Treatment of Cotton Knitted Garments with Natural Silk Fibroin for Skin Care and Ultraviolet Radiation Protection

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Abstract: This study aimed to investigate some chemical structure of Egyptian natural silk fibroin (NSF) as well as using their solutions with knitted cotton fabrics for the production of functional clothing for skin care and protection from UV radiation. As for the fibroin chemical composition consists of residues of 23 amino acids whose ratio varies between different areas of its supramolecular structure. Glycine, alanine and serine were the most abundant amino acids, together comprising 83.24% of the total amino acids present. By after 15 consecutive days of application on twenty volunteers, the designed/tested tools manufactured from knitted cotton fabrics treated with NSF and thickening agents (starch or gum arabic) such pillow and T-shirt induced significant improvement in all panel test evaluation factors including moisturization, softening, relaxation, and overall appearance. Also, cotton knitted fabric treated with NSF showed good class of UV protection (UPF values 15-24) which improved by treating with different thickening agents and recorded very good class (UPF values 25-40). In conclusion, like of those industrial applications will be opened new avenue in the field of medical and cosmetic sciences through producing of some effectiveness and low coast functional clothing for skin care and protection from UV radiation.
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Keywords: fibroin structure, ultraviolet protection factor, spectral analysis, functional clothing, T-shirt.

1. Introduction

Silk fibers produced by cultivated *Bombyx mori* mulberry silkworm mainly consist of two proteins, sericin and fibroin with a share of 28 and 72%, respectively (Xu *et al.* 2006). They also contain minor amounts of residues of other amino acids and various impurities: fats, waxes, dyes, and mineral salts. Each silk fiber is composed of two sub-fibers. Each of which fibroin is the core. The two cores are coated and wrapped as together with sericin, the glue-like proteins and is removed after degumming (Altman *et al*., 2003).

Silk fibroin, like creatine and collagen, belongs to fibrillar proteins (Finkel'shtein and Ptitsyn, 2002). The elements of the supramolecular structure of silk fibers are macrofibrils with a width of up to 6.5 -10^5 nm, which, in turn, consist of helically packed nanofibrils 90-170 nm in diameter. Nanofibrils may play an important role in imparting enhanced strength to silks. The molecular weight of natural silk fibroin reaches 370 000 Da; fibroin macrochain length, 150 nm; and macrochain diameter, 0.45 nm (Yunusov, 1978). Fibroin consists of 18 amino acids (Ayutsede *et al.,* 2005). Research has shown that fibroin consists of both light and heavy molecular chains forming crystalline and amorphous regions with a share of about two-thirds and one-third, respectively (Zhang *et al.,* 2007). Also, fibroin consists to 3/4 of nonpolar hydrophobic amino acids, it is necessary to take into account also hydrophobic (dispersion) interactions making fibroin resistant to the majority of solvents.

Recently, many researchers have been interested in silk fibroin because of its properties such as biocompatibility, biodegradability, moisture absorption, moisture retention, oxygen and water vapor permeability, affinity to skin and minimal inflammatory reactions (Meinel *et al.,* 2006 and Khan *et al.,* 2008). Due to that properties fibroin powder or solution have found extensive applications in fields like additive to food and cosmetic, separation techniques as well as other biomaterials in clinical diagnostics and drug delivery systems (Sakabe *et al.*, 1989; Park *et al.,* 2004; Santin *et al.*, 1999). Additionally, SF has been widely used in tissue engineering because of specific functional properties, including excellent biocompatibility, good oxygen and water vapor permeability, and biodegradability (Horan *et al.,* 2005 and Murphy *et al.,* 2008). Considering the above literature review, this research aimed to present a novel and original application for silk fibroin solution through processing of knitted cotton fabrics, for the production of functional clothing for skin care and protection from UV radiation.

2. Materials and methods

2.1 Materials

The *B. mori* silk cocoons were kindly supplied from silk worm cultivates, Elbagour City, Minoufiya Governorate, Egypt. The cocoons were kept in air-dried room until use. Chemical reagents in analytical grade were used.

