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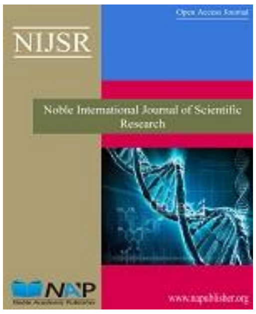

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Extraction and Visible Absorption of Sorghum Bicolour Dye and Its Fastness Qualities on Textile Substrate in Exhaustion Emersion

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Abstract: The recent discovery of the harmfulness of synthetic dye on 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 are the most explored and experimented. Sorghum bi-colour (Guinea corn) is one of such plants. In this study therefore, the liquid extract of sorghum bi – colour was optimized using different alkalis and its potentials as fabric dye was analyzed through exhaustion method of hot and cold water using cotton and linen fabrics. Dye characterization was done using spectrophotometer in the range between 460nm to 780nm. Results show that cotton to an extent showed high level of absorbency and hot water extract a better method of dye extraction. The UV reading at 50% dilution showed highest absorbency value of 2.269 at 546nm wavelength. The colours obtained ranged from lilac to brown hues.

Keywords: Sorghum Bi-Colour, Dye, Visible Absorption, Fastness, Exhaustion, Extraction.

1. Introduction

Natural dyes have been used as colourants for textile materials before the discovery of synthetic dyes. The recent discovery of the toxic nature of synthetic dyes and their harmful effects to human has renewed interest in the production, application, exploration, experimentation and use of natural dyes [1]. The use of natural dyes was further enhanced by the negative environmental effects of synthetic dyes due to pollution of air and water because of the huge waste incurred in its processing and use [2]. Natural dyes are considered as eco-friendly due to their ability to be renewed and biodegraded. They are skin friendly and may also provide health benefit to the wearer [1]. Natural dyes have been used in cosmetics, food, leather, medicine and also possess therapeutic properties [2]. According to Shelke, et al. [3] in [4] natural dyes extracted from plants, fruits and flower contains pigments such as anthocyanin, chlorophyll, betalains and many more which could interact with the wavelengths of visible light to either being reflected or transmitted by plant tissues. These dyes are derived from natural sources of plants-barks, roots, leaves and flowers, insect secretions, and minerals. The most explored is plant and sorghum bi – colour is one of such plants. Sorghum bi-colour (guinea corn) has a red colour natural dye derived from sorghum shell [5].

Sorghum plant is used for forage, hay or silage and some types of stem are 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. Food and Agriculture Organization of the United Nations FAO [6], described Sorghum as an inflorescence (head) and grain (edible seed) in the form of a panicle, spikelets borne in pairs and extensively branching roots and mostly referred to as semi-arid plant. It is the fifth most important cereal crop in the world, the sorghum grass family has hollow stems (culms) that are plugged at intervals (the nodes), with leaves arising at the nodes. FAO described the leaves generally as differentiated into a lower sheath hugging the stems for a distance and a blade [7]. It is a perennial crop which can be harvested many times during the year. Sorghum is a multi-purpose grain even as adhesive in the manufacture of plywood [8, 9]. They vary in colour from pale yellow through reddish brown to dark brown depending on the cultivar [10]. Sorghum grain is a staple foodstuff in semiarid tropics of Asia and Africa. 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 as reported by Rampho [10]. 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.

Sorghum is a crop, when stored properly stays 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) to the animals. It equally possesses other domestic uses as it is used in the production of items such as bed mat, fencing, building of huts and shades, colouring of leather etc. It can also be used as musical instruments 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 by selling the seeds which serves as food. The stems are also used to extract juice as well as colour solution when wet. Guinea corn is used to give specific colour e.g. reddish brown which is specifically prepared for medication for the treatment of hepatitis, jaundice, and anaemia and colouring of porridge [11].

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 [12]. 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. To this fact there is need to optimize the liquid extract of sorghum by colour, analyse its potentials as fabric dye and carry out dye characterization for its UV level of observance for easy handling and usage.

2. Materials and Methods

Sorghum plants-stems, leaves (sheaths) and stalks (all have the colouring matter) were collect 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 a specialist from Department of Forestry, Federal College of Forestry and Mechanization Afaka, Kaduna State.

2.1. Preparation of Sorghum Plant

A manual weighting scales (camry premium) was used to measure 50g weight of matured sorghum plant's leaves (sheaths), stem and stalk after sorting out the debris and contaminated substances. They were cut into pieces and put in a pot.

