

Evaluating the Comfort Properties of Plasma Treated and Plasma Untreated Cotton Fabrics Finished with Plant Extracts

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ABSTRACT: Plasma treatment improves wet ability, hydrophobic finishing, adhesion, product quality, functionality in fabrics without alteration of inherent properties of the textile material. In this study to prove that plasma treatment has these advantages, plasma treated cotton fabrics finished with two plant extracts was compared with untreated plasma treated cotton by taking different comfort properties as functional tests. The effect of plasma treatment on comfort properties like fabric stiffness, air permeability and absorbency was investigated. From the study it may be concluded that plasma treatment improves absorbency, drape and air permeability. The treatment timing shall also be increased to improve the comfort and other physical mechanical properties of the fabrics. Hence, plasma treatment is a good substitute for chemical finishing as it causes no environmental pollution.

KEYWORDS: Plasma, cotton, air permeability, absorbency, plant extract

I. INTRODUCTION

Growing demands on the functionality of textiles as well as the environmental friendliness of the finishing processes increase the interest in physically induced techniques for surface modification and coating of textiles. Plasma is one among such treatments that is getting good attention these days for its application as a pre-treatment and finishing technique for textiles. Plasma is a gaseous state of matter that contains excited species such as ions, free electrons and large amounts of visible, Ultra-Violet (UV), Infra-Red (IR) radiation. Plasma state can be generated by electrical discharge, fusion, flames and mechanical electromagnetic radiation [1]. Plasma is an ionized gas which is a distinct fourth state of matter. In the ionized state, at least one electron is not bound to an atom or molecule converting the atom or molecule into positively charged ions. As temperature increases, molecules become more energetic and transform sequentially into solid, liquid, gas and finally plasma which justifies the title fourth state of matter [2].

Plasma treatment has been used to induce both surface modification and bulk property enhancement of textile material, resulting in improvements in textile products ranging from conventional fabrics to advance composite. These treatments have been shown to enhance the dyeing rates of polymers, improve color fastness and wash resistance of fabrics and change the energy of fibre and fabric [3]. The plasma gas particles act on the fabric surface in nanoscale so as to modify the functional properties of the fabric [4]. The Plasma modifies the surface of the fabric by the bombardment with high energy electrons and ions [5].

Plasma treatment have been used to induce both surface modification and bulk property enhancement of textile material, resulting in improved textile products ranging from conventional fabric to advanced composites [6]. Eco-friendly plasma treatment can be carried out during different stages of fabric formation such as fabric preparation,

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dyeing and finishing of cotton, wool, silk and most of the man-made fibres. Plasma gas particles etch on the fabric surface in nano scale, so as to modify the functional properties of the fabric [7].

II. RELATEDWORK

Plasma technology is a surface sensitive method that allows selective modification in the NM-range. The textile that has to function is placed in a reaction chamber with any gas preferably nitrogen, oxygen or argon creating plasma, which interacts with the surface of the textiles. This technology has been introduced industry for applications such as removing sizing, adding functionality to the textile and modifying the surface properties of textiles. It is applicable to most of textile materials for surface treatment. Different kinds of plasma gases provide special functionality to textile materials such as UV-protection, antibacterial, medical function, bleaching, flame retardancy, wetability, hydrophobic finishing and product quality without any alternation of the inherent properties of the textile materials [6].

Hence in this research, to prove that plasma treatment has these advantages, plasma treated cotton fabrics finished with two herbal extracts was compared with untreated plasma treated cotton by taking different comfort properties as functional tests.

III. MATERIALS AND METHODS

Fabric procurement and properties: Cotton

Cotton fabric material, plain weave 40s medical grade was commercially procured from a weaving unit, Tirupur, Tamil Nadu, India.

Cotton fabric: Plasma treatment application

The usage of oxygen can modify the wettability of cotton and other cellulosic materials. It also alters the tensile properties and functional behavior of the fabric. It improves air permeability and drape properties. Due to these properties the investigator selected oxygen and argon gases for the study. 20 and 40 minutes were selected as timing for the treatment.

