Journal of Applied Arts & Sciences
مجلة الفنون والعلوم التطبيقية
كلية الفنون التطبيقية
جامعة دمياط
Damietta University

The Effect of Changing Structural Factors and Treating with Silver Nanoparticles on the Functional and Microbiological Properties of Cotton Sportswear

تأثير تغير عوامل التركيب البنائي والمعالجة بجزيئات الفضة النانوية علي الخصائص الوظيفية والميكروبيولوجية للملابس الرياضية القطنية

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Abstract

Recently, The world is looking for protective clothing from microbes in various areas of life. Therefore, the textile industry has witnessed the introduction of new functional properties for fabrics such as microbial resistance using various techniques such as nanotechnology.The research goal to produce sportswear used in martial arts with new functional characteristics such as the ability to absorb water, Air permeability, Tensile strength,elongation, and Antimicrobial .The player's suit for this sport is exposed to the strong tension of the hostile player as well as the growth of bacteria due to the direct contact between the players and the presence of an appropriate medium for the growths bacterial. The fabrics were produced by changing several factors such as changing the proportion of materials used (Ag NPs), textile constructions and square meter weight, we will get different types of sportswear. Some tests such as antibacterial activity, Air permeability, tensile strength, and elongation are done. The results showed that by increasing the weight of the square meter and number of intersection in measurement unit and concentration of Ag NPs, the functional properties of the fabrics produced have become appropriate for the purpose of the research.

Keywords: Sportswear, Silver nanoparticles, Treatment, fabrics.

1. Introduction

Sportswear plays an important role in the daily life of most human beings, [1] when designing or purchasing sportswear you should take care of some characteristics, the most important of which is the feeling of the wearer' comfort. The feeling of comfort when wearing clothes greatly affects professional and athletic performance during competition or training. Sportswear can be divided into three groups (participation in some sports activities - wearing sportswear as a fashion product - wearing them at leisure and feeling comfortable) [2].

(ISSN 2537-1061) (Print)
(ISSN 2537-107X) (Online)

Modern sportswear is often designed to meet the needs of all categories, but when the sport needs to attract and tighten between players and constant friction with hands such as self-defense sports, [3] here must be taken into account some of the characteristics that must be available in sportswear such as resistance to friction and tearing, ability to absorb moisture, and light weight. As well as resistance to different microbes because of direct contact by hands between players. This research paper suggests predicting the physiological and psychological comfort needed by players in self-defense sports such as (gymnastics, taekwondo, karate ... Etc.) [4].

2. Materials and Methods

It is not possible to achieve all required properties for sportswear in a simple structure of any single fiber. The right type of fiber should be in the right place. The behavior of the fabric is mainly depending on its base fiber's properties. The most important properties are fiber type; weave construction; weight or thickness of the material and presence of chemical treatments for sports wear.

2.1. Materials

2.1.1 Cotton Fibers;

Cotton fiber is amazingly versatile, whether alone or blended, it outsells all other fibers combined. Consumers know that fabrics made from cotton which its tensile strength is 4.2to 5.5 g/den and its elongation is (3-7%) when it drys (5). It absorbs humidity with ratio (8.5%) , visual appeal, durability and value. It is a good combination of softness and comfort. Therefore, it was chosen in this research.

2.2. Fabric Structure;

Two types of structural compositions were selected

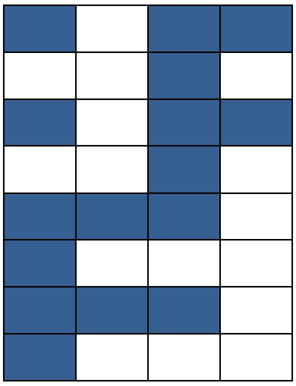

Fig 1. double weave structure

2.2.1 Double Fabric;

Actually, double clothes are the fabrics, which contain two layers of yarns those are woven one above the other and stitched together. Double clothes have at least two series of warp yarns, and two series of weft yarns, namely face and back. Double cloths fabrics are popularly known as two ply fabrics. The upper layer is formed by interlacing the face warp yarns with the face weft yarns, and the lower layer is formed by interlacing the back warp yarns with the back weft yarns[3]. The reasearchers used warp rib weave in both layers with checker style to connect two layers as shown in figure 1.

