Egypt.J.Chem. **Vol. 63**, No. 5. pp. 1757 - 1765 (2020)

Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Effect of Geometrical Yarn Parameters: Conventional and Compact Ring Spinning on Certain Functional Properties of TiO2NPs Treated Woven Cotton Fabrics

Ahmad Salman[1], Fatma A. Metwally[1], Manal K. El-Bisi[2], Ghada A.M. Emara[3]
[1]*Textiles Dept., Faculty of Applied Arts, Helwan University, Egypt.*
[2]*Textile Division- Cellulosic Fibers Dept, National Research Center, Egypt.*
[3]*Ministry of Trade & Industry, Egypt*

NANOTECHNOLOGY became a core of many research works specially in textiles field as it is being applied to obtain such effective properties that were not exist until its applications in smart textiles. The development of fibers spinning techniques have created a relationship between the geometrical parameters of yarns and performance properties of the resulted fabrics. Fabrics woven using compact cotton yarns found to have better UV protection and water-vapor transmittance than those of combed yarns. The compactness, evenness and low hairiness of such yarns have created an integrated structure that enhanced fabrics UV protection and water-vapor passage through fabrics. TiO_2NPs have improved total fabrics performance specially for UV protection, while samples of compact yarns had a better result for both properties.

Keywords: Fabric wettability, Geometrical yarn parameters, Nanoparticles, Self-cleaning, UV protection,

Introduction

Fabrics' physical, mechanical, thermal, or even appearance and comfort properties are mainly depending on fiber and yarn properties. Yarn properties are depending on fiber properties and spinning process, and the latter is set according to yarn end use.

Different fabric properties are highly depending on yarn properties which is formed by its geometrical parameters such as: fiber length and fiber diameter and spinning process as for example combed yarns are better in quality than carded ones while compact yarns are the best among all. Also, ring spun yarns are different than those of open-end ones [1].

In yarn production, fibers as a raw material state have no definite orientation or configuration. The first stage in a yarn production process is therefore the cleaning and disentangling of the raw material by blowing process. Yarn evenness depends on fiber parallelism, the fibers must be already straight and parallel which is reached by the final stage of disentanglement that is called carding. However, only very few fibers in a card sliver have a straightened shape, which means that there is an extra process to reach the parallelism [2, 3].

Combed yarns have always been considered as a quality reference among all yarns in textiles industry but it does not mean it is faultless. Combed yarn affects different thermal comfort properties of some fabrics as pilling protection, higher both tearing and bursting strength, higher dyes absorbency, higher air permeability and better fabric appearance [2]

In conventional ring spinning, yarn is characterized with lower exploitation of fiber tenacity and greater hairiness which results in poorer appearance due to spinning triangle which is a triangle shape between the nip line of the front drafting rollers and the twist insertion point, while compact ring spinning is the modification of the conventional ring spinning as the spinning triangle had been almost eliminated. The splayed out

*Corresponding author e-mail: ghd_emara@yahoo.com
Received 14/10/2019; Accepted 31/10/2019
DOI: 10.21608/ejchem.2019.18226.2113

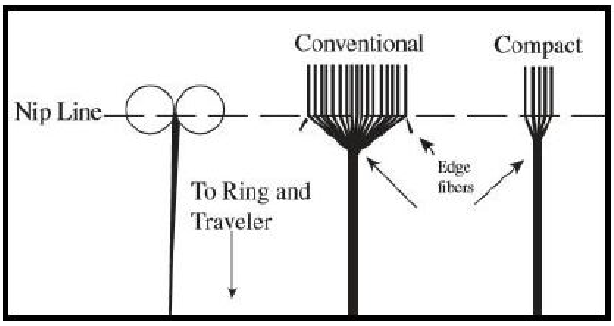
fibers are condensed using air suction. Also, these fibers are contributed to the yarn structure under the same tension, which results in increasing yarn strength and decreasing yarn hairiness as shown in Fig (I.1) [2, 4, 5].

While nanotechnology is defined as the understanding, manipulation and control of the matter at length scale of nanometer so that the physical, chemical and biological properties of materials can be engineered, synthesized or altered to develop the next generations of improved materials, devices, structures and systems.

