UPF Assessing on Different Weft Knit Fabric Structures - A Critical Review

Habeebunissa[1], Anish Sharmila M[2]

[1]Research Scholar, Hindustan Institute of Technology and Science, India
ORCID Id: 0000-0003-1563-7664

[2]Assistant Professor, Hindustan Institute of Technology and Science, India
ORCID Id: 0000-0002-1130-0709
Corresponding Author Email: *anishs[at]hindustanuniv.ac.in*

Abstract: ***The presence of UV radiation in our environment poses a serious risk of sunburns, premature skin aging, immune suppression, PMLE, and even the development of skin cancers. There has been an increasing awareness of the necessity of ultraviolet (UV) protection in recent years in light of the rising incidence of skin cancer and other detrimental effects of prolonged exposure to sunlight. Various studies provide information on the factors that affect the improvement of UPF values in cotton fabrics. The effect of stretching of knit fabric on the ultraviolet protection factor (UPF) of cotton and its blend offers a prediction model for determining UPF based on yarn and fabric properties. Statistical analysis through linear regression models helps to examine the relationship between fabric weight, thickness weight-to-thickness ratio, stitch density, and UPF (ultraviolet protection factor). This review paper critically analyses works conducted by researchers over a period of the decade to discuss the efficacy of UPF on various fabric construction parameters such as fabric weight, fabric thickness, structure, application of UV absorbers, Air Permeability, etc., on different knitted fabric structures. This critique may be useful for scholars, researchers, members of the textile industry, etc. for developing fabrics with better UV protection.***

Keywords: Knit fabric, Structure, UPF, Weft Knitting, Machine Gauge, Optimization

1. Introduction

Sunlight, our primary energy source, emits Ultraviolet (UV) radiation, with UVA (315−400 nm), UVB (280−315 nm), and UVC (100−280 nm) wavelengths. UV radiation's high energy can harm human skin significantly. Clothing offers convenient UV protection, but not all garments are equally effective. UV protection finishes are crucial, especially in hot and humid climates. Sun-protective clothing claims to shield against solar UV radiation. The textile industry's environmental impact, including water and chemical use, necessitates eco-friendly finishes. Chennai residents' UV protection practices, knowledge, and awareness of protection-finished garments were examined. Excessive exposure to UV rays induces sunburn, damages the skin, and is susceptible to skin cancer. Garments with UV radiation absorbers are vital for effective protection. Developing eco-friendly finishes is essential due to the textile industry's environmental concerns (Das, 2010; Eby Chacko; Khan, 2016).

Table 1: Ultraviolet Protection Factor Ratings

UPF Rating	Protection Category
15 to 24	Good
25 to 39	Very Good
40 to 50+	Excellent

As shown in Table 1, it is important for a fabric to possess a UPF rating over 25 to guarantee a high level of protection against ultraviolet radiation. This is in accordance with the ASTM Standard for Sun Protective Clothing and Swimwear which is considered the industry standard in rating sun-protective clothing:

Factors affecting UPF rating of fabric are: -

- Yarn Composition (cotton, polyester, etc)
- Compactness of weave or knit.
- Colour shade
- Stretch/Porosity
- Wetness/Moisture content
- Faded garments may have reduced ratings
- Post treatments such as wet finishing (Saravanan, 2007)

The duration of exposure to UV radiation may be short or very long, such as during an 8- to 12-hour exposure out of doors. Therefore, any measure of radiation penetration for clothing must be maintained for a long time. The implementation of the UV protection factor as the standard tool for assessing the extent of ultraviolet radiation penetration into fabric was established in Australia. (Adam, 1998) The main objective of this review paper is to assess the ultraviolet protection factor of various weft-knitted fabrics.

Knitting Technology:

Knitting technology encompasses a diverse range of methodologies, machines, and procedures employed for the production of textiles by the inter-looping of yarn. The field of knitting technology encompasses the use of various knitting machines and techniques to interconnect or intertwine loops of yarn, hence producing Knit fabrics. The technology of knitting may be categorised into two primary classifications: weft knitting and warp knitting. The term "hand knitting" pertains to the act of producing knitted fabric only through the use of knitting needles and the manual dexterity of one's hands. In contrast, machine knitting entails the utilisation of knitting machines to mechanise the procedure of constructing knitted textiles. A range of knitting machines are employed for different purposes, such as circular knitting machines, flat knitting machines, and warp knitting machines. (Saptarshi Maiti, 2022)

Warp knitting is a method where individual loops are formed in the fabric using separate yarns, aligned parallel to the fabric's edge. These yarns are guided into the knitting machine's bars. Various structures like tricot, raschel, and milanese are utilized (Kyosev, 2022). Tricot involves interlooping yarns in a zigzag pattern, creating a durable textile commonly used in robust applications like upholstery and technical fabrics. Raschel, utilizing both needle and sinker beds, produces intricate patterns, ideal for lace, curtains, and lingerie. Milanese, with eyelet-like openings, gives a mesh-like look, ensuring breathability and lightness, making it suitable for sportswear and netting (Saptarshi Maiti, 2022).

