Antibacterial and Mosquito repellency properties of Plasma treated cotton fabrics pre-treated with *Vetiveria zizanioides* and *Phyllanthus niruri* extracts

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ABSTRACT

Antibacterial activity, mosquito repellency and comfort properties in plasma treated cotton fabric pre-treated with herbal extracts were selected as primary aim in the present study. Qualitative phytochemical analysis of *Vetiveria zizanioides*and *Phyllanthus niruri* was analysed. FT-IR analysis was also investigated for the plant extracts to reveal the functional groups attributing to its biological properties. Antibacterial activity and mosquito repellency were studied using standard test methods. Comfort properties like air permeabilityand absorbency were determined using AATCC standards. Phytochemical analysis showed the presence of alkaloids, flavanoids, tannins, phenols, terpenoids and saponins. FT-IR analysis revealed the peaks attributed for the presence of functional groups like O-H (alcoholand phenol groups), C-H (Aliphatic group), CH2stretch (cellulose group). The SEM imagesof plasma untreated samples exhibited more protruding fibres on the surface of open wovenfabric. Antibacterial activity of plasma treated *Vetiveria zizanioides* finished fabric samples exhibitied inhibitory zones of 36 mm and 35mm and plasma treated fabric with extracts of *Phyllanthus niruri* showed inhibitory zones of 38mm and 36mm against *Escherichia coli* and *Staphylococcus aureus* respectively. Mosquito repellency of plasma treated fabric (*Vetiveria zizanioides* and *Phyllanthus niruri*) showed 72% and 76% repellency respectively; whereas plasma untreated fabric samples revealed only 56%. 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, Antibacterial activity, Mosquito repellent, *Vetiveria zizanioides. Phyllanthus niruri.*

INTRODUCTION

Textiles have such an important bearing on our daily lives that everyone needs toknow something abouttextiles. From earliest times, people have usedtextiles of varioustypes for covering, warmth, personal adornment and even to display personal wealth. Textilesare still used for these purposes and everyone is an ultimate consumer. A textile is any type of material made from fibre or other extended linear material such as thread oryarn. The production of textiles is an ancient craft, where speed and scale of production have been altered almost beyond recognition by mass production and an introduction of modern manufacturing techniques (Thomas, 2006). Now textile industries all over the world are facing challenges in the field of quality and productivity, due to the globalization. The highly competitive atmosphere and the straight ecological parameters have ensured that the prime concern of the textile processor is quality and environment. Again, the guide line of the processes thus in turn, makes it essential for innovations and changes in the processes. As aresult, the research and development strategies of the textile processors will be highly focusedand the challenges will face many changes in the textile industry. Eco-friendly products arehighly beneficial to our health as also to the environment. The quality of our lives can be greatly improved with the use of these green products that are made from natural raw material. The manufacturing of these products causes minimal harm to the environment.

Cotton has the excellent properties such as absorbency, biodegradable, breathable, drape, easily sterilized, high wet-strength, insulating properties, non-allergic, renewable resource, softness and water retaining capacity (Gopalakrishnan and Aravindan, 2005). The cotton fabric has good property of withstanding severe treatment, especially during dyeing and finishing (Barkerand Midgley, 2007).

Eco-friendly plasma treatment can be carried out during different stages of fabric formation such as fabric preparation, dyeing and finishing of cotton, wool, silk and most of the man-made fibers. Plasma gas particles etch on the fabric surface in nano scale, so as to modify the functional properties of the fabric (Bruno et al, 2010). Anti-bacterial finish causes afabric to inhibit the growth of microbes. The humid and warm environment found in textile fibre encourages the growth of the microbes. Infestation by microbes can cause cross-infection by pathogens and the development of odour where the fabric is worn next to the skin. In addition, stains and loss of fibre quality of textile substrates can also take place.

Mosquito repellent textiles are one of the revolutionary ways in advance. The textile field provides the much needed features of driving away mosquitoes, especially in the tropical areas. There are many chemicals available for achieving mosquito repellent on textiles. But most of the chemicals are banned from the World Health Organization (WHO)due to their harmfulness towards the environment. Therefore, researchers have shifted theirfocus towards natural mosquito repellent compiled with the requirements of WHO (Debbounet al., 2007). Mold, mildew, fungus, yeast, bacteria and virus are part of our everyday life andfound everywhere in the environment. Natural herbs carry herbal property will be beneficial to the human body (Deepak et al., 2011).

Some of the herbal compounds obtained from plants are well known from time immemorial as anti-bacterial products. These plant products are applied directly on skin orwounds as paste or incaution either for skin care or wound healing. Keelanelli (*Phyllanthusniruri*) has the property of venereal disease, gonorrhea, can be controlled by *Phyllanthusniruri*. For excessive body heat, intestine ulcer, urinary tract infections, urinary stone anddiabetes;it is a good remedy(KuttanandHarikumar, 2012).

