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Nilüfer Yıldız Varan
Pamukkale University, nvaran@pau.edu.tr, Denizli-Turkey

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ORCID ID	0000-0003-1100-4413
Correspoding Author	Nilüfer Yldız Varan

APPROACHES TO CONTROLLING MICRO-ORGANISMS IN COTTON AND COTTON/ELASTANE CLOTHINGS

ABSTRACT

Antimicrobials are substances or mixtures of substances used to destroy or suppress the growth of harmful microorganisms such as bacteria, viruses, or fungi on inanimate objects and surfaces. In this study, an alternative method is presented using triclosan agents that can kill bacteria and viruses to help keep patient, operating, and emergency rooms free of germs. Samples were treated with triclosan to achieve antimicrobial/antiviral/antifungal properties for further designs to help comfort and bacteria, virus, fungi (BVF) resistantance during use. The physical, and mechanical properties of triclosan treated cotton and cotton/elastane fabrics in comparison with untreated control samples was investigated. The results showed that a small significant decrease was observed for tensile strength (strip and grab methods), tear strength and seam strength. Besides, statistically a small significant decrease was observed with the increase in triclosan concentration for all samples. The panama weaves showed the lowest tensile strength and the highest tear strength and statistically small significant decrease was observed for all treated samples. The antimicrobial tests showed that all treated samples have a very good antimicrobial activity which can also lead to antivirus protection by providing hygienic environment for the users during future designs.

Keywords: Triclosan, Antimicrobial, Protection, Cotton, Clothing

1. INTRODUCTION

Antimicrobials (also called biocides and antimicrobial pesticides) are substances that kill or slow the spread of microorganisms such as bacteria, viruses, or fungi, and they are crucial in helping to prevent and stop the spread of harmful microbes. Antimicrobials are used to protect a variety of treated goods from microbiological deterioration, staining, and odors. These chemicals are also used in sanitizers and disinfectants as well as preservatives of paints, adhesives, wood, and other materials or in the case o antibiotics, used to treat systemic infections [1 and 2]. Several approaches have been used to incorporate antimicrobial agents into or onto fibers. These include topical application of antimicrobial agents, ion exchange reactions with charged fibers, dyeing fibers with antimicrobial agents, adding antimicrobial agents to the liquid polymer before spinning. The main purpose of these treatments is to prevent decay of fabrics due to microbial attack [3]. The microorganism’s growth on textiles causes a range of undesirable effects both for the material and the user which include also the generation of reduction in mechanical strength, stains and discoloration and an increased likelihood of user contamination [4, 5 and 6]. Several approaches have been used to incorporate various

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antimicrobial agents into or onto various fibers using padding, dyeing, ion-exchange, incorporation in the polymer before spinning, antimicrobial release and antimicrobial synthesis. For example, treating of the fabrics through antimicrobial agent applications through padding is easy to practice and control and the process is cheap and the agent can be applied at high speeds and the manufacturers claim that the fabrics are highly effective. However, performance depends on persistent the antimicrobial agent is [7, 8, 9, 10, 11, 12 and 13]. Mechanism of action of antimicrobial agents are also important. Most antimicrobials seem to act intra-cellularly, thus requiring their uptake by the cell [14]. They may also distrupt, destroy, or crosslink the cell wall or to increase the permeability of the cell wall allowing leakage. These antimicrobials can act extra-cellularly, possibly permitting them to be immobilized on the surface. It is important to recognize the mode of action when designing antimicrobial fabrics. Another important criteria is controlling the spread of infections within our health centers and medical textiles need to meet in order to play an integral role to ensure that these strategies succeed [15 and 16]. Various antimicrobial fabric finishes are on the market with different antimicrobial mechanisms to kill microbes including silver, chitosan, polyhaxamethylene biguanide, quaternary ammonium cations, triclosan, zinc pyrithione [17, 18 and 19]. Triclosan (2,4,4′-trichloro-2′-hydroxydiphenylether) is a chlorinated aromatic compound that has functional groups representative of both ethers and phenols (see Figure 1). In the structure, phenols often show antibacterial properties that makes triclosan a broad-spectrum antimicrobial agent with a MIC of less than 10ppm against many common bacterial species.

