Abstract

Healthcare and hygiene products in the medical sector uphold a prime responsibility to prevent the passage of bacteria or other harmful organisms from non-sterile to sterile areas. This has been currently possible with increased awareness and concern about the healthcare/hospital textiles. Along with protection, various products are accommodated with several functional properties such as comfort, odour-free, and hygiene aspects. This manuscript presents an insight into the development of such textiles by application of the grapeseed oil (*Vitis vinifera* L.), a by-product of the winemaking industry. The fabric structures chosen for the study are relevant to the end uses of textile products in the medical applications such as 100% texturized polyester, 100% micro-polyester, polyester/viscose, and polyester/cotton woven fabrics. All polyester fabric samples have been pre-treated with an optimized concentration of trichloroacetic acid-methylene chloride (TCA-MC) solvent and further treated with four different grapeseed oil concentrations (5, 10, 15, and 20%). The antibacterial and comfort properties of the treated fabric samples have been evaluated and analysed. The treated fabric samples show the substantial antibacterial activity of 49 and 40%, respectively, against *S. aureus* and *E. coli* bacteria after 50 home laundry washing cycles.

Keywords

Polyester structures · Grapeseed oil · FTIR · Antibacterial properties · Comfort properties · Liquid barrier properties

Introduction

The healthcare textile sector is an emerging sector for developing countries where people are now aware of the risks of blood-borne diseases. As a result of the rapidly growing population and rising standard of living, helped in identifying a vast potential for healthcare textiles [1]. In the current scenario, researchers are focussed on the evolutions of such kinds of healthcare textiles that accomplish multifunctional properties such as comfort properties, thermal, and breathability as well as effective against microbe attacks [2–4]. The application of green textiles is critical in the rapidly developing healthcare textile market. Numerous researchers have recently reported on the advancement of healthcare textiles made of natural materials [5–7]. Researchers are concerned for replacement for synthetic agents, considering the increasing consumer demand for sustainable, environmentally friendly products [8, 9]. Natural bioactive compounds are frequently obtained from plants and include phenolics and polyphenols, which are gaining popularity for usage in fabrics due to their widespread availability, biological compatibility, non-toxic nature, and environmentally friendly approach. Several methods have been suggested to investigate the numerous potential applications of such herbal agents in the manufacture of multifunctional textiles, including antimicrobial textiles, aromatic textiles, insect repellent textiles, flame retardant textiles, and UV protection textiles [10–14]. Textile antimicrobial modification has become required to protect against diseases caused by pathogenic...
microorganisms. To impart antimicrobial properties to textiles, researchers have set a new standard for the development of new non-toxic and environmentally friendly compounds [15–19]. Several researchers have examined the effect of natural functional finishes on the comfort qualities of fabrics [16, 20, 21]. The majority of natural antibacterial agents have been observed to be insoluble and to have an adverse effect on the physical and other functional properties of fabrics. Several researchers have proposed several novel approaches for injecting textiles with natural (bioactive) substances [21–23]. Since many of these natural substances come into contact with textiles, they lose their bioactivity. Intensive research is therefore considered necessary in order to identify and develop new effective antibacterial compounds which are also environmentally benign. As a result, a number of novel approaches such as resin crosslinking and the incorporation of liquid bioactive components such as essential oils into the sol–gel matrix are being developed to overcome the limitations of wash cycles on finished textiles [24].

A novel approach has been evolved to investigate the implementation of grapeseed oil on different polyester-based textiles. Grapeseed oil is typically extracted from grape seeds, which are a significant by-product of the winemaking process. Numerous researchers have examined the composition of grapeseed oil and concluded that it includes a considerable number of phenolic components such as flavonoids, carotenoids, phenolic acids, tannins, and stilbenes, as well as catechins, epicatechins, trans-resveratrol, and procyanidin B1. Additionally, it is reported that the antibacterial activities are mostly due to resveratrol and flavanol compounds [25–28]. There has been no research conducted so far on the antibacterial and comfort qualities of grapeseed oil-treated fabrics.

