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Extraction, optimization and evaluation of turmeric root (*Curcuma longan*) dyeing conditions on cotton fabric

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Abstract
Dye is a coloured substance that chemically bonds to the substrate to which it is applied. This distinguishes dyes from pigments, which do not chemically bind to the material to which they impart colour. The aim of this research is to extract, purify, characterize, and optimize dyeing conditions on cotton fabric. The extraction of dye from turmeric root powder shows that, 50 g of turmeric root powder produces a yield of 24%. The standard method was used to scout 1.7g, which is equivalent to (4x2cm) of cotton fabric. The weight of the cotton fabric was observed to decrease. This was attributed to the removal of impurities such as gum, wax, and other colorants. The mordanting of the cotton fabric was observed to increase the weight of the fabric. This is because the mordant attaches itself to the fabric. The optimum concentration for dyeing using turmeric root dye extract is 2.0 g/dm^3. The ideal dyeing time and temperature are 60 minutes and 90^0C respectively. The colour fastness of optimally dyed fabric to washing and rubbing exhibits a good fastness, which is highly acceptable. An attempt should be made to improve the fastness properties of dyed fabric by varying the mordant concentration as well as using different mordant.

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Keywords: Cotton, Dye, Extract. Turmeric

Introduction

Natural dyes are a non-toxic alternative to conventionally used synthetic dyes that are causing irreversible damage to the planet [1]. By using natural dyes, there is a direct cut back on the toxic chemicals being released that are associated with synthetic dye [2]. Synthetic dyes are not environmentally friendly as their synthesis involve extreme conditions such as high pH, high temperature, strong acids, and heavy metal catalysts. Synthetic dyes are toxic, carcinogenic and can cause skin and eye irritation [3]. Synthesis generates a large amount of effluent which contains toxic chemicals generated as side products. Synthetic dyes are not biodegradable; they accumulate on lands and in river causing ecological problems [4]. Many natural dyes have antimicrobial properties, making them safer for kids in particular [5]. Advantages of natural dyes such as its non-allergic, non-toxic, biodegradation and eco-friendly on textiles makes them suitable for consideration [6]. There are huge applications of natural dye on textile so it is clamorous to promote technology for extraction [7].

Turmeric is a golden spice derived from the rhizome of the *Curcuma longa* plant, which belongs to the Zingiberaceae family [8]. Since ancient times, turmeric has been used as the principal ingredient of dishes originating from Bangladesh and India for its color, flavor, and taste. It is also used in social and religious ceremonies in Ayurvedic and folk medicines against various ailments, including gastric, hepatic, gynecological, and infectious diseases [8, 9]. Dry turmeric contains 69.43% carbohydrates, 6.3% proteins, 5.1% oils, 3.5% minerals, and other elements [10]. The bioactive chemical constituents in turmeric have been extensively investigated.

To date, approximately 235 compounds, primarily phenolics and terpenoids, have been identified from various species of turmeric, including twenty-two diarylheptanoids and diarylpentanoids, eight phenylpropenes as well as other phenolics, sixty-eight monoterpenes, 109 sesquiterpenes, five diterpenes, three triterpenoids, four sterols, two alkaloids, and fourteen other compounds [11]. Curcuminoids (mostly curcumin) and essential oils (primarily monoterpenes) are the major bioactive constituents showing different bioactivities. Calebin-A, vanillic acid, vanillin, quercetin, and other phenolic compounds have also previously been identified from turmeric [8, 12].

Yakubu *et al.* [13] studied Natural dye produced from heartwood of *Baphia nitida* and was tested on cotton fabric. It was observed that 16.91% was obtained as percentage yield of the dye. The color of the dye extract was red. The results of the FTIR characterization suggested the presence of OH, C-H, CHO, C≡N, C≡C, C=O, N=O, C=C, C-Cl and C-Br functional groups in the dye extract. The GC-MS separated and identified 30 compounds. Among the compounds identified from the dye extract, Benz (a) anthracene, 7,8 - dimethyl, has the highest percentage area of (35.09%) and 1,3,5 - Triazine - 2,4,6 - triamine has the lowest percentage area. The chromophores in the dye extract are N=O and C=O. The natural dye extract was applied on the cotton fabrics without a mordant. The color fastness to washing shows that 2-3 and 4 was experienced for color change and staining respectively while the color fastness to rubbing shows that 3-4 and 2-3 color changes was experienced for dry and wet rubbing respectively without mordant. The outcome of color fastness of the dye will show a very good affinity to remain on the fabric when mordant is applied.