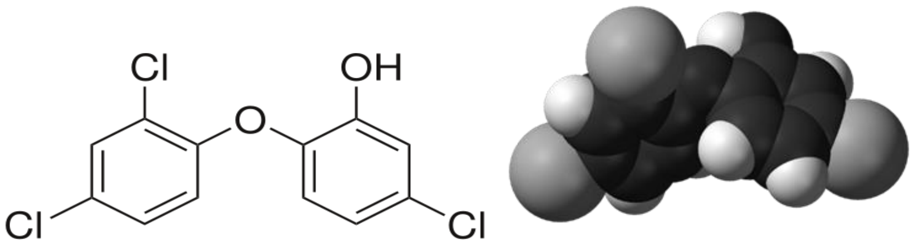

Figure 1. Structure of triclosan [20]

At lower concentrations, triclosan appears bacteriostatic and is seen to target bacteria mainly by inhibiting fatty acid synthesis which is already illustrated in Figure 2. Triclosan’s rapid alternating ether bond rotations disrupt secondary bonding between chain monomers in the resin state to reduce viscosity and enhance polymer blending. Thus, triclosan is considered for a polymer additive with multiple properties to be an antimicrobial with additional benefits as a nonpolar toughening agent and a hydrophobic wetting agent. The triclosan material relationships with alternating ether bond rotations are in a complete different form of medium by comparisons with known antimicrobial properties that upset bacterial cell membranes through rapid fluctuating mechanomolecular energies. Also, triclosan bond entanglements with secondary bonding can produce structural defects in weak bacterial lipid membranes requiring pliability that can then interfere with cell division [21 and 22].

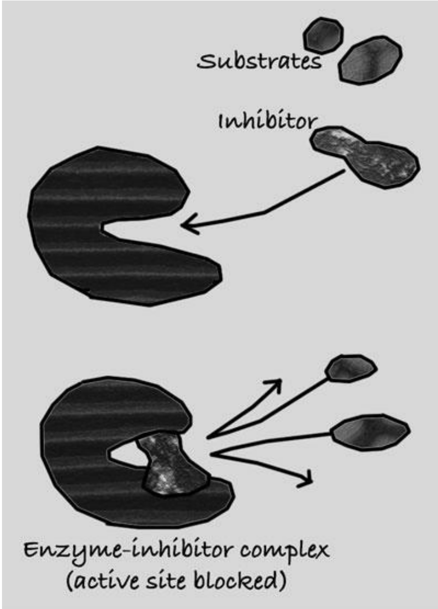

Figure 2. Triclosan antimicrobial mechanism [20]

Iyigundogdu et al. studied the antimicrobial activity of textiles treated with 3% sodium pentaborate pentahydrate, 0.03% triclosan, and 7% Glucapon and they found the modified cotton textile goods attained very good antimicrobial and antiviral properties [23]. Jiang et al. studied an antimicrobial agent, was synthesized from cyanuric chloride, sulfanilic acid and triclosan. The synthesized compound was coated on cotton fabrics and found the novel materials showed very good antibacterial properties against *S. aureus* and *E. coli* [24].

2. RESEARCH SIGNIFICANCE

It is aimed to impart antimicrobial properties to help comfort and bacteria resistance during use of triclosan antimicrobial agents in different concentrations on cotton and cotton/elastane woven fabrics. Additionally, the physical, and the mechanical properties of triclosan treated samples in comparison with untreated control samples were investigated in order to point out the change in performances of cotton and cotton elastic fabrics that will be used for clothing for further designs.

3. EXPERIMENTAL STUDY

3.1. Materials

Triclosan obtained from Ciba (Hunstman Int.) was analytically pure. The fabrics were obtained from Shamrock Textile Company. They are desized, scoured and bleached 100% cotton (Co) and 97%Co/3% cotton/elastane fabrics. Initial properties of the fabrics are presented in Table 1.

