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Utilization of Dyes from Local Plant Materials-*Baphia nitida* (Red and Yellow Camwood), *Curcuma lunga* (Tumeric) and *Tectona grandis* (Teak leaves) as Fabric dyes

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ABSTRACT

The constituents of some selected local plants: Red *Baphia nitida* (BN1) and yellow *Baphia nitida* (BN2) camwood; *Curcuma lunga* known as turmeric (CL) and *Tectona grandis* known as teak leaves (TG) from Abakaliki were extracted using aqueous and organic solvents: distilled water, methanol and chloroform. The residues of the different extraction solvents were labeled BN1A and BN2A for aqueous extracts; BN1C and BN2C for chloroform extracts and BN1M and BN2M for methanol extracts respectively. The *Cucuma lunga* extracts were labeled CLA, CLC and CLM for aqueous, chloroform and methanol solvents respectively while *Tectonia grandis* TGA, TGC and TGM extracts were labeled according to the solvent used in the extraction. These extracts were used in their crude form to dye cotton and polyester fabrics; the cotton was used as a natural fiber and the polyester was used as a synthetic fiber. The fabrics when dyed with the extracts showed different colours but exhibited poor dyeing properties. These fresh were mordanted with metals salts such as $CuSO_4$, $FeCl_3$, $SnCl_2$ and $K_2Cr_2O_7$ and dyed with fresh samples of the extracts. These mordanted fabrics showed different colours were fast to wash, alkali and acid.

Keywords: Constituents, Dyeing, Extract, Fabrics, Fast, Mordant, Plants, Properties.

INTRODUCTION

Plants form an important part of life as human beings and animals depend on them for food, colourants, medicine, shelter and air[1]. The leaf, bark, roots and twigs extracts of *Baphia nitida* (red and yellow species) are used in ethnomedicine in the treatment of constipation, skin disease, veneral disease, flatulence and smallpox[2-3]. The tubers of *Cucuma lunga* are used as eye wash, skin diseases, yellow fever, antimicrobials, carminative and antimalarial while the fruits, seeds and bark of of *Tectona grandis* are used locally to treat dyspepsia, headache, skin disease, toothache and as astrigent and toothache[4-8].

A dye is coloured and regarded as any coloured substance that has the affinity to the substrate to which it is being applied by bonding, physical bonding or by mechanical adhesion and could be from plants and animals or as synthetic dyes. Natural dyes are colourants derived from plants such as seeds, leaves, stems, fruits or from invertebrates or could be of mineral origin. These natural dyes are simple to apply, are environmentally friendly and cheap. The main idea of extracting dyes from natural plants is to avoid environmental pollution and to use eco-friendly and biodegradable materials as such; considerable research is going on around the world on the extraction and application of natural dyes in textile industries. Synthetic dyes are manmade dyes, which though in some cases may have better properties, cheaper in a way, available in commercial quantity but are toxic and are not environmentally friendly. Colourants both natural and synthetic are characterized by their ability to absorb or emit light in the visible region of the electromagnetic spectrum and man has used natural colourants for decades. Dyes could be used in the colouring of textile, paper, leather, woods, pharmaceuticals, food, cosmetics and petroleum products. Colours could be used as a means of identification, improvement of aesthetics, warning, concealment etc.[9-21].

The utilization of *Baphia nitida* for skin care is common in Nigeria especially the South Eastern part where women use the pulverized stem bark to treat acne and pimples. In addition, *Curcuma lunga* turmeric powder is used for the same purpose. *Tectona grandis* has been a good source of naphthaquinones[23].

In this article, the author investigated the use of these plant samples in their crude form as possible dyes for the local textile industries. The unmordanted and mordanted samples of these locally available plants were considered for their dyeing properties; fastness to acid, alkaline and wash, hoping for their probable potential as replacement indigenous dyes for commercial purposes.

General experimental procedures

All reagents purchased from BDH Chemical Ltd. Poole England were of analytical Grade. Mettler P2010 weighing balance was used.

