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Nanotechnology Application in Garments for Healthcare Workers

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THE SAFETY of healthcare workers has become a serious concern; therefore, a need for protection against bacterial penetration and transmission is realized. The purpose of this study is to investigate the functional and antimicrobial properties of cotton: polyester woven fabrics used as garment for healthcare workers uniforms (HCWU). (silver nanoparticles) AgNPs nano finish material is used as antimicrobial agent. The effect of polyester ratio and AgNPs concentration on tensile, water absorbance and antimicrobial properties of these fabrics has been examined. The findings of this study revealed AgNPs can be used effectively as an antimicrobial agent for woven cotton: polyester blended fabrics. The tensile strength, breaking extension, water absorbance of blended woven fabrics are significantly affected by the polyester percentage and the concentration of AgNPs. The produced fabrics were used in garments supplement design for healthcare workers such as doctors, nurse's uniforms.

Keywords: Design, AgNPs, HCWU, Cotton/ Polyester and Garments.

A major concern for healthcare workers (HCW) is the problem of transmission of pathogens and bacteria from their patients to themselves and the reverse contamination. It was reported that about one-half of all surgical procedures resulted in an accident where at least one medical worker was contaminated with blood[1]. Any blood contamination could pose a risk of transmission of bacteria[2]. Because of this potential contamination, protection is a major concern. Healthcare workers uniforms (HCWU), which include surgical gowns, scrub suits, lab coats, and nurses uniforms, are often used as barriers to help eliminate or reduce the risk of infection for both the doctor and the patient [3,4] Pissiotis, *et al.*[5] reported that as early as the 1800s, a need for HCWU especially surgical gowns was recognized because the blood from patients would splatter on the doctor's clothing and skin. Any bacteria in this blood could cause an infection to the doctor. In addition, many patients and some doctors died from bacterial transmission from soiled garments. To help combat this problem, surgeons Lister, Pasteur and Semmelweis wanted to make an aseptic barrier to help protect both doctors and patients from bacteria in the operating room [5] . It was reported that the first use of sterilized surgical gowns and caps in the operating room was in 1833 [6] .

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HCWU include surgical gowns, scrub suits, lab coats, and nurses' uniforms. They are categorized as reusable or disposable. Scrub suits, lab coats and nurses' uniforms are often made of reusable fabrics[4] ; however, surgical gowns are frequently made of either reusable or disposable fabrics[3]. The characteristics of reusable and disposable HCWU are dependent on fiber type, construction, and finishes to determine its optimal usage for protection. Reusable fabrics used for HCWU can be used over 50 times after laundering and sterilization [7], but sterilization occurred at more than 100°C which lead to a lack of consumer old fabrics. So the application of nanotechnology of these fabrics is very important to prevent contamination and bacterial transmission and increase consumer age of those fabrics[8,9]. There are other materials can be applied for the same purpose such as chitosan derivatives[10-12]. Reusable HCWU are used in many aspects of the healthcare industry such as in clinics, hospitals, and veterinary offices. Batra[8] reported that reusable surgical gowns continue to represent 20% of the total number of HCWU being used. Reusable HCWU are often made of cotton, polyester, or cotton and polyester blend woven fabrics with a plain weave [4]. In a plain weave, the warp yarn operates in an "over-one" and "under-one" pattern with the filling yarn throughout the fabric [13]. This weave pattern can provide a sturdy, comfortable fabric when made from cotton or cotton/polyester blend fiber.

The aim of this study focuses on investigating the performance of reusable HCWU which is made from cotton: polyester blended woven fabrics with different ratios of polyester content. These healthcare worker uniforms were treated with AgNPs (Ag NPs) as a broad-spectrum antibacterial agent. The effects of both polyester ratio content and Ag NPs concentration on the tensile properties, water absorbance and antibacterial properties for such type of fabric is the core of this study. After the experimental study, an application was made for choosing the best design of healthcare workers to use it.

Experimentals

Materials

The yarns used in this study made from cotton, polyester and blends of them with different ratios of polyester content. The properties of cotton and polyester fibers are given in Table 1.

TABLE 1. Properties of cotton and polyester fabrics.

Fiber	Cross section	Length, mm	Linear density, dtex	Tenacity, cN/tex	Breaking extension, %
Polyester	circular	44	2.20	45	29
Cotton	-	35	1.52	30.5	6.3

The weft yarns were spun from different ratios of polyester, *i.e.* 0%, 20%, 40%, 60%, 80% and 100%. The 0 % polyester ratio means that the ring spun yarn made from pure cotton (100% Egyptian cotton), and 100% polyester ratio means that the ring yarns are made from pure polyester. Whereas the warp yarns produced from 100% Egyptian cotton for all fabric samples, except for sample No. six, which spun from 100% polyester fibers. These ring spun yarns were used on the weaving machines to weave six different fabric samples with the following particulars:

- Warp yarns: made from100% cotton, except for sample No. six which produced from 100% polyester.
- Weft yarns: made from cotton: polyester blended fibers with different ratios of polyester ranging from 0% to 100%.
- Warp yarn count: 40/2 Ne
- Weft yarn count: 20/1 Ne.
- Warp yarn density: 110 ends / inch.
- Weft yarn density: 76 ppi.
- weave structure: plain 1/1.
- Fabric width: 166 cm.
- Fabric weight: 186 g/m^2
- Sodium hydroxide, hydrogen peroxide (H2O2), Egyptol , sodium silicate and AgNPs solution were all of laboratory grade reagents.