Pretreatment of polyester-based fabric structures with an optimal concentration of the interacting solvent trichloroacetic acid-methylene chloride (TCA-MC) was performed in this study [29]. This solvent-induced crystallisation process affects both amorphous and crystalline regions, increasing the number of gaps and cracks in the structure and allowing external substances to enter more easily. According to earlier research, the TCA-MC reagent has a strong affinity for polyethylene terephthalate (PET) and dissolves its complex polymer matrix in 5 min at room temperature at a concentration of around 25% (w/v). As a result, a lower TCA-MC concentration will be sufficient to allow grapeseed oil to permeate the compact PET structure. [29, 30]. This work examines the functional properties of all treated polyester fabric samples, including their liquid barrier and antibacterial properties, as well as their comfort properties.

Materials and Methodology

Four different polyester fabric structures 100% texturized polyester, 100% micro-polyester, polyester/viscose, and polyester/cotton of 165 g/m² have been developed using oxford weave (derivative of plain weave). Fabric characteristics are presented in Table 1. Laboratory grade trichloroacetic acid (CCl₃-COOH), methylene chloride (CH₂-Cl₂), and acetone (CH₃-CO–CH₃) have been used. Commercial grade grape seed oil (C₁₈H₃₂O₂) having molecular weight of 280.445 has been used for the study [25].

The pre-treatment of all four polyester fabric samples has been carried out in a close trough with an optimized concentration of 1% (w/v) of TCA-MC solvent for a 3-min duration at room temperature. The treated samples are then rinsed with methylene chloride followed by acetone to remove any residual reagent. The pre-treated textile samples are then dried in an open atmospheric condition before treating them with grapeseed oil [29].

The TCA-MC pre-treated-polyester fabric samples are then immersed in a solution of 5, 10, 15, and 20% concentration of grape seed oil. The treatment is carried out with the help of acetic acid by maintaining a material to liquor ratio of 1:25 at 80 °C for 20 min. Subsequently, the fabric samples are washed thoroughly with hot and cold water before testing and characterization. A physicochemical reaction occurs between the polyester structure and the grapeseed oil structure, which is represented in Fig. 1. The hydrogen bonding between the PET structure and the grapeseed oil structure can be seen in Fig. 1. As a result, an ester is formed between the end chain –COOH group of polyester and the –OH group of flavanol in the grapeseed oil structure.

Test Methodology

Antibacterial activity against both Gram-positive and Gram-negative bacteria is evaluated by using AATCC 147 qualitative test for both the treated and untreated samples. Quantitative analysis has been carried out using AATCC 100 standard. The Staphylococcus aureus (Gram-positive) and Escherichia coli (Gram-negative) bacteria are chosen. Fourier transformation infrared (FTIR) spectrometer make Bruker, alpha model from Germany has been used for characterization. By featuring the molecular motions (stretching, bending, and torsion of the chemical bonds), FTIR gives a distinctive signature of the chemical or biochemical substances found in a sample. Water impact penetration test is carried out using AATCC RA63:2000 test method to measure the wetting resistance and penetration of water. The water repellency of the treated fabric

123
sample is evaluated according to AATCC 127 test method by using hydrostatic pressure head apparatus M018 (by SDL Atlas). Resistance of protective clothing materials to penetration by blood-borne pathogens using visual penetration is evaluated by ASTM F1670 test method on M018 (by SDL Atlas). Protective clothing: “pass/fail” determinations are based on detection of visual penetration. Sessile drop test technique is used according to ASTM D7334-08 to measure the contact angle on surface of fabrics in the presence of liquid/water droplet of 0.1 L resolution using—PCA-11 (by kyowa) instrument. The permeability to water vapour is determined according to standard ASTM E96. During the test, the samples are placed on a vibration-free turntable containing 8 dishes rotating uniformly at 5 m/min so that all the dishes are exposed to the same average ambient conditions. The water vapour permeability is calculated using the following formula:

\[
\text{WVP} \, (\text{g/m}^2/\text{day}) = \frac{24M}{At}
\]

where \(M\) is the loss in mass (g), \(t\) is time between weighing (h), and \(A\) is internal area of dish (m²).

The drying rate is the rate at which water evaporates from the outside surface of a fabric and is tested in accordance with AATCC RA63. The moisture management properties are tested in accordance with AATCC 195.

