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Augmented Application of Modified Fabrics for Producing Multi-Functional Fashionable Apparel Using Khayamiya Heritage

Rehab M. Kotb
Textile and Clothing Division, Faculty of Women for Arts, Science, Education, Ain Shams University, Cairo, Egypt

END-USES applications of finished and modified textile materials are diverse, ranging from basic clothes to technical and industrial ones as well as represent a challenge for both researchers and manufacturers. Apparel products have multiple functions that started from primary protection, insurance, graceful of fashion to enhancement, and sustainability of the quality of life. Application of functionally finished fabrics for intended end uses may be a challenge in the apparel design process that produces a special product with specific requirements. Producing such apparel items integrates and transfers the flat textile material to the fashion design process and the three-dimensional final product. Recently, the essential need of a human to wear has changed with time, due to the new lifestyle, needs, priorities, and people's awareness. This study aims to apply the obtained multifunctional finished cotton and silk fabrics that afforded UV protection and antibacterial causing odor properties, as well as sustainable light fastness ability, to produce multifunctional apparel products that integrate the functional apparel design process considering the fashionable and upscale concepts. In addition to emerging of novel trends and technologies in the textile finishing field and different applications. As well as using Egyptian Khayamiya heritage as an aesthetic aspect to promote and maintain an effective and traditional handicraft technique.

Keywords: Multi-finishing, UV blocking, Anti-odor, Functional apparel, Khayamiya

Introduction

Today, the need for versatile finishes in the textile market has increased rapidly due to competition, increased values, and increased market share. In addition to the stylistic characteristics, users' requirements and demands are interpreted by their functional properties that can be imparted by applying innovative approaches to textile finishing and functional apparel manufacturing. Functional fashion is a design environment in which apparel and accessories are the products of design processes, which are determined by the specific requirements of the user: functionality wearability and desirability. Recently, the use of protective textiles such as UV protection and anti-odor treatments for textiles has increased substantially, due to increasing consumer awareness in the fields of hygiene, particularly in the primary textile industries such as daily wear, sportswear, underwear, sockets, and shoes. Textiles are closely related to the different skin and the environment microorganisms. The presence of heat and humidity in the skin provides an ideal environment for bacteria to grow, as shown in Fig. 1. Such microorganisms in some cases cause undesirable odors, bleeding, skin allergies, and skin infections, so to control unpleasant odor the bacteria need therefore to be stopped from multiplying. Protecting human skin from harmful UV rays is an acute problem with the dramatic rise in skin disorders. As the ozone layer was far less protective, more UV light hits the earth. Long-term exposure to Ultraviolet light can progress to a variety of skin disorders, namely skin aging acceleration, photodermatoses (acne) and skin cancer, skin inflammation and corneal scarring [1,2].

*Corresponding author, rehabmkotb@women.asu.edu.eg, rehabmkotb@yahoo.com
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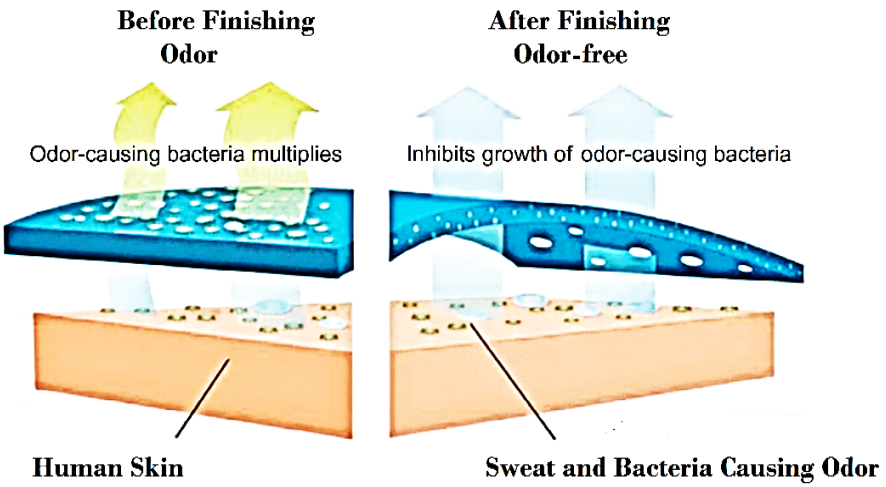


Fig. 1. Schematic of the anti-odor effect of anti-odor finishing.

The functional apparel design process

Functional apparel or clothing may be defined as the items that designed and manipulated to specific performance and function for intended users added to their conventional functions. The field of functional apparel is versatile where each functionality has its own specifications and requirements [3]. Most recently, the functionality of clothing has been introduced by the inclusion of functional or smart materials in part using either mechanically such as weaving or knitting or chemically such as coating, printing, and dyeing. Furthermore, smart and functional textiles and clothing; as classified in Fig. 2.; are now becoming the most integral part of people's lives as wearable technology so that they simplify human life to the environmental stimuli [3,4].

