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Eco-Friendly Dyeing of Cotton and Polyester Fabrics with Natural Dyes Extracted from Different Varieties of Kola Nuts

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Abstract

Cotton and polyester fabrics are among the important textile materials used for various purposes most especially in clothing. The fabrics are increasingly dyed with synthetic dyes which in most cases appears hazardous to the wearers and those engaged in the dyeing operations. In the present study, dyes were extracted from three varieties of kola nuts (Red, white and bitter) and applied to cotton and polyester fabrics. Three mordanting techniques (pre, simultaneous and post mordanting) were adopted in all the dyeing. The fastness properties of the dyed fabrics were evaluated. The result of these assessments reveals that dyeing carried out with simultaneous mordanting produces the best result of all round fastness properties (wash, light, perspiration and pressing) with red kola dye extract. The result, further reveals the viability of the colouring object from red kola and when properly investigated could serve as a possible substitute to hazardous synthetic dyes that remain a serious threat to the environment.

Keywords

Eco-Friendly Dyeing, Cotton, Polyester, Natural Dyes, Kola Nuts

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1. Introduction

In many developing countries like Nigeria, Uganda, Ethiopia India and Iran, natural dyes can offer not only rich and varied source of dyestuff, but also the possibility of an income through sustainable harvest and sale of these plants. The utilization of natural dyes could be traced back during Bronze Age in Europe, which involves primitive dyeing techniques involving sticking dye-yielding plants to fabrics or rubbing crushed pigments onto cloth. The method become sophisticated with time and dyeing techniques using natural dyes from crushed fruits, berries and other plant materials which were boiled into the fabric were developed (Jothi, 2008; Ado *et al.,* 2014). Some of the well known ancient dyes include madder; a red dye obtained from the roots of *Rubia tinctorium*; blue indigo from the leaves of *Indigofera tinctoria*; Yellow dye from the stigmas of saffron plant and bright red dye obtained from cochineal, an insect native to Mexico (Siva, 2007; Vankar, 2000). The use of natural dyes for textile dyeing purposes; however decreases to a large extent after the discovery of synthetic dyes in 1856, as a result, use of natural dye were virtually neglected (Saravanan and Chandramohani 2011).

Recently there have been revivals of the growing interest on the application of natural dyes due to world-wide environmental consciousness on hazards caused by synthetic dyes. Presently, there is an excessive use of synthetic dyes which is estimated at around 10,000,000 tons per annum. The

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production and application of synthetic dyes however releases large amount of waste and unfixed colourants to the environment thereby causing serious health hazards. (Samanta and Agarwal 2009). Natural dyes have better biodegradability and generally have higher compatibility with the environment; they are non-toxic, non-allergic to skin, non-carcinogenic, easily available and renewable (Kulkarni, 2011; Mohanty *et al.,* 1987).

Kola nut belongs to the family *Sterculiaceae*. The tree grows about 40 feet high. Its leaves have length of 6–8 inches which is pointed at both ends. The seeds are extensively used as condiments by the natives of western and central tropical Africa, Negros of the west India and Brazil. Kola nuts is abundantly grown in south western Nigeria and consumes by many, however, it was reported to contain caffeine and some other harmful substances which could adversely affect the living system. The consumption of kola nuts therefore should be discouraged and the present study thus, intends to extract colourant from kola nut and apply it on cotton and polyester fabrics with a view to present an alternative to the public that kola nut can be economically viable plant material, and could also serve as an important source of eco-friendly natural dye for dyeing textiles (Ado *et al.,* 2014; SCTD, 2009).

2. Material and Methods

All glass wares were washed with a detergent rinsed with distilled water and dried in an oven before use. Chemical reagents of analytical grade purity were used. Cotton and polyester fabrics were kindly supplied by African Textile Mill in Kano, Nigeria. Fastness properties measurements were performed at Africa textile mills laboratory using standard equipments. Locally available Kola nuts from Ujile Market in Kano, Nigeria were purchased.

2.1. Dye Extraction

Powdered Kola nuts were soaked in distilled water, heated in a beaker and kept over a water bath for 2 hours to facilitate quick extraction. It was filtered and the filtrate collected in a separate beaker (Saravanan and Chandramohan, 2011; Wanyama *et al.,* 2011).

2.2. Dyeing

Cotton and polyester samples were dyed with the three different dye extract. Wetted fabrics were entered into the dye baths containing required amount of dye extract and water. However, after 10 minutes, 5g/litre of sodium carbonate and sodium chloride were added. The dyeing was carried out for one hour at 60^{o}C and further subjected to pre, simultaneous and post–mordanting using myrobolan and metal salts (Kumerasan *et al.,* 2011).

2.3. Mordanting

Pre-mordanting: Fabrics were mordanted with metal salts and myrobolan (3% o.w.f) prior to dyeing. It was carried out at 60^{o}C for 30 minutes with material to liquor ratio of 1:20.

