ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

OPTIMIZATION OF DYEING PROCESS PARAMETERS FOR DYEING OF COTTON FABRIC USING EXTRACTS OF ALOE SUCCOTRINA

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Abstract: *There is presently an intentional shift in research from synthetic dyes, which are considered as harmful to the environment to more environmentally friendly dyes such as natural dyes that are derived from plant and animal sources. Apart from being friendly to the environment, some natural dyes have the unique advantage of being able to impart antimicrobial and antifungal finish properties to fabric hence introducing therapeutic potentials in them. For proper dyeing of fabric, dyeing parameters need to be optimized to achieve the best fastness results. In this paper, we investigate and report the optimum dyeing conditions for the dyeing of extracts from Aloe succotrina, a unique royal purple dye, onto cotton fabric. Dyeing was done on pure, scoured and mercerized fabric sourced from Rivatex East Africa in Eldoret. Four conditions namely, temperature, pH, dye concentration and time were optimized by measuring the highest colour strength (K/S) value. To further evaluate the colour of the dyed fabric, CIELAB values were recorded for each of the optimized parameters using a spectrometer. The optimum dyeing conditioned were as follows, the optimum pH was 7.1, temperature 100 ℃, dyeing concentration undiluted and time 60 Minutes.*

Key words: *Natural dyes, colorants, synthetic dyes, colour strength, environmentally friendly*

1. INTRODUCTION

Natural dyes as the name suggests, are dyes that are derived from nature, and includes colorants from insects, plants such as turmeric, heena , fish such as shellfish and mineral rocks such as the red ochre [1], [2]. This, have historically been the main sources of color and pigment until the year 1856 when the first synthetic dye was invented. Synthetic dyes had advantages over most natural dyes because they had reliable shades that were more permanent, long lasting and sustainable [3], [4]. Despite these advantages, research has shown that synthetic dyes are harmful to the environment causing among other diseases cancer and allergies. Unlike their synthetic counterpart, natural dyes have been shown to easily degrade once in the environment hence, there is increasing interest on the possibilities of natural dyes as substitutes to synthetic dyes.

Apart from their environmentally friendliness, natural dyes have been shown to impart antimicrobial, antifungal and UV protection properties on to the fabric. Within the slopes of Elgeyo Marakwet County in Kenya, lies a unique species of *Aloe*, named the *Aloe succotrina*. This plant, can be separated from other species of *Aloe*, by its royal purple sap which is often harvested for its pigmentation properties [5], [6]. In Kenya, the plant has been used for the dyeing of sisal bags commonly called "Kiondos" by the Marakwet community of Kenya. Despite its potential as a source of natural dye, limited research has been done on its dyeing abilities or its optimization. In this paper, we discuss the optimization of the extracts of the *Aloe succotrina* sap in dyeing cotton for the first time.

2. MATERIALS AND METHODS

2.1 Materials

Cotton fabric used for this study was white, pure, scoured and mercerized, which was sourced from Rivatex Mills, in Eldoret Kenya. The dyes pH was adjusted using NaOH and HCl obtained from Sigma Aldrich and supplied by Kobian Laboratories Nairobi. The *Aloe succotrina* plant was Collected from Sisiya in Elgeyo Marakwet county at the slopes of Kerio Valley Kenya (latitude 0°,58' 56.2" N, longitude 35°, 40' 0.01" E).

2.2 Methods

2.2.1 Extraction of dye

The outer layer of the leaf was first separated from the fleshy latex part manually. It was then crushed in a blender and filtered to remove the pulp from the liquid dye [7].

2.2.2 UV-Vis spectra of the dye

The UV-Vis spectra was measured between 200-800nm via a single beam Beckman- Coulter Model DU^{R}720 UV-Vis

2.2.3 Optimization of parameters used for dyeing

Dyeing parameters optimized included, dye concentration, temperature, pH and dyeing time. With the exception when a specific parameter was being studied, the conditions used for dyeing was a temperature of 60°C, materials to liquor ratio 1:20, dyeing time of 1 hr and an undiluted crude extract [8], [9].

