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Research Paper

UV protection properties of cotton *Khadi* fabric using *Eucalyptus globulus* dye extract

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■ **ABSTRACT :** This research has been taken upto develop eco-friendly *Khadi* fabric having UV protective action meanwhile concerned with the extraction of dye using *Eucalyptus globulus* dyeat various dyeing concentrations. Optimal results were achieved by dyeing at 90°C-100°C for 90 minutes using the pre-mordanting method with different mordants *i.e. Punica granatum*, *Phyllanthus emblica, Terminalia bellirica* and *Acacia catechu*.The evaluation of dyed samples in terms of ultraviolet radiation (UPF) and colour fastness to washing, rubbing and sunlight was done. The results of colour fastness to washing and rubbing showed good to very good and colour fastness to light showed good to moderate results. The data, which is obtained, showed that the mordanted samples have high dye uptake with excellent UPF values.

■ **KEY WORDS:** Natural mordants, Dye, Ultraviolet protection factor, *Khadi* fabric, Colour fastness

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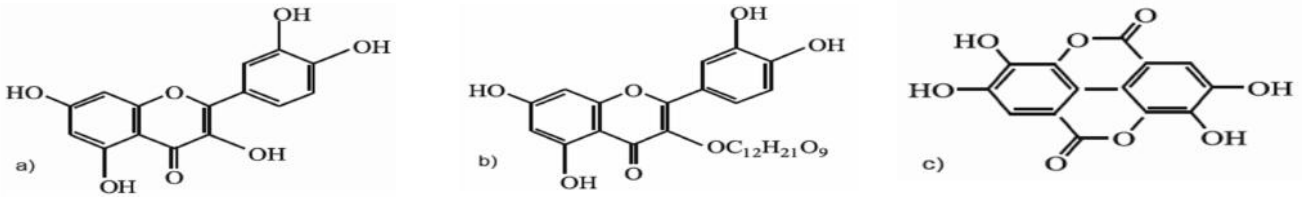
Sunlight is a form of electromagnetic radiation in the form of ultraviolet (UV), visible and infrared radiation (Sarkar, 2007). Ultraviolet radiations are just about 7 per cent of total solar emission with spectrum extends from 290 nm to 400 nm but it has a huge dangerous effect on human skin. Chronic overexposure can lead to connective-tissue damage, premalignant lesions and malignancies (basal or squamous cell cancer, and perhaps melanoma skin cancer) (Czajkowski *et al*., 2006). Textiles offer the safest protection from harmful UV radiations using umbrellas and various accessories such as hats, sunglasses, hand gloves and summer coats etc (Kimlin *et al*., 2010 and Utrillas *et al.,* 2010). The protectiveness of these materials depends on fabric construction (porosity, weight and thickness) fabric composition, (natural, artificial or synthetic fibres) and the nature of the treatment to the fabric like dyeing and finishing that may be natural or synthetic (Hoffmann *et al.,* 2001 and Gies *et al.,* 2006). Most of the researches have been focused on the UV-protection properties of natural fibres (Hustvedt and Crews, 2005 and Feng *et al.,* 2007). Ultraviolet (UV) radiations are carcinogenic, damage to skin cells in repeated UV exposure which leads to the develop skin cancer. It has been found that some commercial clothing items provided a limited UPF (less than 15). Khadi is an Indian handspun and hand-woven cloth, was proposed in 1920 by "Mahatma Gandhi" during the freedom struggle (Tiwari *et al.,* 2017). It prevents skin rashes and imparts a very elegant and sober look. *Khadi,* has specific physical and chemical



Quercetin (C.I. 75670) *Rutin*(C.I. 75730) *Ellagic acid* (C.I.75270)

Fig. A : Colour compositions of the eucalyptus leaf extractdye

properties such as high-water absorption, high comfort and good dyeability and is the symbol of Indian's identity (Pant and Sharma, 2009).

