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Antimicrobial activity of cotton and silk fabrics dyed *with Datura stramonium* (Jimson weed) plant leaf extracts

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Functional finishes are agents that are applied to fabrics to make them suitable for specific uses and contribute a specific attribute to a fabric without altering its appearance. In this context, the present study reveals the importance of dyed fabrics with *Datura stramonium* plant leaf extracts to control antibiotic-resistant bacteria, which have been a threat to human health and posed noticeable challenges confronted with medical physicians in the treatment of many infectious diseases. More still, the importance of using natural dye is not limited to its antimicrobial and other medicine values but also to its wide range of advantages via elimination of environmental pollution due to the usage of synthetic dyes. 100% plain woven, desized, scoured and bleached cotton fabric samples and 100% degummed and bleached hand knitted silk fabric samples were dyed with aqueous extracts from *D. stramonium* plant leaves in combination with Alum and Iron Sulphate as mordants using post-mordanting method and then tested against two strains of *Staphylococus aureus* (Gram-positive bacteria) and *Pseudomonas aeruginosa* (Gram-negative bacteria) using Agar diffusion method as per SN195920-1992 standard. The fastness properties (wash fastness, light fastness and rubbing fastness) of the dyed fabrics were assessed following guidelines from The American Association of Textile Chemists and Colorists (AATCC) and International Organization for Standardisation (ISO) testing methods. Spectrophotometric experiments were employed to evaluate the colour strength (K/S) of the dyed samples. The antimicrobial activity results showed that for both cotton and silk dyed fabric samples; there was an interruption of the microbial growth beneath the fabric and a clear zone of inhibition around the fabric. Dye ability and fastness results showed that dyed fabric samples with *D. stramonium* extracts using mordants had relatively high colour strength (K/S) values as compared to the control fabrics which were dyed without a mordant and their colorant was more stable to light, rubbing and washing, respectively.

Key words: Antimicrobial activity, silk fabric, cotton fabric, *Datura stramonium* extract, mordants.

INTRODUCTION

With the presence of a huge number of synthetic drugs, natural bioactive agents within the plant kingdom continue to be part of the health care either in developed or developing economies. (Resmi, 2014). Healthy and active lifestyles have led to a rapidly increasing market for a wide range of antimicrobial textiles, which intern,

have stimulated intensive research and development efforts (Sasmita et al., 2013). *Datura stramonium* (Jimson weed) is grown in many areas across the world annually. It belongs to the Solanaceae family and is known to be a medicinal herb. Several findings show that *D. stramonium* plant contains compounds like alkaloids, saponins, steroids, tannins, and glycosides which exhibit antimicrobial properties (Soni et al., 2012; Alapati and Sulthan, 2015; Manikandan and Ananth, 2016). Due to its bitterness and poisonous nature, it is traditionally used in many drugs for the treatment of skin disorders, ear pains, coughs, fever, gastric pains, asthmatic attacks, sprains, muscle pains, cramps contusions, snakebites, piles, convulsions, gums during toothache and applied on dog bite wounds (Alapati and Sulthan, 2015; Aqib Sayyed, 2015).

Recently, various research have shown that indeed textile fibres provide an excellent substrate and conditions for the growth of micro-organisms (Morais and Guedes, 2016; Bhuyan et al., 2016). These micro-organisms can transfer infectious diseases as well as cause discolouration, bad odor, and garment degradation. In a bid to overcome these pathogenic organisms, antimicrobial and self-cleaning properties were imparted onto textile materials (Oh and Na, 2014). Also, as a result of the growing concern for the environment, the use of natural products to impart various functions to textiles has attracted increasing attention. This has been well examined by the use of *Citrus grandis osbeck* for its antimicrobial effect on fabrics (Yi and Yoo, 2010) and use of *Aloe vera* extract and its natural antibacterial finishing for textile applications (Nadiger and Shukla, 2017). Several reports have confirmed that natural dyes can be used not only to provide colour but also reduce microbial growth (Narayanaswamy et al., 2013; Ali, 2015; Rajendran, 2011; Bhuyan et al., 2016). Like these, many natural resources that impart antimicrobial properties to textiles were found and investigated deeply.

