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Effect of Titanium Nano-Silicate Treatment on Functional and Appearance of Garment Linen Fabrics Blended with Cotton

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Abstract

The appearance of garments is almost the main important property for people when wearing garments in parallel with the comfort and durability of the garment. This work aimed to enhance the appearance of linen blended cotton garments' fabrics while maintaining the comfort and durability properties. Five different weaving fancy structures (Simple crepe weave, 8-thread crepe cord satin weave, Mock leno, broken twill, and 8-thread huck a back), and three different treatment concentrations (0%, 1%, and 2%) were used to modify the garments' fabric appearance. Two-way ANOVA test was used to analyze data. It was found that the difference in the weaving structure affected thickness (mm), Air permeability ($cm^3/cm^2/sec$), Weft Tensile strength (N/mm^2), Warp Elongation (%), Weft Elongation (%), Weft Flexural rigidity, and the pilling appearance grade of the garment fabrics samples significantly. However, the difference in the $TiSiO_4$ concentrations had significant effects on thickness (mm), Air permeability ($cm^3/cm^2.sec$), Warp Elongation (%), Warp Flexural rigidity, Weft Flexural rigidity, and the pilling appearance grade of the garment fabrics samples. Also, quality factors were calculated for all samples to evaluate their performance. It was found that the difference in the weaving structure of the garment linen fabrics blended with cotton affectedfunctional and appearance properties of the different concentrations. The results showed that different structures require different concentrations of $TiSiO_4$ because of different behaviors of deposition and absorption of nano molecules from one structure to another. The best weaving structure to improve the performance of garment linen fabrics blended with cotton was the broken twill 4/4, the lowest structure in the order was the mock leno. Treating garments' fabric by$TiSiO_4$ with 2% concentration ranked the highest in each of the simple crepe weave structure, the 8thread crepe cord satin , the broken twill , the 8-thread huck a back structure

"Keywords: TiSio4, Linen, Cotton, Fancy structures, Comfortability, Appearance."

1. Introduction

Garments are the basic materials we use every day and provide psychological comfort[1]. people must choose their clothes according to their needed properties [2], [3], [4]. Cellulosic fabrics are noted for comfortability, absorbency, sustainability, and softness,which give them benefits over synthetic fibres[4], [5].

Flax fibers are among the most basic natural fibers since they can be taken from plant stems [6]. In recent years, linen has seen a virtual renaissance. Customers' interest in it is trending upward, especially in the clothing market. Since fiber is now a preferred material for many fashion designers, there has been a significant increase in demand for enormous quantities of the material. The fiber is actually referred to as "flax," but when it is spun into yarn or woven into fabric, it is called linen. Similar to several other natural fibers, linen has faced an absence of serious attention from academics and users since the mid-1900s. The primary cause of the issue may be the rapidly growing synthetic fiber sector. Given that both cotton and this textile fiber are cellulosic, their chemical processing is relatively similar. However, the production path is slightly altered based on the usual contaminants found in flax. The processing equipment used for cotton can likewise be utilized for linen [7]. A large part

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of the production of fabrics depends on blending different types of fibres with different blending ratios to reduce costs, and modify the properties [8]. In a summary, the key advantages of linen-cotton fabrics are their breathability, moisture absorption, durability, sustainability, and versatility, making them a popular choice for various textile applications, offer superior comfort to clothing, which makes them highly well-liked and often utilized in the clothing industry [9].

By incorporating nanomaterials into textiles, one can alter their characteristics and give them new ones. These materials function to enhance the characteristics of these fabrics and confer onto them new attributes, such as resistance to friction, resistance to microbes, UV protection, and correct water-repellency[10], [11].

In the textile industry, silicones are widely used as lubricants, elastomeric finishes, coatings, and performance enhancers (softeners and water repellents). They are also used as fabric finishes for coatings, print paste softeners, and antifoam agents for fabric and carpet dyeing. In the processes of bleaching, dyeing, and washing, silicone antifoaming compounds are frequently utilized. Silicones also function as wetting agents, water repellents, softeners, and fiber lubricants for spinning, winding, and cutting. The requirements of industrial sewing machines with high speeds are fulfilled by silicone thread lubricants [12].

$TiSiO_4$is a chemical compound composed of titanium, silicon, and oxygen, known as Titanium Sulfate, is a chemical compound used in the treatment of textile wastewater. It is a key component in the electrocoagulation process, which is a method of removing contaminants from wastewater. In the context of textile wastewater treatment, $TiSiO_4$ plays a crucial role in the removal of suspended solids, color, and chemical oxygen demand (COD) from the effluent [13].

Nano $TiSiO_4$ particles are used in various applications, including; textile wastewater treatment: The nanoparticles can be used in electrochemical and coagulation processes to remove contaminants like suspended solids, color, and COD from textile effluents, surface coatings as thin films of TiN/Si_3N_4 nanocomposites containing $TiSiO_4$ can be deposited on surfaces to improve their properties [14], and Nanomaterials research for unique structural and electronic properties of $TiSiO_4$ monolayers have been studied for potential applications in nanoelectronics and spintronics [15].

Nano $TiSiO_4$ is a high-purity, high-density ceramic nanoparticle with a small particle size that can be leveraged for various industrial and research applications, particularly in the context of textile wastewater treatment [14], [15].

$TiSiO_4$ nanoparticles are applied to cotton woven fabric using the in-situ method, Exhaustion Method, Pad-Dry-Cure Method, and Coating Method. These methods offer different approaches to applying $TiSiO_4$ nanoparticles to textiles, each with its specific process and intended outcome, such as antibacterial, antimicrobial, or self-cleaning functionalities[16], [17], [18], [19].

Based on the search results provided, $TiSiO_4$ (titanium silicon oxide) nanoparticles have been used for the multifunctional finishing of textile fabrics, particularly cotton, and polyamide. $TiSiO_4$ nanoparticles can provide antibacterial properties to cotton fabrics [17]. The nanoparticles are used to produce antibacterial cotton fabrics [18]. Additionally, titanium dioxide (TiO_2) nanoparticles have been used for the antimicrobial finishing of polyamide fabrics The search results indicate that TiO_2 nanoparticles can be applied to polyamide fabrics to impart antimicrobial properties [17].