Simultaneous mordanting: Fabric were treated with both dye extracts and metal salts concurrently (3% o.w.f) at 60^{o}C for 30 minutes with material to liquor ratio of 1:20.

Post-mordanting: Fabrics were dyed with dye extracts and samples were taken out of the bath, squeezed and used for treatment with (3% o.w.f) metal salts without washing. Mordanting was carried out at 60^{o}C for 30 minutes with material to liquor ration of 1:20 (Chandramohan *et al.,* 2012).

At the end to the dyeing process, the samples were washed with water and then dried in air. Finally the dyed samples were soaped with 2g/L soap solution at 50^{o}C for 10 min, followed by rising and drying under the sun (Kumerasan *et al.,* 2011).

2.4. Colour Fastness Tests

Fastness to washing: The dyed specimens of dimension 5cm × 4cm were placed between two pieces of dyed white fabrics of the same dimension. Three pieces attached to each were held together by stitching round the edges to make a composite specimen. The specimens were placed in wash liquor containing 25cm^3 of 2g/litres detergent solution, heated and then removed thoroughly, rinsed and assessed using the grey scale (Nkeonye, 1987).

Fastness to light: strips of the fabrics and the blue wool standard were cut and mounted on a cardboard paper and half portions of the specimens were covered to block the source of light from getting to that portion. The specimens were exposed to artificial light source in a fadeometer instrument for two weeks. Specimens were then removed and the extents of their fading were assessed in comparison with the blue wool standard (Nkeonye, 1987).

Fastness to perspiration: Two different solutions (acidic and alkaline) were used. Composite specimens were immersed separately in the solutions using liquor ratio of 20:1 the specimens were left in it for 30 minutes at room temperature after which were brought out, drained and placed in between to glass slides for four hours. They were then removed and dried. The colour changes of the dyed fabrics were assessed using a grey scale.

Fastness to pressing: This was carried out by positioning 5cm × 4cm dyed fabric on a piece of dried white cloth of the same size and then pressed with a hot iron for 20 seconds. The change in colour of the dyed material and the degree of staining of the undyed cloth were assessed using grey scale.

Fastness to damp pressing: This was carried out by placing the dyed fabric (5cm × 4cm) between the dried white cloth and a wet white cloth of the same size. The wet white cloth was placed on top while the dried white cloth was placed below. They were then pressed together for 20 seconds. The change in colour of the dyed material and the degree of staining of white cloth were assessed using grey scale.

3. Results and Discussion

3.1. Preparation and Optimization of Aqueous Extract of the Kola Nuts

The red kola was found to discharge colour in hot water very easily compared to white and bitter kola which discharges little colour. However, increasing the quantity of red kola (powdered), boiled for two hours resulted in increase in colour strength and depth. It was observed that, the red kola dye extract possess an orange colour where as that of the remaining (two extract white and bitter kola) were light yellow.

3.2. Dyeing Behaviour of the Dye Extracts

Red kola dye extract was found to be substantive on cotton fabrics but less substantive on polyester fabrics. On the other hand, white and bitter kola dye extract was also substantive to cotton fabrics but less substantive on polyester fabric. However, the dye uptake by the fabrics was found to be good in simultaneous mordanting methods. This could be attributed to better dye diffusion brought about by the mordants.

3.3. Fastness Properties of the Dyed Fabric

The Fastness properties of cotton fabrics dyed with red kola dye extract with copper sulphate, ferrous sulphate, potassium dichromate and Myrobolan using the three mordanting methods is as shown in table 1.

Table 1. Fastness properties of cotton fabric dyed with red kola dye extracts.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	3	3	3	3	3
	Post-mordanting	3	4	3	3	3
	Simultaneous mordanting	4	4	4	4	4
Ferrous sulphate	Pre-mordanting	3	4	3	3	3
	Post-mordanting	3	3	4	4	3
	Simultaneous mordanting	4	4	5	5	4
Potassium dichromate	Pre-mordanting	3	3	2	2	2
	Post-mordanting	3	2	4	4	3
	Simultaneous mordanting	4	4	3	3	4
Myrobolan	Pre-mordanting	2	2	2	2	3
	Post-mordanting	3	3	2	2	3
	Simultaneous mordanting	3	3	4	4	3

Table 2. Fastness properties of cotton fabric dyed with white kola dye extract.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	2	2	3
	Simultaneous mordanting	3	3	3	2	2
Ferrous sulphate	Pre-mordanting	2	3	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Potassium dichromate	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	3	2	2
	Simultaneous mordanting	3	3	3	3	3
Myrobolan	Pre-mordanting	2	2	2	2	2
	Post-mordanting	3	2	3	2	2
	Simultaneous mordanting	3	3	3	3	3

It is evident from the result that simultaneous mordanting with these metal salts and Myrobolan produces appreciable results of fastness properties, however, pre-mordanting and post mordanting methods does not produces good results of fastness properties as evident from the result obtained. These could be attributed to the fact that dye –fibre interaction was weak and also the rate of diffusion of the dye was very slow and hence less substantive on the fabrics. This disagrees with findings of Kumerasan *et al.,* 2011 that excellent fastness to washing was observed except for pre – mordanting using Myrobolon: potassium dichromate combination.

