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SUSTAINABLE FABRIC DYEING: ANALYSIS OF COLOUR PROPERTIES AND ACCEPTABILITY OF COTTON FABRICS DYED WITH DYESTUFFS EXTRACTED FROM SELECTED PLANTS

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ABSTRACT

This study investigated the colour properties and acceptability of cotton fabrics dyed with dyestuffs extracted from selected plants, as a sustainable approach to textile dyeing. The research focused on the extraction of natural dyes from Sorghum bicolour *leaves and* Hibiscus sabdariffa *calyces, the development of composite dyes, and the evaluation of both the colourimetric characteristics and consumer acceptability of the dyed fabrics. A research and development design were adopted. A colourimeter was employed to determine the L*, a*, and b* colour parameters, while a five-point rating scale was used to assess the acceptability of the treated fabrics, with a decision rule of 3. Five coded fabric samples dyed with the extracts were evaluated by sixty respondents. Data were analysed using frequency, mean, and standard deviation. Findings revealed that sample HYS4 recorded the highest lightness value (L* = 54.82), indicating greater brightness, while ABS6 had the lowest (L* = 47.00). The a* values indicated that all samples exhibited reddish hues, with SXB1 showing the highest redness (a* = 14.50) and ABS6 the least (a* = 9.13). The negative b* values confirmed the presence of blue tones, with HYS4 being the bluest (b* = –19.21) and SXB1 showing the least blueness (b* = –6.39). In terms of sensory evaluation, all samples achieved mean scores above 3.0, indicating good acceptability across organoleptic attributes such as colour, texture (sight and touch), odour, evenness of shade, and overall appearance. The study concluded that dyestuffs derived from* Sorghum bicolour *and* Hibiscus sabdariffa *possess the potential for effective and sustainable dyeing of cotton fabrics, both for domestic use and in the textile industry. It recommended the utilisation of these natural dyestuffs as eco-friendly alternatives to synthetic dyes, promoting sustainability and reducing environmental impact within textile production processes.*

Keywords: *Extraction, application, dyes, fabric and sustainability.*

INTRODUCTION

The African continent is endowed with a diverse array of plant species possessing the potential to yield novel natural products with dye-producing properties (Wanyama, Kiremire, and Murumu, 2014). Nigeria, in particular, is replete with vegetal resources containing dyes within various plant components, including roots, bark, leaves, seeds, fruits, and flowers; among these, guinea corn exemplifies such a species (Nwoye and Ezema, 2017). Indeed, the nation boasts an abundance of plant species capable of producing dyes, which can generate a spectrum of exquisite and captivating hues. Notable among these dye-yielding plants are *Sorghum bicolor* and *Hibiscus sabdariffa* (Figure 1).

In West Africa, *Sorghum* is commonly referred to as guinea corn, while in Nigeria it bears local designations such as Okababa, Dawa, and Okili, and it pertains to the tribe Andropogonae (Adegbola, Awagu, Kamaldeen, and Kashetu, 2013). Osabohiern (2014) further elucidates that *Sorghum* is known as kopo-mopo-re-corn in Yoruba, millomaize in the United States, dura in Sudan, great millet and guinea corn in West Africa, kafir corn in South Africa, Mtama in Eastern Africa, and Jowar in India. The leaves of *Sorghum bicolour* constitute a vital reservoir of carbohydrates, proteins, and minerals—including calcium, selenium, manganese, and iron—wherein bioavailability is contingent upon interactions with anti-nutritional factors (Oyetaya and Ogunrotimi, 2012). As a source of natural dyes, *Sorghum bicolour* (guinea corn) derives its nomenclature from the intrinsic pigmentation inherent to the plant.

Fig. 1: *Sorghum bicolor* and *Hibiscus sabdariffa* Plants

The *Hibiscus sabdariffa* plant, a tetraploid member of the Malvaceae family, is recognised by various vernacular names, including Soursour in Sierra Leone, dab or bissap in Senegal and neighbouring regions, oseille de Guinée or Roselle in French-speaking areas, marakwanga in Northern Uganda, and Jamaican sorrel or Florida cranberry in the Caribbean (Yılmaz and Bahtiyari, 2017). Ozougwu and Anyakoha (2016) contend that the roselle plant has been extensively employed for diverse applications, such as beverage production, newsprint manufacturing, medicinal and pharmacological purposes, and food colouration; nonetheless, its substantial pigment content notwithstanding, it remains underexplored as a dye source for fabric colouration.

