Creation of a Functional Cotton Headcover (turban/ bonnet) Via Lac and Turmeric Natural Dyes

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Abstract:

Functional textiles and clothes have attracted increasing attention in recent years. Apparel possessing antibacterial and antioxidant functions can offer health care effects. Cotton head covers with antioxidant and antibacterial functional properties were created by using a sustainable approach in the current study. The sustainability was applied through using microwave dyeing for knitted cotton fabric with lac and turmeric natural dyes as well as chitosan bio- mordanting. The microwave dyeing was optimized by studying the dyeing time (3-11 min), the microwave power (100 - 900 W), salt concentration (0-10 %) for both lac and turmeric dyes, and the pH of the dyeing bath (2-6) for lac dye and (4-8) for turmeric dye. The deposition of chitosan on cotton fabric was confirmed by scanning electron microscopy for the cotton surface. The color strength of cotton fabric reached 11 and 8.3 for lac and turmeric dyes, respectively with no salt dyeing after chitosan treatment. This result was obtained at 450 W, 7 min, and pH 3 for lac dye and 100 W, 3 min, and pH 7 for turmeric dye. both perspiration and washing fastness (the staining on cotton) properties of lac dyed cotton fabrics were enhanced in the case of chitosan treatment. But in the case of turmeric dye, the fastness properties to wash and light were improved after chitosan treatment. The functional properties of antioxidant and antibacterial were evaluated for both lac and turmeric dyed cotton fabric. The antioxidant activity for turmeric and lac dyed cotton fabrics reached 61.25% and 11% respectively. The antibacterial activity against three strains of bacteria (Bacillus cereus, Staphylococcus aureus, and Escherichia coli) was evaluated using the turbidity method and both lac and turmeric dyes showed antibacterial activity.

Keywords:

Chitosan, Turmeric dye, Fashion, Cotton fabric, Natural dye, Antioxidant.

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1- Introduction:

The field of functional clothes is broad, varies, and includes many functions. Each function type has its requirements for materials, technologies, and procedures. It is well known that clothing serves different purposes, from fundamental protection to aesthetic appeal. However, functional clothing is a general word that refers to all such forms of clothes or assemblies that are particularly constructed to give the user a pre-defined performance or functionality, in addition to its essential functions (Guptaa, 2011).

Textiles are crucial to raising the standard of living for people. Different textile functionalities have seen a considerable increase in demand in recent years. The need for protection against dangerous agents like germs, UV light, free radicals, and others has arisen as a result of growing public knowledge of their negative effects. (Yadav et al., 2019). Functional antibacterial and antioxidant clothes can confer health benefits. The development and spread of bacteria on textiles can result in skin infections, mildew growth, disease spread, allergic reactions, and unpleasant odors. Moreover, Antioxidant-containing textiles can scavenge free radicals produced by skin aging and shield skin tissues from oxidative stress and damage when in touch with skin (Li et al., 2019; Mocanu et al., 2013).

These functional properties can be achieved by the application of natural dyes that afford an effective way of going green chemistry in textile finishing and coloration, which is related to their various environmental benefits such as high biocompatibility, full range availability, low toxicity, and eco-friendly (Rather et al., 2019; Yusuf et al., 2017). In addition to that, natural dyes have good UV protection, antibacterial activity, and antioxidant activity when applied to textile materials (Mulec & Gorjanc, 2015; Rather et al., 2017).

Turmeric and lac natural dyes can be employed for cotton fabric to create colored multifunctional textiles (Yadav et al., 2019). The most often used natural dye for textile dyeing is turmeric. Turmeric has a high amount of phenolic compounds called curcuminoids. The main component of curcuminoids is known as curcumin, the active coloring ingredient in turmeric (Mulec & Gorjanc, 2015; Ravindran et al., 2007). Turmeric is the brightest yellow natural dye and is well-known for its antioxidant, antibacterial activity, and UV protection (Mulec & Gorjanc, 2015; Ravindran et al., 2007) . Mirjalili et al. used turmeric natural dye to color polyamide fabric and found that turmeric was an effective natural dye to produce antibacterial polyamide fabric (Mirjalili & Karimi, 2013). In order to replace the metallic salts in turmeric dyeing for cotton fabric, Hosen et al. successfully explored the use of lemon and colocasia extract as a bio- mordant (Hosen et al., 2021a).