2.2 Methods

2.2.1 Preparation of natural silk fibroin (NSF) solution

To prepare fibroin solution, silk cocoons were first degummed for 30 min in a boiling solution of sodium carbonate (0.02 M) followed by thorough rinsing. This treatment was repeated twice and then the obtained fibroin filaments were dried in a vacuum oven at 35 0C (Binder, Germany). To dissolve the fibroin filaments, Ajisawa's method (Ajisawa 1998) was employed, in which 15 g of fibroin filaments was added to a bath of water-ethanol (Sigma)-calcium chloride (Sigma) (194 g^{-92} g^{-111}g) and left to swell for 20 min. The bath was then heated to 60 ^{0}C. Complete dissolution occurred after about 7 h. To purify the fibroin solution, dialysis against distilled water was carried out for 72 h by a tubular cellulosic membrane (Sigma D 9527, 175 mL/foot). After dialysis, the solution was centrifuged (7500 rpm) (Jouan Centrifuge, France) for 15 min and then left for 20 min. The solution was finally filtered by vacuum.

2.2.2 Sericin and fibroin measurement

Protein determination was done as followed by Lowry procedure (Lowry *et al.*, 1951).

2.2.3 Amino acid analysis of NSF

Samples hydrolysis, filtration and derivatization: Fibroin samples (2.0 mg) were dissolved in 2.0 ml of a mixture hydrochloric acid (6N)/ Propionic acid (96%) by the ratio of (1:1) at room temperature for 20 min with slight vortexing. Solubilized samples were vacuum dried in pyrolyzed vials and purged at argon gas. Hydrolysis was carried out by placing 200 ul of constant boiling 6N HCI in the bottom of the react vial along with two sodium sulfite crystals. The vessel was again purged with argon gas, sealed under vacuum and placed at 150 °C for 1 hour. Sodium sulfite is used as an oxygen scavenger and aids in the recovery of cysteine, serine, and threonine. Upon hydrolysis all samples were filtered (Whatman GF/F 0.2 µm) under gentle vacuum pressure (< 5 psi) and stored in pre-cleaned (Decon-90) 1 ml plastic screw-top bottles, in freezers (-20 0C) until analysis. The hydrolyzed samples were derivatized with OPA-2ME reagent was prepared according to Lindroth and Mopper (1979).

Chromatographic instrumentation:

HPLC was performed using a Merck-Hitachi HPLC system (Merck-Hitachi, Japan) equipped with a Merck-Hitachi Models L-6200 intelligent pump, Merck-Hitachi L-6000 pump, a Rheodyne injection valve fitted with a 20 µL loop (Alltech, Carnforth Lancashire, UK) and F-1050 fluorescence detector (Merck-Hitachi, Japan). Results were recorded on a Merck-Hitachi (Japan) Model D-2500 chromato-integrator.

HPLC condition:

Amino acids chromatographic separations were carried out with a 150 x 4.6 mm stainless-steel Econosphere C-18 reversed-phase column containing 3 µm packing (Alltech, Carnforth Lancashire, UK). A guard column 7.5 x 3.2 mm containing 5 µm, C-18 reversed phase packing (Alltech, Carnforth Lancashire, UK) was attached directly to analytical column. A gradient elution using methanol was performed for better analytes separation and column cleansing prior to subsequent injections. The mobile phases consists of 50 mM sodium acetate (pH 5.7) containing 5% THF ("A" phase) and methanol ("B" phase). The elution profile was : 0-2 min, 5-10% B; 2-11 min, 10-35% B; 11-20 min, 35-65% B; 20-22%, 65-100%B; 22-24 min, isocratic 100% B; 24-30 min, 100-5%B. Separations were performed at ambient temperature using a flow rate 1.5 mL min-1. The fluorescence detector was set to operating at 340 nm in the excitation and 455 nm in the emission mode.