The term 'dye' originates from the Old English words 'Daeg' or 'Daeh', signifying colour (Ravi and Mahendra, 2014). In contrast, Ozougwu and Anyakoha (2013) define dyes as organic chemical compounds that confer enduring colouration upon substrates. Natural dyes have long been utilised for tinting foodstuffs, leather, and natural protein fibres such as wool, silk, and cotton—principal domains of application since prehistoric eras (Samantha and Agarwal, 2009). However, natural dyes exhibit limitations in fastness, which may be ameliorated through co-application with mordants, thereby yielding vibrant and durable colours (Chakrabarti and Vignesh, 2011).

Mordants function as chemical agents that facilitate a reaction between the dye and the fabric, thereby enhancing colour fixation. They achieve this by amalgamating with the dye pigment to form an insoluble complex (Wipperlinger, 2004). Penetrating deeply into the fibre, mordants react with the dye to engender a stable hue (Earth, 2016). Likewise, Bechtold and Mussak (2009) posit that a mordant, as a discrete chemical entity, binds with the dye to augment its affinity for the fibre, rendering the colour resistant to light and laundering; moreover, certain mordants may modulate the hue of specific dyes, potentially darkening, brightening, or substantially altering the shade.

Natural fibres derive from botanical, faunal, or mineral origins (Forster, 2014). Among these, cotton fabric stands as one of the most adaptable, longstanding, and ubiquitous materials available to humankind, having served in apparel production for millennia. Cotton fibre, a natural variant, is procured from the *Gossypium hirsutum* plant (Anyakoha, 2015). Ozougwu and Anyakoha (2013) emphasise that natural dyes exhibit optimal compatibility with natural-fibre fabrics, whereas synthetic dyes align preferentially with synthetic textiles.

Colour constitutes a facet of visual perception, yet the chromatic attributes of a dye frequently serve as the paramount impetus for procuring textiles and garments. Texture, conversely, encompasses a sensory interplay of tactile and visual impressions. Diverse textures assimilate light variably, thereby modulating fabric colouration; consequently, identical dyes applied to disparate textures may yield divergent shades. Visual perception of light arises from the interplay of absorption and reflection upon the material's surface, which may manifest as hard, soft, rough, or smooth, and evoke sensations of warmth or coolness (Ozougwu and Anyakoha, 2013). The authors further delineate the tactile dimensions of texture as encompassing coarseness, softness, rigidity, or crispness. The solubility of a dye in water, or its dispersibility in solvents, governs the uniformity of shading; insoluble residues or crystalline deposits on the fabric's surface engender uneven dyeing, which is deemed unacceptable. Ultimately, dyes, whether synthetic or natural, that impart an objectionable odour to the fabric are intolerable; an exemplary dye, therefore, ought to confer an agreeable fragrance upon the material.

Organoleptic properties of fabrics rank among the principal influencers of consumer preferences in apparel selection; whilst synthetic dyes can fulfil this criterion, natural dyes offer a viable alternative. Vegetable-derived dyes, however, have yet to be comprehensively harnessed in fabric dyeing; *Sorghum bicolour*, a prolific contributor to agricultural waste in Nigerian farmlands, exemplifies such untapped potential. Similarly, *Hibiscus sabdariffa* remains underutilised as a prospective dye source.

Objective of the Study

The broad objective of the study is to determine the Colour Properties and Acceptability of Composite Dyestuffs Developed from Selected Plants on Cotton Fabric. The specific objectives are to:

1. determine the colour properties of the dyed fabrics
2. Investigate the acceptability of the fabric dyed with the dye extracts and composites in terms of organoleptic attributes.

Research Hypotheses

HO_1: There is no significant difference in the acceptability of fabric dyed with the extracted dyestuffs and the composite developed.