The search results also discuss the use of TiO_2 nanoparticles for the treatment of textile wastewater containing dispersed dyes[20], [21]. The TiO_2 nanoparticles were found to improve dye removal from polyester fabrics, with higher dye removal rates achieved when the TiO_2 treatment was done after the dyeing process compared to before [21].

Overall, the search results demonstrate that both $TiSiO_4$ and TiO_2 nanoparticles have been explored for various textile treatment applications, including providing antibacterial and antimicrobial properties, as well as improving dye removal from textile wastewater [17], [18], [21].

Finishing textiles typically results in thicker fibers, less drape and smoothness, a decrease in washing fastness, poor mechanical qualities, and a decrease in users' comfort [22]. For that; it comes the aim of this work to study the effect of titanium nano-silicate treatment on the function and appearance of garment linen fabrics blended with cotton and find the best condition of treating linen/cotton fabrics for enhancing appearance while assuring good mechanical properties.

2. Experimental Work

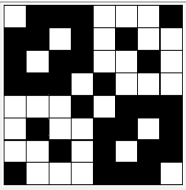
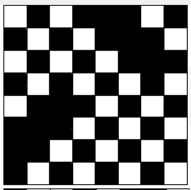
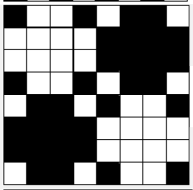
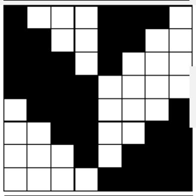
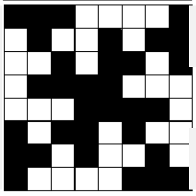
2.1. Material

Combed cotton yarns with a yarn count of 40/2 Ne were used as warp yarns by 28 ends/cm, While linen weft yarn with a yarn count of 20/1 Ne, by 22 picks/cm. ($TiSiO_4$) nano powder <50 nm particle size (BET), 99.8%trace metal basis synonym: silicon titanate, silicon titanium oxide, and titanium silicate by molecular weight 139.95, produced from Sigma-Aldrich was used for treatment.

2.2 *Method*

Picanol Jacquard machine was used by 176 cm width and weaving speed of 160 picks/min for producing five different linen/cotton garment fabric structures based on plain, satin, and twill structures illustrated in Table (1). Samples were treated by titanium silicon oxide. All five garment fabric structures were treated by 1%, and 2% concentrations from $TiSiO_4$ and then compared with blank samples for modifying appearance properties for garment use.

Table 1: Specification of samples

Sample Code	*Weaving Structure Code*	*Weaving Structure Name*	*Weaving Structure Pattern*	*Tisi0₄ Treatment Concentration*
S1 (Blank1)	1	Simple crepe weave		0%
S2				1%
S3				2%
S4 (Blank2)	2	8-thread crepe cord satin weave		0%
S5				1%
S6				2%
S7 (Blank3)	3	Mock leno		0%
S8				1%
S9				2%
S10 (Blank4)	4	Broken twill		0%
S11				1%
S12				2%
S13 (Blank5)	5	8-thread huck a back		0%
S14				1%
S15				2%

All tested samples were preconditioned at the specified ambient conditions (20°C +/- 2 and 65% +/- 2 RH), following ISO 139, 2005 [21].
The five blank linen blended cotton garment fabrics and their treated samples were characterized by measuring their mass per unit area regarding ASTM D3776 [22], thickness regarding ASTM D1777 [23], and air permeability regarding ASTM D737 [24] properties. Tensile strength, Elongation regarding ISO 13934-1 [25], Flexural rigidity regarding ISO 9073-7 [26], and pilling resistance grade regarding ASTM D4970/D4970M [27].

3. Result and discussion

Due to the efficiency of different variables on the properties of the produced samples, an ANOVA two-way test with a significance level (p-value=0.05) has been performed, as exposed in Tables (2-7). The results specified that the difference in the weaving structure coded (1, 2, 3, 4, and 5) affected thickness (mm), air permeability ($cm^3/cm^2/sec$), weft tensile strength (N/mm^2), warp elongation (%), weft elongation (%), weft flexural rigidity, and the pilling appearance grade of the garment fabrics samples significantly.

Although the difference in the $TiSiO_4$ concentrations (0%, 1%, and 2%) had significant efficiency effects on thickness (mm), air permeability ($cm^3/cm^2.sec$), warp elongation (%), warp flexural rigidity, weft flexural rigidity, and the pilling appearance grade of the garment fabrics samples.

3.1 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' mass per unit area (g/m^2)

As observed at Figure 1; it is shown that different structures and different treatment concentrations affected the mass of the sample per square meter, and it's clearly shown that the 8-thread crepe cord satin weavestructure (code: 2) has the higher mass per square meter in all treatment conditions, this is regarded that this structure has more interlacing areas of plain structure which use taller length of yarns.

But, by applying a two-way ANOVA test (Table 2); it was found that this effect is not significant. The calculated p-values released that different weaving structures when all other variables such as material and density are stable and also the different concentrations of $TiSiO_4$ concentration while treating the garment fabrics have a non-significant effect on the mass per square meter by p-value 0.353 and 0.098, as it's sensed that this effect isn't constant in all cases as it changed from treatment concentration to other.

