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EXTRACTION, APPLICATION AND ASSESSMENT OF THE FASTNESS PROPERTIES OF DYES FROM TURMERIC PLANT (CURCUMA LONGA) AND ITS EFFECT ON COTTON WOVEN FABRICS

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Abstract: *This study assessed the extraction, application and fastness properties of dyes from Turmeric plant and its effect on cotton woven fabric using Alum and Potash as mordants. The specific objectives of the study were to; determine the yield of turmeric dyes extracted with n-hexane, Methanol and water; examine the nature of the chromophores and auxochromes present in turmeric dyes by ultra-valent (UV) visible and Furrier transform infrared (FTIR) spectroscopy respectively; assess the effect of Alum and Potash mordants on the colour fastness of cotton woven fabric dyed with turmeric plant and to evaluate the acceptability of cotton woven fabrics dyed with natural dyes from turmeric plants by panelist. The study adopted an experimental research design; Microwave extraction technique was used to extract the natural dyes from dried turmeric roots. The natural dyes were applied to samples of cotton woven fabric followed by determination of the wash and light fastness properties of the prototypes. A panelist consisting of 15 members rated the organoleptic attributes on a five (5) point scale. UV-visible spectroscopic showed that methanol extracted the polar and non-polar colouring matters in the turmeric dye with bands at 288nm, 310nm and 420nm. (FTIR) showed several stretches which correspond to the curcumin structure present in turmeric. The dyes extracted were also in the colour range of yellow to orange and gave several effects with the mordants used. Findings revealed that turmeric dye extracted with methanol and mordanted with alum has the highest mean of 5.67 when exposed to sunlight and washing. The study therefore concludes that turmeric dye can be a good natural alternative for cotton fabric dyeing with good colorfastness properties. Based on the findings of this research work, the study recommends that; more advanced spectroscopic techniques such as nuclear magnetic resonance (NMR) should be used to characterize turmeric dyes and the dyes can be applied on textile production, cosmetics and drugs. Alum and Potash should be used as mordant to get the best in terms of both wash and light fastness of cotton fabric.*

Keywords: *Turmeric plant, cotton woven fabric, Alum, Potash, mordants*

1.0 INTRODUCTION

1.1 Background to the study

The awareness of the importance of natural dyes has made it more relevant worldwide in the context of increasing environmental consciousness (Farell, 2012). The non-toxic, biodegradable and eco-friendly properties of natural dyes made them exceedingly popular amongst scientists and industrialists. Production of synthetic dyes has been predominantly dependent on the petrochemical source and some synthetic dyes contain toxic or carcinogenic amines which are not eco-friendly (Punrattanasin, et al., 2014). The harmful effects of synthetic dye and chemicals used in dyeing have brought about the alternative preparation of dye using natural sources Selvi et *al.*, (2014). This is mainly attributed to strict environmental standards set by many countries to avoid the health hazards associated with synthetic dyes used in textiles. Recently, most of the commercial dyers and textile export houses have started re-looking to the maximum possibilities of using natural dyes for dyeing and printing of different textiles for targeting a niche market. Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic dyes. On the other hand, synthetic dyes, which are widely available at an economical price and produce a wide variety of colours, sometimes cause skin allergy and other harmfulness to the human body, produce toxicity/chemical hazards during their synthesis, release undesirable/hazardous/toxic chemicals etc. For successful commercial use of natural dyes for any particular fibre, the appropriate and standardized techniques for dyeing for that particular fibre-natural dye system need to be adopted to obtain newer shades with acceptable colour fastness behaviour and reproducible colour yield.

Plant source means any part of the plant; wood, root, leaf, bark, twig, flower, fruit and seed. Our surroundings have various types of trees; shrubs, small trees and large trees. Every tree is also planted or cultivated in our surroundings not only for shade and ornamental purposes but also for other uses, such as buildings, paper, medicines, fuel, adhesives, plants, inks, textiles, etc. Natural dyes have been used as a means to colour textiles for centuries. All the dyes until the latter half of the nineteenth century were made of different parts of plants and animals. Natural dyes are deep and soft in colour shades when compared with synthetic dyes. And they are useful for human health because they have antimicrobial, insecticidal and healthy properties which are due to the origin of them extracted from plants. Most natural dyes are non-substantive dyes, which mean that they have very little colouring power within themselves and require the aid of mordants, to penetrate the yarn or fibre. Nowadays, most natural dyes use chemical mordants such as alum, copper sulphate, iron or chrome. Charus and Gupta (2012), described a mordant as an element that quickens the chemical reaction taking place between a fibre and a dye. Mordant helps to open up the fibre to enable the dye to be absorbed and improve the fastness of the dye on the fibre. They also deepen the shade of dye and can change the final colour giving rise to a new colour. The application of dye to a textile with which the dye does not combine readily can sometimes be improved by using a mordant. Some mordants are heavy metals such as chrome and are destructive to fibre and toxic to the skin. Aluminium sulphate (alum), ferrous sulphate and other acidifying dye-fixing agents including tannic and citric acids act as an intermediary between fibre and basic dye Charus, *et, al.* (2012).Colour fastness is the ability of a dye to resist fading or staining caused by sunlight, washing, perspiration (dilute acids and alkalis), crocking or rubbing and other organic solvents used in laundering and dry-cleaning (Anyakoha 2017). Natural dyes are known for their use in the colouring of food substrate, leather, and wood as well as natural fibres like wool, silk, cotton and flax as major areas of application since ancient times.

Presently, the global interest in natural dye has increased tremendously. Natural dyes perform very crucial educational, economic, pharmacological, sociocultural, political, religious as well as psychological roles. They are highly commended for their health and environmental benefits over some synthetic dyes which are toxic, non-biodegradable and carcinogenic. Natural dyes are also valued for the preservation of traditional dyeing arts and crafts. The very high demand for safe dyes in sustainable supply to meet the ever-increasing volume required in the wood, food (Obadina and Oyewole, 2007), paper and photography industries, pharmacology (Chenghaiah et al., 2010; Owoade et al., 2015), educational institutions (Spenser, 2011; Bassey et al., 2012), homes, leather and leather product, textiles and clothing industries (Onwualu, 2006; Jothi, 2008), requires more research and development efforts in sourcing dyes from natural sources. No fabric dyeing or printing can be successfully achieved without a sustainable supply of quality dyes. Globally, the clothing and textile sector has played major roles in employment and income generation for many nations. In Nigeria, for instance, within the past 15 years, there were up to 180 functional textile mills in the country employing about 800,000 people. The available report showed that out of 13 subsectors in the manufacturing sector, the textile sector comprising cotton textiles and synthetic fabrics continued to account for a significant proportion of the overall growth of manufacturing production (Central Bank of Nigeria (CBN) Annual report, 1995). According to Kumaresan *et al*., (2012), Natural turmeric dye has no side effects on the skin and it has no harmful effect on the environment also. This study, therefore, focused on the assessment of the fastness characteristics of turmeric dye on cotton using Alum and Potash as mordants.

1.2 Statement of the problem

The harmful effects of synthetic dye and chemicals used in dyeing have brought about the alternative preparation of dye using natural materials Selvi et *al.*, (2014). This is mainly attributed to strict environmental standards set by many countries to avoid the health hazards associated with synthetic dyes used in textiles (Fithriyah, 2013). Despite positive contributions of synthetic dyes to the educational and health sectors of the economy, recent studies on dyes have proven that it causes cancer, skin irritation and pollution of environment thereby making it unfriendly. Also, there has been a problem of under-utilization of local plants with potentials of yielding dyes for fabric colouration within Nigeria especially Benue State.The high demand for safe dyes in sustainable supply to meet the ever-increasing volume required in the photography industries, textiles industries and homes has been a great challenge. Thus making this research more relevant and timely.

1.3 Objectives of the study

The main objective of the study was to assess the fastness characteristics of Tumeric dyes on cotton fabric using Alum and Potash as mordants. The Specific Objectives of the study were to

i. determine the yield of turmeric dyes extracted with n-hexane, Methanol and water
ii. examine the nature of the chromophores and auxochromes present in turmeric dyes by UV visible and FTIR spectroscopy respectively
iii. assess the effects of Alum and Potash mordants on the colour fastness of cotton fabric dyed with turmeric plant
iv. evaluate the acceptability of cotton fabrics dyed with natural dyes from turmeric plants by panelist.

This study will benefit turmeric farmers by creation of new markets and additional source of income.it will also benefit textile manufacturers by reduced reliance on synthetic dyes and chemicals so as to meet the growing demand for sustainable and eco-friendly products. About healthcare sector, it will be of help by maintaining hygiene, antimicrobial, antibacterial, anti-inflamatory properties and prevent the spread of infections. Finally, consumers will reduced environmental impact of textile production, and provision of healthier and safer clothing options.

2.0 LITERATURE REVIEW

This section deals with the theoretical framework, conceptual framework and the review of related empirical studies.

2.1 Theoretical Framework

2.1.1 Chromophore Auxochrome Theory

This theory was propounded by Otto Witt in (1876). His emphasis was to correlate colour with molecular structure. According to him, a dye consists of a chromophore group and a salt-forming group called an anchoring group. He further speculated that coloured compounds were the result of a grouping of atoms and so he called it chromophore. Otto Witt established that by adding the auxochromophore, the dye could stick to a piece of fabric (Fathi, 2019). The researcher adopt this chromphore Auxochrome theory because it is most suitable for the study as it treats the variables of the dye components.