Lac dye is a naturally occurring red color made from two anthraquinone components: laccaic acid A (Lac A) and laccaic acid B (Lac B), which are derived from the insect Coccus lacca or Laccifer lacca (Chimprasit et al., 2021; Mongkholrattanasit et al., 2014; Wei et al., 2013) . Lac dye has been used to color foods and cosmetics as well as to dye silk (Chairat et al., 2005, 2008; Kongkachuichay et al., 2002), wool (Kamel et al., 2005), and cotton (Chairat et al., 2008) fibers(Liu et al., 2013). Several studies have modified the surfaces of fabrics to increase their affinity to lac dye. Boonla et al used plasma treatment to improve the adsorption of lac dye on silk fabric and found that the adsorption capacity was much improved for the plasma-pretreated samples, and the best improvement of adsorption capacity for lac dyeing on silk was found using the Ar-treated silk sample (Boonla & Saikrasun, 2013). In another study the poly(ethyleneimine) (PEI) has been used to enhance the lac dye adsorption to cotton fabric. And it was discovered that PEI increases cotton fibres' ability to adsorb dye and reduces fibres' ability to lose dye (Janhom et al., 2004). Rattanaphani et al. also found that the pretreatment of cotton with chitosan provided a significant enhancement of dye uptake onto the cotton as well as a decrease in the dye desorbed from the cotton compared to the results of lac dyeing in the presence of NaCl or lac dyeing in the absence of chitosan. (Rattanaphani et al., 2007). Also, ultrasonic technique proved effectiveness in dye-uptake of cationised cotton fabric with lac dye(Kamel et al., 2007).

Cotton is the most used textile fiber because of its essential features, including biodegradability, hydrophilicity, breathability, comfort, and adaptability. Consequently, cotton is considered an excellent substrate for printing, dyeing, and as well as for adding high-performance features (Abou Elmaaty et al., 2018). As a result, its use in various products is increasingly popular, including clothing, bed linens, and head scarves. (Yadav et al., 2019). Due to its numerous properties, cotton is the most popular textile material used to knit fabric, especially for summer clothing and sportswear. One-third of the world's textile market is made up of knitted fabrics, which have several desirable qualities like elasticity, stretchability, and comfort when worn (Elgohary et al., 2021).

Innovative techniques have been used, such as coating the fabric with chitosan to improve the dyeability of cellulosic fibers, which are more challenging to dye with natural dyes than protein-based fibers. (Yadav et al., 2019). Chitosan is a polycationic amino polysaccharide that has acquired great importance as a new functional material for textile materials mainly because of its biocompatibility, non-toxicity, and fabulous biological properties. (Lim & Hudson, 2003). Chitosan is N-deacetylated derivative of chitin, and Chemically it is composed of β-(1, 4) linked to 2-amino-2-deoxy-β-D-glucopyranose (Bhuiyan et al., 2017; Shahid-ul-Islam et al., 2018). Chitosan have been used in different studies to replace the metal salts in natural dyeing and printing (Bhuiyan et al., 2017; Dev et al., 2009a; Sundrarajan et al., 2012; Teli et al., 2013)

In the current study microwave irradiation was used to dye cotton fabric with turmeric and lac dyes, Microwave irradiation can dye different fabrics with high coloration efficiency and fastness properties in a short time and with low energy (Ghaffar et al., 2019; Kiran et al., 2019) Microwave irradiation has grown significantly in importance in the textile sector in recent years. Microwave is considered a green heating tool as it eliminates pollution and saves energy (Rizk et al., 2020; Xue, 2017). Adeel et al. used microwave as a sustainable isolation tool for a yellow natural colorant from cinnamon bark for silk dyeing. In addition to using the microwave to improve the yield of color extracted from cinnamon bark, using bio-mordant extracts also made the process more environmentally friendly and sustainable (Adeel et al., 2020). Another study investigated harmala seeds as a unique source of yellowish-red natural colorant for cotton dyeing using microwave treatment. This study discovered that the exploration of novel dye-yielding plants for dyeing is significantly impacted by microwave irradiation, making the dyeing process more efficient in terms of cost, time, and energy (Adeel et al., 2018).

The microwave dyeing of cotton fabric with the lac and turmeric natural dyes has received little attention as well as, functional properties including antibacterial and antioxidant properties after microwave dyeing. So, the main objective of this study was to create fashionable and functional head cover (turban / bonnet) through the dyeing of knitted cotton fabrics with lac and turmeric natural dyes by microwave to obtain dyed fabrics with antimicrobial and antioxidant properties. This study was also concerned with the sustainability in the dyeing process by using chitosan as bio-mordant and microwave as green heating tool.

