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Optimization of Sorghum Bi-colour as Fabric dye using Exhaustion Method

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Abstract Centuries before the discovery of synthetic dyes, natural dyes were the only dye open to mankind. Historically, the first synthetic dye was developed in 1856 and during the industrialization of textile production, the rate of synthetic dye production became enormous and as a result, the use of natural dye almost went extinct. However, the recent discovery of the harmfulness of synthetic dye towards the human body and its toxic effects on the skin enhanced the use and intense research on varying natural plants, animals, minerals and insect secretions as colourants for textile substrates. Of all, plants – bark, roots, leaves and flowers is the most explored and experimented. Sorghum bi-colour L (Guinea corn) is one of such plants. In this study therefore, the liquid extract of sorghum bi–colour L was optimized using different alkalis and its potentials as fabric dye was analyzed through exhaustion method using cotton and linen fabrics. Hot and cold water extraction method was used to determine the best method of extracting the dye. The results show that cotton to an extent showed high level of absorbency than linen and hot water extract is a better method of dye extraction. The colours obtained ranged from lilac to brown hues.

Keywords Sorghum bi-colour, dye, potential, fabric, exhaustion, extraction

Introduction

Down in history, natural dye has been a colourant for textile substrates before the discovery of synthetic dye in 1856 by Sir Henry Perkins through the use of coal tar in the laboratory. The use of plants as source of colourant for textile substrate was as old as man. A plant dye which is an aspect of natural dye was open to man to explore and experiment. The use of synthetic dye was so intense due to global industrialization and the obvious advantages of having brilliant and numerous colours not found in the colours from the nature among others. These conditions almost shelved off natural dye to the verge of extinction. However the recent discovery by Saxena and Raja (2014) [1] of the toxic nature of synthetic dyes and their harmfulness to human skin based on their production and application has revived the search, exploration, experimentation and use of natural dyes. The use of natural dyes was further enhanced by the negative environmental factors of synthetic dyes which are pioneered by pollution of air and water due to the huge waste incurred in its processing and use. Several of these dyes have been banned because they cause allergy-like symptoms or are carcinogens [2]. Natural dyes on the other hand have been considered as eco-friendly due to their ability to be renewed and biodegraded. They have been found to be skin friendly and may also provide health benefit to the wearer and can equally be used to dye synthetic fibers [1]. Research has also shown that natural dyes were used in cosmetics, food, leather, in medicine and also possess therapeutic properties [3].

These dyes are derived from natural sources of plants-barks, roots, leaves and flowers, insect secretions, and minerals and research shows that plant is the most explored. Sorghum bi-colour (guinea corn) is one of those plants. Natural dye of sorghum red pigment is a kind of natural product from sorghum shell [4]. It has been used in the production of alcohol. The whole plant is used for forage, hay or silage. The stem of some types is used for building; fencing, weaving, broom making and firewood. Industrially it can be used for vegetable oil, waxes and dyes. It is grain sorghum and is usually ground into a meal that is made into a porridge, flatbreads and cakes. The early knowledge of sorghum as dye creates an opportunity for further investigation on how viable this plant can be in producing more colours using varying mordant mostly in alkaline medium. This paper then goes to investigate these possibilities of obtaining more colours and the dyeability of sorghum bi-colour L extract on fiber substrates as well as it wash and light fastness qualities on fiber.

(A) *Plant materials*

Guinea corn "(sorghum guanines) is a name for durra, a grain traditionally grown in Asia, the Middle East, Africa and southern Europe. This is a cane like grass, up to 6m tall with large branched clusters of grains. The individual grains are small- about 3-4 mm in diameter. They vary in colour from pale yellow through reddish brown to dark brown depending on the cultivar [5]. Sorghum grain is a staple foodstuff in semiarid tropics of Asia and Africa.It was typically ground into meal and made into bread. It is known as Indian millet, African mil1et or pearl millet. African Guinea corn grows on a variety of soils but needs well drained highly alkaline sandy soil. Its need to rainfal1 range of about 400–750 mm, 380–650 mm rainfall is also adequate. It is grown in areas which are too dry. Sorghum is planted in may-June in the Northern Nigeria 10-15 cm apart. Sorghum guineas are commonly called guinea corn. It is drought tolerance. 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 wil1 resume leaf production and flower when conditions again become favourable for growth. Late drought stops leaf development but no floral imitations [5]. 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 [6].

