

Wool/polyester blends with UV protection and disperse printing

H. M. Khalil

Faculty of Applied Arts, Printing, Dyeing and Finishing Department, Helwan University, Cairo, Egypt,
bopart_star@yahoo.com

Abstract:

A novel method for improving disperse print quality and UV-protecting efficiency of blended fabric wool/polyester was developed by combining UV-SUN[®] CEL LIQ as a UV-absorber or TiO₂-NPs as a blocker of UV into the disperse printing paste [β CD (10g/Kg), PEG-600 (20g/Kg), DMDHEU (10g/Kg), Citric acid (10g/Kg), Na-alginate (500g/Kg), and Disperse dye (20g/Kg)]. The achieved results reveal that when other parameters remain constant, the improvement in UV-protective capability follows the decreasing order TiO₂ NP's > UV-SUN[®] CEL. The depth of dispersed printings, on the other hand, is the polar opposite. The amount of UV-protective agent put into the fabric surface, as well as the positive impact of the utilized disperse dye on blocking and/or absorbing damaging UV-B radiation, influence UV-protection ability. Even after 15 washing cycles, the UV-protection characteristic imparted is still effective.

Keywords:

Wool/polyester blended fabric, disperse printing, UV-protecting, Nanosized material, UV-absorber, or UV-blocker.

Paper received 27th February 2021, Accepted 13th April 2022, Published 1st of May 2022

1- Introduction

UVR is a type of electromagnetic radiation with wavelengths ranging from 150 to 400 nanometers. UV-radiation is classified as UV-A (315-400 nm), UV-B (280-315 nm), which causes skin cancer and burns, and UV-C (315-400 nm) (100-280 nm). This type is totally absorbed by ozone and the atmosphere's oxygen and never reaches the Earth's surface (1-4).

As a result, in recent years, researchers have focused on developing UV-absorbers such as derivatives of *o*-hydroxyphenyl hydrazines, *o*-hydroxyphenyl triazines, *o*-hydroxybenzophenones (5-9) and/or inorganic blockers of UV such as TiO₂ nanoparticles (9-13) and ZnO nanoparticles to add or enhance the properties of protection against harmful UVR and their negative effects such as damage, skin (13-17, 9).

UV protection is determined by the type of fibre, fabric construction, coloring chemicals employed, and finishing processes applied (9).

The goal of this study is to create a combined processes to enhance the disperse printability and UV-blocking efficiency of a blend fabric (wool/polyester) by TiO₂ NP's as a UV-blocker or incorporating UV-SUN[®] CEL as a UV-absorber into the disperse printing paste [β CD, Citric acid, PEG-600, DMDHEU, Na-alginate, and Disperse dye].

2. Experimental

2.1. Materials

The fabric used in this study was mill-scoured, and semi-bleached wool/polyester (50/50, 230g/m²) blend.

Cavasol[®] W7 [beta cyclodextrin with seven glucose

units, Wacker, Germany], Dialgin[®] LV-100 [Na-alginate of low viscosity, BF-Goodrich Diamalt, GmbH, Germany], UV-SUN[®] CEL LIQ [UV-absorber based on oxalanildin, Huntsman, USA], and Arkofix[®] NDF liquid C [low formaldehyde-reactant resin based on modified N-methylol dihydroxyethylene urea, Clariant), were of commercial grade.

In addition, commercial disperse dyes namely Disperse Blue 183, and Disperse Red 74 Sinochem Ningbo, China, were used in this study.

Ti-tetraisopropoxide [analytical grade, sigma], and other laboratory, grade chemicals such as citric acid, nitric acid and PEG-600 were employed.

2. 2. Methods

2.2.1. Preparation of TiO₂-NP's

TiO₂-nano sol was synthesized by mixing titanium iso-propoxide (1%), as a precursor, with 100 ml of water containing nitric acid (1%) at room temperature to prepare the stock solution. The mixture was vigorously stirred for 20 hr's prior to using.

