A Study on the Surface Modification of the Knitted Bamboo Fabric by DC Atmospheric Air Plasma and its Effect on Hydrophilicity

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Abstract: Plasma treatment is an excellent surface modification technique used to enhance the comfort, wicking, and functional properties of fabric without using chemicals. The present work is concerned with the hydrophilic enhancement of the bamboo knitted fabric using DC atmospheric air plasma treatment. The DC air plasma treatment was carried out at various pressures; exposure times; inter-electrode distances; and currents to optimize the process parameter for the fabrics to increase the hydrophilicity rate. The effect of plasma treatment on the fabric was studied using a wicking test (AATCC 79) and percentage weight loss (ASTM D3776) of the fabric. The physical properties of the treated and untreated bamboo fabric were also analyzed using water absorption, abrasion resistance, air permeability, bursting strength, and stiffness. The surface topology and the chemical characterization of the plasma-treated fabric were studied using HR-SEM and FTIR analysis respectively. The result revealed that the optimized plasma-treated bamboo fabric showed the highest hydrophilic rate when compared with the untreated fabric and thus the treatment was feasible. In the HR SEM analysis, the treated fabric showed the etching effect but not in untreated fabric. The chemical change in the plasma-treated fabrics has represented the FTIR stretch responsible for the hydrophilicity. Hence this kind of plasma-treated bamboo for health care and hygiene products is the need of the hour.

Key words: Plasma, bamboo fabric, hydrophilicity, physical properties.

1. Introduction

The ability of textiles to transmit moisture significantly impacts the thermo- physiological comfort of the human body, which is regulated through perspiration, both as vapor and liquid. The moisture fabric reduces the body heat and makes the wearer to become tired. So,the clothing worn in direct contact with the skin should facilitate the rapid evaporation of moisture into the atmosphere (Venkatesh and Gowda, 2013). To achieve this, the fabric must possess two key properties: first, it should efficiently absorb perspiration from the skin surface, and second, it should effectively transport this moisture away from the body to the surrounding environment, thereby enhancing the wearer's comfort.

Moisture moves into the atmosphere through two processes: diffusion and wicking. Knitted fabrics, with their sl ightly uneven surfaces, often feel more comfortable than woven fabrics with the same fiber composition.This phenomenon occurs because fabrics with uneven surfaces have less direct contact with the skin (Higgins and

Anand, 2003). In recent years, there has been a significant increase in research focused on the absorption properties of textiles used in apparel, healthcare, hygiene products, and sportswear. It gives the crucial role of absorption in moisture management and overall performance (Venkatesh and Gowda, 2013).

Wettability can be adjusted through surface modification techniques, including exposure to plasma, flame, chemicals, enzymes, and other agents. Plasma is an ionized gas with balanced positive and negative charges. It can be found under a wide variety of temperatures and pressures.Plasma can be described as a gaseous state characterized by the presence of various excited species, including ions, free electrons, and a substantial quantity of visible, ultraviolet, and infrared radiation, as well as other particles, depending on the specific gas employed. Plasma technology represents a clean and dry process that offers several advantages compared to traditional chemical methods. It is often considered a more economical and environmentally friendly approach (Morent et al., 2008).

Plasma treatment is a cost-effective method that doesn't need water or chemicals. It enhances the comfort, functionality, and appearance of regenerated cellulosic fabrics, while also being kinder to the environment by reducing pollution (Venkatesh and Gowda, 2013).Plasma treatment enhances textiles by introducing features like water repellency, long- lasting hydrophilicity, improves mechanical and electrical properties, antibacterial effects, and biocompatibility. These benefits are due to nanoscale modifications to the fibers. Additionally, the overall feel and bulk of the textiles stay the same. Plasma surface treatment is a powerful tool that changes the fabric's polymer surface, adding new functional groups and causing some slight changes in its texture (Pandiyaraj and Selvarajan, 2008).The plasma gas particles etch the fabric surface at the nanoscale, thereby modifying its functional properties (Geyter et al., 2008). Plasma treatment enables textiles to become either hydrophilic or hydrophobic. This technique modifies both the surface chemistry and topography of the fabric, thereby enhancing adhesionor repellence properties and confining functional groups to the surface (Malek & Holme, 2003).

The fabric's surface is activated in a manner that enhances properties such as wettability, dyeability, hydrophilicity, adhesion, and other finishing processes without compromising its bulk properties (Hartwig, 2002). In the case of bamboo fabrics, a linear relationship was observed between the treatment duration and the absorption rate of the bottom surface.A recent study demonstrated that air, argon, and oxygen gas plasma treatment have a significant impact on the moisture properties of bamboo knitted fabrics (Venkatesh and Gowda, 2013).

This study investigates the use of atmospheric air plasma treatment on bamboo knitted fabric to obtain hydrophilicity. A comprehensive evaluation of key comfort-related properties, including abrasion resistance, air permeability, bursting strength, stiffness, and water absorption, has been conducted. The etched surface topology of the plasma treated fabric was studied using HR SEM analysis.