The functional apparel design process is originated in demand for clothing to meet s specific needs of different users. This requires the designer to have full awareness and understanding of the users, their environment and activity before begging the design process. When the functionality or performance of the garment is at the forefront of the design process, apparel design may readily cross over into the domains of medicine, protective wear and performance sports. Adjustments can be made by optimizing the body shape and offering support and contouring, which help to tackle the issue of wearer vanity and performance that improving the life quality for various classes of users [5]. These requirements are the first step in the functional design process. Each class of functional apparel has its requirements, but there are some basic requirements for all classes that can be categorized into physiological, biomechanical, ergonomic, and psychological. The physiological requirements deal with the people's anatomy-shape, size, mass, strength and body metabolic activities, in addition to the need for the human body to feel comfortable in the apparel as a whole. The biomechanical requirements relate to the mechanical specifications of the wearer body in addition to the kinematic, dynamic and behavioral of human activity. As well as the mechanical structure, strength, mobility, and movements of the users. The ergonomic requirements dictate that apparel matches the mechanical needs of the body such as range of motion, degree of freedom of joints and the whole body. The psychological requirements relate to how apparel consider the people's feeling, thinking and interact to their surrounding environment when they wear them. Hence, the aesthetic aspect of functional apparel is very important as much as performance and function aspects. Additionally, there are other common and necessary requirements for all functional apparel that they should be light in weight, thermoregulatory, elastic, antimicrobial, aesthetic and durable. Some applications demand specialized requirements such as UV resistance, fire retardant, anti-ballistic, anti-bacterial, abrasion resistance and water repellence [6]. Once the user requirements have been established, the next step in the functional apparel design process is choosing the appropriate fabric material that chemically or mechanically finished, then applying to dyeing and/or printing, hence acquiring their functional properties. Regarding their natural origin and properties, natural fibers especially cotton and silk, have long been

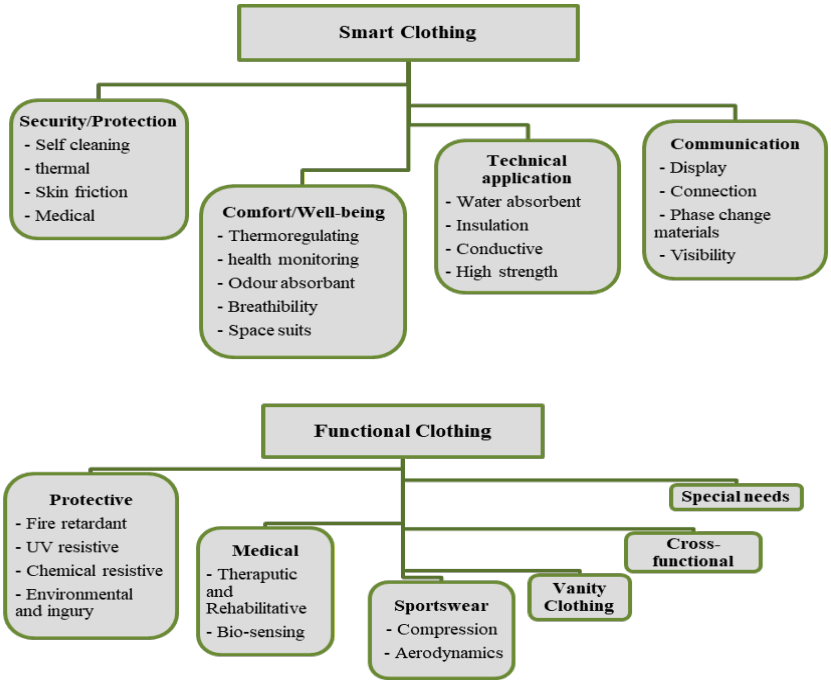


Fig. 2. Smart and functional clothing categories.

used in the textile industry. They acquire wide acceptance and appreciation between peoples as apparel products because of their properties such as good moisture absorption, dyeing affinity, thermal tolerance, perspiration management and comfort, good folding, shiny aspect, soft handle, good elegant drape. The next step in the design process is pattern engineering, and finally, the garment assembly allowing them to fulfill the predetermined requirements, comfort, protection and functionality [2,6].

Textile and clothing are the most suitable interface between the environment and the human body. They can reflect, absorb and scatter solar wavelengths, but in most cases, they do not provide full sun screening properties. UV absorbers are organic compounds that absorb UV radiation shielding the skin. The function of a UV absorber finishing of textiles is to absorb UV radiation effectively throughout the UV region (280-400 nm). UV absorbers convert the electronic excitation energy into thermal energy through a fast-reversible intramolecular proton transfer reaction [2]. Textiles act as carriers for microorganisms, especially in natural fibers such as cotton and silk because of their hydrophilic nature. Pathogenic bacteria such as mold and fungi affect both the fabric itself and the users. These results in unpleasing skin odor, damage to clothing, discoloration, stains, reduction in fabric mechanical strength, and even skin diseases. Antimicrobial treatments were thus used to sustain hygiene and resist pathogens infections especially in hospitals, nursing houses, medical clinics, schools, hotels, and public places. They prevent unpleasant odor on intimate apparel, underwear, socks, athletic wear, and even daily use outfits. Additionally, the unpleasant odor has a negative impact on textiles and their comfort properties and the aesthetic function [2].

Khayamiya heritage

The vibrant ornamental qualities of Khayamiya are recently gaining recognition by designers from other fields such as fashion, interior design, visual art, and textile crafts, however, it remains inexplicable that such an; intensely visual aspect; of Egyptian vernacular culture is not highly regarded, or even widely considered, as a national icon of Egypt [7].

Khayamiya or Egyptian tentmaker applique is a traditional Egyptian architectural textile handicraft. Designers from various fields are gaining recognition of the vibrant ornamental qualities of this craftsmanship. Nevertheless, such a visual aspect of Egyptian vernacular culture remains unexplainable and not widely regarded as the symbol of national design in Egypt. The Egyptian tentmakers (Khayamgy) are mainly men, a group of skilled craftsmen that live in Cairo and

engage in workshops along the Tentmakers Street (El Khayamiya Street or Souq El Khayamiya Street). [8]. The talented tentmakers are sewing by hand stitching the patterned colorful cotton appliques over heavy cotton back that gives protection from environmental effects. There are popular variations of designs and motifs include geometric and architectural arabesque ornaments derived from Fatimid and Mamluk periods and the Egyptian Lotus flowers derived from Pharaonic visual culture. There are four main forms of Khayamiya: Khedival, Touristic, Street, and Contemporary, as shown in Fig. 3 (a,b) [7].