Methods

-The fabric samples were desized on 0.5 g/l non-ionic detergent at boiling temperature for 30 min and rinsed in hot water for 5 min. After desizing, fabric samples were scoured using a solution containing 2 g/l sodium hydroxide and 1g/l non-ionic detergent (Egyptol) at 95^0C for 90 min. The scoured fabric is bleached with 15g/l H_2O_2 (50%) and 2g/l sodium silicate at 90^oC for 1 hr. After the treatment, the samples were thoroughly washed with hot water to remove adhered chemicals completely from the fabrics.

- Each bleached fabric sample was padded separately in silver nano particles solution 400 ppm (10%, 20%, 30% and 40 %) in presence/without of binder (based on acrylate). Fabric samples have been dried at 80-85^oC afterward to maintain the residual moisture content at 8-10%. The dried fabric samples were cured at 130^oC for 1 min (pad- dry- cure method).

Estimation of the overall polyester ratio

In order to assess the effect of overall ratio of polyester fibers in the fabric samples on their different properties, we had to calculate the total percentage of polyester fibers in the fabric samples under study. The overall percentage ratio of polyester fibers in the studied fabrics was calculated, for sample No. 1-5, from the following equation [14, 15] :

$$\text{Polyester, \%} = \frac{P\% \times wef_d \times wef_c}{wef_d \times wef_c + wap_d \times wap_c}$$

where,
P% : the percentage of polyester in the weft yarns
Wef_d: weft yarn density, pick/cm
Wef_c: linear density of weft yarns, tex

Wap_d: warp yarn linear density, tex , and
Wap_c: warp yarn density, picks/cm

From the above equation, the percentage of polyester in the whole woven fabrics is listed in Table 2 due to the different ratios of polyester in weft yarns accordingly.

TABLE 2 . The percentage of polyester in the woven fabrics.

Sample No.	Polyester ratio in warp yarn, %	Polyester ratio in weft yarn, %	Polyester ratio in the whole fabric, %
1	0	0	0
2	0	20	8.2
3	0	40	16.4
4	0	60	24.6
5	0	80	32.7
6	100	100	100

Laboratory testing

Before testing, all fabric samples were conditioned and then tested under standard atmospheric conditions 20 ± 2 °C and 65 ± 5% relative humidity.

Tensile properties

The tensile strength and breaking extension of treated and untreated fabric samples were measured in the warp and weft direction. The tensile strength was measured according to ASTM D2256-66T (ASTM Test Method, 1972). Breaking extension was determined according to ASTM procedure D-2296-66T. Strips of 5 × 20 cm were taken for tensile strength testing. Ten test results were recoded and average for each fabric sample.

Water absorbance

Water absorbance of the fabrics was determined by means of absorbance time (absorbency) measurements before and after treatment according to AATCC Test Method 79 [(16)] . In this test method the fabric sample is placed over the top of a beaker so that the center of the fabric is unsupported. Distilled water was dropped on the fabric at 1 cm of the surface, and the time required to completely absorb the water drop was recorded as absorbance (wetting) time. The shorter wetting time indicates better wettability.

Antimicrobial activity test

The antimicrobial activity of the samples was evaluated quantitatively .The shake flask method, a standard test method, was used to measure the reduction rate in number of bacterial colonies formed and provided our quantitative data. *Staphylococcus aureus*, AATCC 6358, a gram positive bacterium, was the testing bacterium. In this procedure, a + 0.1 g sample was dipped into a test tube containing *Staphylococcus aureus* culture solution in which the bacteria concentration was 1.5-3.0*104/ml .The test tube was shaken at 35^{o}C for 1 hr on a rotary shaker at 100rpm and 1:100 dilutions of the test solution were made. One millimeter of the dilute test solution was poured onto TGE agar broth, and when this had been incubated at 35^{o}C for 24 hr, the number of bacterial colonies in the agar broth was counted. The reduction rate in the number of bacterial colonies was calculated using the following equation:

$$\text{Reduction of bacteria (\%)} = (A-B)/A*100$$

where A: a number of bacterial colonies before shaking and B: a number of bacterial colonies after 1 hr shaking.

Statistical analysis

To explore the effects of polyester percentage and concentration of silver nano-particles on the physical and antimicrobial properties of cotton/polyester blende woven fabrics, 6×4 mixed factorial design was performed. All data results were analyzed statistically for each measured response using SPSS statistical package. Two-way analysis of variance (two-way ANOVA) was used to determine whether a response was significantly influenced by the independent parameters at significance level $0 \leq \alpha \leq 0.05$(17) . A regression analysis was executed to detect the relationship between the polyester percentage and concentration of silver nano-particles and each property of the woven fabrics. The non-linear regression models are of the following form:

$$Z= a_o+ a_1 x+ a_2 y + a_3 x^2 + a_4 y^2 + a_5 xy$$

where,

Z= dependent variable, *i.e.* one of the fabric properties.

x = overall polyester ratio in the woven fabric, %

y = concentration of silver nano-particles, %

a_o = constant , and

a_1, a_2, a_3, a_4, a_5 = regression coefficients

The validation for these regression models were implemented using coefficient of determination, R^2. R^2 measures the reduction in the total variation of the dependent variable (cotton/spandex tensile properties) due to the multiple independent variables (spandex linear density, spandex filament drawing ratio, and twist multiplier). R^2 takes on values between 0 and 1. When the R^2 value approaches 1, the model fits the data results very well and it becomes reliable to be used in predicting.

