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Aloe vera gel finished 3D spacer knitted sports textiles

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In this study, polyester fibre has been converted in to 3D spacer knitted fabric which is fully hydrophobic in nature. The silicone based hydrophilic softeners are applied on the surface of one side of 3D spacer fabric to make it hydrophilic layer using spraying techniques. The hydrophilic layer of 3D spacer fabric is then finished with aloe vera gel for its use in sportswear. Bioactive compounds available in aloe vera gel, such as tannin, phenols, saponins, terpenoids, and flavonoids, have been tested using a thin layer chromatographic technique. Aloe vera gel extract and gel finished fabrics are assessed for antibacterial activity by using agar well diffusion method and parallel streak method. The test results provide excellent antibacterial property at the inhibition zone of 33mm against *Escherichia coli* and 35mm against *Staphylococcus aureus*. Physical and comfort properties of aloe vera gel finished spacer fabric and normal polyester knitted sports fabric are assessed using ASTM and AATCC standards. The test results obtained from aloe vera gel finished spacer fabric are found higher with respect to fabric thickness, fabric weight, water vapour permeability, bursting strength, vertical wickability, and air permeability as compared to normal polyester knitted sports fabric. It can also be used for protective textiles, agro textiles, aerospace textiles and medical textiles.

Keywords: Aloe vera gel, Antibacterial property, Bioactive compounds, Knitted fabrics, 3D polyester spacer fabrics, Sportswear

1 Introduction

The progressive new textiles utilized in sports activities and entertainment enterprise are popularly known as sports textiles. Today, demand for sports is found excessive towards the overall performance for equipment and clothing. Fibres like polyester, polypropylene, cotton, nylon, viscose rayon, etc are used for sportswear. Mostly polyester fabrics are used in sports textiles for their unique properties like quick dry, does not absorb water, resist wrinkles, good dimensional stability, resistant against dirt, alkalis, mold and lofty organic solvents[1,2]. Aloe vera belongs to asphodelaceae family, and Liliaceae group. However, the great first-class aloe vera plant comes from the barren region of southern California[3,4]. Several trade names of *Aloe barbadensis* miller plant are recognized, such as aloe, aloe vera, aloe capensis, aloe spicata, barbados aloe, and cape aloe[5]. Many bioactive compounds are available in aloe vera gel, such as phenol, saponins, terpenoids, flavonoids, tannin, etc. Such bioactive compounds are responsible for attaining excellent antibacterial property, antioxidant property, antiviral, anticancer, wound healing and cancer sores. The use of aloe vera gel is found very huge in different industries, specifically food and cosmetics, agriculture, chemical and pharmaceutical industry[6-8]. In this study, polyester fibre is converted to 3D spacer knitted fabric which is of fully hydrophobic in nature. The silicone based hydrophilic softeners are applied on the surface of one side of 3D spacer fabric and then it is converted in to hydrophilic layer using spraying techniques. The hydrophilic layer of 3D spacer fabric is finished with aloe vera gel and then used for making sportswear.

2 Materials and Methods

2.1 Materials

3D polyester warp knitted spacer fabric was produced from South India Textile Research Association, Coimbatore, Tamil Nadu. Raschel warp knitting machine with two needle bar was used to produce 3D spacer fabric with 130cm machine width. The courses per cm of the spacer fabric was 14 and wales per cm of the spacer fabric was 30, Six guide bar with 22 gauge raschel machine was used for constructing 3D spacer fabric. Aloe vera herbal plant was collected from the local areas of Sathyamangalam, Tamilnadu, India for the study.

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2.2 Methods

2.2.1 Segregation of Gel from Aloe Vera Stem

Aloe vera plant contains three layer, viz inner, middle, and outer layer. Inner and outer layers are green dermis. Middle layer is a colorless mucilaginous gel obtained from the parenchymatous cell of fresh leaves of aloe vera[9]. Aloe vera was washed with tap water. Top and bottom spines, located along the leaf margins, were removed with the help of sharp knife. The mucilage layer, present between the inner and outer layer of green dermis, was also removed with the help of sharp knife. After removing the green dermis, the clear gel is obtained and it is used for finishing application[10].