2.1.2 Theory of Natural dyes

According to Vankar (2017), natural dyes are defined, as elements of natural resources, and these dyes are generally classified as a plant, animal, mineral, and microbial dyes based on their source of origin, although plants are the major sources of natural dyes. Natural dyes per se are sustainable as they are renewable and biodegradable. The experience with natural dyeing has given an insight to explore plants in the neighbourhood. Finding fibre colours in plants that grow easily and fast has led to a new world of fibre colours that give exotic shades. These natural colours have richness and lustre that synthetics can never attain. It has become a common misconception that natural dyes only produce beiges and browns and other washed-out shades. In reality, vibrant, fast natural colours can be produced, which are comparable with and often surpass the colours of synthetics. Apart from the sources of these dyes, it is perhaps the commitment of those propagating them and the near clinical efficiency with which dye is extracted, produced, and used, which is responsible for the unique nature of natural dyeing and producing stable colouration.

2.2 Conceptual Framework

2.2.1 Concept of Tumeric

Turmeric (Curcuma longa) is a plant that belongs to the ginger family and is widely used as a spice in cooking, traditional medicine, and cosmetic products. Turmeric is widely available, making it an attractive source of natural dye. A study by El-Nagar *et al.,* (2016) found that turmeric dye was more cost-effective than synthetic dyes for coloring cotton fabrics. The active compounds in turmeric that are responsible for its color, taste, and health benefits are called curcuminoids, which include curcumin, demethoxycurcumin, and bisdemethoxycurcumin. Curcumin is the most abundant and biologically active curcuminoid, and it is responsible for the bright yellow color of turmeric (Sahoo *et al*. 2021).In addition to curcuminoids, turmeric also contains other pigments that contribute to its color, such as turmerone, atlantone, and zingiberene. These pigments are found in the essential oil fraction of turmeric and are responsible for its aroma and flavor (Kocaadam & Şanlier, 2017).Turmeric is therefore, a natural source of dye that is non-toxic and biodegradable. It is also effective in coloring cotton and silk fabrics without causing any adverse environmental effects.

2.2.2. Concept of Colour Fastness Properties of Natural Dyes

Colour fastness is the resistance of a material to change in any of its colour characteristics or extent of transfer of its colourants to adjacent white materials in touch or both for different environmental and use conditions or treatments like washing, dry cleaning etc or exposure to different agency heat, light etc. Fading means changes in the colour with or without loss of depth of shade for exposure to particular environment/agency/treatments either by lightening or darkening the shades. Bleeding is the transfer of colour to a secondary material in contact with accompanying white fibre material of similar/dissimilar nature. The colour fastness is usually rated either by loss of depth of colour/ colour change in the original sample or it is often expressed by staining scale meaning that the accompanying material gets tinted/stained by the colour of the original fabric when the accompanying white fabrics of similar/dissimilar nature are either in touch/ made to touch by some means of test procedure/protocol (Ashis *et al*. 2011).

2.2.3 Lightfastness test for cotton fabrics dyed with natural dyes

Extensive work has been carried out to improve the light-fastness properties of naturally dyed textiles. A comprehensive review of different attempts taken for improving the colour fastness properties of dyes on different textile fibres by different means is reported (Kamboj *et al*, 2022). The said review includes tannin-related after-treatments for improving the wash fastness and light fastness of mordant dyes on cotton; some of these treatments might apply to selective/specific natural dyes. Most natural dyes have poor light stability (as compared to that of the best synthetic dyes), and hence the colours in museum textiles are often different from their original colours. The relative light stability of a range of dyes has been reviewed (Adrosko, 2012) along with studies involving a change qualitatively. These colour changes are studied quantitatively where it is expressed the changes in terms of the Munsell scale and also in CIE colour parameters (Ayakoha, 2017).

2.2.4. Wash fastness of cotton fabrics dyed with natural dyes

To examine and improve wash fastness (Anyakoha, 2017), tests are carried out under standard conditions (50 ^{o}C) and also at 20 ^{o}C with a washing formulation used in conservation work for the restoration of old textiles. Some dyes undergo marked changes in hue on washing, shown to be attributed to even small amounts of alkali in washing mixtures, highlighting the necessity of knowing the pH of alkaline solutions used for cleaning textiles dyed with natural dyes. As a general rule, natural dyes (on wool) have only moderate wash fastness as assessed by the ISO 2 test. However, logwood and indigo dyes exhibit better fastness when applied to different textiles. The nature of detergent solutions suitable for the conservation of naturally coloured artwork has been examined (Prabhu & Bhute, 2012). A liquor containing 1g/l of sodium polyphosphate is found to be best resulting in marginal changes in hue with natural dyes applied on wool or silk (Anyakoha, 2017). The small increase in cleaning efficiency attributable to the alkali must be balanced against possible colour changes in the natural dyes, apart from possible damage to the protein fibre under alkaline conditions. In the ISO 2 test, the fastness of the indigo and logwood is superior to that of the native natural dyeing such as privet berries and water lily root respectively, but in the comparison of native and imported yellow, reds, red/purples, greens and browns, there is little difference between the two groups (Anyakoha, 2017). It is found in a recent report that treatment with 2%CTAB or sandofix-HCF improved the wash fastness to nearly 1 unit and treatment with 1% benzotriazole improved the lightfastness of dyed jute textiles nearly half to one unit (Samanta et al, 2006; 2007; 2010 & 2011; Samanta & Agarwal, 2008).

2.2.5 Concept of Cotton Fabric

Cotton is one of the most commonly used textile fibres in the world having any desirable characteristics such as comfort, soft hand, good absorbency, colour retention, reasonable strength and machine ability. However, most natural dyes has little affinity for cotton and are required to be as mordants (Asif et al., 2020).

Cotton Fabric Characteristics

Cotton has been grown for food, fibre and even fuel for over 60000 years. You can find cotton in your clothes, sheets, and towels and cotton is also used to make things like rope, US Curency, paper, cooking oil, bathmats, bathropes, beedsheets, blankets, duvets, curtains, wall hangings, animal feed, packaging, and biofuels. Manfacturers use cotton to make medical supplies and this fabric is also used to make industrial thread and tarps. Benefits versality of cotton are numerous. Cotton is easier to wash and care for than other fabrics. Cotton is a natural crop that has used by humans dated back to 600BC, cotton is harvested like many other crops by humans who farm untill the land has been in labour worth its intention. It has been a tremendous process but one so worth it because of the tremendous benefits of its use in fabrics. Cotton is popular because it's very easy care for and comfortable year-round. In hot, humid weather, cotton breathes 'as the body perspires, cotton fibres absorps the moisture and release it on the surface of the fabric, so its evaporates. In cold weather, if the fabric remains dry, the fibres retains body heat, especially napped fabrics.Cotton is easy to clean, it can be laundered or dry cleaned. It withstand high water temperature, so it can be boiled and thus sterilized. It does wrinkle easily and is prone to shrinkage. However, blending cotton with other fibres for pants, skirts, shirts, curtains, dresses, sheets and childrens cloth.

2.2.6 Mordant in Cotton Dyeing with Natural Dyes

Grover & Patni (2011), describes a mordant as an element that quickens the chemical reaction taking place between a fibre and a dye. They open up the fibre to enable the dye to be absorbed and improve the fastness of the dye on the fibre. The Limitation on colour yield and poor fastness properties prompted a search for ideal mordants, the chemicals which increase natural dye uptake by textile fibres. Different types of mordants yield different colours even for the same natural dye. Therefore, the final colour, their brilliance and colour fastness properties are not only dependent on the dye itself but are also determined by the varying concentration and skilful manipulation of the mordants. Thus, a mordant is more important than the dye itself. Moreover, the ideal mordant for bulk use should produce an appreciable colour yield in practicable dyeing conditions at a low cost, without seriously affecting the physical properties of fibre or the fastness properties of the dyes. Also, It should not cause any harmful effect during processing and the dyed textile material should not have any carcinogenic effect during use.

2.2.7 Extraction of natural dyes from plants

Extraction of the colour component from the source natural dye material is an important step for dyeing any textile substrate to maximize the colour yield. Moreover, standardization of the extraction process and optimizing the extraction variables both, for a particular source of natural dye material have technical and commercial importance on colour yield and cost of the extraction process as well as dyeing cost. The natural dyes can be taken from various vegetable sources like flowers, stems or wood, roots, bark, etc. as well as animal sources and mineral sources. The colour component present in these sources needs to be extracted so that it can be applied suitably to textiles (Affat, 2021). Natural dyes of different origins can be extracted using an aqueous method i.e. by using water for the extraction with or without the addition of salt/acid/alkali/alcohol in the extraction bath, supercritical fluid extraction, enzyme-assisted extraction, alcoholic/organic solvent extraction by using relevant extracting equipment or soxhlet extraction method with the use of alcohol and benzene mixture and finally to the filtrate, evaporate and to dry using ultrafiltration equipment or centrifuge rotatory vacuum pump/or by extraction under reduced pressure. Nowadays, there have been industrial methods available for extracting colour components/purified colour substances from natural dyes for their easy applications (Affat, 2021). The collected source material is generally shadow dried in air or sun-dried within a temperature range of 37-40°C for the moisture content of the source natural dye material is reduced to 10-15% with proper drying since most of the material has a moisture content of 40-80% and cannot be stored without drying. After drying, grinding is carried out to break down the material into very small units or preferably powder form. Extraction refers to separating the desired colour component by physical or chemical means with the aid of a solvent. Optimum conditions of extraction variables are determined by extracting the natural colour component from the source material by varying the extraction parameters of liquor and measuring the optical density of corresponding coloured liquor by using a spectrophotometer (Samanta & Konar, 2011). Also, the gravimetric yield of colour can be measured by filtering the extraction liquor through a standard filtration process followed by evaporation of solvent, washing and finally drying to get the purified natural colour.