2. Experimental

2.1. Materials

2.1.1. Fabrics

100% cotton fabric (single jersey 126 g/m^2).

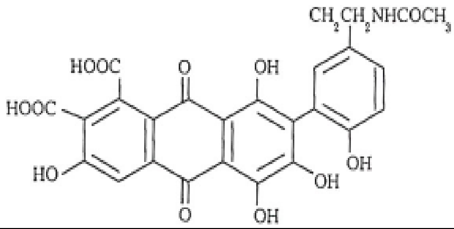
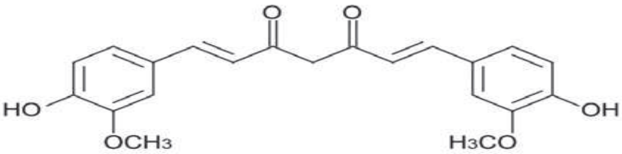
2.1.2. Chemicals

Chitosan powder (medium molecular weight-Deacetylated chitin, Poly(D-glucosamine) 75:85% deacetylated from Sigma-Aldrich Chemie GmbH), Sodium sulfate (anhydrous powder), and acetic acid (96% solution) were of laboratory grade chemicals from Sigma-Aldrich Chemie GmbH and non-ionic detergent from dystar company.

2.1.3. Dye

The powder of Lac natural dye was purchased from ALPS Industries Ltd - Sahibabad- India, and turmeric powder was purchased from local market were used in the current study. The chemical structure of the used dyes is listed in table (1)

Table 1. The chemical structure of the used natural dyes

Dye	**λmax. (nm)**	**Chemical structure**
Lac	530	
Turmeric	430	

2.2. Methods:

2.2.1. The chitosan treatment for cotton fabric

Cotton fabric was treated with chitosan by pad-cure method on laboratory padder. The treatment bath was composed of 1% (o.w.b.) chitosan and 2% (o.w.b.) acetic acid. Cotton samples were padded through two dips and two nips in the finishing bath to approximately 100% wet pick up. Then, the fabric was (dry- cure) in one step at 120 o C for 5 minutes. After that, the samples were washed with 2g/L non-ionic detergent at 40 o C for 8 min and rinsed with hot then with tap water and air- dried.

2.2.2. Extraction of turmeric dye

1% of turmeric solution was prepared by boiling the aqueous solution of turmeric for 30 minutes and finally filtered.

2.2.3. Microwave Dyeing

The chitosan treated cotton fabric was dyed with 13% (o.w.f) lac and 20% (o.w.f) turmeric dyes with sodium sulphate (0-10 % o.w.f.) and M: LR (1:50). The dyeing process was carried out in microwave oven with different power intensities (100-900 W) for different periods of time (3-11min) and the pH was adjusted to (2-6) for lac and (4-8) for turmeric dye. After that, the dyed samples were washed with 2g/L non-ionic detergent at 60 o C for 10 min and rinsed with hot then with tap water and air dry.

2.3. Testing and analysis

2.3.1. Scanning electron microscopy (SEM)

The surface of cotton samples was evaluated before and after chitosan treatment by using A JEOL-Model JSM T20 scanning electron microscopy (SEM) operating at 19 kV to obtain photomicrographs of the fiber surface.

2.3.2. Color strength (K/S)

Color strength (K/S) of the dyed cotton samples was measured on Mini Scan XE spectrophotometer using Hunter lab universal software, which based on Kubelka – Munk equation (1) which stated below.

K/S= (1-R) 2/2R (1)

Where: K, S, and R are the absorption coefficient, scattering coefficient, and reflectance, respectively.

2.3.3. Color fastness:

The light, wash, and perspiration fastness properties of the dyed cotton samples were evaluated according to AATCC: Colorfastness to Light – 16-2004.2005 test method, AATCC: Colorfastness to Laundering, Home and Commercial Accelerated 61-2003.2005, and AATCC: Colorfastness to Perspiration 15-2002.2005 test method, respectively.

2.3.4. Antioxidant Activity:

The antioxidant activity of cotton fabrics was

measured using ABTS radical cation decolorization assay (Re et al., 1999).
The scavenging capability of ABTS+ at 734 nm was calculated according to Equation (2):

$$Antioxidant\ activity\ (\%) = \frac{A_{ctrl} - A_{spl}}{A_{ctrl}} \times 100 \qquad (2)$$

where Actrl is the initial absorbance of the ABTS+, and Aspl is the absorbance of the remaining ABTS+
in the presence of fabric sample. The average of three tests for antioxidant activity was reported.

