mg/cm^2
L= the mean length of overhanging portion in centimeter
Overall flexural rigidity

$$G_o = G_w \times G_f$$

Where
G_w- warp way flexural rigidity, and
G_f - weft way flexural rigidity.

In the same way bending length and flexural rigidity of all samples, controlled and finished scoured fabric were measured.

Air permeability: Air permeability of a fabric is the volume of air measured in cubic cm passed per second through 1 square cm for the fabric at a pressure of 1 cm head of water. Paramount Air Permeability master was used to find the air permeability of the fabric using ASTM D 737 test method. Air permeability was calculated with the help of following formula:

$$\text{Air Permeability} = \frac{\text{Rate of flow of air}}{\text{Exposed area}}$$

AP = k × Rotameter reading

Where
k is the conversion factor i.e. = 8.333 (the 20 cm^2 area of the fabric was exposed for checking the air permeability in litre/dm^2/minute)

Statistical Analysis: The data for the grey, desized and scoured fabric samples was coded, tabulated and analysed by the application of following statistical tools to draw meaningful inferences. The statistical analysis was done by using the OP$_{STAT}$ provided on the HAU website (online statistical analysis), as well as the statistical formulas explained below.

Percentage change: Percentage change was calculated for change in geometrical, mechanical and comfort properties of fabric under study. It was obtained according to the
Formula:

$$\text{Percentage change (\%)} = \frac{\text{Difference between values of controlled and finished samples}}{\text{Value of controlled samples}}$$

Mean: Arithmetic mean is calculated by obtaining the sum of all the observations and then divided by total number of observations in the set. In the study, mean was calculated for the physical and performance properties of the fabric.

$$\text{Arithmetic mean} = \frac{\sum_{n=1}^{k} x^n}{k}$$

Where,
X - Sum of all the observations
n - Total number of observations

Standard Deviation: The standard deviation is the positive square root of the arithmetic mean of the squared deviations of observation in the data series about its arithmetic mean is called standard deviation i.e. it is the square root of variance. Standard deviation was used to calculate the error in the mean of different fabrics.

$$\text{Standard Deviation} = \frac{\sqrt{\sum \text{Xi2}}}{\text{n}}$$

Standard Error: The standard error of the mean (SEM) is the standard deviation of the sample mean's estimate of a population mean. In the study, the standard error was used to calculate the error in the mean of physical and performance properties of different fabrics. SEM is usually estimated by the sample estimate of the population standard deviation (sample standard deviation) divided by the square root of the sample size (assuming statistical independence of the values in the sample):

$$\text{SEr} = \frac{\text{x}}{\sqrt{\text{n}}}$$

Paired T-test: It was applied to test the significance of change in the physical properties of pretreated fabric from the untreated controlled fabric. The formula used was:

$$t = \frac{\bar{d}\sqrt{n}}{s} \text{ with } n-1 \text{ d.f.}$$

Where
d = the mean of the difference of untreated controlled and pretreated fabric
n = Number of observations
S = Standard deviation of the difference computed by usual formula:

$$s = \sqrt{\frac{1}{n-1}\left\{\frac{(2d^2)}{n} - 2d^2\right\}}$$

Results and Discussion

The present study was undertaken to check the effect of pretreatment on physical properties of cotton fabric. The physical properties of cotton fabric were studied by using standard test methods. The results are presented as follows:

Effect of pretreatment on physical properties of cotton fabric

The pretreated cotton fabric was studied with respect to change in physical properties i.e. geometrical, mechanical and comfort properties.

Effect of pretreatment on geometrical properties of cotton fabric

Geometrical properties i.e. fabric count, fabric weight, fabric thickness and fabric bulk were tested to analyze the effect of pretreatment on geometrical properties of cotton fabric.

Fabric count, weight, thickness and bulk: The data presented in Table 1 highlighted that the fabric count of cotton fabric was 49±0.58 × 25±1.73 ends and picks per sq. inch and weight observed was 107±2.3 g/m^2. After desizing and scouring, the fabric count in both warp and weft directions was increased to 51±1 and 26±2.31ends and picks per sq. inch and fabric weight increased to 107.4±3.10 g/m^2 with 4.00, 4.00 and 0.37 percent increase and 1.73, 0.35 and 0.10 t-values, respectively. The increase in fabric count and fabric weight was found to be non-significant. The thickness and bulk of cotton fabric was observed to be 0.35±0.04 mm and 3.27±0.04cm$^{3/}$gm which increased to 0.36±0.05mm and 3.35±0.02 cm$^{3/}$gm after preparatory processes with percent increase of 2.85 and 2.45 with 0.17 and 1.92 t-values, respectively. The increase in thickness was non-significant while increase in bulk after desizing and scouring was significant at 5% level of significance. Nur *et al.*, (2016) [10] reported that the loss in fabric weight when the cotton fabric was treated with various concentrations of H_2O_2 and NaOH under different conditions and do not cause any appreciable loss in fabric strength of sample after pre-treatments. Sushila (2018) reported that after desizing and scouring, there was significant increase in weight per unit area, thickness, Bulk, fabric count both in warp and weft directions.

Table 1: Effect of pretreatment on geometrical properties of cotton fabric

Fabric / Physical Parameters		Grey fabric Mean ± S.E	Desized and scoured fabric Mean ± S.E	Per cent change	t-value
Fabric count (ends and picks per square inch)	Warp	49±0.58	51±1.00	+ 4.00	1.73
	Weft	25±1.73	26±2.31	+ 4.00	0.35
Weight per unit area (g/m^2)		107±2.30	107.4±3.10	+ 0.37	0.10
Thickness (mm)		0.35±0.04	0.36±0.05	+ 2.85	0.17
Bulk (cm$^{3/}$gm)		3.27±0.04	3.35±0.02	+ 2.45	1.92*

**Significant at 1% level of significance, *Significant at 5% level of significance

Effect of pretreatment on mechanical properties of cotton fabric

Mechanical properties i.e. tensile strength and elongation were tested to analyze the effect of pretreatment on mechanical properties of cotton fabric.