By applying nanotechnology in textile industry textiles became more durable, comfortable and eco-friendly in addition to low production cost and energy saving [6-9]. Nano materials are now used in various field of industry such as medical and personal care products industries, electronics, packaging and technical textiles industry [10-14].

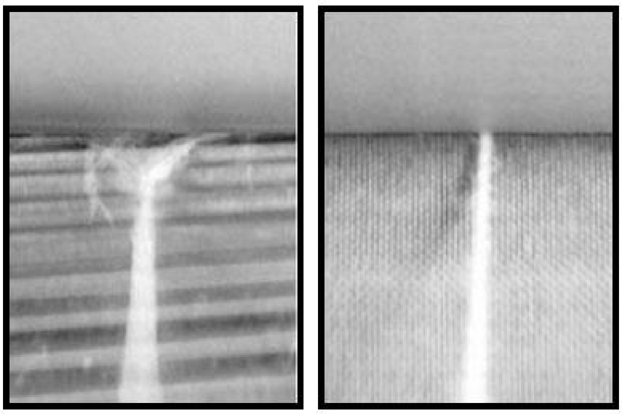
Metal nanoparticles such as zinc oxide, titanium dioxide TiO_2 and a part from titanium dioxide and zinc oxide nano rods found to be more effective to enhance some functional properties when applied to cotton fabrics [9, 15-17].

Anti-bacterial textiles one of nanotechnology applications in this field. Researchers developed silver nanoparticles (Ag NPs) with tailored characteristics which prepared using carboxymethyl chitosan (CMCs) so that it can plays a dual role; as a reducing agent for conversion of Ag+ to Ago and as a stabilizing agent to prevent aggregation of Ago and / or its clusters. Also, the aqueous extract of the shoots of Conocarpus erectus L. (Combretaceae family), was found to be rich in tannins,flavonoids and other phenolics. It showed good inhibitory activity against all tested Gram positive bacteria Moreover, the characterization of nanosized zinc oxide particles and their application in the



(a)

Fig. (I.1a) Edge fibers in both conventional and compact ring spinning (2)



(b) (c)

Fig. (I.1b, I.1c) Conventional and compact ring spun yarn (2)

pretreatment processes of cotton textiles found to be resistant against bacteria and fungus, color strength enhancement and fastness properties improvement [18, 20]

This research work aimed at measuring how could the geometrical parameters of cotton yarns affect the final performance of certain nanoparticles treated fabrics. One nanoparticles treatment was used which is TiO_2 NPs and two geometrical yarn parameters were chosen which are conventional and compact ring spinning. UV protection (UPF), self-cleaning and wettability properties of the treated fabrics were measured.

Materials and Methods

In order to determine how far does geometrical yarn parameters affects the wettability self-cleaning and UV protection functions of TiO_2NPs treated woven cotton fabrics, a methodology was designed. This methodology targeted two geometrical yarn parameters, one cotton grade, one yarn count, three weaving structures and TiO_2NPs treatment divided into two main parts as follows:

The first part: materials selection and fabric production.

The second part: TiO_2NPs treatment and fabric testing before and after treatments.

Materials selection and fabrics production

All samples are woven using 100% 150/48 Polyester warp with 60/cm yarn density. Yarns and fabrics specifications are listed in Tables 1 and 2:

TiO_2 NPs Treatment

All samples were treated by TiO_2 nanoparticles (TiO_2NPs) supplied by Aldrich Chemical Company, USA with the following crystal structure, tetragonal, a = 0.3785 nm, c = 0.9514 nm) from literatures it has band gap = 3.2 eV which is equivalent to a wavelength of 388 nm using: Citric Acid (CA) and Sodium Hypophosphite (SHP). The solution contains TiO_2 (0.5%), sodium hypophosite SHP (2%) as catalyst and citric acid as cross linking agent

TABLE 1: Yarns Specification

No.	Cotton Grade	Yarn Type	Yarn Count(Ne.)	TPI
1	Giza 86	Combed	60/1	33
2		Compact	60/1	33

