Egypt.J.Chem. **Vol. 63**, No. 1. pp. 145 - 154 (2020)

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

The Enhancement of the Functional Properties of Polyester Microfiber Single Jersey Using Some Nano-materials

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IN this study knitted single jersey samples by polyester microfiber (150/288) yarn count were manufactured. Three different machines gauge (20-24-28) was performed. The polyester knitted fabrics were treated with nano clay and nano silica with two concentrations (1.5% & 3%). The samples specifications as stitch length, stitch density and tightness factor were measured while weight, thickness, bursting, UPF, air permeability and stiffness properties were tested. The treated polyester samples dyed with dispersing dyes and the fastness properties were carried out. Furthermore, FTIR was determined to characteristics the modified fabrics and the moisture regain% of samples was estimated. The result presented that the nature of nano treatment plays a striker role in the functional properties of knitted samples as well as although the result referred to improving in samples characteristics and the air permeability were detected. In addition, depending on the radar area, nano silicon dioxide more effective than a nano-clay treatment with different concentrations and the knitting machine gauge (24) offered the highest rating.

Keyword: Polyester microfiber single jersey, Nano-materials and UPF, Air permeability.

Introduction

Demand of weft knitted garments has increased over the years in the domestic and export markets due to its comfortability. **[1]** Generally knitted fabrics characteristic with a good stretch ability which caused due to its looped structure. Single jersey one of the main knitted fabrics which used in different garment, especially on summer clothes. Although single jersey performed many advantageous properties such as breath ability and lightness than other knitted fabric, it suffered weakness at some functional properties e.g bursting and ultraviolet protection. **[2]**

Nowadays, microfibers have found their way into varied applications and their novel properties offer huge potential in both functional and aesthetic trends. Flexibility, regularity and good elongation contribute to the improvement in many properties of knitted fabrics such as softness, drape ability, dimensional stability than normal fibers **[3].** Furthermore, microfibers have been categorized as one of an important moisture management fibers due to its wick ability which help wearer to be dry and cool. Therefore, microfiber fabrics occupy an essential position for performing several apparel, clothing and garments. **[4]** Polyester is one of the most widely microfibers due to its economic advantage. Many articles presented its influence on fabric characteristics such as light weight, softness, more resilience/ recovery and better cover. **[5]** Nanotechnology applications in textile finishing is aimed to impart multifunctional properties to textile which are achieved through changing fabrics of molecular level by nano technology process**. [6, 7]** Nanofinishing technology is an approach to the production of highly active surfaces to have UV blocking, antimicrobial activity, flame retardant, water repellant, resilience, dimensional stability,

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Received 20/5/2019; Accepted 14/10/2019
DOI: 10.21608/ejchem.2019.2868.1804
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burst, hydrophobicity, self-cleaning and thermal properties. **[8, 9]** TiO_2, ZnO, SiO_2 and Al2O_3 are imparting UV protection and decrease the static charge of polyamide and polyester fibre. **[10]** TiO_2 nanoparticles have the potential to improve UV resistance, antistatic, as well as self –cleaning by photo-catalastysis. **[11]** The use of silver nano particales is important as several pathogenic bacteria. **[12]** The nano clay montmorillonite and modified nano clay can be used as sorbent for nonionic, anionic, cationic dyes. **[13, 14]**

The flame retardant properties of cotton fabric enhanced by nano clay plasma treatments. **[15]** The polyester fabrics were treated with methyl red dye, bulk TiO_2 and nano TiO_2, to improve anti static charge and ant flammable property. **[16]** Metal Oxide nano particles of TiO_2, ZnO, Al_2O_3 and MgO exhibit photo-catalytic ability, electrical conductivity, UV absorption and photo oxidizing capacity agents chemical and biological species. **[17]** A composite fiber with nano particles of TiO_2 or MgO can provide self -sterilizing function. **[18]** Polyester and viscose fabrics and its blend were treated with commercial SiO_2 nano particle the influence of treatment on moisture regain, tensile strength, elongation %, anti-pilling, anti-static charge as well as coloration properties was determined. It was found that the durability of antibacterial and color of SiO_2 nanoparticle treated fabrics were improving the adhesion of SiO_2 nano particle to the surface of polyester and viscose fibers using acrylate based copolymer binder. **[19, 20]** Nano kaolin developed some functional properties on viscose fabrics. **[21, 22]**

In this paper, the treatments with nano silicon dioxide (SiO_2) or nano clay (kaolin) were carried out in order to study its impact on the functional properties of the polyester microfiber knitted (single jersey) fabrics and identify its compatibility for summer clothes. In the same vein, determine the effect of treatments on dyeing with disperse dyes as well as the fastness properties.