2.2.2 Identification of Bioactive Compounds using TLC

The major bioactive compounds, such as phenol, flavonoids, terpenoids, saponins and tannins, available in the aloe vera gel was analyzed using thin layer chromatographic technique (TLC). The bioactive compounds present in the aloe vera gel are more complex and difficult to separate from inherent nature. In order to separate such high complex bioactive constituents from gel, the mobile phases and spraying agents were used. The fraction of compounds and increase in polarity of the bioactive compound were analyzed using column chromatography. When the suitable spraying reagent based on bioactive compounds are sprayed on TLC chromate plate, different colour compound spots[11-13] are observed. The bioactive compounds are visualized in the chromate plate and marked in the form of individual colour spots. Each spots was measured using the following *Rf* value.

$$\mathrm{Rf} = \frac{\text{Distance covered by sample (cm)}}{\text{Distance covered by solvent (cm)}} \quad \ldots (1)$$

The bioactive constituents, mobile phase and their corresponding spraying agents are presented in Table 1. The TLC technique is most widely suitable for the isolation of low molecular weight compounds.

2.2.3 Antibacterial Property of Aloe Vera Gel

Two millilitre of aloe vera gel was mixed with 20mL of 90% methanol for screening the antibacterial property against two bacteria [*Escherichia coli* (ATCC 25922)] and [*Staphylococcus aureus* (ATCC 25923)]. For most of the herbal plant extracts, the antibacterial property was assessed using agar well diffusion method (NCCLS-1993). Sterile Muller-Hinton agar plates (MHA) was inoculated with standard culture broth. Dimethyl sulfoxide (DMSO) was mixed with aloe vera gel to make 50mg/mL concentration. Sterile cork-borer (6mm) was used for pouring the 6mm inoculated media on the MHA plates to form well. A well was filled with 30μL solution of gel, such as positive control (Gentamicin 30 mcg) for bacteria and negative control (DMSO) as a solvent respectively. The well containing aloe vera gel+bacteria (*Escherichia coli* and *Staphylococcus aureus)*+solvent (DMSO) was kept at room temperature (27°C) for 30 min and incubated overnight at 40°C for 22 h. After incubation, the formation of clear inhibition zone (mm) around the well was observed and it will determine the antibacterial property of the aloe vera gel[13,14].

2.2.4 Chemical based Silicone Finish for Improving Hydrophilic Property of 3D Spacer Fabric

Most of the silicone softeners has a linear chain of amino polydimethyl siloxanes. The silicone softeners applied on the top layer of the polyester fabrics changes the intermolecular structure of the fabric, particularly variation occurs in polymer chain length, functional groups, type of reactive end groups, and bonding between the silicone finish and the fibre. The silicone chains, attached to the functional ester groups present in the polyester, should result in efficient silicone distribution on the surface of the fabric and thus attain hydrophilic property of layer on the fabric surface and maximum softness of the fabric[15].

2.2.5 Spraying Method

The 3D polyester spacer fabric is placed on the wooden table. Finishing solution was made from aloe vera gel. The structural changes occurred after the application of silicone softener on the 3D spacer fabric. The silicone finished layer of the spacer fabric, formed by cross linking with hexagonal structures,

Table 1 — Thin layer chromatography analysis of aloe vera gel

Bioactive compounds	Mobile phase	Spraying agent	Rf value	Presence of compounds	Colour of spots
Tannin	Methanol	10% Ferric chloride	0.71	++	Grey
Phenol	Ethyl acetate	10% Ferric chloride	0.73	++	Green
Terpenoids	Ethyl acetate	11% Aluminium chloride	0.58	+	Light blue green
Flavonoid	Ethyl acetate	11% Aluminium chloride	-	-	No spot
Saponins	Methanol	10% Ferric chloride	0.45	+	Light orange

should result in hydrophilic nature. The finishing solution was sprayed by using high pressure spray guns with a nozzle distance of 15cm from the fabric. Two to three times spray of the aloe vera gel solution is done on the top hydrophilic layer of the fabric for cooling purpose and to attain excellent antibacterial activity. After finishing, the finished fabric was kept at 27°C for 2 days[16,17].

