COLOUR EXTRACTION FROM GUINEA CORN (SORGHUM BI- COLOUR L) AS TEXTILE DYE USING TREE EXTRACTS AS MORDANTS

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ABSTRACT

The search for natural dyes have been revived greatly due to the global environmental issue of the recent discovery of the harmful nature of some synthetic dyes on human skin. For this reason, the Global Organic Textiles Standard (GOTS) permits the use of safe synthetic dyes only. Recent researches have shown that most of natural dyes and mordants are safer to human than synthetic. Hot and cold water extracts from sorghum bi-colour plant were applied on cotton and linen (direct dyeing) to investigate its dyeing characteristics – dye-ability and fastness potentials. The discovery of the synthetic or chemical harmfulness further necessitated a move away from the use of chemical substances in the improvement of the dye-ability and fastness potentials of these extracted dyes on textile substrates. Consequently, exploration of the possibility of plant extracts as mordant becomes an option of investigation. Thus mordants used in this particular experiment were derived from mahogany, locust bean and shear butter tree barks. The results of the experiment show that cotton has high rate of dye intake, than linen. On a similar note the colours obtained depend most on the use of different or no mordant. Hot water extraction appears more effective, while the colours obtained ranges from deep to light lilac and various shades of brown colour. From the result samples, the three tree mordant dyeing show not much difference in colour.

Key Words: Colour, Extraction, Guinea corn (Sorghum bi-colour L), Textile, dye, Fabric

INTRODUCTION

Before the ready available imported factory – made dyes, locally produced dyes were described as colouring agents. People have dyed fabrics and other materials for more than 5,000 years, with the use of a fixing agent (mordant) using locally produced vegetable dyes. The discovery of synthetic dyes in 1856 became an epoch in the history of textile which was further magnified by global industrialization. Dye which is defined as a substance that is used to change colour of things such as clothes, hair etc (Merriam Webster, 2015) became a necessary material in the production of industrial goods as it creates attractiveness, variety and enables choice. when dye is applied on materials such as fiber, it must not only be capable of attaching itself to the substances or materials' surface for a period of time, but it should have resistance to laundering and cleaning with chemicals like soap and detergents as well as resist fading due to exposure to sunlight and perspiration, . Such property is known as colour fastness, an important property in the production of textile goods.

The use of dye stuffs is as old as textiles themselves and pre-dates written history. Dyes are obtained from two main sources; the natural dyes and synthetic dyes. Natural dyes can be defined as those organic materials that have the ability to color fiber (Saxena and Raja, 2014). These dyes can be obtained either from plants, animals and insects secretions. Until the mid-19th century, all dyestuffs were made from natural materials, mainly vegetables and animal matter. Vegetable dyes can

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be extracted from bast, fruits, leaves, bark, flowers, roots and stems of different plants. These category of dyes are highly sought afterrecently because they have been investigated and found to be eco-friendly due to their ability to be renewed and biodegraded. As a result they are skin friendly and may also provide health benefit to the wearer and can equally be used to dye synthetic fibers (Saxena and Raja, 2014). According to MD. Mahabub Hassan et al, (2015), natural dyes were used to give colour to raffia, cotton cloth, as well as in the tanning of leather and the preparation of cosmetics, food, in medicine and also possess therapeutic properties.

Various colours can be obtained using various fixing agents called mordant. Mordant is a chemical that fixes a dye in or on a substrate by combining with the dye to form insoluble compound. Most plant dyes are not fast on fabric; mordant is then used to enhance the fastness quality of such dyes. But some plants or leaves have inherent colour fastness on fabric, they are referred to as substantive plants and those needing fixative are called fugitives. Some of these dyes are useful as indicators, stains, or solvent dyes and the fact that textile fibers especially cellulosic, do not have much affinity for the majority of the natural dyes (Bailey and Bailey, 1976), makes it more imperative for addition of mordants which acts as a link between the fiber and the dyestuff. This creates an enabling environment for the dye molecules, especially from the fugitive plants, to be transferred into the amorphous parts of the fiber. Sorghum can be said to be a substantive plant, but most often mordants are added to enhance the colour output on substrates and also to achieve varying colours on different substrates. Natural dye sorghum red pigment is a kind of natural product from sorghum shell (Lui et al, 2013). Sorghum is a genus with many species and subspecies, and there are several types of sorghum, including grain sorghums, grass sorghums (for pasture and hay), sweet sorghums (for syrups), and Broomcorn. The focus of this species page is on *Sorghum bicolor L*, or grain sorghum.