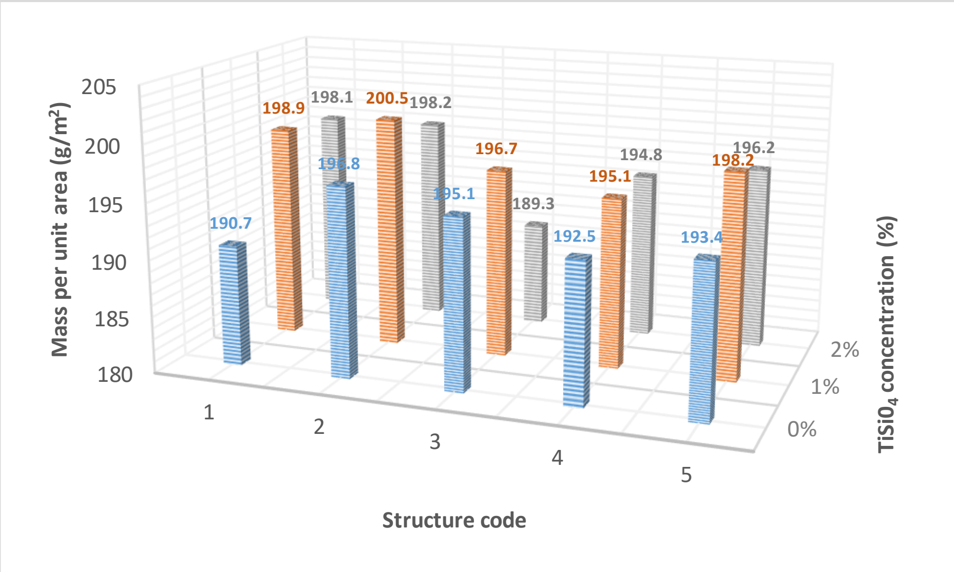


Figure 1. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' mass per unit area (g/m^2)

Table 2: Analysis of Variance for mass per unit area (g/m^2)

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	36.187	9.047	1.28	0.353
$TiSiO_4$ %	2	44.417	22.20	3.15	0.098
Error	8	56.349	7.044		
Total	14	136.953			

3.2 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' thickness(mm)

As observed in Figure 2; it is shown that different structures and different treatment concentrations affected the sample thickness, and it's clearly shown that the simple crepe weave structure (code: 1) has the higher thickness in all treatment conditions followed by the broken twill (code:4) and then 8thread crepe cord satin weave (code:2) then comes the 8 thread huck a back structure (code: 5) and finally came to the mock leno structure (code:3) with the least thickness within these structures. this is regarded as the difference in the weave factor of the applied weave structures.

Also, it is shown in Figure 2 that the higher concentration of $TiSiO_4$ treatment gave higher thickness regarding the swelling of the threads as a result of immersion in the preparation solution. These effects' significance was assured by applying a two-way ANOVA test (Table 3) with p-vale=0.000 for the both effects of different weaving structures and the different concentrations of $TiSiO_4$ treatment.

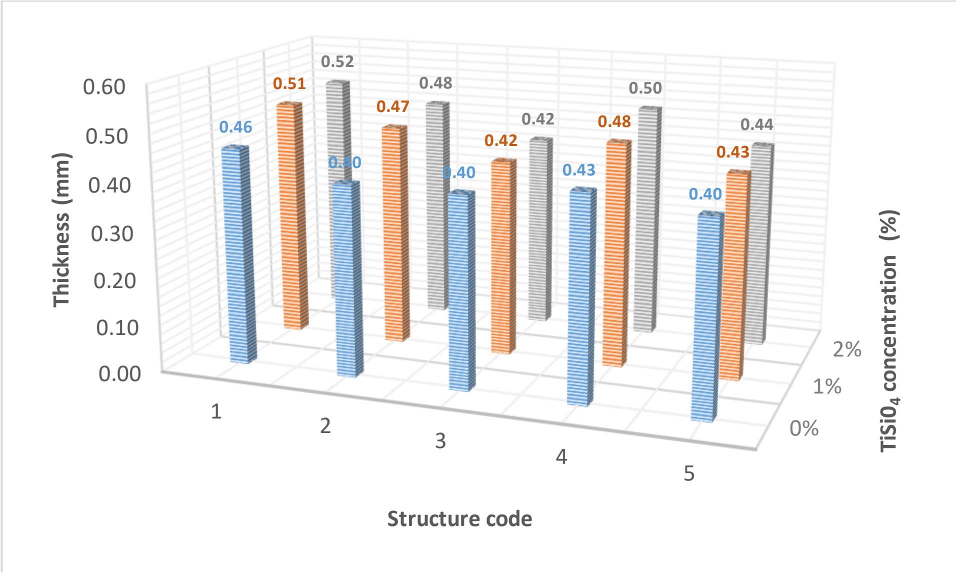


Figure 2. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' thickness(mm)

Table 3: Analysis of Variance for thickness (mm)

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	0.0138933	0.003473	20.63	0.000
TiSiO4 %	2	0.0082533	0.004126	24.51	0.000
Error	8	0.0013467	0.000168		
Total	14	0.0234933			

3.3 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' air permeability ($cm^3/cm^2/sec$)

As observed in Figure 3; it is shown that different structures and different treatment concentrations affected the samples' air permeability, and it's clearly shown that the sample crepe weave structure (code: 1) has the higher air permeability in all treatment conditions followed by the broken twill (code:4) and then 8thread crepe cord satin weave (code:2) then come the 8 thread huck a back structure (code: 5) and finally came the mock leno structure (code:3) with the least air permeability within these structure. this is regarded as the difference in the thickness which is affected by the floating length in each structure of the applied weave structures by affecting the interlacement among the yarns.

It was concluded from the thickness and the air permeability results; that the increase in thickness in these structures was due to the lack of tightened yarns together, which created spaces between them that allowed air to pass through. Also, it is shown in Figure 3 that the difference in $TiSiO_4$ treatment concentration affected the air permeability of the garment fabrics by increasing after 1% and then a little decrease after 2% of the $TiSiO_4$.

This may be attributed to when treating only 1% of $TiSiO_4$ chemical bonds have done between yarns and $TiSiO_4$,causing an opening between yarnswhich allows air to pass through. But, when treated with a higher concentration of 2% TiSiO4, this causing that some extra particles precipitate inside these openings causing some decrease in this air permeability again.