Results and Discussion

Tensile strength

Tensile strength has been accepted as one of the most important attributes of woven fabrics. It is the main characteristic that distinguishes it from non-woven and knitted fabric. The strength of a woven fabric depends not only on the strength of constituent yarns, but also on the yarn and fabric structure and many other factors (13) . In this study, the tensile strength of the woven fabrics was measured in both warp and weft directions. The effects of polyester percentage and silver nano particles concentration with and without binding on fabric tensile strength in warp and weft directions were illustrated in Fig.1 - 4. The statistical analysis showed that both independent variables have a significant influence on the fabric tensile strength at 0.01 level for all cases except for the tensile strength of woven fabric in weft direction with the presence of binder. From these figures it is shown that polyester percentage has a positive impact on the fabric tensile strength in warp and weft direction; this may be due to the higher strength of polyester fibers incorporated in the fabrics. The statistical analysis proved that increasing the polyester ratio leads to an increase of woven fabric tensile strength in warp direction by about 29% for fabrics treated with and without binder. In the case of weft direction, the increase of polyester ratio increased the fabric tensile strength by approximately 24% and 27% with and without binder, respectively.

From these figures it can also be seen that the concentration of silver nano-particles has a positive effect on the fabric tensile strength in warp and weft direction with and without binder. An increasing trend was detected assuring that as the concentration of the silver nano-particles increases the fabric tensile strength reacts in the same manner. The statistical analysis proved that increasing the concentration of silver nano-particles from 10% to 40% leads to the increase in the fabric tensile in warp direction by 7% and 4% for fabric samples treated with and without binder. In the case of fabric tensile strength in the weft direction, increasing AgNPs concentration causes the increase in the fabric tensile strength by approximately 10% and 5% for the fabrics treated with and without binder. Generally it can be inferred that the breaking strength of nano-finished samples is more than unfinished fabric owing to the linkage formation between fibers and yarns, while there is no determinable trend in this property.

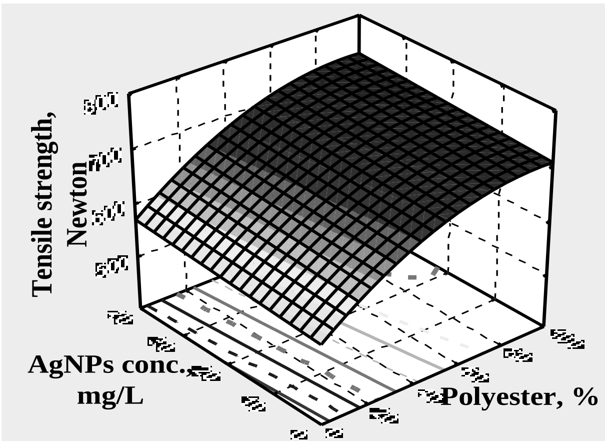

Fig. 1. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric tensile in warp direction without binder.

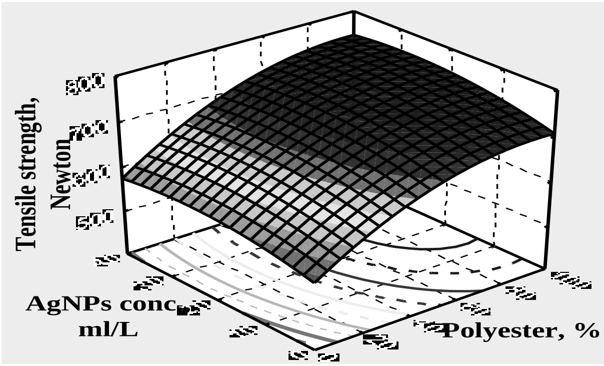

Fig. 2. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric tensile in warp direction with the presence of binder.

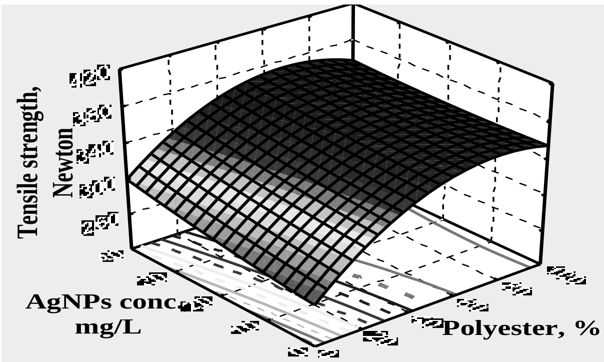

Fig. 3. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric tensile in weft direction without binder.

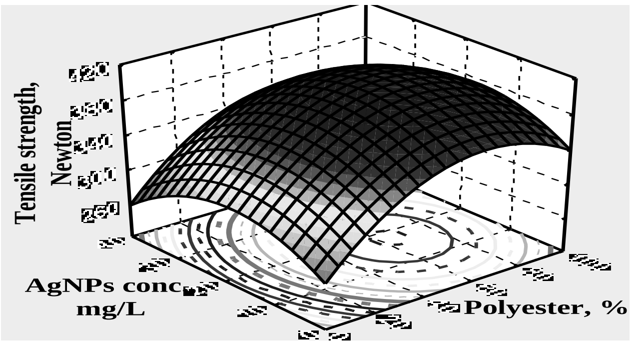

Fig. 4. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric tensile in weft direction with binder.