MATERIALS AND METHODS

The study adopted Research and Development Design (R and D). The design is suitable for this study because it involved the development of composite dyes derived from *Sorghum bicolour* Leaves and *Hibiscus sabdarifa* calyces.

Dried Leaves of *Sorghum bicolour* and *Hibiscus sabdarifa* were purchased at Ipata market, Ilorin, Kwara State. Cotton fabric and alum were bought at Oja-Oba market, Ilorin, Kwara State. The equipment used for the experiments is: mortar and pestle, sieve, knife, spatula, weigh balance, measuring cylinder, funnel, and bowls, which are provided at the Department of Home Economics and Food Science, University of Ilorin.

Dye Extraction: The solvent extraction method was adopted for extracting the dye, as described by Lizamoni, Smita, and Ava (2021). The collected dried *Sorghum bicolour* leaves were chopped into smaller bits. 200g of this was added to 1000ml of methanol (absolute) and then left for three days. This was then filtered using a cotton fabric and a filter funnel. The filtrate was kept airtight in a container. Dried calyces of *Hibiscus sabdarifa* were milled and then 200g of this was added to 1000ml of methanol (absolute), then left for three days. This was then filtered using a cotton fabric and a filter funnel. The filtrate was kept airtight in a container.

Development of Product

Development of composite dyes: The dye extracts HYS4 and SXB1 were made into a composite by mixing the samples in different volumetric proportions, thereby three composite samples of 75-25%, 25-75% and 50-50% were developed and two 100% of the extract were also developed. Each of these samples measures 100ml.

Substrate Treatment: the fabric was cut into 24" by 14", which measures 25g. The cotton fabric is washed with warm soapy water so as to remove the fabric finishes applied on it, finishes like wax and starch. This is to allow the fabric to be able absorb the dye efficiently. Also, Mordanting: 5g of alum and 1g of table salt was dissolved in 500ml of boiling distilled water. Each of the fabric was mordanted for 2 hours after which they were removed.

Contemporary plain dyeing method was adopted for the dye's application (Ozougwu and Anyakoha, 2016). The dye bath was prepared with 120ml of the dye liquor in 500ml of distilled water for each of the samples. The fabric is then immersed in the dye bath, and heated to 80c for 15minutes, it was then left to cool for 5 hours after which the fabric was removed and dried in an airy shady place. This procedure was repeated for the remaining four samples and so five different dyed fabrics were developed. Colour properties of the dyed fabric was analyzed using colorimeter to measure the CIE L* a* b* values of each of the dyed fabrics

Instrumentation

The instrument used for data collection is Organoleptic Attributes Acceptability of Treated Fabric Evaluation (OAATFE), was validated by three experts in the field of clothing and textiles.

Data Collection: The instrument used for data collection is Organoleptic Attributes Acceptability of Treated Fabric Evaluation (OAATFE), which was adapted for this study, with a rating scale of 1-5 with 5 Very highly Accepted (VHA), 4 Highly Accepted (HA), 3 Averagely Accepted (AA), 2 Unaccepted (U) 2 and 1 Highly Unaccepted (HU).

Data was collected from the respondents during the assessment sessions. The researcher with one trained research assistant, assisted in the distribution of the samples to the respondents and distribution of the assessment sheet. The research assistant was trained on the basis of test panelists' sessions; distribution and collection of completed assessment sheet. Completed copies of the assessment sheet was collected and checked in order to ensure their completeness by the participants. Evaluation session was conducted in University of Ilorin, Department of Chemistry and Department of Home Economics and Food Science. The respondents comprised of forty students from Department of Chemistry and twenty students from Home Economics, University of Ilorin, Ilorin South, Kwara state.

The five dyed fabrics, **HYS4:** 100% *Hibiscus sabdarifa,* **SXB1:** 100% *Sorghum bicolor,* **ASH8:** 75% *Hibiscus sabdarifa* and 25% *Sorghum bicolor,* **ABS6:** 25% *Hibiscus sabdarifa* and 75% *Sorghum bicolor,* **ABH3:** 50% *Hibiscus sabdarifa* and 50% *Sorghum bicolor* –blindly coded. The scores for all organoleptic acceptability were recorded on the evaluation forms.