These effects' significance was assured by applying a two-way ANOVA test (Table 4) with p-vale=0.000 for the effects of different weaving structures and p-value=0.028 for the effects of different concentrations of $TiSiO_4$ treatment.

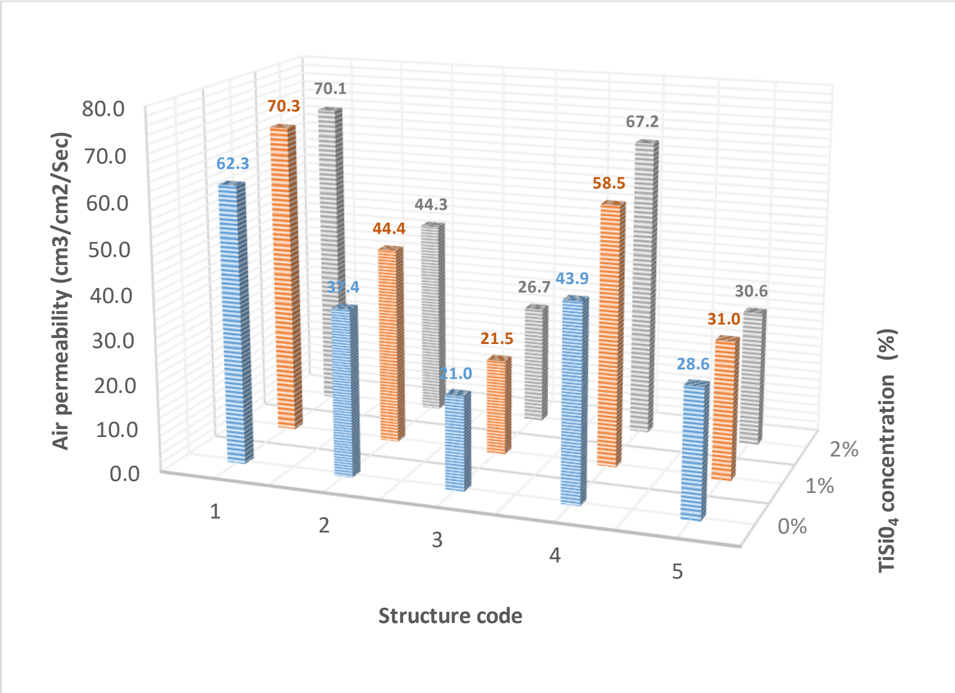


Figure 3. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' air permeability (cm3/cm2/sec)

Table 4: Analysis of Variance for air permeability ($cm^3/cm^2/sec$)

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	4041.10	1010.28	52.71	0.000
TiSiO4 %	2	221.11	110.56	5.77	0.028
Error	8	153.33	19.17		
Total	14	4415.55			

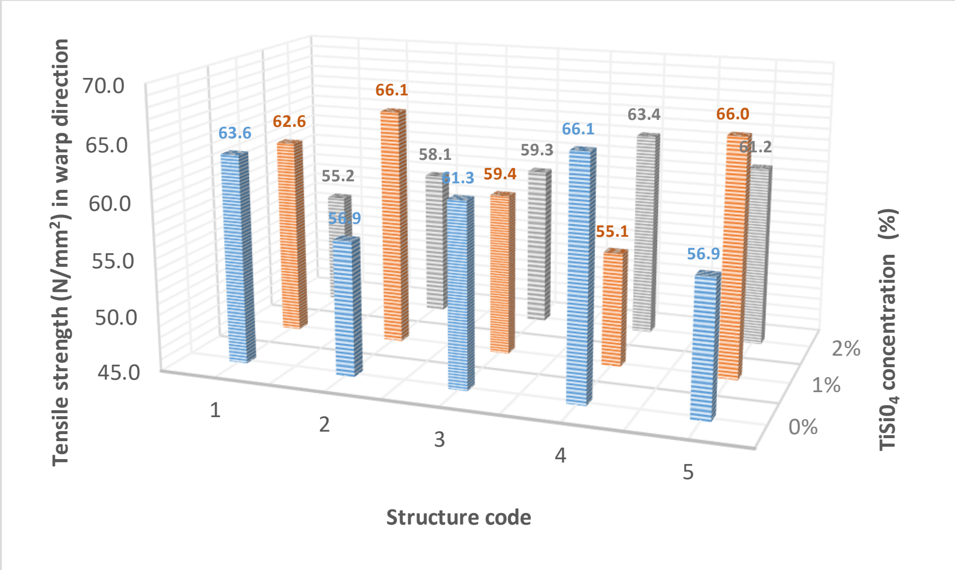
3.4 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' tensile strength (N/mm^2)

Figure 4-a shows; that the tensile strength of the linen blended cotton garment fabric in warp direction while the warp material is cotton, affected by the weaving structure and by the $TiSiO_4$ treatment concentration.

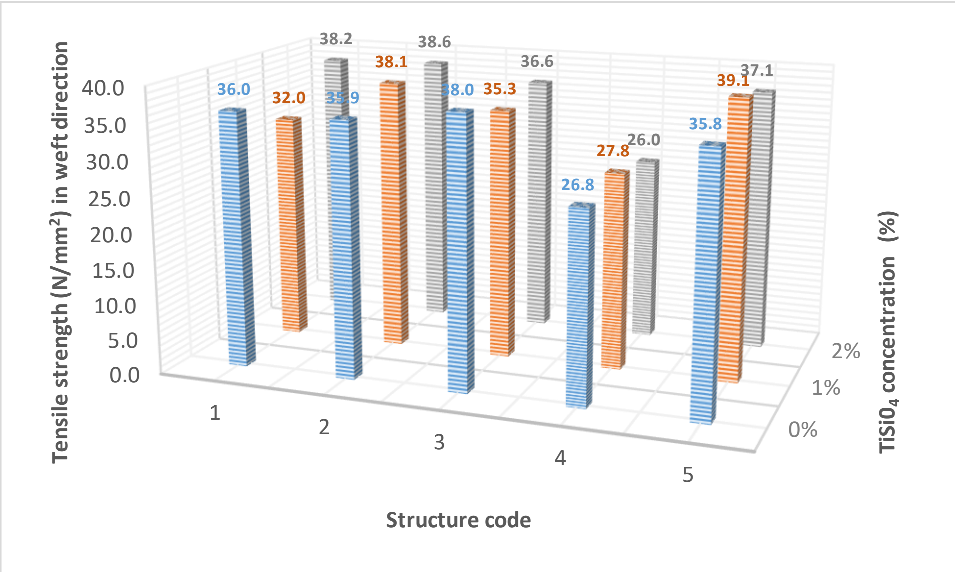
But ANOVA two-way analysis found that this effect is a non-significant effect by p-value=0.992 for the structure difference effect, and p-value= 0.739 for the treatment concentration difference effect as seen in Table 5.