2.2.8 Extraction of natural dyes from plants using solvent-assisted systems

Due to increasingly stringent environmental regulations, supercritical fluid extraction (SFE) has gained wide acceptance in recent years as an alternative to conventional solvent extraction for the separation of organic compounds in many analytical and industrial processes. In the recent past decade, SFE has been applied successfully to the extraction of a variety of organic compounds from herbs, and other plant materials as well as natural colourants from source natural dye material. With increasing public interest in natural products, SFE may become a standard extraction technique for sourcing natural dye material and other herbs and food items. Supercritical fluid extraction using carbon dioxide as a solvent has provided an excellent alternative to the use of chemical solvents. Over the past three decades, supercritical CO2 has been used for the extraction and isolation of valuable compounds from natural products (Konar, 2011). Supercritical fluids are utilized to extract and purify natural colourants from eucalyptus bark (Vankar et al. 2017). Extraction of dye from food is best achieved with ethanol/oxalic acid. The comparative behaviour of other red food dyes is also studied and a process developed for the extraction of natural dye from the leaves of the teak plant is carried out using aqueous methanol. A brick red shade from dyeing for silk/wool using the isolated dye in presence of different mordants is achieved. Extraction (Yadav *et al.*, 2019) of well-grounded henna leaves, directly in a solvent-assisted dyeing process, employing organic solvent: water (1:9) as the dyeing medium is studied and superior dyeing properties are obtained when applied to polyester. Natural dye is obtained from grape skin waste by using a soxhlet extractor, and later on, distilled under a vacuum to obtain the concentrated dye solution.

2.2.9 Isolation and characterization of the colourant molecules from each dye plant

Dye compounds from natural resources especially from plants are increasingly becoming important alternatives to synthetic dyes for use in the textile industry (Slama *et al* 2021). The perception of colour is the ability of some animals, including humans, to detect some wavelengths of electromagnetic radiation (light) differently from other wavelengths. Dyes possess colour because they

i. They must absorb light in the visible spectrum (400 –700 nm);
ii. They must have at least one chromophore (colour-bearing group);
iii. They must have a conjugated system, i.e., a structure with alternating double and single bonds;
iv. They must exhibit the resonance of electrons, which is a stabilizing force in organic compounds (Samanta et al., 2009).

When any one of these features is lacking from the molecular structure, the colour is lost. In addition to chromophores, most dyes also contain groups known as auxochromes (colour helpers), examples of which are carboxylic acid, sulfonic acid, an amino group, and a hydroxyl group. The word auxochrome is derived from two roots. The prefix auxo is from auxein, which means increased. The second part, chrome, means colour, so the basic meaning of the word auxochrome is colour increaser. This word was coined because it was noted originally that the addition of ionizing groups resulted in a deepening and intensifying of the colour of compounds. While these are not responsible for colour, their presence can shift the colour of a colourant, and they are most often used to influence dye solubility. To know the structure of the colourant in each dye extract that was derived from different plants, it was first necessary to separate the coloured molecules by column chromatography. The structure elucidation of separated and isolated compounds was then identified through spectroscopic methods such as UV-visible, FT-IR, and mass spectroscopic methods. Although these are tedious methods, they help in matching the structures with phytochemical literature and data.

The presence of colourant and its chemical nature was ascertained by spectroscopic and chromatographic analysis of the dye extract. *UV-visible* analysis of aqueous and/ or methanolic extract was carried out on a Thermo Heλios α model spectrophotometer at a resolution of 1 nm. *FT-IR* analysis of methanolic extract was carried out by the Vertex 70 model of Bruker. *HPLC* was taken generally in a methanol-water (60:40) system on the C18 column with a flow rate of 1 mL on Waters HPLC.

2.2.10 Preparation of cotton fabric and dyeing with natural dyes

Cotton is purely cellulosic fibre and is found throughout the world with many varieties and qualities. In general, cotton fibre-based textiles are resized (for woven fabric only), scoured and bleached as a preparatory process before dyeing with synthetic dyes. In many places of the world, the age-old process followed in preparing a cotton cloth and its dyeing with natural dyes followed by artisan/cottage level dyers is given below (Mohanty et al, 2006):-

a. Dunging - The cloth is soaked for one night in a solution of water and fresh dung.

b. Washing - Next morning, the cloth is thoroughly washed, rinsed and water sprinkling is continued over the cloth at short intervals until evening, then it is finally washed and dried

c. Steaming– Then the cloth is steamed for one night in an ordinary Khumb or washer man's steaming pot

d. Steeping in alkaline lye - The cloth is soaked in a mixture of water, oil [castor oil or gingili oil], and alkali (sodium carbonate or soda known as sajikar or papadkhar).

e. Rinsing- Cloth is then again rinsed thoroughly and spread out to dry.

f. The last two processes are repeated for several days, the details varied in different localities, but generally from 3 to 7 days. In a specific case, the cloth is kept in the solution for some time, and then taken out, rinsed and dried twice daily.

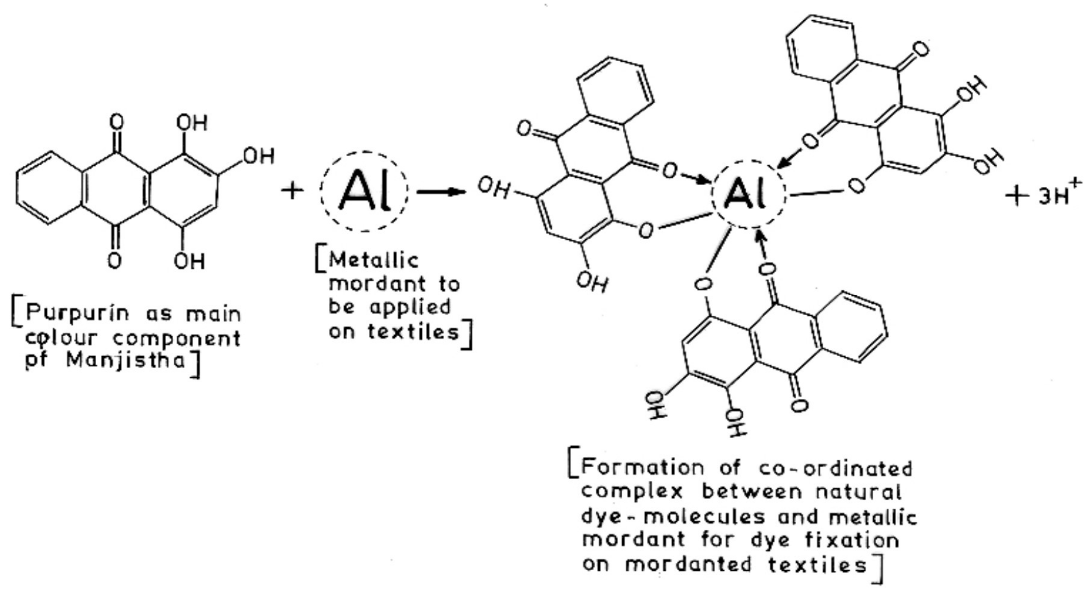
g. Washing- The cloth is then finally washed in clean water, but not so thoroughly as to remove the whole of the oil, and finally dried in the air under the sun.

h. Galling-The cloth is then soaked in a solution of harda (haritaki) or myrobolan (Terminala chebula) extracts. Behda or bahedas (terminala belerica) is also used instead of harda. The period during which the cloth is kept in the harda extract varied in different places but it is continued until the fabric assumes a yellowish tint.
i. Drying - The cloth is spread or wrung out for drying.
j. Mordanting- The cloth is then pre-mordanted by dipping it in a solution of potash alum and water. In some places, gum or a paste of tamarind seed (tamarind kernel powder) is added to make it sticky. In some parts of kutch, fuller's earth is also used by some dyers. The cloth is thus ready for subsequent dyeing.
k. Dyeing- For dyeing the cloth is generally boiled with an aqueous extracted solution of the natural dye until all the colouring matter is absorbed by the cloth.
l. Further dunging- In some places, the cloth is further soaked in dung for one night and batched before final wash and drying.
m. Drying - The dyed fabric is next washed and spread out to dry gradually in the air under the sun. Water is sprinkled at a certain interval over the cloth, to brighten the colour, this process is continued for 2-4 days.
n. Finishing - If required, the cloth is finally starched by dipping it in a paste of rice or wheat flour, or a solution of babool gum and then dried (Saxena and Raja, 2014).
However, nowadays, many small-scale dyers/export-oriented units follow much shorter economical and standard recipe-based optimized processes for the natural dyeing of cotton yarns/fabrics. Before natural dyeing usual method of desizing (acid bath), scouring (soap & soda) and H_2O_2 bleaching are followed. Well-prepared cotton textiles are then mordanted (single or double mordanting using harda and aluminium sulphate individually or in combination) before being subjected to dyeing with an aqueous extract of selective natural dyes at the standardized condition of process variables of dyeing. E.g., the dyeing conditions may be as follows: dyeing time, 30 -120 minutes (depending on shades); dyeing temperature, 70- 100°C; material to liquor ratio, 1:20 -1:30; concentration of natural dye, 10-50% (owm) or more; common salt concentration, 5-20g/L and pH, 10-12. In each case after the dyeing is over, the dyed samples are repeatedly washed with hot and cold water and then finally, the dyed samples are subjected to soaping with 2g/L soap solution at 60 ^{0}C for 15 min, followed by repeated water wash and line dried. For improving its wash fastness, treatment with an ecofriendly cationic dye fixing agent is advisable.

