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A Study on Dyeing Properties of Kigelia Africana (Lam.) Benth. Fruit Extracts

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Abstract
The present study aims to contribute more to the already existing natural dyes in the textile industry. This study focuses on the extraction of natural dye from the fruit of *Kigelia africana* (Lam.) Benth. The dye was extracted from fruit fibers by solvent extraction method. The compounds present in the dye were analyzed through UV-Visible Spectrophotometer and FTIR analysis. The dyeing was performed on cellulose and protein fibers i.e. cotton and silk threads. The fastness properties of the dye were enhanced by suitable mordants and auxochromes.

Keywords: *Kigelia africana*, Natural Dye, Eco-Friendly, Spectroscopy.

1. Introduction

Dyes are substances which impart color to textiles, paper, leather, etc. such that the colors are not altered readily by washing, heat, light or other factors to which they are exposed.[1]. They possess the quality of color because they absorb light in the visible spectrum and have at least one chromophore.[2]. Dyeing is the interaction between a dye and fiber along with the movement of the dye in the fiber which adds more value to the raw textile materials.[3]. There is evidence that dyeing methods are almost 4000 years old. These ancient methods made the use of natural dyes as the only available type of dyes existing then. But with the rise of the Industrial revolution in Europe, the increasing demand of readily available and inexpensive dyes resulted in the evolution of synthetic dyes in the 1900s, where nearly 90% of industrial dyes were synthetic.

The usage of synthetic dyes began with the use of mauve - the first commercially successful synthetic dye. They were also known as 'coal tar dyes' as they were manufactured from coal tar. However, with the emergence of petroleum feedstocks the coal tar byproducts were replaced by petroleum products to obtain specific colors, attributes and ranges [4] (e.g. Mauve, magenta and azo dyes). Petroleum based products in dyeing cause skin allergies, toxins and their synthesis also release various undesirable toxic chemicals. [1].

In recent years, research has been carried out to find alternatives against these synthetic dyes, one of which is the use of natural dyes. The term 'Natural dye' implies all the dyes derived from natural sources like plants, animals and minerals. As compared to synthetic dyes, natural dyes produce very uncommon,

soothing and soft shades [5]. Commonly reported natural dyes are - indigo, madder, cochineal, etc. [6]. Natural dyes are non-toxic, ecofriendly and biodegradable hence, the present research focuses on extracting a natural dye from the fruit of *Kigelia africana* which could be an addition to the existing natural dyes.

Kigelia africana (Lam.) Benth. Syn *K.pinnata* (Jacq.) DC, one of the members of the Bignoniaceae family, is widely distributed across South, Central and West Africa. It is commonly known as sausage tree and has huge fruits (avg. 0.6 m in length and 4 kg in weight) hanging from long fibrous stalks. The flowering season is from August to October and the fruiting season lasts from December to June. Its distribution is all over India but found abundantly in West Bengal. Some of the characteristics of fruit are bitterness, astringent taste or smell. Baked fruits are used to ferment beer and boiled ones yield a dye. It is known to have many traditional, medicinal and ethnobotanical uses due to the presence of the chemical constituents B-sitosterol, norviburtinal, furanone derivatives, four iridoids; 7-hydroxy viteoid II, 7-hydroxy eucommic acid, 7-hydroxy-10-deoxyeucommiol and 10-deoxyeucommia along with seven others known iridoids isolated from the fruits. They also isolated phenylpropanoid derivatives identified as 6-p-coumaroyl-sucrose together with ten known phenylpropanoid and phenylethanoid derivatives and flavonoid glycoside from the fruit.[7] Research has been carried out to explore the dye obtained from the flower and heartwood of this plant.[8][9] The dyeing properties of *K. africana* fruit have not been explored, hence the present research is an attempt to extract the fruit dye.

2. Materials and Method

A. Plant material

Unripe fruits of *K. africana* were collected from Bhandup Pumping Station, Mulund (East), Mumbai, 400081. Inner fibers of fruit were used to extract the dye by solvent extraction method and percent yield of fruit dye was calculated.

B. Extraction of dye

A range of polar to non-polar solvents were used to carry out the extraction and the potent solvents were further selected for final extraction.

The extraction was done using 100 gms of fruit in 1000 ml of solvents - Methanol and Ethanol at suitable temperature in a water bath for approximately 1 hour.