Dass *et al.*, [14] studied the extraction and testing of natural dye from Cissus populnea stem bark and its application on cotton fabric was studied. The maximum absorbance of crude dye from Cissus populnea stem bark extract at different temperature was measured by Ultra Violet-Visible spectrophotometer in a wavelength range of 495 nm-535 nm. It was observed that, the effect of time on dye extraction showed increase in intensity of dye as time increases. Ultra Violet-Visible spectrophotometer also showed that as the extraction time increases the absorption wavelength (nm) also increases from 450 nm to 560 nm. This was ascribed to the high yield of extract and the subsequent evaporation of solvent. Effect of temperature on extraction showed that as the temperature increases from 40℃ to 100℃ the dye intensity also increases.

The natural dye selected for this study is curcumin pigment, which is extracted from turmeric. Curcumin, or bis(4-hydroxy-3-methohyphenyl)-6-diene-3,5-dione, is derived from the rhizome of the plant *Curcuma longan L*, as shown on Plate 1 which is popularly called turmeric, a member of the Zingiberaceae family [15]. The aim of this research is to extract, purify and optimize dyeing conditions on the cotton fabric.

Plate 1: Plant used for the research work Turmeric root (*curcuma longan*)

Materials and Methods

Sampling and sample preparation

The sample was collected at government secondary school, Wukari Local Government of Taraba state. The sample was washed with water, peeled, and dried in the shade. The dried sample was ground into a powder form, ready for extraction.

Scouring process

The scouring process was carried out using 3M of sodium hydroxide. To each of the cotton fabric. 50 ml of the prepared sodium hydroxide was used to carry out the scouring process for 1h at 100^0C [16].

Bleaching process

To each of the cotton fabric, 3M of sodium hypochlorite was measured with measuring cylinder and 100 ml of the prepared solution was used to carry out the bleaching process for 1 hour at 100^0C [17].

Mordanting method

The mordanting was carried out prior to dyeing the cotton fabric. A 5% concentration of the mordant was prepared, which is used to carry out the mordanting. The fabric was immersed in 50 ml of the mordant solution for about 60 minutes at 60ºC. After mordanting, the fabric was taken out and squeezed by hand before being immersed in the dye bath [18].

Extraction and Purification of natural dye

A hot method of extraction was used to extract the dye from the turmeric root. Weighing 50 g of turmeric root powder into 500 ml of distilled water in a 500-ml pyrex beaker yielded the yellow natural dye. At 60ºC, the mixture was heated and stirred for 1 hour. After that, it is allowed to stand for 30 minutes before being filtered. The filtrate was dehydrated to obtain the dye. A dye solution was prepared and used for dyeing the fabric [19].

Dyeing process

The cotton fabric to be dyed was added to the dye solution in the bath and dyeing was carried out at certain concentration, temperature and time using a fixed amount of liquor ratio (1:100).

During dyeing, the fabric was frequently stirred in order to obtain the good penetration of dye molecules into the fabric. After dyeing, the dyed sample fabric was thoroughly washed with cold water to remove the unfixed dye particles and squeezed by hand. Then, the dyed fabric will be dried at room temperature [20].

Optimization of dyeing concentration

To determine the best dyeing concentration, different dye concentrations (0.5, 1.0, 1.5, 2.0, and 2.5 g/dm^3) were prepared. The cotton fabric was dyed at a constant temperature and time. The absorbance of dye solutions before and after dyeing was recorded at the optimum wavelength. The dye concentration giving the maximum amount of dye absorbance was taken as the optimum dye concentration [21].

Optimization of dyeing temperature

To optimize dyeing temperature, dyeing was carried out at 50^0C, 60^0C, 70^0C, 80^0C, 90^0C and 100^0C. Using optimum concentration over a constant time. The absorbance of dye solutions before and after dyeing was recorded at the optimum wavelength. The temperature at which the maximum amount of dye could be absorbed was taken as the optimum dyeing temperature [22].