Medicinal plants like neem, keelanelli (*Phyllanthusniruri*) and Vetiver root (*Vetiveria zizanioides*) are used for production control of mosquito (Drew, 2005). The Vetiver root is easily found in nurseries, garden stores and other plant dealers and distributors. Related to lemon grass, Vetiver oil has medicinal properties. Vetiver root is a fast growing grass that is non-invasive, very deep rooting, insect and vermin proof. The aromatic roots are used in potpourri and perfumes. The essential oil from the roots is used in perfumery.

More importantly, as it has become norm these days, the success of research is in its applicability to the industry and society. The work reported in the paper endeavors to showcase the benefits of environmentally, friendly processes to the Indian and global textile industry based on scientific data. Therefore, the paper briefly provides the status of Indian textile industry and the necessity for the industry to adopt modern and sustainable practices such as plasma treatment it will be an onerous task toelaborate the state of the textile industry in India and several research endeavors an alternatives to conventional textile processing and finishing treatments. Indian textile industry is predominantly natural fibre based and hence the introductory chapter sets the stage for developing new products for the industry using green preparatory techniques such as plasma and finishing treatments using natural and herbal products.

MATERIALSANDMETHODS

Fabricprocurementandproperties:Cotton

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

Cottonfabric:Plasma treatmentapplication

The usage of oxygen can modify the wet ability 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 the sepropertiesthe 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 19inch 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 x 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 tabulated in Table-1.

Table-1:Parameterofplasmaapplication

S.no	Criteria	Parameters
1	Gas	Oxygen
2	Inter-electrodespacing	3.5cm
3	Plasmacurrent	2.1mA
4	Plasmapower	600 W
5	Exposuretime	2 minutes
6	Pressure	$1.5x10^{-2}$bar

Medicinalplants

Two medicinal plants, Keelanelli (*Phyllanthusniruri*) and Vetiver *(Vetiveriazizanioides)* were collected and authenticated from Department of Plant Science, Tamil Nadu Agricultural University, Coimbatore, India. Leaves of the plants were used in the study.

Methanol extracts of medicinal plants (Thilagavathi and Kannaiyan, 2008)

A fresh leaf of Keelanelli (*Phyllanthusniruri*) and Vetiver (*Vetiveriazizanioides*) was shadow dried at 37°C. Drying was done to reduce the moisture content of leaves to less than20%. Dried leaves of Keelanelli (*Phyllanthusniruri*) and Vetiver *(Vetiveriazizanioides)* were grounded to make fine powder for the extraction of desired materials. Finepowdered materialwas extracted to obtain the active substances with suitable solvent (methanol). 10 grams of powdered leaves of Keelanelli (*Phyllanthusniruri*) and Vetiver *(Vetiveriazizanioides)* 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 cureprocess(Joshi et al., 2009)

Three sets of fabric sample were used in this study. In the first set of samples (Plasma treated cotton) the herbal extracts of Keelanelli (*Phyllanthusniruri*) and Vetiver *(Vetiveriazizanioides)* were finished separately. In the second set of fabric samples (plasmauntreated 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 5min (Table-2).The fabric was immersed in the prepared anti-bacterial and mosquito repellent solution in the ratio of 1:20 of the material liquor ratio of three times with the binder in the ratio of 9 : 1 for the effective penetration into the fabric. Then the fabric was passed through the padding mangle between the rollers for uniform application of the solution. The finished plasma treated and untreated fabrics were subjected to evaluate for its comfort properties along with control fabrics.

Table-2:Fabricsamplepreparationforfinishingusingpaddingmangle

S.No.	Particulars	Parameters
1.	Finishing solution Material liquor ratio(MLR)	1 : 20
2.	Binder solution	9 : 1
3.	Curing temperature	80°C – 100°C
4.	Curing time	2 minutes

Selection of Extraction Procedure

Extraction refers to the separating of a desired material by physical or chemical means with the aid of a solvent. The extraction of a selected natural source can be carried out by various methods like aqueous, alkaline, acidic or alcoholic methods. In case of alkaline and acidic extractions, solutions of any alkali or acids used. In alcoholic extraction, alcohols like ethanol or methanol are extensively used for the extraction process. Alcoholic extraction using ethanol is more effective to extract the active ingredients of the natural sources. Hence, the herbal powder was subjected to alcoholic extraction.

SolventExtractionofHerbs

Extraction was carried out by dissolving 6 grams of the herbal powders of keelanelli*(Phyllanthusniruri)* and vetiver root *(Vetiveriazizanioides)* in 100 ml consisting of 80% ethanol and distilled water. The containers were closed and kept for overnight under shaking condition for proper dissolving of the compounds into solvent. Then the extract was filtered using Whatman no.1filter paper, the filtrate was collected and evaporated at room temperature.

Recipe for Herbal Extraction

Powder	:	6gm
Ethanol	:	100 ml consist of 80% ethanol and balance distilled water
Time	:	24hours
Temperature	:	Room temperature
Weight of the fabric	:	1000g

PhytochemicalScreeningoftheHerbalExtract

The selected herbal extracts were tested for the presence of some active chemical compounds such as alkaloides, flavanoids, phenolics, tannins, saponins and terpenoids. The analysis was conducted as per the methods (Khandewal, 2002).

