A Study of the Range of U. V. R. Penetration through Fabrics Produced from Polyester Hollow Fibers

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Abstract: Protective fabrics somehow has become part and parcel of the environment, so the spinning and weaving industry was involved in using fabrics in non-traditional fields as medicine, agriculture and engineering. These fabrics were designed to protect who wears them from the cruel effects of the environment which may cause great harms which lead to fate. Fabrics which protect from U. V. R. are considered as one of the modern uses of fabrics. Sunlight carries for humanity uncountable blessings; nevertheless, exposure to direct sun rays for a long period of time causes many diseases. So sun rays are a double edge weapon, as it is essential for the formation of vitamin "D" in the human body, while it is harmful in the range of weave length between 280 – 320 nanometer. So the human kind need protection against it. These rays have the ability to penetrate through skin layers. Due to the clever and super system of the human body, the skin cells receive sun rays, and absorbs the harmful (U. V. R.) and transfer it again outside skin cells by an excretion process, to get rid of these rays, but this has a certain limit as the quantity of rays in excess to this process remain in the body and is converted into a form of a disease, as it cause burns, and infections in the skin. Some of the cells in skin layers, which carry melamine dye, give the skin brown colour which increases skin self-protection against (U. V. R.). As the time passes by and with the repetition of exposure to sun rays, that leads to occurrence of changes in the D. N. A., and destruction of skin cells, consequently skin cancer occurs. So the deep concern with studying the effects of the (U. V. R.) on the skin became of special importance due to the increase of the rate of skin cancer disease in several countries. As the clothing is the protective barrier from these rays, so the research was concerned in studying this specialty, by producing 15 samples woven from polyester hollow fibers, which practical experiments had proved that polyester is one of weaving materials of least penetration of (U. V. R.). Those samples were of four different weaving structures which are: plain 1/1, twill 2/1, twill 2/2, and twill 3/1. Each of the four structures used was produced with four different numbers of picks per cm which are (16, 18, 20 and 22) picks/cm. After that, was performed a test to measure the penetration of the (U. V. R.) through these produced fabrics at different wave lengths: 290, 300, 310, 320, 330, 340, 350, 360, 370, 380, 390, 400 nanometer. After that the results of these tests were tabulated, and statistical analysis was done, and the graphical relations were drawn. After that, the samples were arranged according to its functional suitability as fabrics, protective against (U. V. R.). Also was performed tests for air penetrability, thickness, water absorption, the weight of fabric per meter square. Also the results of these tests were listed and studying the range of its effect on the criteria of (U. V. R.) penetrability.

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1. Introduction

The continuous decay in Ozone layer made the protection from ultraviolet ray (U. V. R.), the nowadays debate (4). And the world's trend is the prohibition of using Cloro-Floro-Carbon (CFC2) in order to reduce the ratio of chlorine in the air, as these chemical materials cause the destruction of the Ozone layer that protect the atmosphere from the rays issuing from the layers of stratosphere which permits the penetration of (U. V. R.) to the surface of the earth. Thus, the destruction of a part of Ozone layer floods the earth's surface with harmful rays.

It was noticed that any decrease representing 1% of Ozone layer produces an increase in the penetrated (U. V. R.) which amounts to (0.5 – 5%)(2).

Most of skin cancer diseases are principally caused by (U. V. R.) specially the part (B), having wave lengths between wave lengths (290 – 320) nanometer (nm). And also part (A) of wave lengths between (320 – 400 nm.) which may cause skin cancer be generating active oxygen resulting in destroying the DNA(7).

But electromagnetic waves (C) with wave length between (200 – 280 nm), are absorbed by the air, thus not reaching the earth's surface. But electromagnetic waves of short wave length are specified with strong energy, thus acting strongly against human cells (skin)(4).

Last studies assured that it is doses of (U. V. R.) contained in sun's rays. Sun's rays which reach earth's surface contain 6% of (U. V. R.). Thought it was proved these rays harm skin cells and photogenic poisoning. The worst cases of injury is skin cancer (4).

U. V. R. have a bad effect on fibers and dyes. Specially in the presence of high temperature and humidity, causing hydrolysis to both of them. To overcome this, stabilizers are added to the rays' absorbing materials(12, 16). Fabric is considered the factor of main effect on the range of protecting fabrics against (U. V. R.) in the fields of weaving industries. When light falls directly on the fabric, part of the (U. V. R.) is reflected, the material absorbs another portion (U. V. A.), the rest of the rays pass through the fabric (U. V. B.) where it is transmitted by fusion. The ratio of transmitted light according to wave length(15).