The use of natural dyes rapidly declined after the discovery of synthetic dyes in 1856. Widely and commercially used synthetic dyes provide stable colours still cause carcinogenicity (Husain, 2006; Bhatti *et al*., 2012 and Farid, 2015). Natural colourants and dyes are believed to be safe, non-toxic, non-carcinogenic and biodegradable nature because it derived from flora and fauna (Ibrahim *et al.,* 2010; Yusuf *et al*., 2016 and Tiwari and Jain, 2017).

*Eucalyptus globulus*is one of the most important sources of natural dye that belongs to the family *Myrtaceae* and known as Eucalyptus. Mongkholrattanasit *et al.* (2011) studied that the colouring substance of eucalyptus has ample natural tannins and polyphenols. Eucalyptus leaves contain upto 11 per cent of the major component, as well as tannin (gallic acid and ellagic acid) and flavonoids (*quercetin, rutin* etc.) as minor substances. The structures of the colouring components found in eucalyptus leaves are shown in Fig. A. The silk and wool fabrics dyed with eucalyptus leaf extract with or without metal mordants have good to excellent UV protection properties (Bhatti *et al*., 2012). Mongkholrattanasit (2014) experimented on eucalyptus as a dye and found that it is very useful for developing antimicrobial textile.

The study was conducted to test the colour fastness and UV protection properties of cotton *Khadi* fabric dyed with *Eucalyptus globulus* leaves extract.

■ RESEARCH METHODS

Pretreatment of fabric:

Pure cotton *Khadi* fabric (with 0.47mm thickness, 1.55g/m^2 weight and 54×38 fabric count per inch with plain weave) was procured from *Khadi* Gramodhyog. Scouring and pre-treatment with myrobalan extract was done with 2 per cent concentration at room temperature.

Dyes and mordants:

Mordants were purchased from the local market of Udaipur (Rajasthan), India. *Punica granatum*, *Phyllanthus emblica, Acacia Catechu* and *Terminalia bellirica* were used as mordants. The leaves of *Eucalyptus globulus* were collected from university campus, cleaned and dried at room temperature; the dried leaves were grounded in uniform particles. 100g of powdered raw material was taken into 1000 ml distilled water and soaked for overnight. The obtained coloured solution was subjected to heating at 90°C-94°C with continuous stirring for 5 hours. To remove suspended

Fresh leaves Dry leaves Powder of eucalyptus leaves

Fig. B : *Eucalyptus globulus*

impurities, the extracted solution was filtered. The resulting solution was concentrated by keeping in the oven at 45°C for 12hrs. This solution was obtained through aqueous extraction and gave very good light greenish yellow colour.

Mordanting and dyeing

Pre-treated cotton *Khadi* fabric samples with myrobalan were mordanted with selected mordants at three concentrations *i.e.* 5 per cent, 10 per cent and 15 per cent, keeping 1:40 MLR at 90°C for 45 minutes using pre-mordanting method. After mordanting the dye baths were prepared using three optimized dyeing concentrations *i.e.* 10 per cent, 20 per cent and 30 per cent with 1:50 M:L ratio at 90°C-100°C for 90 minutes at pH 8. Both processes, dyeing and mordanting were carried out using the YORCO water bath shaker (YSI-412).

Evaluation of colour fastness properties:

The dyed samples were assessed for colour fastness in respect to washing, rubbing and light. The wash fastness of the dyed samples was evaluated as per the ISO 105-C06:1994 (2010) using Launder-o-meter. The rubbing fastness properties were tested with Crock-o-meter as per Indian standard IS 766:1988 (Reaffirmed 2004) which is based on ISO 105-X12:2001 test method. Light fastness was conducted on digital light having water-cooled mercury blended tungsten lamp, according to ISO 105-B02:1994 (Amd.2:2000) and samples were exposed to xenon lamp for 24 hours at standard testing conditions.