Table 1. Structural properties of fabrics

Fabric Code	Fabric Structure	Fiber Content	Weight (g/m^2)	Cover Factor	
				Warp	Weft
A	1/1 Plain	97%Co/3% Elastane	132.5	20	14
B	1/1 Plain	100% Co	112.8	18	12
C	2/2 Panama	100% Co	120.3	14	18
D	2/1 Twill	100% Co	262.1	28	14

3.2. Method

3.2.1. Treatment of Fabric Samples with Triclosan

First 150ml water warmed up to 25ºC–30ºC. With warm water triclosan chemical agent was diluted and mixed. Then the rest of the water was added and and warmed up to 30ºC. Triclosan solution was stirred continuously for 10 min at magnetic mixer. The temperature was kept at between 25ºC–30ºC by continuous warming and stirring. Exhaustion method was used to apply triclosan antimicrobial onto cotton fabrics using a laboratory type Ahiba Nuance machine. The fabrics were squeezed to a wet pickup of %85. The exhaustion temperature was 100ºC, the bath temperature was 20ºC. The samples were treated with 0.04 wt. %, 0.06 wt.%, 0.08 wt. % triclosan antimicrobial agents for 1h, dried at 85ºC for 5 min and cured at 160ºC for 3 min. In the referencing system for fabric samples, the cotton/elastane plain wovens were prefixed with a 'A', 'B' for the cotton plain wovens, 'C' for the cotton 2/2 panama wovens, 'D' for the cotton 2/1 twill wovens, for fabric samples treated with different concentrations, the samples treated with 0.04 wt. % triclosans were prefixed with a 'X', 'Y' for the fabric samples treated with 0.06 wt.% triclosans, 'Z' for the fabric samples treated with 0.08wt. % triclosans and 'U' for the untreated samples.

3.2.2. Antimicrobial Activity

The experimental method used to determine the antimicrobial effects was AATCC Test Method 100: 2004 "Assessment of Antibacterial Finishes on Textiles" Standards, using Staphylococcus Aureus ATCC 6538 (2.00×10^5 CFU/ml) test inoculum [25]. The variables were calculated from Equation (1) respectively. The AATCC Test Method 61 (2A): 2012 "Colorfastness to Laundering: Accelerated" was used to evaluate the washing durability. The samples were evaluated after 20 and 30 washes.

$$R=\frac{100\,(C-A)}{C} \quad (1)$$

where R is the percentage reduction of bacteria, A is the number of bacteria recovered from the inoculated treated sample and C is the number of bacteria recovered from the inoculated untreated control sample.

3.2.3. Physical and Mechanical Properties

Physical and mechanical properties were tested in order to evaluate the fabric properties in terms of tensile strength (strip and grab method), stitch strength and tear strength before and after antimicrobial treatments. The samples were conditioned for 24 hours at 20ºC, 65% relative humidity in the physical testing lab before testing. Tensile strength (strip method), tensile strength (grab mehod), tear strength, and seam strength were measured according to relevant standards (ISO 13934-1, 2013; ISO 13934-2, 2014; ISO 13937-1, 2000; ISO 13936-1, 2004) [26, 27, 28 and 29].

3.2.4. Statistical Analysis

The statistical analysis of the experimental data was performed using JMP version 8.0.2 software package (SAS Institute, Inc., Cary, NC). The statistical analysis includes the analysis of variance (ANOVA). For the one-way ANOVA, p-values less than 0.05 were considered statistically significant.

4. RESULTS AND DISCUSSION

4.1. Antimicrobial Activity

The antimicrobial properties of the control and treated samples bound with 0.06 wt.% triclosan cotton samples are presented in Figure

3 as it is the optimum antimicrobial proportion. The total population of *Staphylococcus aureus* (*S. aureus*) ATCC 6538 on each sample was determined. After the antimicrobial tests were performed, the live vibrio concentration of the standard blank sample at zero contact time, as well as that of a standard blank sample oscillated for 24h and that of the antimicrobial fabric sample oscillated for 24h, were compared. It’s found that triclosans were strongly fastened to cotton and cotton/elastane fabrics and the modified fabrics have a very good antimicrobial activity. The total population of Staphylococcus aureus (S. aureus) ATCC 6538 on Z samples treated with 0.06 wt.% triclosan is presented as it is the optimum antimicrobial proportion. It’s found that triclosans were strongly fastened to cotton fabrics and all modified fabrics have a very good antimicrobial activity. The growth rate of S.aureus decreased with increasing wash cycles due to the weakening of the bonds. It’s found that the cotton samples treated with triclosan, retained their effectiveness even after 30 wash cycles. The percentage reduction of bacteria (%) is still observed between (93-95)%.

