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Cotton Knit Fabric Dyed with Natural Indigo and UV Protection

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Abstract

The main objective of this research were to 1) study knit fabric structure, physical properties and color values of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo and 2) compare the effectiveness in UV protection of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo. Physical properties tested stitch density, fabric thickness, bursting strength, air permeability values were measured before and after washing, color values tested L^* a^* b^* C^* and h^* values and the effectiveness in UV protection of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo was then measured as follows: ultraviolet protection factor (UPF), percentage of UVA and UVB transmittance, and percentage of UVA and UVB blockage values were measured before washing, after five washing and 10-hour light exposure in both dry and wet conditions. It was found that the stitch density values of the cotton knit fabric dyed with natural indigo were a little greater than those of the cotton knit fabric structure undyed (white color) when measured before washing while their fabric thickness values of the cotton knit fabric dyed with natural indigo were a higher than those of the cotton knit fabric structure undyed (white color) when measured after washing while their bursting strength values of the cotton knit fabric structure undyed (white color) were a higher than the cotton knit fabric dyed with natural indigo when measured both before and after washing, and air permeability values the cotton knit

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fabric dyed with natural indigo indigo were a higher than those of the cotton knit fabric structure undyed (white color) when measured both before and after washing.

It was also found that the cotton knit fabric structure undyed (white color) showed unprotect levels of effectiveness in UV protection when tested before and after laundering, light exposure in both dry and wet conditions. While the cotton knit fabric dyed with natural indigo, it was also found that showed very good to excellent levels of effectiveness in UV protection when tested before and after laundering, light exposure in both dry and wet conditions.

Keywords: UV Protection, Dyed with Natural Indigo, Cotton Knit Fabric

1. Introduction

As it is known radiation of this type emitted by sun in the range between 100 and 400 nm is subdivided into UV-C (100 - 280 nm), UV-B (280 - 315 nm) and UV-A (315 - 400 nm) [1]. Higher layers of the atmosphere absorb the Radiation of UV-C range which is most dangerous to living species. Human skin has to be protected against excessive radiation of the UV-B type. It was proved that the excessive radiation of this range is the origin of premature skin ageing, sunburn, allergies and even skin cancer. The UV-A radiation is less dangerous but also its overdoes can result in similar effects as described above.

In 2002, an estimated 54,200 new cases of melanoma skin cancer alone were diagnosed [2]. As results of these growing concerns, special attention was focused by textile researchers on the fabric permeability to the UV radiation in the recent years [2]. The UV radiation transmitted through a textile fabric consists of the waves that pass unchanged through the pores of the fabric and scattered waves that have interacted with the fabric. The reported that manufacturers of sun protection clothing face a confusing array of information because the published literature contains many contradictory claims [3]. Many research studies were conducted to establish the parameter that affect the UV permeability of the textile garment. Some studies concluded that the compactness and the weight of the fabric are the most relevant parameter, while other claim that dark color shades offer more protection. In the two situation, the garments tend to be less comfortable to wear in hot weather.

Other than drastically reducing exposure to the sun, the most frequently recommended form of UV protection is the use of sunscreens, hats, and proper selection of clothing. Unfortunately, one cannot hold up a textile material to the sunlight and determine how susceptible a textile is to UV rays. Even textiles which seem to be non-light transmitting may pass significant amounts of erythema-inducing UV irradiation [4]. Therefor knowledge of the factors that contribute to the protective abilities of textiles is vital. Important factors include fiber composition, fabric construction and wet-processing history of the

fabric such as color and other finishing chemicals that may have been applied to the textile material [5].

Sever different effects occur when UV-R strikes a textile surface and the UV-R is broken into several components. A portion of the radiation is reflected at the boundaries of the textile surface. Another part is absorbed when it penetrates the sample, being converted to a different energy form; the remaining portion of radiation travels through the fabric and reaches the skin. This part of UV-R is appropriately referred to as the transmission component. Today, there are two methods for determining the UPF-an in vivo method and an in vitro method. The in vivo method is recorded by determining the minimal erythema does (MED) and without textiles on test subjects. When this in vivo method is used, a distinction is made between the "on skin" method, in which the fabric sample is applied directly to the skin of test subjects, or the "off skin" method, in which the fabric is placed at a distance of 2 mm from the skin surfaced during the measurements [6]. Using the in vitro method, the UV transmission of the fabric is determined by spectrophotometry, after which the UPF is then calculated from this value [7].