The statistical analysis proved that the regression relationship which can be used to predict the tensile strength of woven fabrics in the warp direction at different levels of polyester ratios and AgNPs concentrations have the following non-linear forms:

Tensile strength, Newton (for treated fabrics without binder) = $548.8+3.4\ x +0.54\ y - 0.02\ x^2$
Tensile strength, Newton (for treated fabrics with binder) = $550.57+3.4\ x +2.8\ y - 0.02\ x^2 + 0.004\ xy – 0.06\ y^2$

The statistical analysis proved that the coefficient of determination for these models equal 0.85 and 0.91 for fabrics treated without and with binder, respectively. This means that these regression models fit the data very well.

In the case of fabric tensile strength in weft direction, the regression lines which correlate the polyester percentage and concentration of silver nano-particles with the tensile strength have the following non-linear forms:

Tensile strength, Newton (for treated fabrics without binder) = $266 + 2.4\ x + 0.59\ y - 0.015\ x^2 – 0.08\ xy + 0.006\ y^2$

Tensile strength, Newton (for treated fabrics with binder) = $274 +2.97\ x +4\ y - 0.02\ x^2 -0.005\ xy – 0.11\ y^2$

The coefficient of determination for these models was found to equal 0.90 and 0.93 for fabrics treated without and with binder. This means that these models fit the data very well.

The statistical analysis also showed that the presence of binder during the application of the silver nano-particles enhanced the tensile strength of woven fabrics in both warp and weft directions significantly. It was found that the presence of binder increased the tensile strength of woven fabrics by 5% and 6.5% for warp and weft directions, respectively.

Breaking extension

Equally important to the fabric strength is its ability to extend under load. When the fabric is subjected to tension in one direction, the extension takes place in two main phases. The first phase is decrimping or crimp removal in the direction of the load. The removal of the crimp is accompanied by a slow rate of increase of the load. The second phase is the extension of the yarn during which the fabric becomes stiffer; the stiffness depends mainly on the character of the yarn. The more is the crimp in the yarn, the more extensible is the fabric [13].

The breaking extension of woven fabrics according to the variations of polyester percentages and the concentration of silver nano-particles in warp and weft direction were depicted in Fig. 5-8. The statistical analysis showed that polyester percentage has a profound effect at 0.01 significant level on the fabric extension in warp and weft directions. On the other hand the concentration of AgNPs was found to have a significant effect on fabric breaking extension at 0.05 significant level. From these figures it can be seen the positive influence of polyester ratio on the fabric breaking extension. An increasing trend was detected assuring that as the polyester ratio increases the fabric breaking extension also increases for all cases. The polyester percentage increases from 0% to 100 % leads to an increase of the fabric breaking extension in warp direction from 14% to 37% and from 12% to 36% for woven fabrics treated with and without binders, respectively. In the case of breaking extension in weft direction, the increase of polyester percentage have increased the fabric breaking extension from 17% to 38% for fabrics treated with and without binders. The increase of fabric breaking extension in warp and weft direction with the increase of polyester ratios may be ascribed to the increase of breaking extension of polyester fibers which incorporated in the woven blended fabrics.

It is also noticed from these figures that the concentration of silver nano-particles has a positive impact on the fabric breaking extension in warp and weft direction. For all cases, an increasing trend was detected confirming that as the concentration of silver nano – particles increases the breaking extension in both directions behaves the same trend. Increasing the silver nano-particles from 0% to 40% leads to an increase of fabric breaking extension in warp direction by approximately 20% and 5%, for fabrics treated with and without binder. For breaking extension in weft direction, the increase in concentration of silver nano - particles causes increasing the breaking extension by 38 % for all fabric samples. The significant influence of the concentration of silver-nano particles can be attributed to the reinforcement of fibers and yarns by treatment with nano-silver particles.

The regression relationships which correlate the fabric breaking extension in warp direction with polyester percentage and silver nano-particles concentration have the following forms:

Breaking extension, % (for treated fabrics without binder) = $11.4 + 0.03\ x + 0.15\ y + 0.002\ x^2 - 0.003\ xy - 0.0037 y^2$

Breaking extension, % (for treated fabrics with binder) = $11.3 + 0.07\ x + 2.8\ y - 0.002\ x^2 - 0.002\ xy + 0.03\ y^2$

The statistical analysis proved that the coefficient of determination for these models equal 0.81 and 0.88 for fabrics treated without and with binder, respectively. This means that these regression models fit the data very well.

In the case of fabric breaking extension in weft direction, the regression lines which correlate the polyester percentage and concentration of silver nano-particles with the breaking extension has the following non-linear forms:

Breaking extension, % (for treated fabrics without binder) = 11.3 – 0.04 x + 0.56 y + 0.03 x^2 - 0.003 xy - 0.08 y^2

Breaking extension, % (for treated fabrics with binder) = 11 – 0.01 x + 0.5 y+ 0.003 x^2 - 0.005 xy – 0.006 y^2

The coefficient of determination for these models was found to equal 0.86 and 0.89 for fabrics treated without and with binder. This means that these models fit the data very well.

The statistical analysis finally revealed that the presence of binder in the fabric treatment has no significant impact on the fabric breaking extension in warp and weft directions.

