Grapeseed oil (*Vitis Vinifera* L.) treatment on polyester based fabrics to develop antibacterial and physiologically comfortable health-care and hygiene textiles

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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, odor-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 48% and 39% respectively against *S. aureus* and *E. coli* bacteria after 50 home laundry washing cycles.

Introduction

The health care textile sector is an emerging sector for developing countries where people are now aware of the risks of blood borne diseases. As a result, the rapidly growing population and the emerging standard of living helped identify a vast potential for health care textiles [1]. In the current scenario, researchers are focused 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]. In the fast-growing healthcare textile market, the application of green textiles is of great importance. Many researchers have reported the development in medical textiles using natural materials in recent years [5-7]. Apparently, given the drastic consumer demand for sustainable environment-friendly products, the attention for alternatives to synthetic agents is a cause of concern among researchers [8-9]. Natural bioactive agents are mostly extracted from plants (Aloe vera, tea tree and eucalyptus oil (EO), neem, grapefruit seed, Tulsi leaf extracts, etc.), include phenolics and polyphenols (simple phenols, phenolic acids, quinones, flavonoids, flavones, flavanols, tannins and coumarins), terpenoids, essential oils, alkaloids, lectins, polypeptides and polyacetylenes and thanks to its wide availability, biological compatibility, non-toxic nature, the ecological approach is gaining wide acceptance for use in fabrics. Many approaches have been made to explore the various possibilities of such herbal agents for manufacturing highly functional textiles, such as antimicrobials, deodorants/ aromatics, insect repellents, fire retardants, UV protection are some of the revolutionary properties that have been added to fabrics in the recent years [10-14]. Antimicrobial modification of textiles has become necessary to barrier from infections by pathogenic microorganisms. In order to provide an antimicrobial effect to textiles, researchers have set a major benchmark in the discovery and development of new non-toxic and ecological agents [15-18]. The effect of natural functional finishes on the comfort properties of the fabric has been documented by a few researchers [16, 19-20]. It has been reported that most of the natural antimicrobial agents are insoluble and adversely affect the physical and other functional properties of fabrics. The researchers proposed several new strategies to immerse natural (bioactive) agents into the textiles [21-23]. When they normally react with textiles, bioactive agents often lose their bioactivity. Intensive analysis is thus deemed to be explore and exploit the more efficient use of environmentally sensitive antimicrobial agents. As a result, a variety of new approaches are applied to overcome the limitations of wash cycles on finished textiles such as crosslinking of agents with resin and the inclusion of liquid bioactive components such as essential oils in the sol-gel matrix. Also, Microencapsulation by phase separation/coacervation followed by application of microcapsules by pad dry cure methods are recently in trend. [24].

A novel approach has been evolved to investigate the implementation of grapeseed oil on various textiles. Generally, grapeseed oil is obtained from the seeds of grapes, a substantial by-product of the winemaking process. It has been reported previously that grape seed oil is a source of rich phenolic compounds including flavonoids, carotenoids, phenolic acids, tannins, and stilbenes, catechins, epicatechins, trans-resveratrol, and procyanidin B1. It has been stated somewhere that the resveratrol is mainly responsible for antimicrobial properties [25-28]. No work has been done so far on the grapeseed oil-treated textiles to investigate its antibacterial and comfort properties.

In this research article, polyester-based fabric structures are pretreated with an optimized concentration of interacting solvent trichloroacetic acid-methylene chloride (TCA-MC), which influences the amorphous and crystalline region (Solvent induced crystallization) and finally responsible to produce more voids and cracks to facilitate the easy entry of molecules to entrap within the structure. In previous studies it has been stated that the interacting power of the TCA-MC reagent is very high with the polyethylene terephthalate (PET) and it dissolves the complex polymer matrix of PET at about 25% (w/v) concentration in 5-minute duration at room temperature. The lower concentration of the TCA-MC reagent is sufficient enough to facilitate the entry of grapeseed oil into the compact polyester structure [29-30]. The functional characteristics of these polyester fabric samples, i.e., water repellency and antibacterial properties, together with the comfort characteristics, are discussed in this article.