Fabric Parameters:

Various studies have explored the impact of fabric characteristics on ultraviolet (UV) skin protection. Grancarić, Penava, and Tarbuk (2005) investigated different fabric constructions and their influence on UV protection measured by the ultraviolet protection factor (UPF). Stankovic, Popovic, Poparic, and Bizjak (2009) focused on yarn twist and surface geometry in textiles. Vidhya and Rekha (2012) studied the UPF of bamboo fabric, assessing three knit structures colored with plant-derived dyes. Wong et al. (2013) found that UV protection in knitted textiles goes beyond fabric thickness or weight alone.

KAN (2014) examined the UPF of weft knitted textiles, considering fabrics made with 20Ne cotton yarn and Coolmax yarn. They measured UPF values under different states: dry, relaxed, and stretched. Nazaré, Flynn, Davis, and Chin (2014) evaluated the mechanical qualities of firefighter turnout gear, particularly outer shell fabrics containing melamine fibers.

Wong et al. (2016) provided valuable insights for textile professionals and consumers regarding UV-protective knitwear. Other significant contributions include Kan, Yam, and Ng (2013) and Wong et al.'s studies on the influence of reactive dyes (2016) and UV protection in weft-knitted fabrics (2016). These studies collectively enhance our understanding of UV protection in textiles, benefiting the textile industry and consumers alike.

In a study by N. A. Ibrahim (2009), the UV Protective Factor (UPF) of cotton knit fabrics was examined. Different knit structures, including interlock, pique, and parasol, with GSM ranging from 158 to 232, were treated with TinofastVR CEL, a UV absorber. Gray fabrics demonstrated higher UPF compared to scoured and bleached ones, essential textile processes. Deposition of metal oxide on bleached cotton knit fabric, combined with UV absorber treatment, boosted UPF. Metal oxide applications ranked as follows: Cu > Zr > Zn > Al > None, enhancing both UPF and antibacterial properties in cotton knit fabrics during softening processes.

Fabric Structures

(Akaydin, 2010) investigated the Ultraviolet radiation permeability properties of the basic weft knitted fabric. The fabrics were treated with reactive dyes. It was found that the dark-colored fabrics had higher UPF. There was a positive relationship between the GSM of the fabric and the UPF property. He concluded that white or light-colored fabrics are not suitable for ultraviolet protection. He further specified that interlock fabrics add higher ultraviolet protection than single jersey or rib fabric.

Furthermore, (Wong W.-y. , Lam, Kan, & Postle, 2016.) investigated the impact of different knitted fabric constructions on the UPF of grey and bleached cotton fabric. Interestingly, this research showed that considerable modification of knitted structures can improve the UV protective ability of fabrics which can be a better alternative instead of using a chemical approach at a secondary level. They strongly recommended that fabric constructed in a specific structure was the simplest and the cheapest solution in order to achieve good UV protection without the use of any of the additional finishing processes.

The study used 100% organic cotton yarn with a 3/40s count on a computerized flat knitting machine, STOLL CMS 822 of 14G, to create various fabric structures, including Single Knit (all knit, knit tuck, Knit Miss 25%, Knit Miss 50%) and Double Knit (1 x 1 rib, half cardigan, full cardigan, half Milano, full Milano, interlock). Plied yarns were preferred for added strength, uniformity, abrasion resistance, and appearance. Fabric thickness, weight, stitch density, and porosity were correlated with UPF.

Fabrics with miss stitches exhibited higher UPF values, while greige single-knitted fabric showed better UPF post-bleaching, possibly due to shrinkage. However, bleaching removed natural pigments and impurities. Among all structures, interlock and knit-miss (50%) demonstrated the highest UPF values. High fabric thickness didn't consistently provide better UV protection; the Knit-Tuck structure, with low stitch density and higher porosity, had lower UPF values. The examination underscores the significance of knit structures in determining UV protection properties.