Other natural coloured dye such as yellow came from the bark of the shingale-wood tree (Terminalia Ivorerosis; Yoruba “afara” , Igbo “edo”) in the south and in the north from rhizome of turmeric (circuma longa; Hausa “gangamua'). Traditionally to prevent running, the dyes were fixed or rendered insoluble by a mordant, generally wood ash. Blue dye is one of the earliest natural dyes known to man from an isolated plants of the genus “Indigofera tinctoria” which grows in India, China, Japan, Central America, West Indies Brazil, South and Central Africa, Java (Indonesia) etc. Indigo also grows in a certain part of Nigeria (Etcher 1976). He added that other domestic dyes are gotten from the leaves and barks of many plants and trees that are utilized in producing other colours of dyes. He also mentioned that shades of red can be obtained from leaves of guinea corn (*Sorgum vulagre*), leaves of teak (*Lawsonia innermis*), barks and roots of African rose wood (*Pterocarpus erinaceous*), wood of the cam wood (*Baphia nitida*). He explained further that the sap of old physic nut tree (*Jatropha curcas*) produces a black dye (Etcher 1976 in Udeani, 2015). Most of these colours are enhanced with the use of mordant mainly in form of alkalis. This experiment is carried out with tree liquid extracts of khaya senegalensis (mahogany), pakia biglobosa (locust beans), and vitellaria paradoxa (shear butter) as mordants instead of the normal alkalis.

A colourant, as described by Chemical Industry Education Center (ICEC) on the other hand, can have affinity for a substance either from nature or in artificial way by mainly treatment of the

material surface or the amorphous region of the fiber polymer system in order to add beauty to its surface (ICEC, 2013). The early invention of dye started from early man who used natural sources such as soils, tree-roots, animal blood, flowers, fruits, charcoal, leaves and barks to beautify their homes or houses, body decorations etc. The dyes that are obtained from animal sources are called cochineal, and those that are got from minerals are Ocher. Lately there has been increasing interest in natural dyes as the public become aware of ecological and environmental problems related to the use of synthetic dyes. Use of natural dyes cut down significantly on the amount of toxic effluent resulting from the synthetic dye process.

Natural dyes can provide the much needed alternative to the complex world of chemical dyes. These dyes are environmentally sound and can be grown by organic methods. They are inherently carbon neutral. Vibrant colours can be produced from natural dyes. Apart from the ecofriendly and the biodegradable nature of natural dyes, the new colours produced from natural dyes exhibit ease and simplicity of use and are generally reliable with regards to strength and composition. The produced colours are certainly reproducible. For these reasons the interest in the use of natural dyes is growing because it is perceived to provide an environment-friendly fabrics and garments. Natural Dyes can make textile industries more competitive, by reducing production costs and eliminating the huge expenses of chemical imports and toxicity.

Thematic Studies

A. The plant sorghum

Guinea corn "(sorghum guanines) is a name for durra, a grain traditionally grown in Asia, the Middle East, Africa and southern Europe. It was typically ground into a meal and made into bread. It is known as Indian millet, African millet or pearl millet (Wikipedia contributors, 2006,). Africa Guinea corn grows on a variety of soils but needs well drained highly alkaline sandy soil. It needs rainfall range of about 400 - 750mm, 380 - 650mm rainfall is also adequate (Wilson and white man 1965 in fao.org, 2015). It is grown in areas which are too dry. Planted in May-June in the Northern Nigeria 10 - 15cm apart. Sorghum guineas is commonly called guinea corn. It is drought tolerant. The great advantage of sorghum is that it can become dormant under adverse condition and can resume growth after relatively severe drought. Shoot removal lowers its capacity to withstand drought and stops growth before floral initiations and the plant remains vegetative. It will resume leaf production and flower when conditions again become favorable for growth. Late drought stops leaf development but no floral imitations (Rampho and Reynolds, 2005). Sorghum cultivation is done on wide range with good drainage as it can extract water from low sources due to its deep roots. Sorghum requires full seed bed preparation for good performance. Well-spaced sorghum with sufficient rainfall do not need fertilizer for good performance (Vurv.cz, 2015).

