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Antioxidant and Antibacterial Bio-functionalization Properties of Cotton Fabric Dyed with Acetonic Extracts of Prosopis Juliflora using BioMordants

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Abstract

Natural dyes have been taunted as a potential alternative to their often-hazardous synthetic counterparts due to their degradability, non-toxicity and eco-friendliness. In addition to their dyeing properties, natural dyes are equally known to have medicinal properties such as antimicrobial and antifungal activities. Prosopis juliflora, commonly referred to as Mathenge, is a noxious weed listed by International Union for Conservation of Nature (IUCN) among the most unwanted plants. In Kenya, the plant has adverse effects on livestock and the environment. The aim of the study, was to develop biofunctionalized fabric with antioxidant and antibacterial properties that can be used for their medicinal properties using natural dyes extracted from P. juliflora. The objectives of this study, were to evaluate the effects of biomordants on the dyeing properties of the extracts of P. juliflora and to evaluate the antioxidant and antimicrobial textile finishing properties of the natural dye on cotton fabric. The bio-mordants used were tannic acid and mango bark. The antioxidant activity of the dyed cotton fabric was determined by use of 2,2 -diphenyl-1-picrylhydrazyl radical (DPPH) method whereas the antimicrobial properties of the dyed fabric, were done against Escherichia coli and Staphylococcus aureus strains of bacteria using the absorbance method. The use of bio-mordants increased the color strength from 0.63 to 0.76 and 0.79 for mango bark and tannic acid respectively. On the other hand, P. juliflora dyed fabric, equally showed antioxidant properties of 69.4 %, with the dye imparted on the fabric, showing potent antimicrobial reduction abilities of 64.34 % and 66.72 % against E. coli and S. aureus, respectively, to the fabric. Therefore, from the results, it can be concluded that P.juliflora dye, is suitable for use as a natural dye with potent antimicrobial properties hence it can be used for the development of medicinal fabric.

Key Words: Natural dye, bio-mordants, antioxidant, antimicrobial

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Introduction

As the name suggests, natural dyes are dyes that are derived from different forms of nature such as plants, insects and minerals and includes common dyes such as red ochre and heena derived from Lawsonia inermis (Deveoglu, Karadag, Torgan & Yildiz, 2018; Yilmaz, Calkir & Aciklyildiz 2018) . On the other hand, synthetic dyes are industrially processed dyes and account for more than 98 % of the present coloration market with their advantage being that they are cheap to manufacture, they are reproducible and are of reliable fastness (Manyim,Kiprop, Mwasiagi, Achisa & Odero, 2021; Odero, Kiprop, K'Owino, Arimi & Manyim,2020).

In order to compete favorably with synthetic dyes, the natural dyes industries have refocused their research and innovations on the development of new multifunctional and multipurpose material that not only have value addition, but also have extra functionalities and applications (Pinho, Henriques, Oliveira, Dias & Soares, 2010). This, has led to the rise of biofunctionalized fabric which includes the modification of the surface of fabric to be fire repellant, water repellant, insect repellant, UV-protective, antimicrobial, antifungal et cetera (Xu et al., 2017). Presently, several compounds have been used for the biofunctionalization of fabric such as phenols, organometallic compounds, chitosans, nanoparticles, phytochemicals, triclosan (Kamboj, Jose & Singh, 2021).

Aim of the Study

The aim of the study, was to develop biofunctionalized fabric with antioxidant and antibacterial properties that can be used for their medicinal properties using natural dyes extracted from P. juliflora.

Objectives of the Study

The objectives of this study, were to evaluate the effects of biomordants on the dyeing properties of the extracts of P. juliflora and to evaluate the antioxidant and antimicrobial textile finishing properties of the natural dye on cotton fabric.

Literature Review

The dyeing industry as a whole, dates back to approximately 4000 BC, where it is suggested that primitive forms of dyeing existed. Archaic forms such as the leaves of plants, specific fish, minerals and stem barks were used as natural sources of dyes. This was so until 1856, when the first synthetic dye named mauveine was discovered by William Henry Perkins who accidentally synthesized a brilliant purple dye as he was trying to make quinine to be used for the treatment of malaria (Benkhaya, Mrabet & Harfi, 2020). The advantage of the dye was that it was cheap, easy to reproduce and of reliable shade. This, opened doors to the discovery of more synthetic dyes with the current variants of dyes exceeding 100,000 variants with the disadvantage of most synthetic dyes being that they have been linked to allergies, cancers and environmental pollution.