2.2.11 Principle of dyeing with natural dyes using mordants

Ashis *et al*. (2011) maintained that most of the natural dyes have no substantivity on cellulose or other textile fibres without the use of a mordant. The majority of natural dyes need a mordanting chemical (preferably metal salt or suitably coordinating complex forming agents) to create an affinity between the fibre and dye or the pigment molecules of natural colourant. These metallic salts as mordant form metal complexes with the fibres and the dyes. After mordanting, the metal salts anchoring to the fibres attract the dye/organic pigment molecules to be anchored to the fibres and finally create the bridging link between the dye molecules and the fibre by forming coordinating complexes. Aluminium sulphate or other metallic mordants anchored to any fibre, chemically combine with certain mordantly functional groups present in the natural dyes and are bound by coordinated/covalent bonds or hydrogen bonds and other interactional forces as shown in figure 1

Figure 1 Mechanism of fixation of natural dyes through mordants



2.3 Related Empirical Studies

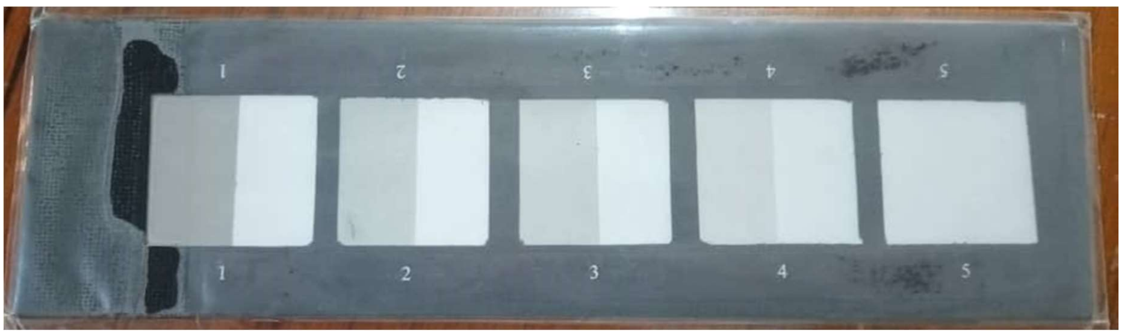
Sofyan et al, study the effect of of type and methods of mordants towards cotton fabric dyeing quality using Jengkol (Archidendron Jiringa) Pod waste and the results show that ype of mordant was affected by the intensity and color strength of the fabric.

Faiza et al (2022) carried out a study on eco-friendly dyeing of cotton using waste-derived natural dyes and mordants stated that because of the environmental burden of synthetic dyes, there has been a revival in practicing natural dyeing globally. Natural dying uses metallic mordants for improving dyes fastness properties. However, metallic mordants are also toxic. Both the dyes and mordants were extracted from plant waste using water as a green solvent. The extracted dyes fabric were then applied to the cotton fabric using a natural mordant. The dyed fabric samples were characterized for color yield, fastness properties, ultraviolet protection and antibacterial activity activity. The wastes of sugarcane bagasse wheat bran and rice husk were used dye and mordant extraction. It was found that by increasing the extraction temperature from 30 to 6o ^{0}c, the dye yield increased. From the K/S value, it was observed that pre-mordanting gave better colour strength than post-mordanting or metal-mordanting. The overall ratings for the wasting and crocking were 3-4 and 4-5 respectively. No significant antibacterial activity was observed in the dyed samples. However, excellent ultraviolets protection was observed.
Another study was conducted by Heliyon et al., (2022), looked at the perspective on sustainable color and textile coloration using natural plant resources revealed that color performance and quality, economy, eco-friendly, and health considerations are fundamental criteria for a suitable natural plant dye. The study also finds out that natural dyes do not only produce delicate and subdued shades but also have the potential of novel features to achieve active textile substrates with performance properties such as deodorizing, anti-oxidant, anti-microbial, antifeedant, UV protection etc.

3.0 METHODOLOGY

The research design adopted for this study was the true experimental research design and quasi-experimental research design. True experimental research design relied on statistical analysis to prove or disprove a hypothesis. It was used since it is most accurate for establishing a "cause-effect" relationship within a group. The quasi-experiment was used to determine the acceptability of the dyed prototypes by a group of panellists. The study was carried out in Makurdi Local Government area, Benue State. The turmeric was gathered from farmlands within Joseph Sarwuan Tarka University. The extraction of the dyes from turmeric was done in the Chemistry Department, while dyeing and fastness rating will be done in the Textile Dyeing and Printing Laboratory in the Department of Home Science and Management, Joseph Sarwuan Tarka University. The research made use of three research instruments which were Greyscales, Tumeric Dye Fastness Test Rating Scale (TDFTRS) instrument and Tumeric Dyed Cotton Fabrics (TDCFA) Instrument.

a. **Grey Scales:** The grey scales were used to rate the fastness to sunlight and washing according to the International Standard Organisation (ISO), specifications.



b. **Tumeric Dye Fastness Test Rating Scale**: The Tumeric Dye Fastness Test Rating Scale (TDFRS) instrument was developed and used to record the mean ratings of the triplicate results of the fastness test with grey scales.
c. **Tumeric Dyed Cotton Fabrics Acceptability (TDCFA) Instrument**. Tumeric Dyed Cotton Fabrics Acceptability (TDCFA) Instrument was used to test the acceptability of cotton fabrics dyed with turmeric dye extracted by microwave and mordanted with Alum, Potash and a non-mordant sample extracted with water, methanol, water and n-hexane.

Data were collected in five stages;

Stage 1: The sourcing of turmeric dyes from within Joseph Sarwuan Tarka University and extraction of dyes from turmeric using microwave extraction method and three different solvents, namely; water, methanol and n-hexane

Stage 2: The UV visible and FTIR spectroscopy of the extracted dyes

Stage 3: The mordanting and application of dyes extracted with methanol, water and n-hexane dyes on cotton fabric samples

Stage 4: The colour fastness test to washing and sunlight was conducted according to the International Standard Organization standards

Stage 5: The acceptability of the dyed cotton fabrics was done to ascertain the acceptability of the organoleptic attributes of turmeric cotton dyed fabric samples by the panellist

Nine sets of cotton fabrics each measuring 30x30cm were cut and washed with water to remove the size material which may be present in the fabrics.

1. Dye Extraction

The tool used a domestic microwave oven Electrolux model EMM2007X with 2450 MHz Magnetron frequency, maximum delivered power of 800 W, 220 V voltage. Oven dimension with a length 46.1 cm, width 28.0 cm and height 37.3 cm. The extraction process is carried out in a three-round neck flask extractor equipped with a condenser placed at the top of the oven. The temperature inside the extractor flask was measured with K 1/16 inc thermocouple type fitted to a microwave oven. Raw materials were milled and sifted to a certain size (35-60 mesh). Powder and solvent were fed into an extractor. Water flowed on the cooling system (condenser). After the extraction process in the oven is complete, the extract then filtered with filter paper (Whatman no.1, 90 mm diameter) using a vacuum filter. The obtained extract solution was concentrated and dried at a temperature of 60-80°C to a constant weight.

2. Mordanting of the cotton fabric samples

Nine sets of cotton fabrics each measuring 30x30 cm were pre-mordanted with alum and potash and a non-mordanted sample. Fifteen percent of alum based on the weight of the fabric is dissolved in a small amount of water. Then the cold water was added to get the material to liquor ratio of 1:100. Then the fabric to be mordanted is added to the solution. Mordanting is carried out at 60ºC for about 30 minutes. After mordanting, the sample fabric is taken out and squeezed by hand and then immersed in the dye bath.

3. Dyeing of the samples

The procedures adopted by Ozougwu and Anyakoha (2017). Three pieces of cotton fabric samples measuring 30cm by 30cm each was scoured or washed thoroughly in warm water three times with detergent to remove all sizing. In three different stainless pots containing 1500 ml distilled water and 0.3g sodium carbonate ($NaCO_3$) each, 4g Aluminum sulphate (AlSO4, alum) were dissolved in the first pot, 4g of Potash dissolved in the second pot. The third stainless pot containing 0.3g sodium carbonate and 1500 distilled water was not added any dye fixing agent or mordant (control). The three wet-scoured cotton fabric pieces was immersed in each of the solutions and gently but thoroughly stirred so that the fabrics will open out in the solution. Each was then heated, held to boil at 80 to 90°C for 1 hour and allowed to cool overnight in the solution. The mordanted cotton fabric samples was labelled; alum mordanted cotton (AMC), Potash Modanted cotton (PMC), and non-mordant cotton (NMC) for respective dyes. The experiment was repeated in triplicates and a total of 27 cotton fabrics were dyed.

Determination of the organoleptic attributes of cotton fabrics dyed with turmeric dyes using Alum and Potash mordant

The method adopted by Ozougwu and Anyakoha (2016), was adopted in determining the organoleptic attributes of cotton fabrics dyed with turmeric dyes were determined by a panel consisting of 15 judges made up of 5 academics, 5 Technologist and 5 postgraduate students in the Department of Home Science and Management in Joseph Sarwaun Tarka University. This department offer courses related to dye production and utilization. Their areas of specialization were in Clothing and Textiles. The Lecturers and the postgraduate students (who also teach and work with dyes in their respective establishments) are in a better position to give an accurate evaluation of the organoleptic quality of dye produced from the turmeric plant. They are also co-consumers. The table below shows the Tumeric dye attributes and range of means for making decisions. An attribute with a mean score of 3.00 was taken as agreed while an attribute with a score less than 3.00 is disagreed.

Table 1. Tumeric dye attributes and range of means for taking Decisions

S/No.	Attributes	Range of means for taking decisions				
		5.00-5.90	4.00-4.50	3.00-3.90	2.00-2.90	1.00-1.99
1	Colour hue	very warm	Warm	fairly warm	Cool	very cool
2	Colour value	very light	Light	fairly light	Dark	very dark
3	Colour chroma/Brightness	very bright	Bright	fairly bright	Dull	very dull
4	Texture (sight)	very smooth	Smooth	fairly smooth	rough	very rough
5	Texture (feel)	very soft	Soft	fairly soft	crisp/coarse	very crisp
6	Odour (smell)	very pleasant	Pleasant	Odourless	offensive	very offensive
7	Evenness of shade	very even	Even	fairly even	uneven	very uneven

(Anyakoho,U. 2017)

Determination of light fastness properties of cotton fabrics dyed with turmeric dyes and mordanted with Alum and Potash

Each of the strips of the prototype cotton samples was subjected to a light fastness test according to the international standard organization (ISO/AO3:1993), specification. The samples were mounted in an exposure frame and exposed to sunlight for 30hours 5 days. Gray scale was used to rate the extent of fade and the triplicate tests were recorded with the TDFTRS instrument.