- *Khedival Khayamiya* interpreted between 1867 and 1914. It is usually made by using large appliqued panels in indigo, red, and white on beige canvas, often featuring with vertical blue stripes.
- *Touristic Khayamiya* interpreted from the 1890s through to the present day and was notably popular after 1922. They are smaller and figurative appliques, usually featuring motifs from ancient Egypt or modern Egyptian scenes. International travelers as popular Egyptian souvenirs globally distributed them.
- *Street Khayamiya* represented panels made for outdoor uses in Egypt, like the Suradeq seating area or landscapes for public events and ceremonies.
- *Contemporary Khayamiya* is an applique panel made for different uses that can be divided as the following sub-genres:
- *Arabesque* that consisting of elaborate interlinked patterns and dominates contemporary art form.
- *Folkloric* such as the legends of Goha character and other folkloric ornaments such as geometrical shapes.
- *Orientalists* such as street scenes located in Cairo, Calligraphy usually based on the Holy Quran and Arabic letters.
- *Pharaonic* designs and ancient Egyptian art [7].

(a) **(b)**

Fig. 3 (a-b). (a) Street Khayamiya Siwan (panel) from a twentieth-century Suradeq, and (b) Pharaonic Khayamiya.

This study aims to apply the obtained multifunctional finished cotton and silk fabrics to produce multifunctional apparel products that integrated the functional apparel design process considering the fashionable and upscale concepts. As well as using the unique Khayamiya heritage technique as an aesthetic aspect in an unusual application for producing six functional, added value, and fashionable female apparel.

Experimental Work

Materials

Fabrics

Different fabrics were used in this study; scoured and half-bleached 100% cotton fabrics [plain weave (1/1) 90 g/m^2, 140 g/m^2, 170 g/m^2; and twill weave (2/1) 215 g/m^2] were purchased from Misr Company for Spinning and Weaving, Egypt. As well as scoured 100% silk fabric plain weave (1/1) 93 g/m^2 was purchased from Al-Gammal Company, Suhag, Egypt.

Chemicals and Dyes

Chitosan (low molecular weight), glacial acetic acid, citric acid, sodium hypophosphite, peptone, beef extract, and agar were laboratory grade chemicals, UV-SUN® a reactive anionic UV absorber based on oxalanilides was kindly supplied by Huntsman. A nonionic detergent Hostpal® CVL-EL, Novacron® Red LS-B (C.I. Reactive Red 270), Novacron® Yellow LS-R (C.I. Reactive Yellow 208), Novacron® Navy LS-G (C.I. Reactive Blue 264), Novacron® Turquoise H-GN, and Novacron® Black LS-N were kindly supplied by Huntsman (formally Ciba Specialty Chemicals).

Microorganisms

Staphylococcus epidermis (*S. epidermis*) a Gram-positive odor-causing bacteria, was used for the estimation of antibacterial imparting anti-odor activities.

Media

Nutrient broth/agar medium: contains beef extract (3 g/l), peptone (5 g/l), for a solid medium (15 g/l) agar was added. This medium was sterilized for 20 min at 121°C under pressure.

Methods

Fabrics treatment and dyeing

Before undergoing the treatment, cotton and silk fabrics were washed in a bath containing sodium carbonate [2 g/l] and Hostpal® CVL-EL a nonionic detergent [5 g/l] at 60 ºC for 30 minutes. The fabrics were then thoroughly rinsed with water and finally dried at ambient temperature. The optimum treatment type and conditions were obtained as mentioned in detail in the previously published work [2].

- *Pretreatment with chitosan:* Firstly, cotton and silk fabrics were pretreated with chitosan [1% w/v] that dissolved in citric acid [10% w/v], sodium hypophosphite [7 g/l], and glacial acetic acid [0.5% w/v] and applied by exhaustion method for 30 minutes at 60 °C with material to liquor ratio (M: LR) (1:40).

- *Simultaneously UV absorber treatment and dyeing:* Cotton and silk fabrics were subjected to simultaneously salt-free UV absorber treatment [3% o.w.f.] UV-SUN® and/or dyeing, tie and dye dyeing with the aforementioned different reactive dyes, applied by exhaustion method with M: LR (1:50), and the dyeing process was carried out as described elsewhere [2]. Then all dyed fabrics were washed with nonionic detergent [5 g/l] at 60 °C for 20 minutes, and M: LR (1:50).

Testing and evaluation

Washing procedures

The treated fabrics were washed for 10 and 30 repeated washing cycles to evaluate the obtained optimum treatment durability and sustainability of the acquired functional properties according to the AATCC test method (124-2006).

UV blocking ability

The amount of ultraviolet protection provided by cotton and silk fabrics was evaluated by measuring ultraviolet radiation (UVR) transmission using a UV-Shimadzu 3101-PC-Spectrophotometer. The ultraviolet protection factor (UPF) values were calculated according to the Australian/New Zealand Standard (AS/NZS-4399-1996). The following equation based on the percent ultraviolet radiation transmittance through the specimen was used to calculate the UPF.

$$UPF = \frac{\sum E\lambda \cdot S\lambda \cdot \Delta\lambda}{\sum E\lambda \cdot S\lambda \cdot T\lambda \cdot \Delta\lambda} \quad (1)$$

Where $E\lambda$ is the relative erythema spectral effectiveness, $S\lambda$ is solar spectral irradiance in W/cm^2/nm, $T\lambda$ is the spectral transmittance of the fabric (measured), and $\Delta\lambda$ is the bandwidth in nm. [2].