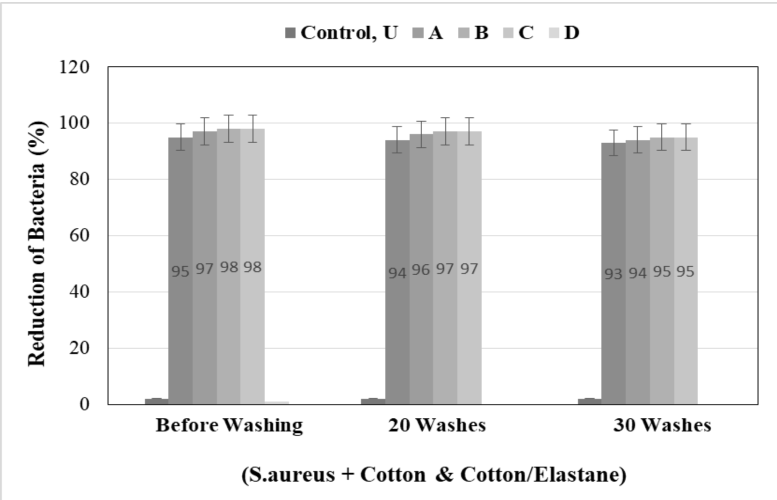

Figure 3. Antimicrobial test results of the control and triclosan bound with cotton samples

4.2. Physical and Mechanical Properties

4.2.1. Tensile Strength (Strip Method)

The results are presented in Figures (4-5). A small significant decrease in tensile strength was observed after triclosan treatments and a small significant decrease was observed with the increase in triclosan concentration. It was observed the triclosan treatment caused a restriction in the movement of yarns in the structure resulting a significant decrease in the elasticity. Cotton plain fabrics showed the highest tensile strength in warp direction. Panama fabrics showed the lowest tensile strength in warp direction while they showed the highest tensile strength in weft direction.

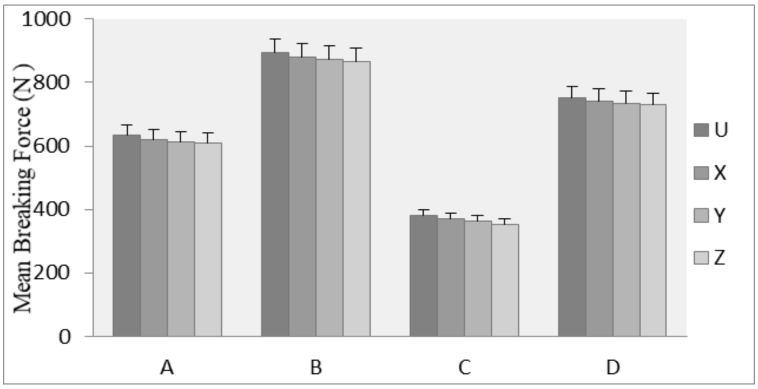

Figure 4. Tensile strength (strip method) in warp direction for untreated and treated fabric samples

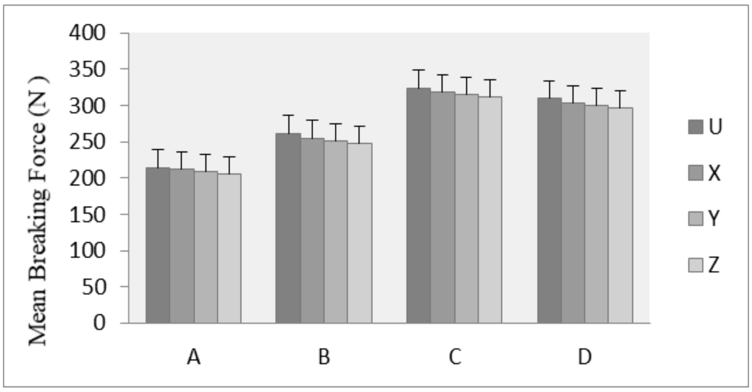

Figure 5. Tensile strength (strip method) in weft direction for untreated and treated fabric samples

4.2.2. Tensile Strength (Grab Method)

The results are presented in Figures (6-7). A small significant decrease in tensile strength was observed after triclosan treatments and a small significant decrease was observed with the increase in triclosan concentration. This is attributed to triclosan treatment caused a swelling of fibers in the fabric structure which decreased the number of yarns per area resulting a restriction in the movement of the yarns. Cotton plain fabrics showed the highest tensile strength and panama fabrics showed the lowest tensile strength in warp direction. Twill fabrics showed the highest tensile strength and cotton/elastane fabrics showed the lowest tensile strength in weft direction.