There is also another important factor in the way of protection against (U. V. R.), i.e. human skin color. A man with light skin has self-protection sufficient to (5 – 10) minutes. And when he wears protection clothing, the security period reaches to (1.5 – 3) hours(5).

It is possible to provide protection against these rays by means of:

- Reflection of 100% of rays, by using dense fabrics, and preparatory materials for protection.
- Untreated fabrics can acquire this specialty by washing them in washing machines using industrial cleaners or smoothing materials containing protection materials.
- Use absorbent materials and dyes to radiation.

It is also possible, that protection against (U. V. R.) causing skin cancer by interrupting these rays.

Ceramic is recommended to be used in preparation because it absorbs visible infrared rays. Aluminum and aluminum silicates have tremendous ability to reflect (U. V. R.). Titanium oxide absorbs these rays(5, 13).

An ultraviolet protection factor can be calculated from the following equation:

$$upf = \frac{\sum_{290nm}^{400nm} E_\lambda \times S_\lambda \times \Delta_\lambda}{\sum_{290nm}^{400nm} E_\lambda \times S_\lambda \times T_\lambda \times \Delta_\lambda}$$

Where:

E_λ = CiE erythemal spectral effectiveness.

S_λ = Solar spectral irradiance.

T_λ = Spectral transmittance of the sample.

This factor changes according to manufacturing specifications, kind of fibers, covering factor, fabric colour, density of dyes, presence of materials giving light glitter, preparation and also the conditions of washing process(7).

The research proved(5) that whitened cotton strings allow the full penetration of rays, but the penetration is decreased in the case of raw strings because the dyes and natural waxes absorbed it.

Polyamide fibers allow the rays to penetrate, but polyester fiber allow the penetration of 10% of rays. Micro-fiber allows only 5% of the rays to penetrate, in opposition to other fibers like cotton which allows penetration of (30 – 40%) rays through it(1, 11).

The more dense is the strings in fabrics, the more is the ratio of protection. Humidity present in fibers leads to increase in quantity of rays penetrated.

Also washing processes, number of washes, and also dry-cleaning on the penetration of rays itself(6).

The penetrability of fabrics or the openings existing in it are considered one of principal indications in the transfer of rays. Some of the scientists qualify the ideal fabric against rays as the fabric containing the least number of weaving openings, taking into consideration that weaving structures is the first effective which limits the penetration of these rays(7).

Also the thickness of fabrics affects the factor of protection against (U. V. R.). So the thick fabrics used as light barrier give protection to humans from these rays produced from direct sun light which amounts to nearly 99%. Also the dyes plays an important role in increasing the protection factor and dark colours give better protection(14). Table (1) shows protection factor against ultraviolet radiation through fabrics.

Table (1) Protection factor against ultraviolet radiation through fabrics

Upf Range	Uvr protection category	Effective uvr transmission (%)	Upf rating
15 – 24	Good	4.2 to 6.4	15 , 20
25 – 39	Very good	2.6 to 4.1	25, 30, 35
40 – 50 , +50	Excellent	2.5	40, 45, 50 , +50

[2] The Experimental Work:

One textile material used in this research, polyester hollow fiber.

Table (2): The specifications of the machine used for produced all samples

No.	Property	Specification
1	Model	GTV Dornier
2	Shedding system	Dobby
3	Year of manufacturing	1983
4	Picking device	Rigid rapier
5	Speed of loom	280 picks per minute
6	Width of machine	2 m
7	Number of healds	16
8	Type of shedding	Open shade
9	Take up motion	Positive
10	Lett off motion	Positive

Table (3) The specifications of produced samples

No.	Property	Specification
1	Warp type	Polyester Hollow Fiber
2	Weft type	Polyester Hollow Fiber
3	Count of warp yarns	(16.7 × 2) denier
4	Count of weft yarns	(16.7 × 2) denier
5	Warp set (ends per cm)	32 ends per cm
6	Weft set (picks per cm)	16, 18, 20 and 22 picks per cm
7	Fabric structure	Plain 1/1, twill 2/1, twill 2/2 and twill 3/1
8	Reed used (dents per cm)	8 dents per cm
9	Denting	4 ends per dent
10	Drafting system	On line (directly)
11	Number of healds used	12 healds +2 for selvges
12	Width of warp in reed	150 cm