2.2.2. Combined functional finishing and printing

The wool/polyester fabric samples were anti-UV finishing and disperse printing using the flat screen technique and the following print paste formulations:

Components	g/kg paste
a- Disperse dye	20
Na-alginate (10%)	500
Citric acid	10
DMDHEU (35%)	10
β CD (Cavasol [®] W7)	10
PEG-600	20

(without using carrier)	
b- UV-protector	
UV-Sun [®] CEL	0-20g
or TiO ₂ -NP's	0-20g
c- H ₂ O	X
Total	1000g

Printed fabric samples were then dried at 85°C for 5 min and steam fixed at 110°C for 20 min using Ariolt[®] CSL-Steamer-Italy, rinsed thoroughly, soaped for 15 min at 60°C in the presence of 2g/L Leomin[®] W (nonionic wetting agent and detergent-BASF), then thoroughly rinsed and finally dried at 85°C for 5 min.

2.2.3. Testing

The depth of the obtained disperse prints, expressed as K/S, was measured at the wavelength of the maximum absorbance using an automatic-filter spectrophotometer, and calculated by the Kubelka Munk equation (Judd & Wyszeck, 1975)(18):

$$K/S = (1-R)^2 / 2R$$

where K,S, and R are the absorption coefficient, the scattering sufficient and the reflectance at the wavelength of maximum absorbance of the used dye respectively.

Fastness properties to washing, crocking, perspiration and light of printed fabric samples were evaluated according to AATCC test methods:

(61-1972), (8-1972), (15-1973) and (16A-1972) respectively.

UV-protection factor (UPF) was evaluated according to AS/NZS 4399-1996 standard.

The durability to wash (after 15 launder cycles) was determined according to AATCC test method 135-2000.

3. Results

To achieve simultaneous, disperse printing and anti-UV protection on wool/polyester, UV-absorbers such as β -CD and UV-SUN[®] CEL, as well as UV-blockers such as TiO₂-NPs, were mixed into the finishing/ printing paste before steam fixation. The effects of β -CD content and the type and concentration of UV-absorber, on the simultaneous step were investigated.

3.1. Beta cyclodextrin content

Fig.1 shows that increasing the β -CD concentration up to 10g/kg enhance the depth of color (K/S) (19), increasing the beta cyclodextrin concentration results a slight decrease in the depth of resulted printings, and increasing the K/S value of printed samples is created to the positive effect of corporation β -CD moieties onto the printed fabric through use of covalent bonds, thereby generating hydrophobic cavities within / onto the fabric(20, 21).

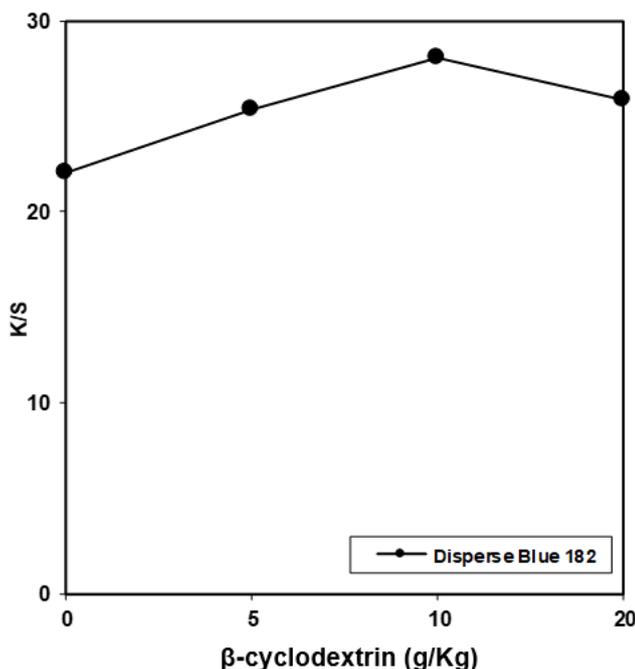


Fig.1. Effect of incorporation of β -cyclodextrin on K/S of the obtained prints into disperse printing.