Cover Factor

The fabric's cover factor significantly impacts its UV protection. Knit fabrics often offer lower UV protection than woven ones due to their greater stretch ability. Kan, Yam, and Ng (2013) explored the impact of stretch on Cotton and Cotton/Coolmax blended fabrics. Coolmax, known for air permeability and comfort, has minimal stretch. Various yarn combinations, including regular and Supima cotton, were spun using conventional and torque methods. Circular knitting at 20G gauge produced fabrics. Conventional ring-spinning provided superior UV protection, emphasizing yarn twist's role in UPF. Combed Supima cotton yielded better UPF than regular combed cotton. Fabrics blending regular and Supima cotton also displayed good UPF. The combination of Coolmax and cotton achieved the highest UPF. Dry fabrics and stretched conditions reduced UV protection, as pores opened to UV radiation. This investigation emphasizes the significance of spinning technology, yarn composition, and stretch in fabric UPF.

Effect of Knit Structure on UPF

An examination on the UV protection factor (UPF) of knitted fabrics using combed cotton yarn (30 Ne) on a 14G computerized flat knitting machine. Various structures, including Plain Knit, Lacoste, Knit Tuck, Pineapple, and more, were created. After knitting, fabrics underwent scouring and neutralization. Tests measured fabric weight, thickness, stitch density, and UPF. Single-knitted fabrics with knit and miss structures exhibited superior UPF due to the float pattern created by miss-stitches. However, these fabrics were heavy, possibly unsuitable for summer wear. Among double-knitted structures, interlock fabric offered the highest UPF but was also heavy. Researchers recommended further research to reduce fabric GSM for summer-appropriate garments (Wong W.-Y., Lam, Kan, & Postle, 2013).

Table 2: 100% Cotton Yarn Specification

Type of Cotton Fiber	Yarn Count (Tex)	Spinning Method
Combed Cotton	20	Conventional Ring Spinning
Combed Cotton	15	Conventional Ring Spinning
Combed Supima Cotton	20	Conventional Ring Spinning
Combed Supima Cotton	15	Conventional Ring Spinning
Combed Supima Cotton	12	Conventional Ring Spinning
Combed Supima Cotton	10	Conventional Ring Spinning
Combed Supima Cotton EsTex	20	Torque free Ring Spinning
Combed Supima Cotton EsTex	15	Torque free Ring Spinning
Combed Supima Cotton EsTex	12	Torque free Ring Spinning
Combed Supima Cotton EsTex	10	Torque free Ring Spinning

(Wong W.-Y. , Lam, Kan, & Postle, 2013.)

The fabrics were statistically analyzed on the basis of primary fabric parameters such as thickness, weight (GSM), and stitch density. The UPF measurements were calculated according to the AS/NZS 4399 standard. Followed by calculating the ratio of thickness to weight of the fabric as per ASTM D1777-1996, and the stitch density (through visual observation) was calculated using the formula

Stitch Density (N) = Course per inch (cpi) × Wales per inch (wpi)

Fabric Weight:

To examine the correlation between weight, thickness, and weight-to-thickness (W/T) ratio in single and double knitting constructions, respectively, is done in this work. The Correlation Analysis was employed to determine the relative impact of a factor that predicts the result. The initial study focused on examining the association between fabric weight and UPF in single-knitted textiles, revealing a favourable relationship between these two variables. This implies that an increase in the GSM of the cloth will result in a corresponding rise in the UPF. In comparison to the plain and pineapple structures, it was discovered that single-knit fabrics, such as KT11, KM11, KT22C, KM22C, KT22W, and KM22W, consistently had higher R and R2 values. Additionally, it was reported that the association between UPF and fabric weight of double-knitted structures differs significantly. The only double knitting structure that exhibits an apparent negative link between fabric weight and UPF is the half Milano, which had a negative R-value. Double-knit fabrics are two-layered fabric structure that is generally produced using two needle beds. As a result, the mean fabric weight of the double-knit fabric was often higher. Therefore, it demonstrates that one of the factors affecting the UPF between single and double-knitted constructions is fabric weight.

Table 3: Relationship of UPF and Fabric Weight

Category of Knit Structure	Structure type	Regression Correlation Result
Single Knit	Single Jersey	Positive
	Pineapple	Positive
	Lacoste	Positive
	KT11	Positive
	KM11	Positive
	KT22W	Positive
	KM22W	Positive
	KT22C	Positive
	KM22C	Positive
Double Knit	Half Milano	Negative
	Full Milano	Positive
	Half Cardigan	Positive
	Full Cardigan	Positive
	Rib 1X1	Positive
	Interlock	Positive

(Wong W.-Y. , Lam, Kan, & Postle, 2013.)