Sorghum grain ranks 5th in cereals for global production (fao.org, 2015). The Columbian encyclopedia described sorghum as annual or short-term perennial, culms up to 4 m or more high, sweet except in grain types; panicle 8-40 cm long, lose or contracted; sessile spikelets 4- 6 mm long. Snowden 1936 in fao.org, (2015) described sorghum's leaf as panicle loose and open, the upper branches slender and often drooping. Mature glumes of sessile spikelets either red or reddish brown, or straw coloured or yellowish, sometimes flushed with dark red or reddish brown; grain predominantly red or reddish brown.

There are no creeping rhizomes and the mature sessile spikelets are persistent, less than twice as long as wide, not ridged in the middle, 3-4.5 mm wide (Chippendall, 1955 in fao.org, 2015). The bicolor sorghums are characterized by long, clasping glumes at least three-fourths as long as the broadly elliptical grain (de Wet, Harlan & Kurmarohita, 1972 in fao.org, 2015).

B. Sorghum as an economic plant.

Sorghum is a crop, when stored properly, can stay for a number of years without being harmed by insects or any form of infections. The leaves and stems of guinea corn serve as food (fodder) for the animals. It equally possesses other domestic uses to the society as it is used in the production of items such as bed mat, fencing, building of hut and shades etc. It can also be used as musical instrument such as flute. About 40 - 60cm of the stems is consumed in the form of sugarcane. It is also used to generate income locally. Some juice is extracted from the stem as well as colour solution when wet. Guinea com is also used to give specific colour e.g. reddish brown which is specifically prepared for medication or to colour porridge (De Alencar Figueiredo et al, 2010).

(C) Sorghum as dye

Sorghum bi-colour (guinea corn) is so named due to the inherent colours possessed by the plant. The reddish brown colour is physically seen on every part of the plant and these were used for the extraction except the seeds that is grown for food. This feature seem to be an evidence that sorghum corn is high in tannin (wisc.com, 2015). The colour was extracted by boiling and the quantity to be boiled and water depend wholly on the amount of cloth to be dyed. The fact that the traditional practice of dyeing items with natural plant dyes is fast going extinct is the attraction to this experiment.

1. Materials and Methods

Sorghum plants were collected from a home farm in Zango Igabi local government area of Kaduna State Nigeria. The plant was harvested or collected by hand. It was identified by Mr. Tunde Shodimu of Department of Forestry, Federal College of Forestry Mechanization Afaka Kaduna State.

A. Preparation of Sorghum plant for experiment

Matured sorghum plant – leaves, stem and stalk were collected, cut into pieces, to be boiled in a pot. The leaves, stems and stalks were arranged in a pot with water enough to cover the specimen.

B. Dye Extraction

The dye was extracted using boiling method.

50grammes of sorghum's leaves and stalk were gathered and boiled in 3litters of water in a pot for 1hour. The reddish brown liquid was decanted into a container after boiling.

C. Mordant for Experiment

The mordants used for this experiment were natural tree liquid extracts from Shear Butter (vitellaria paradoxa) called *kadanya* in Hausa, Mahogany (Khaya Senegalensis) called *madachi* in Hausa, and Locust Beans (Pakia biglobosa) called *dorawa* in Hausa. The leaves and barks of each of these trees were collected, pounded and boiled separately to extract the liquid that forms the mordant for this experiment. These liquid extracts were used because they appear to possess high tannin content. The presence of tannin was suspected as these plants' extracted liquids were used traditionally to give colour to the floor of a newly built house. This inspired the use of plant extract as

mordant for textile dyeing.