Tests and Analysis:

In this part, several tests were carried out in order to evaluate the produced fabrics, these tests were:

- **The penetration of ultraviolet radiation percentage**, this test was carried out according to the method used at the National Institute for Standards.
- **The Air permeability**, this test was carried out according to the (A. S. T. M. Standards, D 737.75)(8).
- **The fabric thickness**, this test was carried out according to the (A. S. T. M. Standards, D 3776)(9).
- **The fabric weight**, this test was carried out according to the (A. S. T. M. Standards, D 3787)(10).
- **The water absorption percentage**, estimated the percentage of water to soak through the fabric to find the difference between the sample weight before and after the absorption process by following the following steps:
  1. Be prepared for the test samples, and cut in a square form.
  2. Sample be placed in an electric furnace in order to have gained moisture sample.
  3. The weight of the sample after it had pulled out of the oven and then immersed in water for two minutes. Have been identified using time-hour suspension.
  4. After the sample was weighed out of water, was to find the difference between the sample weight before and after the absorption process.
  5. To find the percentage of drinking water as follo

$$\text{Percentage of drinking water} = \frac{\text{Increase in weight due to water absorption}}{\text{Original weight (before absorption)}} \times 100$$

[3] Results and Discussion:

Results of experimental tests carried out on the produced samples were presented in the following table (4) and graphs and were statically analyzed for statistically

Number of Picks per Cm:

Table (4) shows the effect of number of picks per cm, air permeability, thickness, fabric's weight per square meter and water absorption percentage upon the penetration of an ultraviolet radiation percentage (all other specifications being constant). From this table, it can be observed that there is an inverse relationship between the number of picks per cm and the penetration of ultraviolet radiation percentage; this can be illustrated as the picks per cm increases, the number of fibers in square unit increases. Also, this leads to the increasing in the number of interlaces per square cm, then the number of porous of the fabric decreases and the air permeability decreases, then the ultraviolet radiation penetration decreases. On the other hand the ultraviolet protection factor increases at all different wave lengths.

Tables (5), (6), (7) and (8) illustrate the regression equation and correlation for the effect of number of picks per cm upon the penetration of an ultraviolet radiation percentage at all different wave lengths and ultraviolet protection factor.

Table (4) The results of the penetration of an ultraviolet radiation percentage test through produced samples at all different wave lengths

Fabric Structure	Fabric Properties					Wave Length (nanometer) (nm)												U. V. - B (%)	U. V. - A (%)	upf
	No. of picks per cm	air permeability cm^2/cm^3/S	thickness (mm)	water absorption (%)	weight of m^2 (gm)	290	300	310	320	330	340	350	360	370	380	390	400			
plain weave	16	11.37	0.38	121.2	190.51	0.2228	0.2487	0.325	0.8591	1.253	1.501	2.315	5.132	11.04	16.95	19.89	21.75	0.25	7.8	117.47
	18	7.36	0.39	99.4	206.4	0.2114	0.2367	0.2975	0.7492	1.073	1.361	2.1	4.817	10.62	15.96	19.01	20.93	0.23	7.55	122.02
	20	4.85	0.4	81.2	212.59	0.1965	0.2109	0.2838	0.6012	0.9384	1.064	1.932	4.109	9.863	15.34	18.47	20.54	0.21	7.31	129.71
twill wave 2/1	16	58.23	0.405	125.38	186.58	0.2075	0.2213	0.2518	0.3082	1.294	1.537	2.693	5.519	11.51	16.95	19.94	21.86	0.28	8.27	110.18
	18	47.23	0.408	105.34	192.05	0.1877	0.2113	0.2408	0.2884	1.286	1.433	2.657	5.09	11.24	16.68	19.63	21.6	0.25	7.87	114.19
	20	38.17	0.412	96.4	204.47	0.145	0.1558	0.1816	0.2786	1.147	1.351	2.162	4.416	10.22	15.65	18.77	20.77	0.23	7.73	127.1
	22	32.87	0.415	76.6	211.34	0.1162	0.148	0.1511	0.1526	0.8489	1.199	1.817	3.874	9.369	14.7	17.79	19.87	0.18	7.28	144.93
twill wave 2/2	16	59.03	0.42	125.43	181.61	0.2125	0.2441	0.4807	1.556	2.017	2.533	3.262	5.815	11.57	16.62	19.46	21.22	0.45	8.63	84.53
	18	49.17	0.423	117.66	190.4	0.1892	0.2257	0.3204	1.173	1.54	1.9	2.559	4.872	10.55	15.72	18.64	20.48	0.31	7.92	105.3
	20	40.83	0.425	102.6	199.9	0.1668	0.2045	0.2579	0.853	1.14	1.431	2.151	4.362	9.732	14.83	17.82	19.76	0.25	7.86	125.84
	22	33.87	0.43	97.68	209.16	0.1488	0.1877	0.1923	0.7156	0.9003	1.219	1.855	3.703	8.8	13.82	16.73	18.64	0.19	7.43	138.98
twill wave 3/1	16	64.33	0.432	130.5	180.3	0.4532	0.5417	0.621	1.509	1.903	2.264	3.128	5.762	11.7	16.96	19.82	21.71	0.49	8.75	82.03
	18	50.33	0.434	121.6	190.34	0.2457	0.3609	0.5683	1.479	1.724	2.092	2.541	5	10.68	15.75	18.6	20.52	0.43	7.95	90.69
	20	44.2	0.435	118.5	196.7	0.2114	0.3052	0.3143	0.946	1.305	1.55	2.238	4.498	9.816	14.78	17.64	19.56	0.29	7.91	116.9
	22	40.8	0.438	107.88	208.77	0.1853	0.2167	0.2411	0.8459	1.214	1.419	2.057	4.137	9.328	14.23	17.06	18.92	0.27	7.59	122.75

