Extraction, Chemical Modification and Characterization of Turmeric Dye *(Curcuma longa)* and its Application on Cotton Fabric

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Abstract: Curcuma longa is a tropical plant whose rhizomes has been used to dye cloth since at least 2500 BCE but being a natural dye, it has poor to moderate fastness. In this study, an attempt was made to extract turmeric dye from Curcuma longa rhizomes and carry out its chemical modification by the choline chloride method to improve its fastness property when applied to fabrics. Turmeric dye was extracted from the rhizome using acetone and further crystallized with hexane to form the curcumin, the concentrated yellow dye. The characterization of the extracted dye and modified dye was carried out using Fourier Transform Infrared (FTIR) spectroscopy. Dyeing of cotton fabric was carried out using the extracted dye and the modified dye. Fastness properties was also determined on the dyed fabric. Fastness properties of natural Curcuma Longa dyed cotton fabric ranged from moderate [2] to good [4] and that of modified Curcuma Longa dyed cotton fabric ranged from good [4] to excellent [5]. This indicate that the modified fabric has better fastness properties. Dye manufacturing from local plants should be supported using chemical modification to achieve better fastness properties on dyed fabrics.

Key Word: Chemical modification, Dye, FTIR, Turmeric, Fabric

I. Introduction

Generally, dyes are used for colouring of foods, drugs, leather, cosmetics, petroleum products and textile materials among other things. These materials are dyed for different purposes, for instance, in leather industries; one of the reasons for dyeing the leather is to make it adaptable for fashion styling (Adeyanju et al., 2021; Opera et al., 2014). Petroleum products are coloured for identification of fuel adulteration (Adeyanju *et al.*,2021; Ezeokonkwo and Okoro, 2014) andfor differentiation of various petroleum products (Rostad, 2010).Most substances are generally dyed to enhance appearance and aesthetic value of finished products. In recent times, many people are becoming more conscious of the need to use natural dyes in food colouring as against synthetic dyes (Dweck, 2009). Some of the approved dyes are being delisted due to legislative action as well as consumer interest (Garcia and Cruz-Remes, 1993). Again, natural food colourant contain some biological active components such as lycopene, carotenes, canthaxanthin and quercetin which plays a vital role in human health (Okafor *et al.,* 2016).

Turmeric (a yellow dye) is a good colouring agent (Yankar et al., 2007) which is used as a spice and as natural food colourant. Turmeric has been reported to have a powerful antiseptic effect that revitalizes the skin while Indigo, a dark blue dye has a cooling sensation (Gravier and Patni, 2011). Dyes are coloured substances that chemically bonds to the substrate to which it is being applied (Booth and Gerald, 2000). They are molecules that can be dissolved in water or some other carrier so that they will penetrate the fiber (Patra et al., 2000).

The colour of a dye is dependent upon the ability of the substance to absorb light within the visible region of the electromagnetic spectrum (380-750nm). An earlier theory known as Witt's theory stated that a coloured dye has two components, a chromophore which imparts colour by absorbing light in the visible region and an auxochrome which intensifies the colour but this theory has been superseded by modern electronic structure theory which states that the colour in dyes is due to excitation of valence pi-electrons by visible light (Bafana et. al., 2011).

The colouring matter in turmeric is called curcumin ($C_{21}H_{20}O_6$). Curcumin is a yellow-orange compound extracted from curcuma rhizomes, especially Curcuma longa, obtained through extraction with solvent and extract purification through crystallization. The chemical composition of the commercial product is often the mixture of curcuminoids derived from curcuma invaried proportions. The concentration of the three major curcuminoids of different samples of Curcuma longa presented an average composition of 50 - 60% curcumin, 20 - 30% demethoxy-curcumin and 7 - 20% bidemethoxycurcumin (Li et al., 2011). In figure 1:

In curcumin (Cur): R_1 = -OCH_3; R_2 = -OCH_3

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Demethoxycurcumin (DMC): R_1 = $-OCH_3$; R_2 = H

Bisdemethoxycurcurmin (BDMC): R_1 = H; R_2 = H

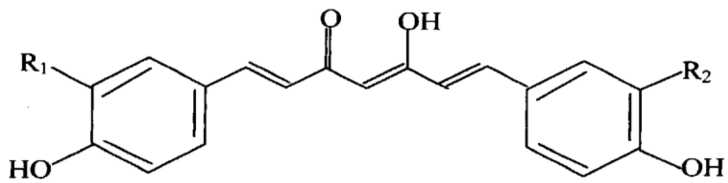

Figure 1: Curcumin

Natural dyes are limited and their fastness properties are not so well as well as the colour tones also limited. It has been generally perceived that naturally extracted colours give faint and less compatible colours compared to synthetic ones, (Adeyanju et al., 2021). Therefore, the aim of this study is to extract natural turmeric dye from rhizomes of turmeric, chemically modify the dye in order to improve its fastness properties and relate this to the potential application on cotton fabric.

This study has the potential to promote the preservation of the ancient and traditional dyeing technology that generate livelihood for artisans/dyers as potential employment generation facility. This study will also show how modification of turmeric dye could improve its fastness properties and help to decrease the loss of dyes, avoid fading and help to increase the usage of natural dyes because they are advantageous to humans.