2.2.4 NSF applications: Skin cosmetic tools preparation

2.2.4.1 Production of T-shirts and Pillow from cotton knitted fabric treated with NSF

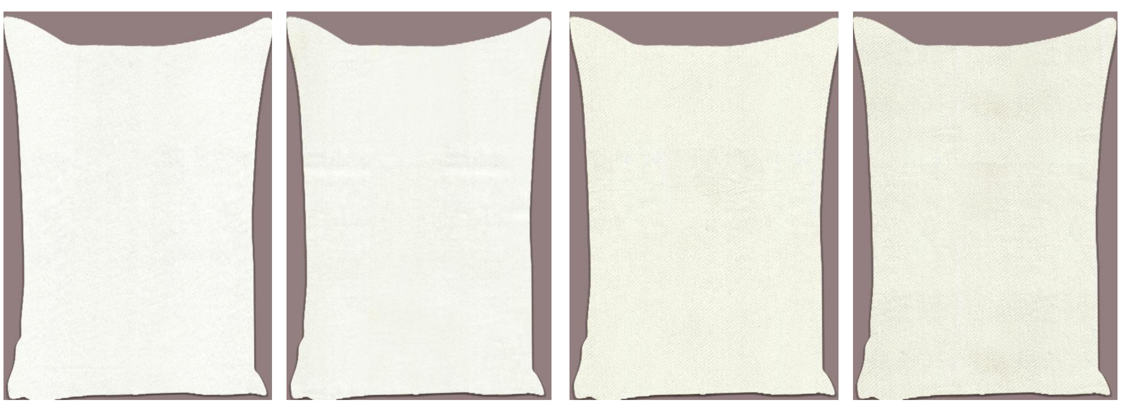
In a trying to open a new avenue in the field of skin cosmetic, untreated and treated cotton knitted fabrics have been applied in producing T-shirt and pillow as follow: Cotton knitted fabrics (Double Knit, Inter lock, Delta for Spinning and Weaving, AlMahalla El-Kobra, Ghabia Governorate, Egypt) were brushed on tables, sprayed with NSF solution (2.5%) by using aerosol bottles (ElNegma ElZahabia Factory, Egypt) followed by sprayed with thickening agents, starch (1%) or GA (0.5%) solutions. The fabrics were dried at room temperature (24±3 ^{0}C for 8 hrs) and brushed by using thermal compressor for 2 seconds and directed to T-shirt (Figure 1) and pillow (Figure 2) manufacturing through the various stages of production including design, cutting, sewing (Singer, Japan) and iron (vapor machine, Japan).

2.2.4.2 Evaluation of the suggested and designed skin cosmetic tools

The applying protocol was approved in advance by the Scientific Research Ethics Committee, Faculty of Home Economics, Minoufiya University, Shebin El-Kom, Egypt. Subjects were recruited from the Minoufiya University community. A total of 20 healthy men (mean age 25.42 years, range 20-36 years) formed the study group. They volunteered to apply one of the suggested and designed pillow and T-shirt suggested for skin cosmetic tools over 15 consecutive days. The study subjects met daily during the 15-day of the experimental period and examined in the presence of the study investigator and assistants. Moisturizing efficiency of skin cosmetic tools was evaluated according to panel tests designed by the assistance of dermatologilists in Minoufiya University Hospitals.

KF (Untreated) **KF plus NSF** **KF + NSF + starch (1%)** **KF + NSF+ GA (0.5%)**

Figure 1. T-shirts manufactured from cotton knitted fabric (KF) untreated and treated with NSF plus thickening agents



KF (Untreated) **KF plus NSF** **KF + NSF + starch (1%)** **KF + NSF+ GA (0.5%)**

Figure 2. Pillow manufactured from cotton knitted fabric (KF) untreated and treated with NSF plus thickening agents

2.2.4.3 Evaluation of fabrics and T-shirt for ultraviolet radiation protection

UV absorbance through a fabric is the crucial factor determining the UV protection of textiles was measured according to Hoffman et al., (2001). Ultraviolet protection factor (UPF) is the scientific term used to indicate the amount of Ultraviolet (UV) protection provided to skin by fabric. It was measured in vitro using ultraviolet absorbance analyzer (SPECTRO UV-VIS Spectrophotometer (D2 lamp power supply), LaboMed, Inc. USA) according to standard AS/NZ 4399 (AS/NZ, 1996). Fabrics were classified with UPF values ‹ 15, 15 – 24, 25 – 39 and 40 or greater equal UV protection Class No Class, Good, Very good and Excellent, respectively. Measured UPF values were also correlated to the color strength of the dyed fabrics. All parameters were measured on triplicates and the values were presented as mean ±SD.

3. Results and discussion

3.1 Protein measurement of natural silk fibroin

The protein content of sericin and fibroin is given in table (1). It was found that Egyptian silk cocoon composed of 71.23% fibroin and 28.77% sericin. The protein content of fibroin was 0.4201 mg mL^{-1} and sericin was 0.2550 mg mL^{-1} for the Egyptian silk cocoon. The present data are in accordance with that obtained by (Elhassaneen and Hussien, 2012).