(B) *Sorghum as an economic plant.*

Sorghum is a crop, when stored properly, can stay for number of years without being harmed by insects or any form of infections. The leaves and stems of guinea corn serve as food (fodder) to the animals. It equally possess 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 40-60 cm of the stems is consumed in the form of sugarcane. It is also used to generate income locally. The stems are also used to extract juice as well as colour solution when wet. Guinea corn is also used to give specific colour e.g. reddish brown which is specifically prepared for medication or to colour porridge [7].

(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 seems to be an evidence that sorghum corn is high in tannin [8]. 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 Zangon Aya, Igabilocal government area of Kaduna State Nigeria. The plant was harvested or collected by hand. It was identified by a specialist in the Department of Forestry, Federal College of Forestry and Mechanization Afaka Kaduna State. The design of this study is experimental design and the main aim of this experiment is to investigate the potentials of sorghum bi-colour L as textile dye and its ability to produce more colours using alkaline compounds.

A. *Preparation of Sorghum plant for experiment*

Matured sorghum plant – leaves, stem and stalk were collected, cut into pieces, long enough 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, stems and stalks 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. *Exhaustion Method*

Exhaustion was described by Hasan et al (2015) [2] as the amount of dyestuff which is diffused in the fiber from the dye bath at the time of dyeing. The degree of exhaustion and fixation of the dyestuff was measured by Hasan et al by using DT A 01 Perkin Elmer Singapore and the consideration of the colour concentration of mordants. In this paper, exhaustion will be considered as the level of absorbency and the depth or intensity of the colour exhibited by the fiber after immersion in the dye bath.

D. *Mordant for Experiment*

The mordants used for this experiment were caustic soda and hydrosulpate, potash and salt. These alkalis were used because they appear to be the major components used with synthetic and natural dyes especially in home dyeing.

E. *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.

F. *Other Materials and Tools*

The following are the tools and materials used for the experiment: hand glove, dye bath, water, sorghum leaves, stems and stalks, heat source, pot, measuring spoon and scale. Alkalis used are table salt, hydrosulphate and caustic soda, and potash.

G. *Preparation of Dye Solution*

Each of these alkalis was used individually to form a separate solution for this experiment. Alkalis were mixed directly with the aqueous extracts.

H. *Procedure of Dying*

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 of various alkalis application with the extract and their reaction and fastness qualities on textile substrate (cellulose- cotton and linen).

I. *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.

(i) Sorghum extract without mordant (Direct dyeing)

Items for the experiment

* 400 ml 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 400 ml of sorghum bi-colour dye extract and boil for 1 hour.

(ii) Sorghum extract with mordant:

Extract with Caustic Soda and Hydrosulphate:

* 400 ml of sorghum dye extract.
* 4 pieces of 3 by 6 inches of cotton and linen fabrics.
* 8 gm of caustic soda and hydrosulphite each.
* Boiling Time – 1 hour.

Procedure

Mix 8 gmof caustic soda and hydrosulphite mordant into 400 ml of sorghum bi-colour dye extract and stir to mix. The colour of the solution changed to brown. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Extract with Potash

* 400 ml of sorghum bi-colour dye extract
* 4 pieces of 3 by 6 inches (2 each) of cotton and linen fabrics.
* 8 gm of potash.
* Boiling Time – 1 hour.

Procedure

Mix 8 gm of potash mordant into 400 ml of sorghum bi-colour dye extract and stir to mix. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Extract with Salt

* 400 ml of sorghum dye extract.
* 4 pieces of 3 by 6 inches (2 each) of cotton and linen fabrics.
* 8 gmof common table salt

Boiling Time – 1 hour.

Procedure

Mix 8gmof common table salt mordant into 400 ml of sorghum bi-colour dye extract and stir to mix. There was no change in the colour of the solution. Pour solution into dye bath container. Immerse sample fabrics and boil for 1hour.

Light and Wash Fastness Quality Tests

After the experiment, the sampled fabrics were subjected to wash and light fastness test using Grey Scale of rating 1-5 grade and Blue Scale of rating 1-8 grade in order to determine their resistance to continuous repeated action of soap solution as used in washing and how much the colour will fade when exposed to sunlight respectively.

Results and Discussions

*T*he following are the results of the experiments carried out after immersion of sorghum bi-colour (guinea corn) dye extracted through aqueous boiling method.