Spectroscopic Study–FTIR Analysis

The FTIR spectral analysis was carried out to identify the functional groups present in *Vetiveriazizanioides* and *Phyllanthusniruri*. Spectra were collected on a bench FTS 3000MX spectrometer (Varian Instruments, Randolph, MA) equipped with KBr beam splitter. Fourier transform infrared spectroscopy (FTIR) was an analytical tool to identify the nature of chemicals present in the herbal powder. It also helps to know to what extent the moleculesof the finishing chemicals are attached with fibre molecules of the specimen. The samples were analyzed for their variations in chemical groups using FTIR spectroscopy. The same test was carried out by (Ushaetal, 2010). Infrared spectroscopy was used to identify and quantitatively analyze chemical compounds, mixtures, extent of reaction, and molecular structure. Different chemical compounds absorb infrared radiation at frequencies corresponding to their own molecular vibration frequencies. According to Kale and (Balaskar2010), Infrared(IR) spectroscopy is a chemical analysis technique which measures the absorption of different IR frequencies by a sample positioned in the path of an IR beam. The main goal of the IR spectroscopic analysis was to determine the chemical functional groups in the sample.

Scanning Electron Microscopy Analysis

Scanning Electron Microscopic analysis was done to study the surface morphology of the fabrics. The surface morphology of the finished and plasma treated finished cotton fabrics with guava leaf keelanelli *(Phyllanthusniruri) and* vetiver *(Vetiveriazizanioides)* treated fabric was studied (JEOL/EOJSM6390). Metal coating was used as the conducting material to analyze the sample. The SEM working on an accelerating voltage range from 0.5-20KV and the specimen size is 8 mm to 150mm for finishing fabric.

Anti-bacterial Assessment Test (ENISO20645)

The antibacterial activity of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) was tested using standard ENISO 20645 test method. The test specimens were cut into pieces (20mm in diameter) and its antibacterial activity was tested. All the test cultures (*Escherichia coli* and *Staphylococcusaureus*) were inoculated in a sterile Nutrient broth (Composition g/L: Peptone: 5g; Yeastextract: 5g, Beef extract: 3g, Sodium chloride: 5g; Final pH - 7.0 ± 0.2) and allowed to attain the growth for 24 to 48 hours. Using sterile 4mm inoculating loop, one loop full of culture(*Escherichia coli* and *Staphylococcus aureus*) was transferred by swabbing all around the surface of the Mueller-Hinton agar plate (Composition g/L: Acid hydrolysate of Casein:17.5g; Starch:1.5g, Sodium chloride:5.0g, Agar17.0g; Final pH-7.0±0.2) and also covering the central area of the petridish. For each test organism, separate Mueller-Hint on agar plates were used in a sterile zone. All the inoculated plates were incubated at 37°C for 24hours. The test plates were examined for the clear zone of inhibition around the finished fabrics. The antibacterial activity was expressed in terms of inhibitory zones measured in millimeter for each sample against test organisms.

Mosquito Repellency Test

The mosquito repellency behavior of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) was tested using Excito-chamber standard test. Anopheles mosquitoes were identified based on morphological keys and they were collected during the evening hours. All mosquitoes were starved of blood and sugar of 4 hours before the tests.

Repellency Behavioral Tests

Specially designed two extra repellency test chambers were used to evaluate the efficiency of repellent activity. The wooden outer chamber of excito-repellency testing device measures 34 cm × 32 cm × 32 cm and faces the front panel with the single escape portal. Thebox is composed of a rear door cover, an inner Plexiglas glass panel with a rubber latex-sealed door, a Plexiglas holding frame, a screened inner chamber, an outer chamber, a front door, and an exit portal slot. Mosquitoes were deprived of all nutrition and water for a minimum of 4 hours before exposure.

Laboratory tests were performed during daylight hours only and each test was repeated four times. Observations were taken a tone-minute interval of 30minutes. After each test was completed, the number of escaped specimens and those remaining in the chamber were recorded separately for each exposure chamber, external holding cage, and paired control chamber. Escaped specimens and those remaining in the chamber, for the treated samples, were held separately in small holding containers with food and water.

Comfort Properties

The comfort properties (air permeability, absorbency test) of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) was determined using standard AATCC test methods.

Fabric Air Permeability [10] (ASTMD737–04)

Air permeability of a fabric is the volume of air measured in cubic cm passed per second through 1sq.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 0.25mm. The rate of air flow was read from the Rota meters. They were calibrated to indicate air flow incubic centimeter per second at 27°C and 760mm of mercury. The area of the sample exposedto air was one inch in diameter. From the reading Rota meter air permeability was calculated using the following formula:

Air permeability= Average rate flow /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 (Gunasekaran et al., 2019)

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 set of fabric samples. One end of the sample strip was pasted with a glass rod 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.