Table 1. Percentage and contents of proteins in *Bombyx mori* Egyptian silk cocoons

Parameter		Fibroin	Sericin
Percentage in silk (%)	Range	67.11 - 74.1	25.9 - 32.89
	Mean ± SD	71.23±2.56	28.77±2.11
Protein content ($mgml^{-1}$)	Range	0.3912 - 0.4547	0.2258 – 0.2794
	Mean ±SD	0.4201±0.0210	0.2550±0.0190

3.2 Structure (amino acid) of natural silk fibroin

The amino acid composition of the Egyptian silk cocoons fibroin of *Bombyx mori* is shown in Tables 2 and 3. As for the fibroin chemical composition consists of residues of no less than 20 amino acids whose ratio varies between different areas of its supramolecular structure. Glycine, alanine and serine were the most abundant amino acids, together comprising 83.24% of the total amino acids present. Cocoons silk fibroin is composed predominantly of the small side-chain amino acids glycine, alanine, and serine, which would allow them to conform to the antiparallel β-pleated sheet model proposed by Pauling and Corey (1953) for *Bombyx mori.* We report some levels of sulfur containing amino acids (met+cys, 0.92%), theorizing that these residues play important roles in the amorphous domains of the polymer through disulphide bonds. The pendant fragments of fibroin macromolecules are nonpolar side chain (Glycine, alanine, methionine, tryptophane, valine, phenylalanine, proline, isoleucine and leucine), 75.15; uncharged polar side chains (Asparagine, serine, glutamic acid, cystine, threonine and tyrosine), 20.78% and charged polar side chains (Asparatic acid, glutamic acid, histidine, arginine and lysine), 4.12%. Since fibroin consists to 3/4 of nonpolar hydrophobic amino acids, it is necessary to take into account also hydrophobic (dispersion) interactions making fibroin resistant to the majority of solvents (Sashina *et al.,* 2006)**.** The results of the present study, protein and amino acid contents of Egyptian natural silk fibroin, were dramatically not differed with that recorded in many countries (Sashina *et al.,* 2006; Prasong *et al*., 2009 and Manohar and Venkateswara, 2011).

3.3 Evaluation of the suggested and designed skin care tools

By After 15 consecutive days of application on twenty volunteers, the designed/tested tools manufactured from knitted cotton fabrics treated with NSF and thickening agents (starch or GA) such pillow and T-shirt induced significant improvement in all panel test evaluation including moisturization, softening, relaxation, and overall appearance. Such as shown in Table (4) the highest values for all of these factors were recorded for pillow followed by T-shirt, respectively. Prolonged using of pillow has reduced the signs of aging and wrinkling skin of the all face areas. Such effects are mainly attributed to the unique physical and chemical properties of silk fibroin. These properties include nontoxicity, biocompatibility and biodegradability (Foo and Kaplan, 2002). Due to their unique properties, silk has been focused as biotechnological and biomedical resources (Reviewed in Padamwar and Pawar, 2004). Also, it has been used in various fields such as cosmetics, food additives and medical materials (Min *et al.,* 2004 and Taddei *et al.,* 2006). In addition, silk fibroin can be prepared in various forms such as gel, powder, film, matrix or fiber depending on applications (Park *et al*., 2004 and Reviewed in Padamwar and Pawar, 2004).

3.4 Ultraviolet protection factor (UPF) of cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agent

Data in table (5) shows the ultraviolet protection factor (UPF) and ultraviolet protection class (UVPC) of cotton knitted fabric treated with varying concentrations of natural silk fibroin (NSF). It can be observed that the ultraviolet protection factor (UPF) values increase with an increase of NSF concentration. It is clear that UPF values for NSF applied at higher concentrations gave higher UPF values. For example, the UPF of the cotton knitted fabric at a 0.25% NSF on weight of fabric was 11.2 and that increased to UPF 20.6 at a concentration of

1%. Samples of cotton knitted fabrics treated with NSF could be classified as having no class UV protection (UPF values ‹ 15) to good UV protection (UPF values between 15 – 24). Many previous studies reported that UPF values are dependent on a multitude of fabric construction factors such as pores in the fabric, thickness, and weight in addition to processing parameters such as dyeing and finishing (Sarkar and seal, 2003 and Hussien and Elhassaneen, 2013).