2. Materials And Methods

Bamboo fabric was procured from Sevvel International, Tirupur, India. The fabric was as such used for plasma treatment.

2.1 Plasma treatment

The treatment was carried out in a 12" DC plasma chamber. The samples of size (40×40 cm) were placed on the lower electrode. The chamber was first evacuated to a base pressure of 10^{-3} mbar using a rotary pump (Hindhivac, India). Atmospheric air was used as working gas was admitted in to the chamber by means of a needle valve. The treatment was carried out at different pressures, exposure time, inter-electrode distance and current in order to optimize the process parameters for the fabrics. The DC air plasma treatment was carried out for a gas pressure of 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10 and 0.22 mbar; inter electrode distance 4, 5, 6, 7 and 8 cm; DC current of 0.4, 0.6, 0.8 and 1.0 mA and for plasma exposure time of 3, 4, 5, 6 and 7 seconds to obtain maximum hydrophilicity.

2.2 Assessment of hydrophilicity - Wicking test (AATCC 79)

A treated fabric strip (2 cm × 17 cm) was hung above the surface of distilled water in a glass beaker, with its hor izontal bottom edge just touching the water. Capillary action caused spontaneous wicking. The height of the liqu id rise boundary was measured every 5 seconds for up to 60 seconds over two trials.

2.3 Physical properties of treated fabrics

2.3.1 Abrasion (AATCC 119-2004)

The abrasion test was conducted to assess a fabric's resistance to damage caused by friction. This resistance is influenced by factors such as fiber fineness, yarn twist, and fabric weave structure. Yarns with a firmer and tighter twist generally exhibit greater abrasion resistance. The fabric specimen was placed over a foam rubber cushion and rubbed in multiple directions against a wire screen mounted on a weighted head. Abrasion was performed for 50 revolutions, and the initial and final weights of the fabric were recorded.Three readings were recorded and mean percentage abrasion was calculated.

$$\mathrm{Abrasionresistance}(\%)\ \frac{\mathrm{Weightbeforeabrasion}-\mathrm{Weightafterabrasion}}{\mathrm{weightbeforeabrasion}}\times 100 \quad (1)$$

Four readings for every sample were taken and the average was calculated.

2.3.2 Air Permeability (ASTM D737-96)

This test measures how much air passes perpendicularly through a fabric under a specific air pressure

difference. Factors like construction and finishing can affect air permeability by altering the length of airflow pa ths

through the fabric. The test was carried out using an air permeability testing apparatus, with a pressure gauge an d flow meter for measurements. The samples were tested at 65% relative humidity and a temperature of 21°C.Fi ve readings were recorded and mean percentage air permeability was calculated.

The air permeability of the given fabric is calculated using the following formula

$$\mathrm{Airpermeability} = \frac{\mathrm{Rotormeterreading}}{3600\times\mathrm{areaofthefabric}}\,\mathrm{Cu.Cm/s/cm} \quad (2)$$

2.3.3 Bursting test (ASTM D 3787)

This test determines the resistance of textile fabrics to bursting and is widely applicable to various knitted and non-woven fabrics.A hydraulic bursting strength tester was used to assess the fabric's bursting resistance. According to BS (1974), the fabric samples were clamped over an elastic diaphragm using a flat annular clamping ring. Increasing fluid pressure was applied to the underside of the diaphragm until the specimen burst. The operating fluid could be liquid or gas. Six samples were placed over the diaphragm in a flat, tensionless condition and secured with the clamping ring. Pressure was increased smoothly until the specified bursting strength of the fabric was reached. Three readings were recorded and mean percentage bursting was calculated.

2.3.4 Stiffness (ASTM D6828 – 02, 2007)

This test measures fabric stiffness by assessing the force needed to push a sample through a slot of a predetermined width with a metal blade operating at a specified capacity.Three readings were recorded and mean percentage stiffness was calculated.

2.3.5 Water absorption (ASTM-BS 3449)

Five specimens each 80 × 80 mm were cut at 45° to the warp direction.The first step involved conditioning and weighing the samples. They were then submerged in distilled water at a temperature of 20±1°C to a depth of 10 cm. A wire sinker was used to maintain the specimen at the desired depth. The samples were left in that position for 20 minutes. After removing the specimen from sinker they were shaken 10 times in a mechanical shaker. They were then transferred directly to pre weighed airtight containers and then reweighed. Absorption was calculated by following formula

$$\text{Absorption}(\%) = \frac{\text{Massofwaterabsorbed}}{\text{Originalmass}} \times 100 \quad (3)$$

Three readings were recorded and mean percentage absorption was calculated.