Drop Test

The drop test is a count of the number of drops required to penetrate through to the under scale of the fabric when all the drops fall on the same spot (AATCC Technical Manual, 2008). A burette filled with distilled water was clamped in a stand. The stand was mounted in an embroidery frame and was placed at the base of the stand. The distance between the sample and the burette nozzle was kept constant. The nozzle of the burette was opened just to allow a drop of water to fall on the sample. The stop watch was started simultaneously and it was stopped when the drop of water was fully absorbed. The time taken for this was noted.The same procedure was carried out for the unfinished and finished and plasma treated finished samples. The mean value was calculated to get accurate value.

Sinking Test

Sinking time test is a simple test that helps to measure the wet ability of a fabric (AATCC, 2008). In this method, each fabric was cut into a number of equal sized squares of1” x 1” and added to a 1000 ml beaker which was filled with distilled water. The stop watch was started when the fabric struck the surface of water and stopped when the last corner was sunk below the water surface. The test was repeated 10 times for all the fabrics and the mean time for the sinking was calculated and recorded.

RESULTS AND DISCUSSION

Phytochemical Screening of the Herbal Extract

Qualitative phytochemical analysis of plant extracts was carried out using standard procedures to identify the constituents. This analysis reveals the presence of phenolic compounds in Vetiver (*Vetiveriazizanioides*) and keellanelli(*Phyllanthusniruri*). Vetiver and keellanelli powder phytochemical screening show the presence of alkaloids, flavanoids, tannins, phenols, terpenoids and saponins (Table-3). This powder seems to have aromatic, anti-fungal, anti-spasmodic and mosquito repellent property. These plant extracts have anti-microbial efficiency which was also confirmed by various literatures. The Vetiver and keellanelli extract has anti-bacterial activities. These effects are probably due to the presenceof phenolic compounds. Hence these extracts were used to incorporate anti-bacterial finish to the fabrics.

Table-3:Phytochemical Screening of plant extracts

S.No.	Phytochemicals	PlantExtractsof	
		***Vetiveriazizanioides* (Vetiver)**	***Phyllanthusniruri* (Keellanelli)**
1	Alkaloid	+	++
2	Flavonoid	++	+
3	Tannin	+	++
4	Phenol	++	++
5	Terpenoid	+	+

6	Saponin	-	+

Evaluation of Functional Groups Using FTIR Method

The FTIR spectral analysis was carried out to identify the functional groups present in keelanelli (*Phyllanthusniruri*) and vetiver root (*Vetiveriazizanioides*) extracts. Fourier Transform Infra-Red analysis exhibited in many functional groups based on the wavelength and percentage of transmittance. The results are presented in Table-4.

The peak obtained for keelanelli leaves (*Phyllanthusniruri*) reveals the presence offunctional groups like O-H (alcohol and phenol groups), C-H (Aliphatic group), CH2 stretch (cellulose group). The peaks obtained for vetiver root (*Vetiveriazizanioides*) reveals the presence of functional groups like C-H stretch (Aliphatic), O-H stretch (Alcohol and phenol groups), O-H (Alkene groups). These functional groups confirm the presence of alkaloids and phenols in the four selected herbal samples. The presence of the functional groups is responsible for the anti-bacterial and mosquito repellency activity. Different peaks obtained based on the presence of functional groups attributing to their specific wavelength were presented separately for both plant extracts in Fig. 1and Fig. 2 respectively.

Table-4:FT-IRanalysis

S.No.	Samples	Wavelength(cm^{-1})	Functionalgroups
1.	Keelanelli(*Phyllanthus niruri*)	1624	O-H stretch (Alcohols and Phenols)
		2309	C-O stretch
		3356	O-H stretch(Alkenes)
2.	Vetiver root (*Vetiveriazizanioides*)	1035	C-O stretch
		3396	O-H stretch (Alcohols and Phenols)
		3289	O-H stretch (Alcohols and Phenols)

Fig.1: FTIR analysis of *Phyllanthusniruri* extract

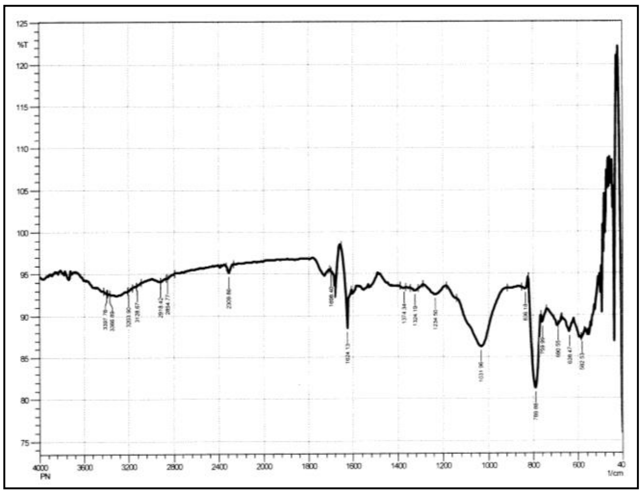
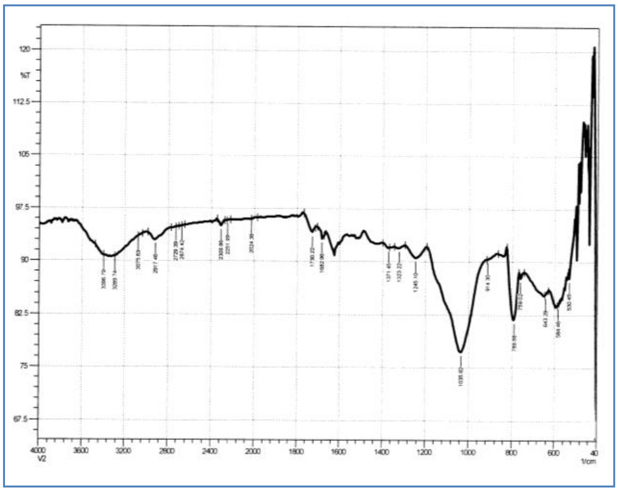