The leaf extracts of *D. stramonium* were studied and approved to have excellent antimicrobial activity against micro-organisms based on the availability of large amounts of bio-active compounds such as tannins, flavonoids and alkaloids, which are effective against bacterial and fungal infections (Bhuyan et al., 2016). Also, it has been proved that these antimicrobial agents which have varying composition and concentration in different plant parts are usually accumulated as secondary metabolites in plant cells (Tawiah et al., 2016) and that leaves possess the highest antimicrobial activity levels thus opted for in therapeutic applications (Gutarowska et al., 2013). In respect to that, the use of *D. stramonium* leaf extract as a textile finish on 100% cotton and silk fabrics and its dyeing potential has not been examined and reported in any form.

In the current study, the interaction of extracted natural dyes from the plant species, *D. stramonium* with cotton and silk fabrics using selected mordants and their potential antimicrobial efficacy against *Pseudomonas aeruginosa* and *Staphylococcus aureus* bacterial species which are known to cause cross infections in the hospitals as well as being responsible for causing unpleasant odors in textiles were investigated. A comparative study of the colour strength and fastness properties with respect to Alum and Iron Sulphate used as mordants is also reported.

MATERIALS AND METHODS

Collection of materials

Desized, scoured and bleached plain weave 100% cotton fabric samples were purchased from Southern Range Nyanza Textiles Limited and 100% degummed and bleached mulberry silk hand knitted fabric samples from Uganda National Sericulture Centre, Kawanda, Wakiso district, Uganda.

The leaves of *D. stramonium* plant were collected from nature around Busitema University campus, Busia district, Uganda.

Distilled water, Sodium Sulphate for dye exhaustion, Potassium Aluminium Sulphate (Alum) and Iron Sulphate used as mordants, analytical balance, mortar, pestle and Nutrition agar (MHA) were all obtained from Textile labs, Moi University.

Preparation of the sample

Jimson weed (*D. stramonium)* leaves were washed thoroughly with running tap water followed by distilled water to remove soil particles, shed dried at room temperature for 4-5 days, ground using a mortar and a pestle into powder form and sieved to remove any large residues.

Dye extraction

The obtained powder sample of 150 g was added to 1000 ml of distilled water at the boil for 1 h to extract the dye. The obtained mixture was cooled at room temperature and filtered through Whatman No. 1 filter paper and used for dyeing immediately.

Dyeing of fabric samples

Some of the cotton and silk fabric samples were dyed using post-mordanting method with Alum and Iron Sulphate used as mordants according to Miah et al. (2017) while others were dyed without using a mordant.

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Dyeing of cotton fabric samples without a mordant

With slight modifications, cotton fabrics were dyed according to Mohan (2012) whereby bleached cotton fabric samples (8×10 cm) were dipped in a dye bath (150 cm^3) and after 10 min, 20% on weight of fabric (O.W.F) of sodium sulphate was added. With intermittent stirring, the dyeing was done for an hour at 50°C. Thereafter, dyed samples were squeezed to remove excess dye and then using a non-ionic soap solution (2 g/l) at 50°C for 10 min, the fabric samples were washed, rinsed with running tap water and dried at room temperature.

Dyeing of cotton fabric samples with mordants (Alum and Iron Sulphate)

The same dyeing procedures were followed as mentioned earlier, with the exception that a mordant solution (100 cm^3) of 10% OWF at 60°C was used to soak the dyed samples for 30 min at a material to liquor ratio of 1:20. Then non-ionic soap solution (2 g/l) was used in washing the dyed fabric samples at 50°C for 10 min prior to rinsing with running tap water and finally drying at room temperatures.

Dyeing of silk fabric samples without a mordant

Silk samples dyeing was done according to Janani and Winifred (2013) method with slight modifications. During dyeing, the beakers were covered to minimize the addition of oxygen to the solution. Intermittent stirring was done after every 10 min. Pieces of degummed and bleached silk fabrics measuring (8×10 cm) were soaked in distilled water and thereafter transferred to dye bath liquor (700 cm^3) and the mixture heated gradually to 60°C while stirring for 30 min. Then they were removed from the dye bath and rinsed repeatedly in clean water until no more colour change was observed in the cleaning water. Finally, the dyed samples were dried at room temperature.