Figure 4-b shows; that the tensile strength of the linen blended cotton garment fabric in weft direction while the weft material is linen, is affected by the weaving structure and by the $TiSiO_4$ treatment concentration. ANOVA two-way analysis found that the structure difference has a significant effect by p-value=0.001.

However, the treatment concentration difference has a non-significant effect by p-value= 0.768 on the Linen Blended Cotton Garment Fabric as seen in Table 6.



(a)



(b)

Figure 4. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' tensile strength (N/mm^2); (a) in the warp direction, (b) in the weft direction

Table 5: Analysis of Variance for tensile strength (N/mm^2) in the warp direction

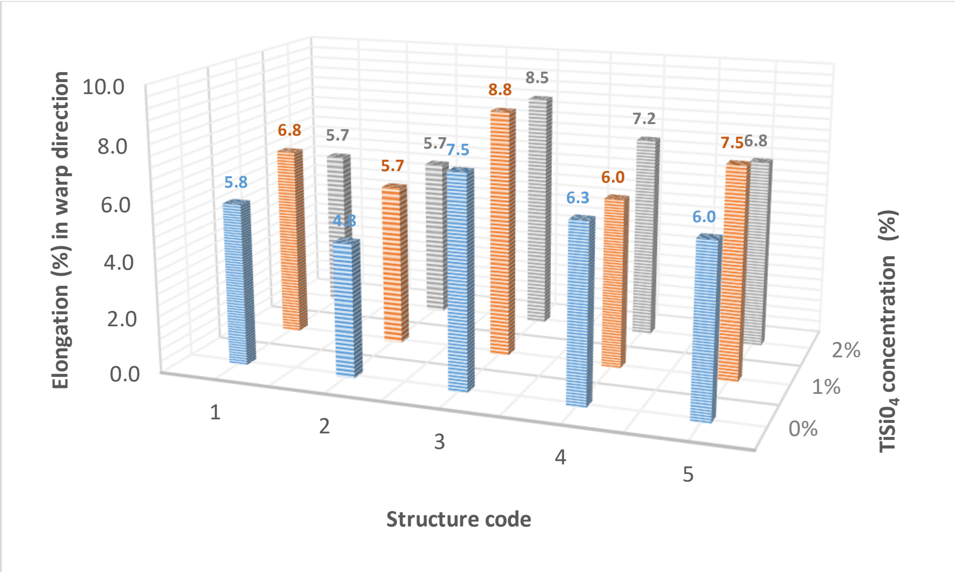
Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	5.43	1.36	0.06	0.992
$TiSiO_4$ %	2	14.64	7.32	0.31	0.739
Error	8	186.03	23.25		
Total	14	206.10			

Table 6: Analysis of Variance for tensile strength (N/mm^2) in the weft direction

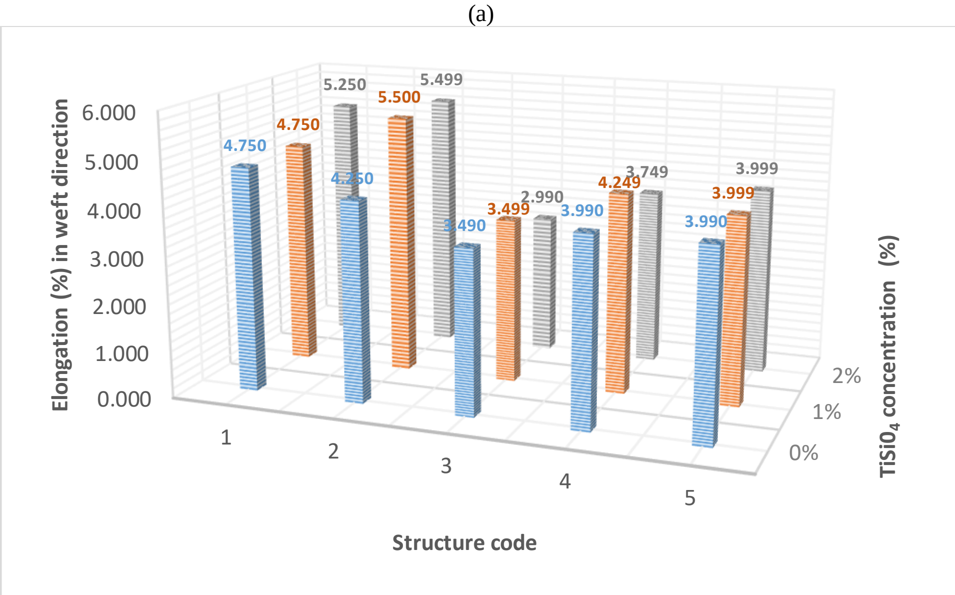
Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	241.150	60.288	14.84	0.001
$TiSiO_4$ %	2	2.215	1.108	0.27	0.768
Error	8	32.505	4.063		
Total	14	275.871			

3.5 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' elongation (%)

As observed in Figure 5-a; it is shown that different structures and different treatment concentrations affected the sample elongation in the warp direction, and it's clearly shown that the mock leno structure (code:3) has the highest elongation in all treatment conditions followed by the broken twill (code:4) and then the 8 thread huck a back structure (code: 5) then come simple crepe weave structure (code: 1) and finally came to the 8thread crepe cord satin weave structure (code:2) with the least elongation percentage in the warp direction within these structures. This may be regarded as the difference in the warp yarn crimp percentage happening due to different yarn motions in each structure. Also, it is shown from Figure 5-a that also, the different concentrations of $TiSiO_4$ treatment gave a difference in the elongation percentage in warp direction regarding the chemical bonds that happened between cotton material and the $TiSiO_4$. These effects' significance was assured by applying a two-way ANOVA test (Table 7) with p-vale=0.001 for the effects of different weaving structures and p-value=0.040 for the effect of different concentrations of $TiSiO_4$ treatment showing a higher effect of the structure design than the effect of the treatment concentration.