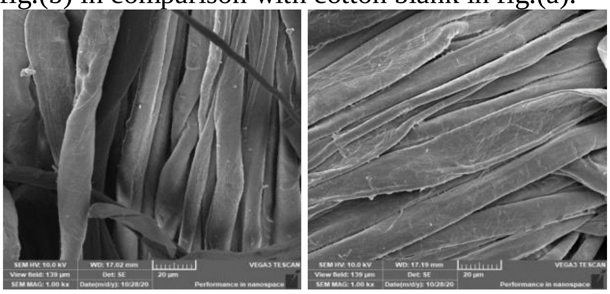
2.3.5. Antibacterial activity (Turbidity method)

The antibacterial activity of cotton samples was determined by turbidity method according to Bhat et al. and Balouiri et al. against two Gram-positive bacteria (Bacillus cereus and Staphylococcus aureus NRRL B-767), and a Gram-negative bacterium (Escherichia coli ATCC 25955) (Mounyr Balouiri et al., 2016; Rama Bhat P. et al., 2011). Briefly, 30 µl of the tested microorganism (106 colony-forming units (CFU)/ml) were inoculated into 3 ml of nutrient broth in standard test tubes containing cotton samples (2x2cm2). Test tubes were incubated at 35±2°C for 24h under shaking conditions. Antibacterial activity was evaluated by measuring the optical density at 620 nm and comparing it to the blank sample.

3. Results and Discussion

3.1. The treatment of cotton fabric with chitosan

Cotton fabrics were treated with 1% chitosan as a bio-mordanting bath to dye with natural lac and turmeric dyes. Chitosan treatment of cotton fabric has numerous features; antibacterial properties, cationization & salt elimination, improving the color strength, and bio mordanting for natural dyes. The role of chitosan as a mordant may be related to the presence of amino groups which get protonated in acidic medium and offer the sites for attachment of the dye which is mainly anionic in nature (Teli et al., 2013). The fabrics were evaluated by Scanning electron microscope (SEM) before and after treatment as shown in fig. (1). The deposition of chitosan clearly appears on the cotton fabrics in fig.(b) in comparison with cotton blank in fig.(a).



(a) (b)

Fig. 1. SEM photographs of cotton fabrics
(a): Cotton blank and (b): chitosan treated cotton fabric

3.2. Optimization of lac and turmeric microwave dyeing

3.2.1 Dyeing time:

The chitosan treated cotton fabrics were dyed with lac and turmeric dyes in the microwave oven at different periods of time. The results in fig. (2) illustrate the effect of dyeing time on the color strength of lac and turmeric dyes. From the results, it is clear that the color strength of cotton fabric dyed with lac dye in the microwave increased when the dyeing duration was increased up to 7 minutes and decreased after that. While the color strength of cotton fabric dyed with turmeric dye in the microwave decreased by increasing dyeing time.
These results revealed that microwave is a time effective technique for natural dyeing of cotton fabric where, the dyeing time has been reduced to only 7 mins for lac and 3 mins for turmeric dyes. This result matches previous studies where the microwave decreases the dyeing time of silk fabric with cinnamon bark natural dye (Adeel et al., 2020).

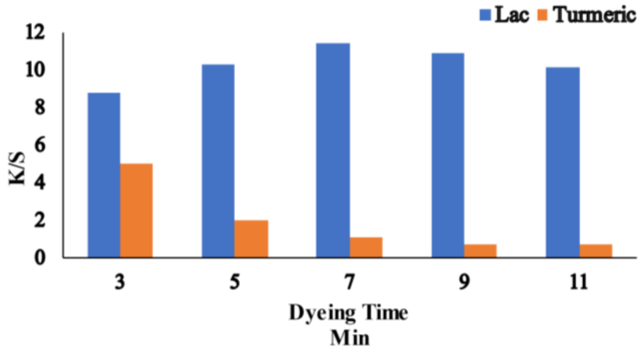


Fig. 2. The effect of dyeing time on the color strength of lac and turmeric dyed cotton fabric

3.2.2 Microwave power

The power intensity is considered a substantial factor in microwave dyeing. Where, heating levels at a specific point always accelerate the dye bath to an excessive degree, causing the rate of retardation and the rate of dyeing to equalize, resulting in maximum fixation and good color strength (Adeel et al., 2020) . Therefore, the results in fig. (3) demonstrated that high color strength of cotton fabric was achieved at 450W and 100W for lac dye and turmeric dye, respectively. These findings demonstrate the sensitivity of the turmeric color to high energy levels (high temperature), which could lead to degradation of the colorant; this result matches the previous study (Ma et al., 2020). But in case of lac dye the low heating level cannot accelerate dye molecules to rush towards the surface-modified fabric whereas high heating either cause desorption of dye molecule or cause colorant degradation due to which low tint strength is observed (Adeel et al., 2020).