Fabric Thickness:

An assessment on UV protection in knitted fabrics using 30 Ne combed cotton yarn and a 14G computerized flat knitting machine. Various structures were created, and fabrics underwent scouring and neutralization. Testing included fabric weight, thickness, stitch density, and UPF measurements. Single-knitted fabrics with knit and miss patterns showed superior UPF due to miss-stitch float patterns. However, these fabrics were heavy, possibly unsuitable for summer. Among double-knitted structures, interlock fabric had the highest UPF but was also heavy. Researchers suggested reducing fabric GSM for summer wear. Another study analyzed fabric parameters affecting UV protection using combed cotton, Supima cotton, and Supima EsTex fibers with different yarn counts. Various weft knitting structures were created on a 14G computerized flat knitting machine. Fabrics underwent chemical pre-treatment via scouring and bleaching processes (Wong W.-Y., Lam, Kan, & Postle, 2013).

Weight-to-Thickness Ratio:

In addition to the weight and thickness, the ratio pertaining to these two criteria was also considered. The relative weight of each structure was represented by the weight-to-thickness parameter, which can be computed using

$$Weight\ to\ Thickness\ ratio\ \left(\frac{W}{T}\right) = \frac{Fabric\ Weight\ (g/m^2)}{Fabric\ Thickness\ (mm)}$$

This investigation analyzed the correlation between weight-to-thickness ratio (W/T) and UPF in knitted constructions. Single-knit structures exhibited a positive correlation between mean W/T and UPF. Only 1X1 Rib in double-knitted constructions showed a slight negative correlation. Linear regression confirmed a positive connection between mean W/T and UPF in both single and double-knitted structures.

Double-knitted constructions displayed exceptionally high correlation values (above 0.8), indicating a strong positive relationship. In contrast, single-knit structures showed lower correlation values, suggesting a minor positive link between mean W/T and UPF. Notably, mean W/T ratio was a determining factor for UPF in double-knit structures but not in single-knit ones.

Stitch Density

The number of courses and wales within a given unit area is stitch density. In this study, stitch density was determined by multiplying the wale density by the course density.

Stitch density (N) = Course per inch (cpi) × Wales per inch (wpi)

Machine gauge, yarn properties, and knitting structure affect stitch density. Higher stitch density typically results in reduced pore size, impacting UPF (UPF = 100/porosity). This study explores the correlation between stitch density changes and UV radiation transmission. Correlation analysis assesses the statistical link between stitch density and UPF.

Single Knit Structure

In single-knitted constructions, stitch densities mostly correlated positively with UPF, except KT22C. In double-knitted structures, all but 1x1 Rib had a positive relationship between stitch density and UPF. For most constructions, higher stitch density led to higher UPF. However, exceptions were observed; 1x1 Rib and KT22C showed negative correlations, suggesting factors beyond stitch density influenced UPF in these structures. Linear regression confirmed the positive link between stitch density and UPF in all knitted constructions, indicating higher stitch density generally means higher UPF.

Knitted fabric structures with knit-and-miss loops tend to achieve higher UPF values than those with knit-and-tuck loops. Miss loops draw knit loops closer, increasing stitch density. The miss-loop floats at the fabric's back, reducing UV penetration and elevating UPF. In the study, fabric factors affecting UPF were examined within and between structures, employing linear regression. Stitch density, weight-to-thickness ratio, and thickness weight emerged as UPF influencers, with weight being the primary determinant across various knitted fabric constructions (KAN, 2014; Wong W.-y., Lam, Kan, & Postle, 2016; E Louris, 2018).

Another study assessed UV protection in colored cotton knitted fabrics with different structures under stretched and wet conditions. 32s count 100% cotton yarn was used, and fabrics were constructed on a 16G gauge Albi circular knitting machine. Scouring and bleaching pre-treatment removed natural pigment and impurities. Measurements of fabric thickness, weight, stitch density, stitch length, and porosity, a crucial factor in UV resistance, were conducted (Wong W. Y., Lam, Kan, & Postle, 2014).