Optimization of dyeing time

To optimize dyeing time, dyeing was carried out at optimum concentration and temperature for 20, 30, 40, 50, 60, and 60 minutes. The absorbance of dye solutions before and after dyeing was recorded at the optimum wavelength. The time when the maximum amount of dye could be absorbed was taken as the optimum time for dyeing [23].

Wash fastness properties

The dyed fabric was first cut (4x2cm) after which the undyed white fabric was cut (4×2) and were machine-stitched to give one piece of fabric. Exactly 100 ml of water was measured with measuring cylinder, 3 g of detergent (*Viva plus*) was weighed using weighing balance and dissolved in the 100 ml water contained in the beaker. The stitched fabric was introduced into the detergent solution and was stirred vigorously for 10 minutes, then rinsed and dried at room temperature [24].

Rubbing fastness properties

The dyed fabric was first cut (4x2cm) after which the undyed white fabric was cut (4×2) for both (dry and wet rubbing). For dry rubbing, the undyed white fabric was rubbed against the surface of dyed fabric for 10 minutes. For wet rubbing, the undyed white fabric was first immersed in water (wet) and was rubbed against the dyed fabric for 10 minutes [25].

Results and Discussion

Extraction and purification of dye extract

Plate 1 is sample of pulverized Turmeric root (*curcuma longan*) powder and Plate 2 is the dye extract of the Turmeric root dye. The result of the extraction and purification of dye extract described in Table 1 which shows that, the percentage yield from 50 g of turmeric root powder was 24% dye extract. The color of the dye extract is a deep yellow.

Plate 2: Sample of pulverized Turmeric root (*curcuma longan*)

Plate 3: Dye solution Turmeric root (*curcuma longan*)

Table 1: Extraction and purification of dye extract

Turmeric root powder (g)	Weight after extraction and purification	Actual yield (g)	Percentage yield (%)
50	38	12	24

Scouring and bleaching of cotton fabric

The result of the purification of the cotton fabric, as described in Table 2, shows that the scouring and bleaching of the cotton fabric was carried out with sodium hydroxide and sodium hypochlorite, which led to a decrease in the weight of the cotton fabric. This is because the scouring and bleaching process removes impurities such as wax, gum, fat, etc. from the cotton fabric, thereby decreasing its weight [17]. Yakubu *et al.* [13] studied the scouring and bleaching on cotton fabric, the results showed that there is a progressive decrease in the weight of fabric after scouring and bleaching due to removal of natural wax and non- fibrous impurities, making the fabric permanently white and brighter and as such the weight is reduced. This is in agreement with the current study.

Table 2: Scouring and bleaching of cotton fabric

Weight of fabric before scouring (g)	Weight of fabric after scouring and bleaching(g)	Weight lost (g)
1.7	1.584	0.116

Optimization of dyeing concentration

To determine the optimum concentration for dyeing, dyeing was carried out at different concentrations such as 0.5 g/dm3, 1.0 g/dm3, 1.5 g/dm3, 2.0 g/dm3, and 2.5 g/dm3 of the dye extract in 100 ml of water to form dye solution. The results

in Fig. 4.1 show that for scoured fabric with and without mordant, show that from 0.5 g/dm3 to 2.0 g/dm3 the amount of dye absorbed increases and declines at 2.5 g/dm3.This means that, at 2.0 g/dm3, scoured fabrics with and without mordant have attained their optimum absorption or equilibrium, respectively. An increase in dye concentration leads to an increase in the amount of dye absorbed until the cotton fabric reaches equilibrium [18]. Therefore, the optimum concentration for dyeing using turmeric root dye extract is 2.0 g/dm3 for scoured fabric with and without mordant, respectively. However, the amount of dye absorbed at optimum concentration for scoured fabric with and without mordant is 21% and 25%, respectively. Scoured fabric without mordant has a high amount of dye absorption compared to scoured fabric with mordant. This is because the scouring process makes the fabric more hydrophilic, which enables it to absorb more of the dye in solution [17], while the application of mordant on the fabric increases the shade [18].