The machine was set at 600 W. The initial pressure was maintained at 0.050millbar. The Bleached Plain Fabric was set at room temperature. The samples were fixed on 22 X 19 inch frame by clips. The frame was fixed at 3.5 cm distance from bottom rod. The machine was closed and the motor started. The gas was passed to main chamber through gas cylinder. The time duration was set the pressure was raised up to 1.5×10^{-2} bar. After the process are complete machine stops automatically. The details about the parameter of plasma application used in the present study were below tabulated.

S. No	Criteria	Parameters
1	Gas	Oxygen
2	Inter-electrode spacing	3.5 cm
3	Plasma current	2.1 mA
4	Plasma power	600 W
5	Exposure time	2 minutes
6	Pressure	1.5×10^{-2} bar

Medicinal plants

Two medicinal plants, *Psidiumguajava*, (Guava) *Achyranthes aspera* (Prickly chaff flower) were collected and authenticated from Department of Plant Science, Tamil Nadu Agricultural University, Coimbatore, India. Leaves of the plants were used in the study.

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Methanol extracts of medicinal plants [8]

Fresh leaves of *Psidiumguajava* and *Achyranthes aspera* was shadow dried at 37°C. Drying was done to reduce the moisture content of leaves to less than 20%. Dried leaves of *Psidiumguajava* and *Achyranthes aspera* were grounded to make fine powder for the extraction of desired materials. Fine powdered material was extracted to obtain the active substances with suitable solvent (methanol). 10 grams of powdered leaves of *Psidiumguajava* and *Achyranthes aspera* were extracted in 100ml of 80% methanol for 18 hours under shaking condition separately. For every 6 hours the solution was sonicated for 20 minutes to obtain the exact antibacterial substances of the medicinal plants.

Finishing of plant extracts in plasma treated and untreated cotton using pad-dry cure process [9]

Three sets of fabric samples were used in this study. In the first set of samples (Plasma treated cotton) the herbal extracts of *Psidiumguajava* and *Achyranthes aspera* were finished separately. In the second set of fabric samples (plasma untreated cotton) similar plant extracts were finished separately. Cotton fabric without plasma treatment and plant extract was used as a third set of fabrics (control). All the fabric samples except control fabric were finished with plant extracts using a pneumatic padding mangle with 8% citric acid as a standard binding solution at a pressure of 3 psi with 100% wet pickup followed by drying at 80°C and curing at 160°C for 5 min. The finished plasma treated and untreated fabrics were subjected to evaluate for its comfort properties along with control fabrics.

Comfort Properties

This property was evaluated to find out the comfort properties of 3 groups of fabrics (control, plasma treated and plasma untreated fabrics). Test includes fabric stiffness, air permeability and absorbency.

Fabric Stiffness

Stiffness is the ability of a textile fabric to resist changes in shape due to bending deformation. The bending properties like stiffness, drape, handle and crease recovery are the prime parameters of evaluating the fabric. Stiffness is the ability of a material to resist deformation. Bending length is the length of a fabric that will bend on its own weight, to a definite extent. It is a measure of the stiffness that determines the draping quality. The Shirley stiffness tester was used to determine the stiffness of the fabrics. A scale of 15 cm length and 2.5 cm width formed the templates. Ten samples were cut at random both in the warp and weft directions from each of the fabrics from 3 groups of fabrics. Each fabric along with the scale was mounted on a horizontal platform. The scale was moved along with the sample slowly until the fabric fell to the edge of the platform and the tip of the fabric coincided with the index line, which was viewed in the mirror. The bending length was recorded from the scale marked opposite to the zero on the side of the platform.