Table (6) shows the ultraviolet protection factor (UPF) and ultraviolet protection class (UVPC) values of cotton knitted fabric treated with NSF and different thickening agents. Cotton knitted fabric treated with NSF showed good class of UV protection (UPF values 15-24) which improved by treating with different thickening agents and recorded very good class (UPF values 25-40). Comparison of two thickening agents showed that the gum arabic gave the highest UV protection on cotton knitted fabric (UPF, 34.8). From the results, it is clear that GA thickening agent is well known for its ability to form coordinate complexes and in this experiment all readily chelated with the fabric and NSF residues. Montenegro and Boiero1 (2012) reviewed that the tendency of GA polysaccharides to associate in aqueous solution. These molecular associations can deeply affect their function in a particular application due to their influence on molecular weight, shape and size, which determines how molecules interact with other molecules and water. There are several factors such as hydrogen bonding, hydrophobic association, an association mediated by ions, electrostatic interactions, which depend on the concentration and the presence of protein components (such as in NSF) that affect the ability to form supramolecular complexes. It was also reported that, by using mild UV-radiation, it is possible to induce GA crosslinking (Kuan *et al.,* 2009). The process reduced the solution viscosity and improved emulsification properties. This GA modification can be used in food products requiring better reduced viscosity emulsifying properties such as dressings, spreads, and beverages, as well as in other nonfood products such as lithographic formulations, textiles, and paper manufacturing.

Table 2. Amino acid composition of Egyptian *Bombyx mori* fibroin

Amino acids	Residues per 100 total residues		
	Total	Heavy areas	Light areas
Cysteic (Cyst)	0.11± 0.02*	0.05± 0.01	0.41±0.03
Asparatic acid (Asp)	1.74 ± 0.22	0.73± 0.08	16.02±2.07
S-CM cystein	0.22± 0.09	0.07±0.00	0.16±0.02
Glutamic acid (Glu)	1.32 ± 0.21	0.69±0.03	9.21±1.16
Asparagine (Asn)	0.29 ± 0.08	0.00	0.00
Serine (Ser)	13.10 ± 1.14	13.65±1.22	6.82± 2.13
Glutamine (Gln)	0.94 ± 0.07	0.08±0.02	0.69±0.08
Gylcine (Gly)	41.01 ± 3.76	47.91±4.21	8.02±1.22
Cysteine (Cys)	0.28 ± 0.04	0.06±0.00	0.18±0.03
Histidine (His)	0.16 ± 0.02	0.06±0.01	1.48±0.05
Threonine (Thr)	0.81 ± 0.11	0.32±0.04	3.10±0.78
Alanine (Ala)	29.13 ± 2.87	28.78±3.17	17.02±2.01
Arginine (Arg)	0.63 ± 0.10	0.08±0.02	2.61±0.32
Tyrosine (Tyr)	4.98 ± 0.33	3.52±0.63	2.52±0.73
Ornithine (Orn)	0.00	0.00	0.00
Methionine (Met)	0.31 ± 0.05	0.11±0.03	0.42±0.03
Tryptophane (Trp)	0.39 ± 0.07	0.05±0.00	0.17±0.03
Valine (Val)	2.21 ± 0.12	1.82±0.05	8.01±1.11
Phenylalanine (Phe)	0.59 ± 0.06	0.25±0.02	3.06±0.12
Proline (Pro)	0.41 ± 0.09	0.55±0.03	2.80±0.04
Isoleucine (Ile)	0.59 ± 0.17	0.21±0.02	8.11±1.07
Leucine (Leu)	0.51 ± 0.05	0.11±0.02	8.15±0.84
Lysine (Lys)	0.27 ± 0.02	0.90±0.04	1.04±0.03
Total	100.00	100.00	100.00

* Each value represents the mean of three replicates ±SD

Table 3. Amounts of various amino acid side chains in Egyptian *Bombyx mori* fibroin

Amino acids	Residues per 100 total residues
Small side chains (Gly + Ala + Ser)	83.24 *
Polar residues (Asp + Glx)	4.29
Basic side chains (Lys + His + Arg)	1.06
Cyclic imino side chain (Pro)	0.41
Aromatic side chain (Phe + Tyr)	5.57
Sulfur containing (met + cys)	0.92
Aliphatic side chain (Ala + Val + Ile)	31.93
Hydroxyl side chain (Set + Thr)	13.91
Residues of short chain (SC)	83.24
Residues of long chain (LC)	16.76
Ratio (LC/SC)	0.20
Nonpolar side chains (Gly+Ala+Met+Try+Val+Phe+Pro+Ile+Leu)	75.15
Uncharged polar side chains (Asn+Ser+Glu+Cys+Thr+Tyr)	20.78
Charged polar side chains (Asp+Glu+His+Arg+Lys)	4.12

* Each value represents the mean of three replicates

Table 4. Panel tests values (Mean±SD) of the pillow and T-shirt suggested for skin- care tools