Experimental

Materials

Samples manufacturing

Three groups of weft knitted polyester fabrics were manufactured with three different machine gauges (20 - 24 - 28). Each group obtained five samples. Single jersey structure with Yarn count: 150 / 288 denier polyester microfiber was performed. A setup of high yarn tension level was applied. Number of wales and courses for a blank sample from each group were measured while stitch density, stitch length and tightness factor were calculated. Table 1 presents the specifications of untreated samples.

Chemicals

The clay (kaoline) from (Sinai desert, Egypt), this clay was thermally treated at 800 C^0 for 2 hrs. In automatic electrical furnace to assure complete decomposition and to get active amorphous NK. This was carried out in the National Research Centre of Housing and Building at the chemistry department. The nano particle of nano silicon dioxide (SiO_2) is obtained from Sigma – Aldrich, Germany. Methyl alcohol and acetic acid of laboratory grade were used.

Dyestuffs

Disperse dye Samaron Pink HFG (C.I. Disperse Red 185) was used.

Treatments

The samples from polyester microfiber were immersed in a methylene solution 1:10 and containing nano kaoline or nano silica (silicon dioxide) concentrations (1.5% or 3%) at room temperature for 30 min.,at liquor- to goods ratio of 10:1, then padded to pick up 100%.The treated samples were put in microwave oven for 1min., power 1000 to dry. Then the samples were rinsed in cold tap water, and fixed at 150°C for 5 min. Finally, the fabric is washed thoroughly with tap water and air dried.

TABLE 1. Specifications of Blank samples with nano-material concentration 0%

Sample Machine gauge	Concentration percentage (%)	Stitches Density [W] Wales W/cm	[C] Courses C/cm	[S] Stitch density Stitches/cm²	Stitch length (mm)	[k] Tightness Factor
20	0%	14.8	22	327.4	2.69	1.517
24	0%	14.4	24.3	349.92	2.56	1.594
28	0%	16.5	22.8	376.2	2.53	1.613

Dyeing with disperse dye

The dye bath of C.I. Disperse Red 185 was prepared by pastingthe dye with 1% acetic acid in hot water, then added 2g/l of carrier. The dye bath was gradually heated to 100°C. The sample fabric was added to the bath and the dyeing continued for 60 min., at liquor ratio 1:50. The dyed sample was thoroughly washed in warm and cold water and air dried.

Measurements

Aiming to achieve the goals of the research some functional properties were tested and classified into two categories.

1 **Mass per unit area (Weight test):** according to (ASTM, D3776)

2 **Thickness Test:** according to (ASTM, D1777).

3 **Burst strength testing**: according to (ASTM-3786-01)

4 **Air permeability:** according to (ASTM D737–96)

5 **UPF:** according to (AATCC 183-2004,ASTM-D6603-00)

6 **Stiffness:** according to (ASTM – D1388).

7 **Moisture Regain:** Moisture Regain measured according (ASTM – D2654) (1982). **[23]**

8 **Color intensity (K/S):** Color strength (intensity): K/S Color intensity of the dyed fabric (k/s) was measured at the wavelength of the maximum absorbance using a SF600+-CT Data colors spectrophotometer**. [24]**

9 **Washing Fastness:** according to the AATCC test method (AATCC Technical Manual, Method 36, (1972), 68, 23, (1993)) using LaunderOmeter. **[25]**

10 **Infrared Spectra:** Infrared spectra were recorded on FT-IR Nicolet 5 DX Spectrophotometer. The samples were examined as 1.5% KBr pellets.

Results and Discussion

Physical and mechanical properties

Effect of nano treatment on Density

Table 2 and 3 show the specification of treated knitted polyester fabrics with different concentrations of nano silicon dioxide or nano clay (kaoline). The findings clarify the effect of nano treatment where the number of wales and courses per cm changed, consequently influence on different factors such as stitch density and tightness. The results show the increase in both number of yarns and concentrations of nano material increasement the density.