Materials And Methodology

Four different polyester fabric structures 100 % texturized polyester, 100% micro-polyester, polyester/ viscose and polyester/cotton of 165 g/m² using Oxford weave (derivative of plain weave) are used. The characteristics of the materials are presented in Table 1. Laboratory grade trichloroacetic acid (CCl₃-COOH), methylene chloride (CH₂- Cl₂) and acetone (CH₃-CO-CH₃) are used. Commercial grade grape seed oil (C₁₈H₃₂O₂) having molecular weight of 280.445 is 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 3-minute duration at room temperature. The treated samples are then rinsed with methylene chloride followed by acetone to remove any adhering reagent. Later, the samples are dried in an open atmospheric condition before process it with grapeseed oil [29].

The TCA-MC pretreated-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 material to liquor ratio of 1:25 at 80°C for 20 minutes. Subsequently, the fabric samples are washed

thoroughly with hot and cold water before testing and characterization [29-30]. A physiochemical reaction takes place in between polyester structure and grapeseed oil structure and is represented as:

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. The FTIR spectrum, thus, gives information about the functional groups of the compound. The water repellency of the treated fabric 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 evaluate 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 presence of liquid/water droplet of 0.1 μL resolution using - PCA-11(by kyowa) instrument.

The permeability to water vapor 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 vapor loss rate (MVTR, water vapor transfer rate) is calculated using the following formula:

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

where M is the loss in mass (g), t time between weighing (h), and A internal area of dish (m^2).

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.

Results 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 physiological comfort and antimicrobial properties.

Surface morphology and characterization

The surface morphology of the untreated and TCA-MC pre-treated grapeseed oil-treated micro-polyester fabric samples are shown in Figure 1. From figure 1(b), 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 attach with the structure during treatment. Figure 2 represents the average spectra of the untreated micro polyester samples and 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 grape seed oil treated sample shows a large band peaking at about 3415 cm^{-1} corresponding to the OH stretching. It can be due to polysaccharides and/or lignin as stated in previous studies [27]. Asymmetric and symmetrical stretching vibrations of the CH_2 groups are observed at 2920 and 2855 cm^{-1} , respectively. They are mostly concerned with the lipid or lignin chains of hydrocarbons. In the fingerprint area, as opposed to the untreated micro polyester sample, the grape seed 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 2(b), depicts the elementary analysis of the treated samples and further confirmed the presence of grapeseed oil elements on the surface [28].

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 2 shows the antibacterial activity of the untreated and treated samples after 50 wash cycles. This equates to 50 home cleanings with AATCC 61. After 50 washes, all treated samples shown substantial antibacterial activity. It is also observed from table 2, that the finish concentration significantly affects the antibacterial activity of the treated samples. Table 2 reveals that CFU/ml ($\times 10^{-8}$) for untreated sample is 80 for *S. aureus*. As the concentration of the grapeseed oil rises from 5% to 20% the CFU/ml ($\times 10^{-8}$) decrease from 25 to 11 for texturized polyester fabric and thus increase the antibacterial activity of the treated samples. The polyester/ viscose fabric treated with 20% grapeseed oil show maximum antibacterial activity of 48% and 39% 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. Figure 3 shows the antibacterial activity on polyester/ viscose fabric sample before and after treatment. The untreated samples fig. 3(a) and 3(d) show maximum growth of bacteria underneath and around the samples. From figure 3(b) and 3(e) 20% grapeseed oil treated polyester/ viscose samples, the bacterial growth is restricted around the treated samples and a clear inhibition zone is visible even after 50 washes (See fig. 3c and 3f).