2.2.3.1 Optimization of dye concentration

With all the other variables held constant, the concentrations of the bath were as follows the dyeing concentrations were varied as follows; crude undiluted, and dilutions of 1:1. 1:2, 1:3 and 1:4 and the fabric dyed.

2.2.3.2 Optimization of dyeing pH

With all the the other variables held constant, the pH of the dye was varied at 3.0, 5.2, 7.1, 9.0 and 12. The pH was adjusted to the desired value using HCl and KOH. The dyed fabric were then washed to remove excess dyes and then dried under shade before their colour strengths analysis.

2.2.3.3 Optimization of dyeing temperature

Five experiments were done to determine the colour strengths at temperatures;25, 40, 60, 80 and

100 ^{o}C with all the other factors held constant.

2.2.3.4 Optimization of dyeing time

All the other factors were held constant but the dyeing times were varied from; 10 min, 20 min, 30 min, 40 min, 50 min to 60 min.

2.2.4 Colour strength and Cielab measurements

CIE L*, a*, b* measurements were done using an X-rite spectrometer SP60- illuminant D65-10 Mode. Cie C and H° and colour strength were calculated using equations 1,2 and 3 below [10], [11]

Chroma (C) =* $\sqrt{a^2 + b^2}$ **(1)**

Hue Angle(h) = $tan^{-1\frac{b}{a}}$ **(2)**

Colour strength $\frac{K}{S} = \frac{(1-R)^{\,2}}{2R}$ **(3)**

3. RESULTS AND DISCUSSION

3.1 UV Spectra of *Aloe Succotrina*

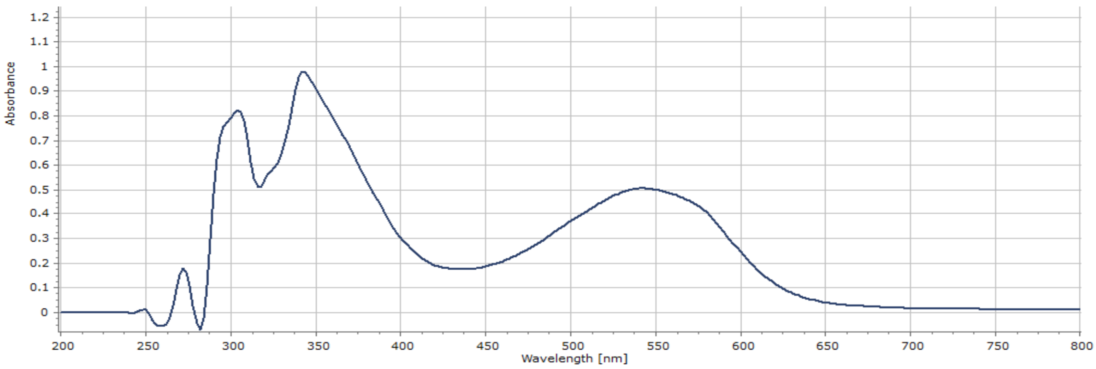

Fig. 1. *Represents the UV spectra for the purple Aloe succotrina dye*

As seen in figure 1 above, two peaks were observed one around 540 nm and the other at around 340 nm. The peak around 540, is characteristic for purple coloured anthocyanin, whose peaks usually absorb at wavelengths of around 540-580. Examples of some anthocyanins that absorb around this region include petunidin (λ_{max}=543), malvidin (λ_{max}= 542) and delphinidin (λ_{max}= 546) [12]

3.2. Evaluation of effect of dyeing parameters on the colour strength (K/S)

To examine the most effective points that are to be used for dyeing, the colour strengths of the fabric are usually measured [13]