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	Showed high rate of dye absorption. The colour took a	Just as in cotton, it took a while to observe colour	Lost muchcolour which reduced the	Showed more loss of colour after	Have affinity to the dye extract	Have affinity to the dye extract and

extraction	while to show but high stain of lilac colour was observed.	change. The absorption rate was less than cotton. The stain was still lilac colour but less in intensity.	intensity of the colour. The stain still remained lilac.	desizing with a lighter lilac stain	and can be used for pattern creation.	can be used for pattern creation.

Table 2: Sorghum Extract with Caustic Soda and Hydrosulphate

Solution	Observation				Inference	
	Before washing		After washing			
	Cotton	Linen	Cotton	Linen	Cotton	Linen
The colour of the solution changed to brown after mixing extract with the alkalis. A precipitate was formed	The fabric took a while to absorb the dye (low absorption rate). There was a change in colour from brown to reddish peach.	Showed high absorption rate than cotton. The same colour as cotton but with high intensity	The stain washed off during desizing andalmost disappeared leaving carton colour.	The same as in cotton but with a visible peach	Have less affinity to the solution than linen and not fast	Have moderate affinity to the solution. Showed very light stain of peach. A little fast.

Table 3: Sorghum Extract with Potash

Solution	Observation				Inference	
	Before washing		After washing			
	Cotton	Linen	Cotton	Linen	Cotton	Linen
There was no change in the colour of the mixture, although a little precipitate was formed.	The fabric showed stain of dark reddishbrown colour. Absorption was high and the colour intensity was dull	Showed also very deep reddish brown colour as seen in cotton with equal colour intensity and the same rate of extract absorption	After desizing, the fabric colour changed to grayish brown but there was loss of colour which reduced the colour intensity.	Linen fabric exhibited the same properties as was observed in cotton but with little patches of peach.	Have moderately high affinity to the solution of extract and potash but with low fastness quality.	Have more affinity to the solution than cotton. Showed better retention of colour

Table 4: Sorghum Extract with salt

Solution	Observation				Inference	
	Before washing		After washing			
	Cotton	linen	Cotton	Linen	Cotton	Linen
There was no change in the solution after mixing salt with sorghum extract.	Showed high absorption of the dye solution and a very good stainof deep red violet colourwith high intensity.	Equally showed high absorption of the liquid. Fabric showed grayish red violet with dull intensity compared to cotton	Loss of colour leaving a stain of deep lilac	High loss of colour leaving a stain of grayish lilac	Excellent fast for cotton	Good fast if the colour is desired.

Table 5: Light Fastness Test Result Using Blue Scale of Grade 1-7

S/No	Samples	Grade	Degree of Fading	Light Fastness Type
1	sorghum without mordant (b/w- cotton)	4	significant fading	V. Fair
2	sorghum without mordant (b/w-linen)	4	significant fading	V. Fair
3	sorghum without mordant (a/w - cotton)	5	moderate	Good
4	sorghum without mordant (a/w- linen)	6	slight fading	V.good
5	sorghum dye extract with caustic soda &hydros (b/w-cotton)	6	slight fading	V.good
6	sorghum dye extract with caustic soda &hydros (b/w - linen)	5	moderate	Good
7	sorghum dye extract with caustic soda &hydros (a/w - cotton)	7	v.slight fading	Excellent
8	sorghum dye extract with caustic soda &hydros (a/w - linen)	6	slight fading	V.good
9	sorghum dye extract with potash (b/w- cotton)	5	moderate	Good
10	sorghum dye extract with potash (b/w - linen)	4	significant fading	V.Fair
11	sorghum dye extract with potash (a/w - cotton)	3		Fair
12	sorghum dye extract with potash (a/w - linen)	4	significant fading	V. Fair
13	sorghum dye extract & salt (b/w - cotton)	7	v.slight fading	Excllent
14	sorghum dye extract & salt (b/w - linen)	6	slight fading	V.good
15	sorghum dye extract & salt (a/w- cotton)	7	v.slight fading	Excllent
16	sorghum dye extract & salt (a/w - linen)	6	slight fading	V.good

NOTE: b/w--- before wash; a/w---- after wash.