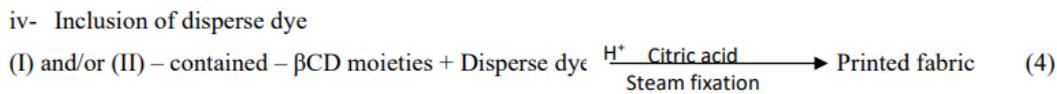
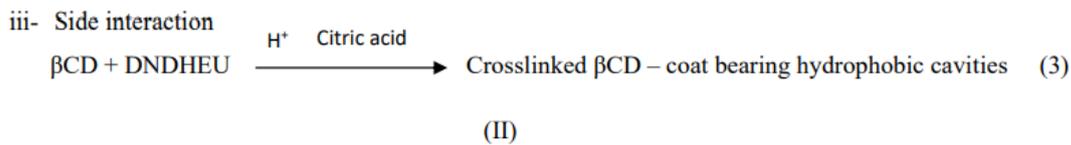
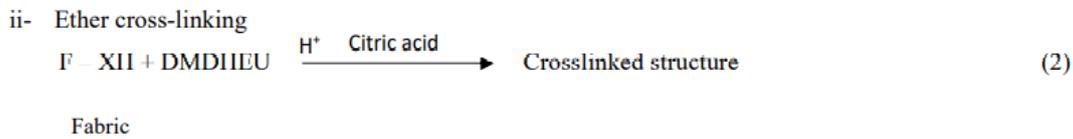
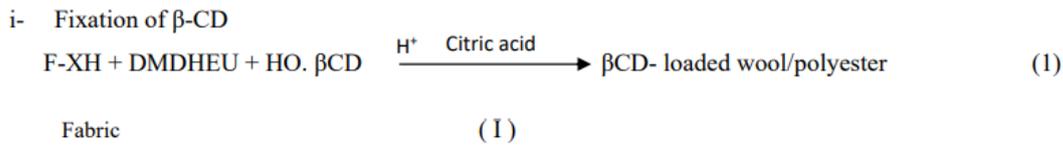
Disperse Printing formulation: Disperse dye (20g/Kg); Sodium alginate (10%) (500g/Kg); citric acid (10 g/Kg); Arkofix[®] NDF (10g/Kg); β -CD (0-20g/Kg); PEG-600 (20g/Kg).

Drying followed by steam fixation at 120 °C/20min.

The following is the most likely interaction mechanism between citric acid, DMDHEU, β -CD, disperse dye, and the fabric during in the steaming fixation process (19, 22).

Furthermore, an increase in β -CD content, above 10 g/Kg, results in a decrease in K/S. which is

attributed to increased printing formulation viscosity, side reactions with beta cyclodextrin, and partial hydrolysis of the beta cyclodextrin, which impedes the movement and mobility of disperse dye molecules, resulting in a decrease in K/S of obtained disperse prints (23,24).



3.2. UV-protective agent

The effect of additional TiO_2 nano particle size, as a UV-blocker, or UV-SUN[®] CEL, as a UV-absorber, on the depth of printed fabric is shown in Fig. 2(a). It shows that raising the 10g/Kg concentration in the disperse printing paste, together with other ingredients, increases K/S of the printed samples. As a direct result of blocking and/or a reduction in

the number of dyes sits on fabric, increasing the concentration beyond 10g/Kg results in a slight decrease in K/S and/or a reduction in the number of dye sits on fabric, reducing the transfer of disperse dye from printing paste film to surface of the fabric during the fixation step, i.e. lower depth of shade values.