Plate 1; Trunk, leaves and bark of Mahogany (English), "*Madachi"* (Hausa), Khaya Senegalensis (Botanical name). Photos by Dauda Adamu Manila



Plate 2: Trunk, leaves and bark of Locuts beans (English), "*Dorawa*" (Hausa), Pakia biglobosa (Botanical name). Photos by Dauda Adamu Manila



Plate 3: Trunk, leaves and bark of Shear butter (English), "*Kadanya"* (Hausa), Vetilleria paradoxa (Botanical name). Photos by Dauda Adamu Manila

A. Fabric Used for the experiment

The fabrics used for this experiment were picked from natural cellulosic fiber group (cotton and linen). Cotton is the most common and most widely used textile fabric. It is the cheapest natural fiber used in cloth application. The plant is indigenous to many sub-tropical countries (especially Nigeria). Cotton is chosen for this experiment because it has high affinity to dye, readily available and equally easily affordable. Linen, also a cellulosic fiber is derived from the stem of flax plant and ranks second in usage and availability. It is comfortable, hand washable and light weight. Linen also absorbs dye. These fibers were selected for their ergonomity, availability and affinity to dye.

These fibers were washed with detergent to remove impurities like starch and other additives used during weaving and dried in an open air drying line. After dyeing, a part of these fibers was washed with soap to ascertain the fastness of the dye on fibers – cotton and linen. Fabric is prepared by washing with detergent to remove impurities.

B. Other Materials and Tools

The following are the tools and materials used for the experiment: hand glove, dye bath, water, heat source, pot, measuring cylinder and scale.

C. Preparation of Dye Solution

Each of these tree mordant extracts was used individually with the dye extract to form a separate solution for this experiment. Mordants were mixed directly with the aqueous extracts of sorghum plant.

D. Procedure of Dyeing

In carrying out this experiment, the extract of sorghum bicolour obtained from hot aqueous extraction was used for both direct and mordant dyeing. The direct dyeing was carried out to investigate the level of tannin present in sorghum bi colour due to the obvious colour present in almost all the parts of the plant. Mordant dyeing on the other hand was to investigate the result of the use various natural tree liquid extract application with the sorghum extract and their reaction and fastness qualities on textile substrate (cellulose- cotton and linen).

E. Procedure

The following procedures were used in the experiment of the dyeability of sorghum bi colour as dye using textile materials of cotton and linen and tree extracts of khaya senegalensis, pakia biglobosa, and vitellaria paradoxa as mordant.

(i) Sorghum extract without mordant.

Items for the experiment

- 400ml of sorghum dye extract
- 4 pieces of 3 by 6 inches of cotton and linen fabrics.
- Boiling Time - 1hour.

Procedure

Immerse sample fabrics into a dye bath containing 400mls of sorghum bi-colour dye extract and boil for 1hour.

(ii) Sorghum extract with mordant:

Sorghum Extract with *khaya senegalensis* liquid extract

- 400ml of sorghum dye extract.
- 4 pieces of 3 by 6 inches of cotton and linen fabrics.
- 200ml of liquid extract mordant.
- Boiling Time - 1hour.

Procedure

Mix 200ml of *khaya senegalensis* liquid extract mordant into 400ml of sorghum bi-colour dye extract and stir to mix. The colour of the solution changed to deep brown. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Sorghum extract with *pakia biglobosa* liquid extract.

- 400ml of sorghum dye extract.
- 4 pieces of 3 by 6 inches of cotton and linen fabrics.
- 200ml of liquid extract mordant.
- Boiling Time - 1hour.

Procedure

Mix 200ml of *pakia biglobosa* liquid extract mordant into 400ml of sorghum bi-colour dye extract and stir to mix. There was a slight change in the colour of the solution (slight deeper brown). Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Sorghum extract with *vitellaria paradoxa* liquid extract

- 400ml of sorghum dye extract.
- 4 pieces of 3 by 6 inches of cotton and linen fabrics.

- 200ml of liquid extract mordant.
- Boiling Time - 1hour.

Procedure
Mix 200ml of *vitellaria paradoxa* liquid extract mordant into 400ml of sorghum bi-colour dye extract and stir to mix. There was no change in the solution colour as the colour still remained brown. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Sorghum extract with the three mordants

- 400ml of sorghum dye extract.
- 4 pieces of 3 by 6 inches of cotton and linen fabrics.
- 70ml of *khaya senegalensis* liquid extract, 70ml of *pakia biglobosa,* and 70ml of *vitellaria paradoxa*. These makes 210ml of liquid extract mordants
- Boiling Time - 1hour.