The transmission of UV-R through a specimen is recorded on a spectrophotometer or a spectroradiometer at known wavelength intervals [6]. The calibrates lines of an electrical discharge in mercury vapor. Reference wavelength for both mercury arc emission and holmium oxide absorption are provided in the ASTM International practice E 275, Standard Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near-Infrared Spectrophotometers [8]. On the basis of these studies, the following measurements can be made: UPF, UV-A transmittance, UV-B transmittance, the percent blocking UV-A, and the percent blocking UV-B.

Knitting is the construction of an elastic, porous fabric, created by interlocking yarns by means of needles. Knitted fabrics can be made much more quickly and easily than woven fabrics at comparatively less cost [9]. Knitted fabrics are generally light in weight, comfortable in wear even during travel, but yet require little care to keep their neat appearance. The tendency of knits to resist wrinkling is another factor to boost up their popularity [10]. Knitted fabrics are used for designing active clothing such as sports clothing. Their elastic nature permits for abundant physical activity. Knitted fabrics are produced by two general methods. Warp knitting and weft knitting. They are made as flat or tubular fabrics depending on the end use. Tubular fabrics may not have any seams at the sides where as flat fabrics are stretch just like woven fabrics.

"Reference [11] said that There are two types of knitted fabrics : weft-knitted and warp-knitted." Weft-knitted fabric is made by looping together long lengths of yarn. It can be made by hand or machine. The yarn runs in rows across the fabric. If a stitch is dropped it will ladder down the length of the fabric. The fabric is stretchy and comfortable and is used for socks, T-shirts and jumpers. In warp-knitted fabric the loops interlock vertically along

the length of the fabric. Warp knits are slightly stretchy and do not ladder. Warp-knitted fabric is made by machine. It is used for swimwear, underwear and geotextiles.

Knit fabrics are comfortable, easy to sew, and travel beautifully. From stretch jersey knits to double knits, this fabric is perfect for creating maxi dresses and skirts, children's clothing, sweaters, and much more. Shop thousands of knit fabrics in every color and print imaginable for your next project [12].

In this study, cotton knit fabric structure were yarn dyed with natural indigo (kram plant or Indigoferatinctoria Linn) cotton knit fabric structure were characterized with respect to Stitch Density, fabric thickness, Bursting Strength Air Permeability, color values. Ultraviolet Protection Factor (UPF) was measured using UV Penetreation and protection Measurement System: Camspec M 350 UV / Visible spectrophotometer.

2. Materials and method

2.1 Materials

The yarns of cotton used for the dyeing was 100 percent cotton and knit fabric structure. It was cleaned and bleached. The natural indigo dye used of the Sakon Nakorn province. The AATCC multifiber test fabric and the AATCC standard detergent were used for the laundering test. The AATCC blue wool standard fabric was used in the light exposure test.

2.2 Plant Materials

Fresh materials of *Indigofera tinctoria* Linn. was collected from the Upper North of Thailand. Indigo dye was made into paste and solubilized using sodium hydroxide and sodium hydrosulfite. The liquor – goods ratio was 40: 1. After thirty minutes of dyeing the yarns of cotton were removed and oxidized by drying in air. The fabrics were then rinsed in deionized water and washed using a non-ionic detergent and dried.

Figure 1: The yarns of cotton dyed with natural indigo *(*kram plant or *Indigofera tinctoria Linn)*

2.3 knit Fabric Structure

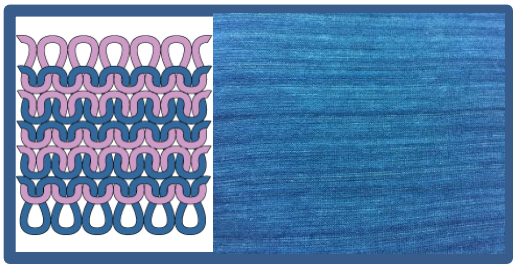

Figure 2: Weft-knitted fabric is made by looping together long lengths yarn of cotton dyed with natural indigo

2.4 Color measuring

The L*, a*, b*, C* and h* values of the dyed samples were determined using a spectrophotometer (Spectraflash 500 Xenon Flash lamp , Diffuse/8.)