Where: UPF: ultraviolet protection factor.
UV-B: transmittance percentage in the range (290 – 315) nm
UV-A: transmittance percentage in the range (315 – 400) nm

Table (5) Regression equation and correlation for produced samples using plain 1/1 weave structure

Property	Regression equation	Correlation
UV-B (%)	Y = -0.01 X + 0.41	-1
UV-A (%)	Y = -0.1225 X + 9.75833	- 0.9999
UPF	Y = 3.06 X + 67.9866	0.9892

Table (6) Regression equation and correlation for produced samples using twill 2/1 weave structure

Property	Regression equation	Correlation
UV-B (%)	Y = -0.016 X + 0.539	- 0.9829
UV-A (%)	Y = -0.1555 X + 10.742	- 0.9830
UPF	Y = 5.858 X + 12.798	0.9664

Table (7)Regression equation and correlation for produced samples using twill 2/2 weave structure

Property	Regression equation	Correlation
UV-B (%)	Y = -0.042 X + 1.098	- 0.9739
UV-A (%)	Y = -0.183 X + 11.437	- 0.9505
UPF	Y = 9.1945 X -61.033	0.9950

Table (8)Regression equation and correlation for produced samples using twill 3/1 weave structure

Property	Regression equation	Correlation
UV-B (%)	Y = -0.04 X + 1.13	- 0.9645
UV-A (%)	Y = -0.176 X + 11.394	- 0.9205
UPF	Y = 7.4185 X -37.859	0.9681

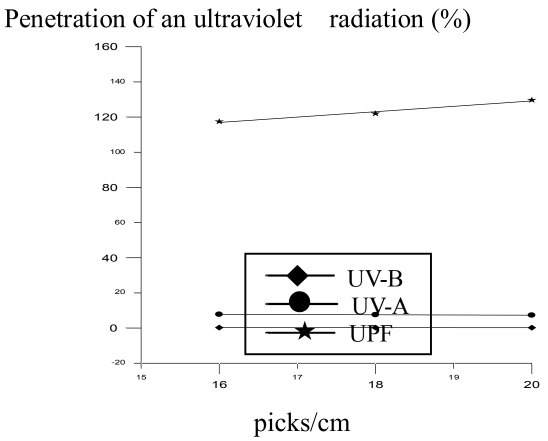

Fig. (1)The effect of picks/cm upon the penetration of an ultraviolet radiation percentage and upf for produced samples using plain 1/1 weave structure