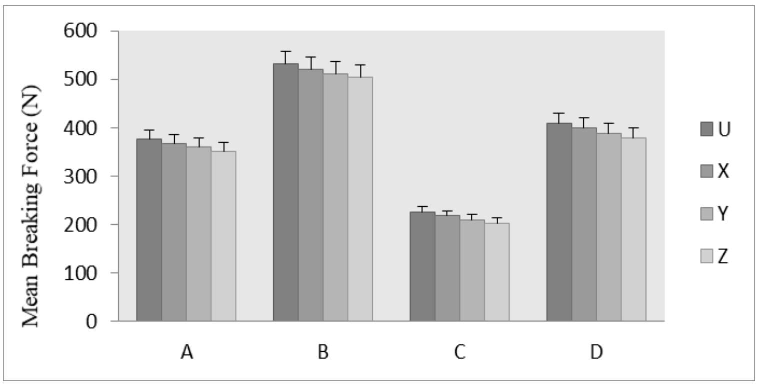

Figure 6. Tensile strength (grab method) in warp direction for untreated and treated fabric samples

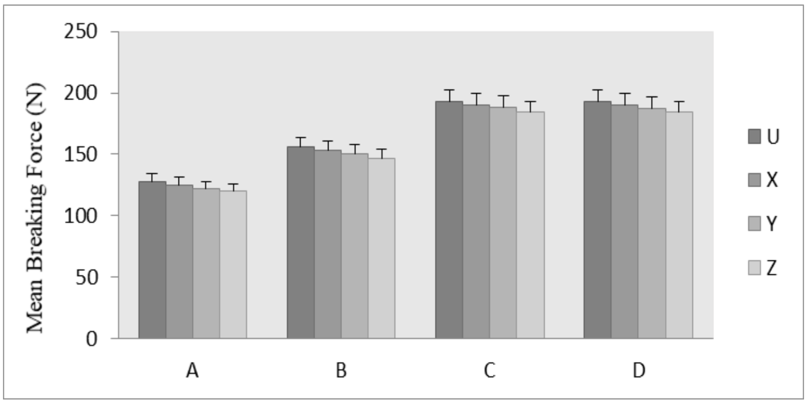

Figure 7. Tensile strength (grab method) in weft direction for untreated and treated fabric samples

4.2.3. Effect of Triclosan Treatment on Tensile Strength

ANOVA one-way was used to analyze the effect of triclosan treatment on tensile strength. Using one way analysis of variance, p-value was found as 0.01. The result of the analysis is shown in Table 2. As p-value is smaller than 0.05, it can be estimated that triclosan treatment has a significant effect on tensile strength.

Table 2. ANOVA and estimation of parameters from tensile strength

ANOVA one way						
Source of Variance	SS	df	MS	F	P-value	F crit
Between Groups	80.0833	1	80.0833	8.1028	0.0173	4.9646
Within Groups	98.8333	10	9.8833			
Total	178.9166	11				

4.2.4. Tear Strength

The results are presented in Figures (8-9). A small significant decrease in tear strength was observed after triclosan treatments and a small significant decrease was observed with the increase in triclosan concentration. It was observed the triclosan treatment caused a significant decrease in the number of yarns in the del shape in the region of tear. Panama fabrics showed the highest tear strength and cotton/elastane plain fabrics showed the lowest tear strength in warp direction and panama fabrics showed the highest tear strength and cotton plain fabrics showed the lowest tear strength in weft direction.