Weight (g/m²)

Figure 1 present the weight property of knitted polyester fabrics. The results indicate the impact of nano nature and its concentrations on polyester fabrics weight, Nano silicon of knitted polyester fabrics obtained lighter weight than nano kaoline of knitted polyester fabrics at different machine gauges. Moreover, the samples with 3% nano concentration realized a higher weight compared with samples with 1.5% concentration. On the other hand, the results clarify the effectiveness of machine gauges in sample weight, where the higher the gauge the greater the weight. The justification related to the increasing of stitch density per unit area. It was foud that the high incresment in case the ample machine gauge 28

TABLE 2. Specifications of samples treated with Nano Silicon dioxide

Sample Machine gauge	Concentration percentage (%)	Stitches Density [W] Wales W/cm	[C] Courses C/cm	[S] Stitch density Stitches/cm²	Stitch length (mm)	[k] Tightness Factor
20	1.5%	15.3	21.65	331.24	2.65	1.54
	3%	15.7	22	356.16	2.62	1.55
24	1.5%	15.1	22.83	359.38	2.52	1.62
	3%	15.9	21.85	375.24	2.49	1.63
28	1.5%	17.7	23.6	386.74	2.45	1.66
	3%	17.7	23.8	404.09	2.43	1.68

than other samples. This change in weight may be attributed to happens the shrinkage of samples with treatments.

Thickness (mm)

The results in a figure 2 identify that nano clay treatment attained thicker knitted polyester fabrics compared with nano silicon knitted polyester fabrics and untreated one. It was found that the knitted polyester fabrics with 3% nano concentration obtained a higher thickness than knitted polyester fabrics treated by 1.5% concentration. The results also designate the power of the machine gauges, where the gauge (28) realized the lowest thickness samples than other machine gauges (24) and (20). The explanation is due to the height of the loop, which is associated to stitch length which affected by stitch density.

Moisture Regain %

Table 4 shows the moisture regain % of untreated and treated polyester knitted fabrics with both nano kaolin and nano silica. It was found that the treatment gives a little increase in the moisture regains with nano silicon dioxide only, but the treatment with nano kaoline led to decrease the moisture regain. In this work using SiO_2 nanoparticle as the precursor material which lead to the formation of ordinary SiO_2 nanostructured surface with lower air trapping capability. **[19]**

Treatment condition: (0%- 3% wt./v) at room temperature for 30 min., L: R 10:1, then padded to pick up 100 %, put in microwave oven for 1 min., power 1000 to dry. Then fixed at 150 °C for 5 min.

Burst **(Kgf/Cm^2)**

Figure 3 shows the results burst of the treated knitted polyester fabrics with different concentrations of both nano kaolin and nano silicon dioxide. The results specify that treatment of nano-clay particles achieves more improvement in burst property for knitted samples than nano silicon dioxide treatment. Moreover, the results demonstrate the effectiveness of nano-scale concentration, as there aren't any statistically significant differences between 1.5% & 3% concentrations in nano silicon samples, while 3% is more effective than 1.5% in nano-clay samples. The interpretation could be related to the nature of nano-processing that affects the ability of yarn resistance to mechanical force.

In addition, the results declare that knitting machine with higher gauge (28), increase burst property than lower machine gauges which correlated to the altitude of yarns interlacing at the unit of area.

Ultraviolet protective factor (UPF)

Figure 4 demonstrates the Ultraviolet protective factor UPF of polyester knitted single jersey fabrics treated with nano kaoline or nano silicon dioxide. The findings highlight the impact of the nano-particles, where nano silicon dioxide executed a higher UV protection than nano-clay (kaoline). As well as a contradictory situation was observed, whereas 1.5% nano-kaoline concentration is stronger to increase the UPF property than 3% whilst the opposite on the concentration of nano-silicon. The explanation related to the nature of nano where nano silicon dioxide develops the fabric capability to reflect radiation in contrast to nano clay particles which is more powerful to increment fabric strength.

In addition, the highest gauge of the knitting machine reaches the highest degree of UV protection, which is attributed to the increased density of stitches, which upgrade the cloth to reflect ultraviolet radiation.

Air Permeability(cm^3/cm^2.Sec)

The results in a figure 5 present the air permeability property of the processed polyester fabrics. The chart illustrates that nano treatments conducted a negative impact on the air permeability characteristic compared with untreated samples. Furthermore, the results designate that 1.5% nano concentration is better than 3%. This is due to the changes on yarn diameter, which affected by the absorption of nano-particles and subsequently on fabric pore size. In the same context, the results locate that nano-silicon dioxide is more effective than a nano-clay (kaoline). This results may be attributed to the pentration of the nano material inside the yarns and file off the pores between the yarns.