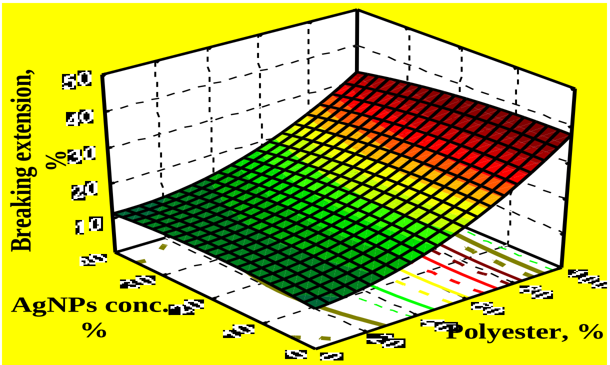

Fig. 5. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric breaking extension in warp direction without binder.

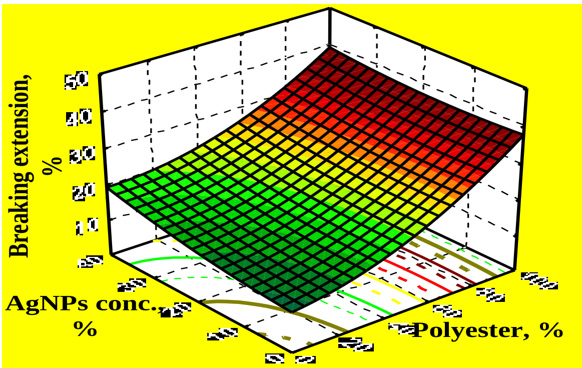

Fig. 6. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric breaking extension in weft direction without binder.

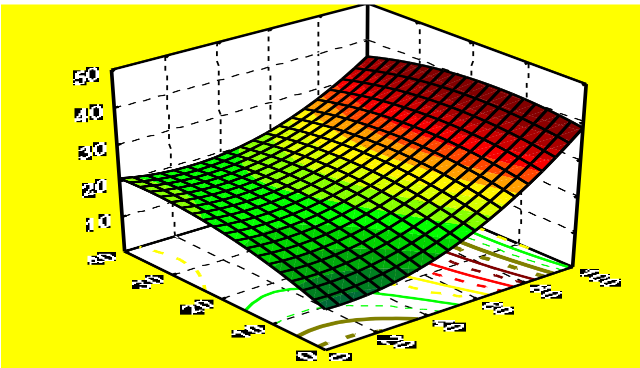

Fig. 7. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric breaking extension in warp direction with the presence of binder.

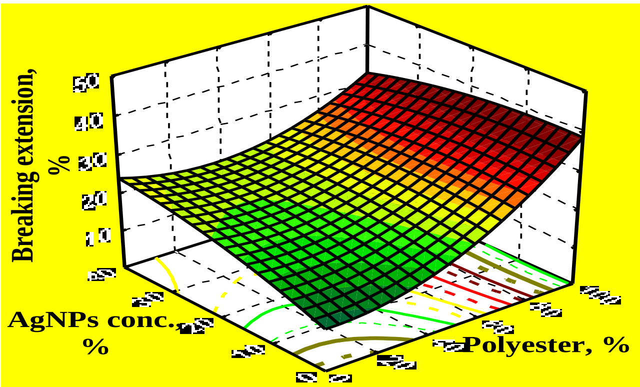

Fig. 8. Response surface of the effects of polyester percentage and concentration of silver nano-particles on the fabric breaking extension in weft direction with the presence of binder.

Water absorbance

The values of wetting time versus the polyester percentage and the concentration of silver nano-particles for treated fabrics without and with the presence of binder were depicted in Fig. 9 and 10, respectively. The statistical analysis proved that the independent variables have a huge effect on the wettability of treated woven fabric in all cases. From these figures it can be noticed that both independent variables have a positive effect on the fabrics' wetting time. The higher the polyester percentage is the higher wetting time. This means that increasing the polyester content in the woven fabrics lowers their wettability. It is also shown that as the concentration of the silver nano-particles increases the higher wetting time occurs, which in turn reduces the fabric wettability.

The statistical analysis proved that increasing the polyester percentage from 0% to 100% leads to an increase of wetting time (reducing fabric wettability) by approximately 98% and 90 % for the treated fabrics without and with the presence of binder. While increasing the concentration of silver nano-particles from 0% to 40% increased the wetting time, which in turn reduces fabric wettability by about 21% and 88% for treated fabrics without and with the presence of binder, respectively.

The regression relationships which correlate the wetting time of the woven fabrics to the polyester percentage and concentration of silver nano-particles have the following non-linear forms:

Wetting time, sec (for treated fabrics without binder) = $2.7 + 0.09\,x + 0.06\,y - 0.005\,x^2 - 0.001\,xy - 0.006\,y^2$

Wetting time, sec (for treated fabrics with binder) = $3.1 + 0.08\,x + 0.3\,y - 0.004\,x^2 + 0.004\,xy - 0.006\,y^2$

The coefficient of determination for these models was found to equal 0.93 and 0.91 for fabrics treated without and with binder. This means that these models fit the data very well.

The statistical analysis also showed that the presence of binder during woven fabrics treatment has a significant influence on the fabric wettability. The presence of binder was found to increase the wetting time, which in turn reduces the fabric wettability. It was observed that the presence of binder increased the wetting time of the treated fabrics by about 54%.