C. Cloth fibres

The dye was then tested on cotton, silk and wool fibers. Each of these threads were kept in the respective extracts under observation for 24-72hrs. Cotton and silk threads showed potent dyeing in both methanolic and ethanolic extracts. Mordants A wide range of mordants (Salt, alum, oil, symplocos, tannins) were initially tested. The pre and post mordanting methods showed that symplocos and tannins were the most potent mordants and hence were used for further processes. [10]

E. Spectroscopy

UV- The UV stability of the dye was observed by exposing varying concentrations of dye (1, 3, 5mg/ml) to sunlight for 30 mins to 180 mins in order to evaluate its photodegradation profile. The sunlight and UV light intensity was measured by using UV meter and Lux meter. Absorbance was recorded on spectrophotometer GENESYS 10S UV-Vis v4.002 2L9P112013 between the wavelengths 200 nm to 700 nm and the data was represented graphically.

The photodegradation profile was also obtained by treating the methanolic extracts by Thiol chelating resins (Indion Ion exchange) for a duration of 30 mins to180 mins with constant agitation.

IR- 1 gm of dried fruit powder was subjected to IR spectroscopy (FTIR Spectroscopy in Potassium Bromide,Perkin Elmer) in order to find functional groups.

Auxochrome - The functional groups of organic compounds present in the dye which were determined by FTIR analysis were studied and accordingly the potent auxochromes were selected for further process.

3. Results and Discussion

Extraction

The solvents ethanol and methanol were the most potent amongst others and hence selected for the extraction. Yield of the unripe fruit fibres from methanolic extract was found to be 15.3% and that of the ethanolic extract was 2.3%.

Spectroscopy

Absorbance of the methanolic and ethanolic extract was observed on the UV-Visible wavelength (200 nm to 700 nm) as shown in the figure below. Photodegradation profile was observed by taking different concentrations of the dye (1 mg/ml, 3 mg/ml, 5 mg/ml) for the duration of 30 mins to 180 mins.

Figure 1.1: UV-Visible spectral analysis of K. Africana fruit extracts (methanol) showing absorption maxima (λ_{max}) at 335 nm.

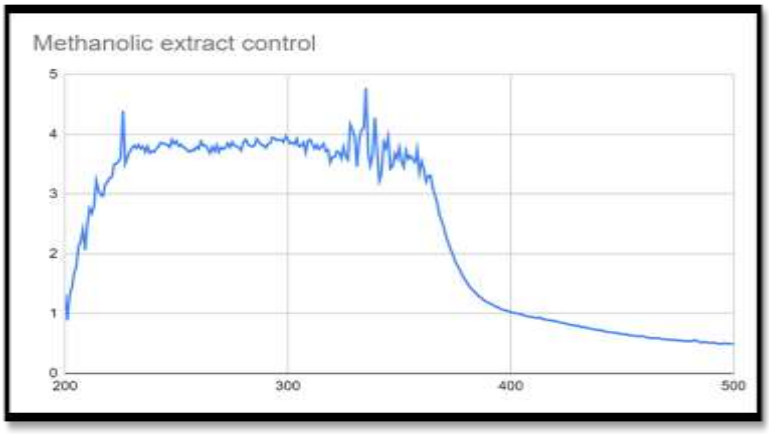


Figure 1.2: UV-Visible spectral analysis of *K. Africana* fruit extracts (ethanol) showing absorption maxima (λ_{max}) at 255 nm.