Procedure
Mix the three liquid extracts mordant of *khaya senegalensis, pakia biglobosa* and *vitellaria paradoxa* liquid extract mordant into 400ml of sorghum bi-colour dye extract and stir to mix. There appear to be no change in the solution colour as the colour still remained brown. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Light and Wash Fastness Test
These tests were carried out using Blue Scale and Grey Scale respectively. This is to determine the degree of fading of this dyed samples when exposed to sunlight as well as to know the resistance of these sampled dyed fabrics to the repeated action of soap solution as used in washing.

Result and Discussion
The following tables show the result of the experiments of direct and mordant dyeing carried out on sorghum bi-colour (guinea corn) dye extracted through aqueous boiling with natural tree mordant liquid extracts from *khaya senegalensis, pakia biglobosa,* and *vitellaria paradoxa.*

Table 1
Sorghum Extract without Mordant (Direct)

Observation					Inference	
Solution	**Before washing**		**After washing**			
	Cotton	**Linen**	**Cotton**	**Linen**	**cotton**	**Linen**
The solution colour showed deep reddish brown after extraction	Showed high rate of dye absorption. The colour took a while to show but high stain of lilac colour was observed.	Just as in cotton, it took a while to observe colour change. The absorption rate was less than cotton. The stain was still lilac colour but less in intensity.	Lost some colour which reduced the intensity of the colour. The stain still remained purple.	Showed more loss of colour after desizing with a lighter purple stain	Have affinity to the dye extract and can be used.	Have ffinity to the dye extract but not as much as cotton.

Table 2
Sorghum Extract with *khaya senegalensis*

Observation						**Inference**
Solution	**Before washing**		**After washing**			
	Cotton	**Linen**	**Cotton**	**Linen**	**cotton**	**Linen**
The colour of the solution changed to deep brown after mixing extract with the liquid mordant extract.	Absorbed more colour than linen with normal absorption rate. There was a change in colour from brown to deep reddish peach.	Showed low absorption rate than cotton. The reddish brown colour was observed with high intensity	Little colour was lost during desizing. The colour became lighter and close to lilac.	The same as in cotton but the high intensity was completely lost. with a little visible peach	Have more affinity to the solution than linen with high fastness quality. This also affirms the tannin presence in the sampled mordant	Have moderate affinity to the solution. Showed lighter but the same colour as cotton. Showed colour fast affirms high tannin presence in the solution.

Table 3
Sorghum Extract with *pakia biglobosa*

Observation					Inference	
Solution	Before washing		After washing			
	Cotton	Linen	Cotton	Linen	cotton	Linen
There was a slight change in the colour of the solution to slightly deeper reddish brown.	The fabric showed high absorption of solution with stain of dark graysh lilac colour. Absorption was high and the colour intensity was modrate	Showed also deep grayish lilac colour a little closer to cotton. The colour intensity was high with the same rate of solution absorption.	After desizing, the fabric colour showed no change as little colour loss was observed with the colour intensity the same.	Linen fabric exhibited high loss of colour leaving a grayish lilac colour.	Have high affinity to the solution of extracts exhibits great enhancement of fastness from mordant.	Have moderate affinity to the solution than cotton. Showed less retention of colour

Table 4
Sorghum Extract with *vitellaria paradoxa.*

Observation					Inference	
Solution	**Before washing**		**After washing**			
	Cotton	**linen**	**Cotton**	**Linen**	**cotton**	**Linen**
There was no change in the solution after mixing sorghum dye extract and liquid extract from *vitellaria paradoxa*	Showed high absorption of the dye solution and a very good stain of deep red brown colour with high intensity.	Equally showed high absorption of the liquid. Fabric showed a deeper red brown with normal intensity compared to cotton	Little or no loss of colour leaving a stain of deep gray lilac,	High loss of colour leaving a stain of gray lilac	Excellent fast for cotton	Good fast if the colour is desired.

Table 5
Sorghum Extract all three tree mordants.