2.2.2 Twill Fabric;

In a twill weave, each weft or filling yarn floats across the warp yarns in a progression

(ISSN 2537-1061) (Print)

(ISSN 2537-107X) (Online)

of interlacings to the right or left, forming a pattern of distinct diagonal lines. This diagonal pattern is also known as a wale. A float is the portion of a yarn that crosses over two or more perpendicular yarns [5]. Reserchers used 1/3 twill weave as shown in figure 2.

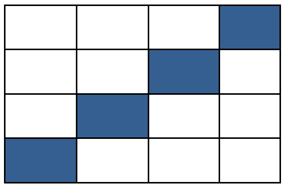

Fig 2. twill weave structure

3. Manufacturing and finishing of fabrics

3.1. Manufacturing

The Six samples of fabrics were produced on the Rapier loom as in table 2. according to the specifications shown in a table 1.

Table 1. The specifications of produced samples

sample number	Fabric structure	Yarn count/ warp	Yarn count/ weft (cm)	weight (g/m2)	Weft yarn
1	Twill	Cotton 30/2	29.5	250	Cotton 24
2	Twill	Cotton 30/2	24	225	Cotton 24
3	Twill	Cotton 30/2	35	275	Cotton 24
4	Double Fabric	Cotton 30/2	21	225	Cotton 26
5	Double Fabric	Cotton 30/2	26	250	Cotton 26
6	Double Fabric	Cotton 30/2	32	275	Cotton 26

Table 2. Specifications of the machine used for producing samples under study

No.	Property	Specification
1	Machine type	Rapiar dornier
2	The manufacturer country	France
3	Shedding system	Dobby
4	Dobby type	Staubli
5	Machine wideh	190 cm
6	Number of healds	10 healds
7	Machine speed	280 – 320 picks/ min
8	Reed used(dents / cm)	12 dents /cm for twill weave, 13 dents /cm for double layer
9	Denting	2 ends per dent

(ISSN 2537-1061) (Print)

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3.2 Finishing and Treatment of fabrics;

Silver Nanoparticles were dissolved in 1% ethylene glycol ($C_2H_6O_2$) solution as a solvent and reluctant solution with different concentrations 200, 400, 600 ppm. Different cotton fabrics were treated with different concentrations of dissolved solution of silver Nanoparticle. The pad-dry-cure method was used to impregnate the silver nanoparticles in cotton fabrics. The fabrics were dipped separately into different concentrations solutions of silver Nanoparticle for a period of 10 minutes, after which the excess solution was removed from the fabric samples through padder and drying process at 80 °C for 5 minutes; finally, the samples were cured at 110 °C for 3 minutes. Table 3. Shows material specifications and treatment solution. Figure 3. Shows SEM for sample no13. (A) Before treatment (B) after treatment.

Was chosen sample no. 1 from Local market as a control sample as cotton and Double Fabric structure were the dominant components in the Sports suit.

Table 3. Material specifications and treatment solution

sample number	Fabric structure	weight (g/m2)	solvent concentration ($C_2H_6O_2$) %	Concentrations Nano silver (ppm)	treatment time (min)	Drying temperature (°C)	Drying time (min)
1	Double Fabric	280	-	-	-	-	-
2	Twill	250	1	200	10	80	5
3	Twill	225	1	400	10	80	5
4	Twill	275	1	600	10	80	5
5	Twill	250	1	200	10	80	5
6	Twill	225	1	400	10	80	5
7	Twill	275	1	600	10	80	5
8	Twill	250	1	200	10	80	5
9	Twill	225	1	400	10	80	5
10	Twill	275	1	600	10	80	5
11	Double Fabric	225	1	200	10	80	5
12	Double Fabric	250	1	400	10	80	5
13	Double Fabric	275	1	600	10	80	5
14	Double Fabric	225	1	200	10	80	5
15	Double Fabric	250	1	400	10	80	5
16	Double Fabric	275	1	600	10	80	5
17	Double Fabric	225	1	200	10	80	5
18	Double Fabric	250	1	400	10	80	5
19	Double Fabric	275	1	600	10	80	5