TABLE 2: Woven Fabric Samples Specifications

Samples No.	Weft Count (Ne.)	Fabric Structure
1-	Combed 60/1	Plain 1/1
2-	Compact 60/1	
3-	Combed 60/1	Basket 3/3
4-	Compact 60/1	
5-	Combed 60/1	Satin 5
6-	Compact 60/1	
7-	Combed 60/1 Compact 60/1	Plain 1/1
8-	Combed 60/1 Compact 60/1	Basket 3/3
9-	Combed 60/1 Compact 60/1	Satin 5
10-	(4) Combed 60/1 (1) Compact 60/1	Plain 1/1
11-	(1) Combed 60/1 (4) Compact 60/1	
12-	(4) Combed 60/1 (1) Compact 60/1	Basket 4/4
13-	(1) Combed 60/1 (4) Compact 60/1	
14-	(4) Combed 60/1 (1) Compact 60/1	Satin 5
15-	(1) Combed 60/1 (4) Compact 60/1	

TiO_2NPs treatment solution was prepared with concentration (4%). Samples were cut into 20 × 30 cm size and then immersed in the solution for 15 minutes. Samples then were squeezed by pressure using the laboratory Padding instrument.

All samples were dried at 100ºC After complete drying all samples were cured at 140 ºC for 3 minutes. Both process drying and curing had been carried out using Raches-Thermo Oven.

Self-Cleaning Test

Self-cleaning of the treated fabrics was carried out according to standardized method of Stain Degradation Assessment (SDA) method, which is developed for the quantitative evaluation of self-c1eaning efficiency of the finished fabric. The method involves first a standardized staining procedure to apply a uniform stain on the fabric, then an instrumental evaluation of photo-degradation of stain in terms of K/S using a template to reduce error, and finally an analysis of K/S values to evaluate stain degradation in percentage.

Stain Application

A solution of methylene blue dye was prepared. Blank (untreated) and TiO_2 NPs treated samples were stained using methylene blue dye of 5 mL dye solution at concentration of 0.1% (wt. %) in distilled water. Samples were immersed in dye solution for 15 minutes. The samples were then dried on a non-absorbing surface with the stained side up.

In order to measure samples self-cleaning ability, blank and TiO_2 NPs treated stained samples were exposed to direct sunlight for 4, 8, 16 and 24 h at ambient conditions.

After exposure time, samples were moved away of light and saved inside a dark pack.

K/S values of the stained specimens before and after the exposure to sunlight were determined using Color-Eye 3100 Spectrophotometer from SDL Inter with 355 nm wave length as shown in Figure (II.2).

The % decrease in K/S (which represent the degree of self-cleaning by photo-degradation of the fabrics) was then calculated at each of the five positions of the specimen by taking K/S before and after the exposure of specimen to sunlight for specific time duration. The % decrease in K/S for each position was calculated using the following formula

$$K/S= (B-A)/B *100$$

Where (A) is K/S of stained and exposed samples and (B) is K/S of stained and unexposed samples. K/S factor refers to samples self-cleaning ability.

Wettability Test

All blank (untreated) and TiO_2 NPs treated samples were cut into 20 × 20 cm size for wettability test, and then each was tightly tensioned over a glass beaker. A dropper was set at fixed length to drop water over each sample. Absorption time needed for this drop to disappear was recorded using a stopwatch according AATCC standards test method,79(1968).

UV resistance test

A 5 × 5 cm^2 size was cut from each blank and treated sample for implementing the UV protection test. Ultraviolet Protection Factor (UPF) values was determined by measuring the Ultraviolet radiation transmittance value of each sample across the wavelength range 280 - 400 nm. The UPF of the treated samples were obtained used Ultra Violet Transmittance Fabric Analyzer-Lab sphere- USA. The UPF values are calculated automatically, in accordance with Australia/Newzeland standard AS/NZS 4399:1996

Results

Water absorption time in seconds was recorded during wettability test. Also self-cleaning percentage (%) were calculated and *UPF* values were registered. all test results are shown in tables 3, 4 and 5.

From table 4, it is obviously clear the differences between blank and treated fabrics. TiO_2NPs treated fabrics had taken less time to absorb the same quantity of water specially those fabrics that woven from compact yarn and plain 1/1 fabric structure. The latter samples have better absorption time if compared with those woven from conventional ring spun combed yarn with the same fabric structure plain 1/1, but differences between compact and conventional ring spun combed yarn for the other fabric structures basket was3/3 and satin 5 not significant as shown in Figure 1.