The gain in weight values (+) is calculated for weight add-on% of the 20% (w/v) grapeseed oil-treated different polyester fabric samples has been calculated as below:

\[
\text{Weight Add-on\%} = \frac{A - B}{B} \times 100
\]

where \(A\) = dry weight of grapeseed oil-treated samples and \(B\) = dry weight of TCA-MC treated samples.

### Result and Discussion

Four different polyester textile substrates 100% texturized polyester, 100% micro-polyester, polyester/cotton, and polyester/viscose blends fabric samples treated with grapeseed oil have been analyzed for their liquid barrier, physiological comfort, and antimicrobial properties.

#### Effect on Weight Add-on%

A comparison of TCA-MC pretreatment grapeseed oil for (−) and ( +) weight change values is shown in Table 2. Prior to weighing, all oven-dried fabric samples are kept at 25 °C and 65% relative humidity for 24 h. A weight loss occurs due to TCA-MC treatment, as shown in Table 2.
Following a 3-min pretreatment with an optimal concentration of 1% TCA-MC, fabric weight loss of 0.90–2.53 g is seen in all cases. From Table 2, the TCA-MC treatment breaks the polymer chain of the polyester structure resulting in weight loss. Table 2 shows that all treated samples gain weight after grapeseed oil treatment. The weight addition % increases from 4.25 to 14.56% with increase in the concentration of the grapeseed oil from 5 to 20%. In 20% grapeseed oil-treated polyester/viscose samples, the maximum weight gain of 14.56% is observed. A minimal weight gain of 4.25% is observed in 100% micro-polyester fabric treated with 5% grapeseed oil. TCA-MC treatment leads in structural alterations in the polyester when employed at low concentrations, which facilitates in the formation of polar groups. This enables natural finishes to adhere to polyester’s compact structure.

### Surface Morphology and Characterization

The surface morphology of the untreated and TCA-MC pre-treated grapeseed oil-treated micro-polyester fabric samples is shown in Fig. 2. Figure 2b indicates that the 1% concentration of TCA-MC reagent is responsible for swelling of the structure. It also creates voids and cracks in the compact polyester structure, enabling the easy entrance of molecules to be attached to the structure during treatment. Figure 3 represents the average spectra of the untreated micro-polyester samples and 20% grapeseed oil-treated micro-polyester samples. The FTIR spectra have been recorded in the wavenumber range of 600–4000 cm\(^{-1}\). It is apparent from the figure that the grapeseed oil-treated sample shows a large band peaking at about 3415 cm\(^{-1}\) corresponding to the OH stretching. Asymmetric and symmetrical stretching vibrations of the CH\(_2\) groups are observed at 2920 and 2855 cm\(^{-1}\), respectively. FTIR peaks at 2855 and 2920 cm\(^{-1}\) also indicate an improvement in the OH stretching of hydrogen bonds. In the FTIR spectra of grapeseed oil-treated polyester, there is an increase in peak height at 1707 cm\(^{-1}\), suggesting an increase in ester group vibrations in addition to ester group vibrations of polyester fibre itself. As shown in Fig. 1, the reaction between the polyester structure and the grapeseed oil structure results in the formation of the ester, which causes a rise in peak height. In the fingerprint area, as opposed to the untreated micro-polyester sample, the grapeseed oil-treated polyester sample has a wide broadening peak, which also confirms the existence of biopolymeric functional finishes in this region. Energy-dispersive X-ray spectroscopy (EDS) analysis has been carried out at higher magnification by the bombardment of higher electron beam to investigate the deterioration, contamination as well for elemental analysis of the fibres to study the presence of grape seed oil finish. Figure 3b depicts the elementary analysis of the treated samples and further confirmed the presence of grapeseed oil elements on the surface of grapeseed oil-treated sample [28].