Antibacterial causing odor efficiency

Staphylococcus epidermis (*S. epidermis*) Gram-positive odor-causing bacteria was used for the estimation of antibacterial imparting anti-odor activity according to the AATCC test method 100-1993. The reduction in the number of bacteria was calculated using the following equation:

$$\text{Reduction rate (\%)} = (A-B)/A*100 \quad (2)$$

Where: A = the number of bacterial colonies recovered from untreated fabrics. B = the number of bacterial colonies recovered from treated fabrics.

Fastness and light fading properties

Colorfastness to wash and light fading of the dyed cotton and silk fabric samples were evaluated according to ISO 105-C10:2006, and ISO 105-B02:1994 (Xenon Lamp), respectively.

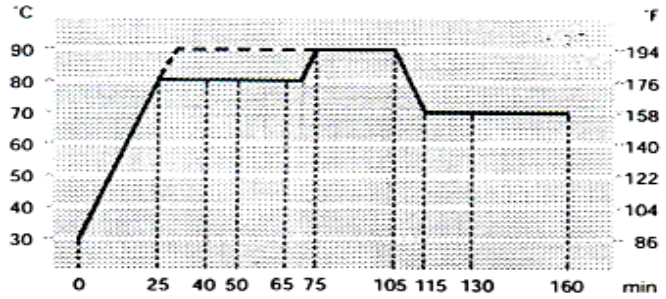


Fig. 4. Dyeing process of reactive dyes.

FTIR analysis

Fourier Transform Infrared Spectroscopy (FTIR) of the untreated and treated samples were recorded by using an FTIR spectrophotometer (JASCO 4700, Japan) in the region of 4000 - 400 cm^{-1} with a spectral resolution of 4 cm^{-1}.

Results and Discussions

Functional finishing properties

Antibacterial causing odor ability, as well as UV protection properties, have been established prominent with users, suppliers, and implementers because they become ever more reassured by their derogatory issues. These approaches included protection from UV radiation and bacteria causing the odor, where a wide range of aesthetic and medical benefits products could be applied to protect both human and textile fabrics from deterioration of UV radiation and bacteria, and other environmental hazards [9].

The optimum treatment conditions and additives were obtained from a series of different treatments and application techniques of a reactive anionic UV absorber based on oxalanilides, chitosan. Additionally, the reactive dyeing was carried out for both cotton and silk fabrics, and the results were discussed as described in the previous work [2].

The enhancements of multi-functional fabrics obtained, such as the excellent UPF category of UV protection classification (50+) for both cotton and silk fabrics. These results may be traced to incorporating UV absorber in the finishing process that is an oxalanilides derivative, which acted as a colorless reactive dye as shown in Fig. 5.

Furthermore, it is acted as a radical oxygen scavenger. Short-wavelength ultraviolet rays excited the UV absorber to a higher energy state, which is absorbed and then dissipated into non-harmful long-wave radiation. This also blocks ultraviolet rays before accessing the fabrics, as well as UV absorber's and dyes multiple shielding efficiency that restricted UV radiation to diffuse through the surface of the material [2].

The results also achieved anti-odor properties for cotton (98%) and silk (99%) fabrics that may be regarded as the fabrics pretreatment with chitosan in the presence of citric acid (CA). These findings may be due to chitosan amino groups that may interact with the metabolism of the bacteria by attaching to the cell's surface and accumulating with DNA in order to suppress the synthesis of mRNA. It was assumed that chitosan can be applied with textiles especially cotton and silk with several treatment techniques and conditions [10].

Chitosan binding mechanisms onto the cotton surface may be, i.e.: (a) a reversible binding that allows a chitosan to be released from the fiber's surface; and (b) an irreversible binding, leading to the permanent bioactivity of textile surface that permitted achieving functionalization of fabric surface for various applications [11,12]. Otherwise, there was a claim that the use of chitosan by pad-dry technique was the most efficient in the quantity of chitosan fixed on fabric after washing, however, this technique may cause unlevelling dyeing that may be regarded to the possibility of chitosan migration in fabric dyeing [13].

It was reported that for the irreversible bonding that implies material-fiber interaction is permeable to the washing process for conventional textile applications. The introduction of carboxyl or aldehyde groups into/onto fiber surface is highly important for irreversible binding since they considered the potential anchoring sites for molecules of chitosan. Consequently, this guaranteed electrostatic attraction between the host material as cotton or silk fibers and chitosan as adsorbent. The carboxyl groups in cotton and/or silk have been established to have different impacts on chitosan interaction compared to aldehyde ones in cotton. Further intermolecular interactions between cotton and chitosan are based on H-bonds and Van der Waal's forces, but under specific conditions and fiber treatments, ionic and/or covalent bonds may be formed [11,12].

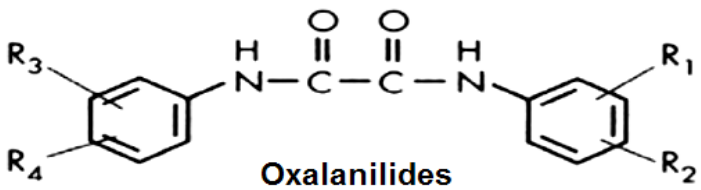


Fig. 5. Structure of oxalanilides-based UV absorbers.

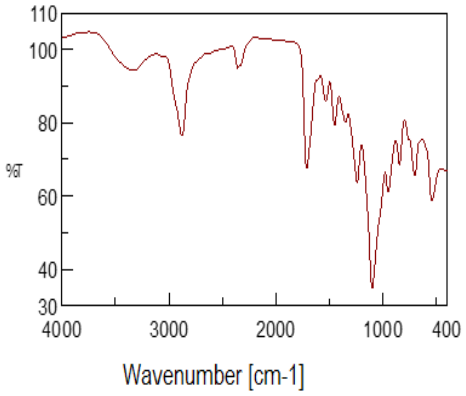
The possible mechanisms may assure better sustainability and durability of chitosan treatment although using exhaustion, which agreed with the results of other's work findings [10].