II. Materials And Methods

The fresh rhizome of Curcuma Longa was obtained from Faringada market, Jos, Plateau State, Nigeria. The rhizomes was washed with water to remove the dust and impurities at the external part of the root and then dried in sunlight. Plain weaved cotton fabric was also obtained from terminus market, Jos, Plateau State, Nigeria.The rhizomes of the turmeric were washed with warm water to remove external materials, sliced and dried in the sunlight for three days and again dried in the oven at 100°C for 40 minutes to remove excess moisture. The dried sample was grinded with mortar and pestle to a fine powder, sieved with 2mm mesh and kept at ambient temperature protected from light in clean polythene bag for subsequent chemical analysis. Crushed turmeric sample (50g) was weighed, transferred into a beaker and 300 ml of acetone was added and the solution was stirred for 48 hrs, the mixture was then filtered with filter paper properly folded into a funnel to separate the filtrate from the residue. The residue was again washed with 150 ml of acetone for complete extraction. Further purification was carried out by crystallization using hexane. The solid formed was collected in a crucible and dried in an oven at a temperature of 100°C for concentration. The resulting dried turmeric paste was grounded into powder and stored in plastic container for subsequent chemical analysis (Popuriand, 2013).

Scouring

Pieces of plain woven cotton fabrics were weighed and the weight of fabric (WOF) was recorded. Beaker was placed on low heat, distilled water and washing soap (25% WOF) was added, the fabric and sodium carbonate was also added into the beaker and it was simmered for 2 hours while stirring. The scoured fabrics were thoroughly but gently washed with pH neutral dish soap, rinsed with tap water and dried at room temperature (Sasha 2010).

Mordanting

Mordanting solution was prepared by dissolving aluminium sulphate (10% WOF) in a beaker placed over the heat containing required quantity of distilled water. Pre-mordanting was done by treatment of the scoured cotton fabric with the metal solution for 1 hour with continuous stirring at temperature of 60°C. It was brought down to cool, the fabric was allowed to soak in the solution overnight and the excess solution was wringed off, rinsed and allowed to dry (Bhattacharya and Shah, 2000).

Chemical Modification of Turmeric Dye

The modification of turmeric dye (curcumin) was carried out using the cholinechloride method; the use of deep eutectic solvent (DES). DES was obtained by the reaction of cholinechloride (l mol) with urea (2 mol) at 90°C until a clear solution was obtained. Curcumin (0.48g) and 0.96g of DES were mixed and heated with stirring for 19 hours at 70°C. The mixture was then dissolved in tetrahydrofuran (THF) and precipitated with water, filtered off and then dried (Abbott et al., 2007).

pH Analysis of the Dye

Dye sample (0.5g) was dissolved in 20 ml of acetone and the pH measurement was taken using pH meter.

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Preparation of Dye Bath and Dyeing Process

Dye stuff, distilled water and sodium chloride (which acts as an electrolyte) were put into a beaker and heated at 80°C. The desized and scoured fabric was put in the dye solution and allowed to simmer for 2 hours with continuous stirring. It was brought down and allowed to remain in the dye solution for 24 hours to enable complete dye uptakeby the fabric (Ding and Freeman, 2017).

The fabric was further washed with pH neutral washing soap to remove unreacted dye, rinsed and dried at room temperature.

Characterization By Ftir Analysis

The FTIR spectra of the natural and modified turmeric dye were recorded using Attenuated Total Reflectance (ATR) of Fourier Transform Infrared (FTIR-8400S) Spectrophotometer at Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria.

Fastness Tests

Colour fastness test on dyed sample was carried out using ISO standard methods. The light fastness of the fabric was examined using ISO/FD/105-B02. Then the colour fading was also evaluated by comparing each sample with standard blue scale. The washing fastness of the sample was tested on the basis of ISO 105-[06:2010]. Shades changes with washing, ironing and sunlight fastness was determined using a grey scale (marks) 1 - 5,1 = poor, 5 = excellent. For fastness to washing tests, all the dyed fabrics were soaked in laundry soap for one hour, washed and rinsed with cold water. The fabrics were then allowed to dry at room temperature. Fastness to sunlight was tested on the dyed fabrics by exposure to sunlight for ten hours every day for three days and fastness to ironing was tested by ironing for five minutes, three times at different intervals for three days.