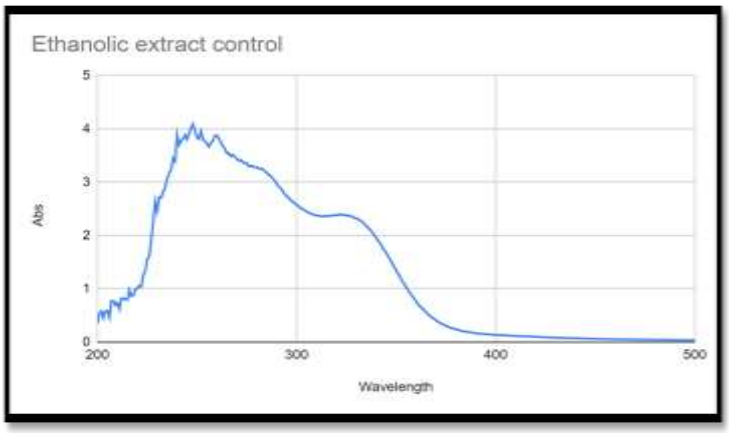
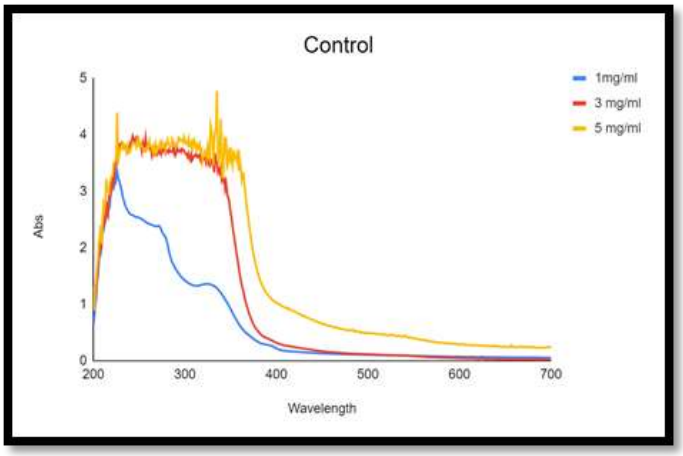
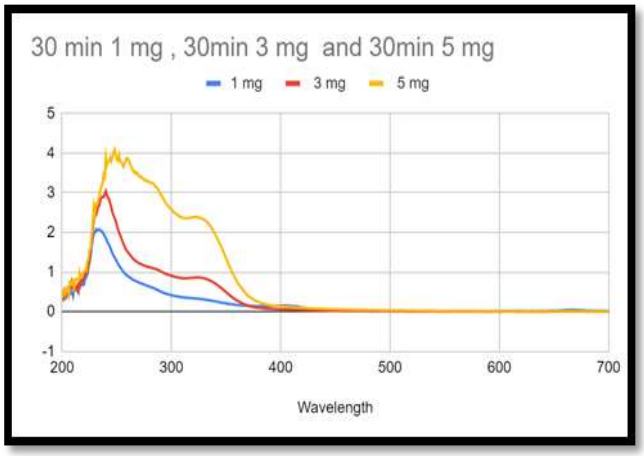


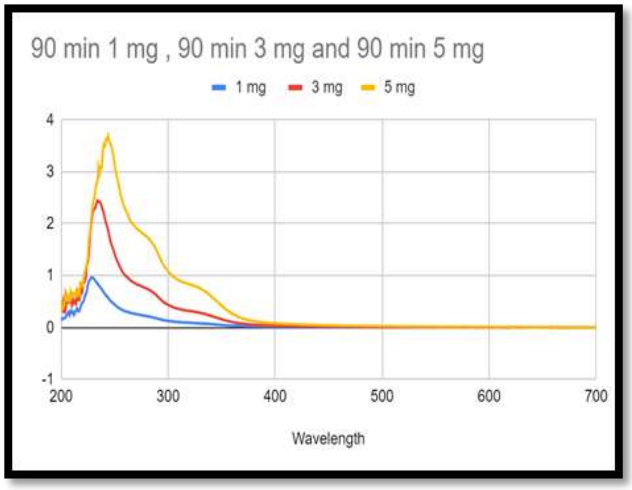
Figure 3 : Effect of *Kigelia africana* ethanol extracts in concentrations of 1mg, 3mg and 5 mg in order to examine its photodegradation potential