4.0 RESULTS AND DISCUSSIONS

This section deals with interpretation of results. The data obtained from this study were analyzed using descriptive statistics of means.

4.1 Results

Objective 1: Determine the yield of turmeric dye extracted with methanol, N-Hexane and water.

Table 4. Yield of Turmeric Dye Extracted with Microwave

Dye	W0 (g)	W1 (g)	% Yield
TDMth	500	300	60
TDNhx	500	170	34
TDHwt	500	50	10

Key

W0 –weight of crude turmeric, W1-weight of turmeric dye

TDMth= Tumeric dye extracted using methanol

TDNhx= Tumeric dye extracted using n-hexane

TDHwt= Tumeric dye extracted using hot water

Objective 2: Determine the Chromophore and Auxochrome groups present in Tumeric Dyes

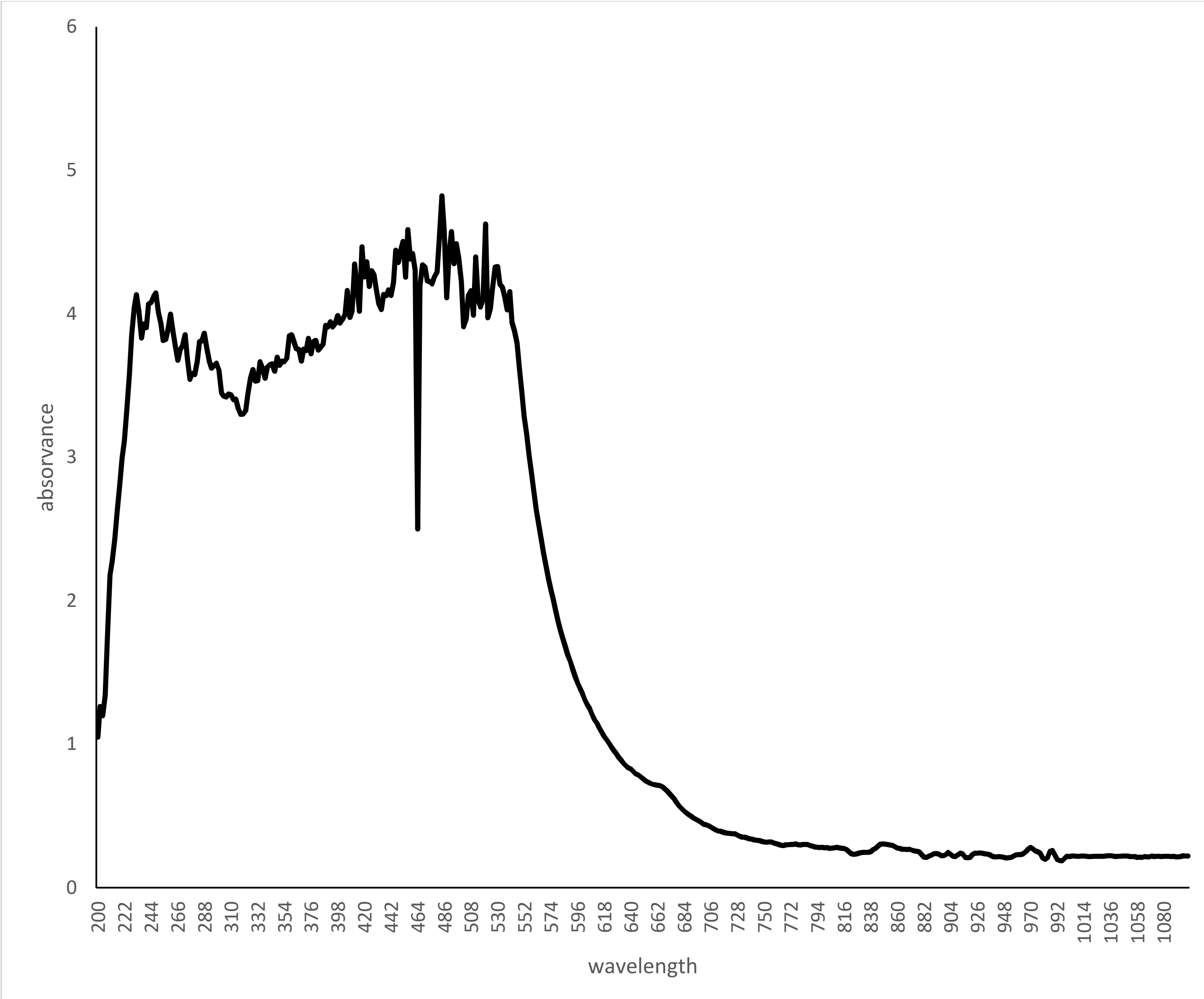


Figure 2. *UV visible spectra of Tumeric dyes extracted with Methanol*

Peaks show absorption at respective wavelength, Broad characteristics UV-visible absorption at around 236-330nm, weak short bands between 368-420nm, sharp bands between 410-462nm and 484-538nm.

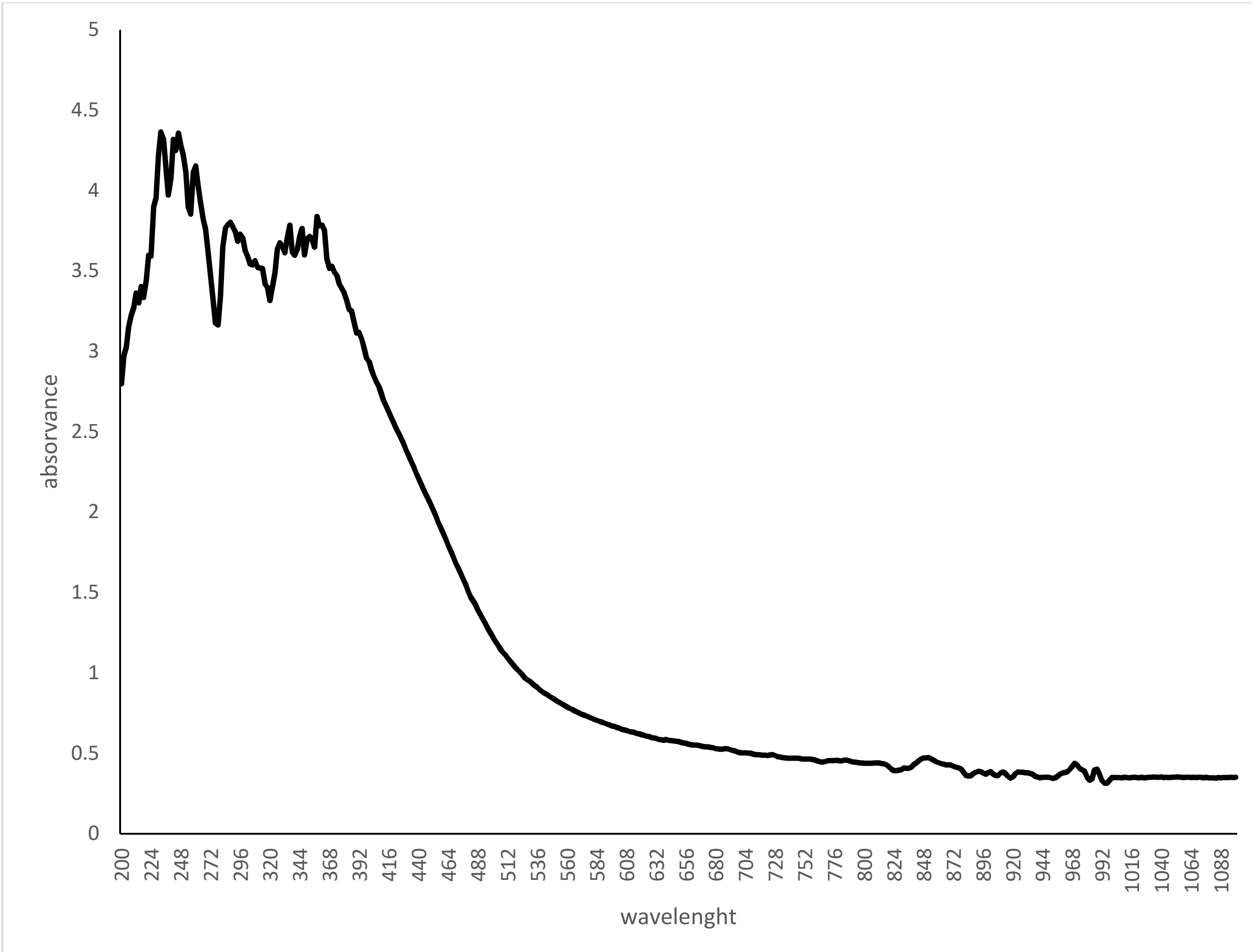


Figure 3. *UV visible spectra of Tumeric dyes extracted with Water*

Peaks show absorption at respective wavelength, *Bands between 400-800nm indicate the presence of visible colours, while colours below and above indicate the presence of non-colouring matters.*