III. Results And Discussion

Results

Table 1: Result of drying analysis

Mass of wet rhizomes (g)	Time taken (hours)
300	0
86.2	72

Moisture contents = C – D

$$\% \text{ Moisture} = \frac{C - D}{c} \text{ x } 100$$

Where

C = Mass of wet sample = 300g

D = Mass of dry sample = 86. 2g

Moisture content (300 – 86.2) g = 213.8g

$$\% \text{ Moisture} = \frac{213}{300} \text{ x } 100 = 71.3\%$$

Fastness Properties

Table 2: Fastness to Washing

Days	Natural Turmeric dye	Modified Turmeric dye
1	4	5
2	2	4
3	2	4

Key: 1 – Poor, 2 – Moderate, 3 – Four, 4 – Good, 5 – Excellent

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Table 3: Fastness to Sunlight

Days	Natural Turmeric dye	Modified Turmeric dye
1	3	4 – 5
2	3	4
3	3	4

Key: 1 – Poor, 2 – Moderate, 3 – Four, 4 – Good, 5 – Excellent

Table 4: Fastness to Ironing

Days	Natural Turmeric dye	Modified Turmeric dye
1	2	4
2	3	4 – 5
3	3	5

Key: 1 – Poor, 2 – Moderate, 3 – Four, 4 – Good, 5 – Excellent

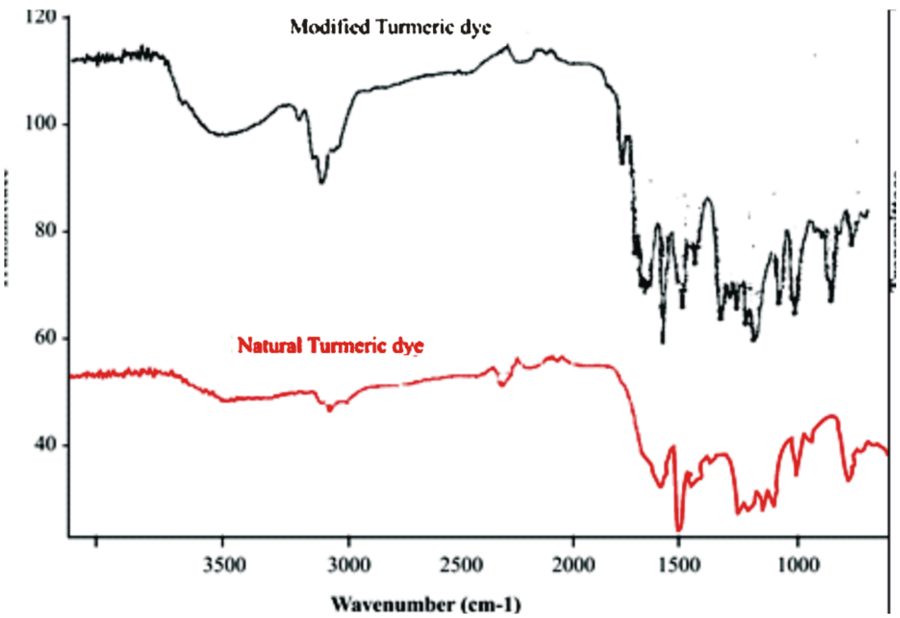

Figure 2: FTIR spectra of Natural and Modified Turmeric dye

IV. Discussion

Table 1 shows the drying of the fresh rhizomes. The moisture content (71.3%) is within the range of moisture content of other rhizomes of the Zingiberaceae family. The pH of natural turmeric dye was found to be 6.19 indicating that the dye is slightly acidic; the pH of the modified turmeric dye was found to be 7.48 indicating that the modified dye is basic. FT–IR measurements for the dye are shown in Figure 2 and Figure 3. The dye FTIR spectra were obtained at different frequency bands. For natural turmeric dye, some of the major bands were obtained with peaks at 2920.4 cm^{-1}, 1675.4 cm^{-1}, 1578.5cm^{-1},1507.7cm^{-1},1427.6cm^{-1},1269.2cm^{-1},which are attributed to O-H stretching of alcohols, C=C stretching of alkanes, C–O stretching of tertiary alcohol, N–O stretching of nitro compounds, O – H bending of carboxylic acid and C–O stretch of alkyl aryl ether respectively, (Adeyanju et al., 2021).Modified turmeric dye shows similar dye absorption peaks with slight shift in the intensity and frequency absorption. However, the major discrepancy between the FTIR spectra of the two dye samples is the peak obtained at 2215.9cm^{-1} attributed to C=N stretching of nitrile in FTIR spectrum of figure 3. This is suggested to be due to the introduction of deep (eutectic) solvent to theturmeric dye during modification. Also, unlikeFTIR spectra of figure 2, figure 3 spectrum shows absorption peak at 818.2cm^{-1} attributed to C-Cl stretching of alkyl halide, (Adeyanju, et al., 2021).The result after washing showed some changes in natural

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dyed fabric from deep yellow to faded yellow while cotton fabric dyed with modified has a better fastness property since the dyed fabric colour remained unchanged.

Result from test fastness to sunlight after exposing the fabric dyed with natural dye showed noticeable change from light yellow to faded yellow. The result of the modified dyed fabric after exposure to sunlight remained unchanged.The result of ironing of the natural dyed fabric showed that there is a noticeable change in the colour unlike the dyed fabric using modified dye which the colour remained unchanged.Generally, the fastness properties for the modified turmeric dye is excellent compared to the natural dye.

V. Conclusion

The aim of this research work was achieved as the product was obtained in proposed powdered form. The colour of the extracted dye obtained was yellow and the colour of the modified turmeric wa sorange-yellow.It was observed that the modification of dye has effect on the dyed fabric by improving the fastness properties.Local dyers should employ the services of experts in the modification of turmeric dyes to achieve better fastness properties.

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