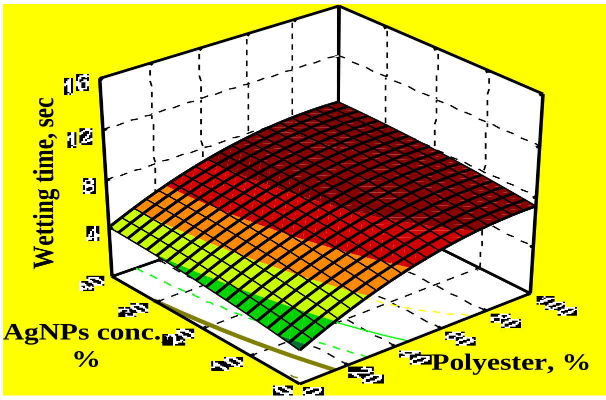

Fig. 9. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the fabric wetting time without the presence of binder.

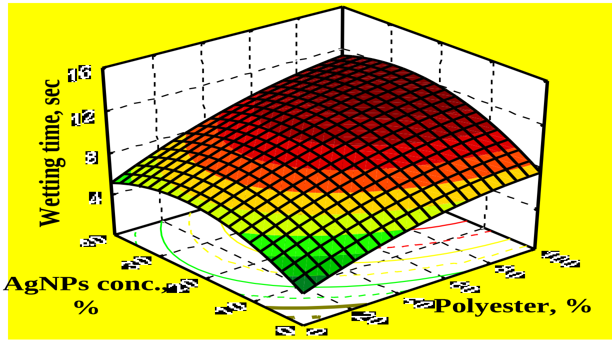

Fig. 10. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the fabric wetting time with the presence of binder.

Reduction of bacteria

Following the physical and mechanical properties of cotton/ polyester blended fabrics, additional testing was performed to determine the antimicrobial capabilities of these types of fabrics. The evaluation of the independent variables for reduction of bacteria was conducted before and after five cycles of washings. The response surfaces of the effects of polyester ratios and silver nano – particles concentration on the reduction of bacteria for fabric samples treated with and without binders were depicted in Fig. 10-14.

The statistical analysis showed that all independent variables have a profound influence on the reduction of bacteria. The polyester ratio and nano–silver concentration were found to have positive influence on the reduction of bacteria. An increasing trend was detected for all fabric samples assuring that as the both independent variables increase the reduction of bacteria also increases.

Increasing polyester ratio from 0% to 100% leads to increasing the percentage of bacterial reduction by about 20% for all fabric samples. Whereas increasing the concentration of silver nano – particles increased the bacterial reduction from 27 to 97% and from 27 % to 73 % for treated fabrics without binder before and after washing, respectively. In the case of treated fabrics with binder, the increase in percentage of AgNPs increased the reduction of bacteria from 27 % to 97% and from 27% to 86% before and after washing, respectively.

For treated fabrics without binder, the regression models which correlate the independent variables to the reduction of bacteria have the following non-linear forms:

Reduction of bacteria, % (for treated fabrics before washing) = $9.1 + 0.66\,x + 7.6\,y - 0.001\,x^2 - 0.02\,xy - 0.16\,y^2$

Reduction of bacteria, % (for treated fabrics after washing) = $7.4 + 0.7\,x + 5.4\,y - 0.002\,x^2 + 0.023\,xy - 0.1\,y^2$

The regression analysis proved that these models fit the data very well with a high R^2 values that is 0.92 and 97 for treated fabrics before and after washing, respectively.

In the case of the treated fabrics without the presence of binder, the regression models have the following forms:

Reduction of bacteria, % (for treated fabrics before washing) = $9.1 + 0.66\ x + 7.6\ y - 0.001\ x^2 - 0.02\ xy - 0.16\ y^2$

Reduction of bacteria, % (for treated fabrics after washing) = $7.4 + 0.7\ x + 5.4\ y - 0.002\ x^2 - 0.023\ xy – 0.1\ y^2$

The coefficients of determination for these models are 0.88 and 0.91 before and after washing, respectively.

For treated fabrics in the case of presence binder before and after washing, the regression models which correlate the bacterial reduction with polyester ratios and silver nano – particles concentration have the following non-linear form:

Reduction of bacteria, % (for treated fabrics before washing) = 9.1 + 0.7 x + 6.6 y - 0.01 x2 - 0.03 xy - 0.16 y2

Reduction of bacteria, % (for treated fabrics after washing) = 7.4 + 0.6x + 6.8 y - 0.008 x2 + 0.02 xy – 0.14 y2

The coefficients of determination of these models equal 0.93 and 0.91 for treated fabrics before and after washing.

Irrespective the washing of fabric samples, the statistical analysis also revealed that the presence of binder enhanced the performance of AgNPs in relation to reduction of bacteria. It was found that the presence of binder increased the bacterial reduction with 8%. It is also observed that the washing of fabric samples declines the bacterial reduction by 15%.