As well as, machine gauge (20) obtained the highest air permeability comparing with others machine gauges.

Stiffness

Figure 6 illustrates the stiffness property of the treated polyester fabrics and untreated one, where the diagram specifies that nano-silicon dioxode is more capable to improve fabric stiffness than a nano-kaoline. The results also reveal to a positive relationship between the nano concentration and the stiffness reduction. Moreover, machine gauge

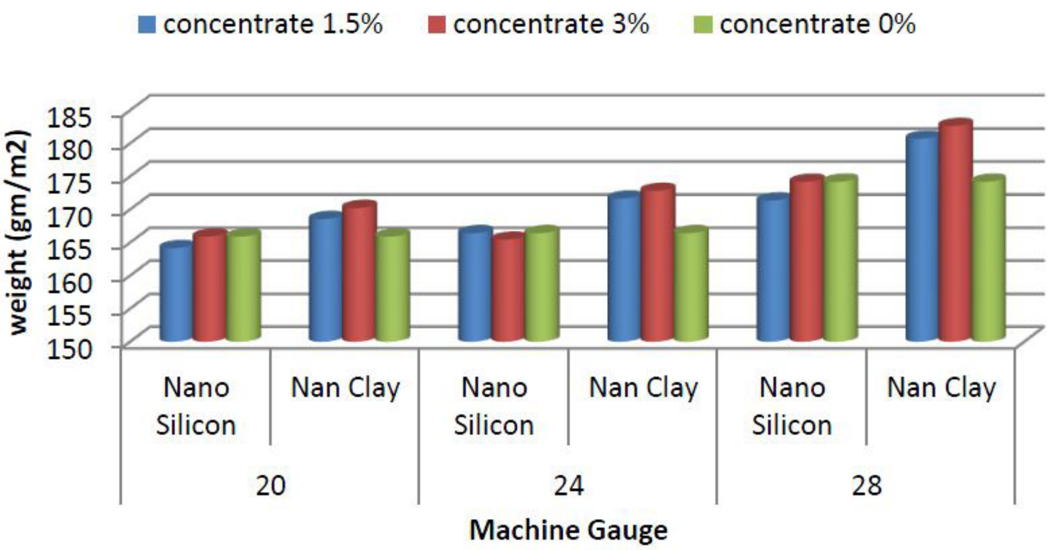

Figure (1) weight diagram of single jersey samples

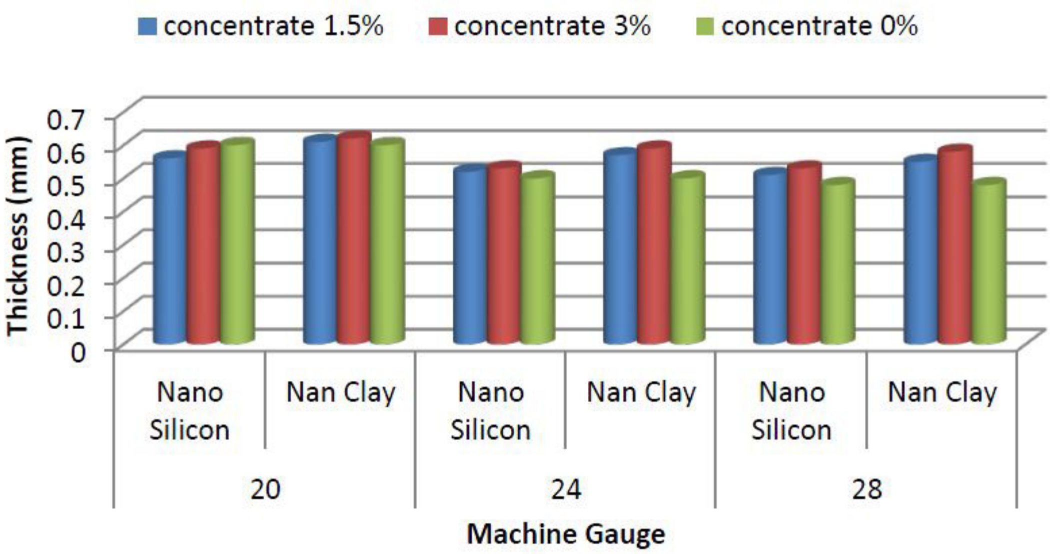