(a)



(b)

Figure 5. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' elongation (%); (a) in the warp direction, (b) in the weft direction

Table 7: Analysis of Variance for elongation (%) in the warp direction

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	13.2725	3.3181	14.09	0.001
$TiSiO_4$ %	2	2.3217	1.1609	4.93	0.040
Error	8	1.8840	0.2355		
Total	14	17.4782			

Table 8: Analysis of Variance for elongation (%) in the weft direction

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	6.3588	1.5897	10.09	0.003
$TiSiO_4$ %	2	0.2417	0.1209	0.77	0.496
Error	8	1.2606	0.1576		
Total	14	7.8611			

When Figure 5-b observed; the effect of the different structures and different treatment concentrations on the linen blended cotton garment fabric elongation percentage in the weft direction, and it's clearly shown that the 8thread crepe cord satin weave structure (code:2) has the highest elongation in all treatment conditions followed by the simple crepe weave structure (code: 1) and then the 8 thread huck a back structure (code: 5) and broken twill (code:4), finally came the mock leno structure (code:3) with the least elongation percentage in the weft direction within these structures. Also, it is shown in Figure 5-b that; also, the different concentrations of $TiSiO^4$ treatment gave some difference in the elongation percentage in the weft direction. These effects' significance was assured by applying a two-way ANOVA test (Table 8) with p-vale=0.003 showing a significant effect of different weaving structures but a non-significant effect with p-value=0.496 for the effect of different concentrations of $TiSiO^4$ treatment.

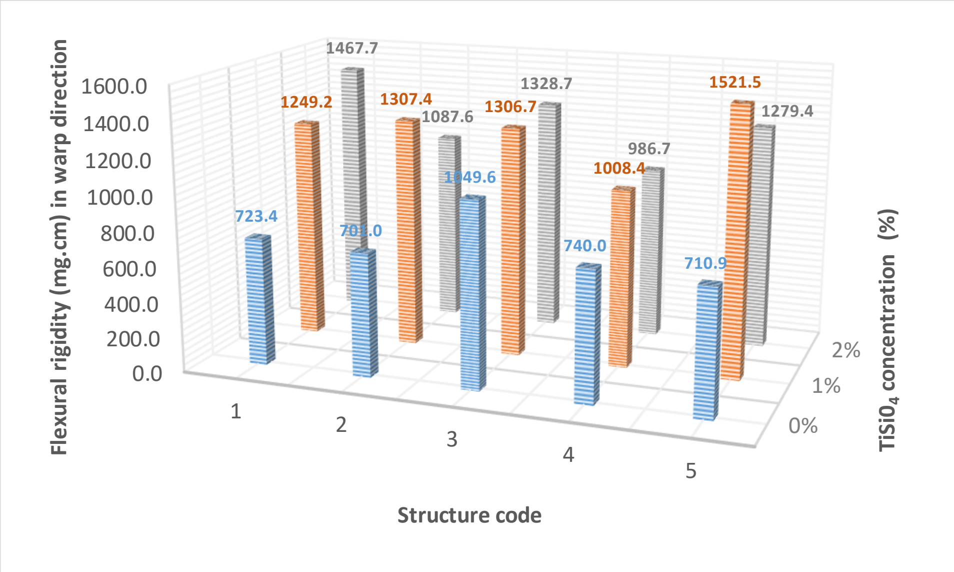
3.6 Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' flexural rigidity (mg. cm)

As observed in Figure 6-a; it is shown that different structures and different treatment concentrations affected the flexural rigidity in the warp direction of the linen blended cotton garment fabric, and it's clearly shown that the different weaving structures affected the flexural rigidity in the warp direction while the warp is from cotton material, but this effect differs from treatment concentration to other. Also, it is shown in Figure 6-a that; the different concentrations of $TiSiO_4$ treatment gave differences in the flexural rigidity in the warp direction regarding the effect of the silicon particles' precipitation on the surface and between fibres causing stiffing of the fabrics.

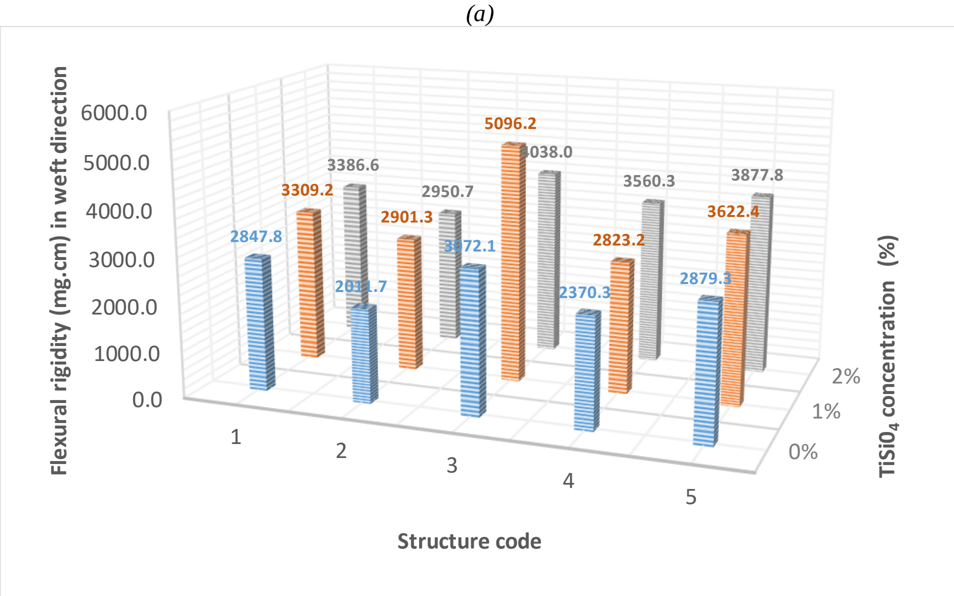
These effects' significance was assured by applying a two-way ANOVA test (Table 9) with p-vale=0.169 for the effects of different weaving structures assuring a non-significant effect of the weaving structure difference on the flexural rigidity in the warp direction and p-value=0.001 with a high significant effect of different concentration of $TiSiO_4$ treatment on the flexural rigidity in the warp direction.