Table 6: Wash Fastness Test Result Using Grey Scale of Grade 1-5

S/No	Samples	Grade	Remark
1	sorghum without mordant (b/w1) cotton	1/2	Poor
2	sorghum without mordant (b/w2) linen	2	Fair
3	sorghum without mordant (a/w1) cotton	3	Good
4	sorghum without mordant (a/w2)	2/3	Good
5	sorghum with caustic soda & hydros (b/w1)	3/4	V. good
6	sorghum with caustic soda & hydros (b/w2)	2/3	Good
7	sorghum with caustic soda & hydros (a/w1)	4/5	Excellent
8	sorghum with caustic soda & hydros (a/w2)	3	Good
9	sorghum with potash (b/w1)	4	V. good
10	sorghum with potash (b/w2)	2	Fair
11	sorghum with potash (a/w1)	2	Fair
12	sorghum with potash (baw2)	4	V. good
13	sorghum & salt (b/w1)	3	Good
14	sorghum & salt (b/w2)	2	Fair
15	sorghum & salt (a/w1)	2/3	Good
16	sorghum & salt (a/w2)	3	Good

NOTE= b/w –before wash; a/w – after wash

1 – Cotton; 2 – Linen

Discussion

The discoveries in this experiment from extraction of dye using aqueous medium to dyeing of fabrics exhibited exciting results. In using different alkalis (caustic soda and hydrosulphate, potash, and salt),it was observed that different colours of varying intensities were obtained from different alkalis and the fixing strength of these alkalis depend highly on the fabric as reported by Burch, (2015) [9]. The use of hot aqueous medium in the extraction proved to be the most effective as agreed by Samanta and Agarwal, (2009), Khan et al (2006), Maulik et al, (2006), Pan et al (2003), Saxena et al (2001) and Sarkar et al (2006) [10-15].The boiling method used in actual dyeing of fabrics proved to be a better method than just soaking as agreed by Maslowski, (2015), Hafiz, Chukwu and Nura (2006) [16-17]. The extracted dye is reddish brown as reported by wisc.com, (2015), vurv.com (2015) [6, 8]**.** The direct dyeing carried out confirmed sorghum dye asa substantive dye although not strong as the colours obtained showed moderate fastness quality (see tables 1, 5 and 6) on both sample fabrics (cotton & linen) while caustic and hydrosulphate with extract showed very poor affinity as seen in table 2, although the carton colour stain showed excellent (cotton) and very good (linen) fast to both light and wash test. The obtained colours range from light lilac (direct & potash), deep red violet (salt), light Peach (caustic soda and hydrosulphate). Cotton showed high absorption in potash and salt application to the dye extract of sorghum bi colour than caustic soda and hydrosulphate. This experiment has made it clear that of all the alkalis used salt showed an excellent fixing characteristic followed by potash (see table 3 & 4). This is in agreement as was reported in Oguntona, (1986), and Nkonye, (1993), Voortman, (2015), Maslowski, (2015) [16, 18-20]. The colours obtained from this experiment showed sorghum and salt result to have the brightest colour intensity, followed by sorghum without mordant.

Finally the dye ability and fastness qualities of dye from sorghum on cotton and linen (cellulose fibers) are not as excellent as wool or silk (protein fiber). Burch (2015) [9] stated that cotton is less suitable for many natural dyes. Again Voortman (2015) [20] admonished that not all plants make good dye material. Also in agreement to this fact is the concluding result of MM, Alam, ML, Rahman and MZ, Haque, 2007 [22] investigation on extraction and effects of henna dye on textile fabrics, that “Considering dye ability and colour fastness, dye from henna matured leaves (natural dye) was highly applicable on dyeing of silk fibre as well as other protein fibre.” In other words, dye from henna leave was highly not applicable on dyeing of cotton or other cellulose fibers. This study then reveals that to an extent cotton is less suitable for many natural dyes and sorghum plant dye extract is one of the many natural dyes. Although numerous different colours were obtained, a few are colour fast to the level of moderately good to excellence rating. Nontheless, while a couple of mordants showed good and moderate fastness to sorghum dye on either cotton or linen or even to both, one exhibited weak and poor fastness quality (see tables). However they cannot be ruled out completely as dye fixers due to the colour change left on the sample fabrics [22].

Conclusion

The result of this study has 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 for a desired colour Sorghum extracted dye can be used to impart desirable colours to textile substrates ranging from deep red violet to light lilac as demonstrated in the tables above.

It also revealed that common table salt is good for fixing natural dyes on natural fibers especially cotton. Also the result of this experiment will add a bust to environmentally conscious consumers with growing need for organic clothing.

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