Dyeing of silk fabric samples with mordants (Alum and Iron Sulphate)

The same procedures were followed as mentioned earlier. Except that after the samples were dyed, they were removed from the dye bath and immediately soaked in a solution of a mordant. Different fabric samples were soaked separately in mordanting solution which was made to stand for 15 min. The dyed samples were then rinsed repeatedly in clean water until there was no more colour change observed in the cleaning water. The samples were thereafter dried at room temperature.

Colour shade measurements

The dyed fabric samples using selected mordants and others without a mordant were characterised using SF 600 Spectra flash reflectance spectrophotometer to evaluate the colour shades produced during dyeing process.

Colour strength of the dyed cotton and silk fabric samples

The colour strength (K/S) values of cotton and silk dyed fabric samples with and without using mordants were determined using the Kubelka-Munk equation as follows:

$$K/S=(1-R)^2/2R$$

where R is the reflectance value at the maximum absorbance wavelength, S is the coefficient of light scattering and K is the coefficient of light absorption. The SP60 series X-rite type spectrophotometer with wavelengths ranging from 390 to 710 nm were used to measure the dyed samples whereby five measurements were taken for each and average results were recorded.

Fastness properties

The fastness properties of dyed cotton and silk fabric samples with and without the use of mordants to light, washing, and rubbing were evaluated based on the AATCC test method 16-2004, ISO 105 CO_2 test method and AATCC test method 8-2007, respectively (American Association of Textile Chemists and Colorists, 2010).

Antimicrobial activity of the dyed fabric samples against *P. aeruginosa* and *S. aureus* strains

In determining the antimicrobial activity of cotton and silk fabric samples dyed with *D. stramonium* leaf extract, *P. aeruginosa* (Gram-negative) was considered due to its popularity of being used as a test organism and its resistance to common antimicrobial agents and *S. aureus* (Gram-positive) bacterial species was used since it is well known for causing cross infections in the hospitals as well as responsible for unpleasant odors in textiles. The strains were cultured on nutrient agar and incubated at 37°C for 24 h and examined for the zone of inhibition.

Assessment of antimicrobial activity of dyed cotton and silk fabric samples

Using the Agar Diffusion method as per SN 195920-1992, the dyed and undyed fabric samples with *D. stramonium* extracts were qualitatively assessed for antimicrobial activity by placing both samples in intimate contact with AATCC bacteriostasis Mueller Hinton agar which has been previously inoculated with an inoculum of test organisms in duplicate Petri-dishes. They were then incubated at 37°C for 24 h and examined for the interruption of the growth along the streaks of inoculum directly beneath the fabric samples and for a clear zone of inhibition beyond its edge using visible observation and a compound microscope.

RESULTS

Colour shades produced by using different mordants

The application of *D. stramonium* dye extracts onto cotton and silk fabric samples with Alum and Iron Sulphate as mordants under post-mordanting method produced variable colour shades as shown in Table 1. Alum mordant produced yellow-green shades on both cotton and silk dyed fabrics, Iron Sulphate gave dark green shades and control experiment (without a mordant) produced slightly dark green shades.

Effect of different mordants on colour strength of the dyed fabrics

With the help of SP60 series X-rite type spectrophotometer,

Table 1. Colour shades produced on cotton and silk fabric samples post-mordanted dyed.

Mordant	Alum	Iron Sulphate	Without a mordant
Cotton fabric dyed samples			
Silk fabric dyed samples			

Table 2. Colour strength (K/S) values of Cotton and silk fabric samples dyed with *Datura stramonium* leaf extract.