Evaluation of ultraviolet protection factor (UPF):

The transmittance of the fabric was measured according to UVA and UVB transmission while the UPF value was calculated using AATCC 183:2004 test method. Transmission or blocking of erythermally weighted UV radiation through fabrics (Gies *et al.*, 2000 and Mongkholrattanasit *et al.*, 2011). The resulting degree of sunburn determined the fabric's protection factor by the exposed skin reported by Gupta *et al.*, 2004; Sarkar, 2004). The UPF for the test fabric can be calculated according to the following eq.:

$$UPF = \frac{\sum_{\lambda=290}^{\lambda=400} E_\lambda S_\lambda \Delta_\lambda}{\sum_{\lambda=290}^{\lambda=400} E_\lambda S_\lambda T_\lambda \Delta_\lambda}$$

where,

E =Erythemal spectral effectiveness

S =Solar spectral irradiance in $Wm^{-2}nm^{-1}$

T= Spectral transmittance of fabric

Δ_λ = The bandwidth in nm

λ = The wavelength in nm.

In Table A, fabrics with a UV protection category in the range of 14 to 24, 25 to 39 and 40 or over are defined as providing "good, very good and excellent Ultraviolet protection, respectively (Ahmed *et al.*, 2015 and Salman *et al.*, 2015).

Table A: UPF rating and prodection categories*

UPF rating	Protection category	%UV radiation blocked
14-24	Good	93.3-95.9
25-39	Very good	96.0-97.4
40 and over	Excellent	97.5 or more

*American association of textile chemists and colourists (AATCC) Test method 183 specifies the protocol for conducting a UV Transmittance test

■ RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Colourfastness properties of dyed samples:

Data regarding colour fastness properties of *Eucalyptus globulus* dyed samples towards rubbing, washing and light has been presented in following tables.

Table 1 depicts, colourfastness ratings of control and mordanted cotton *Khadi* fabric samples dyed with *Eucalyptus globulus* dye. Control samples of *Khadi* fabric obtained 2-3 wash and rubbing fastness ratings.

In case of rub fastness, the highest dry rub fastness ratings were explicated at 15 per cent mordant and 30 per cent dye concentration with all dyed and mordanted samples. Mordanted samples with *Terminalia bellerica* obtained 5 dry-rub fastness rating at 20 per cent dye and 15 per cent mordant concentrations and 30 per cent dye and 10 per cent mordant concentrations whereas it showed excellent rub fastness rating with low concentration of dye and mordants at five-point rating scale followed by other mordanted samples. Samples mordanted with *Punica granatum* obtained excellent wet-rub fastness rating at 10 per cent mordant and 30 per cent dye concentration.

The wash fastness properties of dyed cotton *Khadi* samples, mordanted with *T. bellirica* and *P. granatum* mordants showed very good (4) to excellent (5) colour change (cc) grade and good to very good wash staining ratings ranging from 4-4/5 on grey scale and no staining on adjacent fabric were observed at 10 per cent and 15 per cent mordant and 20 per cent and 30 per cent dyeing concentrations. All other mordanted samples were found to be in the range of good to excellent wash fastness ratings of 3-5 on colour change and colour staining grey scale. Results are supported by the findings of Prabhu and Teli (2014) that the metal tannates present on the material forms insoluble lakes with the natural dyes and responsible for improved fastness properties.

As it can be noticed in Table 2 that the light fastness of control samples with 10 per cent, 20 per cent and 30 per cent concentrations of *Eucalyptus globulus* dye showed fair to moderate fading *i.e.* 3-5 values against blue dye standards of 1-8 rating scale. In comparison with un-mordanted dyed samples, mordanted dyed samples obtained best results of colour fastness properties on cotton *Khadi* fabric. Based on the above results, *P. granatum* and *T. bellirica* gave excellent results of colour fastness tests on cotton *Khadi* fabric. Findings are in confirmation with Arora *et al.* (2012) who opined that the light fastness properties were increased by using different mordants on the cotton fabric. Ali *et al*. (2007) also dyed cotton fabric with eucalyptus *Globulus* and compared the fastness properties of mordanted samples using different conditions of dyeing.