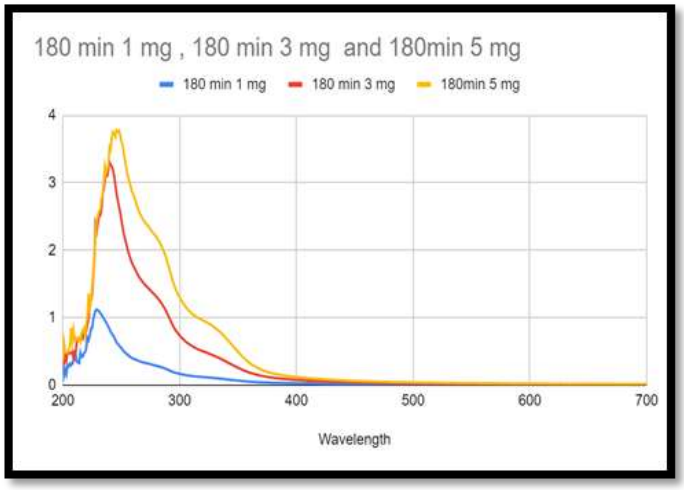
3.1 Control group, exposure at 0 mins



3.2 Exposure to sunlight at 30 mins

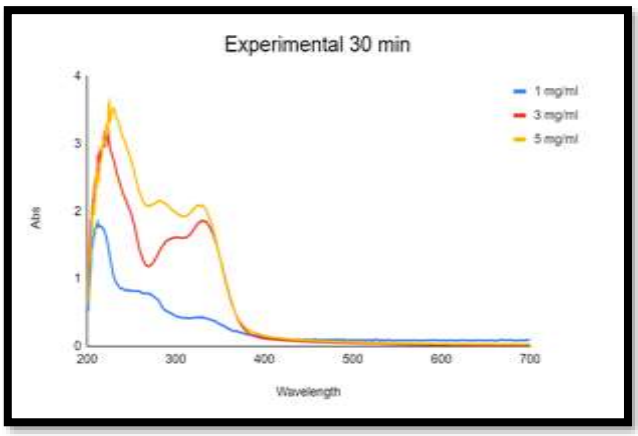


3.3 Exposure to sunlight at 90 mins.

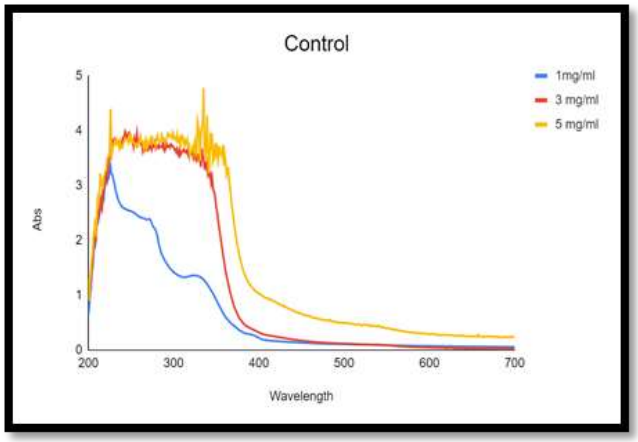


3.4 Exposure to sunlight at 180 mins

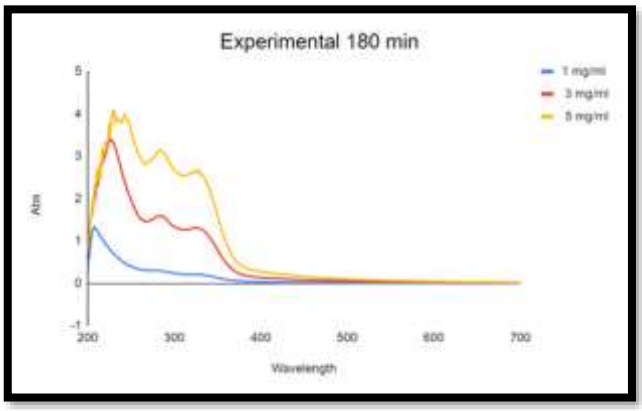
Figure 4: Effect of sunlight the on *K. africana* methanol extracts in concentrations of 1mg, 3mg and 5 mg in order to examine its photodegradation potential