Fig.2:FTIRanalysisof*Vetiveriazizanioides*extract



ScanningElectronMicroscopyAnalysis

Scanning Electron Micrographs of Vetiver (*Vetiveria zizanioides*) and Keelanelli (*Phyllanthusniruri*) extract finished fabric samples and plasma treated Vetiver and Keelanelli extract finished fabric samples were presented in Fig. 2A, Fig. 2B and Fig. 3A, Fig. 3B respectively. The SEM images of fabric samples without plasma treatment exhibited more protruding fibres on the surface of open woven fabric. The structure of the oxygen plasma treated sample was also open and the loose protruding fibers were etched by the plasma which resulted in an increased hydrophobic property.

Fig. 2A: SEM analysis of *Vetiveria zizanioides* finished fabric sample under different magnification

X100 X1500

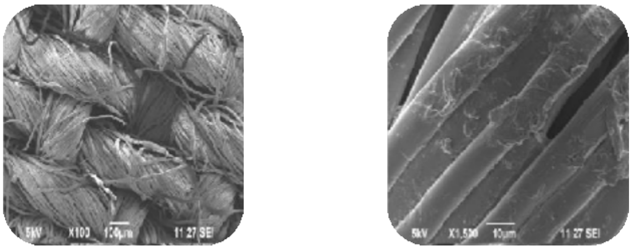
Fig. 2B: SEM analysis of *Vetiveriazizanioides* finished fabric sample (Plasma treated) under different magnification

X100 X1500

Fig. 3A: SEM analysis of *Phyllanthusniruri* finished fabric sample under different magnification

X100 X1500

Fig. 3B: SEM analysis of *Phyllanthusniruri* finished fabric sample (Plasma treated) under different magnification



X100 X1500

Anti-bacterial Assessment Test

The antibacterial assessment of three fabric samples (Plasma untreated, Plasma treated *Vetiveriazizanioides* and Plasma treated *Phyllanthusniruri*) were comparatively tested and the obtained results were presented in Table-6.

Table-6: Antibacterial activity of plasma treated and untreated fabric samples

S. No	Fabrics	Zone of inhibition(mm)		Statistical Analysis			
				Escherichiacoli		***Staphylococcus aureus***	
		Escherichiacoli	***Staphylococcusaureus***	**F value**	**Significance**	**F value**	**Significance**
1	Plasma untreated	0	0	1246.5	0.000*	864.8	0.000*
2	Plasma treated *Vetiveriazizanioides* finished	36	35				
3	Plasma treated *Phyllanthusniruri* finished	38	36				

*Significant at 5% level

Plasma treated *Vetiveriazizanioides* finished fabric samples exhibitied inhibitory zones of 36mm and 35mm against *Escherichia coli* and *Staphylococcus aureus* respectively. Similarly, another sample, plasma treated fabric with extracts of *Phyllanthusniruri* showed inhibitory zones of 38mm and 36mm against *Escherichia coli* and *Staphylococcus aureus* respectively. To prove that plasma treated has significant activity, plasma untreated control fabric was also subjected to similar experimental protocol in parallel. Difference between plasma treated and untreated control samples expressed in terms of zone of inhibition was statistically calculated using one way ANOVA (Statistical package of social sciences, Windows-7) with 5% significant level. The statistical results revealed that there was significant difference in inhibitory zones in terms of antibacterial activity between the finished and control fabrics (F=1246.5 for *Escherichia coli* andF=864.8 for *Staphylococcusaureus*). The obtained results indicated that plasma treated fabric finished with *Vetiveriazizanioides* and *Phyllanthusniruri* extracts inhibited the growth of both *Escherichia coli* and *Staphylococcusaureus*.

Antibacterial activity of the finished fabric expressed in this present research was reviewed from the literature survey. The herbal extracts of *Vetiveriazizanioides* and *Phyllanthusniruri* used for finishing had proved to contain different types of significant biological compounds like alkaloids, flavonoids, terpenoids, steroids, phenols and glycosides (Devi Priya et al., 2021). These phytochemical compounds were proved to be attributing for different biological properties like antibacterial activity, antiviral activity and anti-oxidant activity (Asha Gangadharan et al., 2014).