2.4 Fourier Transform Infra-Red (FT-IR) Spectroscopy

The basic principle is that different bonds and groups of bonds vibrate at unique frequencies. When a molecule encounters infrared rays, it takes in energy at frequencies that are unique to that molecule. This absorbed energy is then analysed and compared to known patterns of identified materials in the FTIR library.

The infrared spectra were acquired using a Bruker Tensor 27 spectrometer from Germany. The untreated and plasma treated samples were assessed by FT-IR for the surface modification. Fabric samples were recorded from 4000 – 400 as scanning range between wave number (cm^{-1}) and % Transmittance.

2.5 High Resonance Scanning Electron Microscopy (HR SEM analysis)

High-resolution scanning electron microscopy (HR-SEM) was used to study the surface morphology of both the untreated and treated bamboo fabrics. The topographical characterization of the fabrics treated with plasma was investigated. Platinum coating was used as the conducting material to analyze the sample.

3. Results And Discussion

3.1 Optimization parameters of DC air plasma

The bamboo fabrics were optimized at different parameters such as gas pressure, power and exposure time to get maximum hydrophilicity. Wettability of the surface and adhesion properties varied according to the nature of the plasma treatment.Plasma treatment enhanced wettability, water repellency, adhesive properties, and overall quality in cellulose fabric (Venkatesh and Gowda, 2013). Furthermore, air plasma treatment optimizes the surface properties of textile materials without altering their inherent characteristics (Venkatesh and Gowda, 2013). The change in fabric properties with respect to the process parameters were discussed below

3.1.1 Effects of DC air plasma treatment on hydrophilicity and weight loss of fabric

The DC air plasma treatment was carried out for gas pressure of 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10 and 0.22 mbar with plasma current of 0.4, 0.6, 0.8 and 1.0mA for the fabrics at different electrode distances (4, 5, 6, 7 and 8 cm) and exposure time (3, 4, 5, 6 and 7 sec). The standard wicking test and percentage weight loss were carried out for determining the optimum plasma treatment parameters to attain the maximum hydrophilicity of the fabrics.

3.1.2 Effect of exposure time

Exposure time versus wicking height and percentage weight loss

The impact of plasma treatment was investigated at different exposure times. When the fabric was exposed for 3 sec of plasma treatment, the wicking height was found to be 1.7 cm, which showed a better hydrophilicity than the untreated fabric. When the exposure time was increased to 4 sec, the wicking height arose to 2.2 cm which was not much high; But when the exposure time was increased to 5 sec the wicking height arose to 2.3 cm followed by 6 sec exposure provided the wicking height of about 2.4cm.

The increase in the efficiency of treatment with the increase in exposure time is already reported by other researchers (Ploetti*et al*., 2003). When the exposure time was increased to 7 sec the wicking height arose to 2.6 cm, but lead to the damage of the treated fabric. This may be due to breakage of chemical groups present on the surface of the fabrics. Therefore 6 sec of exposure was optimized as time to obtain maximum hydrophilicity.Therefore, the increased wettability and wicking of the fabrics were attributed to the enhanced surface roughness and the introduction of polar groups resulting from air plasma treatment. The weight loss of the fabric was evaluated to determine if plasma exposure time had an impact on it. Weight loss observed immediately after plasma treatment was very low (Figure 1). An increase in the rate of absorption was observed as the duration of treatment increases (Venkatesh and Gowda, 2013).

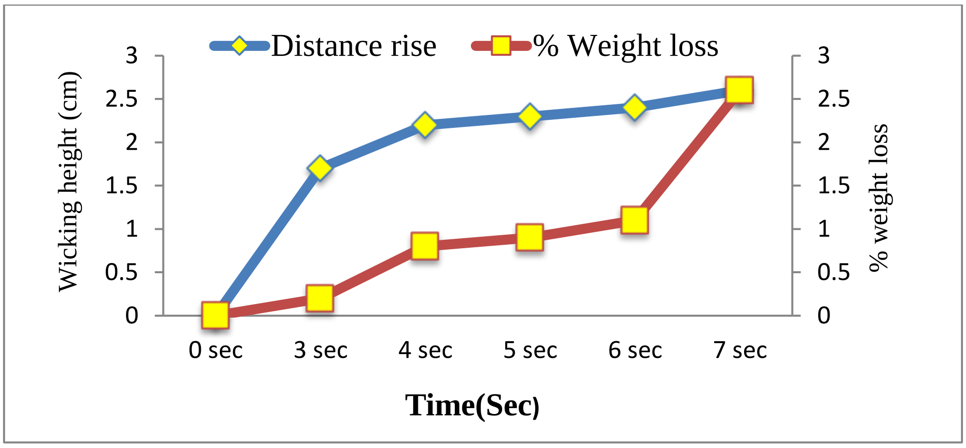


Figure 1: Optimization of DC air plasma treatment time on bamboo fabrics

3.1.3 Effect of inter electrode distance

Inter electrode versus wicking height and percentage weight loss

The plasma treatment was done at different electrode distance by fixing the exposure time in the optimized level.The samples were suspended approximately 18 cm from the cathode due to the longer plasma exposure time (Venkatesh and Gowda, 2013).