| S.no | Fabric type            | Finish conc. (%) | TCA-MC treatment Before (g) | After (g) | Weight change (%) | Grapeseed oil treatment After (g) | Weight change (%) |
|------|------------------------|-----------------|-----------------------------|----------|------------------|-----------------------------------|------------------|
| 1    | 100% texturized polyester | 5               | 5.46                        | 5.39     | 1.30             | 566                              | 5.01             |
|      |                        | 10              | 5.51                        | 5.43     | 1.47             | 5.86                              | 7.92             |
|      |                        | 15              | 5.48                        | 5.40     | 1.48             | 5.97                              | 10.56            |
|      |                        | 20              | 5.59                        | 5.49     | 1.82             | 6.12                              | 11.48            |
| 2    | 100% micro polyester    | 5               | 7.68                        | 7.53     | 1.99             | 7.85                              | 4.25             |
|      |                        | 10              | 7.58                        | 7.42     | 2.16             | 8.12                              | 9.43             |
|      |                        | 15              | 7.76                        | 7.59     | 2.24             | 8.44                              | 11.20            |
|      |                        | 20              | 7.7                         | 7.51     | 2.53             | 8.51                              | 13.32            |
| 3    | Polyester/viscose       | 5               | 7.48                        | 7.41     | 0.94             | 7.94                              | 7.15             |
|      |                        | 10              | 7.43                        | 7.36     | 0.95             | 8.05                              | 9.38             |
|      |                        | 15              | 7.57                        | 7.49     | 1.07             | 8.25                              | 10.15            |
|      |                        | 20              | 7.46                        | 7.35     | 1.50             | 8.42                              | 14.56            |
| 4    | Polyester/cotton        | 5               | 6.75                        | 6.69     | 0.90             | 7.13                              | 6.58             |
|      |                        | 10              | 6.84                        | 6.77     | 1.03             | 7.28                              | 7.53             |
|      |                        | 15              | 6.54                        | 6.47     | 1.08             | 7.11                              | 9.89             |
|      |                        | 20              | 6.41                        | 6.34     | 1.10             | 7.19                              | 13.41            |
Effect on Antibacterial Activity

The effect of grapeseed oil concentration is evaluated qualitatively and quantitatively against both the Gram-positive *S. aureus* and Gram-negative *E. coli* bacteria. The TCA-MC pre-treated different polyester structures were treated with four different concentrations 5, 10, 15, and 20% of grapeseed oil, respectively. Table 3 shows the antibacterial activity of the untreated and treated samples after 50 wash cycles. After 50 washes, all treated samples shown substantial antibacterial activity. It is also observed from Table 3 that the finish concentration significantly affects the antibacterial activity of the treated samples. Table 3 reveals that the mean CFU/ml ($\times 10^{-8}$) for untreated sample is 78, 76, 82, and 84, respectively, for 100% texturized polyester, 100% micro–polyester, polyester/viscose, and polyester/cotton against *S. aureus* bacteria and 108, 106, 111, 115 for *E. coli*. As the concentration of the grapeseed oil rises from 5 to 20%, the CFU/ml ($\times 10^{-8}$) decreases from 25 to 11 for texturized polyester fabric and thus increases the antibacterial activity of the treated samples. The polyester/viscose fabric treated with 20% grapeseed oil shows maximum antibacterial activity of 49 and 40%, respectively, against both bacteria after 50 washes. Since TCA-MC treatment creates voids and cracks in the polyester structure and enables entry of grapeseed oil into the polyester structure, as confirmed from SEM and FTIR analysis of the treated fabric samples, the antibacterial treatment is durable up to 50 washes. Previously, it was reported that the TCA-MC solvent has a strong
Table 3 Effect on the antibacterial properties of TCA-MC pre-treated grapeseed oil-treated polyester structures

| S. No | Fabric type | Finish conc. (%) | Antibacterial activity without laundry (%) | Antibacterial activity after 50 home laundry washes (%) |
|-------|-------------|------------------|-------------------------------------------|-----------------------------------------------------|
|       |             |                  | S. aureus | CFU/ml (x 10^8) | CFU/ml (x 10^8) | Antibacterial activity (%) | CFU/ml (x 10^8) | CFU/ml (x 10^8) | Antibacterial activity (%) |
|       |             |                  | E. coli | CFU/ml (x 10^8) | CFU/ml (x 10^8) | Antibacterial activity (%) | CFU/ml (x 10^8) | CFU/ml (x 10^8) | Antibacterial activity (%) |
| 1     | 100% texturized polyester | 5 | 78 | 25 | 68 | 108 | 48 | 56 | 78 | 65 | 17 |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
| 2     | 100% micro-polyester | 5 | 76 | 23 | 70 | 106 | 44 | 58 | 76 | 60 | 21 |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
| 3     | Polyester/ viscose | 5 | 82 | 18 | 78 | 111 | 41 | 63 | 82 | 58 | 29 |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
| 4     | Polyester/cotton | 5 | 84 | 27 | 68 | 115 | 51 | 56 | 84 | 63 | 25 |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |
|       |             |                  |        |                |                |                        |                |                |                  |