Table 2 and 3 indicate the fastness properties of dyed cotton fabric with white and bitter kola dye extracts. From the results, there were no pronounced fastness improvement with this dye extracts despite the use of mordants. This could be attributed to the fact that the depth of shade of the dye on the fabric was low and the substantivity was also fair. This disagrees with findings of Vankar *et al.* (2008), Vankar, (2002) and Tiwari *et al.* (2001) which found that the use of mordant enhanced substantivity of the dyes and also increases depth of shade.

Table 3. Fastness properties of cotton fabric dyed with white kola dye extract.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Ferrous sulphate	Pre-mordanting	2	3	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Potassium dichromate	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Myrobolan	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3

Table 4. Fastness properties of polyester fabric dyed with red kola dye extracts.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	2	2	2	2	2
	Post-mordanting	2	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Ferrous sulphate	Pre-mordanting	1	1	1	1	1
	Post-mordanting	1	1	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Potassium dichromate	Pre-mordanting	1	1	1	1	1
	Post-mordanting	1	1	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Myrobolan	Pre-mordanting	1	1	1	1	1
	Post-mordanting	1	1	1	1	1
	Simultaneous mordanting	3	2	2	2	2

Table 5. Fastness properties of polyester fabric dyed with white kola dye extracts.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	1	2	2	2	2
	Post-mordanting	1	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Ferrous sulphate	Pre-mordanting	1	1	2	2	2
	Post-mordanting	1	1	1	1	2
	Simultaneous mordanting	2	2	2	2	2
Potassium dichromate	Pre-mordanting	1	1	1	1	2
	Post-mordanting	1	1	2	2	2
	Simultaneous mordanting	2	2	2	2	2
Myrobolan	Pre-mordanting	1	1	1	1	1
	Post-mordanting	1	1	2	2	2
	Simultaneous mordanting	2	2	2	2	2

However, Table 4, 5 and 6 depicts the fastness properties results for polyester fabrics dyed with red kola, white and bitter kola dye extracts respectively. From the tables, only polyester fabric dyed using simultaneous mordanting produces fair results. This could be attributed to the fact that polyester are difficult to dye even with conventional disperse dyes by high temperature and carrier dyeing methods as reported by Nkeonye, (1987).

Tables 7 and 8 describe the normal fastness grades (washing, pressing, bleaching, perspiration etc) and light fastness grades respectively.

Table 6. Fastness properties of polyester fabric dyed with bitter kola dye extracts.

Mordants	Method of Mordanting	Wash	Light	Perspiration		Pressing
				Acidic	Alkaline	
Copper sulphate	Pre-mordanting	1	1	2	2	2
	Post-mordanting	1	2	2	2	2
	Simultaneous mordanting	3	3	3	3	3
Ferrous sulphate	Pre-mordanting	1	1	1	1	2
	Post-mordanting	1	1	1	1	2
	Simultaneous mordanting	2	2	2	2	2
Potassium dichromate	Pre-mordanting	1	1	1	1	2
	Post-mordanting	1	1	1	1	2
	Simultaneous mordanting	2	2	2	2	2
Myrobolan	Pre-mordanting	1	1	1	1	1
	Post-mordanting	2	1	1	1	2
	Simultaneous mordanting	2	2	2	2	2

Table 7. Description of normal fastness grades

Fastness grade	Shade change of tested sample	Fastness	Staining of adjacent white sample
Grade 5	No Change	Excellent	No staining
Grade 4	Slight loss in depth	Good	Very slight staining
Grade 3	Appreciable loss	Fair	Moderate staining
Grade 2	Significant loss	Poor	Significant staining
Grade 1	Great loss in depth	Very poor	Deep staining

Table 8. Description of the light fastness grades.

Fastness grade	Degree of fading	Light fastness
Grade 8	None	Outstanding
Grade 7	Very, very slight	Excellent
Grade 6	Slight	Very good
Grade 5	Moderate	Good
Grade 4	Appreciable	Moderate
Grade 3	Significant	Fair
Grade 2	Extensive	Poor
Grade 1	Very extensive	Very poor

4. Conclusion / Recommendation

The result of the study reveals that red Kola yields more dye extracts with increase quantity of powdered red kola whereas white and bitter kola produces little quantity of dye extract even with increased quantity of powdered nut during extraction. However, dyeing the fabrics with red kola dye extract by simultaneous mordanting produces more promising fastness properties results whereas poor to fair fastness properties was obtained with white and bitter kola dye extract. The results suggest that red kola could have prospect in large scale dyeing of cotton and polyester fabrics. However, appropriate after treatment methods and standardized extraction methods are recommended.

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