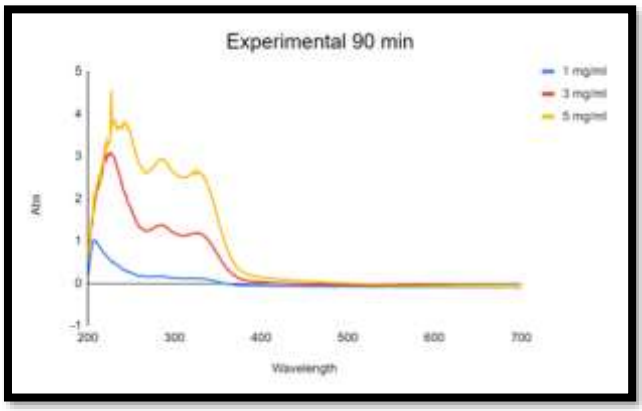


4.1 Control group, exposure at 0 mins.



4.2 Exposure to sunlight at 30 mins





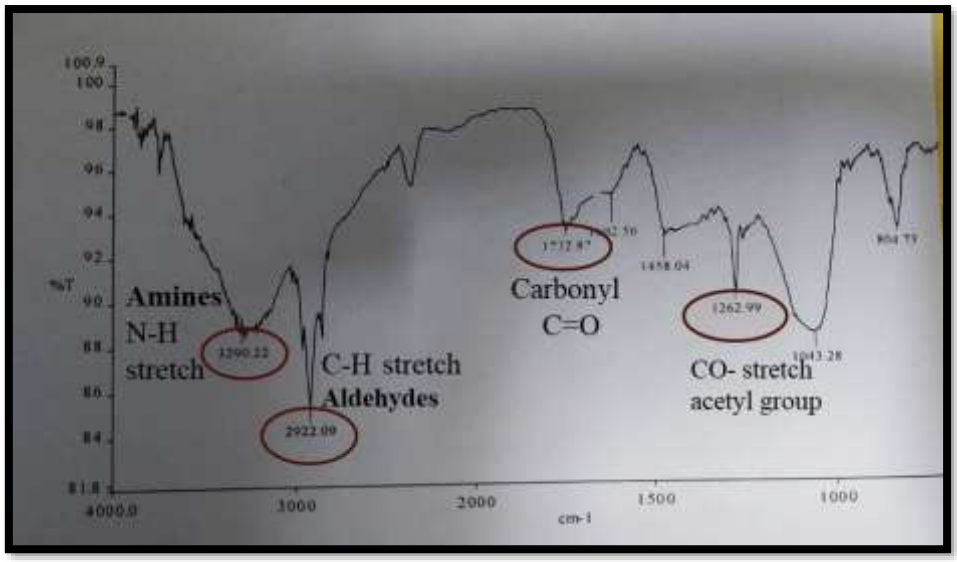
4.3 Exposure to sunlight at 90 mins

4.4 Exposure to sunlight at 180 mins

FTIR analysis: 1 gm of dried fruit powder was subjected to IR spectroscopy (FTIR Spectroscopy in Potassium Bromide, Perkin Elmer) in order to find functional groups. The functional groups of the dye were analysed. On the basis of the functional groups present the potent auxochromes were selected for further process. The fruit extract when subjected to IR spectroscopy, some medium to strong intensity bands were obtained. The table lists IR frequency ranges, appearance of the vibration and absorption for functional groups determined from the fruit extract. [10]

Absorption (cm-1)	Group	Compound Class
3333-3267	N-H stretching	amine salt
3000-2800	C-H stretching	aldehyde
1740-1720	C=O stretching	carbonyl
1620-1600	C=C stretching	α,β-unsaturated ketone
1465-1450	C-H bending	alkane
1310-1250	C-O stretching	aromatic ester
1050-1040	CO-O-CO stretching	anhydride
840-790	C=C bending	alkene

Figure 6 : Observations obtained from FTIR analysis, the different peak values indicate the possible organic compounds present in the dye of *K. africana*



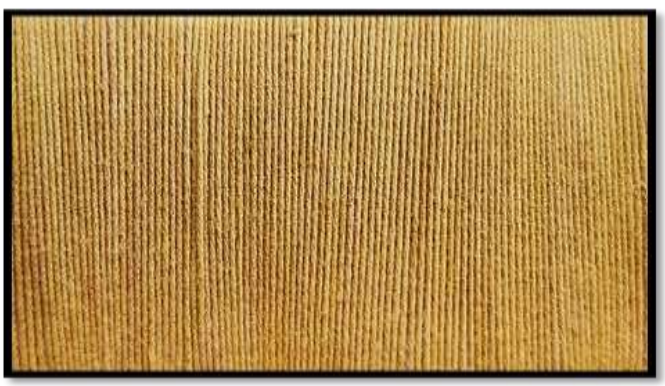
Dyeing

The dyeing properties of extracts were shown when white threads of cotton and silk were both subjected to the methanolic and ethanolic extracts of *K.africana* fruit fibers.

Figure 7 (7.1 - 7.6): Effect of dyeing on cotton and silk fibers with ethanolic and methanolic extracts of *K. africana*

7.1 Control cotton thread

7.2 Control silk thread



7.3 Cotton dyed with ethanol extract

7.4 Silk dyed with ethanol extract

7.5 Cotton fibers dyed with methanol extract

7.6 Silk fibers dyed with methanol extract

Conclusion

Kigelia Africana fruit extracts (methanol and ethanol) can be used as a source of natural dye for dyeing of cotton and silk fibres. The colour shades obtained after the treatment of the fibres with the extracts belong to the group of pastel shades. The combination of auxochrome enhances the dyeing effect on the tested fibres. On the basis of photodegradation and spectrophotometric analysis it can be concluded that the dye gets naturally degraded on exposure to sunlight. We can draw the inference from the data that these extracts could be an alternative source to synthetic dyes. Therefore, Kigelia Africana fruit extracts could be a source of non-toxic, ecofriendly, biodegradable natural dye to the dyeing industries.

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