C* Activity of control sample; T* Activity of grapeseed oil finished samples; A* Antibacterial activity %
interaction with polyester at low concentrations. Polyester’s segmental mobility increases significantly at an optimized TCA-MC solvent concentration [30]. Simultaneously, natural finishes are infused into the polymer during the process, allowing the active components to be embedded into the structure. Moreover, as the concentration of natural finishes increases, so does the chance of active compounds adhering to the fabric. This increases the weight of the treated material and allows the fabric surface to remain functional even after 50 wash cycles. Figure 4 shows the antibacterial activity on polyester/viscose fabric sample before and after treatment. The untreated samples Fig. 4a and d show maximum growth of bacteria underneath and around the samples. From Fig. 4b and e 20% grapeseed oil-treated polyester/viscose samples, the bacterial growth is restricted around the treated samples, and a clear inhibition zone is visible. All 20% grapeseed oil-treated polyester/viscose samples show a clear inhibition zone even after 50 washes as shown in Fig. 4c and f.

**Effect on Liquid Barrier Properties**

The impact penetration test is used to assess the impact of water penetration in healthcare applications. The treatment significantly improves the treated samples’ impact penetration values. This could be owing to the TCA-MC pretreatment improving cover factor. All test samples found to be effect against the AAMI level 2 protection for healthcare applications. Further, it has been observed that all the grapeseed oil-treated fabric samples show significant improvement in the hydrostatic pressure test (Table 4). From Table 4, it is observed that the finish concentration influences the water repellency of the treated fabric samples. As the concentration of grapeseed oil increases, the hydrostatic pressure increases as well. This may be correlated with enhanced cover factor value following TCA-MC treatment with grapeseed oil finish, which further improves the fabric cover factor value. The maximum level of hydrostatic pressure 28.3 cm is observed in 20% grapeseed oil-treated polyester/cotton fabric samples, whereas minimum level of hydrostatic pressure 20.6 cm is observed for 5% grapeseed oil-treated texturized polyester fabric samples. It is also observed that at 20% grapeseed oil concentration, all the treated fabric samples show a hydrostatic pressure of more than 24.6 cm. Although the improvement in the hydrostatic pressure is not suitable for high-performing fabrics like surgical gowns, it is sufficient for the applications like bedsheets or curtains and drapes. Like the hydrostatic head test for water repellency, the blood penetration test has been carried out to study the blood repellency of the treated samples. The treated fabric
Table 4  Effect of treatment on liquid barrier properties and comfort properties