UV protection properties of dyed samples:

UPF strongly depends on the chemical structure of the fibre. A high correlation exists between the fabric porosity and the UPF but it is also influenced by the type of the fibres. Based on the above results, the researcher has selected five best samples for further UPF testing

Table 1 : Colour fastness properties of *Eucalyptus globules* dyed samples

Mordants and its conc.	Dye %	Rubbing fastness								Wash fastness							
		Dry				Wet				CC				CS			
		Control	5 %	10 %	15 %	Control	5 %	10 %	15 %	Control	5 %	10 %	15 %	Control	5 %	10 %	15 %
PE	10	2	2	3	4	2	3	3	4/5	2	3	4	4	2	2/3	2/3	3
	20	2/3	2/3	4	4	2/3	3	4	4/5	2/3	3	4	4	3	3	3	4
	30	3	4	4	5	2/3	4	4	5	2/3	5	4/5	5	3	4	4	4/5
AC	10	2	3	3	4	2	3	2/3	4	2	2	3	4	2	2	3	4
	20	2/3	3	4	4/5	2/3	3	3/4	4/5	2/3	3	4	4/5	2/3	3	3	3/4
	30	3	4	4	5	2/3	3/4	4/5	4/5	2/3	4	4/5	5	3	3/4	4	4
PG	10	2	2	3	4	2	3	3	3/4	2	3	4	4	2/3	3	3	3/4
	20	2	3	4	5/5	2	3/4	3/4	4/5	2	4	4	5	3	3	4	4/5
	30	3	4	5	5	3	3/4	5	5	3	5	5	5	3	4	5	5
TB	10	2	2	3	4	2	3	3	4	2	3	3/4	4	2/3	3	3	4
	20	2/3	3/4	4	5	2/3	2/3	3/4	4/5	2/3	4	4	4/5	3	3	3/4	4
	30	3	4	5	5	3	3/4	4/5	5	3	4	5	5	3	3/4	4	4/5

PE= *Phyllanthus emblica,* AC= *Acacia catechu,* TB= *Terminalia bellerica,* PG= *Punica granatum,* FS= Ferrous sulfate, CC=Colour change, CS=Colour staining Rating* 1-5 where 1-Poor, 2- Fair, 3- Good, 4- Very good and 5- Excellent

Table 2 : Light fastness properties of dyed and mordanted cotton *Khadi* fabric samples

Mordants	D 10%				D 20%				D 30%			
	Control	Mordants			Control	Mordants			Control	Mordants		
		5%	10%	15%		5%	10%	15%		5%	10%	15%
PE	3	4	4	6	4	4	5	6	5	5	6	7
AC	3	3	5	5	4	4	6	5	5	5	6	7
PG	3	4	4	5	4	3	5	6	5	6	7	8
TB	3	4	4	5	4	4	5	6	5	6	7	8

PE= *Phyllanthus emblica,* AC= *Acacia catechu,* PG= *Punica granatum,* TB= *Terminalia bellirica*
Raring 1-8 where 1-poor, 2-fair, 3-moderate, 4-good, 5-better, 6-very good, 7- very slight and 8- excellent

in which, one was control sample and another four were mordanted with different mordants at 30 per cent dye and 15 per cent mordant concentrations. The percentage of UV transmission of control and mordanted cotton *Khadi* fabric samples has been presented in Fig. 1. Table 3 depicts UPF parameters of selected dyed and mordanted cotton *Khadi* fabric samples.