Double Knit Structure

This study highlights the superior UV protection of double-knit fabrics over single-knit ones, echoing previous research. Black fabrics outperformed bleached ones in UV protection. Both stretch and wetness reduced UPF in knit fabrics, affecting both types. Wet fabrics had lower UPF than dry ones due to optical scattering, particularly evident in bleached fabrics with UPF < 15. Black-dyed fabrics displayed excellent UV protection (UPF 40 to 50) in various conditions, except for half-cardigan. The presence of tuck stitches and lower stitch density in half-cardigan led to poor UV protection. Increased stitch density in double-knit fabrics improved UPF, emphasizing that UV resistance depends on structure and porosity, not just weight and thickness (E Louris, 2018; Wong W.-y., Lam, Kan, & Postle, 2016). The influence of stitch types has a greater degree of prominence on the ultraviolet protection factor (UPF) values of double jersey textiles compared to single jersey fabrics. The relative location of the needle beds, also known as gating, has a substantial role in determining the ultraviolet protection factor (UPF) attained by double jersey materials. Single jersey and double jersey textiles, which incorporate miss-stitches, as well as double jersey fabric made using an interlock gating technique, yield a dense and weighty textile that has the potential to greatly enhance UV protection. The researchers further proposed that enhancing the ability to absorb or reflect UV rays is crucial for protection. The objective of achieving maximal blocking of UV radiation in summer clothing may be accomplished by the right selection of yarn and fabric structures. The achievement of standardized methodologies for assessing the UV protection efficacy of fabrics under stretch conditions, while also considering the physiological comfort properties of garments made from densely woven fabrics with high UV performance, can be accomplished through the careful selection of fibers and yarns. (Wong W.Y.,2014), (Wong W.Y.,2016).

In-Vitro Analysis of Constructional Parameters

In Zhang et al.'s 2014 study, fabric structure's impact on 100% cotton knit fabric's Ultraviolet Protection Factor (UPF) was investigated. They used 14G CMS822 flat knitting machines and raw regular cotton yarns to create 15 knit structures, nine single-knit, and six double-knit. Double-knit construction had higher UPF than single-knit. Knit-Miss among single-knit structures showed superior UV protection due to its denser fabric. Knit-Tuck resulted in a more open fabric. Among double-knit structures, interlock had the highest UPF due to its heavy weight and reduced openness. Tuck stitches in double-knit increased UV penetration. Kan C. W.'s 2015 study explored the in vitro analysis of constructional parameters and dye class on cotton knitted fabric's UV protection property. The construction parameters and the categories of the dyes that were used in the study are discussed in the table below,

Table 4: Construction Parameters

Parameters	Category
Fibre	Cotton, Supima Cotton
Type of Cotton Fibre	Combed, Combed Supima
Spinning Technique	Conventional Ring Spinning, EsTex
Yarn Count	30s Ne, 40s Ne
Dye Class	Reactive dyes, Direct dyes, Sulphur dyes
Colour used	Red, Yellow, Blue
Dye concentration	0.1%, 1%, 5%
Pre-treatment	Scouring, Bleaching, Neutralizing

The present scholarly investigation found that the UPF value of dyed coloured fabric produced from combed Supima cotton was lower compared to combed cotton due to the long staple length. Shorter combed cotton blocks/absorbs UV rays effectively. It had been noticed that the ring spun yarn exhibited a greater Ultraviolet Protection Factor (UPF) value compared to the EsTex yarn. This was in accordance with the compactness of the knitted fabric structure, resulting from the use of standard ring spun yarn, which enhances its resistance to the penetration of UV rays. Considering the yarn parameter, fabrics composed of 30s yarn count had a higher Ultraviolet Protection Factor (UPF) value compared to those comprised of 40s yarn count. This observation suggests that coarser yarns give better protection. However, there is a lack of statistically significant variation in the Ultraviolet Protection Factor (UPF) values across textiles of different colors, specifically red, yellow, and blue. Additionally, it was observed that the cloth coloured with sulphur dyes exhibited a reduced Ultraviolet Protection Factor (UPF) in comparison to fabrics dyed with reactive or direct dyes. Furthermore, this study proved that there exists a negative correlation between the fabric's lightness and its UPF characteristics. Overall, it was concluded through this investigation that varied parameters that were considered in fabric construction played a significant role in the UV protection property of knitted cotton fabric.

Optimization of Knit Structures

The quest for optimal comfort and UV protection in knitted fabrics has led researchers to explore the use of desirability functions. These functions provide a way to simultaneously consider multiple factors and optimize the fabric's properties. Previous studies have highlighted the importance of several factors in achieving optimal comfort and UV protection in knitted fabrics.

Researchers analyze fabric properties like wetness, thermal traits, moisture absorption, and air permeability for comfort and UV protection optimization. Numerical techniques, desirability functions, and weighted scores tailor fabrics to meet specific needs. Extensive research enhances properties such as crease recovery, antibacterial features, UV protection, flame resistance, and water/oil repellency, ensuring top-tier comfort, protection, safety, and aesthetics. (Stankovic, Popovic, Poparic, & Bizjak, 2009; Ana Kocić, 2019; Abhijit Majumdar, 2017).