Data Analysis

The data collected was analyzed using frequency, mean and standard deviation. A decision rule of 3.0 was chosen which depicts that the sample is acceptable.

The hypothesis was tested using Analysis of variance (ANOVA) at a 0.05 level of significance, When the probability value is greater than 0.05 the hypothesis was retained otherwise it was rejected.

RESULTS AND DISCUSSIONS

Presentation of Results

Table 1: Colour Properties of the Samples

Sample Codes	L*	a*	b*
HYS4	54.82	11.43	-19.21
SXB1	54.07	14.50	-6.39
ASH8	51.93	11.60	-13.96
ABH3	51.09	10.44	-12.02
ABS6	47.00	9.13	-11.67

Source: Laboratory Work (2022)

Key:
HYS4: 100% *H. sabdarifa*
SXB1: 100% *S. bicolor*
ASH8: 75% *H. sabdarifa* 25% *S. bicolor*
ABH3: 50% *H. sabdarifa* and 50% *S. bicolor*
ABS6: 25% *H. sabdarifa* and 75% *S. bicolor*

Table 2: The Mean and Standard Deviation of the Acceptability of the Organoleptic Attributes the Samples

Sample Codes	Colour	Texture (Sight)	Texture (Touch)	Odour	Evenness of Shade	Overall Acceptability
HYS4	3.80+0.99[ab]	3.65+0.82[a]	3.85+0.84[a]	3.77+0.79[a]	3.83+0.89[a]	4.75+6.52[b]
SXB1	3.87+0.91[a]	3.78+0.69[a]	3.87+0.77[ab]	3.70+0.81[a]	3.67+0.93[b]	3.97+0.71[c]
ASH8	3.43+0.94[c]	3.65+0.86[c]	3.83+0.91[d]	3.50+0.75a	3.23+0.93[d]	3.65+0.97[e]
ABH3	3.50+1.08[b]	3.83+0.85[ab]	3.63+0.82[c]	3.62+0.83[b]	3.55+.1.07[c]	3.80+0.84[d]
ABS6	3.38+0.90[d]	3.62+0.78[a]	3.58+0.87[e]	3.58+0.77[a]	3.45+0.91[e]	3.57+0.87[f]

Source: Field Work (2022)

Key: **HYS4:** 100% *H. sabdarifa*
SXB1: 100% *S. bicolor*
ASH8: 75% *H. sabdarifa* 25% *S. bicolor*
ABH3: 50% *H. sabdarifa* and 50% *S. bicolor*
ABS6: 25% *H. sabdarifa* and 75% *S. bicolor*

Hypotheses Testing

Table 3: ANOVA of Significant Difference in the Acceptability of Samples

	N	Sum of Squares	Df	Mean Square	F	Sig	Significance	Remark
Between groups	60	11551.820	12	962.652	30.829	.000	Significant	Rejected
Within groups		1467.580	47	31.225				
Total		13019.400	59					

α = 0.05 **Source:** Field Work (2022).

Table 8, shows an F-value of 30.829 and a p-value of 0.000 since the p-value is less than the alpha level($p<0.05$) the null hypothesis which states that there is no significant difference in the acceptability of fabric dyed with the extracted dyestuffs and composite dye developed is rejected.

Discussion of Findings

Table one shows the colour properties of the samples with the L* value indicating that sample HYS4 with the value 54.82, is the brightest followed by SXB1 with 54.07, then ASH8 with 51.93, ABH3 with value 51.09, while ABS6 47.00 is the least bright of all the samples. This result showed that dye extracts from *Sorghum bicolor* leaves and *Hibiscus sabdarifa* calyces are the brightest while the composite dyes developed are the least bright. The brightness however decreases as the percentage composition of dye extract from *Hibiscus sabdarifa* calyces decreases. The redness to greenness shows that all the samples are more reddish with SXB1 with a value of 14.50, followed by ASH8, with a value of 11.60, and then HYS4 with a value 11.43, then ABH3 with a value of 10.44 is the reddest with highest value while ABS6 has the least redness with 9.13. All the samples are blue as the values obtained are negative values, while HYS4 is the bluest with a value of -19.21, followed by ASH8, with a value of -13.96, then ABH3 with a value of -12.02, and ASB6 with -11.67 while sample SXB1 has the least blueness with a value of -6.39. The result shows that the blueness is highest in HYS4 and least in SXB1 this shows that dye from *Hibiscus sabdarifa* calyces could give a shade that is closer to blue. Blueness in the composite dyes decreases as the percentage composition of extracts from *Hibiscus sabdarifa* calyces decreases, while redness in the composite dyes decreases as the percentage composition of extracts from *Sorghum bicolor* leaves decrease.