In our present research two herbal sources were used for finishing which expressed excellent antibacterial activity. Similarly many research articles were proved to reveal good antibacterial activity forward different herbal extract finished fabrics (Sumithra and Amutha, 2016) used 50:50 cotton and bamboo blended fabric samples to finish with two herbal extracts (*Galinsogaparviflora* and *Azadirachtaindica*). Antibacterial activity was accessed using EN ISO 20645 test method against *Escherichia coli* and *Staphylococcus aureus*. The pad-dry cure method of the *Galinsogaparviflora* extract finished fabric revealed in hibitory zones of 35mm and 38mm against respective test organisms. Slightly higher inhibitory activity of about 39mm and 40mm was obtained against test bacteria for *Azadirachtaindica* finished 50:50 cotton and bamboo samples. In our present study also, *Hemigraphiscolorata* and *Bacopamonnieri* extract finished nine types of fabric samples revealed good inhibitory zones ranging from 30mm to 38mm against test bacteria. Antibacterial activity results obtained in our present study was found well coincided with the results of Sumithra and Amutha (2016) in terms of inhibitory zones.

In another study, Sumithra and Vasugi Raaja (2014) focused on imparting extracts of *Ricinuscommunis*, *Sennaauriculata* and *Euphorbia hirta*as composite on denim fabrics. The antimicrobial efficiency of composite finished denim fabric samples were evaluated using ENISO 20645 test method. The herbal composite finished fabric revealed inhibitory zones of 25mm and 29mm against respective *Escherichia coli* and *Staphylococcus aureus*. Similar type of herbal composite containing *Hemigraphiscolorata* and *Bacopamonnieri* extract was used for finishing in our present research. The antibacterial activity results obtained in our present study was found well supportive as similar range of inhibitory zones.

Mosquito Repellency Evaluation

Mosquito repellent behaviour of plasma treated and plasma untreated herbal finished fabric samples were compared and the results were presented in Table-5.Significant difference in repellency behaviour was evident from the obtained percentage values. Plasma treated fabric (*Vetiveriazizanioide s*and *Phyllanthusniruri*) showed 72% and 76% repellency respectively; whereas plasma untreated fabric samples revealed only 56%. Plasma treated fabric exhibited more repellency because the application process significantly affects the surface area of the fabric samples; hence more surface area was obtained for the herbal extracts to get absorbed onto the interstices of the fabric samples. This exerts more repellency behavior in plasma treated samples when compared to that of plasma untreated fabric sample.

As per literature survey, it was recorded that, the plasma treatment improves wettability, hydrophobic finishing, adhesion, product quality, functionality in fabrics without alteration of inherent properties of the textile material. 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. 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 the 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 (Sparavigna,2002). Eco-friendly plasma treatment can be carried out during different stages of fabric formationsuch as fabric preparation, 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 (Mehta, 2010).

Table-5: Mosquito repellency efficiency of finished fabrics by improved excito chamber method

S.No.	Sample	Fabric samples	Mosquito Repellency (%)
1	Plasma untreated	100% Cotton	56
2	Plasma treated *Vetiveria Zizanioides* finished	100% Cotton	72
3	Plasma treated *Phyllanthusniruri* finished	100% Cotton	76

Fabric Air-Permeability

The air-permeability of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) were comparatively tested andtheobtained results were presented in Table-6.

Table-6:AirPermeability

S.No.	Samples	Meanvalue (cc/cm.sq./sec)	Loss/ gain (%)	Standard deviation
1	Plasmauntreated	10.01	-	1.2 3
2	Plasma treated *Vetiveria Zizanioides* finished	11.2	1.2	0.7 5
3	Plasma treated *Phyllanthusnirur* ifinished	12.1	2.1	0.5 7
F-value=60.10**				

Mean represents average of three individual readings.**Significant at1%level.

From Table-6, significant difference in terms of air permeability between the plasmatreated and untreated fabric samples were evident. Statistical analysis also proved that there was a significant difference at 1% level within the groups.

Plasma untreated control samples did not show any difference in their breathability asreflected by their air permeability values. Perhaps, Plasma treated *Vetiveriazizanioides* and Plasma treated *Phyllanthusniruri* resulted insignificant increases in the air permeability values of the fabrics. This could be attributed to the surface etching effect of plasma treatment. Literature survey highlighted that the plasma treatment affects the porous structure of the fabric by altering its pore size (Gunasekaran et al., 2019). 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 endeavor, to let more air to pass through the fabric structure resulting in increased air permeability. The obtained results were found to be supportive with the above hypothesis, showing fabrics have higher breathability after plasma treatment.

AbsorbencyProperty-DropTest

The absorbency property in terms of drop-test of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) were comparatively tested and the obtained results were presented in Table-7.

Table-7:DropTest

S.No.	Samples	Meanvalue (seconds)	Loss/gain (%)	Standard deviation
1	Plasma untreated	14.3	-	0.76
2	Plasma treated *Vetiveria Zizanioides* finished	6.2	-54.2	0.84
3	Plasma treated *Phyllanthus niruri* finished	5.7	-59.7	0.87
F-value=322.65**				

Mean represents average of three individual readings.**Significant at1% level.