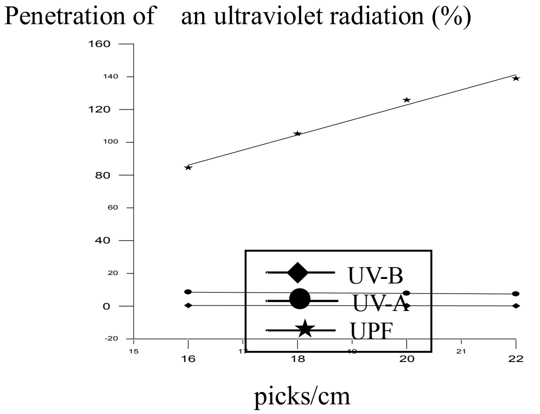

Fig. (3)The effect of picks/cm upon the penetrationof an ultraviolet radiation percentage and upf for produced samples using twill 2/2 weave structure

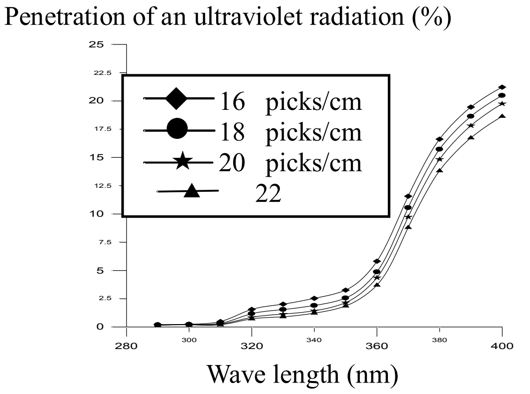

Fig. (5) The relationship between wavelength and the penetration of an ultraviolet radiation percentage for produced samples using twill 2/2 weave structure

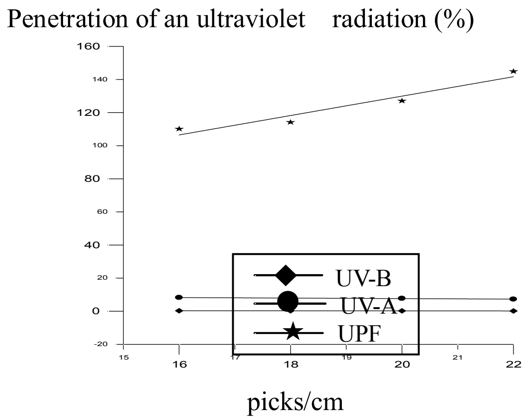

Fig. (2)The effect of picks/cm upon the penetration of an ultraviolet radiation percentage and upf for produced samples using twill 2/1 weave structure

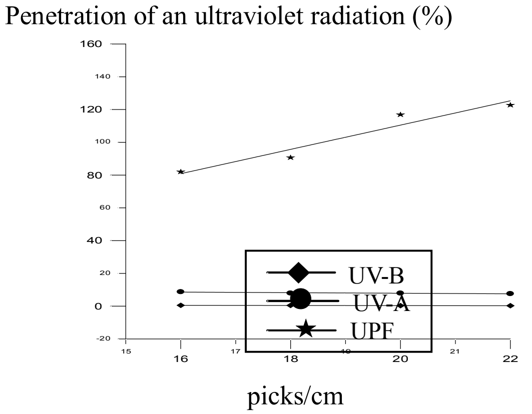

Fig. (4)The effect of picks/cm upon the penetration of an ultraviolet radiation percentage and upf for produced samples using twill 3/1 weave structure

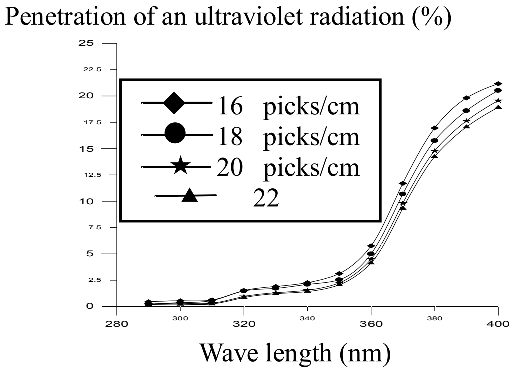

Fig. (6) The relationship between wavelength and the penetration of an ultraviolet radiation percentage for produced samples using twill 3/1 weave structure

Weave Structure:

Figure (7) and table (4) illustrated the effect of changing the weave structure upon the penetration of an ultraviolet radiation percentage. From this figure and table, it can be noticed that the plain weave structure has the lowest penetration of an ultraviolet radiation than the other weave structures, and then it has the greatest ultraviolet protection factor. On the other hand, twill 3/1 has the greatest penetration of an ultraviolet radiation than the other weave structures, then twill 2/2 and twill 2/1 com in the second and third order. After twill 3/1 weave structure (all other specifications being constant). I can report that: the increasing in interlaces in the plain weave structure, the decreasing in the number of porous between picks and ends and the lowest float length caused that, the number of porous of produced samples to be lower and the penetration of an ultraviolet radiation through the fabric as such reduce. So the ultraviolet protection factor increases.