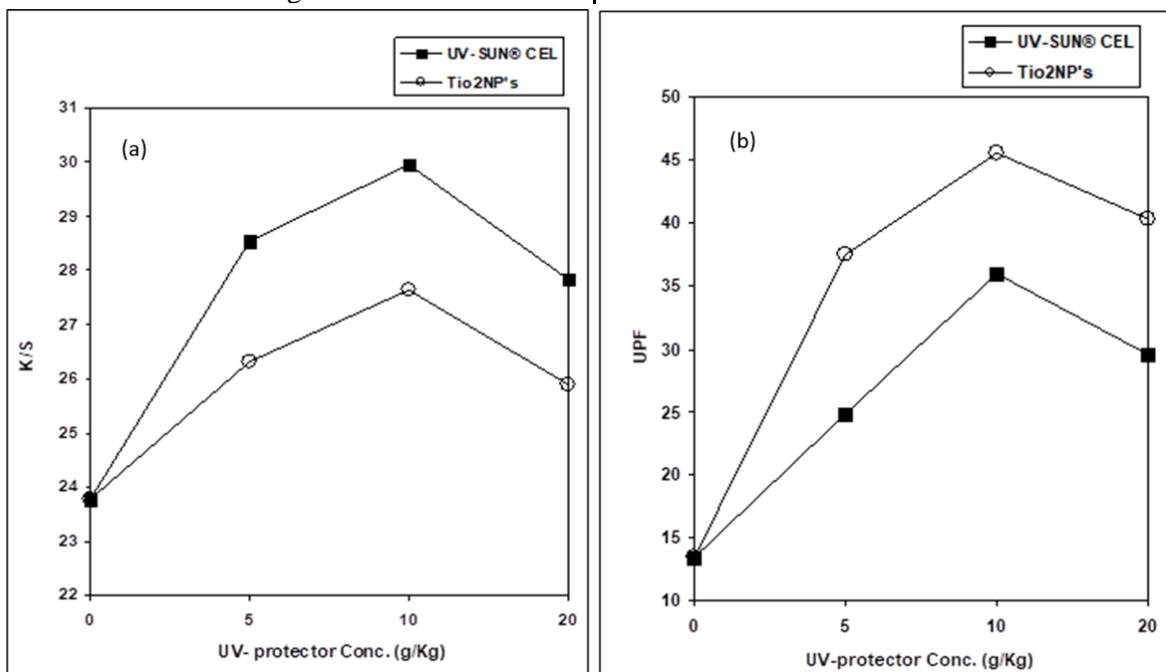


Fig.2. Effect of anti-UV type and concentration on K/S (a) and UPF (b) of the functionalized disperse prints.

Disperse Printing formulation: Disperse dye (20g/Kg); Sodium alginate (10%) (500g/Kg); citric acid (10g/Kg); Arkofix[®] NDF (10g/Kg); β -CD (0-20g/Kg); PEG-600 (20g/Kg); UV-agent (0-20 g/Kg)

Drying followed by steam fixation at 120 °C/20min.

The decreasing order was followed by an increase in K/S values: UV-SUN[®] CEL > TiO₂-NP's (5).

The difference in UPF factor as a function of UV-SUN[®] CEL and TiO₂-NP concentration is shown in

Fig. 2(b). Incorporation of UV-SUN[®] CEL, by inserting UV-SUN[®] CEL on/within the wool/polyester fabric, 10g/Kg, results in a significant enhancement in UPF values, as shown

in Fig. 2(b). UV-SUN[®] CEL treated fabrics have a higher UV-B absorption capacity as well as the ability to disperse energy, resulting in significant UPF values.

The addition of 10g/Kg nano TiO₂-Sol to the printing paste results in a significant increase in the UV protection value, indicating that the printings produced have outstanding UV-protection capacity. The UV-blocking functionality imparted to the disperse printed fabric demonstrates the good impact of nano-sized TiO₂ on increasing UV-blocking efficiency, which is most likely owing to their increased surface area and high UV absorption (26-29, 5). Furthermore, the absorption ability of the TiO₂-NPs-loaded substrate in the UV-region of 280-400nm determines the enhancement in UV-blocking ability of printed samples (28,30).

Table 1. Effect of UV-protective/ printing properties of printed wool/polyester blended fabric using different disperse dyes along with β -CD in the printing paste.

g/Kg)	UV-Protector	K\S	Incr. in K/S (%)	WF		RF		PF				LF	UPF
				Alt	C	Dry	Wet	Acidic		Alkaline			
								Alt	C	Alt	C		
Disperse Blue 183	None	23.97	-	3-4	4	3-4	4	3-4	3-4	4	4	4	13.41
	UV-SUN [®] CEL (10g/Kg)	29.97	25.97	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	35.91 (28.02)
	TiO ₂ -NP's (10g/Kg)	27.15	14.12	5	4-5	4-5	5	4-5	4-5	4-5	4-5	4-5	45.56 (37.44)
Disperse Red 74	None	5.14	-	4	3	4	4	4	4	4	4	4	18.57
	UV-SUN [®] CEL (10g/Kg)	9.18	78.9	4-5	3-4	4-5	4-5	4-5	4-5	4-5	4-5	4-5	30.01 (26.15)
	TiO ₂ -NP's (10g/Kg)	8.16	58.75	5	4	4-5	4-5	4-5	5	4-5	5	4-5	32.18 (28.36)

Disperse Printing: Disperse dye (20g/Kg); Sodium alginate (10%) (500g/Kg); citric acid (10g/Kg); Arkofix[®] NDF (10g/Kg); β -CD (10g/Kg); PEG-600 (20g/Kg); UV-protector (10 g/kg); Drying followed by steam fixation at 120 oC/20min. K/S: color depth; WF: wash fastness; RF: rubbing fastness; PF: perspiration fastness; LF: light fastness; Alt: alteration; C: staining on cotton; UPF: ultraviolet protection factor; Values in brackets represent durability to wash after 15 laundering cycles.