When the electrode distance was kept at 4 cm and 5 cm apart, the wicking height was about 2.8 cm and 2.9 cm respectively, but when it was set at 6 cm, 7cm and 8 cm apart, the wicking height dropped to 2.7cm, 2.2cm and 2.0 cm respectively (Figure 2). The fabric treated at 4 cm also showed the higher wicking ability but the percentage weight loss is too higher compared to other distance parameters. For those fabrics treated at a distance of 5 cm, the hydrophilicity was higher. When the distance was reduced below 6cm the distribution of plasma may become non-uniform leading to lesser hydrophilicity.

The electric field strength decreases as the distance from the cathode increases (Wang et al., 2007). The decrease in the value of electric field may cause less amount of energy transfer to the gas molecules, resulting in poor efficiency of plasma treatment at greater inter electrode spacing (Kale and Palaskar, 2010).

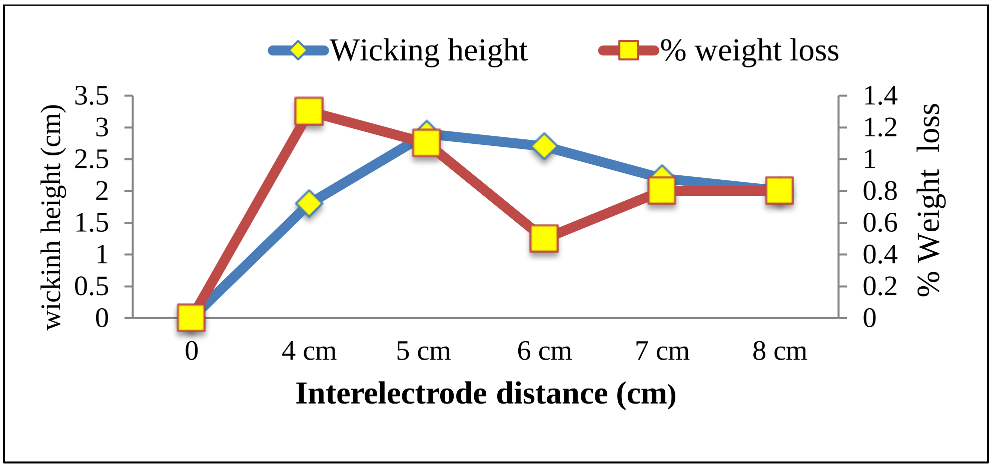


Figure 2: Optimization of DC air plasma inter-electrode distance on bamboo fabrics

On the other hand, when the distance is increased, the interaction becomes lesser due to scattering effects and so the hydrophilicity decreases (figure 2). For an inter-electrode distance of 4, 5, 6, 7 and 8 cm, the percentage weight loss was calculated. When the distance was increased to 8 cm, the weight loss percentage was also reduced implying the decreased interaction of plasma species with the fabric. The optimum value of inter electrode distance for maximum hydrophilicitywas 5 cm.

3.1.4 Effect of pressure

Pressure versus wicking height and percentage weight loss

The effects of DC air plasma treatment were studied at different pressures (0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10 and 0.22 mbar) at constant time and inter-electrode distance which was optimized as 6 sec and 5 cm respectively. The bamboo knitted fabric was treated using low pressure glow discharge plasma at a pressure of 0.5 mbar (Venkatesh and Gowda, 2013).

At a DC air pressure of 0.04 mbar the wicking height was found to be 1.0 cm for 60 seconds and when the pressure increased to 0.05 and 0.06 mbar the wicking height raised to 1.7 and 2.1 cm respectively. When it was further increased to 0.07 mbar the water front was at a distance of 2.8 cm from the base. The fabric was then treated at an increased pressure of 0.08, 0.09, 0.1 and 0.22 mbar, it was thought that the wicking height would increase, but the wicking height was lesser than 0.07 mbar. This may be due to removal of major chemical groups that are responsible for hydrophilicity, as the fabric is been treated for a longer time with high pressure. Therefore, the optimum pressure was optimized at 0.07 mbar. The effect of pressure on DC air plasma treatment on the weight loss of the fabric was studied.

It was observed from the figure 3 that for different DC air plasma pressure, the wicking height was higher for pressure of 0.07 mbar at constant inter-electrode distance of 5 cm, and exposure time 6 sec. This would have attributed to the interaction of the energetic plasma species (ion bombardment) with the fabric surface. Moreover, the inter-electrode distance of 5 cm will favour the extension of plasma from the cathode to the anode contributing to enhanced interaction this in turn leads to more etching of fabric surface and may intensify with the velocity of the plasma species.