2.5 Laundering

The knit fabric structure sample) were laundered 5 times by the Gyrowash Launder-

Ometer (equal to 25 times of hand washing) and 10 times (equal to 50 times of hand washing) Following the AATCC Test Method 61- 2003 condition 1A [13].

2.6 Light exposure

The knit fabric structure (sample) were exposed to light according to AATCC Test Method 16- 2004 No. E Water – cooled Xenon Arc Lamps Continuous light [13] for 10 hours.

2.7 UV Protection of Textiles

Direct and diffuse UV transmittance through fabric is the crucial factor determining the UV protection of textiles [4]. Ultraviolet protection factor (UPF) is the scientific term used to indicate the amount of Ultraviolet (UV) protection provided to skin by fabric. UPF values are analogous to SPF values the only distinction being that SPF values for sunscreens are determined through human testing whereas UPF values are based on instrumental measurement. UPF is defined as the ratio of the average effective UV irradiance calculated for unprotected skin to the average UV irradiance calculated for skin protected by the test fabric.

UPF' s were measured in vitro using a labsphere* UV- 100 F Ultraviolet Transmission Analyzer according to standard AS/NZ 4399: 1996 [14]. Fabric with a UPF value in the range 15-24 were classified as having "Good UV Protection", when the UPF value were between 25 and 39 fabrics were classified as having " Very Good UV Protection" and " Excellent UV Protection" classification was used when he UPF was 40 or greater [14]. In no event was a fabric assigned a UPF rating greater than 50. (Table 1)

Table 1: Ranking of the garment depending on their UV transmission.

UPF	Actual UV Transmission (%)	Category of protection
14 - 24	6.7 - 4.1	Good
25 - 39	4.0 - 2.6	Very good
$\geq$ 40	< 2.5	Excellent

2.8 Experimental plan

This experiment was designed following a complete random design (CRD). The experiment consisted of 2 Treatments with five replications.

2.9 Statistical Analysis

Results are given as mean and standard deviation of the UPFs. Assuming a normal distribution of the raw data it used the unpaired Study t- test to detect difference between in cotton knit fabric structure (white color) undyed with the cotton knit fabric dyed with natural indigo measurement. All reported *P* values are two tailed and *P* values Less than .05 were considered to indicate statistical significance [15].

3. Results and Discussion

From the study fabrics structure, physical properties, it was found that the Stitch density values of cotton knit fabric dyed were a little greater than those of Cotton knit fabric undyed when tested before washing all both wale

and course, the Stitch density values of cotton knit fabric undyed and cotton knit fabric dyed were a equally when tested after washing all both wale and course, are listed in Table 2.

Table 2: Stitch density of cotton knit fabric

Fabric	Stitch density values (sq in, in^2)			
	before washing		after washing	
	Wale	Course	Wale	Course
Cotton knit fabric undyed	26	31	27	36
Cotton knit fabric dyed	27	32	27	36

From the study fabrics structure, physical properties, it was found that the fabric thickness values of cotton knit fabric undyed and cotton knit fabric dyed were a equally when tested before washing, and after washing it was found that the fabric thickness values increased when tested after washing, in case the study fabrics structure, physical properties, it was found that the bursting strength values of cotton knit fabric undyed and cotton knit fabric dyed were decreased when tested all both before and after washing, and in case the study fabrics structure, it was found that the air Permeability values of cotton knit fabric undyed and cotton knit fabric dyed were increased when tested all both before and after washing. are listed in Table 3.