The type of disperse dye used and the UV-protective agent used (UV-absorber or UV-blocker) determine the increase in printing and protection properties. The enhancement in UV-protection ability, on the other hand, is determined by the type of functional additive and follows a declining order: TiO₂-NP's > UV-SUN[®] CEL >> none Even after 15 washing cycles, wool/polyester prints provide excellent UV protection. (5).

4. Conclusion

Functionalized wool/polyester disperse prints were created by individually incorporating UV-SUN[®] CEL (10g/Kg) or TiO₂-NPs (10g/Kg) along with β -CD (10g/Kg), DMDHEU (10g/Kg), citric acid (10g/Kg), PEG-600 (20g/Kg), Disperse dye (20g/Kg), and Sodium alginate (500g/Kg) in print formulation, printing and steaming at 120oC/20min, As a UV-protecting agent, the improvement in UPF values of the produced disperse prints follows a descending order: TiO₂-

NP's > UV-SUN[®] CEL >> none.

3.3. UV-protection and fastness properties

Table 1 shows the effect of using UV-SUN[®] CEL as a UV-absorber or TiO₂-NP's as a UV-blocker on the printing and UV-protecting properties of printed fabric (wool/polyester) with nominated disperse dyes and beta cyclodextrin in the printing formulation. The obtained data show an increase in fastness properties, K/S, and UV-protecting capacity of the printings. The fastness properties of the printed fabrics using the selected functional additives ranged from very good to excellent, regardless of the disperse dye used.

NP's > UV-SUN[®] CEL >> none.

The fastness properties of the prints obtained with the selected functional additives ranged from very good to excellent. Even after 15 washing cycles, the printed samples retained its excellent UV-protection properties, Finally, the one-step procedure provided can be applied on an industrial scale.

References

- Zhou Y, Yang ZY and Tang RC. (2020). Facile and green preparation of bioactive and UV protective silk materials using the extract from red radish (*Raphanus sativus* L.) through adsorption technique. Arab Journal Chem 13, 3276–3285.
- Ibrahim, N. A., Gouda, M., Hussein, Sh. M., El-Gamal, A. R., and Mahrous, F., (2009). UV-protecting and antibacterial finishing of cotton knits. Journal of Applied Polymer Science, 112, 3589–3596.