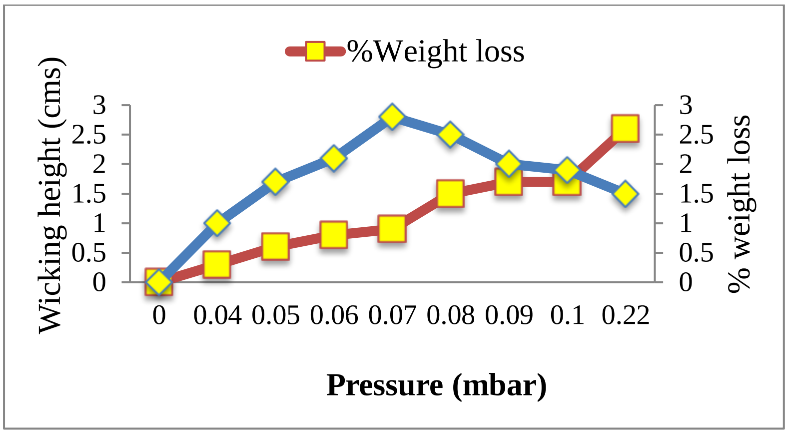


Figure 3: Optimization of DC air plasma treatment pressure on bamboo fabrics

3.1.5 Effect of current

Current versus wicking height and percentage weight loss

To study the variation of hydrophilicity with respect to current, the bamboo fabrics were treated at different values of current (0.4, 0.6, 0.8 and 1.0 mA). The effect of current was studied at optimized pressure (0.07 mbar), inter-electrode distance (5 cm) and exposure time (6 sec).

At a DC air plasma current of 0.4 mA, the wicking height was found to be 2.0 cm for 60 seconds and when the current increased to 0.6 and 0.8 mA the wicking height raised to 2.1 and 2.4 cm respectively. When it was further increased to 1.0 mA, the water front was at a distance of 2.3 cm from the base. The hydrophilicity was found to be higher at a current of 0.8 mA. At fixed external applied voltage, if pressure rises towards atmospheric pressure, the electrode spacing must be decreased (Shishoo, 2007). In other words, if the pressure is constant, the increase in the inter-electrode gap will lead to increase the breakdown voltage (Kale and Palaskar, 2010).

At higher currents, hydrophilicity decreases which would have attributed to degradation of the fabric. Obviously the weight loss percentage was found to be higher when the current was increased above 1.0 mA. Thus the optimized process parameters were pressure 0.07 mbar, inter electrode distance 5 cm, exposure time 6 sec and DC current 0.8 mA for the maximum hydrophilicity (Figure 4).The weight loss of the fabric was propotional to the current applied.

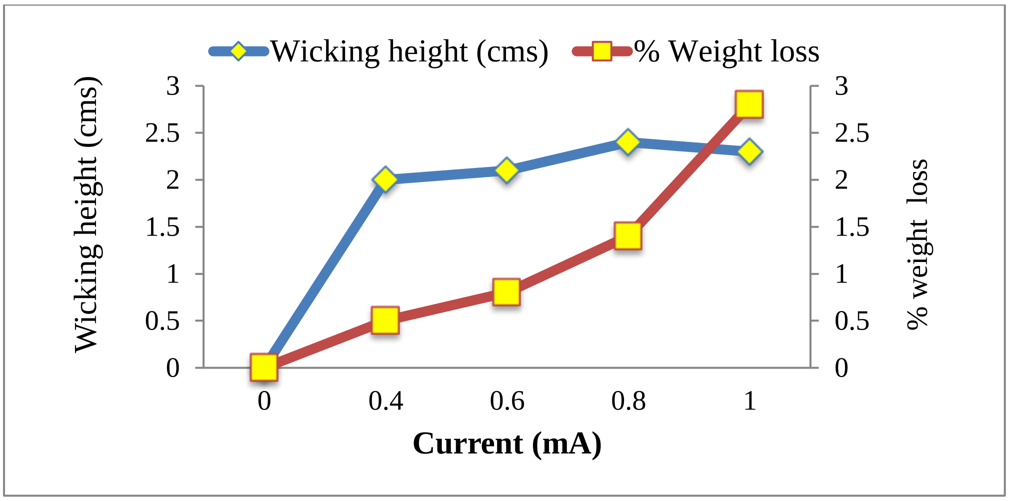


Figure 4: Optimization of DC air plasma - current on bamboo fabrics

3.2 Testing of hydrophilicity of the treated and untreated fabrics - Wicking test

The changes in the hydrophilic properties of the untreated and treated fabrics were evaluated using the standard wicking test. The increased hydrophilicity of the plasma-treated fabric compared to the untreated fabric can be attributed to the etching effect of the plasma on the fabric surface. The fabric pretreated showed higher wicking rate which could be due the etching effects of plasma. Wong et al. (2000) also found that plasma pretreatment improved hydrophilicity.