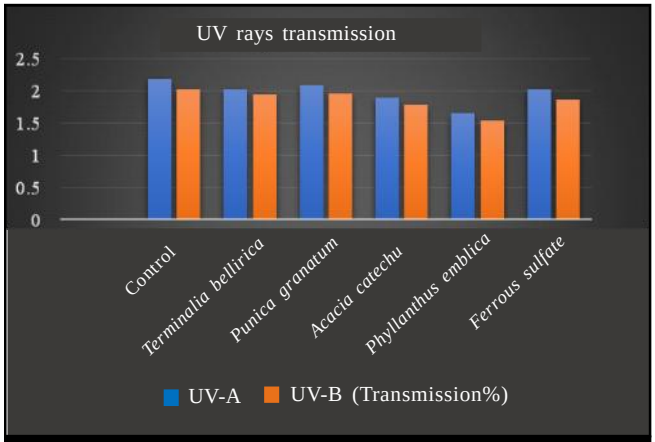


Fig. 1 : Ultraviolet rays (UV-A and UV-B) transmission

For a fabric to be labeled as sun safe, it should have a minimum UPF of 15 and maximum UPF > 50. It was interesting to note that even control sample of *Khadi* cotton (undyed)obtainedmean UPF of 50.5, which comes under excellent category of protection. Further, the mordanted samples also have a UPF value more than 50 and provide an excellent protection against harmful UV rays. *Phyllanthus emblica* mordanted samples obtained higher UPF valuesfollowed by other mordanted samples.

UPF of *Terminalia bellirica* mordanted samples dyed with *Eucalyptus globulus* dye came out to be 56.7 and able to block 97.97 per cent and transmit 2.03 per cent of UV-A radiations at the same time able to block 98.06 per cent and transmitting 1.94 per cent of UV-B radiations whereas *Phyllanthus emblica* and *Punica granatum* mordants obtained 67.0 and 51.6 UPF rating by blocking 98.35 and 97.91 UV-A radiations and 98.46 and 98.04 UV-B radiations, respectively. UPF of *Acacia catechu* mordanted samples found 58.0, thus, all mordanted and unmordanted samples came under excellent UV protection category.

The UV transmission at 30 per cent concentration of aqueous extract of *Eucalyptus globulus* dye clearly revealslowest transmission value of *Phyllanthus emblica*. It can be seen that as the UV transmission becomes less, the fabric became a very good UV rays' blocker and able to provide more protection from sun rays.

Therefore, it is clearly perceived with the findings of Feng *et al*. (2007) that the values of spectral transmittance decreased with different mordants such as AlK $FeSO_4$, $SnCl_2$, $(SO_4)_2$ and $CuSO_4$, having different effects on the dyed fabric's spectral transmittance, besides it, the colour shades and colour depth of the fabric can be related to ultraviolet transmittance (Saleh, 2013), whereas the light colours transmit more ultraviolet radiation than dark ones (Wilson *et al*., 2008). The results confirmed that *Eucalyptus globulus* dye extract had potential applications for fabric dyeing and produced environment friendly cotton *Khadi* fabric having excellent UV protection properties. As the percentage of UVA and UVB transmission value is decreased, the UPF is increased and it can be attributed to shrinkage, which reduces fabric porosity (Iqbal *et al.*, 2008). In the findings of Driscoll (2000), the dyed fabric protects more than un-dyed ones.

Conclusion:

It can be concluded that cotton *Khadi* fabric can be effectively used as eco-friendly textile material by using *Eucalyptus globulus* dye which provided beautiful shades with good colorfastness properties with the use of mordants. Dyed *Khadi* fabric samples also exhibited

Table 3 : UPF parameters of selected dyed and mordanted cotton *Khadi* fabric samples

Test parameters	Test method	UPF	Blocking (UV-A)%	Blocking (UV-B)%	P.C.*
Control	As per AATCC 183	50.5	97.81	97.98	Excellent
T. bellirica		56.7	97.97	98.06	Excellent
P. granatum		51.6	97.91	98.04	Excellent
A. catachu		58.0	98.11	98.21	Excellent
Ph. emblica		67.0	98.35	98.46	Excellent

The term PC* represents protection category according to the Australian capital territory (ACT) cancer council recommended *http://www.actcancer.org/*

excellent UV protection and blocking to UVA and UVB rays from reaching to the skin and obtained very less transmission of UVA and UVB rays. Even light to medium shades of dyed samples also evinced excellent UV protection. All the dyed and mordanted samples provided excellent protection to the human skin from sun rays and manifested high protection against UV light with cotton *Khadi* fabric.

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