| S. No | Fabric type     | Finish concent. (%) | Impact penetration test (g) | Hydrostatic pressure test (cm) | Resistance to blood (pass/fail) | WVP (g/m²/24 h) | Contact angle (°) | Dry rate (%/min) |
|-------|-----------------|---------------------|-----------------------------|---------------------------------|--------------------------------|-----------------|------------------|------------------|
|       |                 |                     | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated | Untreated | Treated |
| 1     | 100% texturized polyester | 5 | 2.36 | 0.86 | 6.5 | 20.6 | Fail | Fail | 1.31 | 1.16 | 45.7 | 54.3 | 1.326 | 0.618 |
|       |                 | 10                   | 2.36 | 0.82 | 6.5 | 22.6 | Fail | Fail | 1.31 | 1.12 | 45.7 | 58.1 | 1.326 | 0.571 |
|       |                 | 15                   | 2.36 | 0.75 | 6.5 | 23.5 | Fail | Fail | 1.31 | 1.10 | 45.7 | 68.9 | 1.326 | 0.526 |
|       |                 | 20                   | 2.36 | 0.72 | 6.5 | 24.6 | Fail | Fail | 1.31 | 1.10 | 45.7 | 75.6 | 1.326 | 0.442 |
| 2     | 100% micro-polyester | 5 | 2.21 | 0.76 | 8.5 | 21.5 | Fail | Fail | 1.28 | 0.66 | 78.0 | 79.2 | 2.326 | 0.889 |
|       |                 | 10                   | 2.21 | 0.68 | 8.5 | 24.6 | Fail | Fail | 1.28 | 0.53 | 78.0 | 80.4 | 2.326 | 0.871 |
|       |                 | 15                   | 2.21 | 0.65 | 8.5 | 24.5 | Fail | Fail | 1.28 | 0.51 | 78.0 | 81.2 | 2.326 | 0.842 |
|       |                 | 20                   | 2.21 | 0.58 | 8.5 | 28.2 | Fail | Fail | 1.28 | 0.48 | 78.0 | 84.1 | 2.326 | 0.786 |
| 3     | Polyester/viscose | 5 | 2.48 | 0.79 | 5.5 | 20.7 | Fail | Fail | 1.31 | 1.20 | 35.5 | 65.7 | 1.977 | 0.824 |
|       |                 | 10                   | 2.48 | 0.72 | 5.5 | 22.6 | Fail | Fail | 1.31 | 1.18 | 35.5 | 71.4 | 1.977 | 0.795 |
|       |                 | 15                   | 2.48 | 0.68 | 5.5 | 23.3 | Fail | Fail | 1.31 | 1.17 | 35.5 | 73.2 | 1.977 | 0.761 |
|       |                 | 20                   | 2.48 | 0.63 | 5.5 | 26.9 | Fail | Fail | 1.31 | 1.15 | 35.5 | 80.0 | 1.977 | 0.724 |
| 4     | Polyester/cotton | 5 | 2.44 | 0.83 | 6   | 22.9 | Fail | Fail | 1.44 | 1.31 | 62.6 | 67.5 | 0.778 | 0.513 |
|       |                 | 10                   | 2.44 | 0.77 | 6   | 23.6 | Fail | Fail | 1.44 | 1.27 | 62.6 | 72.3 | 0.778 | 0.476 |
|       |                 | 15                   | 2.44 | 0.75 | 6   | 25.4 | Fail | Fail | 1.44 | 1.25 | 62.6 | 76.4 | 0.778 | 0.447 |
|       |                 | 20                   | 2.44 | 0.72 | 6   | 28.3 | Fail | Fail | 1.44 | 1.22 | 62.6 | 81.5 | 0.778 | 0.413 |
samples have been tested for blood repellency at 13.8 kPa pressure. It has been observed that all of the treated samples failed to pass the blood repellency test.

The water and blood repellency properties are also justified by contact angle testing. The increase in contact angle with the increase in the concentration of grapeseed oil also shows the improvement in water repellency.

**Fig. 5** a, c, e, g, respectively, shows the contact angle of untreated 100% micro-polyester polyester, 100% texturized polyester, polyester/viscose, polyester/cotton and (b, d, f, h), respectively, shows the contact angle of 20% grapeseed oil-treated samples.
characteristics (Fig. 5). Figure 5a-b shows the moderate increase in contact angle of the micro-polyester fabric structure from $78^\circ$ to $84.1^\circ$ with a 20% finish concentration of grapeseed oil. Similarly, from Fig. 5c–d, 20% grapeseed oil-treated texturized polyester fabric shows a significant increase in the contact angle from $45.7^\circ$ to $75.6^\circ$. Similar trends are observed in case of grapeseed oil-treated polyester/viscose and polyester cotton fabric samples.
Fig. 8 Effect on moisture management properties of 20% grapeseed oil-treated (a–b) 100% texturized polyester, c–d 100% micro-polyester, e–f polyester/viscose, and g–h polyester/cotton
Figure 5e–f shows the contact angle of polyester/viscose treated fabric increases from 35.5° to 80° with a 20% finish concentration. In Fig. 5g–h, it is evident the contact angle significantly increases from 62.6° to 81.5° for polyester/cotton fabric with 20% finish.