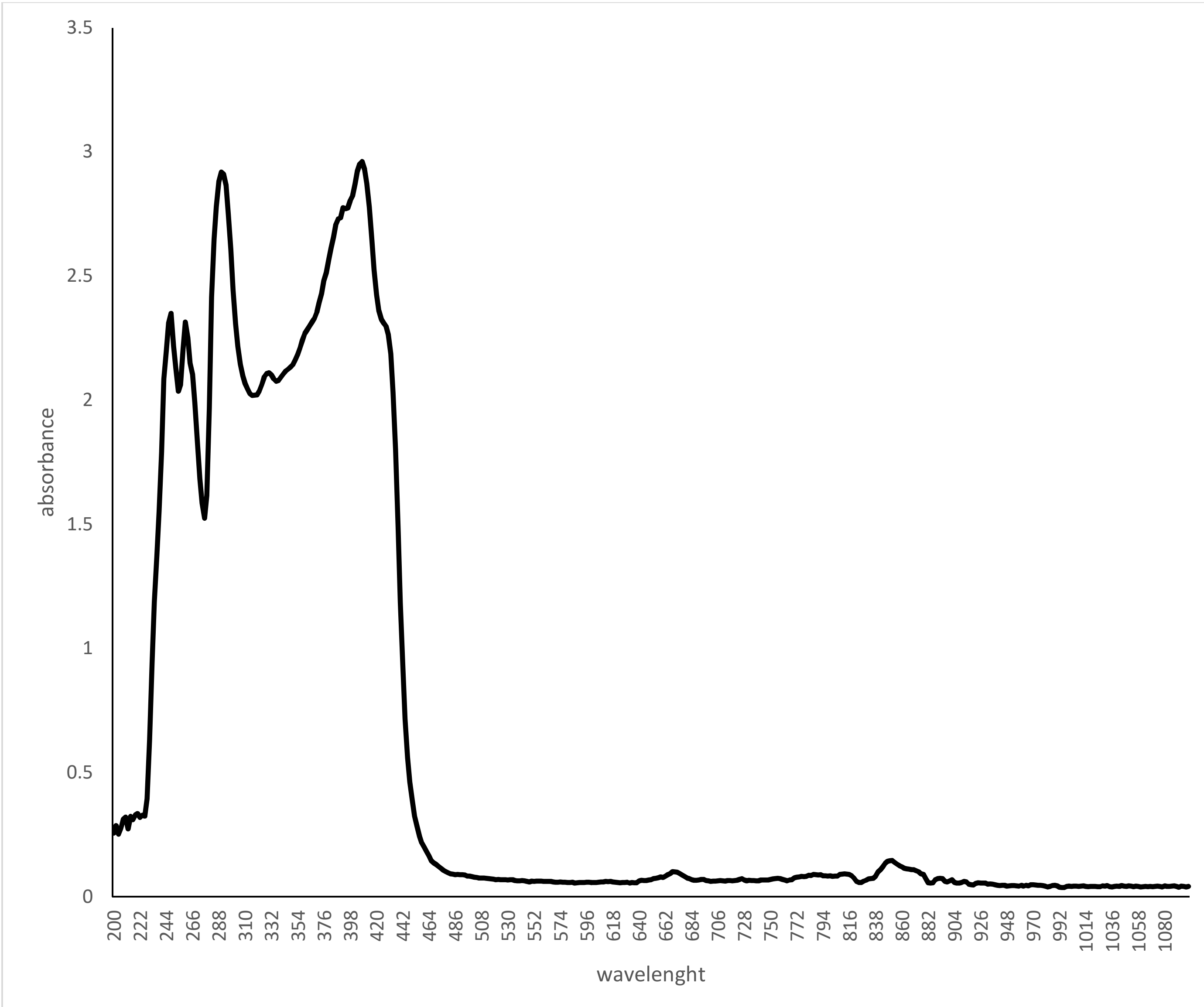
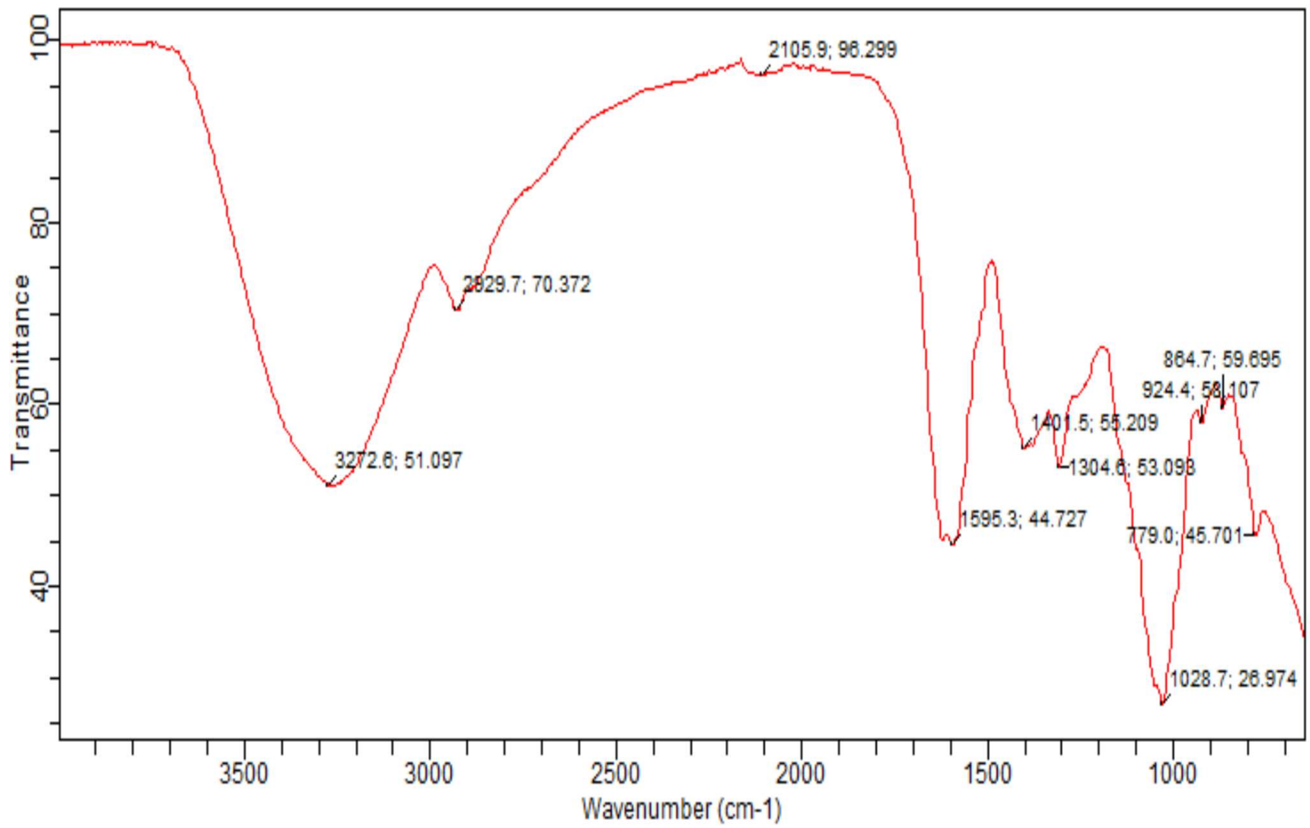
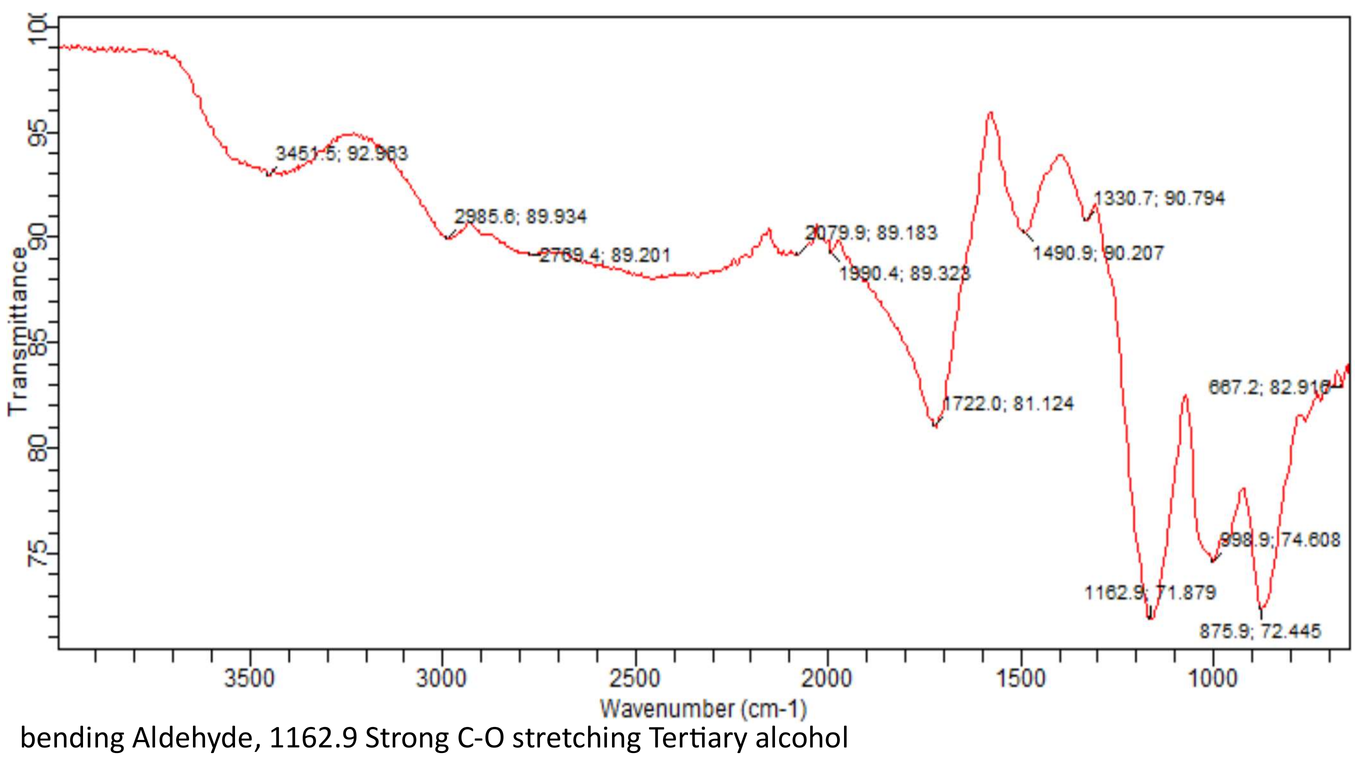