Sample collection and preparation

Exactly 1500 g of stems of *Baphia nitida* (red and yellow species) and yellow rhizomes of *Curcuma lunga* (tumeric) were sourced from a forest in Ikwo community of Abakakliki Ebonyi State, Nigeria respectively while 1300 g of fresh green leaves of *Tectona grandis* (teak leaves) were collected from Amagu in Abakaliki metropolis of Ebonyi State. The samples were gathered in the month of June 2016.

Identification of plant samples

The plant materials were identified by a taxonomist, Prof. C. Onyekwelu in the Department of Applied Biology, Faculty of Science, Ebonyi State University Abakaliki, Nigeria.

Extraction of constituents of the plant samples

Baphia nitida and *Curcuma lunga* samples were washed with distilled water to remove dirt and sun dried for 240 hours. The fresh leaves of *Tectona grandis* were washed in distilled water and soaked in 2500 L methanol for 10 min to stop enzymatic reactions and dried at ambient temperature 240 housrs. These samples were pulverized separately and 100 g of each sample was taken and soaked in 500 mL of chloroform, methanol and distilled water and left to stand for 168 h respectively[23].

The solution mixtures of the samples were filtered and the filtrates evaporated to dryness on a sand bath to yield 43.55 g red *Baphia nitida* aqueous extract (BN1A) and 5.58 g yellow *Baphia nitida* aqueous extract (BN2A). Also 9.21 g red *Baphia nitida* chloroform extract (BN1C) and 9.24 g yellow *Baphia nitida* chloroform extract (BN2C). For the methanol solvent; 14.57 g red *Baphia nitida* methanol extract (BN1M) and 25.65 g yellow *Baphia nitida* methanol extract (BN2M) respectively. The *Cucuma lunga* yields were 15.30 g aqueous extract (CLA), 3.06 g chloroform extract (CLC) and 32.45 g methanol extract (CLM). The yields from the *Tectonia grandis* were 39.61 g aqueous extract (TGA), 6.62 g chloroform extract (TGC) and 3.69 g methanol extract (TGM). All the samples were soluble in ethanol and sparingly soluble in water except *Tectona grandis* that was soluble in the two solvents.

Preparation of dye baths

Twelve dye baths were prepared in all. For preparation of the dye baths, 1.00 g of each sample; BN1A, BN1C, BN1M, BN2A, BN2C, BN2M, CLA, CLC, CLM, TGA, TGC and TGM was placed a in 500 mL beaker along with 2.00 g of NaOH and 2 g Na_2SO_4 respectively. To this was added 150 mL distilled water and heated to a temperature of 45^{o}C until a uniform mixture/was obtained.

Dyeing of cotton and polyester fabrics

Twelve pieces of 30 cm x 30 cm of each of the white fabrics (cotton and polyester) were prepared by boiling in 10% NaOH for 15 min to remove starch and other impurities and then introduced into each dye bath and the temperature was raised to 80°C. This allowed to simmer at that temperature for 30 minute. The dye bath was removed from source of heat and allowed to cool to 40°C for 15 minute. The fabrics were removed from the cooled dye bath, rinsed with distilled water and allowed to dry at room temperature for 6 h, the dried fabrics exhibited different colours.

Fastness tests of unmordanted fabrics

Colour fastness to acid

Twelve pieces of each fabric cotton and polyester (5 cm x 5 cm) from the dyed 30 cm x 30 cm were dipped in 10 % HCl for 5 min removed without rinsing and allowed to dry at room temperature.

Colour fastness to alkali

Another twelve pieces of each fabric (5 cm x 5 cm) cut from the dyed 30 cm x 30 cm were dipped in 10 % NaOH solution for 5 min removed without rinsing and allowed to dry at room temperature.

Wash fastness

Again twelve pieces of each fabric (5 cm x 5 cm) from the dyed 30 cm x 30 cm were soaked in 10% soap solution for 6 h, washed for 5 min rinsed in water and dried at room temperature[19].