The obtained results also showed enhancement in dyeability and achieving the approach of minimizing cost and pollution by using no salt simultaneously UV absorber finishing and reactive dyeing. That may be regarded as the crosslinking of chitosan with cotton and silk fabric in the presence of CA introduced available positively charged dye sites on fabrics surface as discussed above [14,15].

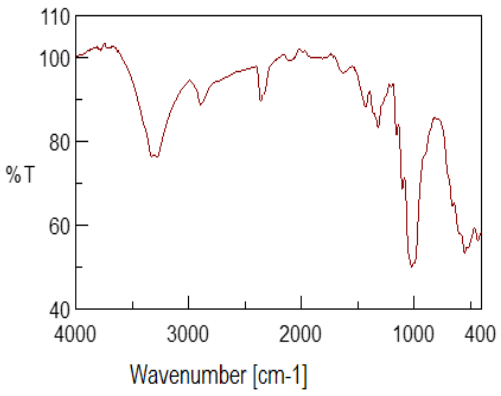
The cationic structure of chitosan induced adsorption by electrostatic interactions of anionic compounds such as dyes and finishing materials, contributing the demanded high degree of exhaustion in salt-free treatments and dyeing. The treatments also improved the fastness to light and wash the dyed cotton and silk fabrics. This may be regarded as that the massive existence of cationic groups in the molecular structure of treated fabrics improved the interaction between fabrics and dye, which in turn enhanced the diffusion of dye molecules into the fabrics. As well as the presence of UV absorber sustained dyed fabrics shade from degradation by UV radiation so enhancing fastness to light property [2,16].

FTIR analysis

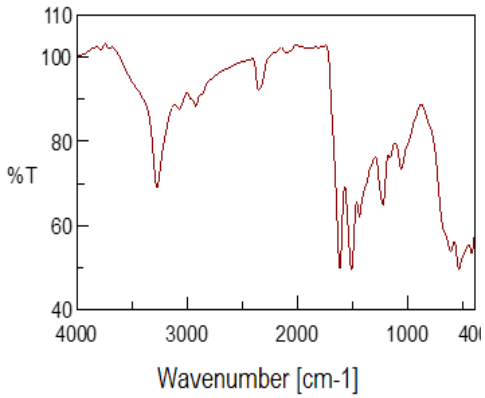
It was observed from Fig. 6. that the characterizations between untreated and treated cotton fabric was the broadband attributed to hydroxyl groups (H-bond) that diminished due to fabric pretreated with chitosan post finished with UV absorber, as well as the appearance a peak in the range of 3057 cm^{-1} to 3779 cm^{-1} that attributed to OH stretching. Also, it was noticed the appearance of a new peak at 3708 cm^{-1} and 3783 cm^{-1} for N-H stretching (chitosan and/or UV absorber), besides the appearance of N-H bending at 1630 cm^{-1}, 1717 cm^{-1}, 1800 cm^{-1} that attributed to C=O stretching. Whereas, in the case of silk fabric the results were different, it was noticed that there was a remarkable increase in peak intensity because of the fact that silk, UV absorber, and chitosan had a similar NH_2, OH, C=O and NH function groups [2].



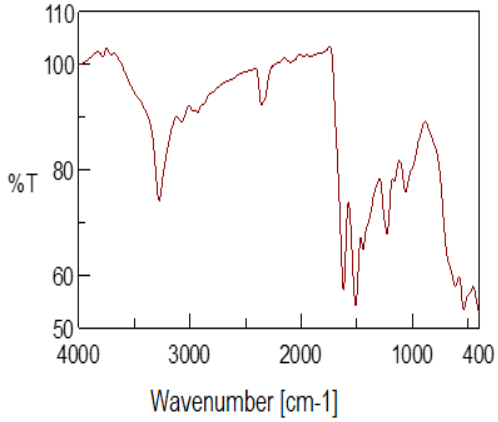
I. Untreated cotton fabric



II. Cotton pretreated with chitosan post finished with the UV absorber



III. Untreated silk fabric



IV. Silk fabric pretreated with chitosan post finished with the UV absorber

Fig. 6. FTIR spectra of cotton and silk fabrics before and after treatments.

The final obtained fabrics were applied in the production of sustainable functional apparel offering protection against UV radiation and bacteria causing the odor. The optimum results (Table 1) showed that using chitosan, UV absorber, and reactive dye produced multipurpose protective cotton and silk fabrics. Protective properties such as UV-blocking activity achieved a remarkable enhancement in UPF values (50+) and excellent protection category. Anti-odor efficiency was measured by antibacterial reduction percentage achieved 98% for cotton and 99% for silk fabrics. Significant enhancement in dyeability values of cotton and silk fabrics, as well as excellent fastness to light, were demonstrated. The durability of the modified fabrics was assessed after 30 repeated washing cycles and the treatment formulations showed sustainable functionality and enhanced properties.

Generally, long-lasting and natural antibacterial effect, odor-preventing abilities, excellent UV protection, optimum skin compatibility, good moisture absorption, improving dyeability maintained color strength, biodegradability, and environmentally friendly properties of chitosan and UV absorbers that made them ideal candidates for fabricating different types of daily wear and functional apparel [1].