From Table-7, significant difference in terms of drop test absorbency between the plasma treated and untreated fabric samples were evident. Statistical analysis also proved that there was a significant difference at 1% level within the groups. The absorbency rate in terms of drop test for Plasma treated *Vetiveria zizanioides* finished sample and Plasma treated *Phyllanthus niruri* finished sample was found higher than plasma untreated control fabric sample. Absorbency was recorded within 6.2 seconds and 5.7 seconds for the plasma treated samples respectively; whereas, untreated sample absorbed after 14.3 seconds. As plasma treatment etches the surface, it endeavours to enhance the surface area of the fabric; which in turn increased the hydrophilic property. The increase in surface area results in increased surface adsorption; the process thus reported to be responsible for more spreading of water droplets on the surface which is reflected in reduced time inthe drop test.

Sinking Test

The absorbency property in terms of sinking test of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthus niruri*) were comparatively tested and the obtained results were presented in Table-8.

Table-8: Sinking Test

S.No.	Samples	Meanvalue (Seconds)	Loss/ gain (%)	Standard deviation
1	Plasma untreated	15.6	-	0.48
2	Plasma treated *Vetiveria Zizanioides* finished	8.7	-55.9	0.65
3	Plasma treated *Phyllanthusniruri* finished	9.5	-53.6	0.54
F-value=1615.18**				

Mean represents average of ten individual readings.
**Significant at1%level.

FromTable-8, significant difference in terms of sink test absorbency between the plasma treated and untreated fabric samples were evident. Statistical analysis also proved that there was a significant difference at 1%. The absorbency rate in terms of drop test for Plasma treated *Vetiveria zizanioides* finished sample and Plasma treated *Phyllanthusniruri* finished sample was found higher than plasma untreated control fabric sample. Absorbency was recorded within 8.7 seconds and 9.5 seconds for the plasma treated samples respectively; whereas, untreated sample absorbed after 15.6 seconds. As plasma treatment etches the surface, it endeavours to enhance the surface area of the fabric; which in turn increased the hydrophilic property. The increase in surface area results in increased surface adsorption; the process thus reported to be responsible for more spreading of water droplets on the surface which is reflected in reduced time in the sink test.

Vertical Wicking Test

The absorbency property in terms of vertical wicking of three fabric samples (Plasma untreated, Plasma treated *Vetiveria zizanioides* and Plasma treated *Phyllanthusniruri*) were comparatively tested and the obtained results were presented in Table-9.

Table-9:VerticalWickingTest

S.No.	Samples	Meanvalue (cm)	Loss/ gain (%)	Standard deviation
1	Plasma untreated	10.2	-	0.46
2	Plasma treated *Vetiveria Zizanioides* finished	5.4	50.5	0.68
3	Plasma treated *Phyllanthusniruri* finished	4.6	56.2	0.57
F-value=88.91**				

Mean represents average often individual readings. **Significant at1%level.

From Table-9, significant difference in terms of vertical wicking between the plasma treated and untreated fabric samples were evident. Statistical analysis also proved that there was a significant difference at 1%. The absorbency rate in terms of vertical wicking plasma treated *Vetiveria zizanioides* finished sample and plasma treated *Phyllanthusniruri* finished sample was found higher than plasma untreated control fabric sample. Absorbency was recorded within 5.4 seconds and 4.6 seconds for the plasma treated samples respectively; whereas, untreated sample absorbed after 10.2 seconds. As plasma treatment etches the surface, it endeavours to enhance the surface area of the fabric; which in turn increased the hydrophilic property. One of the important parameters to understand the wicking process is the mass increment caused by absorbed water. The increase in the wicking height in both weft and warp direction in the fabric, obviously increases the overall mass of water absorbedby the fabric.

And also, with increase in the wicking height, decreases the mass increment per centimeter interval, indicating that the mass increment gradient at each1cm interval becoming smaller. This mechanism of action is due to the gravitational effect and the hygroscopicity of the fabric. In general, the moisture transport is said to be one of the main factors that influence the physiological comfort of the fabric, specifically in sportswear. While sweating occurs, because of the difference in concentration of the liquid molecules and difference in pressure on both sides of the clothes, they absorb the moisture and transfer it outside. In case, the clothes are not able to absorb the sweat within short interval or if the amount of sweat and perspiration is more than the capacity of absorption of the clothes, then there occurs and uncomfortable clothing. The improvement in comfort of the textiles can be achieved by understanding mechanism of liquid transport. The moisture transport in the textiles can be expressed by a process called wicking which involves spontaneous transportation of liquid in to a porous system through capillary force that has often been used (Fohr*et al*, 2002).