Effect on Water Vapour Permeability (WVP)

The water vapour permeability results of all untreated and treated samples are shown in Table 4. Polyester/cotton fabric samples show the highest WVP among all fabric samples. Higher density of cotton fibres reduces the number of fibres in the same linear density of yarn, as compared to all polyester fibres. Therefore, the volume of fibres in the yarn is higher in case of polyester fibres, which makes the fabric more compact as compared to cotton fabrics, providing lower water vapour permeability in polyester fabrics. The treatment of grapeseed oil reduces the WVP of all treated fabric samples, which is statistically significant at $p < 0.05$ with $f$-ratio value 16.87322 and $p$ value 0.0002. Figure 6 shows the water vapour permeability results of untreated and treated fabric samples with 20% grapeseed oil. 100% polyester fabric treated with grapeseed oil shows substantial reduction in the WVP value, as compared to texturized polyester, polyester/viscose and polyester/cotton fabrics, whereas polyester/cotton and polyester/viscose fabrics show marginal decrease in WVP after treatment with 20% grapeseed oil.

Effect on Dry Rate Properties

Table 4 shows the dry rate of all grapeseed oil-treated samples. All the test samples show decrease in the drying behaviour of all treated samples. Figure 7 illustrates the effect of grapeseed oil functional finish on the dry rate property of different fabric samples. Generally, the 100% micro-polyester fabrics exhibit higher dry rate as compared to the 100% texturized polyester, polyester/cotton, and polyester/viscose fabric blends. From Fig. 7, it is evident that the grapeseed oil finish over the fabric surface significantly affects the rate of drying. The results are statistically significant at $p < 0.05$ with $f$-ratio value 35.05 and $p$ value < 0.0001. It has been observed that the rate of drying decreases due to the presence of the grapeseed oil finish over the fabric surface. It may be due to the bonding of water molecules with the oil molecules.

Effect on the Moisture Management Properties

Table 5 shows the moisture management results of all the treated samples. The observed top wetted radius is 15 mm for polyester/cotton and polyester/viscose fabric samples as compared to 5 mm for micro-polyester and texturized polyester fabrics. This is because of the hydrophilic nature of cotton and viscose fibres, which absorb the moisture and spread it farther. Top absorption rate for texturized polyester fabrics is comparable to polyester/cotton fabric, but the bottom wetting time is much higher, and therefore, the bottom absorption rate and accumulative one-way transport are also lower. Similarly, bottom-wetted radius is also higher for polyester/cotton and polyester/viscose fabric samples, because of absorption of moisture and its transport to the other sides of fabrics. The top spreading speed and bottom spreading speeds for polyester/cotton and polyester/viscose fabric are observed higher as compared to polyester fabrics. Top wetting time is 2 s-3 s for polyester/cotton and polyester/viscose fabrics, whereas it is observed 10 s in case of texturized fabrics. Figure 8 shows the graphical representation of all grapeseed oil-treated samples and their liquid spreading behaviour.

Conclusion

The study provides the combined effect of physiological and antibacterial properties for healthcare and hygiene textiles. Grapeseed oil finish possesses a significant effect on the antimicrobial and physiological properties of the treated samples. The antibacterial activities have been found to be significant even after 50 washes for all treated fabric samples. A microbial resistance of 49 and 40% is observed, respectively, against both *S. aureus* and *E. coli* bacteria after 50 home laundry washes. The finish concentration of grapeseed oil holds a major influence on the physiological properties of all the treated samples. The comfort properties are highly influenced by the concentration of the grapeseed oil finish. The polyester/cotton fabric is found to be having maximum water repellency of 28.3 cm. Also, all treated samples show better water repellency at 20% concentration of grapeseed oil finish. The contact angle properties of the treated samples also improved after treatment. From moisture management testing, 100% micro-polyester- and 100% texturized polyester-treated fabric samples are found to be water repellent. Polyester/cotton and polyester/viscose treated fabric samples are found to be water-absorbing. Among the tested samples, polyester/viscose grapeseed oil-treated fabric can be considered as an optimal material for healthcare and hygiene applications, with good

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antimicrobial efficiency, good WVTR, high dry rate, moderate water repellency with improved contact angle.

**Funding** No funding was received for conducting this study.

**Declarations**

**Conflict of interest** The authors declare that there are no conflicts of interest.

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