2.2. Dye Solution Extraction

The dye was extracted using boiling method. The leaves, stems and stalks were arranged in a pot with 3liters (3000 ml) of distilled water to cover the sample. The mixture was heated for 1hr from saturation temperature of 100^{o}C.

2.3. pH Measurement

The pH value of the sample was determined from the extracted solution using pH model Jenway.

2.4. Percentage Yield of Dye

The dye yield percentage was determined by evaporating 100ml of extract solution under water bath and the residue weighed.

2.5. Paper Chromatographic Analysis

Chromatographic analysis was taken as described by Gumel and Ali [13] but the chromatogram was run at 45minutes. Two different solvents were used. Butanol, acetic acid, and water in the ratio of

40:10:50 as described by Vogel [14] in [13] and water, ethanol and ammonium hydroxide in the ratio 20:20:10 [15]. This solvent mixtures were run in different tanks and the reading taken.

2.6. UV/Visible Absorption Measurement

The reading was taken after dilution of dye extracted solution with distilled water in a ratio of 5:5 using spectrophotometer PEC Medical USA. The sample was scanned between 460 nm – 780 nm and the highest observance level was taken.

2.7. Exhaustion Method

Exhaustion was described by Md. Mahabub, et al. [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 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.

2.8. Mordant for Experiment

The mordants used for this experiment were caustic soda and hydrosulphate, potash and salt. They are considered to be environmentally friendly.

2.9. Fabric for the Experiment

Cotton and linen were used for this research. These fibers were selected for their ergonomity, availability and affinity to dye. After dyeing, half each of these fibers were washed with washing soap (sodium carbonate) to ascertain the fastness of the dye on fibers – cotton and linen. A desized cotton and linen of 3” x 6” (8 cm x 15 cm) were bleached and scoured with 0.5 g of sodium carbonate (washing soda) in warm water. Rinsed in clean water dried in room temperature.

2.10. Preparation of Dye Solution

Alkalis of 8 g each were used in 400mls of the extract to form a separate solution for this experiment. Alkalis were dissolved directly with the aqueous extracts.

2.10.1. Dyeing Experiment

The extract of sorghum bicolour 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 (s) on textile substrate (cotton and linen).

2.10.2. Dyeing With Sorghum Extract Without Mordant

Desized fibers of 8 cm by 15 cm of scoured cotton and linen were immersed in 400 ml sorghum dye solution and heated at 100 ^{o}C for 60 minutes. The dyed fibres were removed and washed in cool water with washing soda.

2.10.3. Dyeing Sorghum Extract With Mordant

The research used simultaneous mordanting method as described by [16]. The mordants caustic soda and hydrosulphate, salt and potash were used separately with the aqueous extract to form a solution for dyeing of textile substrate – cotton and linen.

Each of the selected mordant of 8 g was dissolved in three different beakers of 400 ml of sorghum extract dye bath solution. The scoured cotton and linen samples were placed in the dye/mordant mix solution and heated at 100 ^{o} C for 60minutes. The dyed fibres were removed and cool washed with washing soda.

2.11. Fastness Properties Test

After dyeing, each of the mordanted and unmordanted fiber was subjected to wash and light fastness test.

2.11.1. Light Fastness Test

Light fastness was accessed using ISO 105 – A02 standard - the blue wool scale readings and values of 1-7 (1-poor and 7-excellent). The test samples were exposed to sunlight for 72 hours, 24hrs per day, at an angle of 45°c at which end the samples were removed and the change compared with control (original) unexposed samples.

2.11.2. Wash Fastness Test

The wash fastness test was carried out using heating mantle machine and ISO SDC standard procedure. Soap solution was prepared containing 5 g of soap in 1000 ml of distilled water (5%). Each of the dyed samples was cut into (2*2cm), and placed between two adjacent pieces of un-dyed fabric to enable the assessment of the degree of staining and the percent depth of shade of sample measured. 20 ml of soap solution was measured from volumetric flask, 5ml of sodium carbonate was measured too from another volumetric flask, and 25 ml of distilled water was added to it which make up 50 ml of Liquor Ration (L: R=50), and the fabrics were impregnated in the beaker, the heating was commenced at temperature of 40-65 °C at period of 30 minutes to allow proper penetration of solution into the samples. Finally, the composite was then removed, rinsed and dried. the assessment of color change and staining was done with the standard "Grey Scale" rating between 1-5, 1 is poor while 5 is excellent.

3. Results and Discussion

Table 1 shows the physical properties of dye extract from sorghum sheaths and stems. The extraction produced a reddish brown solution with pH value of 6.50 (Table 1) indicating a slight acidic condition due to the extracted colour as reported by Martins and Ojukwu [17] in Gumel and Ali [13]. The boiling method of extraction produced 45.3% of dye, an indication that heating at saturation temperature is a good method and effective in natural dye extraction [18-23].