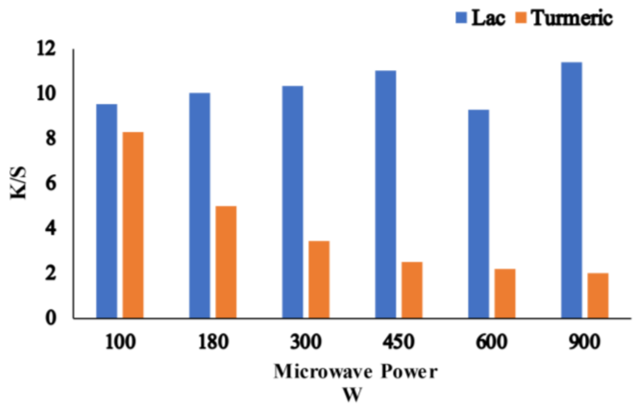


Fig. 3. The effect of microwave power on the color strength of lac and turmeric dyed cotton fabric

3.2.3 Salt concentration

The addition of the salt in the dyeing bath adds value in the coloration of fabric by reducing the repulsion between the negative charge of dye & the fabric thereby developing the attractive forces between them to give maximum color strength (Adeel et al., 2020). But in the current study, the treatment of cotton fabric with chitosan could eliminate the utilization of salt. The results in fig. (4) revealed that the maximum color strength is achieved with no salt dyeing and decreased by raising the concentration of salt with both lac and turmeric dyes. Due to the presence of amino groups, the chitosan fiber carries a positive charge , whereas lac and turmeric dyes have a negative charge. Because of the opposite charges of the surface active sites of chitosan treated cotton fabric and the dye molecules, there is a strong electrostatic interaction between the cotton fabric. But with addition of electrolyte, sodium sulfate in the solution can release SO4-2, which might compete with the dye molecules for the surface active sites of chitosan treated cotton, and thus decrease the adsorption quantity of the dye (Liu et al., 2013).

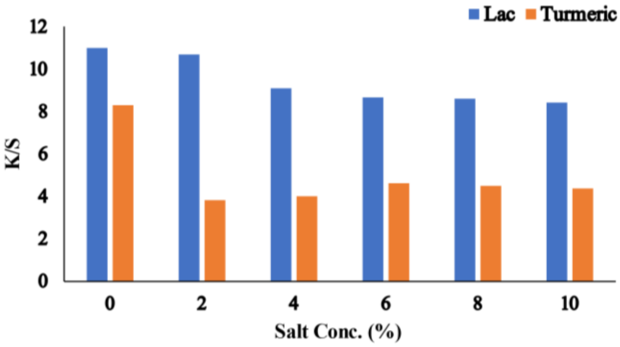


Fig. 4. The effect of salt concentration on the color strength of lac and turmeric dyed cotton fabric

3.2.4 pH of dye bath:

The pH is considered a substantial factor in natural dyeing; from fig. (5) and (6) it can be observed the great effect of pH on the color strength of both lac and turmeric cotton dyed fabrics. In case of lac dye fig. (5) the maximum color strength was achieved 11 at pH 3 and it decreased by increasing the pH. This result can be interpreted by increasing the amount of lac dye adsorbed on cotton fabric by decreasing the pH degree (Rattanaphani et al., 2007) . Moreover, most of the amino groups, (−NH2) of chitosan will be in the protonated cationic form (−NHC3+) in an acidic solution which enhances the ionic attraction between the anionic lac dye and cationic groups of the chitosan and fibers (Rattanaphani et al., 2007). But in the case of turmeric dye fig. (6), the color strength increased by increasing the pH degree, reached the maximum value 8.3 at pH 7, and decreased after that. The elevation in pH made the dye and fabric more anionic, which repelled each other and caused inferior dyeability at higher pH (Rizwana Naveed et al., 2022). These findings are consistent with the previous research showing that the superior color strength was obtained by using the pH of the dye bath equal to neutral (Ma et al., 2020). The cotton samples with maximum color strength after optimization for lac and turmeric dyeing are shown in fig. (7)