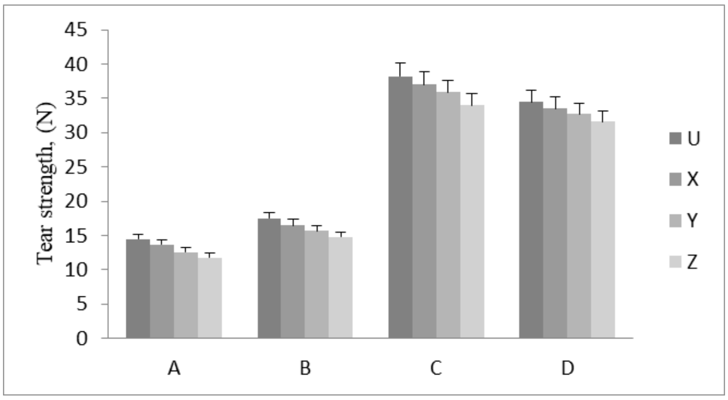

Figure 8. Tear strength in warp direction for untreated and treated fabric samples

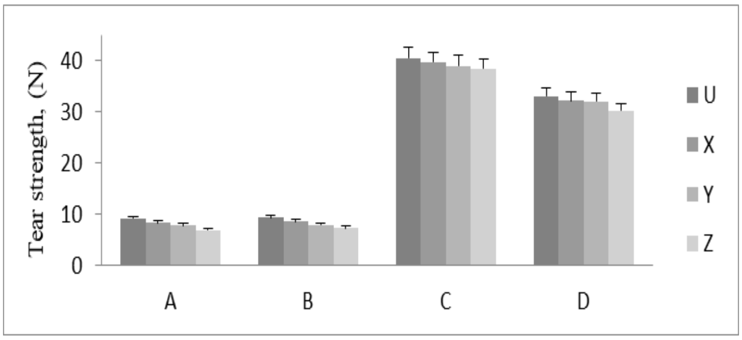

Figure 9. Tear strength in weft direction for untreated and treated fabric samples

4.2.5. Effect of Triclosan Treatment on Tear Strength

ANOVA one-way was used to analyze the effect of triclosan treatment on tear strength. Using one way analysis of variance, p-value was found as 0.008. The result of the analysis is shown in Table 3. As p-value is smaller than 0.05, it can be estimated that triclosan treatment has a significant effect on tear strength.

Table 3. ANOVA and estimation of parameters from tear strength

ANOVA one way						
Source of Variance	SS	df	MS	F	P-value	F crit
Between Groups	560.3333	1	560.3333	21.8595	0.008	4.9646
Within Groups	256.3333	10	25.63333			
Total	816.6666	11				

4.2.6. Seam Strength

The results are presented in Figures (10-11). A small significant decrease in seam strength was observed after triclosan treatments and a small significant decrease was observed with the increase in triclosan concentration. This is attributed to triclosan treatment caused a restriction in the movement of yarns in the fabric structure resulting a significant decrease in the elasticity. Cotton/elastane plain fabrics showed the highest seam strength and panama fabrics showed the lowest seam strength in warp direction. Twill fabrics showed the highest seam strength and panama fabrics showed the lowest seam strength in weft direction.

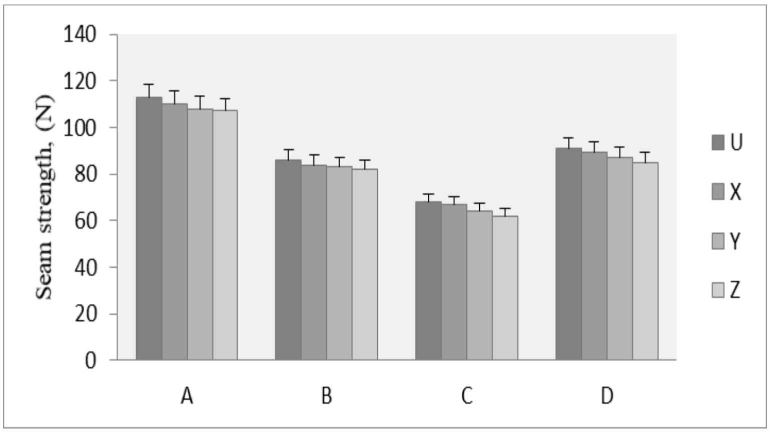

Figure 10. Seam strength in warp direction for untreated and treated fabric samples