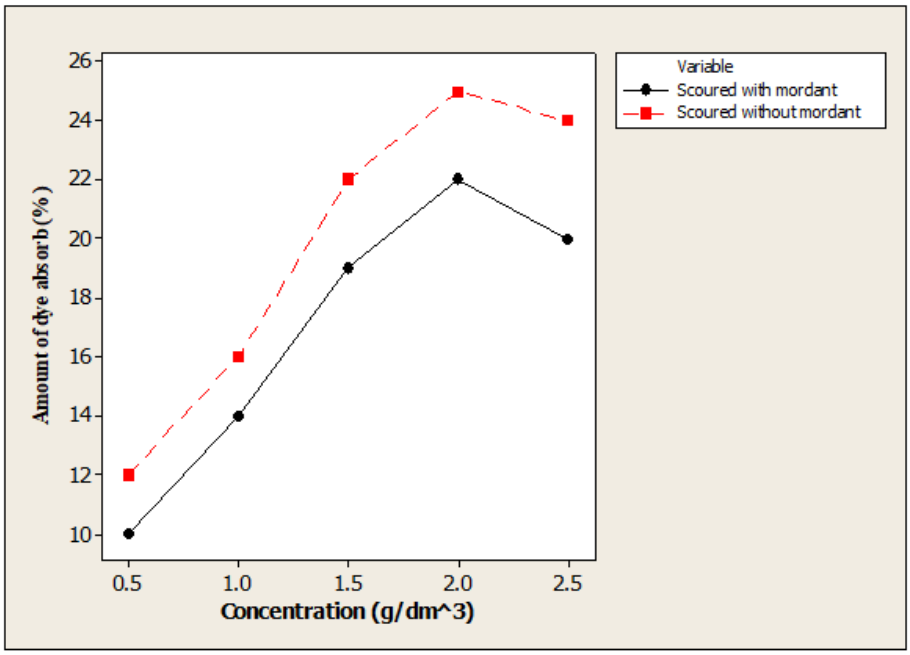

Fig 1: Optimization of dyeing concentration at 60oC, 30 min

Optimization of Dyeing Time

To determine the optimum dyeing time, dyeing was carried out at optimum dyeing concentration for scoured fabric with mordant and scoured fabric without mordant for 20, 30, 40, 50, 60, and 70 minutes. The results in Figure 2 show that an increase in dyeing time leads to an increase in the amount of dye absorbed [19]. Longer dyeing times create higher absorbance until dye exhaustion attains equilibrium [20]. Therefore, the optimum dyeing time using turmeric root dye extract is 60 minutes for scoured fabric with and without mordant. However, the amount of dye absorbed by scoured fabric with and without mordant at the optimum dyeing time is 30% and 33%, respectively.