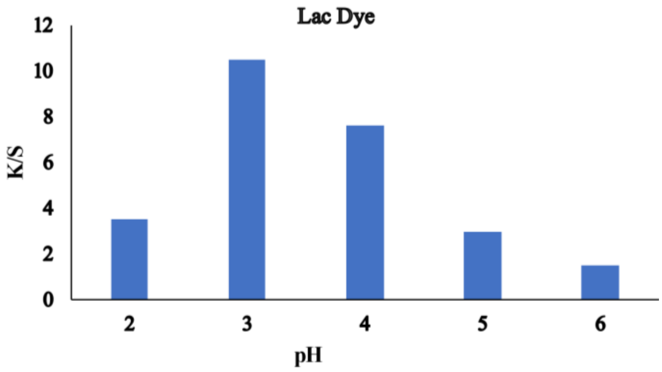


Fig. 5. The effect of pH on the color strength of lac dyed cotton fabric

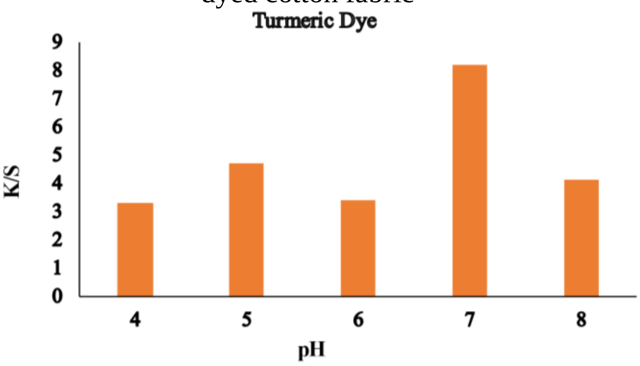


Fig. 6. The effect of pH on the color strength of turmeric dyed cotton fabric

a b c d

Fig. 7. The cotton samples: a: blank of lac dye, b: optimum lac dye, c: blank of turmeric, and d: optimum turmeric dye

3.3. Fastness properties:

The fastness properties against washing, light, and perspiration of dyed cotton fabrics were evaluated for both lac and turmeric natural dyes. From the findings in table (2), it was observed that the light fastness of cotton fabric dyed with lac dye has not changed after the chitosan treatment. But staining on cotton of washing fastness was enhanced from very good (3-4) to excellent (4-5) rating. Also, the perspiration fastness of lac dyed cotton fabrics was enhanced in case of chitosan treatment. These results are matched with the findings of Rastogi et al. who used (Discofix DBA) as a cationic agent for cotton fabric to dye with lac dye. And it was found that the cationized cotton which was dyed with lac dye exhibited a good color yield and wet fastness properties even without mordanting (Rastogi D et al., 2000). Moreover, the fastness properties to wash and light of cotton fabric dyed with turmeric dye improved after chitosan treatment but the fastness properties to perspiration did not change. These results matched with the previous study (Hosen et al., 2021b).

Table 2. The fastness properties of lac and turmeric dyed cotton fabric

Dye	Washing fastness			Light fastness	Perspiration fastness					
					Alkali			Acid		
	Color change	Staining on cotton	Staining on wool		Color change	Staining on cotton	Staining on wool	Color change	Staining on cotton	Staining on wool
Lac dyed	4-5	3-4	4-5	4	3-4	4	3-4	3-4	4	3-4
Chitosan/ Lac	4-5	4-5	4-5	4	3-4	4	4	4	4	4
Turmeric dyed	3	3	3	2	4	4	4	3-4	3-4	3-4
Chitosan/ Turmeric	4-5	3	4-5	3-4	4	4	4	3-4	3-4	3-4