Tensile strength and elongation: The results obtained in Table 2 revealed that the tensile strength in both warp and weft directions of cotton fabric was 14.61±1.56 kg and 11.65±1.12 kg which reduced to 14.56±0.41 kg and 14.56±0.41 kg after desizing and scouring thus showing percent change of 0.34 and 2.83 with 0.03 and 0.17 t-values, respectively. The decrease in tensile strength of fabric samples in both warp and weft directions was found to be non-significant.

The elongation in both warp and weft directions of cotton fabric was 19.00±0.38 % and 20.00±0.37%. After desizing and scouring, the elongation in both warp and weft directions increased to 19.20±0.65 % and 20.90±0.96 %with 1.05 and 4.50 percent change and 0.21 and 0.77 t-values, respectively. Kumari (2019) showed that there was decrease in tensile strength and increase in elongation of desized and scoured grey cotton fabric after desizing and scouring.

Table 2: Effect of pretreatmenton mechanical properties of cotton fabric

Fabric / Physical Parameters		Grey fabric Mean ± S.E	Desized and scoured fabric Mean ± S.E	Per cent Change	t-value
Tensile strength (kg)	Warp	14.61±1.56	14.56±0.41	- 0.34	0.03
	Weft	11.65±1.12	14.56±0.41	- 2.83	0.17
Elongation (%)	Warp	19.00±0.38	19.20±0.65	+1.05	0.21
	Weft	20.00±0.37	20.90±0.96	+4.50	0.77

**Significant at 1% level of significance, *Significant at 5% level of significance

Effect of pretreatment on comfort properties of cotton fabric

Comfort properties, i.e. bending length, flexural rigidity, moisture regain and air permeability were tested to analyze the effect of pretreatment on comfort properties of cotton fabric.

Bending length and flexural rigidity: The data presented in Table 3 revealed that the bending length of cotton fabric was 4.01±0.6 cm in warp direction and 4.60±0.13 cm in weft direction. After desizing and scouring, the bending length in both warp and weft directions decreased to 3.94±0.03 cm and 4.54±0.39 cm with 1.74 and 1.30 percent change and 0.12 and 0.14 t-values, respectively. The decrease in bending length was found to be non-significant.

The flexural rigidity of cotton fabric was observed to be 0.35±0.01 mg-cm which decreased to 0.32±0.04 mg-cm after desizing and scouring with percent decrease of 8.60 with 6.02 t-value. The decrease in flexural rigidity after desizing and scouring was found to be significant at 1% level of significance. The results are supported by the finding of Nagpal (2017) who reported that moisture regain, bending length and tensile strength of fabric decreased after scouring.

Table 3: Effect of pretreatment on comfort properties of cotton fabric

Fabric / Physical Parameters		Grey fabric Mean ± S.E	Desized and scoured fabric Mean ± S.E	Per cent Change	t-value
Bending length (cm)	Warp	4.01±0.60	3.94±0.03	- 1.74	0.12
	Weft	4.60±0.13	4.54±0.39	- 1.30	0.14
Flexural rigidity (mg-cm)		0.35±0.01	0.32±0.04	-8.60	6.02**

**Significant at 1% level of significance, *Significant at 5% level of significance

Air permeability and moisture regain: It was clearly observed from the data in Table 4 that the air permeability of grey fabric was 677litre/dm^2/minute which decreased to675 litre/dm^2/minute after desizing and scouring. There was 0.30 percent decrease in the air permeability value. The moisture regain of cotton fabric sample was 7.62±0.54 %. After desizing and scouring, the moisture regain was decreased to 7.52±0.47% with 1.31 percent change and 0.14 t-value. The decrease in moisture regain after desizing and scouring was found to be non- significant. Poonia (2018) [11] reported that after desizing and scouring there was decrease in the air permeability and moisture regain.

Table 4: Effect of pretreatment on comfort properties of cotton fabric

Fabric / Physical Parameters	Grey fabric Mean ± S.E	Desized and scoured fabric Mean ± S.E	Per cent Change	t-value
Air permeability (litre/dm^2/minute)	677	675	-0.30	0.00
Moisture regain (%)	7.62±0.54	7.52±0.47	-1.31	0.14

**Significant at 1% level of significance, *Significant at 5% level of significance

It is evident from the results shown in Table 1, 2, 3 and 4 that after desizing and scouring, there was significant increase in weight per unit area, thickness, bulk, fabric count both in warp and weft directions and elongation in both warp and weft directions, while there was non-significant decrease in moisture regain, bending length, tensile strength, flexural rigidity and air permeability.

After desizing and scouring, there was removal of starch as well as cellulosic matter and other impurities which resulted in compactness and closeness of weaves. The change in physical properties of the fabric may therefore be attributed to the compactness of the weave. Rulhania *et. al.* (2021) [13] found that there was increase in bending length and flexural rigidity whereas air permeability and moisture regain decreased after desizing and scouring of the cotton fabric.

Conclusion

Pretreatment such as desizing and scouring were performed for removal of the impurities and starch present in cotton fabric. It was concluded from above findings that after preparatory processes, an increase in geometrical properties, decrease in mechanical and comfort properties were observed. Among all the physical properties, bulk was increased significantly whereas flexural rigidity decreased significantly. Therefore, in the test results, it was found that pretreatment had an effect on physical properties of cotton fabric.

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