TABLE 3: Wettability test results

Sample No.	Absorption Time (Sec)	
	Blank	TiO_2NPs Treated
1	37	5
2	28	3
3	63	3
4	54	4
5	102	3
6	100	4
7	51	4
8	56	4
9	85	2
10	39	4
11	40	3
12	33	5
13	79	3
14	74	4
15	35	2

TABLE 4: Self-Cleaning (%)

Sample No.	Self-Cleaning (%)	
	Blank (Untreated)	TiO2 NPs Treated
1	82.7	93.33
2	82.2	94.3
3	82.2	93.4
4	83.2	93.48
5	79.5	91.43
6	79.4	91.6
7	82.7	90.38
8	81.1	92.5
9	79.4	91.67
10	83.5	95
11	83.2	95.1
12	82.4	94.9
13	85	95
14	80	90.24
15	80	91.1

TABLE 5: UV Resistance Test Results

Sample No.	UPF Values	
	Blank	TiO_2NPs Treated
1	17.3	43.9
2	17.8	46.9
3	17.8	54.0
4	16.8	43.5
5	20.5	49.3
6	20.6	61.6
7	17.3	39.4
8	18.9	42.4
9	20.6	67.3
10	16.5	48.8
11	16.8	49.9
12	17.6	34.2
13	15.0	54.5
14	20.0	68.3
15	20.0	74.6