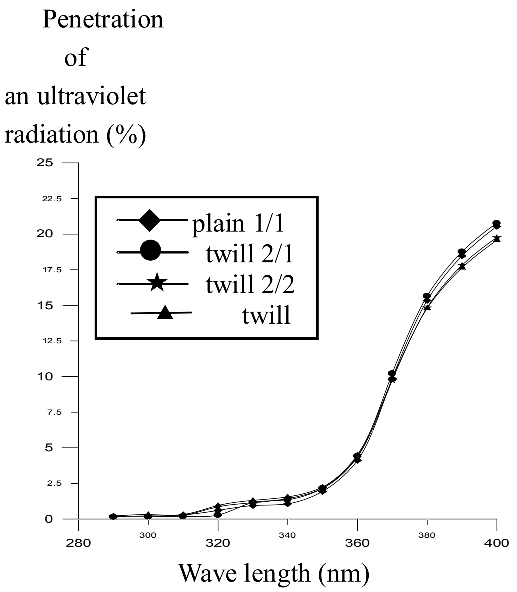

Fig. (7)The relationship between wavelength and the penetration of an ultraviolet radiation percentage for produced samples at 20 picks/cm

Evaluate The Quality Of Research Samples:

The arrangement of samples produced under study according to their quality.

Table (9) The quality of functional properties percentages for samples produced under study, as well as arranged in accordance with these quality

Fabric Structure	No. of picks per cm	air permeability $cm^2/cm^3/S$	thickness (mm)	water absorption %	weight of m^2 (gm)	% *Air permeability* (−) $\frac{\sigma_{\min}(10)^2}{\sigma_i}$	% *Thickness* (+) $\frac{\sigma_i(10)^2}{\sigma_{\max}}$	% *Water absorption* (−) $\frac{\sigma_{\min}(10)^2}{\sigma_i}$	% *Weight of* m^2 (+) $\frac{\sigma_i(10)^2}{\sigma_{\max}}$	Sum	Arrangement according to the quality
plain weave	16	11.37	0.38	121.2	190.51	42.66	86.76	63.2	89.61	282.23	6
	18	7.36	0.39	99.4	206.4	65.9	89.04	77.06	97.09	329.09	2
	20	4.85	0.4	81.2	212.59	100	91.32	94.33	100	385.65	1
twill wave 2/1	16	58.23	0.405	125.38	186.58	8.33	92.47	61.09	87.77	249.66	15
	18	47.23	0.408	105.34	192.05	10.27	93.15	72.72	90.34	266.48	10
	20	38.17	0.412	96.4	204.47	12.71	94.06	79.46	96.18	282.41	5
	22	32.87	0.415	76.6	211.34	14.76	94.75	100	99.41	308.92	3
twill wave 2/2	16	59.03	0.42	125.43	181.61	8.22	95.89	61.07	85.43	250.61	13
	18	49.17	0.423	117.66	190.4	9.86	96.58	65.1	89.56	261.1	12
	20	40.83	0.425	102.6	199.9	11.88	97.03	74.66	94.03	277.6	8
	22	33.87	0.43	97.68	209.16	14.32	98.17	78.42	98.39	289.3	4
twill wave 3/1	16	64.33	0.432	130.5	180.3	7.54	98.63	58.7	84.81	249.68	14
	18	50.33	0.434	121.6	190.34	9.64	99.09	62.99	89.53	261.25	11
	20	44.2	0.435	118.5	196.7	10.97	99.32	64.64	92.53	267.46	9
	22	40.8	0.438	107.88	208.77	11.89	100	71	98.2	281.09	7

Where(3):

σ_i : value spread sheet $\sigma_{\min}$: the smallest value spread sheet $\sigma_{\max}$: the greatest value spread sheet