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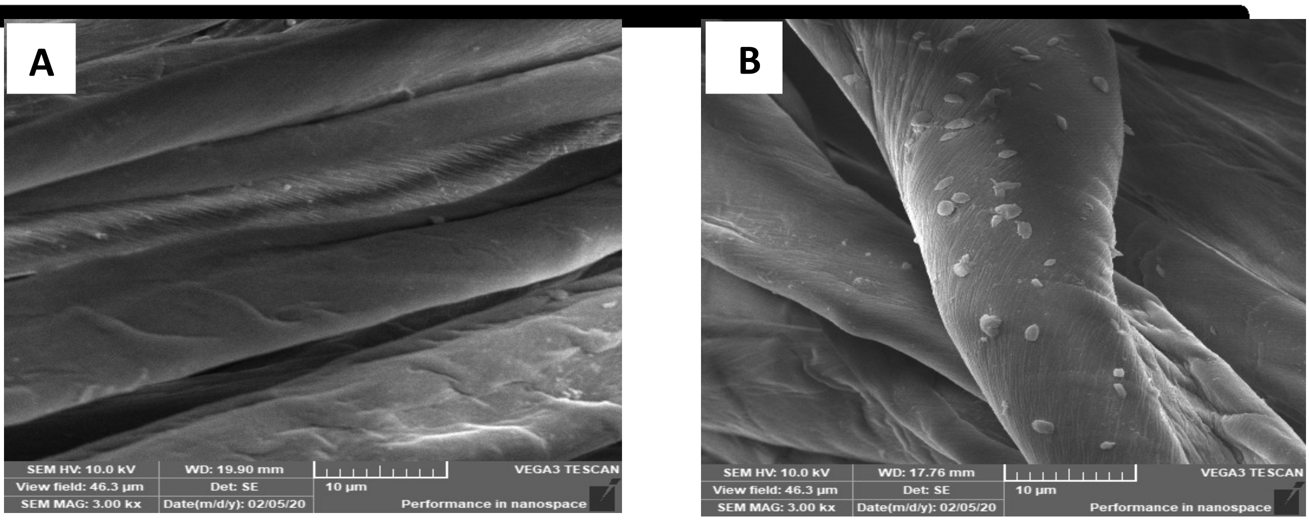

Figure 3. SEM for sample (13); (A) before treatment (B) after treatment

4. Results and Dissections;

Table 4. Summary of test result fabric before treatment

Sample no.	Fabric structure	Tensile strength g/den	elongation %	Air permeability cm2/sec	UPF	Thickness (mm)	weight (g/m2)	Antimicrobial test	
								Staphylo-coccus aureus G+VE	*E. Coli G-VE*
1	Double Fabric	70	20	10.54	0.3	1.4	280	0	0
2	Twill	120	20	4.32	0.1	1.4	250	0	0
3	Twill	95	19	6.83	0.1	1.46	225	0	0
4	Twill	90	22	2.51	0.15	1.48	275	0	0
5	Double Fabric	70	18	22.2	0.2	1.34	225	0	0
6	Double Fabric	95	23	14.7	0.3	1.35	250	0	0
7	Double Fabric	105	23	8.95	0.3	1.37	275	0	0