Mordant	Method	Cotton fabric (K/S Values)	Silk fabric (K/S Values)
Control	-	1.2	1.3
A	Post	1.5	2.5
B	Post	1.8	5.3

A-Potassium Aluminium Sulphate (Alum), B-Iron Sulphate, Control-Cotton and silk fabric samples dyed without a mordant, Post-Post mordanting.

reflectance values at maximum wavelengths were obtained thus colour strength (K/S) values of cotton and silk fabric samples dyed with *D. stramonium* extracts computed and recorded as shown in Table 2. Cotton and silk fabrics dyed using Iron Sulphate mordant showed the highest colour strength (K/S) values of 1.8 and 5.3, respectively followed by 1.5 and 2.5, respectively for using Potassium Aluminium Sulphate (Alum) as mordant and finally 1.2 and 1.3, respectively for control fabrics. This was further clearly demonstrated as shown in Figure 1 for both cotton and silk fabrics. Also, it was observed that silk dyed fabrics showed better colour strength values as compared to cotton dyed fabrics when using both mordants as well as without the mordant.

Fastness properties

Tables 3 and 4 show fastness properties of the various samples dyed with and without mordants added to the leaf extracts of *D. stramonium*. The control sample exhibited moderate to good (3 - 4) fastness properties in most aspects for both fabrics though, for the case of silk fabrics, fastness ratings were more satisfactory. The mordanted fabric samples all showed good to excellent (4 - 5) fastness properties to light, washing, and rubbing.

Assessment of antimicrobial activity of dyed cotton and silk fabric samples

The results of the agar diffusion method against the test organisms *P. aeruginosa* and *S. aureus* are as shown in Figures 2 and 3. The zone of bacterial inhibition is indicated by diffused colour around the dyed fabric samples and a weak growth towards them. This was further clarified with the help of Table 5 where dyed fabric samples for cotton (D_2c) and silk (D_2s) showed maximum antimicrobial activity on both *S. aureus* and *P. aeruginosa* tests with a weak microbial growth towards them as

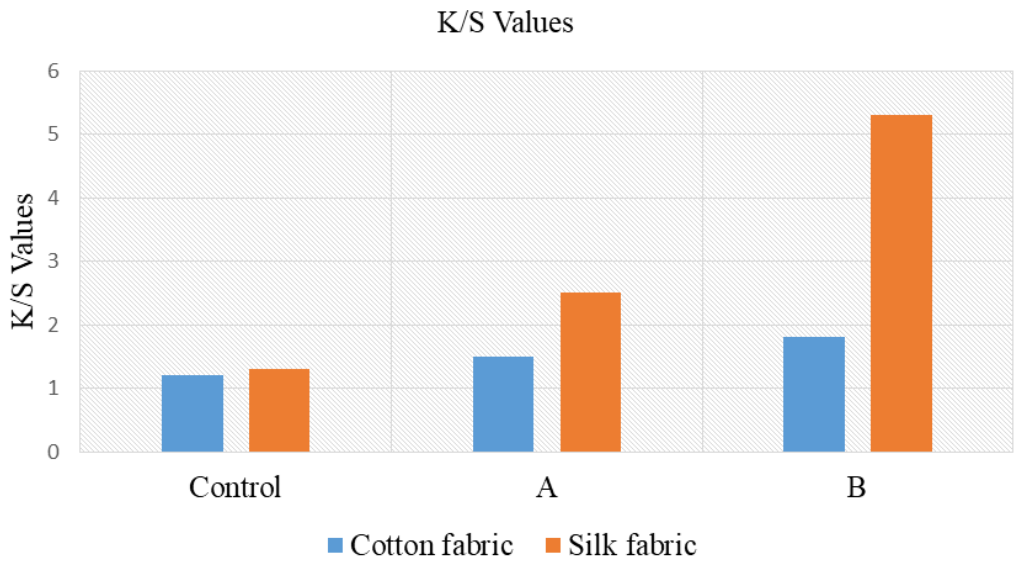

Figure 1. Showing the colour strength (K/S) values of dyed cotton and silk fabric samples.

Table 3. Fastness properties of cotton fabric samples dyed with *Datura stramonium* leaf extract.

Mordant	Method	Light fastness	Wash fastness		Rubbing fastness	
			CC	CS	Dry	Wet
Control		4	3	4	4-5	3-5
A	Post	4-5	4	4-5	5	4-5
B	Post	4-5	4	4-5	4-5	4

A-Potassium Aluminium Sulphate (Alum), B-Iron Sulphate, Post-Post mordanting, Control-Cotton fabric samples dyed without a mordant, CC-Colour change, CS-Colour staining, 3-Moderate, 4-Good and 5-Excellent.