Water repellency and resistance to blood

It has been observed that the all the treated fabric samples show significant improvement in the hydrostatic pressure test (Table 3). From table 3, It is observed that the finish concentration influences the water repellency of the treated fabric samples. As the grapeseed oil concentration increases, the hydrostatic pressure also increases. 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 14.6 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 highly 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 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 characteristics (Figure 4). Figure 4(a-b) shows the moderate increase in contact angle of the micro-polyester fabric structure from 78° to 84.1° with a 20% finish concentration of grapeseed oil. Similarly, from figure 4(c-d), 20% grapeseed oil-treated texturized polyester fabric shows a significant increase in the contact angle from 45.7° to 75.6°. Similar trends are observed in case of grapeseed oil treated polyester/ viscose and polyester/ cotton fabric samples. Figure 4(e-f) The contact angle of polyester/ viscose treated fabric increases from 35.5° to 80° with a 20% finish concentration. In figure 4(g-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 3. Polyester/ cotton fabric samples shows the highest WVP among all fabric samples. Higher density of cotton fibres reduce 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 $p < .05$ with f-ratio value 16.87322 and p-value 0.0002. Figure 5 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

Figure 6 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 figure 6, 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 $< .0001$. 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 4 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 is 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 side 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 2s-3s for polyester/ cotton and polyester/ viscose fabrics whereas it is observed 10s in case of texturized fabrics. Figure 7 shows the graphical representation of all grapeseed oil-treated samples and their liquid spreading behavior.

Conclusion

The study provides the combine 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 moderate microbial resistance of 48 % and 39% is observed respectively against both *S. Aureus* bacteria 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 higher concentration (20%) 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 antimicrobial efficacy, good WVTR, high dry rate, moderate water repellency with improved contact angle.

Declarations

There is no conflict of interest between authors and any agency. The authors declare no competing interests.

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Tables

Table 1: Fabric Specification

S.no	Fabric	Fabric GSM (g/m ²)	Weave	Yarn density		Linear density		Thickness (mm)
				Warp	Weft	Warp	Weft	
1	100% Micro polyester	165	2/2 oxford weave	64 ^a	44 ^b	2/30 ^c	2/30 ^c	0.85
2	Polyester/viscose (65/35)	165	2/2 oxford weave	64 ^a	44 ^b	2/30 ^c	2/30 ^c	0.85
3	Polyester/cotton (65/35)	165	2/2 oxford weave	64 ^a	44 ^b	2/30 ^c	2/30 ^c	1.1
4	100% Texturized polyester	165	2/2 oxford weave	144 ^a	110 ^b	150 ^d	150 ^d	0.8

a) ends/cm; b) picks/cm; c) Ne; d) den

Table 2: Effect on the antibacterial properties of TCAMC pretreated grapeseed oil treated polyester structures

S. No	Fabric type	Finish conc. (%)	Antibacterial activity without laundry (%)				Antibacterial activity after 50 home laundry washes (%)			
			<i>S. aureus</i>		<i>E. coli</i>		<i>S. aureus</i>		<i>E. coli</i>	
			CFU/ml (×10 ⁸)	Antibacterial activity (%)	CFU/ml (×10 ⁸)	Antibacterial activity (%)	CFU/ml (×10 ⁸)	Antibacterial activity (%)	CFU/ml (×10 ⁸)	Antibacterial activity (%)
1	Untreated sample	-	80	-	110	-	80	-	110	-
2	100% texturized polyester	5	25	69	48	56	65	19	91	17
		10	22	73	44	60	62	23	87	21
		15	15	81	38	65	54	33	82	25
		20	11	86	31	72	48	40	77	30
3	100% micro polyester	5	23	71	44	60	60	25	88	20
		10	19	76	42	62	56	30	85	23
		15	17	79	34	69	51	36	75	32
		20	10	88	29	74	44	45	70	36
4	Polyester/ viscose	5	18	78	41	63	58	28	87	21
		10	15	81	39	65	54	33	83	25
		15	12	85	32	71	48	40	74	33
		20	8	90	27	75	42	48	67	39
5	Polyester/ cotton	5	27	66	51	54	63	21	90	18
		10	23	71	46	58	60	25	86	22
		15	20	75	40	64	55	31	78	29
		20	16	80	33	70	49	39	73	34

Table 3: Effect of finish on water repellency and comfort properties of polyester structures (without laundry)