2.2.6 Antibacterial Property of Aloe Vera Gel Finished Fabric

Two test microorganisms (*E.coli* and *S.aureus*) were prepared in a liquid culture medium. In order to sterilize the perti dishes before starting the test, sterilized molten agar was poured on the petri dishes and completely solidified before inoculating the agar media. By using sterile distilled water, the suspension of two test microorganisms was standardized by two way serial dilution method. In a solidified growth agar plate, using a sterile inoculating loop, one loop full of the diluted inoculum suspension is used to streak five consecutive parallel streaks spaced evenly apart, without refilling the loop. This allows for five parallel streaks varying in concentration. Control and finished fabric swatches were cut into rectangular shape with a size of 25×50 mm. Both control and finished fabric samples were placed evenly across the five parallel streaks. In order to ensure that the test samples are in contact with the inoculated agar medium, a mild pressure is applied on the finished samples on the agar media. Test specimens (control and finished fabric) on the inoculated agar plates are incubated at 40°C for 22 h. After incubation, the plates were removed from the incubator and growth interruption of inoculum agar streaks was observed on the underneath of the fabric. A clear zone of inhibition, occurred outside the fabric specimen, was measured in mm which indicates the antibacterial property of the finished fabric[10,18].

2.3 Development of 3D Spacer Fabric

Polyester fibre was used for making 3D spacer knitted fabric. Raschel warp knitting machine was used to knit the face, middle and back layers with the help of two needle bars and machine width of 130 cm. The courses per cm of the spacer fabric were kept as 14 and wales per cm of the spacer fabric were kept as 30. Six guide bar with 22 gauge raschel machine was used for constructing 3D spacer fabric. Two individual fabrics were combined together by pile threads. The front guide bars 1 and 2 holding 75 denier polyester were used to knit the face fabric on the face needle bar. The back guide bars 5 and 6 hold 75 denier polyester were used to knit the back fabric on the back needle bar. The middle guide bars 3 and 4 hold the 20 denier polyester monofilament spacer yarns and it is used to knit the face and back needle bars in sequence. The spacer fabrics produced by warp knitted structures with the help of two needle bars using raschel warp knitting machine have attained greater flexibility, uniformity and smoothness to the fabrics as shown in Fig. 1[19,20].

2.4 Analysing the Fabric Properties

Thickness of the fabric was evaluated using ASTM D1777-96 standard. Weight of the fabric was evaluated using ASTM D3776-96 standard. Bursting strength of the fabric was evaluated using ASTM D3787-16 standard. The air permeability of the fabric was evaluated using ASTM 737-18 standard. Vertical wicking test of the fabric was evaluated using AATCC 197-13 standard. Water vapour permeability of the fabric was evaluated using ASTM E96-05 standard[21].

3 Results and Discussion

3.1 Investigation of Bioactive Compounds

Five types of bioactive compounds were analyzed from the aloe vera plant using thin layer chromatographic technique, as presented in Table 1.

The Rf values are evaluated by comparing with the standards. The appearance of different colour spots attained during the TLC analysis confirms the presence of bioactive compounds in aloe vera gel.

3.2 Evaluation of Antibacterial Property

Agar Well Diffusion Method

The antibacterial property has been tested for aloe vera gel. It is mainly assessed by two bacterial species, such as *Escherichia coli* and *Staphylococcus*

Fig. 1 — Development of 3D spacer fabric for sportswear.

aureus using agar well diffusion method and the results are presented in Table 2.

An excellent antibacterial property is achieved in the aloe vera gel against two test bacteria with a inhibition zone ranging from 22mm to 29mm. Such inherent antibacterial properties are attained due to the existence of bioactive compounds, such as tannin, phenol, terpenoids, and saponins present in the aloe vera gel.