Observation					Inference	
Solution	**Before washing**		**After washing**			
	Cotton	**linen**	**Cotton**	**Linen**	**cotton**	**Linen**
There was no change in the solution after mixing sorghum dye extract and liquid extract from the three natural tree mordants	Showed high absorption of the dye solution and a very good stain of deep chocolate brown colour with high intensity.	Equally showed high absorption of the liquid. Fabric showed a deeper red brown with normal intensity compared to cotton	Little loss of colour leaving a stain of brighter chocolate brown	Loss of colour leaving a stain of grayish reddish brown.	Excellent fast for cotton	Good fast if the colour is desired.

Discussion

The result of the experiments of direct and mordant dyeing carried out on sorghum bi-colour (guinea corn) dye extracted through aqueous boiling with natural liquid mordant extracted from *khaya senegalensis, pakia biglobosa,* and *vitellaria paradoxa* show that various degrees of colours can be obtained, using different mordant with the same dye liquid extract, ranging basically from extract colour of reddish brown through lilac to grayish brown and even chocolate brown.

The direct dyeing with sorghum dye extract showed the solution colour, deep reddish brown, after extraction as was reported by De Alencar Figueiredo et al, (2010). After dyeing of sample fabrics, cotton showed high rate of dye absorption as was observed by Shaukat et al (2009) and Md. Mahabub Hassan et al (2015). The colour took a while to show but high stain of lilac colour was observed. Linen, just as with cotton, took a while to depict colour change. The

absorption rate was less than that of cotton. The stain was still lilac colour but less in intensity. After desizing, cotton lost some colour which reduced the intensity of the dyed fabric colour. The stain still remained purple while linen showed more loss of colour after desizing with a lighter purple stain. This reveals that cotton has more affinity and high dye ability to sorghum dye solution than linen. The investigation with sorghum extract using *khaya senegalensis* as mordant showed a change in solution colour from light to deep brown and from brown to deep reddish peach on cotton while linen still showed reddish brown. After desizing, the sampled fabrics, though lost colour showed colour very close to lilac though linen's colour is ligher. This also confirmed the tannin presence in the liquid mordant. Cotton still exhibits more dyeability and fastness quality than linen.

The investigation of Sorghum extract with *pakia biglobosa* liquid extract as mordant exhibited change in the solution colour to a slight deeper reddish brown after mixing the two liquids. After dyeing, the sampled fabrics showed grayish lilac colour. Linen showed high loss of colour while cotton depicted great fastness to the dye solution confirming an enhancement of fastness from mordant. Sorghum liquid extract when mixed with *vitellaria paradoxa* showed no reaction and no change in colour. Cotton showcased a very good stain of deep red brown with high intensity which was retained. Linen showed high absorption of dye and even more intense in colour but lost almost all with a little stain of gray lilac left. A further investigation was carried out on mixing all the three mordant with sorghum extract solution to ascertain if there will be anything new but the investigation showed no change in the solution after mixing and the results depicted cotton's high attraction to this liquid with the exhibition of a very good stain of deep chocolate brown with high intensity after dyeing. Linen on the other hand, also showed high absorption of the mixture of dye extract and the natural tree liquid extract mordant. After rinsing, cotton exhibited high fastness quality than linen with a brighter chocolate brown colour while linen after loss of colour left grayish reddish brown which can be used if desired. This therefore gives excellent fast for cotton and good fast for linen.

Generally in this investigation, it was observed that hot water extract is more effective for extraction of dye liquids from natural resources as was observed by Yusuf et al (2005) and Hafiz et al (2012). Conclusively, the dyeability and fastness qualities of dye extract from sorghum on cotton and linen (cellulose fibers) are not as excellent as with wool or silk (protein fiber). Udeani (2015) stated that different investigation has revealed that cotton is less suitable for many natural dyes, although it cannot be ruled out completely as a substrate for carrying out investigations on natural dye sources as desirable stains can still be obtained for various dyeing activities.

CONCLUSION

This study revealed that sorghum plant is not used only as medicine, food for both man and animal but can be useful in the textile industry for dyeing of some natural fibers using the appropriate fixing agent. Sorghum extracted dye can be used to impart desirable colours ranging from deep red violet to light lilac onto textile substrates as demonstrated in these experiments. It equally revealed that tannins inherent in plants can also serve as a fixing agent in maintaining the fastness quality of plant dyes which is a plus especially at this time when environmental safety and ecofriendly materials are in high demand.

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