Application of modified fabrics in functional apparel design and Khayamiya heritage

In this research, the applied functional apparel products were treated in order to fulfill the requirements functional aspects of UV protection and anti-odor end, as well as sustaining the fastness properties of uses. Some proposed fashionable designs for women were drawn and their pattern was performed taking into consideration the special requirements of functional apparel needed for UV protection and anti-odor clothing. Then the cotton and silk fabrics were introduced to layout and cutting using their patterns. The fabrics then treated and dyed using the optimum treatment formulations and dyeing conditions using the same aforementioned reactive dyes. As well as, execution of some Khayamiya heritage designs by hand stitching as aesthetic aspect to make the integration between the structural and aesthetic aspects of fashion design as well as adding value to the obtained functional apparel products.

TABLE 1. Effect of the number of washing cycles on the sustainability of multifunctional properties.

Fabric Type		Optimum Multifunctional Properties							
		UV Protection (UPF Values)		Antibacterial Causing Odor Activity (S. epidermis bacteria causing odor reduction %)		Color Strength (K/S) of C.I. Reactive Red 270		Fastness to Light	
		After 10 Washing Cycles	After 30 Washing Cycles	After 10 Washing Cycles	After 30 Washing Cycles	After 10 Washing Cycles	After 30 Washing Cycles	After 10 Washing Cycles	After 30 Washing Cycles
Cotton	Untreated	8	5	0	0	3.7	1.2	2	1-2
	Treated	50+ (100)	50+ (92)	98	93	9	8.2	5-6	5
Silk	Untreated	14	10	0	0	0.9	0.5	3	2
	Treated	50+ (80)	50+ (73)	99	90	3.6	2.7	6	5-6

Functional apparel design special requirements

When designing the functional apparel, to be acceptable to the user, they must balance functional elements with both structural design and aesthetic considerations, including the important subjective element of comfort. Successful design in the case of protective clothing must respect strictly defined functional requirements and conform to regulatory standards for the specific industry, meaning the following properties: consider is the designed idea appropriate for specific task acquiring satisfactory aesthetic [17].

- It should fit for purpose, durable and does it perform too or exceeds required standards.
- It should be acceptable to the user respecting the culture, traditions, specifications, manufacturing, and costs.

These are only the basic requirements for design when it comes to protective clothing. Additionally, a good, successful design must provide an innovative approach resulting in innovative concepts that simplify existing products, extends norms or breaks new ground in materials, manufacturing or design concept, adds value by exceeding specifications in functionality, ergonomics, and ease of use or other aspects. However, basic fashion considerations must be considered such as:

- Self-perception and identity.
- Feelings and emotions including comfort and wellbeing.
- The appropriate form, style, materials, and color cut, style, and proportion [17].

UV protection apparel requirements

UV protection apparel should be made of light to medium weight fabrics, which support cool and comfortable properties. Since they were suitable for babies, children, outdoor activity workers, some public service workers, and outdoor employees. Clothing designed to offer UV protection to the upper body must provide coverage from the base of the neck down to the hip and cross the shoulders down to three-quarters of the upper arm. Clothing designed to offer protection to the lower body from the waist to below the patella must similarly provide complete coverage [18,19].

Usually using casual and loose-fitting lines, cuts, and silhouettes, as well as half or long-sleeves shirts and long pants. Additionally, using high collars and necklines, a headband, or a wide-brimmed scarf or helmet to protect the head and a hanging flap that can protect the back of the neck and ears .

Anti-odor apparel requirements

The accumulation of bacteria on textiles and apparel not only damages the garment itself but also the user with a multitude of ungenerous effects. The unpleasant odors have a negative impact on textiles and their comfort properties. It damages the aesthetic function of the fabric. The designs of these clothes should cover the axilla, arm, and legs as possible because these parts contained the highest concentrations of odor-causing bacteria [20,21].

Proposed functional apparel designs and applied products

In this research, the designs were analyzed according to the three aspects of fashion design: functional, structural, and aesthetical aspects,as well as the UV blocking and anti-odor functional apparel requirements besides colorfastness to light values, as shown in Fig. 6 (A-B-C-D-E-F).

Functional design (A)

This is a two-piece A-line silhouette long dress inspired by the soul and elements of ancient pharaonic ornaments, as shown in Fig. 7 (A-D). The functional aspects represented in using high boat neckline and the long dress with medium loose to the waist then flared to the hem with its double layers and the long sleeves, which impart UV protection functionality to the whole outfit. Additionally, the long sleeves that are an off-shoulder type imparted anti-odor functionality through covering axilla, arms, legs, and the lower torso. The structural aspects in this design represented in using a boat neckline that supported easily putting in and taking off for the wearer. In addition to off-shoulder style sleeves, which hanged on to the bodice from the sides rather than from the top of the armhole leaving a hole exposing the shoulders and top of arms to support more freedom of movement. The aesthetic aspects are indicated in using the feminine appearance and a smooth look is indicated in this design. Using contrasting warm yellow and cold blue colors in this design made it appropriate for summertime producing a feeling of activity and excitement.

Functional design (B)

This design is a modern casual dungaree inspired by a hot summer atmosphere, as shown in Fig. 7 (B-D). The functional aspects of this

design represented in using the medium fitting style, narrow V-shape neckline bodice, wide-leg under ankle-length pants, the narrow armhole and the removable shawl, which can be used to cover arms or neck areas. All these details and elements imparted good covering and UV protection properties as well as anti-odor efficiency to the entire body. The structural aspect in this design is manipulated in using V-shape neckline and back buttons that allowed easier wearing for the wearer. The horizontal cut joined the bodice and pants as well as using flared pants style support more freedom of movement, enhanced the figure underneath and give the wearer more breathable feeling. The aesthetical aspect of this design achieved by using the contrasting green and pink colors with white shiny shapes. As well as using, a contrasting tie-dyed horizontal cut, which creates a transition between them creating a sense of animation and actual motion suitable for the summer season.