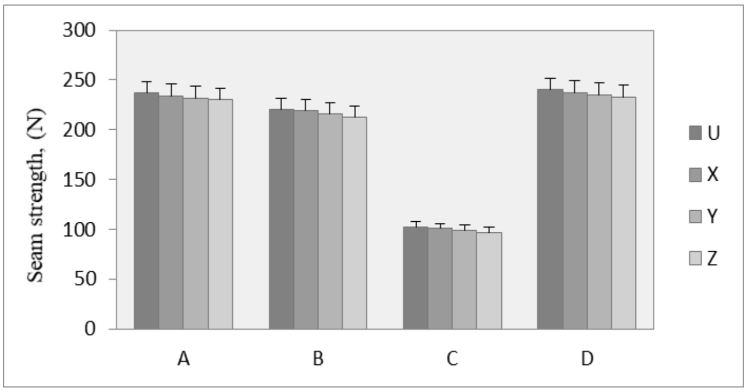

Figure 11. Seam strength in weft direction for untreated and treated fabric samples

4.2.7. Effect of Triclosan Treatment on Seam Strength

ANOVA one-way was used to analyze the effect of triclosan treatment on seam strength. Using one way analysis of variance, p-value was found as 0.0005. The result of the analysis is shown in Table 4. As p-value is smaller than 0.05, it can be estimated that triclosan treatment has a significant effect on seam strength.

Table 4. ANOVA and estimation of parameters from seam strength

ANOVA one way						
Source of Variance	SS	df	MS	F	P-value	F crit
Between Groups	425.0417	1	425.0417	16.4363	0.0005	4.3009
Within Groups	568.9167	22	25.85985			
Total	993.9583	23				

5. CONCLUSION

An alternative method is presented using triclosan agents that can kill bacteria and viruses to help keep patient, operating, and emergency rooms free of germs. Samples were treated with triclosan to achieve antimicrobial/antiviral/antifungal properties for further designs to help comfort and bacteria, virus, fungi (BVF) resistant during use. The antimicrobial tests showed that all treated samples have a very good antimicrobial activity which can also lead to antivirus protection by providing hygienic environment for the users during future designs. The physical and the mechanical properties of cotton and cotton/elastane fabrics used for clothing in further designs were evaluated before and after triclosan agent procedure. All samples were tested in terms of tensile trength (strip method), tensile strength (grab method), tear strength and seam strength.

The tensile strength (strip and grab method), tear strength and seam strength showed a small significant decrease after triclosan treatments. This is attributed to a small significant decrease in elasticity after processes which is releated with the restriction of the slippage of yarns in the fabric structure which decreased the elasticity of the fabric samples resulting a limitation in the movement of yarns. Cotton plain fabrics showed the highest tensile strength (strip and grab methods) in warp direction before and after triclosan treatments. This is attributed to higher fabric density caused a less fabric shrinkage after triclosan treatments thus a higher breaking load per yarn. Panama fabrics showed the highest tear strength both in warp and weft directions before and after treatments which is attributed to higher number of yarns in the del shape in the region of tear. Twill fabrics showed the highest tensile strength (grab method) and seam strength in weft direction before and after treatments which is attributed to higher elasticity of the fabric structure in weft direction. Cotton/elastane plain fabrics showed the highest seam strength in warp direction before and after treatments which is attributed to elastane in the fabric structure provided more elasticity resulting a significant increase in seam strength. A small significant decrease was observed with the increase in triclosan concentration. The results showed that all samples showed a very good antimicrobial activity up to 30 wash cycles. Finally, it's found that the triclosan treatments altered the mechanical and physical properties of cotton and cotton/elastane fabrics but the treated samples still protected their physical and mechanical properties which will still provide comfort during use as clothings in further designs. It is also useful to add that when triclosan use in lower concentrations they appear bacteriostatic and when used in low concentrations could not threat human health which is already approved by the Food and Drug Administration (FDA) and Health Canada [30]. The results of this study can also lead to antivirus protection by providing hygienic environment for the users during future designs.

NOTICE

The preliminary analysis of this research was presented at 5th International Marmara Sciences Congress with the title of "Triclosan Antimicrobials on Woven Clothings and Their Characterization" on 4-5th of December, 2020, Kocaeli.

CONFLICT OF INTEREST

The author declared no conflict of interest.

FINANCIAL DISCLOSURE

The author declare that this study has received no financial support.

DECLARATION OF ETHICAL STANDARDS

The author of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

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