3. Schindler, W. D. & Hauser, P. I. (2004). *Chemical Finishing of Textiles*. Woodhead Publishing Ltd, England , p. 120-126, 157-160.
4. Abidi, N., Hequete, E., Tarimala, S. & Dai, L. L. (2007). Cotton fabric surface modification for improved UV-radiation protection using sol- gel process. *Journal of Applied Polymer Science*, 104, 111-117.
5. Ibrahim, N. A., El-Zairy, E. M. R., Abdalla, W. A. & Khalil. H. M. (2013). Combined UV-protecting and reactive printing of cellulosic/wool blends. *Carbohydrate Polymers*, 92, 1386-1394
6. Ibrahim, N. A., Khalil. H. M., El-Zairy, E. M. R. & Abdalla, W. A. (2013). Smart options For simultaneous functionalization and pigment coloration of cellulosic/wool blends. *Carbohydrate Polymers*, 96, 200-210.
7. Hustvedt, D., & Crews, P. (2005). The ultraviolet protection factor of naturally pigmented cotton. *The Journal of Cotton Science*, 9, 47-55.
8. Saravanan, D. (2007). UV Protection textile material. *AUTEX Research Journal*, 7, 53-62.
9. Alebeid, Omar Kamal & Zhao, Tao. (2017). Review on: developing UV protection for cotton fabric. *The Journal of The Textile Institute*, Dol: 10. 1080/00405000. 2017.1311201.
10. Becheri, A., Maximilian, D., Nostro, P. L., & Baglioni, P. (2008). Synthesis and characterization of zinc oxide nanoparticles: Application of textiles as UV-absorbers. *Journal of Nanoparticle Research*, 10, 679-689.
11. El-Shafei, A., & Abou-Okeil, A. (2011). ZnO/carboxymethyl chitosan bionanocomposite to impart antibacterial and UVprotection for cotton fabric. *Carbohydrate Polymers*, 83, 920-925.
12. Yazdanshenas, M. E., & Mohammad, S. K. (2013). Bifunctionalization of cotton textiles by ZnO nanostructures: Antibacterial activity and ultraviolet Protection. *Textile Research Journal*, 83, 933-1004.
13. Hossain, M. A., Rahman, M. (2015). A review of nano particle usage on textile material against ultraviolet radiation. *Journal of Textile Science and Technology*, 1, 93-100.
14. Bae, H. S., Lee, M. K., Kim, W. W., & Rhee, C. K. (2003). Dispersion properties of TiO₂ nano-powder synthesized by homogeneous precipitation process at low temperatures. *Colloids and Surfaces A: Physicochemical Engineering Aspects*, 220, 169-177.
15. Roessler, S., & Zimmermann, R. (2002). Characterization of oxide layers on Ti6Al4V and titanium by streaming potential and steaming current measurements. *Colloids and Surfaces B: Biointerfaces*, 25, 387-395.
16. Mahltig, B., Helfried, H., & Bttcher, H. (2005). Functionalisation of textiles by inorganic sol-gel coatings. *Journal of Materials Chemistry*, 15, 4385-3498.
17. Po-Hsun, L., Ashok Kumar, S., & Shen-Ming, C. (2008). Amperometric determination of H₂O₂ at nano-TiO₂/DNA/thionin nanocomposite modified electrode, *Colloids and Surfaces B*, 66, 266-273.
18. Judd, D. & Wyszeck, G. (1975). *Color in business science and industry*, 3rd edition, John Wiley & Sons. New York.
19. Ibrahim, N. A., Khalil. H. M. & Eid, B. M. (2015). A cleaner production of ultra-violet shielding wool prints. *Journal of Cleaner Production*, 92, 187-195.
20. Khalil, H. M. (2017). Simultaneous disperse printing and uv-protecting of wool/polyester blended fabric. *International Design Journal*, 7, 387-392.
21. Denter, U.& Schollmeyer, E. (1996). Surface modification of synthetic and natural fibres by fixation of cyclodextrin derivatives. *J. Inclusion phenomena & Molecular Recognition in Chemistry*, 25, 197-202.
22. Ibrahim, N. A., El-Zairy, E. M. R., El-Zairy, M. R. & Khalil. H. M. (2010). Improving transfer printing and ultraviolet blocking properties of polyester-based textiles using MCT- β -CD, chitosan and ethylenediamine. *Coloration Technology*, 126, 330-336.
23. Ibrahim, N. A., Abo-Shosha, M. H., Allam, E. A. & El-Zairy, E. M. (2010). New Thickening agents based on tamarind seed gum and karaya gum polysaccharides. *Carbohydrate Polymers*, 81, 402-408.
24. Ibrahim, N. A., El-Zairy, E.M.R., El-Zairy, M. R.& Khalil, H. M. (2011). Enhancing of printing and UV-blocking properties of polyester and polyester/wool fabrics by aminolysis. *AATCC Review*, 11, 52-58.
25. Hong, K. H. & Sun, C. (2008). Antimicrobial and chemical detoxifying functions of cotton fabrics containing different benzophenone derivatives. *Carbohydrate Polymers*, 71, 598-605.
26. Bringer, J. & Hofer, D. (2004). *Nanotechnology and its applications*. Mellaind Int., 10 (4), 295-296.
27. Ibrahim, N. A., Amr, A., Eid, B. M., Mohamed, Z. E. & Fahmy, H. (2012). Poly (acrylic acid)/ poly (ethylene glycol) adduct for attaining multifunctional cellulosic fabrics. *Carbohydrate Polymers*, 89, 648-660.



28. Yang, H., Zhu, S. & Pan, N. (2004). Studying the mechanisms of titanium dioxide as ultraviolet-blocking additive for films and fabrics by an improved scheme, *J. Appl. Polym. Sci.*, 92, 3201-3210.
29. Alya. M., Al-Etabibi and Morsy Ahmed El-Asasery. (2020). Nano TiO₂ imparting multifunctional performance on dyed polyester fabric with some disperse dyes using high temperature dyeing as an environmentally benign method. *International Journal of Environmental Research and Public Health*, 17, 1377-1385.
30. Morabito, K., Shapley, N. C., Steeley, K. G. & Tripathi, A. (2011). Review of sunscreen and the emergence of nano-conventional absorbers and their application in ultraviolet protection. *Int. J. Cosmetic Sci.* 33, 385-390