Functional design (C)

This design as shown in Fig. 7 (C-D) is a fashionable asymmetrical wrap-neck blouse with kimono sleeve and double layer skirt with uneven lengths. The functional aspects in this design are represented in using fitted blouse style covered the shoulder, using necktie, and upper layer maxi length skirt which imparted UV protection to the bodice, neck, most of arms and legs area. The wrap-neck opening covered chest area, and medium-length sleeves that covered the axilla area as well as using the lower below-knee length skirt, all these elements supported the anti-odor efficiency to the outfit. The structural aspects are achieved in using the warp-neck blouse that supports desired fitting to the bodice area and the kimono sleeves that create a casual but feminine look. Additionally, the asymmetrical double layer A-line skirt supports a suitable easier movement. The aesthetical aspects in this design represented in using asymmetrical blouse style that called attention as well as the uneven skirts that created an exciting mood to the design. Whereas, green color gave the sense of spring and peace, the gradation between these colors represents the mood of consistency. The repetition and distribution of white areas in skirt and blouse produced proportion, harmony and a flow motion to the whole design.

Applied functional product (A). The obtained functional apparel product as shown in Figure 7 (A-P).

Fabric:	100% cotton fabrics [plain weave 140 g/m^2, and twill wave 170 g/m^2] for dress, and 100% silk fabric plain weave (1/1) 93 g/m² for the scarf.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Yellow LS-R (C.I. Reactive Yellow 208), and Novacron® Navy LS-G (C.I. Reactive Blue 264).
Dyeing technique:	Piece dyeing and vertical stripes tie and dye.
Khayamiya style:	Folkloric and Pharaonic Khayamiya.

Applied functional product (B). The obtained functional apparel product as shown in Figure 7 (B-P).

Fabric:	100% cotton fabrics [plain weave 140 g/m^2, and twill wave 215 g/m^2] for dress, and 100% silk fabric plain weave (1/1) 93 g/m² for the horizontal cut in dress and scarf.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Red LS-B (C.I. Reactive Red 270), Novacron® Yellow LS-R (C.I. Reactive Yellow 208), and Novacron® Navy LS-G (C.I. Reactive Blue 264).
Dyeing technique:	Diagonal and horizontal stripes, and flower petals tie and dye.
Khayamiya style:	Pharaonic Khayamiya.

Functional design (D)

The design consists of A-line shape tunic and ankle-length skirt, as shown in Fig. 7 (D-D) that composed of two-pieces. The functional aspects in this design are represented in using the scoop neckline, the loose silhouette of the tunic and long skirt that provided safety to the whole body. In addition, a double layer skirt produced dense fabric to the lower body, which minimizes the amount of radiation penetrated the fabric surface and imparted adequate UV protection. Additionally, using cap sleeves that cover the axilla area and the medium-open neckline shape, as well as maxi double layers, skirt provided required anti-odor efficiency to the wearer. The structural aspects in the design are manipulated in using a scoop neck opening that allows easy putting in and taking off the tunic easily. Its A-line style support freedom of movement and activity to the upper body part as well as the diagonal shape double layer skirt imparted secure and comfortable factors to the design. The aesthetic aspects in this design are shown in using contrasting colors of orange-violet tunic with horizontal and triangle cuts and skirts that created flow motion, unusual and modern look to the whole design.

Functional design (E)

This design is a tent-shaped maxi-length modern dress inspired by oriental Khayamiya spirit, as shown in Fig. 7 (E-D). The functional aspects in this design are represented in using gathered boat-shaped neck opening with removable neck scarf covering the neck, asymmetrical sleeves lengths hiding shoulder and arm areas, and the long skirt reached to ankles, which provided UV protection as well as anti-odor efficiency to the whole body. The whole design functionally adds value via supporting good protection of the garment system, as well as reflects fashion and lifestyle trends. The structural aspects in this design are manipulated in using the loosely fitted tent-shape style with a gathered neck opening that supports easier wearing and movement. Asymmetrical loose sleeves created more freedom to arms of the wearer. The aesthetic aspects in this design are shown in using the mixture of hot light mahogany color inspired by Khayamiya and the cold light blue color. The white random areas created bursting and focal point attention to the design. The alternation and distribution of colors in the design created animation and a pleasing look to the whole design.

Applied functional product (C). The obtained functional apparel product as shown in Figure 7 (C-P).

Fabric:	100% cotton fabrics [plain weave 140 g/m^2, and 170 g /m^2] for skirts and 100% silk fabric plain weave (1/1) 93 g/m^2 for necktie.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Yellow LS-R (C.I. Reactive Yellow 208), and Novacron® Navy LS-G (C.I. Reactive Blue 264).
Dyeing technique:	Mixed diagonal, horizontal stripes, and tie and dye.
Khayamiya style:	Pharaonic Khayamiya.

Applied functional product (D). The obtained functional apparel product as shown in Figure 7 (D-P).

Fabric:	100% cotton fabrics [plain weave 90 g/m^2, 140 g/m^2] for dress and skirt, and 100% silk fabric plain weave (1/1) 93 g/m^2 for horizontal cut.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Red LS-B (C.I. Reactive Red 270), Novacron® Yellow LS-R (C.I. Reactive Yellow 208), and Novacron® Navy LS-G (C.I. Reactive Blue 264).
Dyeing technique:	Piece dyeing, Diagonal and vertical stripes, and flower petals tie and dye.
Khayamiya style:	Pharaonic Khayamiya.