Presently, research has shifted to more eco-friendly natural dyes that are not only dyes but also have unique properties such as UV protection, fire and mosquito

repellant antimicrobial and antifungal properties (Sarwar, Ali, Hussain, Atif, & Majeed, 2018; Xu et al., 2017).

Several compounds have been used in the biofunctionalization of different fabrics which include nanoparticles, where their nanoscale surface modifications of fabric, the use of phytochemicals where specific bioactive compounds are used to impart properties and organometallic compounds with specific properties (Kamboj, Jose & Singh, 2021).

The P. juliflora plant, known in Kenya as the Mathenge plant, is an invasive, ever green noxious weed listed by the international union for conservation of nature (IUCN), as one of the most undesirable plant species in the world. It majorly grows in the arid and semiarid regions with adverse effects on the environment. Recent studies on the P. juliflora plant, has shown that the plant has medicinal properties with potent pharmacological potentials (Noor, Salam & Khan, 1995). Among the biological potentials of the plant include antioxidant properties, antifungal properties and antimicrobial properties. Equally, previous research has valorized the extracts of P. juliflora into natural dyes, of reliable shades and of reliable fastness based on different synthetic mordants (Odera, et al. 2020). In this study therefore, dyeing properties of extracts of P. juliflora, in cotton fabric were functionalized using bio mordants and tested for their potentials as antioxidant and antimicrobial textile finishing products.

Materials and Methods

Chemicals and Cotton

Pure, white and pre-macarized cotton fabric was obtained from, Rivatex East Africa, Eldoret, Kenya.

Collection of Plant Materials

The Prosopis juliflora plant samples were collected from Marigat, Baringo County in Kenya and transported to Moi University for storage awaiting further processing.

Extraction of Natural Dyes from Prosopis juliflora

The extraction method was adopted from (Odero et al., 2020). Briefly, the heartwood of the plant was manually separated from the other parts of the plant and ground into powder using a hammer mill. 500g of the powder was macerated in acetone in a two liter beaker for 48 hours and filtered with Whatman Filter Paper No. 1.

Dyeing Process

The extraction of mango bark bio-mordant was done as described by (Chengaiah, Rao, Kumar, Alagusundaram & Chetty, 2010; Kundal, Singh & Purohit, 2016; Odero, Kiprop, Owino, Arimi & Maiyo, 2020). Pre-mordanting, simultaneous mordanting and post mordanting were used as dyeing methods, 0.5 g of mordant was used, 100 ml of the natural dye bath was used with a material to liquor ratio of 1:40 at a temperature of 100°C, for 1 hour. They were then removed, washed and dried under shade (Janani, Hillary & Philips, 2014).

Colorimetric Analysis

Colorimetric analysis was done using an X-rite spectrometer SP60-EB05003377. The colour coordinates were assessed in form of CIE L*, a*, b* using illuminant D65-10 mode at three points (Ali & El-Mohamedy, 2011; Yusuf et al., 2015).

The relative strength of the dye was then evaluated using the Kubelka–Munk equation as in question 1 below (Kundal et al., 2016).

$$K/S = \frac{(1-0.01R)^2}{2(0.00R)} \ldots \text{Equation 1}$$

where K symbolizes the Sample absorption, S symbolizes scattering and R symbolises Reflectance

Antioxidant Activity

The antioxidant activity of the pure and dyed cotton fabric was evaluated using 2,2 -diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay method (Khaing, 2011; Lawal, Shittu, Oibiokpa, Berinyuy & Mohammed, 2016). Here, both pure and the dyed fabrics measuring 2.54 cm2 were individually immersed in test tubes containing 50ml of DPPH, in 0.15ml methanol and mixed thoroughly. Both samples were then incubated for 30 minutes at room temperature and the subsequent absorbance of the solutions measured using a Beckman- Coulter DUR720 single beam UV-VIS machine at the wavelengths of 517nm. The percentage antioxidant activity was calculated according to equation 2 below.

$$A\% = \frac{A_{Control} - A_{Sample}}{A_{Control}} \times 100 \ldots \text{Equation 2}$$

Where A% is the percentage antioxidant activity, $A_{control}$ the initial absorbance of DPPH solution and A_{sample} is the absorbance of the remaining DPPH solution after incubation with the sample.