Fabric Air Permeability [10] (ASTM D 737 – 04)

Air permeability of a fabric is the volume of air measured in cubic cm passed per second through 1 sq.cm for the fabric at a pressure of one cm. head of water. The Air Permeability Tester consists of a circular clamp to hold the specimen and a spring loaded clamp to press the specimen while testing, the room atmospheric air was drawn through the specimen by means of a suction pump. The rate of air flow was adjusted to desired pressure drop across the fabric which was indicated on drought gauge graduated from 0.25 mm. The rate of air flow was read from the Rotameters. They were calibrated to indicate air flow in cubic centimeter per second at 27°C and 760 mm of mercury. The area of the sample exposed to air was one inch in diameter. From the reading Rotameter air permeability was calculated using the following formula:

$$\text{Air permeability} = \text{Average rate flow} / \text{Area of sample exposed to air (cc/sec/sq.cm)}$$

Then the mean was calculated and analyzed for three groups of fabrics.

Absorbency Properties: Vertical Wicking Test [10] (AATCC – 197)

The Vertical Wicking Method measures the rapidity of absorption. Ten samples were cut into size of 11 inches in length and 1 inch width from each 3 set of fabric samples. One end of the sample strip was pasted with a glass rod

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which was placed on heavy wooden blocks and the other end was allowed to immerse in a tray of distilled water. The rise of the water level in the strip was noted by keeping the length of the fabric as 5cm constant. The same procedure was repeated for all the samples. The mean values of ten readings were calculated and recorded. The vertical wicking of each material was recorded carefully to find the absorbency of original, finished and plasma treated finished fabrics. The mean values of ten readings were calculated and recorded.

Nomenclature

The nomenclature of the sample used in the research work is given below and the same was used throughout the study.

S. No	Nomenclature	Fabric samples
1	A	Original cotton
2	AG1	Guava finished cotton
3	AG2	Plasma treated guava finished cotton
4	AP1	Prickly chaff flower finished cotton
5	AP2	Plasma treated prickly chaff flower finished cotton

IV. EXPERIMENTAL RESULTS

The comfort properties of the plasma treated and plasma untreated plant extract finished cotton fabrics were evaluated and the obtained values were interpreted.

Fabric Stiffness

Warp Direction

From Table – 1, it was obvious that in the comparison made within samples A, AG1 and AG2, a reduction in stiffness was observed in the sample AG1 of 7.06% over the control sample A. Among the samples A, AP1 and AP2, the sample AP2 showed more reduction in stiffness of 16.25% than sample AP1 (8.48%) over the control sample A.

Hence it could be concluded that in warp direction the plasma treated samples namely AP2, expressed higher stiffness reduction when compared with their respective plasma untreated samples.

Weft Direction

In weft direction, as gain in stiffness was observed in both the samples AG1 and AG2 over sample A of which it was higher in the sample AG2 (21.57%) than sample AG1 (17.89%). Among the sample A, AP1 and AP2 also the same trend was noted with higher gain in sample AP2 (24.21%) than sample AP1 (23.68%).

The samples used in the study such as scoured and bleached cotton, are all hydrophilic in nature and hence would have liquid pick-up capability. Herbal finishes applied will serve as a binder and enhance the compactness of the yarn structure. Additionally, as the plasma treatment is a surface modification technique, it results in etching the yarn surface, thereby reducing the yarn linear density. Both herbal finishing treatment and plasma surface modification make the yarn thinner, which results in more ends/inch or picks/inch. This results in more number of yarns in a unit area of the testing specimen due to increase in ends/inch or picks/inch. Such a structure provides more resistance to bending which results in enhancing stiffness as shown in Table-1. In this case, based on the experimental results, fabric cover factor has a predominant influence on the stiffness of the fabric. However, in the case of testing along the warp direction results, the smoothness and thinness of yarns, plasma and plant extract treatment influence the bending of fabrics resulting in reduced stiffness value.