Functional design (F)

This is a feminine and casual design consisted of sleeveless blouse with loosely fitting style and a yoke inspired by Pharaonic costumes, removable shawl, and a wide-leg style long pant, as shown in Figure 7 (F-D). The functional aspects of this design are achieved through using a crew-shape neckline of the Pharaonic flared and large yoke that covered axilla, protected neck, and shoulder areas. Although using sleeveless blouse but the presence of additional shawl could be used to cover the arms to protect them, and the ankle-length pant covered the lower part of the body. All these elements imparted UV protection as well as anti-odor efficiency to the whole design and body. The structural aspects of this design are achieved using the loose style of blouse and pant that supported more freedom of movement and comfort. As well as flared crew-shape neckline which allowed the easy wearing of the design. The additional shawl could be used in different ways around the neck, arms, or as a head tie. The aesthetic aspects are represented in using contrast neutral gray-black color with hot red colors with flowing alternation that created a mood of harmony and glamour to the whole outfit.

Applied functional product (E). The obtained functional apparel product as shown in Figure 7 (E-P).

Fabric:	100% cotton fabrics [plain weave 70 g/m^2, 170 g/m^2] for dress, and 100% silk fabric plain weave (1/1) 93 g/m² for scarf.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Red LS-B (C.I. Reactive Red 270), Novacron® Turquoise H-GN, and Novacron® Black LS-N.
Dyeing technique:	Piece dyeing, vertical stripes, and random shapes tie and dye.
Khayamiya style:	Folkloric and Pharaonic Khayamiya.

Applied functional product (F). The obtained functional apparel product as shown in Figure 7 (F-P).

Fabric:	100% cotton fabrics [plain weave 90 g/m^2, 170 g/m^2] for blouse and pants, and 100% silk fabric plain weave (1/1) 93 g/m² for blouse and shawl.
UV protection ability:	50+ (100) for cotton fabrics, and 50+ (80) for silk fabric.
Anti-odor efficiency:	*S. epidermis* bacteria causing odor reduction 98% for cotton, and 99% for silk fabrics.
Fastness to light:	5-6 for cotton fabrics, and 6 for silk fabric.
Dyes:	Novacron® Red LS-B (C.I. Reactive Red 270), Novacron® Yellow LS-R (C.I. Reactive Yellow 208), and Novacron® Black LS-N.
Dyeing technique:	Mixed stripes and random shapes tie and dye.
Khayamiya style:	Pharaonic Khayamiya.

Conclusion

The approach of this research is the application of multifunctional modified cotton and silk fabrics for producing functional apparel that maintained their protective requirements as well as representing the original Egyptian Khayamiya heritage. Optimum treatment conditions were successfully applied using chitosan, UV absorber, and reactive dyes for producing multipurpose protective cotton and silk fabrics such as UV-blocking achieved a remarkable improvement in UPF values (50+) as an excellent protection category. The anti-odor efficiency was evaluated by the antibacterial reduction percentage of Gram-positive bacteria S. epidermis and achieved 98% for cotton and 99% reduction percentage for silk fabrics. Significant improvement in the dyeability of cotton and silk fabrics are demonstrated as well. The durability of the optimum condition treated fabrics was assessed after 10 and 30 repeated washing cycles and the results showed sustainable UV blocking properties and anti-odor efficiency. The obtained apparel products represented the integration between novel trends in the textile finishing field and the functional apparel design process. Since six fashionable designs were designed according to UV protection and anti-odor clothing requirements. The obtained products sustained their functional protection as well as offered excellent fastness to light properties. Additionally, applying the revived Khayamiya technique to highlight the aesthetical aspect added to the benefits of the functional apparel.

Fig. 7. Multi-functional cotton and silk fabrics applied for functional apparel design and their products.

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تطبيق معزز للمنسوجات المجهزة لإنتاج ملابس وظيفية متعددة الحماية ومواكبة للموضة مع استخدام تراث الخيامية

رحاب محمود قطب
كلية البنات للآداب والعلوم والتربية – جامعة عين شمس – القاهرة – مصر

يتنوع الاستخدام النهائي وتطبيق المنسوجات المجهزة ما بين الاستخدام كقطعة ملبسيه أساسية الى الملابس التقنية والصناعية والتي تمثل تحديا لكل من الباحثين والمصنعين. وتشتمل وظيفة الملابس على المحافظة على جسم الانسان وحمايته من مخاطر البيئة المحيطة ومواكبة اتجاهات الموضة، بالإضافة الى المساهمة في تحسين وتعزيز نمط الحياة. ولقد مثل تطبيق المنسوجات الوظيفية المجهزة تحديا في مرحلة تصميم الموضة الخاص بها، خصوصا تلك التي يتم انتاجها بمواصفات وظيفية محددة وبمتطلبات خاصة. فان انتاج مثل هذا النوع من الملابس الوظيفية يجب ان يتكامل مع تحويل المنسوجات المسطحة من خلال تصميم الموضة الى منتج ملبسي ثلاثي الابعاد. وذلك نظرا للتغير في احتياجات واولويات الانسان وازدياد الوعي في الآونة الأخيرة بسبب التجديد في نمط الحياة. بالإضافة إلى ظهور اتجاهات وتقنيات جديدة في مجال تجهيز المنسوجات وتطبيقاتها المختلفة. فان الدراسة الحالية تهدف الى استخدام أقمشة طبيعية كالقطن والحرير المجهزة والمتعددة الوظائف كالحماية من الميكروبات المسببة للروائح الكريهة والاشعة فوق البنفسجية، لإنتاج ملابس متعددة الوظائف يتكامل فيها تجهيز المنسوجات مع عملية تصميم الملابس الوظيفية، مع مراعاة ومواكبة اتجاهات الموضة. وكذلك استخدام تراث الخيامية المصري لإحياء وابراز تقنية تعد واحدة من الحرف اليدوية التقليدية المتأصلة في التراث المصري.