Table two revealed that all the samples are acceptable in terms of organoleptic attributes, however the level of acceptability differs as shown in table two. For the colour, it is observed that Sample SXB1 is the most acceptable with the mean value of 3.87 while sample ABH3 is the least acceptable with a mean value of 3.38.

For the texture (sight), Sample ABH3 is the most acceptable with the mean value of 3.83 while sample ABS6 is the least acceptable with a mean value of 3.62. For the texture (touch), Sample SXB1 is the most acceptable with the mean value of 3.87 while sample ABS6 is the least acceptable with a mean value of 3.58. However, all the samples are acceptable in term of texture (sight and touch) with mean values higher than 3, this agrees with This is also in consonant with Samanta and Konar, (2011) who postulated that shades produced by natural dyes are usually soft, lustrous and soothing to the human eye. Likewise, the finding is in line with Chengaiah et al., (2010), that observed that natural dyes produce soft texture, feel or "hand" in fabric and give cooling sensations that are calmatives and revitalizes the skin.

For the odour, Sample HYS4 is the most acceptable with the mean value of 3.77 while sample ASH8 is the least acceptable with a mean value of 3.50. This goes in line with the attributes of a good dye given by (Finar, 1973) that quality dye should, have pleasant odour on the fabrics.

For the evenness of shade Sample HYS4 is the most acceptable in with the mean value of 3.83 while sample ASH8 is the least acceptable with a mean value of 3.23. The findings support Ashis and Agarwal (2009), who discovered that natural dyes produce uncommon soothing and soft shades compared to synthetic dyes

Sample HYS4 is the most acceptable in terms of overall acceptability with the mean value of 4.75 while sample ABH3 is the least acceptable with a mean value of 3.57. This agrees with Ozoagwu and Anyakoha (2013) who stated that Organoleptic attributes of cotton fabric treated with dye extracted from roselle calyces identified include: Fairly warm maroon colour hue, fairly light value, fairly brilliant chroma, smooth and fairly soft textures, odourless and even shade which were all accepted as good organoleptic attributes. This also agrees with Finar (1973), who stated that A quality dye should be soluble in water or dispersible in a solvent resulting in evenness of shade or level dyeing in fabric colouration, have pleasant odour on the fabric, and organoleptically appealing.

The null hypotheses raised was rejected as shown in table two, this is because there are significant differences in the mean scores of the acceptability of the organoleptic acceptability of the samples by the respondents and so, there is a significant difference in the potential of the dyed fabric with the composite dyes developed in terms organoleptic acceptability ($p<0.05$).

CONCLUSION

Based on the findings the study concludes that *Sorghum bicolor* and *Hibiscus sabdarifa* are good sources of natural dyes as they are rich in colour yielding compounds. Composite dyes could be developed from these two plants and better hues could be made from them. Also, the dyes plants are good for textile dyeing with appreciable colour. With different shades, dyes from *Sorghum bicolor* and *Hibiscus sabdarifa* can be applied in dyeing cotton fabric both in the home and textile industries, particularly, textile recycle.

RECOMMENDATIONS

a) It is recommended that awareness should be made on the use of natural dyes especially those of plant sources in textile dyeing.
b) The knowledge of natural dye should be added to the curriculum of textiles in courses like Home Economics and Chemistry, as these will broaden the knowledge of students in textile dyeing.
c) Also, the government should sponsor more research work on natural dye exploration as this would help in creating standardized recipe for the use of natural dye especially those from plant sources in textile dyeing.
d) Finally, Dyestuffs from *Sorghum bicolor* and *Hibiscus sabdarifa* should be used in dyeing cotton fabric in home dyeing likewise textile industries can adopt the use these plants.

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