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Sample no.	Fabric structure	Tensile strength g/den	elongation %	Air permeability cm2/sec	UPF	Thickness (mm)	weight (g/m2)	Antimicrobial test	
								Staphyloccoccus aureus G+VE	*E. Coli G-VE*
1	Double Fabric	70	20	10.54	0.3	1.4	280	0	0
2	Twill	107	20	3.33	19	1.9	250	1.6	59.14
3	Twill	94	20	2.59	20	2.4	250.1	3.2	60.57
4	Twill	80	20	1.90	21	2.9	250.1	5.5	66.95
5	Twill	68	19	7.44	20	1.96	225	5.33	29.76
6	Twill	62	19	6.96	21	2.46	225	7.65	37.90
7	Twill	75	18	5.45	22	3.0	225.1	10.23	43.46
8	Twill	88	21	1.90	16	1.98	275	13.66	12.76
9	Twill	87	19	1.33	17	2.48	275.01	16.87	17.23
10	Twill	85	18	0.98	18	2.98	275.2	19.42	23.38
11	Double Fabric	67	18	20.1	18	1.84	225	15.86	27.98
12	Double Fabric	64	18	18.99	19	2.34	225	18.23	31.45
13	Double Fabric	80	20	16.97	20	2.84	225.1	20.8	38.26
14	Double Fabric	94	23	13.12	15	1.85	250	19.21	19.97
15	Double Fabric	92	23	11.9	16	2.35	250	20.93	25.43
16	Double Fabric	90	23	10.80	18	2.85	250	22.19	30.61
17	Double Fabric	105	22	6.98	13	1.88	275	20.21	31.10
18	Double Fabric	105	22	5.12	14	2.47	275	22.93	39.64
19	Double Fabric	105	22	3.90	15	2.87	257.1	24.19	46.65

Evaluation of sportswear performance by measuring physical and mechanical properties of the fabrics was interested by many researchers by using the technologies. However, investigating the effect of fabric construction parameters on the mechanical and safety properties of fabric is the field of interest in this work for indicating the fabric mechanical and safety properties performance.

4.1 Tensile strength and elongation;

Fabric structures are engineered structures that meet the pull load requirements of most sportswear. In use, the fabric membrane is subjected to constant biaxial stress from the inflation pressure or applied tension. The fabric must therefore be resistant to creep or stress avoided, and the opportunity for accidental damage is minimized, by careful detailed design. However, since some accidental damage (mechanical) is almost inevitable during the lifetime of the membrane, the fabric should have high tear

(ISSN 2537-1061) (Print)

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resistant so that tears do not propagate catastrophically from points of damage [7].

4.1.1 Tensile Strength Test;

As shown in figure 4. Sample no.2 has the highest value of Tensile strength when compared with Control sample (Sample no.1) and other samples. However samples no.17, 18 have the highest values after Sample no.2. From pervious results it is clear that. The twill fabric is superior to the double fabric in tensile strength**.** We can report that number of weft yarns per unit in twill weave samples was more which make them more stronger than on double layer.

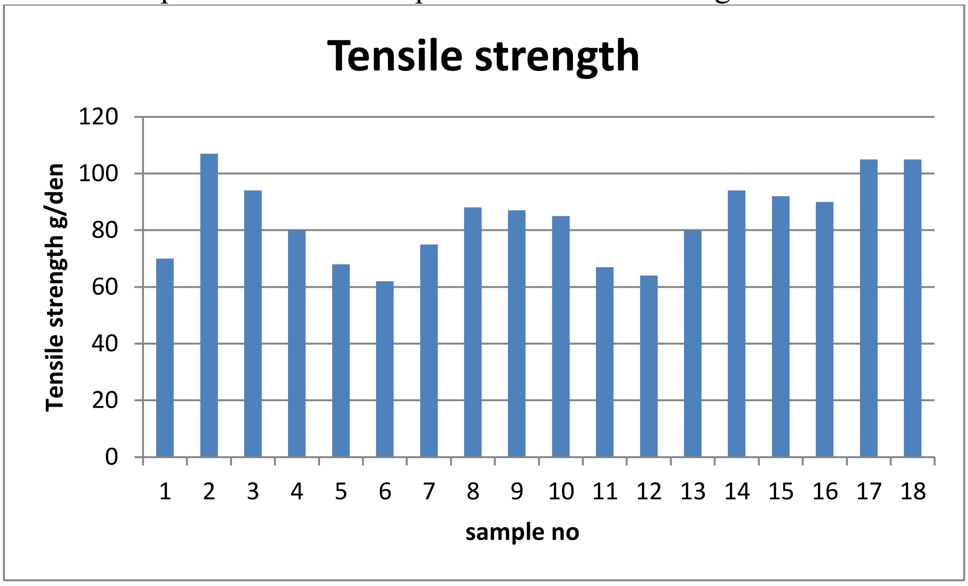

Figure 4. Tensile strength test results

4.2 Air permeability;

Air permeability of textile fabrics plays an important part in certain limited end-use requirements especially sportswear. It can be defined as (Permeability P= the volume of air in cubic centimeters passed per second through 100 square centimeters of cloth, divided by the pressure difference in centimeter of water (P =100V/A .p)

Where V= volume of air in ce /second

A= area of test piece in cm2.