(Ghosh, 2016) investigated on the optimization of knitted fabric comfort and uv protection using desirability function. 100% cotton fabric was constructed using Spaniards for the purpose of this study single jersey and 1X1 rib knitted fabrics were constructed keeping in mind 4 important fabric parameters,

1) One loop length
2) Carriage speed
3) Yarn input tension
4) Yarn count

For the production of single jersey and 1X1 rib knit fabric, a yarn count of 6.5 Ne and 8.5Ne were used respectively. The samples underwent a thorough relaxation process involving washing and conditioning which was subsequently tested for air permeability, thermal conductivity, and the UPF. Increased air permeability of the fabric led to reduced thermal conductivity as well as lower Ultraviolet Protection Factor (UPF). It is important for the fabric's UPF to meet a particular level in order to protect against dangerous UV rays. Therefore, in order to attain a knitted fabric that offers both optimal comfort and effective UV protection, it is imperative to concurrently optimize various parameters. The desirability index was optimized by maximizing several attributes, including air permeability, thermal conductivity, and UV resistance, towards predetermined target values. The experimental findings demonstrate a substantial level of concurrence between the observed and computed values pertaining to the fundamental characteristics of the fabric. This study resulted in the creation of a uni-dimensional grading system ranging from zero to 1, specifically designed for the purpose of evaluating knitted fabric in terms of its Target Comfort and UV resistance capabilities. A similar research was also conducted by (Mal, 2016) where the yarn count used were 5Ne, 7.5Ne, and 10Ne to manufacture a single jersey and 1X1 rib knit fabric on a 12G computerized flat knit machine.

Fabric engineering improved comfort and UV protection for single jersey and 1X1 rib fabrics. These fabrics typically provide comfort but also transmit UV rays. Finding the right balance was a challenge. Loop length and linear density were analyzed to create fabrics with optimal comfort and UV protection. The inherent porous and open structure commonly seen in single jersey and 1X1 rib knit fabric is known to offer enhanced comfort but with increased transmission of UV rays. The study identified the fabric with the desired properties.

1) The single jersey fabric exhibited a thermal conductivity exceeding 40 and an air permeability exceeding 80, while also providing “good protection” against ultraviolet radiation.
2) On the other hand, the 1X1 rib knit fabric offered comparable comfort levels along with excellent protection against UV radiation. The 1X1 rib fabric exhibited superior UV protection and comfort compared to the single jersey fabric manufactured using the same machine gauge.

Fibre Blends ANF Knit Structure

A comparative analysis was undertaken to examine the characteristics of single jersey knitted fabric and single jersey knitted fabric with Lycra. A circular knitting machine, featuring a gauge of 24G and a diameter of 18 inches, was employed to produce a fabric. This machine was equipped with 54 feeders and a total of 1356 needles. The resulting fabric exhibited a consistent loop length of 2.8mm. The tension applied to the yarn input was 5CN. A range of blended fabrics were produced for the purpose of constructing single jerseys, as well as single jerseys with lycra knit fabric. Different fibers and blends that were used in this scholarly investigation are mentioned below,

1) 50% Tensile LF/ 50% Cotton (30s/1)
2) 67% Tensile LF / 33% Cotton
3) 67% Tensile STD / 33% Quarter
4) 70% Bamboo / 30% Cotton
5) 100% Bamboo
6) 100% Modal
7) 100% Micro Modal

8) 100% Egyptian cotton yarns were used.

The relevance of fibre composition and fabric structure on the mechanical properties, UV protection, and moisture transport properties was statistically assessed using Analysis of Variance. Fabrics composed of a cotton/tencel blend, specifically single jersey textiles, exhibited high levels of bursting strength. Hence providing a protective barrier against the occurrence of bursting stress. The bursting strength ratings of single jersey with Lycra samples are lower compared to those of single jersey. The textiles composed of 67% Tencel LF and 33% cotton, as well as 50% Tencel LF and 50% cotton, exhibit superior abrasion resistance compared to fabrics made only of 100% cotton in single jersey construction. It is noteworthy to acknowledge that the micro-modal and Tencel fabrics exhibit a high level of drapability and possess a low initial shear modulus, resulting in a reduced handle withdrawal force when compared to the 100% cotton single jersey sample. Including Tencel and Bamboo fibres into Egyptian cotton as blended yarn enhances the ultraviolet protection factor (UPF) properties of the resulting textile. (Alaa Arafa Badr, 2016)