Skin care tools		Moisturization	Softening	Relaxation	Overall appearance
Pillow	Before treatment	6.30 ± 1.02^{b}*	6.38 ± 1.27^{b}	5.49 ± 2.10^{b}	6.07 ± 0.98^{b}
	After treatment	8.21 ± 0.96^{a}	7.95 ± 1.04^{a}	7.52 ± 1.15^{a}	8.49 ± 1.27^{a}
T-shirt	Before treatment	5.09 ± 0.36^{b}	5.64 ± 1.65^{b}	6.24 ± 1.09^{a}	6.15 ± 1.73^{b}
	After treatment	6.93 ± 1.21^{a}	7.01 ± 0.93^{a}	6.96 ± 0.87^{a}	7.90 ± 0.54^{a}

* Different letters on the same column of each item means a significant difference at $p<0.05$.

Table 5. Ultraviolet protection factor (UPF) and UV protection class (UVPC) of cotton knitted fabric treated with natural silk fibroin (NSF)

NSF conc. (%)	UPF	UVPC
Knitted fabric (NF)	4.9 ± 0.37	No class
KF+ 0.25% silk fibroin	11.2 ± 1.02	No class
KF+ 0.5% silk fibroin	17.3 ± 0.98	Good
KF+ 1% silk fibroin	20.6 ± 1.54	Good

Table 6. Ultraviolet protection factor (UPF) and UV protection class (UVPC) of cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agents

NSF conc. (%)	UPF	UVPC
Knitted fabric (NF)	4.9 ± 0.37	No class
KF+ 1% silk fibroin	20.6 ± 1.54	Good
KF+ 1% silk fibroin + 0.25% starch	29.4 ± 0.92	Very good
KF+ 1% silk fibroin + 0.5% starch	27.5 ± 1.97	Very good
KF+ 1% silk fibroin + 1% starch	30.9 ± 2.01	Very good
KF+ 1% silk fibroin + 0.25% GA	24.2 ± 1.09	Good
KF+ 1% silk fibroin + 0.5% GA	34.8 ± 2.11	Very good
KF+ 1% silk fibroin + 1% GA	26.7 ± 2.40	Very good

3.5 Spectral analysis [UV protection properties] of cotton knitted fabric treated with natural silk fibroin (NSF)

To investigate the UV-protection property of NSF, UV absorption spectra of the cotton knitted fabric with or without treatment were compared and shown in Figure (3). The results show significantly different between the NSF treated and untreated fabrics, which yields a low UV absorbance. The UV absorbance of the untreated fabrics was in the range of about 1.256- 0.872 in the UV-A band, 1.408-1 in.181 the UV-B and about 1.290-1.104 in the UV-C band. This indicates that the absorbance of cotton knitted fabrics treated by NSF appeared to be higher in all UV regions. The results also show that NSF applied at higher concentrations gave higher UV absorbance values. For example, the UV absorbance of the cotton knitted fabric at a 0.25 NSF on weight of fabric was ranged 1.319-0.897 (UV-A band), 1.521-1.284 (UV-B band) and 1.301-1.161 (UV-C band) and that increased to UV absorbance 1.391-1.040 (UV-A band), 1.576-1.351 (UV-B band) and 1.367-1.229 (UV-C) at a concentration of 1%. Generally, the UV protection property of fabrics is evaluated as good when the UV transmittance is less than 5% (absorbance, 1.301) (Feng *et al.,* 2007). The finding of this study, maximum absorption of treated cotton knitted fabric occurs in the UVC region and UVA region, is an important requirement for those at the dangers of this kind of harmful rays.

The effect of thickening agents with different concentrations on the UV protection properties of cotton knitted fabric treated with NSF are shown in figure (4). Cotton knitted fabric treated with NSF in the absence of thickening agents showed a poor UV absorbance ranged 1.225-1.077 For the samples thickened with starch and GA the UV absorbance values were in the range of 1.435-1.271 and 1.430-1.284, respectively. It is clearly seen that the values of the spectral absorbance are increased with all of the tested thickening agents and different thickening agents had different effects on the spectral absorbance of the fabric treated. Also, figure (4) shows the UV protection properties of cotton knitted fabric with NSF by varying quantity of thickening agent concentrations. It can be seen that the UV absorbance values increase with an increase of thickening agent concentration.