P=pressure head of air in cm. of water.

At the fabric surface, the heat dissipates into the surroundings by: conduction through a layer of air close to the outer fabric surface and then by convection, and radiation to cooler surfaces of the environment. However, the fabric provides resistance to the flow of heat [8]. As the fabric cover factor increases, the fabric air permeability decreased (4). However the air permeability of textile fabrics is a property that allows air to pass through the fabric. Due to the manner in which yarns and fabrics are constructed, a large proportion of the total volume occupied by a fabric, in fact, is air space. The distortion of this air space influences a number of important fabric properties such as warmth and protection against wind and rain in fabric [9].

In considering the range of fabric air permeability and its effect upon body comfort, Robinson (6) comments as follows: In air temperatures of 28, 34, and 40 oC, varying the air permeability of their fabric from 12 to 40 cubic feet per minute made no consistent difference in working men's rates of sweating, skin temperatures, and heart rates, nor did it alter to any important degree heat exchange by the avenues of radiation, convection, and evaporation. A change in air

(ISSN 2537-1061) (Print)

(ISSN 2537-107X) (Online)

movement from 5 to184 m /min made practically no difference in this relationship [10]. These results confirmed that the porous cellular weave does not make cooler clothing than the thinner but more tightly woven fabric [11].

4.2.1 Air permeability Test;

As shown in figure 5. Sample no.11has the highest value of Air permeability when compared with Control sample (Sample no.1) and other samples.this is for the pores in this sample out number the pores in the other samples. We also note that the higher the concentration of Nano-silver particles, the less Air permeability. That means when Increases the saturation of the fabric from silver reducing the pore size of the fabric So it reduces the air flow through yarn and fabrics.