Table 3: Fabric thickness, Bursting strength and Air Permeability values of cotton knit fabric

Fabric	Fabric thickness values (mm.)		Bursting strength values (kilopascal /kPa)		Air Permeability values (cm^3/ cm^3/s)	
	washing		washing		washing	
	before	after	before	after	before	after
Cotton knit fabric undyed	0.59	0.63	643.2	610.1	91.03	60.34
Cotton knit fabric dyed	0.59	0.70	586.6	528.3	103.80	65.77

Color values of cotton knit fabric with natural indigo-dyed (Table 4)

From the dyeing of cotton knit fabric with natural indigo- dyed when tested laundering and exposure in before and after condition, it was found that the L* values of cotton knit fabric with natural indigo-dyed were relatively indicating dark colors which were in the course of the indigo- dyed, that the L* values decreased after laundering and after light exposure, indicating darker colors. The change of color after laundering may be due to conditions in the laundering. " Reference [16] reported that the color of the silk fabric dyed with the dyes from mangosteen husks also changed after laundering". The color of the dyed silk become darker are shown in Table 4.

The a* values of cotton knit fabric with natural indigo-dyed are shown in Table 4. All a* values obtained were negative, indicating greenness. When comparing the color of before launderings, after launderings and after light exposure, it was found that the a* values decreased after laundering and after light exposure. In this cases, the cotton knit fabric with natural indigo-dyed had the a* values, indicating the most greenness was it test after light exposure condition.

The b* values of cotton knit fabric with natural indigo-dyed are shown in Table 4. All b* values obtained were negative, indicating blueness which were in the course of the indigo-dyed. When comparing the color of before launderings, after launderings and after light exposure, it was found that the b* values increased after laundering, indicating bluer color, but decreased after light exposure indicating lower blueness. In this cases, the cotton knit fabric with natural indigo-dyed had the b* values, indicating the most blueness was it test after laundering condition.

The C* values of cotton knit fabric with natural indigo-dyed are shown in Table 4, it was found that C* values decreased after light exposure, indicating increased dullness of color. When comparing the color of before launderings, after launderings and after light exposure, it was found that the C* values, indicating the most brightness was it test after laundering condition.

The h* values of cotton knit fabric with natural indigo-dyed indicates the position of color. As shown in Table 4, The h* values of cotton knit fabric with natural indigo-dyed were in a range of green- blue, which were in the course of the indigo-dyed. When comparing the color of before launderings, after launderings and after light exposure, it was found that the h* values increased after laundering and after light exposure, indicating the shifted to a blue hue.

Table 4: Mean L* a* b* C* and h* values of cotton knit fabric with natural indigo - dyed

Color measuring (values)	cotton knit fabric with natural indigo - dyed		
	before launderings	after launderings	after light exposure
L*	28.38	27.66	26.34
a*	-0.88	-0.36	-0.22
b*	-20.82	-21.54	-20.64
C*	20.84	21.54	20.64
h*	267.59	269.06	269.40

The effectiveness in UV protection

UV Protection property of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo are shown in Fig. 3. It was found that the cotton knit fabric structure undyed (white color) showed unprotect levels of effectiveness in UV protection when tested before and after laundering, light exposure in both dry and wet conditions. While the cotton knit fabric dyed with natural indigo, it was also found that showed very good to excellent levels of effectiveness in UV protection when

tested before and after laundering, light exposure in both dry and wet conditions. When comparing the UPF values of the cotton knit fabric dyed with natural indigo, when tested before and after laundering, light exposure in both dry and wet conditions. It was found that the UPF values increased while the tested in wet conditions of tested before and after laundering and after light exposure. "Reference [17] reported that when textiles become wet, by air hydration, perspiration, or water, UV transmission though the fabric can significantly change, with a marked reduction of UPF observed for textiles made from cotton and cotton blends". In a field-based study, it was recently shown that significant UPF values may occur beneath garment, particularly those made of while the cotton knit fabric dyed with natural indigo when wet [18].