Mordanting and dyeing of fabrics

Exactly 0.4 g of stannous chloride ($SnCl_2$), copper (II) sulphate ($CuSO_4$), ferric chloride ($FeCl_3$) and potassium dichromate ($K_2Cr_2O_7$) were weighed out separately into a 250 mL beaker and dissolved in 100 mL of hot water respectively. To each salt were added 0.40 g Na_2CO_3 and 0.60 g Na_2SO_4 and allowed to simmer for 10 min fresh twelve pieces of each cotton and polyester fabrics 5 cm x 5 cm were each soaked separately in each metal salt solution for 45 min at a temperature 60°C. The fabrics were removed and introduced into freshly prepared dye baths using the method in section as described above 2.4. The temperature of the baths was gradually raised to 80°C and allowed to simmer for 1 hour. After 1 h, the dye baths were allowed to cool for 40 min and the dyed fabrics removed, rinsed and spread at room temperature for 6 hours.

Fastness tests of mordanted fabrics

The same procedure used for the fastness property tests for the unmordanted fabrics was followed.

RESULTS

The percentage yield of the plant materials in the three different solvents is shown below as Table 1. Table 2 shows the colour of the plant samples on unmordanted cotton and polyester while Table 3 is the acid, alkaline and wash fastness of the extracts on unmordanted cotton and polyester fabrics with BN1A, BN1C, BN1M, BN2A, BN2C, BN2M, CLA, CLC, CLM, TGA, TGC and TGM. Tables 4 is the result obtained from dyed mordanted cotton and polyester fabrics with BN1A, BN1C, BN1M, BN2A, BN2C, BN2M, CLA, CLC, CLM, TGA, TGC and TGM. Tables 5 and 6 show the acid fastness, alkaline fastness and wash fastness, of samples BN1A, BN1C, BN1M, BN2A, BN2C, BN2M, CLA, CLC, CLM, TGA, TGC and TGM respectively.

Table 1: Percentage Yield of the Plant Materials

Plant	Weight of plant used (g)	Weight of filtrate (g)	% yeild
BN1A	100	43.55	21.78
BN1C	100	9.21	4.61
BN1M	100	14.57	7.29
BN2A	100	5.58	2.79
BN2C	100	9.24	4.61
BN2M	100	25.65	12.78
CLA	100	15.3	15.3
CLC	100	3.06	3.06
CLM	100	32.45	22.45
TGA	100	39.61	19.81
TGC	100	6.62	3.31
TGM	100	3.69	1.85

Table 2: Dyed unmordanted White Cotton and Polyester Fabrics

Plant Extract	Cotton	Polyester
BN1A	white	white
BN1C	Yellow	Light-yellow
BN1M	Light yellow	Brown
BN2A	white	white
BN2C	Peach	white
BN2M	Yellow	Yellow
CLA	white	white
CLC	pink	Orange
CLM	white	white
TGA	white	white
TGC	Reddish-gray	Gray
TGM	Pink	Light blue

Table 3: Properties of Unmordanted Dyed White Cotton and Polyester Fabrics

Extract	Cotton			Polyester		
	Acid fastness	Alkaline fastness	wash fastness	Acid fastness	Alkaline fastness	wash fastness
BN1A	1	0	0	0	0	0
BN1C	0	0	1	1	0	1
BN1M	0	0	0	0	0	0
BN2A	0	1	1	1	1	1
BN2C	0	0	0	1	0	0
BN2M	0	1	1	0	1	1
CLA	0	1	1	1	1	1
CLC	0	0	0	0	0	0
CLM	1	0	1	1	0	1
TGA	1	1	0	0	1	0
TGC	0	0	0	0	0	0
TGM	1	1	1	0	0	1