Antibacterial Activity

The antibacterial activity of the dyed fabrics was assessed using the absorbance method described by Rather et al., (2016). Cotton fabric measuring 1.27cm^2 , was introduced into a 25ml nutrient broth inoculated with two different strains of bacteria namely Escherichia coli and Staphylococcus aureus. The broth, was then incubated at 37 °C in an automated incubator shaker (Unitronic–J.P selector) for 24 hours and then analyzed. The absorbance of the bacteria culture media, was analyzed by measuring the absorbance at the wavelengths of 595nm after another incubation for 24 hours. The percentage reduction in the bacteria growth was determined using equation 3 below.

$$R = \frac{(B-A)}{B} \times 100 \ldots \text{Equation 3}$$

Where R refers to the percentage reduction in microbe population, A refers to absorbance o fmedia inoculated with microbe and introduced dyed cotton fabric and B is the absorbance of media inoculated with microbe and introduced undyed cotton fabric.

Findings

Colorimetric Analysis of Bio-mordanted Cotton Fabric

Bio-mordanting and dyeing with acetonic extracts of P. juliflora formed different shades of brown (Table 1). From the table, it is clear that the use of mordants, increased the colour strengths of the fabric in all the mordanting types.

Table 1

Colorimetric Values of Bio-mordanted Cotton Dyed with P. julflora Natural

Method	*Mordant*	*L**	*a**	*b**	*C**	*H°*	*K/S*
Pre-mordanting	Without	63.5	3.3	19.5	19.8	80.4	0.43
	Mango Bark	74	+1.4	+15.1	15.1	84.5	0.76
	Tannin	79	+2.5	+24.3	23.1	81.2	0.72
Meta-mordanting	Mango Bark	73	+2.1	+16.1	23.8	83.3	0.68
	Tannin	76	+1.2	+21.1	23.1	88.3	0.63
Post-Mondanting	Mango Bark	75	+2.4	+14.5	23.4	84.3	0.71
	Tannin	77	+3.1	+20.2	22.1	85.1	0.79

Antibacterial Activity of the Dyed Cotton Fabric

The results of the antimicrobial activity of the P. juliflora dyed fabric, were analyzed and recorded in Table 2 below.

Table 2

Bacteria Reduction (%) of the Samples of the Fabric

Plant Extract	***Sample***	**Bacteria Reduction (%)**	
		E. coli	***S. aureus***
E. Abyssinica	Undyed cotton (control)	-	-
	Dyed	*58*	*61*
	Mango mordanted	*64.34*	*66.72*
	Tannic acid mordanted	*63.1*	*64.21*

From the table, the results suggest that independently the natural dye in its own, has potential use as a natural dye with antibacterial finish. Equally, the use of mango bark and tannic acids as bio-mordants, led to a higher bacteria reduction efficacy. This could be attributed to the additional phenolic hydroxyls groups from the bio-

mordant extracts that enhance the bacteria inhibition ability of the dye (Chitopoa, Muchachaa, Mangoyi, 2019).

Antioxidant Activity of the Dyed Cotton Fabric

The antioxidant activity of the dyed cotton fabric is as shown in Table 3. It was observed that the antioxidant activity of the cotton fabric dyed and bio-mordanted with tannic acid (78.6%) was highest which could be due to the additional activity from the bio-mordant extracts which has been shown to have good antioxidant activity (Sultana, Hussain, Asif & Munir, 2012).

Table 3

Antioxidant Activity of the Dyed Sample Fabric

Plant	Sample	Antioxidant Activity (%
P. julifrora	Undyed cotton (control)	-
	Dyed	63.1
	Mango mordanted	75.0
	Tannic acid mordanted	69.6

Conclusion

With the present shift in functionalized fabric the P. juliflora¸ biomordanted fabric proved to be a suitable and potent fabric with antibacterial capabilities. The use of mordants improved both the antibacterial activity and antioxidant activity of the fabric. As a result P. juliflora dye extract is suitable for developing bio-functionalized textile fabric.

Recommendation

It is recommended that other bio-functionalization properties of P. juliflora dye on cotton fabric to be studied.

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