Bi-layer weft knitted sportswear fabrics gained interest. They featured inner layers with polyester and Lycra for high wicking and outer layers with cotton, bamboo, Modal, or polyester/viscose. Bamboo fabric offered superior UV protection over cotton and Modal. Knit fabric structure significantly impacted UPF (Ultraviolet Protection Factor). Tuck stitches, usually associated with low UPF, had varied effects based on combination and repetition within the structure. Bilayer fabrics showed high UPF and found application in sportswear. Notably, post-knitting treatments and coloration could further enhance UPF (Ultraviolet Protection Factor) in these fabrics. (Kamal, 2020)

2. Conclusion

Numerous academic studies delve into factors enhancing Ultraviolet Protection Factor (UPF) in cotton textiles, including stretch, knit structure, and fiber composition. Linear regression models have been used to analyze relationships between variables like fabric weight, thickness, weight-to-thickness ratio, stitch density, and UPF. UV absorbers and air permeability affect UPF. Much research primarily focuses on basic weft knit structures, leaving gaps in understanding advanced knitting techniques, higher machine gauge effects, etc. for improved UV protection in summer wear.

Disclosure Statement

No potential conflict of interest was reported by the author(s)

References

[1] Abhijit Majumdar, P. M. (2017). Multi-objective optimization of air permeability and thermal conductivity of knitted fabrics with desired ultraviolet protection. *The Journal of The Textile Institute, 108*(1), 110-116. doi: DOI: 10.1080/00405000.2016.1159270

[2] Adam, J. (1998). Sun-Protective Clothing. *Journal of Cutaneous Medicine and Surgery, 3*(1), 50 – 53.

[3] Akaydin, M. (2010). Research of UV permeability properties of basic weft knitted structures. *Scientific Research and Essays, 6*(16), pp. 2169-2178.

[4] Alaa Arafa Badr, A. H. (2016). Influence of Tencel/cotton blends on knitted fabric performance . *Alexandria Engineering Journal*, 2439–2447. doi:ttp://dx.doi.org/10.1016/j.aej.2016.02.031 1110-0

[5] Ana Kocić a, M. B. (2019). UV protection afforded by textile fabrics made of natural and regenerated cellulose fibres. *Journal of Cleaner Production, 228*, 1229-1237.

[6] Das, B. R. (2010). UV radiation protective clothing. *The Open Tex.Journal, no.3,pp.14-21, 2010.*(no.3), pp.14-21.

[7] David J Spencer. (2001). *Knitting Technology: A Comprehensive Handbook and Practical Guide* (3rd edition, ed.). Woodhead Publishing limited.

[8] E Louris, E. S. (2018). Evaluating the ultraviolet protection factor (UPF) of various knit fabric structures,. *Aegean International Textile and Advanced Engineering Conference*, (pp. p.p. 1-14). doi:doi:10.1088/1757-899X/459/1/012051

[9] Eby Chacko, S. G. (n.d.). A clinico-epidemiological study of polymorphic light eruption in a tertiary care centre in Salem: a region of South India. *International Journal of Research in Dermatology*. doi:http://dx.doi.org/10.18203/issn.2455-4529.IntJResDermatol20170798

[10] Ghosh, A. M. (2016). Optimization of Knitted Fabric Comfort and UV Protection using Desirability Function. *Journal of Engineered Fibers and Fabrics, 11*(4). doi:https://doi.org/10.1177/155892501601100404

[11] Grancarić, A. M., Penava, Ž., & Tarbuk, A. (2005). UV Protection of Cotton: The Influence of Weaving Structure. *HEMIJSKA INDUSTRIJA*.

[12] Kamal, M. S. (2020). Effect of Some Construction Factors of Bi-layer Knitted Fabrics Produced for Sports Wear on Resisting Ultraviolet Radiation. *Egyptian Journal of chemistry, 63*(11), pp. 4369 - 4378.

[13] KAN, C. W. (2014). A Study on Ultraviolet Protection of 100% Cotton Knitted Fabric: Effect of Fabric Parameters. *THE SCIENTIFIC WORLD JOURNAL*.

[14] Kan, C. W. (2015). In-vitro analysis of the effect of constructional parameters and dye class on the UV protection property of cotton knitted fabrics. *Plos one, 10*(7).

[15] Kan, C.-W., Yam, L.-Y., & Ng, S.-P. (2013). The Effect Of Stretching On Ultraviolet Protection Of Cotton And Cotton/Coolmax-Blended Weft Knitted Fabric In A Dry State. *MATERIALS (BASEL, SWITZERLAND).*

[16] Khan, J. A. (2016). Eco Friendly Textile Dyeing and Finishing. *Scitus Academics, LLC*, p.6.