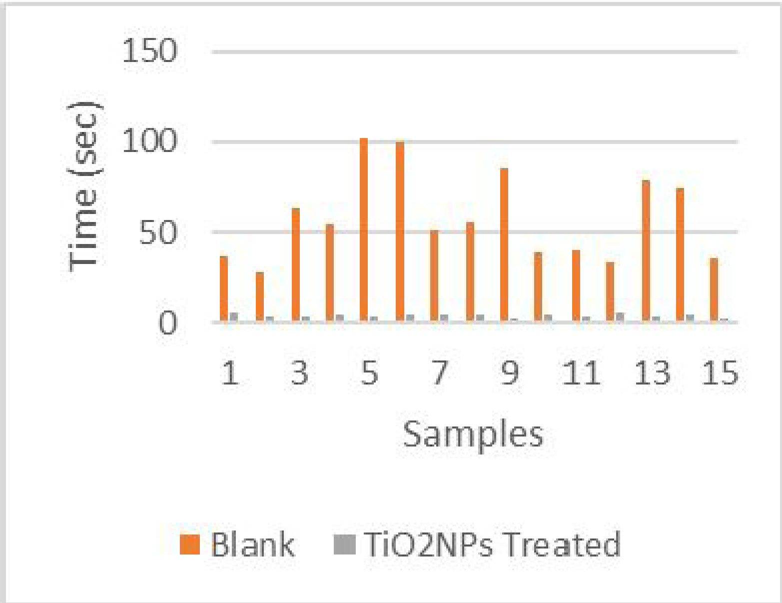


Fig. 2. Effect of TiO2NPs Treatment on Fabric Wettability

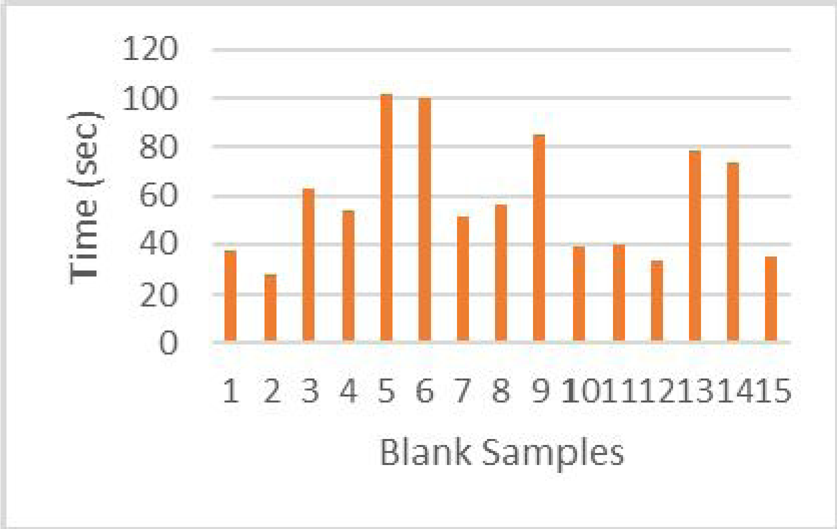


Fig. 3. Effect of Geometrical Yarn Parameters on Fabric Wettability

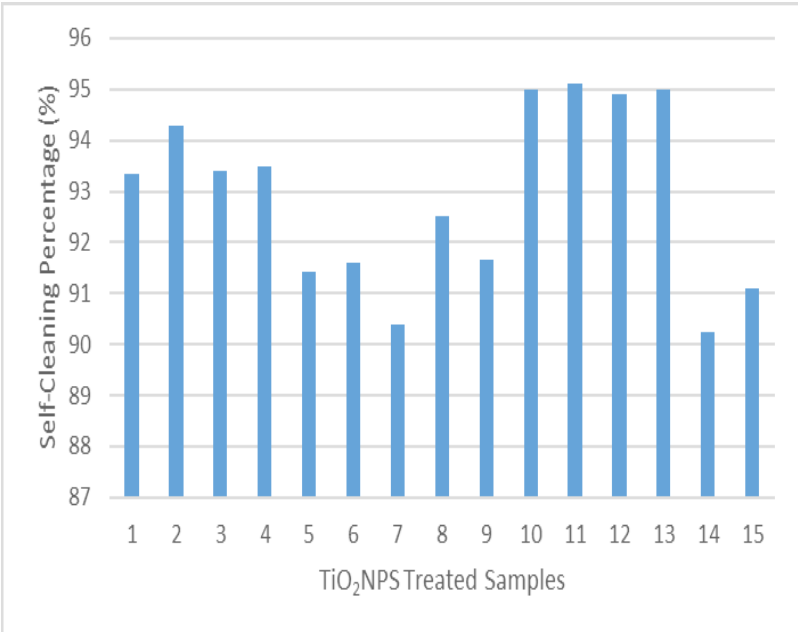


Fig. 4. Effect of TiO_2NPs Treatment on UV protection

From blank samples wettability time values it was found that samples that woven from compact yarns are lower in wettability time than those woven from conventional ring spun combed yarn as shown in Figure 2.

Sample (no. 2) that woven using single compact weft yarn has the less wettability time than those woven using combed and compact weft yarns samples.

However; better water absorption of fabrics woven from compact yarn is due to low diameters, less hairiness and high compactness of compact yarn as hairiness blocks the pores of the fabrics. Low hairiness of compact yarns results in reducing fabric thickness which increases inter-yarn spacing leading to easy passage of water molecules through fabrics which results in highly water vapor permeability that is directly reflected on better comfortability. Moreover; TiO_2NPs treatment has enhanced fabrics water vapor permeability in addition to the compact effect; fabric structure plain 1/1 has affected wettability results if compared with the other basket 3/3 and satin 5 fabric structures.

From table 5, TiO_2 NPs treated fabrics found to have better UV protection than blank ones and the differences were significant as shown in Figures 5 and 6.

From figure 4 it was found that samples woven using satin 5 fabric structure have the highest UPF values among all samples due to high light reflection property of satin structure, while basket 3/3 fabric structure has a higher UPF values than plain 1/1 structure

From Figure 5 it is observed that samples of compact yarn have higher UPF values than those of conventional ring spun combed yarn specially in sample woven using single compact weft yarn. Furthermore, it was found that the more compact weft yarn density the more UPF value; as samples woven using a ratio of 4 compact wefts:1 combed weft have higher UPF values than those woven using a ratio of 1 compact weft:4 combed wefts. This due to higher evenness, lower hairiness and lower thick places of compact yarns that results in an integrated structure that decreases UV rays passage through fabrics and hence; a better fabric UV protection