3= Very fast; 2= Fast; 1= Slightly Fast; 0= Not fast

Table 4: Dyed mordanted White Cotton and Polyester Fabrics

Extract	Cotton				Polyester			
	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$
BN1A	Deep pink	pink	-	-	cream	cream	-	-
BN1C	yellow	yellow	Orange	light pink	yellow	yellow	orange	lemon
BN1M	orange	orange	brown	yellow	orange	orange	orange	Red orange
BN2A	lemon	pink	-	-	cream	cream	-	-
BN2C	Light blue	Light red	-	-	blue	cream	-	-
BN2M	pink	Gray	orange	pink	brown	brown	Dark- orange	gray
CLA	Lemon	Light pink	-	-	brown	cream	-	-
CLC	-	-	-	-	yellow	cream	-	-
CLM	yellow	Light yellow	orange	yellow	yellow	yellow	orange	yellow
TGA	yellow	orange	-	-	cream	Dark brown	-	-
TGC	red	blue	yellow	gray	Dark pink	Pink	Navy blue	Navy blue
TGM	Deep- yellow	pink	-	-	yellow	pink	-	-

Table 5: Acid Fastness Test of the Mordanted Cotton and Polyester Fabrics

Extract	Cotton				Polyester			
	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$
BN1A	3	3	-	-	0	1	-	-
BN1C	3	2	3	3	2	1	3	2
BN1M	3	2	3	3	2	2	3	2
BN2A	1	1	-	-	0	0	-	-
BN2C	1	1	-	-	0	0	-	-
BN2M	3	2	3	3	2	1	3	3
CLA	2	1	-	-	1	0	-	-
CLC	-	-	-	-	0	0	-	-
CLM	2	3	3	3	0	0	-	-
TGA	2	2	-	-	2	2	-	-
TGC	3	3	3	3	2	2	3	3
TGM	3	2	-	-	0	1	-	-

3= Very fast; 2= Fast; 1= Slightly Fast; 0= Not fast

Table 6: Alkaline Fastness Test of the Mordanted Cotton and Polyester Fabrics

Extract	Cotton				Polyester			
	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$
BN1A	3	3	-	-	0	1	-	-
BN1C	3	2	3	3	2	1	3	2
BN1M	3	2	3	3	2	2	3	2
BN2A	1	1	-	-	0	0	-	-
BN2C	1	1	-	-	0	0	-	-
BN2M	3	2	3	3	2	1	3	3
CLA	2	1	-	-	1	0	-	-
CLC	-	-	-	-	0	0	-	-
CLM	2	3	3	3	0	0	-	-
TGA	2	2	-	-	2	2	-	-
TGC	3	3	3	3	2	2	3	3
TGM	3	2	-	-	0	1	-	-

3= Very fast; 2= Fast; 1= Slightly Fast; 0= Not fast

Table 7: Wash Fastness Test of the Mordanted Cotton and Polyester Fabrics

Extract	Cotton				Polyester			
	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$	$CuSO_4$	$SnCl_2$	$FeCl_3$	$K_2Cr_2O_7$
BN1A	3	3	-	-	0	1	-	-
BN1C	3	2	2	3	2	1	3	2
BN1M	3	2	3	3	2	2	3	1
BN2A	1	1	-	-	0	0	-	-
BN2C	1	1	-	-	0	0	-	-
BN2M	3	2	3	3	2	1	3	3
CLA	2	1	-	-	0	0	-	-
CLC	-	-	-	-	2	0	-	-
CLM	3	3	3	3	0	0	2	2
TGA	3	3	-	-	1	1	-	-
TGC	3	3	3	3	2	2	3	3
TGM	3	3	-	-	0	1	-	-

3= Very fast; 2= Fast; 1= Slightly Fast; 0= Not fast

DISCUSSION

Table 1, it could be observed that methanol was the best solvent for the extraction of the constituents of CLM and BN2M while water was the best solvent for BN1A and TGA. Chloroform was not a good solvent for the extraction of the various samples. The red colour of red *Baphia nitida* showed a wavelength of maximum absorption at a longer wavelength of 630-650 nm, the yellow extract at 600-612 nm in the electromagnetic spectrum. The green colour of the Teak leaf showed absorption at 550 nm also in the visible region. These absorption maxima are the resultant effect of the degree of conjugation in the extracts[24]. The plant extracts gave varying colours when unmordanted white cotton and polyester fabrics (5 cm x 5 cm) were dyed with the different twelve plant extracts as could be seen in Table 2, not all the plant dyes gave positive results. These different colours could be as a result of solvent effect and the nature of the fabric being dyed. The fastness properties of the unmordanted cotton and polyester gave very poor results on a scale of 0, 1, 2 and 3, Table 3. The fabrics showed very poor acid fastness, alkaline fastness and wash fastness.