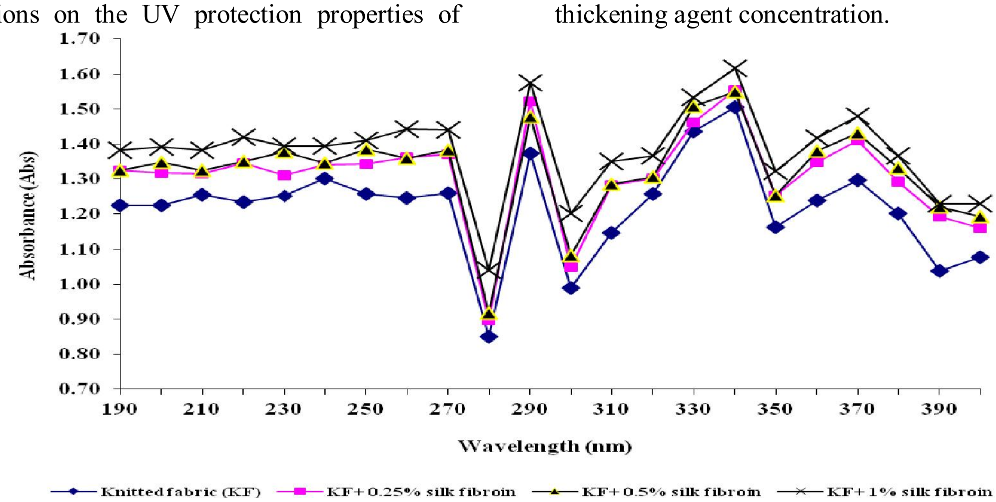


Figure 3. Ultraviolet absorption (Abs) of cotton knitted fabric treated with natural silk fibroin (NSF)

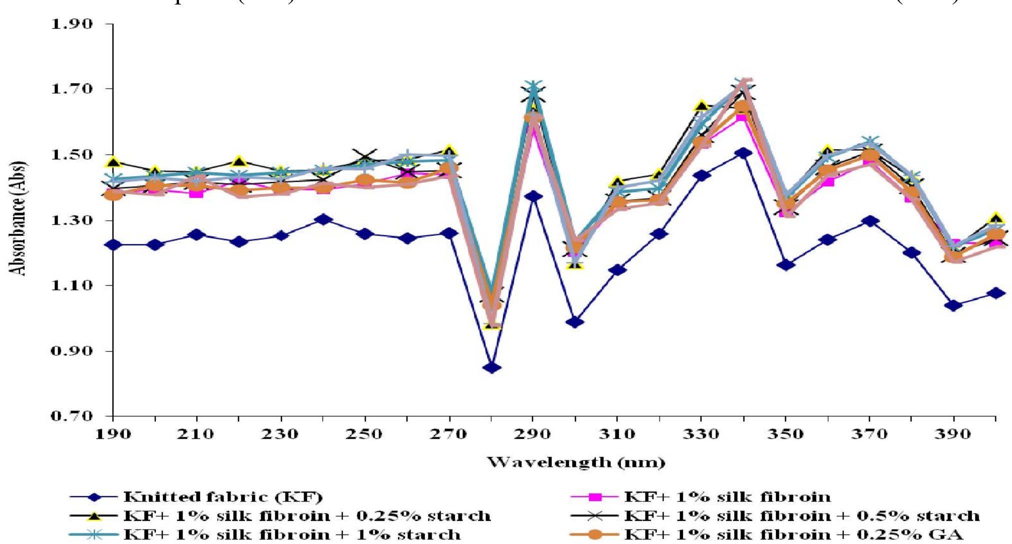


Figure 4. Ultraviolet absorption (Abs) of cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agent, starch or gum arabic.

3.6 UPF and UVPC of T-shirts manufactured from cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agents

Table (7) shows the ultraviolet protection factor (UPF) of T-shirts manufactured from knitted cotton fabrics treated with NSF and thickening agents. It can be observed that the ultraviolet protection factor (UPF) of the manufactured T-shirts record 31.3- 35.7 and could be classified as having very good UV protection (UPF values between 25 and 39). The slight increasing in UPF values in cotton knitted fabrics after manufactured to T-shirt could be attributed to the effect of iron step which affected partially on some fabric construction make changes in some fabric physical characteristics including pores size. Sarkar, (2004) reported that UPF values are dependent on a multitude of fabric construction factors such as pores in the fabric, thickness, and weight in addition to processing parameters such as dyeing and finishing.