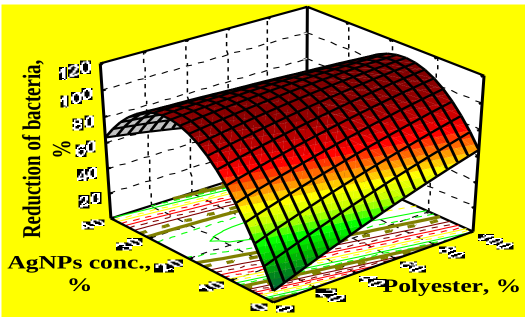

Fig. 11. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the reduction of bacteria for the treated fabrics without binder and before washing.

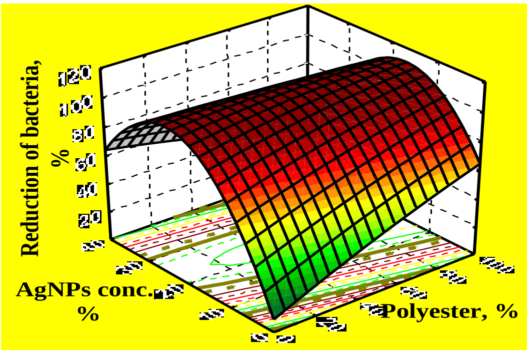

Fig. 12. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the reduction of bacteria for the treated fabrics with binder and before washing.

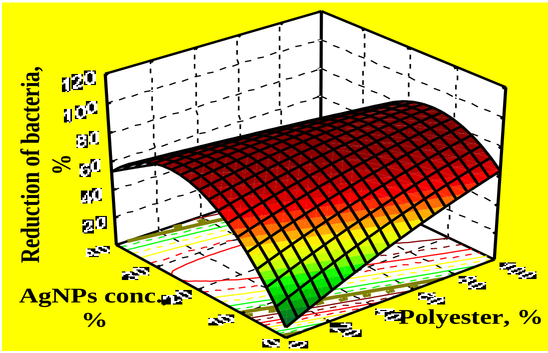

Fig. 13. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the reduction of bacteria for the treated fabrics without binder and after washing.

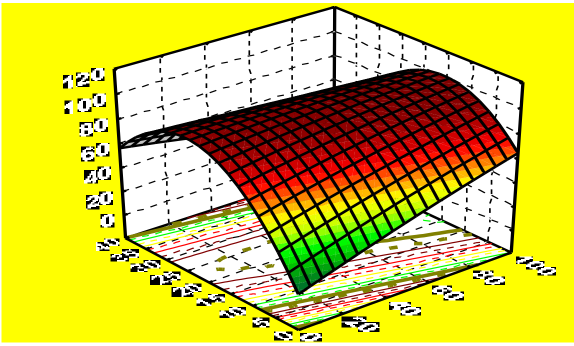

Fig. 14. Response surface of the effect of polyester percentage and concentration of silver nano-particles on the reduction of bacteria for the treated fabrics with binder and after washing.

Application of produced fabrics in HCWU

After the experimental study and determing the best fabric samples with respect to their physical and antimicrobial properties, the statistical analysis proved that the fabric sample which has 24.6% polyester ratio has the best results with respect to their physical and antibacterial properties. Different designs of HCWU had been choose as shown in Fig. 15. To differentiate between these designs with respect to their aesthetic appearance, we conducted a questionnaire and each design has been on fifteen referees. The ratios of agreement between referees have been defined according to the following equation: Ratio of agreement =No. of agreements / (No. of agreement times+ No. of non-agreement times) × 100. The best design whose ratio of agreement is more than 85% was selected.

Table 3 demonstrates agreement ratios for designs. Table 3 showed that the design no. 9 and that no. 3 were the best designs with respect to their aesthetic and functional performance to be treated with the best (higher) concentration of silver NPs, sewn and tailored in the form of healthcare workers.

The designs no. 3 and 9 had been tailored from the fabric sample which has 24.6% polyester ratio. These samples had been treated with the higher concentration of AgNPs.

Conclusions

Nano-silver can be used effectively as an antimicrobial agent for woven cotton: polyester blended fabrics. The statistical analysis revealed that the higher concentration of antimicrobial agent (Ag NPs) is, the larger the tensile strength, breaking extension and reduction of bacteria. It is also found that increasing the polyester content in the treated fabrics leads to an increase of fabric tensile strength and the reduction of bacteria. While increasing the polyester percentage reduces the fabric wettability with significant values. It was found that the presence of binder during the treatment of fabric samples enhanced the reduction of bacteria, but reduced the fabric wettability. The washing process of the fabric samples declined the reduction of bacteria significantly.

TABLE 3. Referees agreement ratios of designs.

Design No.	No. of agreements	No. of non agreements	Agreement ratio
1	13	2	86.6
2	14	1	93.3
3	15	0	100
4	11	4	73.3
5	14	1	93.3
6	12	3	80
7	14	1	93.3
8	13	2	86.6
9	15	0	100
10	14	1	93.3
11	13	2	86.6
12	14	1	93.3

Fig. 15. Different designs of healthcare worker uniforms (HCWU) .

References

1. **Dusaj, S.,** Making composite barrier fabrics for healthcare workers. *Technical Textile International,* **15**(5), 20-22 (1993).

2. **Leonas, K.K.,** Evaluation of five nonwoven surgical gowns as barriers to liquid strikethrough and bacterial transmission. *International Nonwovens and Disposable Association (INDA) Journal,* **5**(2), 22-26 (1993).

3. **Granzow, J. W., Smith, J. W., Nichols, R. L., Waterman, R. S. and Muzik, A. C.,** Evaluation of hospital gowns against blood strike-through and methicillin-resistant *Staphylococcus aureus* penetration. *American Journal of Infection Control,* **26**(2), 85-93(1998).