Figure (2) Thickness diagram of single jersey samples

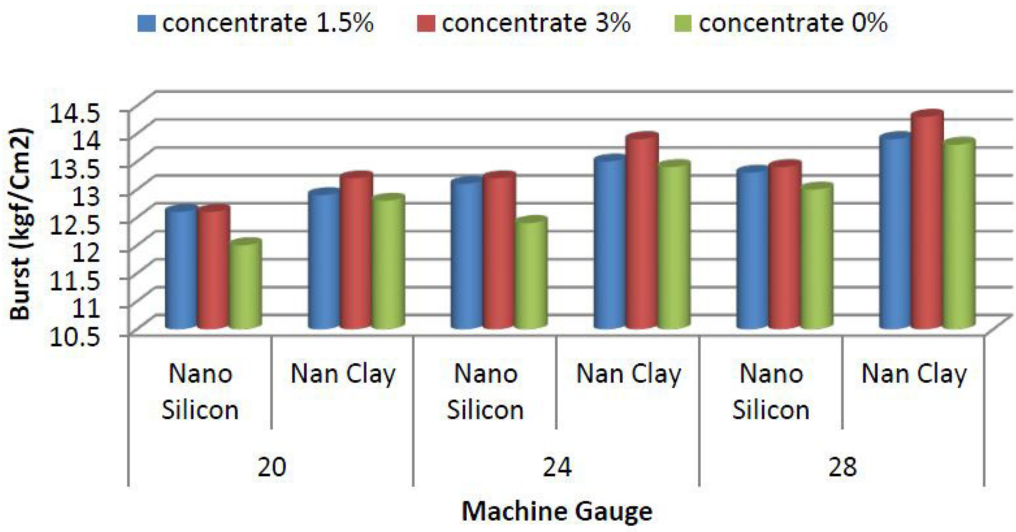

Figure (3) Burst diagram of single jersey samples

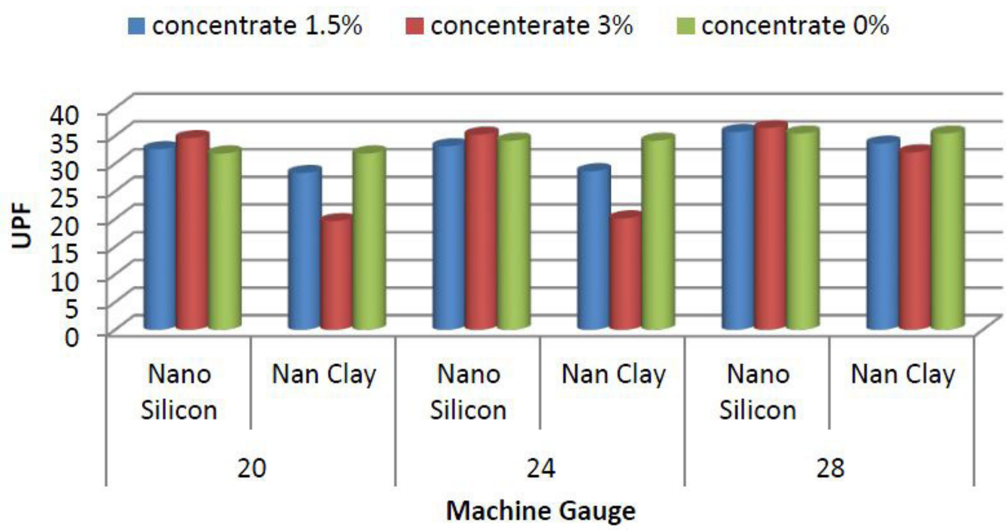

Figure (4) UPF diagram of single jersey samples

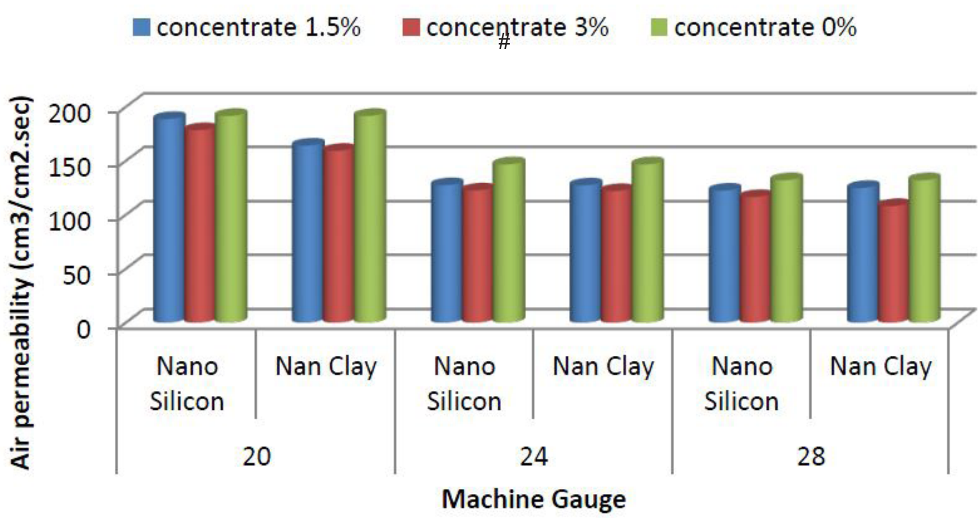

Figure (5) Air Permeability diagram of single jersey samples

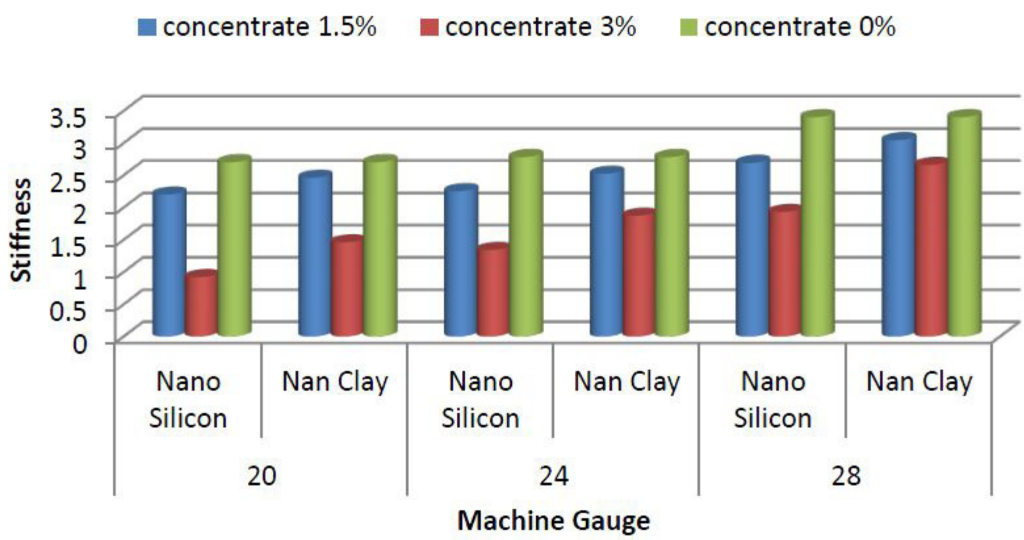

Figure (6) Stiffness diagram of single jersey samples

TABLE 3. Specifications of samples treated with Nano Clay

Sample Machine gauge	Concentration percentage (%)	Stitches Density [W] Wales W/cm	[C] Courses C/cm	[S] Stitch density Stitches/cm²	Stitch length (mm)	[k] Tightness Factor
20	1.5%	15.9	22	349.8	2.586	1.57
	3%	16.33	22.44	366.44	2.526	1.61
24	1.5%	16.14	22.8	367.99	2.446	1.66
	3%	16.64	23.6	392.70	2.412	1.69
28	1.5%	17.32	23.8	412.21	2.415	1.69
	3%	18.11	24	434.64	2.332	1.75

TABLE 4: Moisture regain % of untreated and treated polyester kited fabrics

Sample Machine gauge	Con. Nano g/l	Moisture regain% of Nano kaoline	Moisture regain % of Nano silicon dioxide
	Untreated	0.52	0.52
20	1.5	0.48	0.56
	3	0.44	0.56
	Untreated	0.52	0.52
24	1.5	0.48	0.54
	3	0.45	0.55
	Untreated	0.53	0.53
28	1.5	0.45	0.54
	3	0.46	0.55