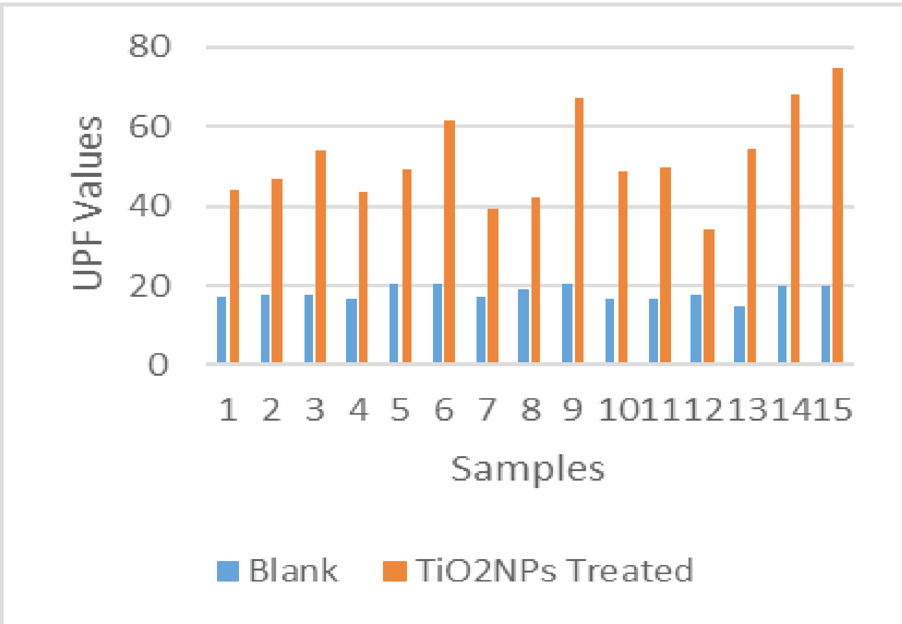


Fig. 5. Effect of TiO_2NPs treatment on UV protection

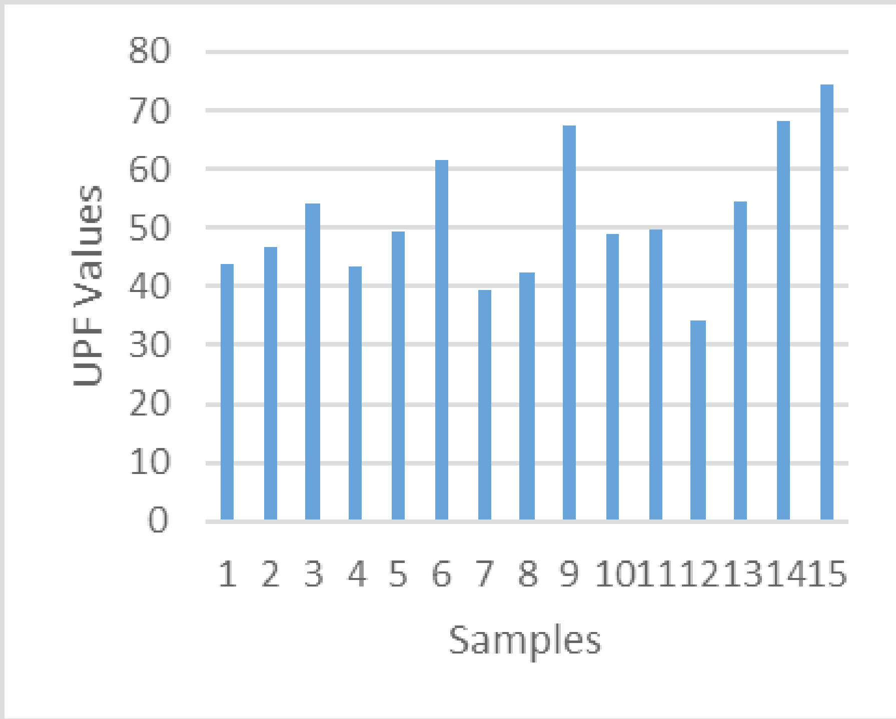


Fig. 6. Effect of TiO_2NPs treatment on UV protection

Conclusion

From the above mentioned results it is observed that TiO_2NPs have highly improved water absorption and UV protection of cotton fabrics. Also a relationship between nanoparticles treatment and geometrical yarn parameters which represented in: conventional and compact ring spinning was found.

Fabrics woven from compact yarns and plain 1/1 structure have the less water absorption time among all samples.

Fabrics woven using one or more compact weft yarn have better UV protection than those of combed weft yarn ones. Higher evenness of compact yarns provides an integrated structure that increase both water-vapor properties and UV protection. Also, TiO_2NPs treatment enhanced compact yarn performance

References

1. Eltahan, E., Structural parameters affecting tear strength of the fabrics tents. Alexandria engineering journal, 57(1): p. 97-105 (2018).