Table 1. Physical properties of dye extract

Dye Plant	**Yield % of Sorghum dye**	**pH Value**	**Colour of Aqueous Solution**	**Solubility**	
				Soaking	**Heating**
Sorghum bi-colour	45.3	6.50	Reddish brown	Slightly soluble	Highly soluble

Table 2 gives colour shades/hues obtained from mordanted and un-mordanted sample. It describes the fastness qualities of each sample before and after washing and impregnation with dye solution. The reading from the paper chromatography shows that there was no other colour in the solution and thereby indicating the presence of only one colour component as indicated by Pavia and Kris [24]. The UV spectrophotometer reading at 50% dilution showed highest absorbance value of 2.269 at 546 nm wavelength. Result obtained in the use of various mordants in dye application revealed changes in solution colour and fabric stains. In using different alkalis (caustic soda and hydrosulphate, potash, and salt) it was observed that different colours of varying intensities were obtained and the fixing strength of these alkalis depend highly on the fabric [25]. The method used in actual dyeing of fabrics proved to be a better method than just soaking (table 1) [7, 26, 27]. The direct dyeing carried out confirmed sorghum dye as a substantive dye although not strong as the colours obtained showed moderate fastness quality (see table 3) on both sample fabrics (cotton & linen) while caustic and hydrosulphate with extract showed average fastness quality to washing as seen in table 2 in both before and after wash an indication of good complex binding after loss of dye as revealed in the work of Gill [28] reported in [7]. The obtained colours range from light lilac (direct & potash), deep red violet (salt), very light Peach (caustic soda and hydrosulphate). Cotton showed high fastness quality to light and good retention of dye before and after wash in salt application (7 and 7 respectively) but exhibited good and fairly good in wash fastness (3-4; 4-5). Potash application to the dye extract of sorghum bi colour showed good (5) and fair (4) light fastness quality before and after wash. The sample cotton dyed with caustic soda and hydrosulphate showed the excellent response to light. This experiment has made it clear that of all the alkalis used in this research salt showed an excellent fixing characteristic on both sampled fabrics followed by potash (see table 2). This is in agreement as was reported in [26, 29-31].

Table 2. Colour shades/hues obtained from modanted and un-mordanted samples

Dye extract and mordants	Solution colour	Fabric colour			
		Before wash		After wash	
Sorghum bi-colour L	Reddish Brown	Cotton	Linen	Cotton	Linen
Un-mordanted	Reddish Brown	Deep Lilac	Deep Lilac	Purple	Light purple
Salt	No colour change	Deep red violet	Grayish red violet	Deep lilac	Grayish lilac
Potash	No colour change but formed precipitate	Dark reddish brown	Deep reddish brown	Grayish brown	Grayish brown
Caustic soda & hydrosulphate	Brown with precipitate formed	Reddish peach	Reddish peach	Carton colour	Carton colour

Table 3 shows the Fastness properties of the dye. 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 [25] stated that cotton is less suitable for many natural dyes. Again Voortman [31] admonished that not all plants make good dye material. Also the concluding result on the investigation on extraction and effects of henna dye on textile fabrics carried out by Alam, et al. [32], agrees that "Considering dyeability and colour fastness, dye from henna matured leaves (natural dye) was highly applicable on dyeing of silk fiber as well as other protein fiber." 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. Nonetheless, 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 desirable stains can still be obtained for various dyeing activities.

Table 3. Fastness properties

Dye extract and mordants	Light fastness				Wash fastness			
	Before wash		After wash		Before wash		After wash	
Sorghum bi-colour L	Cotton	Linen	Cotton	Linen	Cotton	Linen	Cotton	Linen
Un-mordanted	4	4	5	6	1-2	2	3	2-3
Salt	7	6	7	6	3-4	2-3	4-5	3
Potash	5	4	3	4	4	2	2	4
Caustic soda & hydrosulphate	6	5	7	6	3	2	2-3	3

Key: Light fastness: ● 7= Excellent ● 6= V. Good ● 5= Good ● 4= Fair ● 3= V. Fair ● 2= Poor ● 1= V. Poor
Wash fastness: ● 5= Excellent ● 4-5= Excellent ● 4= V. Good ● 3-4 = V. Good ● 3 = Good ● 2-3 = Fairly Good ● 2= fair ● 1-2 = poor ● v. Poor

4. 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. 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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