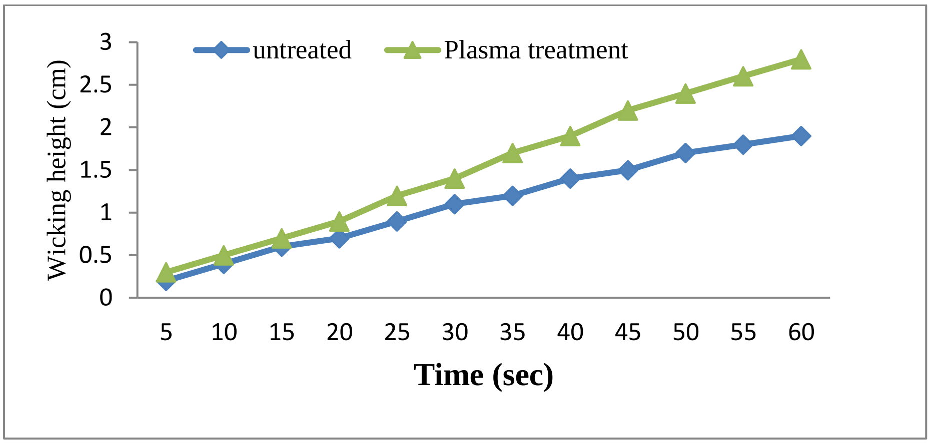


Figure 5: Hydrophilicity of the treated and untreated bamboo fabrics

3.3 Analysis of physical properties of treated and untreated fabrics

The physical parameters of the fabrics such as Air Permeability, Abrasion, Bursting, Water absorption, and Stiffness of the fabrics were studied. Each test was conducted three times, and the average of the results was recorded.

3.3.1 Abrasion resistance (AATCC 119-2004)

The determination of abrasion of treated and untreated bamboo fabrics were done using abrasion tester. The abrasion was determined by visual examination i.e. the appearance of the holes for a known cycle (or) loss in weight of the sample for known cycle revolutions.The difference between the initial and final values was calculated and summarized in Table 1. The results of the weight loss percentage of the treated and control fabrics after abrasion indicated that there was not much alteration in the nature of the fabrics. The resistivity of the treated fabrics to abrasion was evident from the results. The increased weight loss percentage in the treated fabric could be attributed to the etching effects of plasma. This weight loss percentage could be considered negligible as described by Wong *et al.*,(2000).

3.3.2 Air Permeability (ASTM D737-96)

Finishing techniques can significantly affect air permeability by altering the length of airflow paths through a fabric. When a fabric allows some air to pass through, it helps to transfer excess moisture, making the wearer more comfortable. The results from table 1 showed that the untreated bamboo fabric and plasma treated fabric exhibited air permeability range of 1.1963 and 1.2166 $cm^3cm^{-1}s^{-1}$ respectively.The difference was minimal and did not affect the fabric's comfort, as shown by Joseph (1986).There is an increase in the air permeability in the plasma treated fabric due to the etching of fabric surface (Sparavigna, 2008). The results were under the basic concept; an increase in the interstitial pore size of the fabric increases the air permeability as discussed by Ogulata, (2006).

3.3.3 Bursting strength (ASTM D 3787)

The test method covers the determination of the strength of fabrics. The bursting strength of untreated fabric and plasma treated bamboo fabric was 8.5 and 8.25 kg/cm^2 respectively. From the result it was revealed that there was no significant difference in the treated fabric when compared to the control fabric. It proved that the treatment did not affect the bursting strength of the fabrics.

3.3.4 Stiffness (ASTM-D6828-02(2007))

This method measures fabric stiffness by determining the force needed to push a fabric sample into a slot of a specific width using a metal blade at a set speed. The stiffness of untreated bamboo fabric was 2.07 cm; whereas the stiffness of the plasma treated fabric was observed at 1.95. This showed that there is no negligible difference between treated and untreated fabric. However, the difference occurs in the plasma treated fabric due to the surface modification.

3.3.5 Water absorption (ASTM-BS 3449)

The water absorbency rate of the treated and untreated fabric was measured using the static immersion test. Water absorption is a crucial factor in the performance of textile materials. The results from table 1 showed that the untreated bamboo fabric showed 70 % water absorption and treated fabric showed about 81% water absorption.The plasma-treated fabrics showed an increased rate of water absorption. The results were under the basic concept; an increase hydrophilicity of the fabric increased the water absorption. The increase in the water absorption was led by the treatment of plasma that etched the fabric surface (Sparavigna, 2008).

Table 1: Physical parameters of the untreated and treated fabrics

S. No	Fabric treatment	Physical Parameters				Water absorption test (%)
		Abrasion Resistance (%)	Air permeability ($cm^{-3}\ cm^{-2}s^{-1}$)	Bursting strength (kg)	Stiffness (cm)	
1	Untreated	89.8	1.1963	8.5	2.07	70
2	Plasma	88.72	1.2166	8.25	1.95	81

Hence all the above tests confirm that the plasma treatment of the fabric did not alter the comfort properties of the fabric.