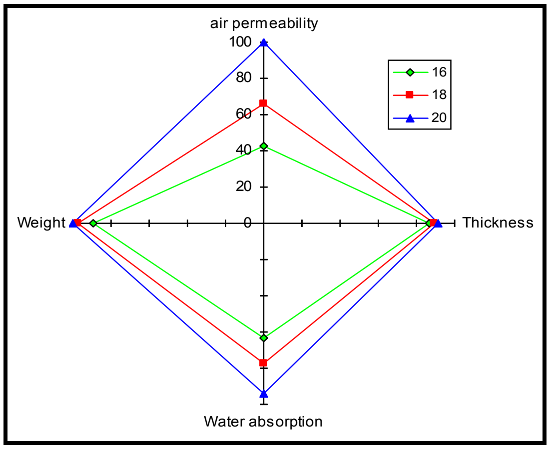

Fig (8):Radar chart for samples which produced with plain weave structure 1/1

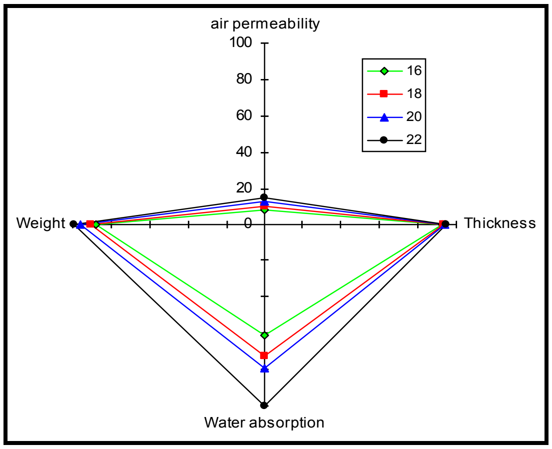

Fig (9):Radar chart for samples which produced with twill weave structure 2/1

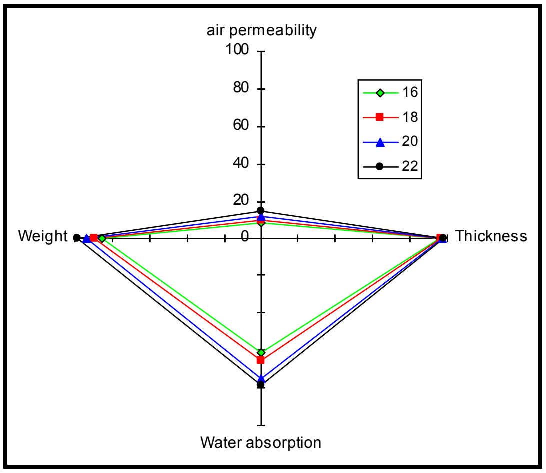

Fig (10):Radar chart for samples which produced with twill weave structure 2/2

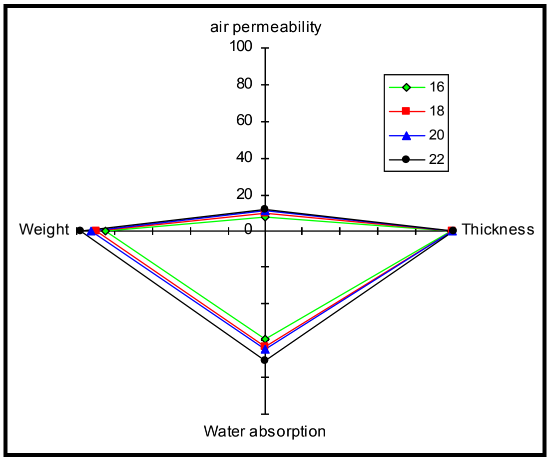

Fig (11):Radar chart for samples which produced with twill weave structure 3/1

Conclusions:

1. There is an inverse relationship between the number of picks per cm and the penetration of an ultraviolet radiation percentage.
2. The study proved that, the number of picks per cm is directly proportional to an ultraviolet protection factor.
3. Increasing length of floating is directly proportional to the penetration of an ultraviolet radiation percentage.
4. The study confirmed the existence of an inverse relationship between the length of floating and the ultraviolet protection factor.
5. Increasing air permeability of fabrics is directly proportional to the penetration of an ultraviolet radiation percentage at all different wave lengths.
6. There is an inverse relationship between the thickness weight of fabric and the penetration of an ultraviolet radiation percentage at all different wave lengths.
7. The study proved that the fabric water absorption percentage is directly proportional to the penetration of an ultraviolet radiation percentage.
8. The sample which produced with plain weave structure and 20 picks per cm gave the best result for the quality of functional properties. On the other hand, the sample which produced with twill 2/1 weave structure and 16 picks per cm gave the worst result for the quality of functional properties.

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