CONCLUSION

Qualitative phytochemical analysis of *Vetiveria zizanioides* and *Phyllanthus niruri* showed the presence of alkaloids, flavanoids, tannins, phenols, terpenoids and saponins. FT-IR analysis revealed the peaks attributed for the presence of functional groups like O-H (alcohol and phenol groups), C-H (Aliphatic group) and CH2 stretch (cellulose group). The SEM images of plasma untreated samples exhibited more protruding fibres on the surface of openwoven fabric. Antibacterial activity of plasma treated *Vetiveria zizanioides* finished fabric samples exhibitied inhibitory zones of 36 mm and 35 mm and plasma treated fabric with extracts of *Phyllanthus niruri* showed inhibitory zones of 38mm and 36 mm against *Escherichia coli* and *Staphylococcus aureus* respectively. Mosquito repellency of plasma treated fabric (*Vetiveria zizanioides* and *Phyllanthusniruri*) showed 72% and 76% repellency respectively; whereas plasma untreated fabric samples revealed only 56%. Comfort properties (air-permeability, absorbency tests) revealed that plasma treated *Vetiveria zizanioides* and plasma treated *Phyllanthus niruri* resulted in significant increase in the airpermeability values of the fabrics. The absorbency rate in terms of drop test, sink test and vertical wicking test for Plasma treated *Vetiveria zizanioides* finished sample and Plasma treated *Phyllanthus niruri* finished sample was found higher than plasma untreated control fabric sample. 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.

References

1. AATCC Test Method, Antibacterial Activity Assessment of Textile Materials. *American Association of Textile Chemist and Colorist*. AATCC technical Manual, 261-262, 1998.
2. Asha Gangadharan, T.K. Nishath, P.J. Benny. Evaluation of phytochemical analysis, anti-oxidant and anti-elastase activity of *Hemigraphiscolorata*. International Journal of Pharmacognosy and Phytochemical Research 2014. 5(4):292-298.
3. Barker, A.F and Midgley, (2007), “Analysis of Woven Fabrics”, Abhishek Publications, Chandigarh, P.13, 154,155.
4. Bruno Burlando, Luisellaverotta, Laura Comara and Elisa Bottinimassa, (2010), “Herbal Principles in Cosmetics: Properties and Mechanisms of Action”, CRC Press, P. 27.
5. Deepak Kumar, Abhishek Srivastava, RaghavVidhyarthi, Dharmendra Gupta and AbhishekKumari, (2011), “Herbal Textiles: Green Business, Green Earth!!” Colourage, Vol. LVIII, No. 4, April, P. 54.
6. Devi Priya M, Vinod Kumar TG and Francis Mathew. Phytochemical screening of Hemigraphiscolorata (Blume) H.G. Hallier Journal of Pharmacognosy and Phytochemistry 2021; 10(6): 360-363
7. Drew, A.J., (2005), “A Wiccan Formulary and Herbal”, the Carrier Press Publication, P. 319.
8. Fohr JP, Couton D and Treguier G. Dynamic heat and water transfer through layered fabrics. Text Res J 2002; 72(1): 1–12.

9. Gopalakrishnan, D. and Aravindan, (2005), "Nonwovens for Medical Textiles", Asian Textile Journal, Vol. 14, No. 4, April, pp. 36, 39, 41.

10. Gunasekaran, G, C. Prakash & S. Periyasamy. Preparation, characterization of bamboo charcoal particles and the effect of their application on thermo-physiological comfort properties of woven fabrics. The Journal of the Textile Institute, 2019;

11. Joshi, S. Wazed Ali, R. Purwar and S. Rajendran (2009), "Eco-friendly Antimicrobial Finishing of Textiles using Bioactive Agents Based on Natural Products", Indian Journal of Fibre and Textile Research, Vol. 34, No. 9, September, pp. 295-304.

12. Kuttan, R. and Harikumar, K.B., (2012), "*Phyllanthus*species, Scientific Evaluation and Medicinal Applications, CRC Press, Taylor and Francies Group, US, P. 27.

13. Mehta, R., (2010), "Plasma Treatment in the Textile Industry", Colourage, Vol. LVII, No. 7, July, pp. 45-48.

14. Mustapha Debboun, Stephen P. Frances, Daniel A. Strickman, publisher CRC Press 2014. New York.

15. Sparavigna, A. and Wolf, R.N., (2005), "The Plasma Advantage", Textile World, Vol. 9, No. 11, pp. 49-51.

16. Sumithra M and VasugiRaaja N. Antimicrobial finishing of denim fabric with herbal extracts. American journal of medical and biological research 2014; 2, 26-30.

17. Sumithra, M and Amutha R. Functional modification on Adhesives Bandage using Natural Herbs. Journal of Textile Science & Engineering 6, 1-5.

18. Thilagavathi and T. Kannaian (2008), "Application of Prickly Chaff (*Achyranthesaspera*Linn) Leaves as Herbal Antimicrobial Finish for Cotton Fabric Used in Health Care Textiles", Natural Product Radiance, Vol. 7, No. 4, pp. 330-334.

19. Thomas, K., (2006), "Know About the Fabric and Their Manufacture", Abishek Publications, Chandigarh, pp. 20, 46-47, 53.