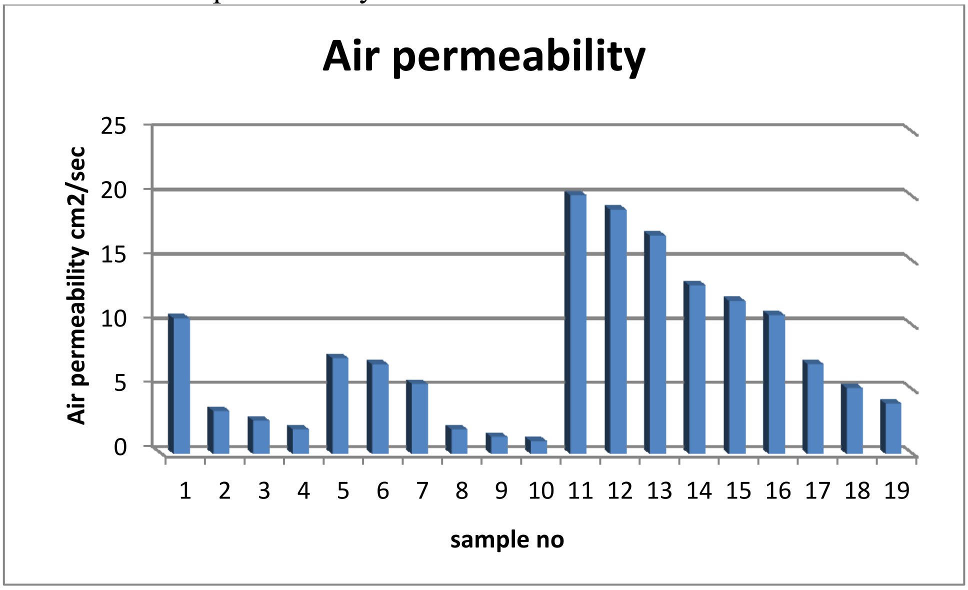

Figure 5. Air permeability test results

4.3 Ultraviolet Protection (UPF);

Textiles have been used by man since antiquity for adornment and protection from elements. Exposure to ultraviolet radiation is the most significant environment factor for the production of skin cancer in human beings. Sun protection must therefore involve a combination of sun avoidance and the use of suitable textiles. The extraterrestrial solar (UVR) spectrum contains (UVC) (wavelength 100-280 nm).UVB (280-315 nm) and UVA (315-400 nm) radiation. However, no UVC and only half of the UVB reach the earth's surface due to absorption by the ozone layer in the upper atmosphere. Further, different wavelengths in the UVB and UVA spectra have vastly different effects in producing biological damage such as erythematic [12].Ultraviolet Protection Factor (UPF) is used to measure the UV protection capability of the fabric/garments covering protection against both UVA and UVB. The test was performed according to the standard (ATCC 183).

4.3.1 UPF Test Results;

As shown in figure 6. Sample no.7 has the highest value of UPF when compared with Control sample (Sample no.1) and other samples. We also note that the higher the concentration of Nano-silver particles, Resistance increased for UPF. From pervious results it is clear that the twill fabric is superior to the double fabric in UPF Results**.** that means when increase number of fibers per cross section Increases the saturation of the fabric from silver**.**

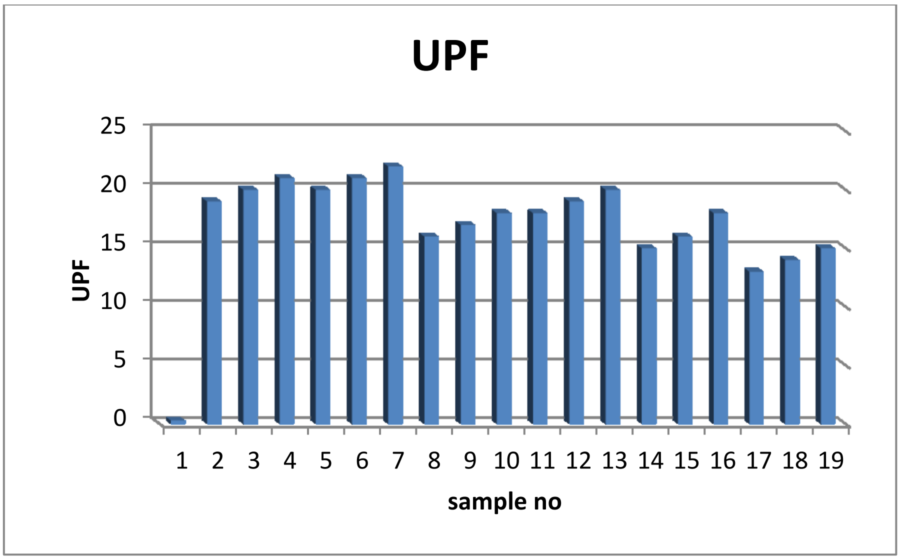

Figure 6. UPF Test Results

4.4 Antimicrobial activity

The in-vitro antimicrobial activities of untreated and treated fabrics were assessed using a reported method Greenwood (1983) and Chun (2009). The fabrics were evaluated for antibacterial activity against Escherichia coli NRRL 3703, Pseudomonas aeruginosa NRRL 32 as gram-negative bacteria and Bacillus cereus NRRL 569, Staphylococcus aureus NRRL 313 as gram-positive bacteria. All fabrics were prepared at a slandered and then sterilized by UV at 30 min. Each microorganism used in this experiment was individually inoculated into tubes containing 5 ml sterile nutrient broth. After the incubations, 1ml of the bacterial suspensions was transferred and absorption was measured at 600 nm. 100% viability was defined as bacterial grown in the absence of fabric samples, 0% viability as medium blanks.

Reduction (%) = (ODb-ODS) / ODb X100

Where ODb: absorbance present on untreated fabrics, and ODS, absorbance present on treated fabrics.