3.4. Functional properties:

3.4.1. Antioxidant properties

The antioxidant activity of cotton fabrics was evaluated using ABTS radical scavenging assay. Results in fig. (8) demonstrated that the lac and turmeric dyes afforded cotton fabrics antioxidant properties. In addition, to that increasing the antioxidant activity in case of dyeing after chitosan treatment and reached 61.25% for turmeric, and 11% for lac dye where, the color strength is increased. The antioxidant activity of turmeric dye is attributed to the curcumin remaining on the surface of the colored materials. Curcumin is the chief component of turmeric dye which has antioxidant, anti-inflammatory, and anti-cancer (Rao et al., 2010). Curcumin is rich in sources of phenolic compounds which are reported to act as antioxidants and help protect human cells against oxidative damage (Lykidou et al., 2021). On the other hand, lac dye is composed of the anthraquinone compounds produced by the insect and contains phenolic hydroxyl and carboxy groups. The hydroxyl-containing anthraquinone compounds from plant extracts usually exhibit certain antioxidant activities, depending on their chemical structures (Liu et al., 2013). Cotton fabric dyed with turmeric dye has antioxidant activity greater than that dyed with lac dye, and the antioxidant properties increased by raising the dye concentration. One of the possible explanations is that the chitosan and lac dye react between both, or that the formulation reacts with the fabric in such a way that the free active groups of lac dye are blocked more than that happened in the case of turmeric dye.

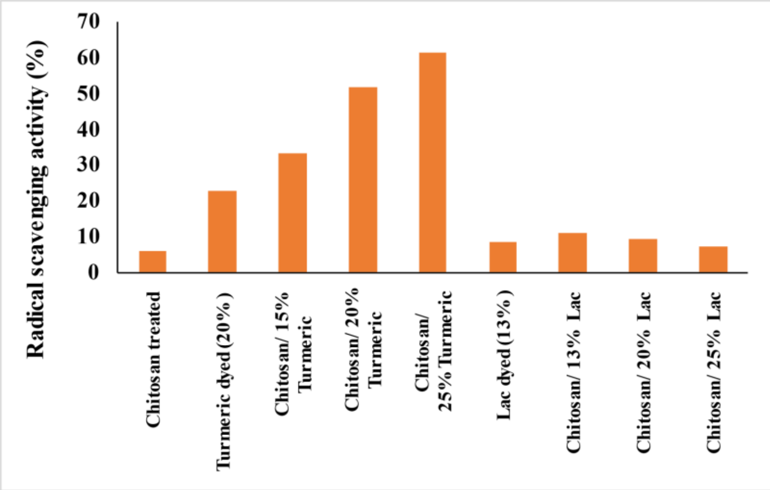


Fig. 8. The antioxidant activity of lac and turmeric dyed cotton fabric

3.4.2. Antibacterial properties:

The antibacterial activity of cotton samples was determined by the turbidity method against two Gram positive bacterium Bacillus cereus (Bc), and Staphylococcus aureus (Sa), and one Gram-negative bacterium Escherichia coli (Ec). Results in fig. (8) exhibit that the control sample showed the higher turbidity (the value was 0.92 for E. coli,0.83 for S. aureus, and 0.87 for B. cereus) which indicated no antibacterial activity. But, the chitosan treatment, lac and turmeric natural dyes provided antibacterial activity for cotton fabrics against S.aureus, E. coli, and B.cerus in diverse ways. In case of chitosan treatment, cotton fabric was conferred the maximum antibacterial properties against S. aureus (the value of turbidity is 0.24) furthermore, the turmeric dyed cotton fabric provided the highest antibacterial activity against E. coli (the value of turbidity is 0.39) and the chitosan treatment followed by turmeric dyeing gave the maximum antibacterial activity against B. cereus (the value of turbidity is 0.22).

The microbial inhibition mechanism of chitosan is related to the interlinkage of the positively charged chitosan with the negatively charged residues at the cell surface of many fungi and bacteria. This interaction causes extensive cell surface alterations and alters cell permeability and leakage of intracellular such as electrolytes, UV-absorbing material, proteins, amino acids, glucose, and lactate dehydrogenase. So, chitosan inhibits the normal metabolism of microorganisms and finally leads to the death of these cells (Dev et al., 2009b). But the antibacterial activity of turmeric dye is related to the presence of phenolic groups in curcumin compounds (Lykidou et al., 2021; Mari selvam et al., 2012). The –OH groups can interact with the cell membrane of bacteria and disrupt its structure, resulting in the leakage of the cellular components; this could help to delocalize electrons that act as proton exchangers and reduce the gradient across the cytoplasmic membrane of the bacterial cells, causing cell death (Shahmoradi Ghaheh et al., 2021).

Although lac dye awarded cotton fabric the antibacterial properties against the three tested bacteria, the antibacterial activity decreased in case of dyeing after chitosan finishing. This result provides evidence of the strong linkage between the functional groups of both chitosan and lac dye which are responsible for antibacterial properties also confirms the results of wash fastness (table 2) and antioxidant properties (fig. 8).