However in the weft direction (Figure 6-b); it is shown that different structures and different treatment concentrations affected the samples' flexural rigidity in the weft direction. When the weft yarns' material was linen, it's clearly shown that the mock leno structure (code:3), has the highest flexural rigidity in the weft direction at all treatment conditions followed by the 8-thread huck a back structure (code: 5), and then the simple crepe weave structure (code: 1), then come broken twill (code:4), and finally came the 8thread crepe cord satin weave structure (code:2) with the least flexural rigidity in the weft direction within these structures.

This may be regarded as the weft material type which is linen, which is affected by different motions in each structure due to its stiffness. Also, it is shown in Figure 6-b that; the different concentrations of $TiSiO_4$ treatment gave differences in the flexural rigidity in the weft direction regarding the effect of the silicon particles' precipitation on the surface and between fibers causing stiffing of the fabrics. These effects' significance was assured by applying a two-way ANOVA test (Table 10) with p-vale=0.015 for the effects of different weaving structures assuring a significant effect of the weaving structure difference on the flexural rigidity in the weft direction and p-value=0.008 with a high significant effect of different concentration of $TiSiO_4$ treatment on the flexural rigidity in the weft direction, showing that the effect of the treatment concentration is higher in the warp direction than in the weft direction. That means that cotton yarns are affected more than linen yarns by treatment with $TiSiO_4$.



(a)



(b)

Figure 6. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' flexural rigidity (mg. cm); (a) in the warp direction, (b) in the weft direction

Table 9: Analysis of Variance for flexural rigidity (mg. cm) in the warp direction

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	191066	47766	2.12	0.169
$TiSiO_4$ %	2	740147	370074	16.46	0.001
Error	8	179899	22487		
Total	14	1111113			

Table 10: Analysis of Variance for flexural rigidity (mg. cm) in the weft direction

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	3674246	918562	6.05	0.015
$TiSiO_4$ %	2	2823775	1411887	9.30	0.008
Error	8	1214054	151757		
Total	14	7712075			

3.7. *Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' pilling grade*

As observed in Figure 7; it is shown that different structures and different treatment concentrations affected the linen blended cotton garment fabrics samples' pilling resistance grade. It's clearly shown that the mock leno structure (code:3) has the highest pilling resistance grade in all treatment conditions followed by the broken twill (code:4) and then the 8 thread huck a back structure (code: 5) then comes simple crepe weave structure (code: 1) and finally came to the 8thread crepe cord satin weave structure (code:2) with the least pilling resistance grade within these structures, Showing that the difference in the weaving structure enhanced the appearance properties of the garments' fabrics due to the difference in the surface design with high and low areas as a weaving effect.

Also, it is shown from Figure 7 that also, the different concentrations of $TiSiO_4$ treatment gave differences in the pilling resistance grade regarding the chemical bonds that happened between linen/cotton material and the $TiSiO_4$ and thesilicon particles' precipitation on the surface and between fibres worked as an adhesin to prevent fibres to go out under rubbing effect. These effects' significance was assured by applying a two-way ANOVA test (Table 11) with p-vale=0.022 for the effects of different weaving structures and p-value=0.01 for the effect of different concentrations of $TiSiO_4$ treatment showing a higher effect of the treatment concentration than the effect of the structure design.

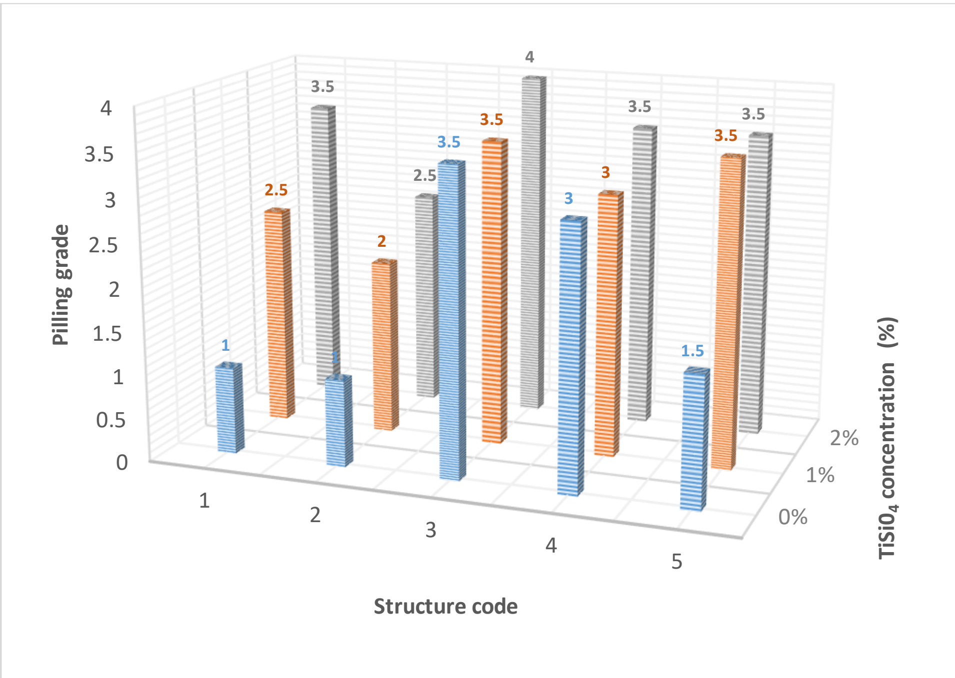


Figure 7. Effect of linen blended cotton fabrics' structure and $TiSiO_4$ treatment concentration on fabrics' pilling grade