4.4.1 Antimicrobial Test Results;

As shown in figure 7. Sample no.19 has the highest value of Antimicrobial Staphylococcus aureus when compared with Control sample (Sample no.1) and other samples.Whil figure 8. Sample no.4 has the highest value of Antimicrobial E. Coli when compared with Control sample (Sample no.1) and other samples.We also note that the higher the concentration of Nano-silver particles, Antimicrobial. From pervious results it is clear that the double fabric is superior to the twill fabric in Antimicrobial Results. That means when increase number of fibers per cross section Increases the saturation of the fabric from silver and thus increases the resistance of microbes**.**

(ISSN 2537-1061) (Print)

(ISSN 2537-107X) (Online)

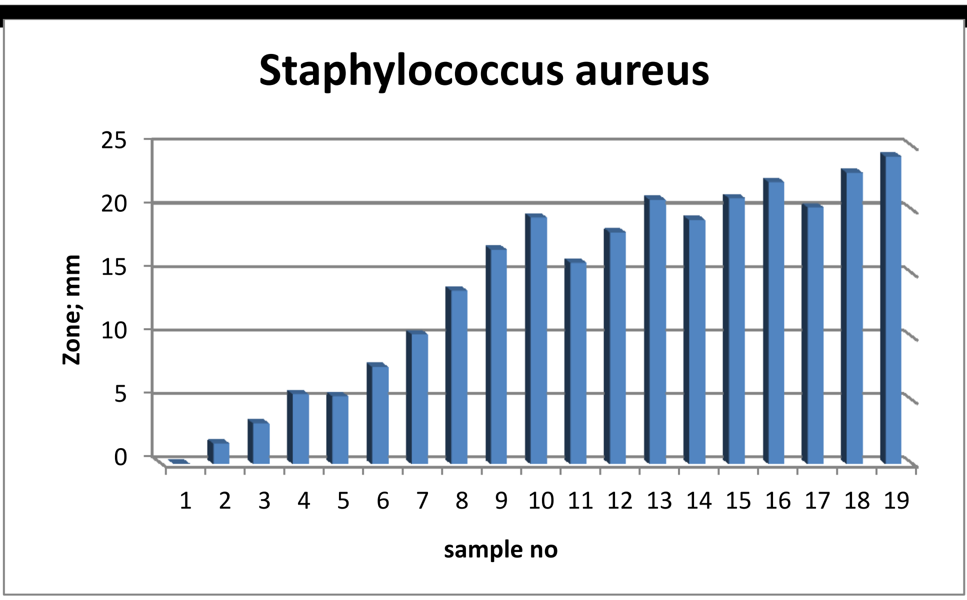

Figure 7. Antimicrobial Test Results

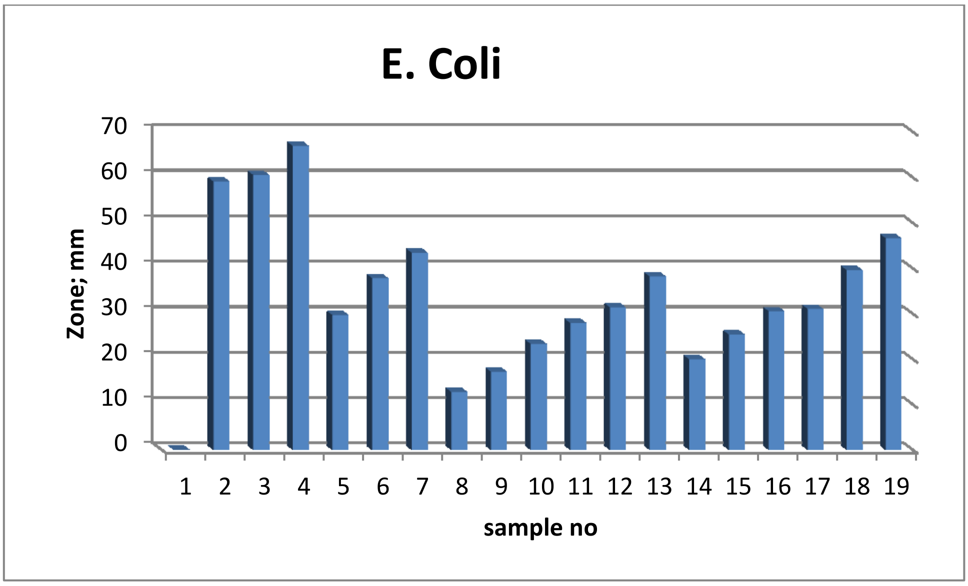

Figure 8. Antimicrobial Test Results

5. **Conclusions;**

Multifunctional properties such as protective properties against bacteria and unpleasant odors can be incorporated in sportswear by Nano finishing, and they are light-weight and flexible with high-impact strength. The wear comfort of sportswear is also positively affected by nanotechnology, enhancing the wearer's performance and efficiency. The athletes withstand high activity levels for a longer period of time due to the breathability of Nano-sportswear. As the study resulted in the following:

- The samples of the fabrics produced under research showed a distinction from the sample of the local market in all characteristics.

- The twill fabric Better in tensile strength than double fabric by increasing the intersections between warps and wefts and increasing the weight of square meter.
- Increasing the concentration of Nano-silver particles reduces the tensile strength for fabrics and affects the air permeability as the air permeability decreases with an increase in the concentration of Nano-silver particles