2. Lawrence, C.A., Fundamentals of spun yarn technology. : Crc Press (2003).

3. Özdil, N., A. Marmaralı, and S.D. Kretzschmar, Effect of yarn properties on thermal comfort of knitted fabrics. International journal of Thermal sciences, 46(12): p. 1318-1322 (2007).

4. Shahid, M.A., et al., Comparative study of ring and compact yarn-based knitted fabric. Procedia Engineering, 90: p. 154-159 (2014).

5. Abou-Nassif, G.A., A comparative study between physical properties of compact and ring yarn fabrics produced from medium and coarser yarn counts. Journal of Textiles, 2014.(2014).

6. Mohamed, F.A., et al., Improving dye ability and antimicrobial properties of cotton fabric. Journal of Applied Pharmaceutical Science, 6(2): p. 119-123 (2016).

7. Ibrahim, H.M., et al., Carboxymethyl chitosan electrospun nanofibers: Preparation and its antibacterial activity. Journal of Textile and Apparel, Technology and Management, 9(2) (2015).

8. Ibrahim, N.A., et al., Enhanced antibacterial properties of polyester and polyacrylonitrile fabrics using Ag-Np dispersion/microwave treatment. AATCC Journal of Research, 1(2): p. 13-19 (2014).

9. PATRA, J.K. and S. GOUDA, Application of nanotechnology in textile engineering: An overview. Journal of Engineering and Technology Research, 5(5): p. 104-111 (2013).

10. El-Bisi, M.K., et al., Super hydrophobic cotton fabrics via green techniques. Der Pharma Chemica, 8(19): p. 57-69 (2016).

11. Ibrahim, H.M., et al., Chitosan nanoparticles loaded antibiotics as drug delivery biomaterial. Journal of Applied Pharmaceutical Science, 5(10): p. 85-90 (2015).

12. Mohamed, F.A., H.M. Ibrahim, and M.M. Reda, Eco friendly dyeing of wool and cotton fabrics with reactive dyes (bifunctional) and its antibacterial activity. Der Pharma Chemica, 8(16): p. 159-167 (2016).

13. Ibrahim, H.M. and E.M.R. El-Zairy, Carboxymethylchitosan nanofibers containing silver nanoparticles: Preparation, Characterization and Antibacterial activity. Journal of Applied Pharmaceutical Science, 6(7): p. 43-48 (2016).

14. Ghasemi, S., et al., Reinforcement of natural fiber yarns by cellulose nanomaterials: A multi-scale study. Industrial crops and products, 111: p. 471-481 (2018).

15. Mohamed, F.A., et al., Improvement of dyeability and antibacterial properties of gelatin treated cotton fabrics with synthesized reactive dye. Bioscience Research, 15(4): p. 4403-4408 (2018).

16. Ibrahim, H.M., M.M. Saad, and N.M. Aly, Preparation of single layer nonwoven fabric treated with chitosan nanoparticles and its utilization in gas filtration. International Journal of ChemTech Research, 9(6): p. 1-16 (2016).

17. Farag, S., et al., Impregnation of silver nanoparticles into bacterial cellulose: Green synthesis and cytotoxicity. International Journal of ChemTech Research, 8(12): p. 651-661 (2015).

18. A. A. Hebeisha, A. S. Alya, c , M.A. Ramadana, M.M. Abd El-Hady a, A.S. Montaser□a and A.M. Farag, “Establishment of Optimum Conditions for Preparation of Silver Nanoparticles Using Carboxymethyl Chitosan”, Egyptian Journal of Chemistry (56), 3, pp. 241- 254,(2013)

19. Mohamed A. Ramadan*1, S.H.Nassar1, Abeer A. Abd El Aty, Mahmoud I. Nassar, Abdelsamed I. Elshamy, Ahmed S. Montaser, F. Kantouch, Antimicrobial Fabrics Using Conocarpus erectus Aqueous Extract, Egyptian Journal of Chemistry, (60).6, pp. 1111 – 1121 (2017).

20. M.A. Ramadan, S.H. Nassar, A.S. Montaser, E.M. El-Khatib and M.S.Abdel-Aziz. Synthesis of Nano-sized Zinc Oxide and Its Application for Cellulosic Textiles , Egyptian Journal of Chemistry, (59), 4, pp. 523 – 535 (2016)..