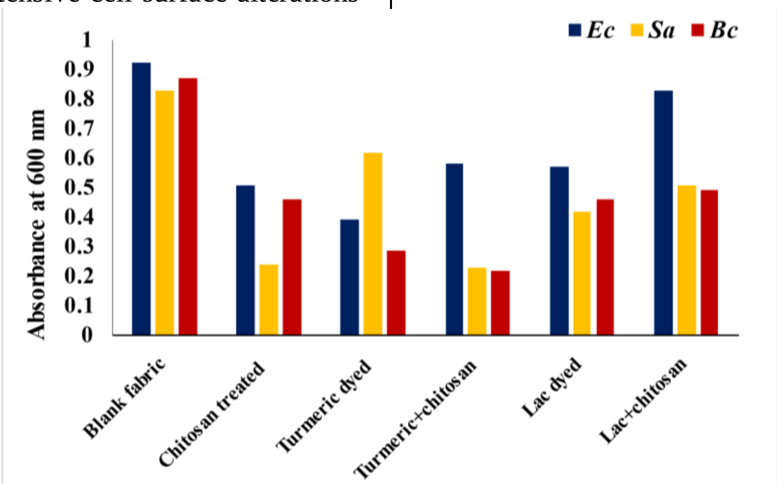


Fig. 9. The antibacterial activity of lac and turmeric dyed cotton fabric

3.5. Functional clothes:

Nowadays, customers not only demand apparel and textiles with essential features and functions but also want additional functions such as protection and healthcare properties. In addition to the conventional idea of creating clothing with better aesthetic value to satisfy users, the insertion of additional functional properties by utilizing new textile products through emerging fields like smart and functional clothes is considered a new trend in the fashion field(Maha M. T. Eladwi & Naglaa A. A. Elsayed, 2015; N. S. Ashour & Omnia Kh. Ahmed, 2016). In the current study, functional cotton head covers (turban and bonnet) were created by employing lac and turmeric natural dyes to introduce fashionable head covers with added value which are both antioxidant and antibacterial functional properties. Hair is an important part of women's appearance; however, hair damage is occurred by environmental stress (UV exposure) or chemicals of hair dyeing. Antioxidants are considered effective ingredients to repair skin /hair systems and protect against oxidative damage (Fernández et al., 2012).

Four cotton head covers were designed to impart women's hair healthy cover (antioxidants and antibacterial) during the sleeping or usage under a scarf / hijab. The tie & dye technique was utilized to dye the head cover in the microwave via turmeric and lac dyes. Fig. (10) shows the created head covers turban and bonnet.

A) Turban (1) and its tie &dye with both lac and turmeric dye

B) urban (2) and its tie &dye with both lac and turmeric dye

C) Bonnet (1) and its tie &dye with both lac and turmeric dye

D) Bonnet (2) and its tie &dye with turmeric dye

Fig. 10. Functional antioxidant and antibacterial head cover (turban/bonne)

Conclusion:

Functional head covers with antioxidant and antibacterial properties were designed and implemented in the current study using the microwave dyeing technique for knitted cotton fabric via lac and turmeric natural dyes. The cotton fabric was dyed by microwave in a short time and with low power intensity where the maximum color strength of cotton fabric was obtained at 450 W for 7 min and 100 W for 3 min for lac and turmeric dyes, respectively. This result affirms that microwave dyeing is considered a sustainable technique in natural dyeing. The bio-mordanting of cotton fabric with chitosan was effective in lac and turmeric dyeing in eliminating the metallic mordants, improving the color strength, and dispensing with the salt where the highest color strength (11 for lac and 8.3 for turmeric) was achieved with no salt dyeing. Moreover, the pH degree is regarded as a considerable factor in lac and turmeric dyeing where the best color strength was attained at pH 3 for lac dyeing and pH 7 for turmeric. The fastness properties of lac and turmeric dyed cotton fabric were affected by chitosan treatment. Lac and turmeric dyes imparted cotton fabric antioxidant and antibacterial functional properties. Turmeric dye after chitosan treatment afforded the cotton fabric with 61.25% antioxidant activity, and lac dye conferred 11%. Furthermore, both lac and turmeric dyes gave the cotton fabric antibacterial activity against three strains of bacteria (Bacillus cereus, Staphylococcus aureus, and Escherichia coli). In the future, more research is needed to apply other bio-mordants for cotton fabric and dyeing with lac and turmeric dyes by microwave technique. As well as evaluate the effect of these bio-mordants on the functional properties of lac and turmeric dyed cotton fabric.

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