Parallel Streak Method

The antibacterial property is also tested by parallel streak method for aloe vera gel finished spacer fabric. It is mainly assessed by two bacterial species, such as *Escherichia coli and Staphylococcus aureus* using parallel streak method (AATCC test method 147-1988). During the parallel streak assay, the fabric finished with aloe vera gel shows maximum inhibition zones of 33mm against *Escherichia coli* and 35mm against *Staphylococcus aureus.* Antibacterial property of aloe vera gel finished spacer fabric against two test bacteria is shown in Fig. 2.

Figure 2 confirms that the finished fabric has an excellent antibacterial activity against two test bacteria. The fabric finished with aloe vera gel shows an excellent inhibition zone of around 35mm for *Staphylococcus aureus* as compared to that for *Escherichia coli.* Such higher inhibition zone is attained due to the existence of bioactive compounds present in the finished fabric.

3.3 Assessment of Fabric Physical Properties

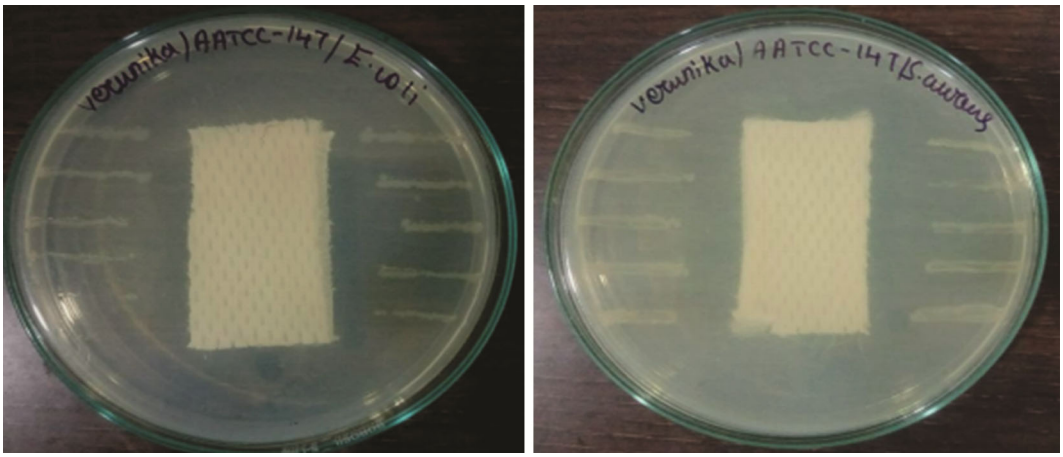
The fabric physical properties, like thickness, weight per square meter, strength, and air permeability are presented in Table 3. The finished knitted spacer fabric is thicker than the normal polyester knitted sports fabric, primarily due to the increase in outer dimension of the fibres. Moreover, the knit structure of spacer fabric is different from the regular polyester sports knit structure. In this work, we used regular single jersey polyester knit fabric. So the thickness of the spacer fabric is higher than the regular sports fabric. It is around 2.7mm for spacer fabric and 0.74mm for regular polyester fabric. The aloe vera gel finish is given to the hydrophilic layer of the spacer knitted fabric. This also increases the thickness. But, the amount of increase due to aloe vera finish is very less.

Table 2 — Analysis of antibacterial property of aloe vera gel against two test bacteria

Samples	Zone of inhibition, mm	
	Escherichia coli	*Staphylococcus aureus*
Negative control (DW)	-	-
Methanol extract	22	25
Ethanol extract	10	15
Aqueous extract	-	-
Standard (Gentamicin)	29	28

Table 3 — Fabric physical properties

Fabric	Thickness mm	Weight per square meter, g/m^2	Bursting strength kgf	Air permeability cm^3/cm^2/s
Normal polyester knitted sports fabric	0.74	190	64.56	37.4
Aloe vera finished spacer knitted fabric	2.7	370	104.82	42



Escherichia coli *Staphylococcus aureus*

Fig. 2 — Analysis of antibacterial property of finished spacer fabric

The weight per square meter of both the spacer and regular polyester sports fabric is also analysed. The weight per square meter (grams per square meter-GSM) of the spacer fabric is found around 370, whereas the GSM of regular polyester fabric is around 190. This increase in GSM is mainly due to the amount of thread required to produce the spacer knit fabric. It is very high in the case of spacer fabric. Whereas, it is less in the case of single jersey fabrics.