Table 11: Analysis of Variance for thickness (mm)

Source	*DF*	*SS*	*MS*	*F*	*P*
Structure	4	6.1000	1.5250	5.30	0.022
$TiSiO_4$ %	2	5.0333	2.5167	8.75	0.010
Error	8	2.3000	2.3000	0.2875	
Total	14	13.4333			

3.8. Ranking samples by quality factor percentage

The quality factor was calculated from all properties' quality percentages for all samples to evaluate their performance and all samples were ranked regarding their quality factor as observed in Table 12.

Table 12: Quality factor calculation of the garment linen fabrics blended with cotton

Structure code	*$TiSiO_4$ percentage*	*weight (g/m^2)*	*thickness (mm)*	*Air permeability ($cm^3/cm^2.sec$)*	*Warp Tensile strength (N/mm^2)*	*Weft Tensile strength (N/mm^2)*	*Warp Elongation (%)*	*Weft Elongation (%)*	*Warp Flexural rigidity*	*Weft Flexural rigidity*	*Pilling*	*Quality factor (%)*	*Ranking samples*
1	0	99.27	87.71	88.61	96.16	92.00	65.71	86.36	96.90	70.64	28.57	77.02	7
1	1	95.17	79.70	100.00	94.67	81.67	77.14	86.36	56.12	60.79	71.43	79.04	4
1	2	95.56	77.83	99.72	83.49	97.62	65.70	95.45	47.76	59.40	100.00	80.01	3
2	0	96.19	99.54	53.23	86.16	91.74	54.29	77.27	100.00	100.00	28.57	74.09	12
2	1	94.41	85.19	63.19	100.00	97.42	65.70	100.00	53.62	69.34	57.14	76.55	8
2	2	95.51	83.42	63.05	87.97	98.54	65.70	99.98	64.46	68.17	71.43	78.58	6
3	0	97.03	99.69	29.93	92.75	97.01	85.71	63.45	66.79	65.48	100.00	75.72	10
3	1	96.24	96.41	30.55	89.80	90.18	100.00	63.62	53.65	39.47	100.00	70.64	15
3	2	100.00	96.60	38.05	89.76	93.53	97.14	54.36	52.76	49.82	114.29	73.96	13
4	0	98.34	93.88	62.48	99.98	68.58	71.43	72.55	94.73	84.87	85.71	82.22	1
4	1	97.03	84.74	83.21	83.42	71.01	68.56	77.25	69.52	71.26	85.71	78.70	5
4	2	97.18	80.23	95.64	95.91	66.46	82.85	68.16	71.04	56.50	100.00	80.03	2
5	0	97.88	100.00	40.65	86.11	91.62	68.57	72.55	98.60	69.87	42.86	73.52	14
5	1	95.51	93.60	44.12	99.91	100.00	85.70	72.71	46.07	55.53	100.00	75.83	9
5	2	96.48	91.89	43.50	92.57	94.86	77.14	72.71	54.79	51.88	100.00	74.69	11

4. Conclusion

This study was conducted to determine the effect of different weaving structures and different concentrations of $TiSiO_4$ on modifying linen blended cotton garments' fabrics. Five weaving structures were developed by three different concentrations of $TiSiO_4$ (0%, 1%, and 2%), and then modified samples were tested and analyzed by a two-way ANOVA test to find each effect's significance on durability, comfortability, and appearance properties. Also, the quality factors of all modified samples were calculated to rank samples regarding their performance. The findings of this analysis are summarized below:

- Linen blended cotton garment fabrics' tensile strength and elongation properties of linen blended cotton garments' fabric greatly affected by the weaving structure. However, mass per square meter, Flexure rigidity, and pilling resistance are greatly affected by treatment concentration.

- It is observed from the difference between p-values of the effect of the treatment in the warp and the weft directions of different properties; that $TiSiO_4$ treatment affects the cotton yams in warp direction than linen yarns in the weft direction of the linen blended cotton garment fabrics.

- The difference in the weaving structure affected thickness (mm), Air permeability ($cm^3/cm^2/sec$), Weft Tensile strength (N/mm^2), Warp Elongation (%), Weft Elongation (%), Weft Flexural rigidity, and the pilling appearance grade of the garment fabrics samples significantly.

- The difference in the $TiSiO_4$ concentrations (0%, 1%, and 2%) had significant efficiency effects on thickness (mm), Air permeability ($cm^3/cm^2.sec$), Warp Elongation (%), Warp Flexural rigidity, Weft Flexural rigidity, and the pilling appearance grade of the garment fabrics samples.

- Appearances of linen blended cotton garments' fabrics were modified by both differences in weave structure and $TiSiO_4$ treatment concentration.

- Quality factor ranked samples and ensured that in fabrics with different weaving structures;Titanium oxide treated samples with a concentration 2% ranked the highest in each of the simple crepe weave structure (code:1), the 8thread crepe cord satin (code:2) , the broken twill (code:4) , the 8 thread huck a back structure (code:5). Also, It was found that the weaving structure has a high effect on garments' fabric performance, as the structure of the broken twill (code:4) ranked first rank regarding the quality factor followed by the same structure by the other structures.

5. Conflicts of interests

"There are no conflicts to declare".

6. Formatting of funding sources

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