TABLE 5. Radar area calculation of knitted samples

Machine Gauge	Treatment Concentration	Radar Area		Variances
		Nano-Silicon	Nano-Clay	
Gauge 20	1.5%	26186.19	22016.38	8693640
	3%	26392.38	17877.24	36253778
Gauge 24	1.5%	26244.43	22865.47	5708675
	3%	26439.24	18604.02	30695360
Gauge 28	1.5%	24993.93	22400.15	3363845
	3%	23210.28	18621.92	10526510

TABLE 6: Colour strength and washing fastness of untreated and treated polyester fabrics dyed with dispers dyes

Sample Machine gauge	Con. Nano g/l	Nano silicon			Nano clay (kaoline)		
		K/S	Washing fastness		K/S	Washing fastness	
			Alt	St_p		Alt	St_p
	0	9.1	4-5	4	9.1	4	4
20	1.5	9.5	4-5	4	9.5	4	4
	3	9.8	4-5	4	9.6	4	4-5
	0	9.2	4-5	4	9.2	4	4
24	1.5	9.9	4-5	4	9.5	4-5	4
	3	10.3	4-5	4	9.8	4-5	4-5
	0	9.2	4	4-5	9.2	4	4
28	1.5	9.8	4-5	4-5	9.5	4-5	4-5
	3	9.9	4-5	4-5	9.9	4-5	4-5

Dyeing condition: 1% (w.o.f) C.I. Disperse, L: R 1: 50, pH 5, at 95°C for 60 min.

Alt: Alteration **St_p**: Staining polyester

TABLE 7: Fourier Transform Infrared Spectroscopy (FTIR) of treated polyester

Peak range 3622 cm^{-1}	Vibration
1630 cm^{-1}	H-OH
974 cm^{-1}	Si-OH
840 cm^{-1}	O-H
1745 cm^{-1}	C=N
1656.88 cm^{-1}	C=O
1066 cm^{-1}	N-H

plays a striker role, as the smaller the gauge the lowest the stiffness.

Radar Area

Table 5 shows the radare area nd varinces of the treated polyester fabrics with both nano silica and nano kaoline. The results in a table 5 demonstrate that nano-silicon treatment is more effective than a nano-clay whether on 1.5% & 3% concentration at different machine gauge. Furthermore, machine gauge (24) achieves the highest radar area which offers the highest rating. In the same vein, the results show that the variances between Nanotreatments decrease at 1.5% concentration than 3%.

Colour strength and washing fastness

Table 6 illustrates the colour strength and washing fastness of untreated and treated polyester knitted fabrics which dyed with disperse dyes. It was found that the treatment with nano silicon dioxide improved the colour strength for all samples than untreated one. But, the treatment with nano kaoline don’t affect on the colour strength, as well as the washing fastness results show some enhancement for the treated than untreated polyester knitted fabrics.

Fourier Transform Infrared Spectroscopy

Fourier Transform Infrared Spectroscopy (FTIR) of treated polyester fabrics with both nanoclay and nanosilica were shown in table 7. The FTIR spectral analysis was performed at region from 4000 to 400 cm^{-1} on a (Thermos Scientific Nicolet iS10, USA). FTIR data reveals the appearance of bands of the characteristic absorption band at 3622 cm^{-1} is assigned to the stretching vibration of $Al(OH)_3$ and $Si(OH)_2$; plus the presence of band at 840, 974, 1630 cm^{-1} related to (O-H), (Si-OH),(H-OH) all are related to the nanosilicon and nanoclay respectively.

The absorption peaks at 1656.88 cm^{-1} are associated with the presence of the C=O stretching of the amide, bending vibrations of the C=N at 1745 cm^{-1}, N-H bending, at 1066 cm^{-1}. The peak at 1571 cm^{-1} is assigned for stretching of NH.

Conclusion

- The treatment with nano silicon dioxide only gives little increase in the moisture regain. Treatment nano kaoline led to decreases the moisture regain.
- The treatment with nano silicon dioxide gives enhancement the colour strength of all samples than untreated one.
- Nature of nano treatment plays a striker role on the functional properties of knitting single jersey whereas nano silicon dioxide helps to improve weight, UPF and stiffness while nano kaoline enhances the thickness and burst properties.
- Nano treatments conducted a negative impact on the air permeability characteristic compared with blank samples.
- Depending on the radar area results, nano silicon dioxide attains more effective than a nano-kaoline treatment with different concentrations on the knitted single jersey for summer clothes furthermore, machine gauge (24) offers the highest rating.
- Variances between nano-treatments decrease at 1.5% concentration than 3%.

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