3.4 FT-IR analysis

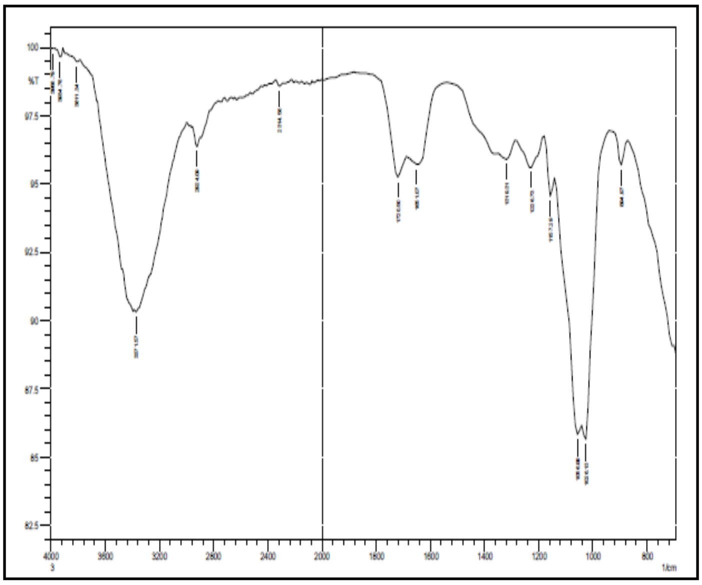
The chemical changes on the fabric surface caused by plasma treatment were analysed using FTIR spectroscopy.The spectra showed the presence of all the peaks associated with different functional groups in both the untreated (control) and treated fabrics. According to Beer's law (Smith, 2018), the concentration of functional groups is directly related to the intensity of their corresponding absorption peaks. The treated and untreated bamboo fabrics were analyzed and were compared with the literature (Chingkap*et al*., 2004) and reported in table 2.The spectra showed the presence of all the peaks associated with different functional groups in the treated fabrics. The concentration of these functional groups was directly related to the intensity of their corresponding absorption peaks.

Untreated bamboo fabrics

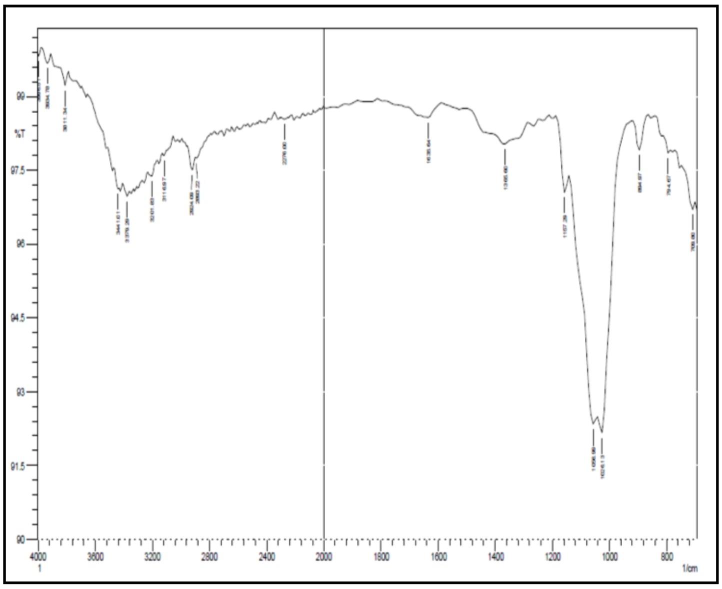
The peak at 1226, 1056 and 1026 cm^{-1} reported the presence of aliphatic amine due to the C–N stretch. The presence of aromatic compounds was observed at the peak of 1319 and 894 cm^{-1}. The peak at 3371 cm^{-1} indicated the N–H stretch which reported the presence of primary, secondary amines and amides. The peak at1720 cm^{-1}corresponded to the presence of alpha, beta–unsaturated esters represented the functional compound of bamboo fabric. The C–H stretch of spectra represented the alkanes at the peak 2924 cm^{-1}. The presence of alkenes and alkyl halides was observed at the peak 1651 (–C=C– stretch) and 1157 (C–H wag) cm^{-1} respectively.

DC Air plasma treated bamboo fabric

In the DC air plasma-treated fabric, the spectra at 2924 and 2893 cm^{-1} indicate the presence of simple alkanes, characterized by absorptions due to C-H stretching and bending. These alkanes contribute to the fabric's hydrophilicity. This was followed by the spectra 3440, 3201 and 3116 cm^{-1} which belonged to the O-H stretch in the DC air plasma treated samples, this indicates that the plasma treatment provided the surface modification to the fabrics.The O-H peak was observed after DC air plasma treatment, indicating the presence of groups capable of accepting water molecules, thus enhancing hydrophilicity. In contrast, the O-H stretch was not present in the untreated fabric. During plasma exposure, the fabric surface underwent various changes. The fabric exhibited maximum hydrophilicity when exposed for 6 seconds, and when the electrodes were placed closer, the air molecules etched the fabric surface, creating space for other molecules to attach. 1157cm^{-1}peak corresponded to C–O stretch of alcohols, carboxylic acids, esters and ethers which would have been formed on the surface of the fabric after the DC air plasma treatment. The C-O stretch has a capacity to acquire water molecules.The results showed that plasma treatment added hydrogen and alcohol groups to the bamboo surface, leading to increased fabric hydrophilicity (Fig. 6), which was further confirmed by HR-SEM analysis.