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Table – 1: Fabric stiffness in warp and weft direction

S.No.	Samples	Mean value (cm)	% loss / gain	Standard deviation	Mean value (cm)	% loss / gain	Standard deviation
1	A	2.83	-	0.0662	1.90	-	0.050
2	AG1	2.63	-7.06	0.0189	2.24	17.89	0.083
3	AG2	2.86	1.06	2.2499	2.31	21.57	0.064
4	AP1	2.59	-8.48	0.0206	2.35	23.68	0.0158
5	AP2	2.37	-16.25	0.0206	2.36	24.21	0.0173

Fabric Air Permeability

The air permeability of cotton finished with guava leaves (*Psidiumguajava*) and prickly chaff flower (*Achyranthes aspera*) extracts unfinished, finished and plasma treated finished fabrics was compared and presented in Table – 2. From the Table – 2 it is obvious that among samples A, AG1 and AG2, both the samples AG1 and AG2 showed increase in air permeability with higher value in sample AG2 (14.86%) followed by sample (11.06%). Among samples A, AP1 and AP2 also the same trend was noted with higher value in sample AP2 (18.32%) than sample AP1 (6.81%).

Interestingly, as is evident from the results, plasma pre-treated samples (AG2, AP2) did not show any difference in their breathability as reflected by their air permeability values. Plasma and herbal treatments resulted in an increase in the air permeability values of the fabrics. This could be attributed to the surface etching effect of plasma treatment. A recent study has shown that the plasma treatment affects the porous structure of the fabric by altering its pore size. With the increase in pore size, wicking transport and air permeability increases. In the case of herbal treatment, chemical finishes serve as a surface binder reducing the surface hairs and hence the fabrics have higher air permeability. Therefore, surface etching, plasma treatment and herbal treatment endeavour, to let more air to pass through the fabric structure resulting in increased air permeability. The results presented in the thesis support the above hypothesis, showing fabrics have higher breathability after plasma and herbal treatments.

Hence it could be concluded that the samples AG2 (14.86%) and AP2 (18.32%) exhibited higher air permeability rates than the plasma untreated samples when compared within and between samples. This may be due to the increase in its porosity that had been created in the fabric samples because of the finishing and plasma treatment.

Table – 2: Fabric Air-Permeability

S.No.	Samples	Meanvalue (cc/cm.sq/sec)	% loss/ gain	Standard deviation
1	A	8.95	-	0.21
2	AG1	9.94	11.06	0.32
3	AG2	10.28	14.86	0.14
4	AP1	9.56	6.81	0.06
5	AP2	10.59	18.32	0.07

Absorbency Properties: Vertical Wicking Test

The findings of the vertical wicking length of the control, finished and plasma treated finished samples are shown in Table – 3. From the Table – 3, it is clear that in the comparison made between the sample A, AG1 and AG2, the sample AG2 (41.75%) showed higher reduction in time for vertical wicking than sample AG1 (11%). The same trend was observed in the samples A, AP1 and AP2 with higher among reduction in time in sample AP2 (38%).

As is evident from the fabric vertical wicking test results, plasma treatment reduces the time for the fabric to wick the water. As the plasma treatment affects the water sorption characteristics, wicking enhances, as reflected in reduced wicking time. Hence it could be concluded that the vertical wicking improved to drastic extent in the plasma treated and

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plasma untreated samples of which it was more in the samples AG2 (41.75%) and AP2 (38.0%). This may be due to the improvement in the absorbency property in the fabric structure because of finishing the process.

Table – 3: Absorbency Properties: Vertical Wicking Test

S.No.	Samples	Meanvalue (sec)	% loss/ gain	Standard deviation
1	A	60.0	-	0.81
2	AG1	53.4	-11.00	1.07
3	AG2	35.1	-41.75	0.73
4	AP1	52.0	-13.33	0.81
5	AP2	37.3	-38.00	0.78

V. CONCLUSION

Plasma treatment is a good substitute for chemical finishing as it causes no environmental pollution. From the study it may be concluded that plasma treatment with oxygen gases improves fabric stiffness, air permeability and absorbency. Plant extracts finished plasma treated cotton fabric showed increase in all comfort properties than the control and untreated plasma cotton samples. Thus obtained results pave way to investigate on more properties of cotton or equivalent fabrics. These properties include physical, mechanical and biological viz., tensile strength, fabric count, antibacterial activity, insect repellency and UPF.

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