***Table 1**: Optimization of dye concentration*

Concentration of dye / Parameter	No dilution	Diluted 1:1	1:2	1:3	1:4
L	60.01	62.76	63.06	69.18	72.16
a	10.52	13.16	12.92	12.03	11.61
b	-7.01	-16.78	-16.90	-13.14	-12.98
c	12.6	21.3	21.3	17.8	17.4
h°	326.3	308.1	307.4	312.5	311.8
K/S	0.85	0.53	0.44	0.22	0.12

Optimization of dyeing concentration showed that the lightness (L) value of the dyed fabric changed as a function of dilution, so that the colour lightness increased as the dye concentration decreased [10]. With a negative value of b suggesting that the colour has a blueish shade. The non-diluted dye had the highest K/S value hence suggesting that the most effective dyeing condition when the concentration is optimized is when the dye is not diluted. This is because, in its non-diluted state, more dye molecules are available to bind with the fabric [14], [15].

***Table 2**: Optimization of pH*

pH of dye / Parameter	3.0	5.2	7.1	9	12
L	70.86	62.57	72.76	73.16	74.11
a	9.95	12.22	7.88	7.87	8.07
b	-3.45	-16.11	-6.02	-9.01	-8.16
c	10.5	20.2	9.9	12.0	11.5
h°	340.9	307.2	322.6	311.1	314.7
K/S	0.71	0.84	0.87	0.75`	0.62

Optimization of pH also shows that as the pH changes from 3.0-12 there is a steady increase in the value of Lightness (L). This showing that as the pH increases, the Lightness of the dye on the fabric equally increases [10]. The pH with the highest K/S value is pH 7 suggesting that it is the condition to dye at.

***Table 3:** Optimization of time*

Time / Parameter	20 MIN	30 MIN	40 MIN	50 MIN	60 MIN
L	72.01	68.98	69.79	66.48	62.57
a	8.72	11.01	11.12	10.62	12.22
b	-4.27	-9.01	-8.05	-7.92	-16.11
c	9.7	14.2	13.7	13.2	20.2
h°	333.9	320.7	324.1	323.3	307.2
K/S	0.16	0.28	0.33	0.83	0.84

Optimization of time shows the highest L value was at 60 Min meaning that it had the lightest colour and the highest K/S value at 60 minutes. Meaning that 60 Minutes is the optimum time for dyeing with the highest value of K/S being the most optimum time [11], [13]. This suggesting that the more the time, the more the interaction between dye and fabric

Table 4: *Optimization of temperature*

Temperature / Parameter	R.T	40	60	80	100
L	62.57	60.23	64.36	64.01	63.55
a	12.22	12.01	11.15	11.17	11.22
b	-16.11	-10.97	-5.56	-5.01	-4.71
c	20.2	16.3	12.5	12.2	12.5
h°	307.2	317.6	333.5	335.8	333.5
K/S	0.84	0.82	0.88	0.88	0.92

The highest L value was at 60 °C meaning that at this point, it was the lightest. The highest K/S value was at temperatures of 100 °C meaning that it is the optimum dyeing temperature this is because as temperature increases the structure of the fabric increases allowing for the uptake of more dye [10], [11].

The fabric dyed under optimum conditions was as shown below in Figure 2.

Fig. 2*: Cotton fabric dyed under optimized conditions*

4. CONCLUSIONS

In this paper, we document the process of optimization of dyeing conditions from extracts of the *Aloe succotrina* plant on cotton. The optimum dyeing conditions were found to be pH of 7.1, temperature of 100 °C, dyeing concentration undiluted and a time of 60 Minutes this, gave rise to a purple coloured fabric.

ACKNOWLEDGEMENT

The authors would like to thank the African Centre of Excellence (II) in phytochemicals textile and renewable Energy (ACE II-PTRE) for funding this project. Equally, Rivatex textile Mills-Eldoret, Mr John Khafafa and Paul Kipkorir are also acknowledged assistance.

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