- The higher the Nano-silver particles concentration, the greater the resistance of the fabrics to the microbe.
- The sample no.11 under reaserch has high air permeability value when compared with Control sample (Sample no.1) and other samples.
- tests show the samples under reasrch have high value of UPF when compared with Control sample (Sample no.1). We also note that the higher the concentration of Nano-silver particles, Resistance increased for UPF.

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مريم أكرم عبد الفتاح بدر، حاتم محمد فتحي إدريس، فيروز أبو الفتوح الجمل – "تأثير اختالف بعض التراكيب البنائية المشتقة من االنترلوك على بعض خصائص الراحة لألقمشة المنتجة" *مجلة الفنون والعلوم التطبيقية، كلية* المجلد الرابع العدد الرابع *الفنون التطبيقية، جامعة دمياط* - اكتوبر ٢٠١٧.

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الملخص

في الآونة الأخيرة ، اصبح العالم يبحث عن ملابس تحقق له الحماية من الميكروبات في شتي مجالات الحياه. ولذلك شهدت صناعة النسيج إدخال خصائص وظيفية جديدة للأقمشة مثل مقاومة الميكروبات وذلك باستخدام تقنيات مختلفة مثل تقنية النانو. يهدف البحث إلى إنتاج ملابس رياضية تستخدم في فنون الدفاع عن النفس بخصائص وظيفية جديدة مثل القدرة على امتصاص الماء ونفاذية الهواء وقوة الشد والاستطالة ومقامة الميكروبات. حيث تتعرض بدلة اللاعب لهذه الرياضة للتوتر الشديد للاعب المعادي وكذلك نمو البكتيريا نتيجة الاتصال المباشر بين اللاعبين ووجود وسيط مناسب لنمو البكتيريا. تم انتاج الاقمشة عن طريق تغيير عدة عوامل مثل تغير نسبة المواد المستخدمة من الفضة النانوية (Ag NPs) الإنشاءات النسيجية ووزن المتر المربع وبذلك سوف نحصل على أنواع مختلفة من الملابس الرياضية تختلف في بعض الخصائص مثل النشاط المضاد للبكتيريا ، نفاذية الهواء ، قوة الشد والاستطالة. حيث أظهرت النتائج أنه من خلال زيادة وزن المتر المربع وعدد التقاطع في وحدة القياس وتركيز Ag NPs أصبحت الخصائص الوظيفية للأقمشة المنتجة مناسبة لغرض البحث.

كلمات مفتاحية: ملابس رياضية - جزيئات الفضة النانوية - معالجة - أقمشة.

(ISSN 2537-1061) (Print)

(ISSN 2537-107X) (Online)