Table 7. Ultraviolet protection factor (UPF) and UV protection class (UVPC) of T-shirts manufactured from cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agents

Treatment	UPF	UVPC
Knitted fabric (KF)	5.2 ± 0.21	No class
KF+ 1% silk fibroin	22.1 ± 1.54	Good
KF+ 1% silk fibroin + 1% starch	31.3 ± 2.01	Very good
KF+ 1% silk fibroin + 0.5% GA	35.7 ± 2.11	Very good

3.7 Spectral analysis [UV protection properties] of T-shirts manufactured from cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agents

UV absorption spectra of T-shirts manufactured from cotton knitted fabric untreated and treated with natural silk fibroin (NSF) plus thickening agents were compared and shown in Figure (5). The results show significantly different between the NSF treated and untreated T-shirts, which yields a low UV absorbance. The UV absorbance of the untreated T-shirt was in the range of about 1.256-0.872 in the UV-A band, 1.408-1.181 in the UV-B and about 1.290-1.104 in the UV-C band. While the UV absorbance of the treated T-shirt with NSF was in the range of about 1.437-1.074 in the UV-A band, 1.626-1.414 in the UV-B and about 1.410-1.279 in the UV-C band This indicates that the absorbance of T-shirt treated by NSF appeared to be higher in all UV regions. Also, T-shirt treated with NSF in the presence of thickening agents showed a rich UV absorbance ranged 1.4721.312. The best treatments were recorded for the samples thickened with GA (0.5%) and starch (1%) which recorded UV absorbance values in the range of 1.472- 1.294 and 1.471- 1.312, respectively. The UPF values as the result of manufactured like of these clothing supplements could be used successfully by the men and women who are exposed to solar and/or professional UV radiation.

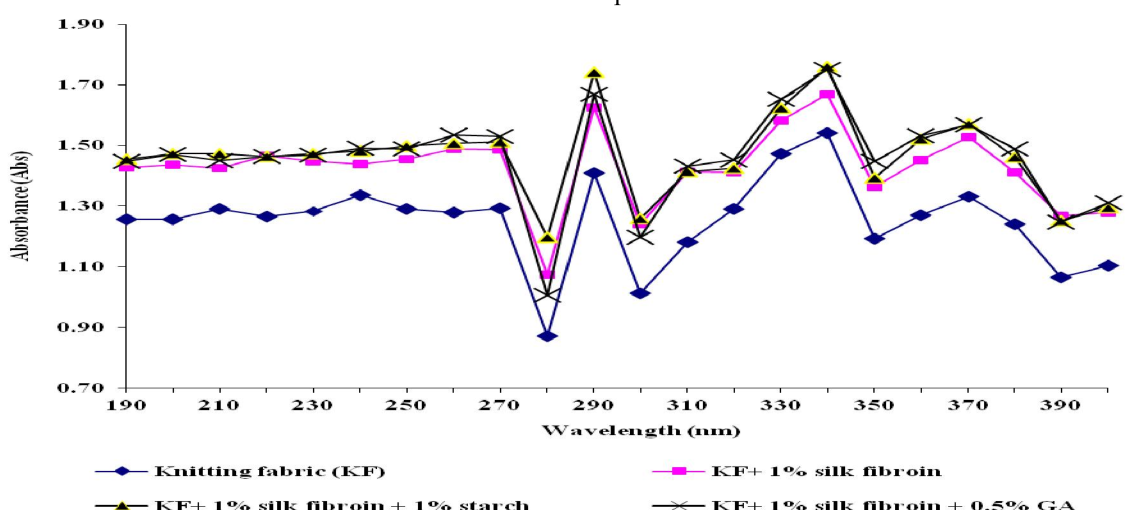


Figure 5. Ultraviolet absorption (Abs) of T-shirts manufactured from cotton knitted fabric treated with natural silk fibroin (NSF) plus thickening agents

4. Conclusion

The chemical structure of Egyptian natural silk fobroin of B. mori was studied. Its protein and amino acid contents were dramatically not differed with that recorded in many other countries with different environmental conditions. Different skin care tools including pillow and T-shirt were designed and prepared by using cotton knitted fabrics treated with NSF plus thickening agent (starch and GA. By applying that tools regularly for 15 days leads to induce significant improve-ment in all panel test evaluation including moisturization, softening, relaxation, and overall appearance. Additionally, like of these knitted fabrics and clothes made from exhibited high UPF values subsequently protection of UV radiation.

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