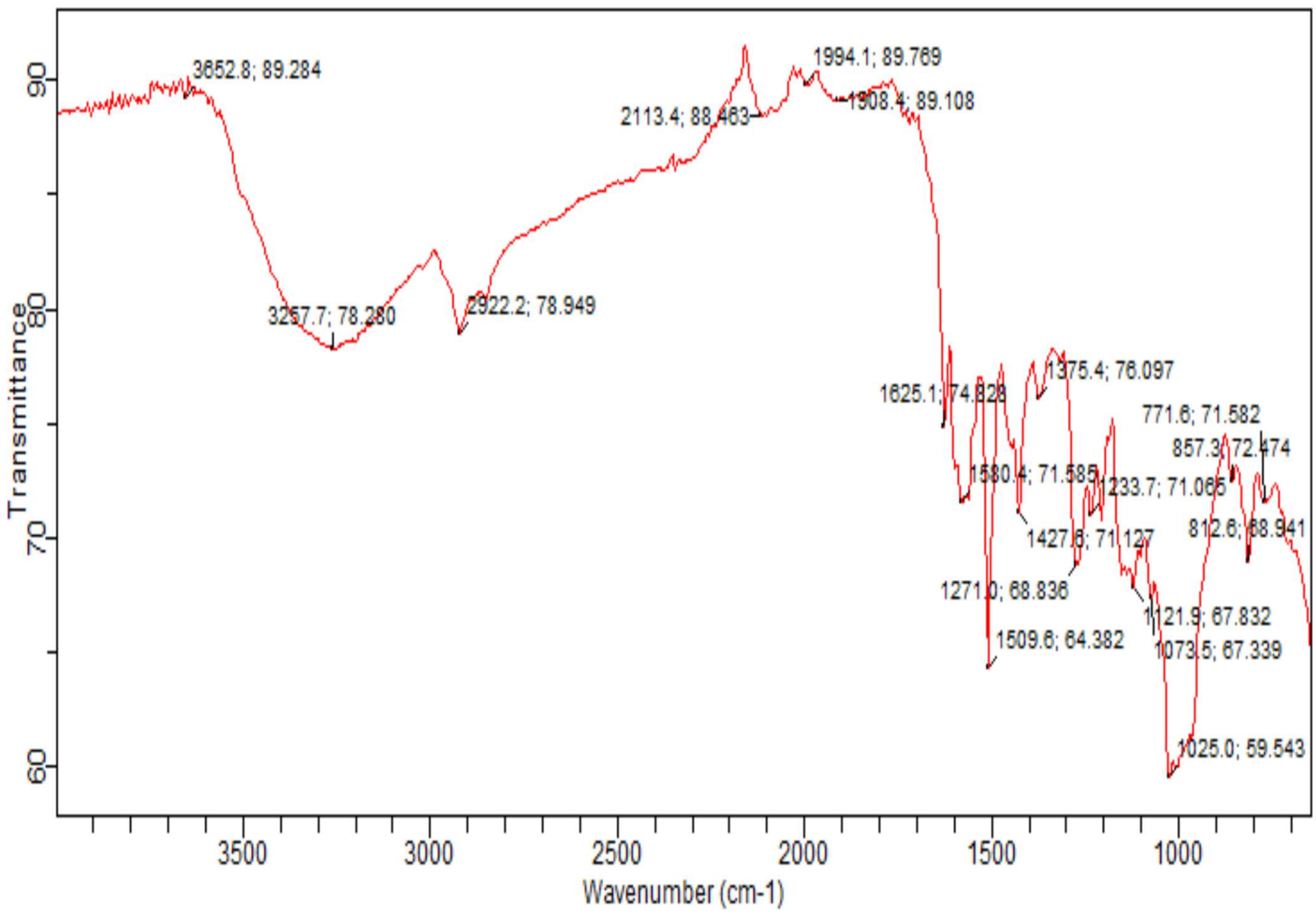
Figure 4. *UV visible spectra of Tumeric dyes extracted with n-hexane*

Peaks show absorption at respective wavelength, *Bands between 400-800nm indicate the presence of visible colours, while colours below and above indicate the presence of non-colouring matters.*





bending Aldehyde, 1162.9 Strong C-O stretching Tertiary alcohol



Amine

Objective 3: Asses the effect of Alum and Potash on colour fastness properties of cotton fabrics dyed with Tumeric Dyes

Plate 1: Light fastness of microwave-extracted turmeric dye extracted with water on cotton fabrics using alum and potash as mordants

Faded part was show effect of exposure to light while the unfaded part was shielded from light
Plate 2: Light fastness of microwave extracted turmeric dye extracted with methanol on cotton fabrics using alum and potash as mordants

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Plate 3: Light fastness of microwave extracted turmeric dye extracted with n-hexane on cotton fabrics using alum and potash as mordants

Plate 4: Wash fastness of microwave extracted turmeric dye extracted with water on cotton fabrics using alum and potash as mordants

Plate 5: Wash fastness of microwave-extracted turmeric dye extracted with methanol on cotton fabrics using alum and potash as mordants

Plate 6: Wash fastness of microwave-extracted turmeric dye extracted with n-hexane on cotton fabrics using alum and potash as mordants

4.1.1 Grey scale ratings for colour fastness for the effects of potash and Alum on cotton fabrics dyed with turmeric dyes extracted by microwave

Table 5. Light colour fastness of dyed cotton fabrics mordanted with

S/N	Solvent	Mordant	8	7	6	5	4	3	2	1	Mean	Remarks
1	Water	Alum	0	0	0	0	0	0	2(2)	1(1)	1.67	NF
		Potash	0	0	0	0	0	0	2(2)	1(1)	1.67	NF
		Non mordanted	0	0	0	0	0	0	2(2)	(1)	1.67	NF
2	Methanol	Alum	0	0	6(2)	5(1)	0	0	0	0	5.67	F
		Potash	0	0	0	0	4(2)	3(1)	0	0	3.67	NF
		Non mordanted	0	0	0	0	0	3(3)	0	0	3.00	NF
3	n-hexane	Alum	0	0	0	5(3)	0	0	0	0	5.00	F
		Potash	0	0	0	0	4(2)	3(1)	0	0	3.67	NF
		Non mordanted	0	0	0	0	4(1)	3(2)	0	0	3.34	NF

Values are greyscale rating for light fastness properties based on ISO 105-A02:1993
The means are mean values from the greyscale rating.
Key
NF - Non Fast, F - Fast

Table 6. Wash colour fastness of dyed cotton fabrics mordanted with

S/N	Extraction Solvent	Mordants	5	4	3	2	1	Mean	Remarks
1	Water	Alum	0	0	0	2(3)	0	2.00	NF
		Potash	0	0	0	2(3)	0	2.00	NF
		Non mordanted	0	0	0	2(3)	0	2.00	NF
2	Methanol	Alum	0	4(3)	0	0	0	4.00	F
		Potash	0	4(2)	3(1)	0	0	3.67	F
		Non mordanted	0	0	3(3)	0	0	3.00	F
3	n-hexane	Alum	5(1)	4(2)	0	0	0	4.34	F
		Potash	0	4(2)	3(1)	0	0	3.67	F
		Non mordanted	0	0	3(3)	0	0	3.00	F

Values are greyscale rating for wash fastness properties based on ISO 105-A02:1993
The means are mean values from the greyscale rating.
Key
NF-Non fast, F-Fast

Table 7 Mean ratings of the colour fastness of cotton fabrics dyed with microwave extracted turmeric dyes to sunlight and washing

S/No.	Attributes	Range of means for taking decisions					Mean	Remarks
		5	4	3	2	1		
1	Colour hue	0	0	3(8)	2(5)	1(2)	3.00	Agreed
2	Colour value	0	0	0	2(9)	1(6)	1.60	Disagreed
3	Colour chroma	0	0	3(2)	2(7)	1(6)	1.73	Disagreed
4	Texture (sight)	0	0	3(1)	2(11)	1(3)	1.87	Disagreed
5	Texture (feel)	0	0	0	2(10)	1(5)	1.67	Disagreed
6	Odour (smell)	0	0	3(15)	0	0	3.00	Agreed
7	Evenness of shade	0	0	3(10)	2(3)	1(2)	2.53	Agreed

S/No.	Extraction Solvent	Mordants	X_1	X_2
1	Water	Alum	2.00	1.67
		Potash	2.00	1.67
		Non mordanted	2.00	1.67
2	Methanol	Alum	4.00	5.67
		Potash	3.67	3.67
		Non mordanted	3.00	1.00
3	n-hexane	Alum	4.34	5.00
		Potash	3.67	3.67
		Non mordanted	3.00	3.34

Values are mean rating for wash and light fastness properties.

Key

X1= Wash fastness properties,

X2= Light fastness properties

Objective 4: Evaluate the acceptability of cotton fabrics dyed with turmeric dyes by panelist

Table 8. The organoleptic attributes of water extracted turmeric dyes on cotton fabrics

Values are ratings from panelists attributes with a mean value of 3.0 and above is “agreed” while attribute below 3.0 is “disagreed”.

Key:

5 -Excellent

4 -Very Good

3 -Good

2 -Poor

1-Very Poor

Table 9. The organoleptic attributes of Methanol extracted turmeric dyes on cotton fabrics

S/No.	Attributes	Range of means for taking decisions					Mean	Remarks
		5	4	3	2	1		
1	Colour hue	0	4(6) / 4(10)	3(5) / 3(7)	0 / 2(2)	0	3.27 / 3.67	Agreed
2	Colour value	0	4(9)	3(5) / 3(6)	0 / 2(3)	0	3.60 / 3.80	Agreed
3	Colour chroma	0	4(9) / 4(5)	3(4) / 3(11)	0 / 1(2)	0	3.33 / 3.53	Agreed
4	Texture (sight)	5(7) / 5(10)	4(4)	3(1) / 3(5)	0	0	4.40 / 4.60	Agreed
5	Texture (feel)	5(13)	4(2)	0	0	0	4.87	Agreed
6	Odour (smell)	0	0	3(15)	0	0	3.00 / 4.83	Agreed
7	Evenness of shade	5(9) / 5(3)	4(4) / 4(10)	3(2)	0	0	4.06 / 4.46	Agreed

Values are ratings from panelists attributes with a mean value of 3.0 and above is "agreed" while attribute below 3.0 is "disagreed".