[17] Kyosev, Y. (2022). *Warp Knitted fabric construction.* Germany: CRC Press, Taylor & Francis Groups,.

[18] Lam, C.-W. K.-L. (2013). Low Stress Mechanical Properties of Plasma-Treated Cotton Fabric Subjected to Zinc Oxide-Anti-Microbial Treatment. *Materials, 6*, 314-333. doi:https://doi.org/10.3390/ma6010314

[19] Mal, P. G. (2016). Mal, P., Ghosh, A., Majumdar, A.,Engineering of knitted cotton fabrics for optimum

comfort in a hot climate. Fibres & Textiles in Eastern Europe, (2 (116), 102-106. *Fibres & Textiles in Eastern Europe*, *2*(116), 102-106.

[20] N. A. Ibrahim, M. G.-G. (2009). UV-protecting and antibacterial finishing of cotton knits. *Journal of Applied Polymer Science*. doi: https://doi.org/10.1002/app.29669

[21] Nazaré, S., Flynn, S., Davis, R., & Chin, J. (2014). Protective Performance of Environmentally Stressed Fabrics Containing Melamine Fiber Blends. *FIBRE TECHNOLOGY*.

[22] Saptarshi Maiti, S. M. (2022). Sustainability analysis for knitting process and products. In *Advanced Knitting Technology The Textile Institute Book Series* (pp. Pages 657-671).

[23] Saravanan, D. D. (2007). UV PROTECTION TEXTILE MATERIALS. *AUTEX Research Journal, Vol. 7*(No 1).

[24] Stankovic, S. B., Popovic, D., Poparic, G. B., & Bizjak, M. (2009). Ultraviolet Protection Factor of Gray-state Plain Cotton Knitted Fabrics. *TEXTILE RESEARCH JOURNAL*.

[25] Subhankar Maity, S. R. (2022). *Advanced Knitting Technology*. Woodhead Publishing. doi:DOI https://doi.org/10.1016/C2020-0-02301-7

[26] Vidhya, M. S., & Rekha, V. B. (2012). Effect of Knitted Bamboo Structures Dyed With Natural Colorants on Ultraviolet Radiation Protection. *JOURNAL OF TEXTILE SCIENCE & ENGINEERING*, .

[27] Wong, W. Y., Lam, J. K., Kan, C. W., & Postle, R. (2014). In Vitro Assessment Of Ultraviolet Protection Of Coloured Cotton Knitted Fabrics With Different Structures Under Stretched And Wet Condition. *RADIATION PROTECTION DOSIMETRY*.

[28] Wong, W. Y., Lam, J. K., Kan, C. W., & Postle, R. (2014). In Vitro Assessment Of Ultraviolet Protection Of Coloured Cotton Knitted Fabrics With Different Structures Under Stretched And Wet Conditions. *RADIATION PROTECTION DOSIMETRY*.

[29] Wong, W.-y., Lam, J. K.-c., Kan, C.-w., & Postle, R. (2016). Ultraviolet Protection of Weft-knitted Fabrics. *TEXTILE PROGRESS*.

[30] Wong, W.-Y., Lam, J. K.-c., Kan, C.-w., & Postle, R. (2013.). Influence of Knitted Fabric Construction on The Ultraviolet Protection Factor of Greige and Bleached Cotton Fabric. *TEXTILE RESEARCH JOURNAL*.

[31] Wong, W.-y., Lam, J. K.-c., Kan, C.-w., & Postle, R. (2016.). Influence of Reactive Dyes on Ultraviolet Protection of Cotton Knitted Fabrics with Different Fabric Constructions", . *TEXTILE RESEARCH JOURNAL*.

[32] Yi-hong Zhang, C.-w. K.-c. (2015). A study on ultraviolet protection properties of 100% cotton knit fabric: effect of fabric structure. *The Journal of The Textile Institute, 106*(6), 648-654. doi: http://dx.doi.org/10.1080/00405000.2014.933514

Author Profile

Habeebunissa is currently working as Assistant Professor at NIFT-Chennai campus and keenly working on UPF Clothing, Computerised flat Knitting structures and Natural Dyeing. She has presented research papers at various National & International conferences.

Dr. Anish Sharmila is currently working as Assistant Professor at Hindustan Institute of Technology & Science and her research interests are Green Synthesis, Nanotechnology, UPF Clothing. She has published research paper in multiple journals of high repute.