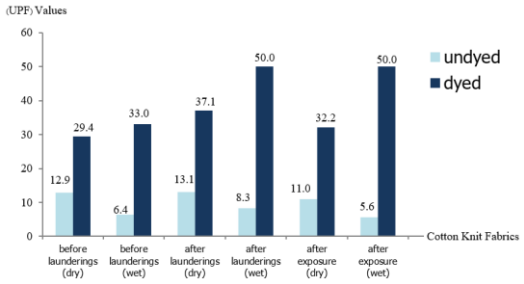

Figure 3: The UPF values of cotton knit fabrics: : before, after launderings and after light exposure

Fig. 4 showed the UVA transmittance % values of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo. It was found that the cotton knit fabric structure undyed (white color) showed unprotect the UVA transmittance % values when tested before and after laundering, light exposure in both dry and wet conditions. While the cotton knit fabric dyed with natural indigo, it was also found that showed very good to excellent levels of the UVA transmittance % values when tested before and after laundering, light exposure in both dry and wet conditions. When comparing the UVA transmittance % values of the cotton knit fabric dyed with natural indigo, when tested before and after laundering, light exposure in both dry and wet conditions, It was found that the UVA transmittance % values increased while the tested in wet conditions of tested before and after laundering and after light exposure. "Reference [17] reported that when textiles become wet, by air hydration, perspiration, or water, UV transmission though the fabric can significantly change, with a marked reduction of UPF observed for textiles made from cotton and cotton blends". One explanation for this is that the presence of water in the interstices of a fabric reduces optical scattering effects and hence, increases UV transmission of textile [19].

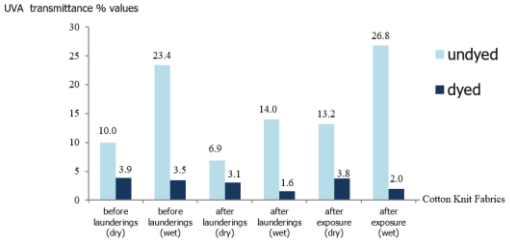

Figure 4: The UVA transmittance % values of cotton knit fabrics: before, after launderings and after light exposure

Fig. 5 showed the UVB transmittance % values of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo. It was found that the cotton knit fabric structure undyed (white color) showed unprotect the UVB transmittance % values when tested before and after laundering, light exposure in both dry and wet conditions. While the cotton knit fabric dyed with natural indigo, it was also found that showed very good to excellent levels of the UVB transmittance % values when tested before and after laundering, light exposure in both dry and wet conditions. When comparing the UVB transmittance % values of the cotton knit fabric dyed with natural indigo, when tested before and after laundering, light exposure in both dry and wet conditions, It was found that the UVB transmittance % values increased while the tested in wet conditions of tested before and after laundering and after light exposure. "Reference [17] reported that when textiles become wet, by air hydration, perspiration, or water, UV transmission though the fabric can significantly change, with a marked reduction of UPF observed for textiles made from cotton and cotton blends. One explanation for this is that the presence of water in the interstices of a fabric reduces optical scattering effects and hence, increases UV transmission of textile [19].

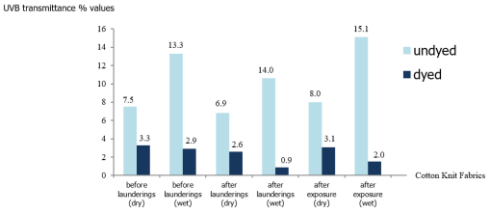

Figure 5 The UVB transmittance % values of cotton knit fabrics: before, after launderings and after light exposure

4. Conclusions

In this preliminary study, the UV transmission of cotton knit fabric structure undyed (white color) with the cotton knit fabric dyed with natural indigo. The cotton knit fabric structure undyed (white color) showed unprotect UPFs of undyed fabrics was significantly enhanced by dyeing with natural colorants especially for fabrics such as the Plain weave or the knit fabric that displayed no protective abilities in the undyed state. The degree of protection imparted after dyeing was a function of the concentration of the colorant in the fabric. Based on the results of this study it can be theorized that the cotton knit fabric dyed with natural colorants can provide very good and excellent protection against ultraviolet rays with the only condition being that either the color has to be a dark hue or the concentration of the colorant in the fabric has to be high [20]. The study results also found that UPFs increased when tested in the wet condition all before, after washing and after light

exposure [21]. Explanation for this is that, most fabrics undergo a combination of relaxation and consolidation shrinkage when washed. Thus, the spaces between the yarns decrease and UV protection increases. The effect of launderings on UPFs raises questions about qualities and factors of other fabrics that decrease UPF (Ultraviolet Protection Factor). However, there is a lack of reports of wash-and-were trials using other fabric types.

5. Acknowledgment

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