Key

5 -Excellent

4 -Very Good

3 -Good

2 -Poor

1-Very Poor

Table 10. The organoleptic attributes of n-hexane extracted turmeric dyes on cotton fabrics

Values are ratings from panelists attributes with a mean value of 3.0 and above is "agreed" while attribute below 3.0 is "disagreed".

4.2 Discussion of results

Objective one: state that dye extracted with methanol yield 60%, N-Haxane 34%, and Water 10%. This evidently shows that methanol has the best potential in comparism to N-Haxane and water. This is in line with Faiza et al (2022) which studied on eco-friendly dyeing of cotton using waste-derived natural dyes and mordants

Objective two: focused on the chromophore and auxochromes present in turmeric dye. Figure 4.1.1 showed the UV Visible absorption of the extracted dyes from turmeric. The absorption peaks found to be below 400nm indicated the presence of non-colouring matter or non-colour absorbing groups in the dyes extracted with methanol. Bands at 464nm indicated the presence of colour groups in the dye. Figure 4.1.2 states that the water-extracted dyes showed absorption at 224nm, 272nm, and 344nm and slight absorption at 416nm. This means that water extracted more of the non-colour groups at that range and slight colour groups at 416nm. Figure 4.1.3 showed n-hexane extracted dyes gave bands 288nm, 310nm and 420nm. the band at 420nm is an indication of colour groups in turmeric dye. The UV visible spectroscopy showed that non-polar solvents or solvents with partially polar and non-polar nature such as methanol are good extraction solvents. These research findings are similar to the findings of Sriwai et al, (2011) in the spectroscopic investigation of the complex of turmeric with copper (II) ions in aqueous solution; the absorption at 316nm, 472nm and 701nm is considered to be associated with absorption due to π- π* transition of curcumin and n- π* curcumin ligand. The bands are responsible for the yellow and intensive yellow hue of curcumin dye extract.

The FTIR spectra of turmeric dyes extracted with water showed absorption bands at 3272.6cm^{-1}, 2829.7 cm^{-1}, 2105.9 cm^{-1}, 1595.3 cm^{-1}, 11401.5 cm^{-1},1304.6 cm^{-1},779 cm^{-1},1028.7 cm^{-1},924.4 cm^{-1},864.7 cm^{-1}. Methanol extract gave absorption bands at 3451. 5cm^{-1}, 2985.6 cm^{-1},2079.9 cm^{-1},1990.4 cm^{-1},1722.0 cm^{-1},1490.9 cm^{-1},1330.7 cm^{-1},1162.9 cm^{-1}, 998.9 cm^{-1}, 667.2 cm^{-1}. The FTIR of n-hexane extract gave bands at 3652.8 cm^{-1}, 3257.7 cm^{-1}, 2922.2 cm^{-1}, 2113.4 cm^{-1}, 1994.1 cm^{-1}, 1908.4 cm^{-1}, 1625.1 cm^{-1},1580.4 cm^{-1}, 1271.0 cm^{-1},1509.6 cm^{-1}, 1427.6 cm^{-1},1378.4 cm^{-1}, 1625.1 cm^{-1}, 1580.4 cm^{-1}, 1271.0 cm^{-1}, 1509.6 cm^{-1}, 1427.6 cm^{-1}, 1375.4 cm^{-1},1233.7 cm^{-1}, 1121.9 cm^{-1}, 1073.5 cm^{-1}, 1025.0 cm^{-1}, 771.6 cm^{-1}, 857.3 cm^{-1}, 816.2 cm^{-1}. The stretches at 3272.6cm^{-1}, 3652.8 cm^{-1}, 3257.7 cm in the extracts are associated with the stretching vibration of the free hydroxyl group of phenol (AR-OH). The bands at 2829.7 cm^{-1}, 2105.9 cm^{-1}, 2985.6 cm^{-1},2079.9 cm^{-1}, 2922.2 cm^{-1}, 2113.4 cm^{-1}, as attributed to sp2 C-H bond stretching, the conjugated carbonyl bond (C=O) with two aromatic rings were accompanied by 1595.3 cm^{-1},1990.4 cm^{-1},1722.0 1908.4 cm^{-1},1625.1 cm^{-1},1580.4 cm^{-1}, 1509.6 cm^{-1}, 1509.6 cm^{-1}. These were similar to the findings of Nur et al (2015) in the preliminary study of natural pigments phytochemical properties of Curcumia longa and Lawsonia inermisL as TiO_2 photoelectrode sensitizer.

Objective three: focused on the effects of alum and potash on the colour fastness of cotton fabrics shows that, fabrics dyed with dye extracted using methanol and hexane, then mordanted with alum gave the best results in terms of light and wash fastness. Table 2 shows the light colour fastness of the dyed cotton fabrics mordanted with various solvents and non-mordanted cotton fabrics. Table 3 shows the wash colour fastness of the dyed cotton fabrics mordanted with various solvents and non-mordanted cotton fabrics. Both Table 2 and Table 3 shows that the colour fastness of the dyed fabrics varied depending on the solvent and mordant used. These were similar to findings of Desalegn , et al (2017), which studied the impact of sunlight exposure to different dyed fabrics on colour fastness to washing.

Objective four: focused on the acceptability of the organoleptic attributes of cotton fabrics dyed with turmeric dyes by panellists and was shown in table 5, 6 and 7. The colours obtained were in the range of yellow to orange with a warm hue, light colour values, fairly bright chroma, very smooth textures of feel, odourless and very even shades. All these attributes were agreed to be present in the cotton fabrics dyed with turmeric dyes using alum and potash mordants. These research findings were similar to Ozougwu and Anyakoha (2016) from Roselle calyces based on its phytochemical composition and evaluation of its organoleptic attributes.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Turmeric dyes were extracted from turmeric roots and analysed using Fouriier–Transform Infrared Spectroscopy (FTIR) and Ultra Vulent (UV) visible, the colour ranged from yellow to deep orange. The result from this study showed that non-polar solvents or partially polar solvents can be used in the extraction of brilliant yellow-orange colour from turmeric and can be applied to cotton fabrics using potash or alum as the two can improve the wash and light fastness and also deepen the colour of the dyed fabric. Specifically, methanol presents the best solvent for the extraction of these dyes and can be recovered at the end of the extraction process which will offset the cost of the solvent. The attributes of the dyed fabrics were all agreed to be acceptable by final consumers as judged by the panellist. The results showed that water does not affect the dyed fabrics irrespective of the mordant used since it did not extract sufficient dyestuff to enable better dye exhaustion on cotton fabrics. Therefore, the research concludes that turmeric dye can be a good natural alternatives for cotton fabric dyeing with good colorfastness properties.

5.3 Recommendations

Based on the findings of this research work, the study recommends that;

i. Methanol gives the best dye yield when used as extraction solvent and therefore should be used as extraction solvent for natural dyes.

ii. The chromophores, auxochromes and hue present in turmeric dyes, ranged from yellow-orange. More spectroscopic techniques should be used to analyse these dyes for further applications in drugs and cosmetics.

iii. Alum and potash should be used as mordant in natural dying since they gave the best in terms of both wash and light fastness of cotton fabric.

iv. Further analysis such as anti-microbial, anti-bacterial and anti-inflammatory test should be carried on dyed cotton fabrics and recommended for hospital and pharmaceutical applications.

5.4 Suggestions for further study

The following suggestions are made for further research:

1. Advanced spectroscopic analysis of chromophores and auxochromes in turmeric dyes; unraveling the molecular basis of dye color through high-resolution techniques.
2. Effects of different dyeing parameters (temperature, pH, dye concentration) on the fastness properties of turmeric-dyed cotton fabrics.
3. Exploration of alternative solvents and extraction techniques for maximizing solubility and extraction of turmeric dyes.

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Table 2: Greyscale ratings for lightfastness Properties

Grade	Degree of Fading	Lightfastness Type
8	No fading	Outstanding
7	Very Slight Fading	Excellent
6	Slight fading	Very good
5	Moderate fading	Good
4	Appreciable fading	Moderate
3	Significant fading	Fair
2	Extensive fading	Poor
1	Extensive fading	Very poor

(ISO 105-A02:1993 reviewed 2020)

3.8 Determination of the wash fastness properties of cotton fabrics dyed with turmeric dyes and mordanted with Alum and Potash

Wash fastness tests were carried out according to International Standard Organization wash fastness test NO. 3. Under the following conditions; Soda wash 2g/l, soap 5g/l, liquor ratio of 50:1, the temperature of 60^{O}C for 30 minutes. Each of the dyed samples of cotton fabrics was sandwiched between undyed cotton and nylon fabrics and agitated for 5 minutes in a 100ml beaker containing the soap solution. The composite samples were then removed, rinsed and the component separated and dried. The change in the colour of the dyed specimens and the staining of the adjacent fabrics Grayscale was used to rate the extent of fade and the triplicate tests were recorded with the TDFTRS instrument.

Table 3: Greyscale rating for wash fastness properties

Grade	Degree of Fading	Lightfastness Type
5	Moderate fading	Good
4	Appreciable fading	Moderate
3	Significant fading	Fair
2	Extensive fading	Poor
1	Extensive fading	Very poor

(ISO 105-A02:1993, reviewed 2020)

3.9 Method of Data Analysis

The data obtained from this study were analyzed using Gen-Stat 64-bit Release 17.1 Copyright 2014, VSN International Ltd. Registered to ICRISAT. Data obtained from wash fastness, light fastness and acceptability of organoleptic attributes were analyzed using descriptive statistics of mean.