Fresh white cotton and polyester fabrics were then treated with solutions of different metal salts called mordants and introduced into the different dye bath solutions of the plant extracts. These plant extracts and the fibers; cotton and polyester formed chelated complexes with mordants or salts of heavy metals such as tin, iron, chromium and copper. Since the chelated complex is, in effect, a bond to the metal ion, then the metal serves as a link to bond these dyes to the cotton and polyester fibers Fig. 1[25]. $CuSO_4$ mordant formed strong bond with plant samples BN1A, BN1C, BN1M, TGA, TGC and TGM. $SnCl_2$ was a good mordant for TGA, TGC and TGM. These mordanted fabric were very fast to acid and washing. $CuSO_4$ and $K_2Cr_2O_7$ mordanted fabric dyed with BN1A, BN1C, BN1M, TGC and TGM were fast to alkaline and acid. Some of the mordanted fabrics gave positive results and very fast colours on the fibers using a scale of 0-3, Table 4. The colour results from TGC varied from red, blue, gray, dark pink and navy blue; intriguing colours that were very fast to acid, alkali and washing. Only two colours were obtained from CLC; yellow from polyester mordanted with $CuSO_4$ and cream colour from that of $SnCl_2$. CLM gave yellow and orange colours with the mordanted cotton and polyester fibers. BN1C gave yellow colours with $CuSO_4$, $SnCl_2$ and $FeCl_3$ mordanted cotton and polyester fabrics but the $K_2Cr_2O_7$ mordanted cotton was light pink while the $K_2Cr_2O_7$ mordanted polyester gave lemon colour. BN1M fraction gave colour ranging from yellow, orange and red orange with all the mordants but brown colour with $FeCl_3$ mordanted cotton. TGC and TGM extracts were samples that could be useful when pink colour is desired in the dyeing of cotton and polyester as long as mordants such as $CuSO_4$, $SnCl_2$ were used. This shows that if different metals are used with the same dye, the resulting colour is always different[25]. CLM, BN1C, BN1M, BN2C, BN2M, TGC and TGM extracts showed good wash, alkaline and acid fastness property. In some, the fastness property was on a scale of 3 and in some cases, the fastness property was on a scale of 1.

The health and environmental problems posed by synthetic compounds of which colourants are included cannot be overemphasized; hence, natural products are gaining attention because of their safety, non-toxicity and environmental friendliness 11, 13, 20. The extracts from these plant species could probably be used like other natural dyes such as indigotin, which is obtained from fermentation of *Indigofera tinctoria* and is used widely to dye cotton fabric in the western part of Nigeria. The aqueous extracts from these plants could be utilized for the colouring of food to enhance the colour in the local food industry, herbal supplements and pharmaceuticals. They might be useful just like the other solvent dyes in the dyeing of natural and synthetic fabrics in the textile industry.

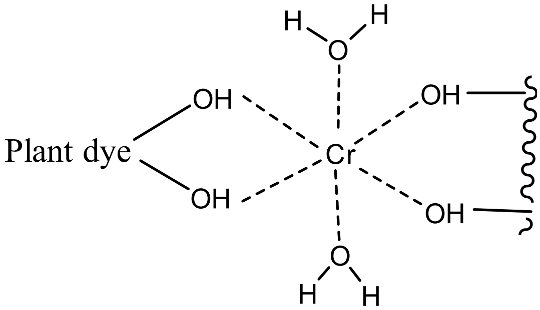

Fig.1. Complex of the mordanting metal, the dye and the fiber

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Conflicts of Interest

The authors declare no conflict of interest.

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