Untreated fabric



DC Air plasma treated fabric

Figure 6: FT-IR Spectrum of the untreated and plasma treated fabric

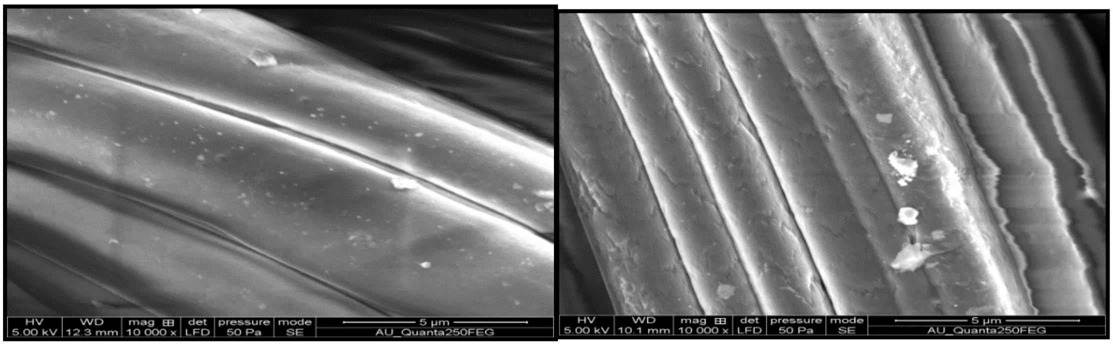
Table 2:Peak Characteristics of the untreated and plasma treated fabrics

S.No	Literature cm^{-1}	Untreated fabric cm^{-1}	Plasma treated fabric cm^{-1}	Peak Characteristics	Respected compounds
1	3500-3200		3440	O-H stretch, H-bonded	Alcohols, phenols
2	3400-3250	3371	3379	N–H stretch	Primary, secondary amines, amides
3	3300–2500		3201,3116	O–H stretch	Carboxylic acids
4	3000-2850	2924	2924,2893	C–H stretch	Alkanes
5	1730-1715	1720		C=O stretch	Alpha, beta–unsaturated esters
6	1680-1640	1651		–C=C– stretch	Alkenes
7	1650–1580		1635	N–H bend	Primary amines
8	1370-1350		1365	C–H rock	Alkanes
9	1335-1250	1319		C–N stretch	Aromatic amines
10	1320-1000		1157	C–O stretch	Alcohols, carboxylic acids, esters, ethers
11	1300-1150	1157		C–H wag ($–CH_2X$)	Alkyl halides
12	1250-1020	1226,1056, 1026	1056,1026	C–N stretch	Aliphatic amines
13	900-675	894	894	C–H "oop"	Aromatics

14	850-550		794,709	C–Cl stretch	Alkyl halides

3.5 High Resonance Scanning Electron Microscopy (HR-SEM analysis)

The surface morphology of the untreated and DC air plasma treated bamboo fabrics were studied using HR-SEM. Figure 7 showed the HR-SEM micrographs of untreated and DC air plasma treated bamboo fabric respectively.HR-SEM micrographs revealed that the interstitial pore size increased in the treated samples compared to the untreated ones. HR-SEM results confirmed that the DC air plasma treatment effectively etched the hair-like projections on the fabric surface. The average diameter of the pores within the fabric matrix also increased, as reported by Nithya et al. (2007). This improvement in pore size contributed to enhanced fabric hydrophilicity.



Untreated fabric **DC Air plasma treated fabric**

Figure 7 : Topographical analysis of the fabric using HR SEM

4. Conclusion

The study concludes that the plasma treated bamboo fabric at the optimized condition (Pressure 0.07 mbar, inter electrode distance 5 cm, exposure time 6 sec and current 0.8mA) had the maximumhydrophilicity when compared with untreated fabric. Moreover, the physical properties of the plasma treated fabric remains unaffected. From the HR-SEM analysis it is found that the atmospheric air plasma modification altered the surface morphology that give rise to the hydrophilicity.Due to the highest hydrophilicity rate, the fabric will have high absorption ratio. Further, the plasma process can be easily amalgamated with the present day industrial set up. The plasma treated bamboo fabrics can be effectively used for sport wear and infant layettes to prevent these garments getting clammy and exhibit quick drying.

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