The result shows that the spacer fabric has higher bursting strength as compared to regular polyester single jersey fabrics. It is around 104 kgf for 3D spacer fabric and only 64 kgf for regular single jersey polyester fabrics. The bursting strength mainly depends on fabric thickness and weight per square meter. Normally, the higher the thickness, the higher is the bursting strength. Similarly, the higher the weight per square meter, the higher is the bursting strength. In this case, the spacer fabric has higher thickness (2.7mm) and weight per square meter (GSM: 370) as compared to regular single jersey polyester sports fabric. In addition to that the 3D spacer fabric has better streachability that increase the breaking load also.

3.4 Fabric Comfort Properties

3.4.1 Fabric Air Permeability

The quantity of air passed through one square centimeter of the finished spacer fabric and normal sports knitted fabric is assessed and the results are presented in Table 3. The quantity of air passed through the aloe vera finished spacer fabric slightly increases the air permeability property as compared to normal polyester knitted sports fabric. In finished 3D spacer fabric, the air permeability increases due to the higher extension, and micropores present in between the fabric create the space after the absorption of gel on the fabric surface and this decreases the flexibility of the fabric.

3.4.2 Fabric Vertical Wicking

The length of wicking up to a particular height with different time intervals of finished 3D polyester spacer fabric and normal polyester knitted sports fabric has been evaluated and the results are presented in Table 4.

It is observed that with the increase in time, the length of wicking increases in the aloe vera gel finished spacer fabric as compared to normal polyester knitted sports fabric. In case of finished fabric, the structural changes from hydrophobic to hydrophilic nature occur due to the finishing of silicone softener, and aloe vera gel finishing on the fabric increases the residual force of water absorbed in the hydrophilic layer of the fabric at the initial point; gradually the water absorption increases at different time intervals.

Table 4 — Fabric vertical wicking test results

Time, min	Wicking height, cm	
	Unfinished fabric	Finished fabric
2	1.5	3.0
4	1.8	4.3
6	2.0	4.9
8	2.8	5.5
10	3.2	6.2

Table 5 — Fabric water vapour permeability test results

Time, min	Water vapour permeability, g/m^2/24h		
	Unfinished fabric	Finished fabric	Index
2	18889.5	241904.7	1280
4	17784.8	241124.2	1356
6	18757.0	240924.2	1284
8	18804.6	241982.5	1287
10	17709.4	240720.8	1359
Mean	18389.0	241331.2	1313.2

3.4.3 Fabric Water Vapour Permeability

The rate of water vapour transmission of the finished 3D polyester spacer fabric and normal polyester knitted sports fabric under standard relative humidity (64%) and room temperature (27°C) has been evaluated (Table 5). The rate of water vapour transmission of the aloe vera gel finished fabric increases as compared to normal polyester knitted sports fabric. In case of finished 3D polyester spacer fabric, the structural changes from hydrophobic to hydrophilic nature results in a slackly hexagonal structure, and therefore increase in the water vapour permeability of fabrics is observed. In the case of normal polyester knitted sports fabric, the water vapour transmission rate decreases due to more compressed fabric structure with higher crystallization nature, which reduces the water vapour permeability of fabrics.

4 Conclusion

In this study, aloe vera gel finished spacer fabric has been fabricated for sportswear applications. The test results provide sufficient amount of bioactive compounds present in the gel for attaining antioxidant, antiviral, wound healing, anticancer and antimicrobial properties. The antibacterial property of finished spacer fabric has been assessed using parallel streak method (AATCC 147). The test results provide excellent antibacterial property at the inhibition zone

of 33mm against *Escherichia coli* and 35mm against *Staphylococcus aureus*. The physical and comfort properties of aloe vera gel finished fabric are found to be improved with respect to fabric thickness, air permeability, weight of fabric, bursting strength, wickability, and water vapour permeability as compared to normal polyester knitted sports fabric properties. It can also be used for protective textiles, agro textiles, aerospace textiles and medical textiles.

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