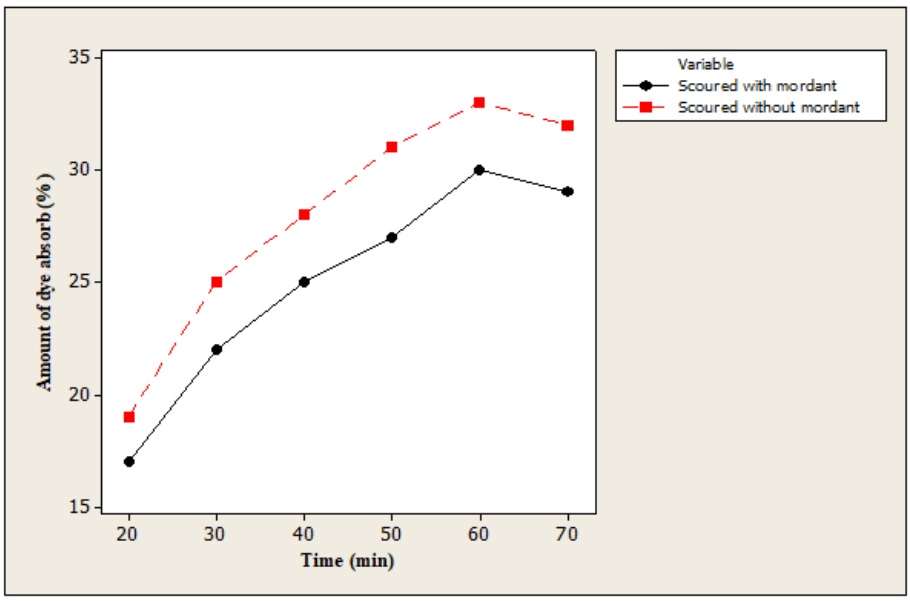

Fig 2: Optimization of dyeing time at optimum concentration and 60oC

Optimization of Dyeing Temperature

To determine the optimum dyeing temperature, dyeing was carried out at the optimum dye concentration and time for scoured with and without mordant at, and. The results in Figure 3 show that an increase in dyeing temperature leads to an increase in the amount of dye absorbed [19]. Longer dyeing temperatures create higher absorbance until dye exhaustion attains equilibrium [20]. Therefore, the optimum dyeing temperature using turmeric root dye extract is 90oC for scoured fabric with and without mordant. However, the amount of dye absorbed by scoured fabric with and without mordant at optimum dyeing temperatures is 48% and 53%, respectively.

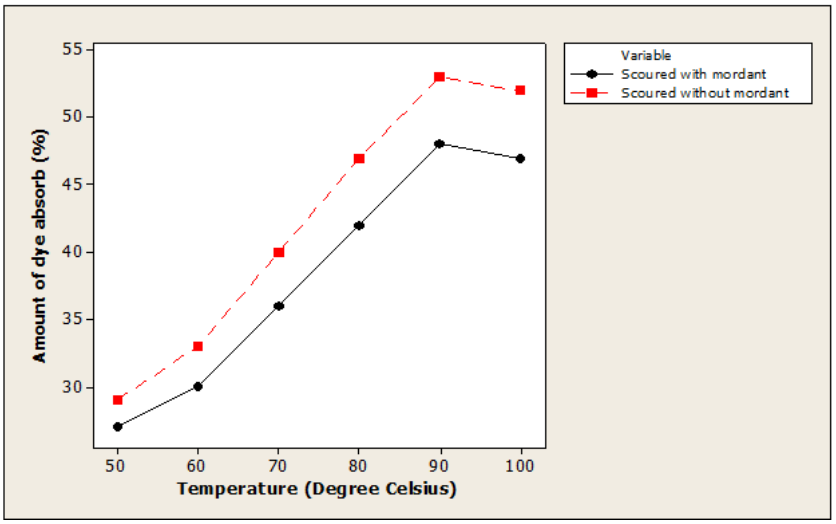

Fig 3: Optimization of dyeing temperature at optimum concentration and optimum time.

Plate 4: Dyed scoured fabric without mordant under optimum conditions

Plate 5: Dyed scoured fabric with mordant under optimum conditions

Colour fastness to washing of optimized dyed cotton fabric

It is evident from the data given in Table 3 that the cotton fabric scoured with mordant exhibited a rating of 4 for colour change and 4/5 for staining, while the cotton fabric scoured without mordant exhibited a rating of 3 for colour change and 4 for staining. The result indicates that colour fastness to washing is highly acceptable [21].

Table 3: Colour fastness to washing for optimum dyed fabric

Fabrics	Colour change	Colour staining
Scoured fabric with mordant	4	4/5
Scoured fabric without mordant	3	4

Colour fastness to rubbing of optimized dyed cotton fabric

Rubbing fastness was carried out in dry and wet conditions. It is evident from the data given in Table 4 that the cotton fabric scoured with mordant exhibited a rating of 4/5 for dry rubbing and 4 for wet rubbing, while the cotton fabric scoured without mordant exhibited a rating of 4 for dry rubbing and 3 for wet rubbing. The results indicate that colour fastness to rubbing is highly acceptable [21].

Table 4: Colour fastness to rubbing for optimum dyed fabric

Fabrics	Dry rubbing	Wet rubbing
Scoured fabric with mordant	4/5	4
Scoured fabric without mordant	4	3

Conclusion

The percentage yield of dye extract obtain in this research work was 24% dye extract. The research work has unveiled the optimum conditions for dyeing on cotton fabric using Turmeric root dye extract. In terms of the dye absorption, scoured fabric without mordant shows greater absorption compare to scoured fabric with mordant. The colour fastness to washing and rubbing shows that colour fastness to washing and rubbing is highly acceptable.

According to the washing fastness, it is recommended that the Turmeric dyed cotton fabric should not be washed together with other fabrics. This is because, the dyed fabric has the tendency to stain other fabric. As for future works, an attempt should be carried out in order to improve the fastness properties of dyed fabric by varying the concentration of mordant, and also the use of different mordant.

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