4. **Neely, A.N. and Maley, M.P.,** Survival of Enterococci and Staphylococci on hospital fabrics and plastic. *Journal of Clinical Microbiology,* **38**(2), 724-726(2000).

5. **Pissiotis, C.A., Komborozos, V., Papoutsi, C. and Skrekas, G.,** Factors that influence the effectiveness of surgical gowns in the operating theatre. *European Journal of Surgery,* **163**(8), 597-604(1997).

6. **Meade, T. W.** Medicine and population. *Public Health,* **82**(3), 100-110(1968).

7. **Sun, G. and Xu, X.** Durable and generable antibacterial finishing of fabrics: Biocidal properties. *Textile Chemist and Colorist,* **30**(6), 26-30(1998).

8. **Hebeish, A., El-Naggar, M.E., Fouda, M.G., Moustafa, M.G., Ramadan, M.A., Salem, S. Al-Deyab and El-Rafie, M.H.,** Highly effective antibacterial textiles containing green synthesized AgNPs. *Carbohydrate Polymers,* **86,** 936– 940 (2011).

9. **Hebeish, A. A., Ramadan, M.A., Krupa, I., Montaser, A.S., Abeer Salama, A.A. and Abdel-Aziz, M.S.,** *In vitro* and *in vivo* antibacterial potential of chitosan – g- acrylonitrile silver nanocomposite against a pathogenic bacterium. *Int. J. Curr, Microbiol. App. Sci.* **4**(3), 5-19 (2015).

10. **Hebeish, A., Ramadan, M.A., Montaser, A.S., Krupa, I. and Farag, A.M.,** Molecular characteristics and antibacterial activity of alginate beads coated chitosan polyacrylonitrile copolymer loaded silver nanocomposite. *JSRR,* **5** (6), 479-488(2015).

11. **Hebeish, A., Aly, A.S., Mohamed, A., Ramadan, M.M., Abd El-Hady, Montaser, A.S. and Farag, A.,** Establishment of optimum conditions for preparation of AgNPs using carboxymethyl chitosan. *Egyptian Journal of Chemistry,* **56**(3), 241-151 (2013).

12. **Hebeish, A.A., Ramadan, M.A., Montaser, A.S. and Farag, A.M.,** Preparation, characterization and antibacterial activity of chitosan-g-poly acrylonitrile/silver nanocomposite. *International Journal of Biological Macromolecules,* **68,** 178-184 (2014).

13. **Alsaid Ahmed Almetwally and Mourad, M.M.,** Effects of spandex drawing ratio and weave structure on the physical properties of cotton/spandex woven fabrics. *The Journal of the Textile Institute,* **105** (3), 235-245(2014).

14. **Alsaid Ahmed Almetwally, Idrees, H. F. and Ali Ali Hebeish**, Predecting the tensile properies of cotton/ spandex core-spun yarns using artificial neural networks and regression models. *The Journal of the Textile Institute*, **105**(11), 1221-1229 (2014).

15. **Mourad, M. M., Ahmed El-Salmawy and Alsaid Ahmed Almetwally**, Core spun yarn and the secret behind its popular appeal. *Textile Asia*, **42** (10)(November), 41-43(2011).

16. AATCC Test Method 79, "Absorbency of Bleached Textiles, American Association of Textile Chemists and Colorists"

17. **Yasser. M. Eid, Ahmed Alsalmawy and Alsaid, A., Almetwally.** Performance of woven fabrics containing spandex. *Textile Asia, XL*1 (5), 39-42, (2010).

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تطبيق تكنولوجيا النانو كمكمل تصميمي في ملابس العاملين في الرعاية الصحية

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لقد أصبحت سلامة العاملين في الرعاية الصحية مصدر للقلق الشديد .لذلك، أدرك الباحث الحاجة لحماية تلك العاملين ضد انتشار البكتيريا وانتقال العدوى .الغرض من هذه الدراسة هو دراسة الخصائص الوظيفية والمضادة للميكروبات لأقمشة القطن/ بوليستر المنسوجة المستخدمة كمكمل تصميمي لملبس العاملين في الرعاية الصحية .تم استخدام جسيمات الفضة النانومترية كعامل مضاد للميكروبات . وقد تم فحص تأثير نسبة البوليستر وتركيز جسيكات الفضة النانومترية على قوةالشد للأقمشة المنتجة، الامتصاصية للماء والخصائص المضادة للميكروبات لهذه الأقمشة .أظهرت النتائج التي توصلت إليها هذه الدراسة أن الفضة النانوية يمكن استخدامها بشكل فعال باعتبارها عامل مضاد للميكروبات للأقمشة المنسوجة من القطن: البوليستر المخلوط حيث قوة الشد، والإستطالة، وامتصاص الماء لهذه الأقمشة المنسوجة والمخلوطة تتأثر بشكل كبير باختلاف نسبة البوليستر وتركيز الفضة النانوية .واستخدمت الأقمشة المنتجة في تصميم الملابس للعاملين في الرعاية الصحية مثل الأطباء والممرضات والزي المدرسي.تم عمل مجموعة تصاميم مختلفة وتم أخذ رأي العاملين في هذا المجال في هذه التصاميم حيث حاذت اعجاب تلك العاملين .