Table 4. Fastness properties of Silk fabric samples dyed with *Datura stramonium* leaf extract.

Mordant	Method	Light fastness	Wash fastness		Rubbing fastness	
			CC	CS	Dry	Wet
Control		4-5	3-5	4	4-5	4
A	Post	5	4-5	5	5	4-5
B	Post	5	4	5	5	4

A-Potassium Aluminium Sulphate (Alum), B-Iron Sulphate, Post-Post mordanting, Control-Silk fabric samples dyed without a mordant, CC-Colour change, CS-Colour staining, 3-Moderate, 4-Good, 5-Excellent.

shown in Table 6. Then dyed fabric samples for cotton (D_1c), (Dc) and Silk (D_1s), (Ds) showed moderate antimicrobial activity on both *S. aureus* and *P. aeruginosa* tests with heavy growth towards silk fabrics and weak growth towards cotton fabrics.

DISCUSSION

Basing on the results presented in this study, dyeing of cotton and silk fabric samples using leaf extracts from *D. stramonium* was done using the post-mordanting method in order to obtain better colour shades. This is in line with findings done by Janani et al. (2014) on mordanting methods. The variations in the colour shades of the dyed fabrics were attributed to the use of different mordants forming characteristic dye-fibre complexes of different shades whereby Potassium Aluminium Sulphate (Alum) produced a yellow-green shade compared to that produced by using Iron Sulphate which was more dark

Figure 2. Agar plate pictures of Cotton fabric samples dyed with *Datura stramonium* against *Staphylococcus aureus* (Staph) and *Pseudomonas aeruginosa* (Pseud) on Mueller Hinton agar. D_1c-Cotton dyed fabric with Alum, D_2c-Cotton dyed fabric with Iron Sulphate, Dc-Cotton dyed fabric without a mordant, and P-Control.

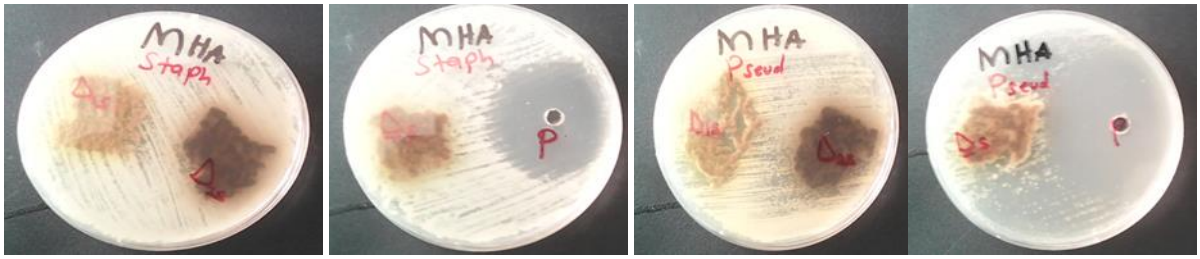

Figure 3. Agar plate pictures of Silk samples dyed with *Datura stramonium* against s *staphylococcus aureus* (Staph) and *Pseudomonas aeruginosa* (Pseud) on Mueller Hinton agar. D_1s-Silk dyed fabric with Alum, D_2s-Silk dyed fabric with Iron sulphate, Ds-Silk dyed fabric without a mordant, and P-Control.

Table 5. Test results of antimicrobial activity of cotton and silk dyed fabric samples.

Organisms	Cotton dyed fabric samples			Silk dyed fabric samples		
	D_1c	D_2c	Dc	D_1s	D_2s	Ds
S. aureus	+	++	+	+	++	+
P. aeruginosa	+	++	+	+	++	+

D_1c-Cotton dyed fabric with Alum, D_2c-Cotton dyed fabric with Iron sulphate and Dc-Cotton dyed fabric without a mordant. D_1s-Silk dyed fabric with Alum, D_2s-Silk dyed fabric with Iron sulphate, Ds-Silk dyed fabric without a mordant. ++ = Maximum antimicrobial activity (interruption of the microbial growth beneath the fabric and a clear zone of inhibition around the fabric); + = Moderate antimicrobial activity (interruption of the microbial growth beneath the fabric but no clear zone of inhibition around the fabric).