S. No	Fabric type	Finish conc. (%)	WVP (g/m ² / 24hr)		Hydrostatic pressure test (cm)		Resistance to blood (pass/fail)		Contact angle (°)		Untrea
			Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	
1	100% texturized polyester	5	1.31	1.16	6.5	14.6	Fail	Fail	45.7	54.3	1.32
		10	1.31	1.12	6.5	22.6	Fail	Fail	45.7	58.1	1.32
		15	1.31	1.10	6.5	23.5	Fail	Fail	45.7	68.9	1.32
		20	1.31	1.10	6.5	24.6	Fail	Fail	45.7	75.6	1.32
2	100% micro polyester	5	1.28	0.66	8.5	21.5	Fail	Fail	78.0	79.2	2.32
		10	1.28	0.53	8.5	24.6	Fail	Fail	78.0	80.4	2.32
		15	1.28	0.51	8.5	24.5	Fail	Fail	78.0	81.2	2.32
		20	1.28	0.48	8.5	28.2	Fail	Fail	78.0	84.1	2.32
3	Polyester /viscose	5	1.31	1.20	5.5	14.7	Fail	Fail	35.5	65.7	1.97
		10	1.31	1.18	5.5	20.6	Fail	Fail	35.5	71.4	1.97
		15	1.31	1.17	5.5	23.3	Fail	Fail	35.5	73.2	1.97
		20	1.31	1.15	5.5	26.9	Fail	Fail	35.5	80.0	1.97
4	Polyester /cotton	5	1.44	1.31	6	17.9	Fail	Fail	62.6	67.5	0.77
		10	1.44	1.27	6	21.6	Fail	Fail	62.6	72.3	0.77
		15	1.44	1.25	6	23.4	Fail	Fail	62.6	76.4	0.77
		20	1.44	1.22	6	28.3	Fail	Fail	62.6	81.5	0.77

Table 4: Moisture management properties of TCAMC pretreated grapeseed oil treated (20% conc.) fabric samples

Fabric sample	Wetting time top (s)	Wetting time bottom (s)	Top absorption rate (%/s)	Bottom absorption rate(%/s)	Top max wetted radius (mm)	Bottom max wetted radius (mm)	Top spreading speed (mm/sec)	Bottom spreading speed (mm/sec)	Accumulative one-way transport index %	OMMC
100% texturized polyester	10.969	120.0	72.0407	0.0	5.0	0.0	0.4482	0.0	-493.068	0.0
100% micro polyester	6.562	89.547	31.779	4.0442	5.0	5.0	0.7407	0.0557	-492.0427	0.0
Polyester/ viscose	3.281	3.656	29.8273	32.3761	15.0	15.0	3.0216	2.7575	97.1322	0.372
Polyester/ cotton	2.813	8.156	72.5221	45.7477	15.0	10.0	2.7629	1.2918	-406.529	0.1236

Figures

(a)

(b)

Figure 1

(a) Morphology of untreated 100 % micro polyester fabric sample, (b) Morphology of grapeseed oil treated 100 % micro polyester fabric sample

Figure 2

(a) FTIR spectroscopy of untreated 100% micro polyester and grapeseed oil treated 100 % micro polyester fabric samples, (b) EDS spectrum of TCAMC pretreated grapeseed oil treated 100 % micro polyester fabric sample

Figure 3

Antibacterial activity against *S. aureus* on P/V fabric (a-c); (a) Untreated sample, (b) 20% grapeseed oil treated sample, (c) 20% grapeseed oil treated sample after 50 home laundry washes and antibacterial activity against *E. coli* on PV fabric (d-e); (d) Untreated sample; (e) 20% grapeseed oil treated sample; (f) 20% grapeseed oil treated sample after 50 home laundry washes.

Figure 4
 (a,c,e,g) respectively shows the contact angle of untreated 100% micro polyester polyester, 100% texturized polyester, polyester/ viscose, polyester/ cotton & (b,d,f,h) respectively shows the contact angle treated samples

Figure 5
 Effect of 20 % grapeseed oil finish concentration on fabric's WVP

Figure 6

Effect of 20 % grapeseed oil finish concentration on fabric's drying rate

Figure 7

(a-b) 100% texturized polyester polyester, (c-d) 100% micro polyester, (e-f) polyester/ viscose and (g-h) polyester/ cotton