Table 6. The microbial growth rate towards the cotton and silk dyed fabric samples.

Organisms	Cotton dyed fabric samples			Silk dyed fabric samples		
	D_1c	D_2c	Dc	D_1s	D_2s	Ds
S. aureus	W	W	W	H	W	H
P. aeruginosa	W	W	W	H	W	H

W-Weak growth rate, H-High growth rate.

green. This was because mordants are known for forming an additional linkage with dye molecules as confirmed by the study done by Narayanaswamy et al. (2013).

The colour strength (K/S) values for dyed fabric samples increased considerably with the use of mordants (Alum and Iron Sulphate) as compared to the control fabric samples (Figure 1) but with Iron Sulphate mordanted fabric samples, their colour strength values

were extremely high emphasizing better-linking properties with the extracted dye. This was attributed by the formation of strong complexes between the mordants and dye molecules as it is in line with findings reported by Wanyama et al. (2014) on characterisation and application of natural dyes.

Based on the colour fastness results presented, the control sample exhibited moderate to good (3 - 4) fastness properties in most aspects for both fabrics though, for the case of silk fabrics, fastness ratings were more improved. The mordanted fabric samples all showed good to excellent (4 - 5) fastness properties to light, washing, and rubbing. This may have been attributed to the presence of tannins in the dye extract (Bhuyan et al., 2016) as well as mordants used which helped the dye to bond well with the fibre matrix. In general, cotton and silk fabrics dyed with the *D. stramonium* extracts using mordants (Alum and Iron Sulphate) gave very good acceptable fastness properties having in mind that natural dyes normally exhibit low substantivity to fibres and fabrics.

In the Agar Diffusion Test results for antimicrobial activity against standard test cultures (Figures 2 and 3), the diffused colour around the dyed fabric samples and a weak growth towards them was an indication of bacterial inhibition. Dyed cotton and silk fabric samples using Iron Sulphate mordant showed maximum antimicrobial activity on both *S. aureus* and *P. aeruginosa* tests as compared to those fabric samples dyed using Alum mordant. This is true since the dye fixation levels vary with different mordants used under suitable conditions thus forming different sizes of inhibition zones (Gupta and Laha, 2007). On the other hand, results showed that there was a high microbial growth rate towards silk fabrics as opposed to the low microbial growth rate towards cotton fabrics. This disparity in the rate of microbial growth is expected to have been caused by the slow release of the active substances from the silk fabric surface to the organisms streaked on the incubated plates containing the culture media.

Conclusions

The study mainly focuses on the antimicrobial activity of cotton and silk fabrics dyed with *D. stramonium* crude plant leaf extracts. The antimicrobial tests demonstrate an exciting opportunity for the naturally dyed fabrics in developing protective clothing against common infections in hospitals and hotels. Two test organisms namely *P. aeruginosa* and *S. aureus* were used in the study and from the results, it can be concluded that both cotton and silk dyed fabrics showed very good inhibitory effects against the two test organisms. A high inhibition zone was recorded with the cotton and silk fabrics dyed with *D. stramonium* leaf extract mordanted with Iron Sulphate in comparison to the fabrics dyed with Alum mordant. The dye ability tests carried out confirmed that the natural herbal extract has a good depth of dyeing towards both fabrics (cotton and silk) but much more with silk fabrics as compared to cotton. The selected mordants used also contributed to significant K/S values that were realized (K/S value = 5.3 for silk mordanted with iron sulphate in comparison with K/S value = 1.8 for cotton fabric mordanted with iron sulphate). It was also noted that the use of both mordants gave results which were significantly higher for silk fabrics than for cotton fabrics. Fastness properties (washing, light, and rubbing) for cotton and silk dyed fabrics ranged from good to excellent. These results clearly show that utilizing extracted natural dyes from *D. stramonium* as dyeing materials significantly facilitate obtaining quality fabrics having both dye ability and antimicrobial properties. However, more research can be done to determine the bioactive principles at various stage of plant growth since their composition varies with the age of the plant and in different species of the same plants.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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