Labyrinth: Fayoum Journal of Science and Interdisciplinary Studies 3 (2025) 1; 53-60

Contents lists available at Egyptian Knowledge Bank

Labyrinth: Fayoum Journal of Science and Interdisciplinary Studies

Journal homepage: https://lfjsis.journals.ekb.eg/

# Functionalization of Some Natural Thread Properties for Needlecraft in Children's Apparel

Noheer Galal [a], Manal M. El-Adawy [a,*], Sahar M. Ali Othman [a], Naglaa Abdulfattah Elsaied Mohammed [a], Samiha M. Abo El-Ola [b]

[a] *Home Economics department, Faculty of Specific Education, Fayoum University, El Fayoum 63514, Egypt.*
[b] *Textile Research and Technology Institute, National Research Centre, Cairo, Egypt.*

ARTICLE INFO

*Keywords:*
Natural dyes
Functionalization
Antibacterial
Antifungal

ABSTRACT

This article discusses using some natural dyes (Turmeric, Natural Yellow 3, Madder, and Natural Red 8) to develop some properties of natural fibers (cotton and wool) as a treatment against bacteria and fungi, as an eco-friendly method. The effects of this on these fibers were studied by conducting tests to measure the values (K\S) color data (L*, a*, and b*) at a specific λ max value. The results showed that the highest values were observed in the samples dyed with turmeric (for both types of fibers), followed by the mixture used to dye them (turmeric and madder). Then the mixture was used with the dye, and finally, madder gave high values. Fastness properties related to light, washing, and perspiration were also determined. The antimicrobial effect (*E. coli*, *Staphylococcus aureus*, and *Aspergillus flavus*) is also detected by performing a microbial count (MIC) test to determine the minimum inhibitory concentration. It was found that antimicrobial activity appeared in varying proportions for the dyed threads compared to the control samples, depending on the type of fiber. The interaction between microbes and the dyes was also investigated. Studies have shown that applying these dyes to cotton and wool threads produces high-quality threads with unique properties including antimicrobial properties, good stability properties, and vibrant colors. Due to their safety and eco-friendly nature these dyes are ideal for producing themed children's clothing on a large scale.

## 1. Introduction

Protecting textiles from microbial damage has grown increasingly important for both consumers and textile manufacturers [1]. Children's clothing with aesthetic appeal and unique character is often handmade using natural threads like cotton or wool. However, these natural materials provide an ideal environment for pathogenic microbes and fungi to thrive, leading to unpleasant odors. Additionally, natural fibers tend to retain oxygen, moisture, and warmth- especially when in direct contact with the skin [2]. The growth of bacteria and mildew not only poses health risks, particularly for children, (such as skin irritations), but also degrades textiles integrity. During use and storage, microbial activity can impair fabric breathability. Cellulolytic enzymes secreted by certain bacteria and fungi cause discoloration, odor, reduced tensile strength and diminished tear resistance- ultimately shortening the garment's lifespan [3]. To mitigate these issues, textile fibers must either be treated with antimicrobial agent or engineered to resist microbial growth. Natural dyes, particularly plant –based ones, offer a viable solution. Historically, natural antimicrobials have been used in textiles since ancient times- for instance, the Egyptians employed spices and herbs to preserve mummy wrappings [5]. Today, such dyes are favored globally for their eco-friendliness and safety [4]. Beyond coloring, natural dyes impart antibacterial, deodorizing, and UV-protective properties. Sourced primarily from plant parts (leaves, bark, flowers, etc.), as well as minerals, fungi, and insects, these dyes are biodegradable, non-toxic, non-carcinogenic nature, and inherently antimicrobial [6, 7, 8, 9]. Their resurgence in modern textiles stems from their low environmental impact, minimal health risks, and sustainable profile [9].

Natural dyes can be categorized into four main types based on their source: plant-derived, animal-derived, mineral-derived, and microbial-derived dyes. Among these, plant-based dyes have historically dominated textile coloring practices. For millennia diverse botanical components- including roots, leaves, twigs, and stems, have served dual purposes as both textile colorants and food dyes. Many of these pigment-producing plants also hold significant value in traditional medical systems [10]. the historical applications of natural dyes extend beyond more coloration. Ancient civilizations utilized mineral-based pigments like black eyeliner and green malachite not only as cosmetics but also as therapeutic agent for eye conditions. For over four millennia, natural dyes have been prized by environmentally-conscious [11]. particularly for their multifunctional properties including: antibacterial and antimicrobial effects, antioxidant capacity, UV-radiation protection, antimalarial

* Corresponding author.
*E-mail address:* manal@fayoum.edu.eg *(M. M. El-Adawy); Tel.: +201006783693*

DOI: 10.21608/ifjsis.2025.328401.1096
Received 17 October 2024; Received in revised form 30 January 2024; Accepted 09 April 2025
Available online 19 April 2025

potential, and anticancer activity [11, 12]. Beyond their practical application, these organic colorants have also played important roles in spiritual practices, with various plant pigments being incorporated into witchcraft ceremonies and religious rituals throughout history [13, 14].

Natural coloring materials encompass a variety of botanical sources, including wood, bark, wood shavings, flowers, fruits, rinds, hulls, husks [14,15], among these, turmeric (*Curcuma longa*) stands out as a notable medicinal plant used for coloring purposes. This tropical plant characterized by its small underground tubers and annual leafy growth, exists in several well-known varieties [16,17,18]. another significant natural dye is madder, a red pigment derived from various Rubia species. The coloring compound is primarily concentrated in plant's root, earning madder the popular designation as the "Queen of Natural Dyes" [19].

Cotton remains the world's most popular and widely used textile fiber. As a natural cellulose fiber obtained from *Gossypium* plants. Cotton offers exceptional breathability and air permeability. These properties, along with its soft texture and year-round comfort, have established cotton as the quintessential all-season fabric [20]. The fiber's high cellulose content and numerous advantageous characteristics make it indispensable for textile applications. The tips the cotton fibers are open and taper towards the base, where they are attached to the seed. During the ginning process, the hairs on the seeds are removed [21]. As shown in Figure 1, a single cotton fiber is composed of multiple layers that form its structure. These include the cuticle; primary wall, secondary wall, and lumen. The layers are interconnected both extremely and internally, yet they differ Physically and chemically. The primary and secondary walls vary in terms of crystallinity and molecular chain orientation. The amorphous cuticle constitutes about 2.5% of the total fiber weight. the secondary wall, which contains the majority of the cellulose, make up roughly 91.5% of the fiber's weight. The lumen contains residual protoplasm [22,23].

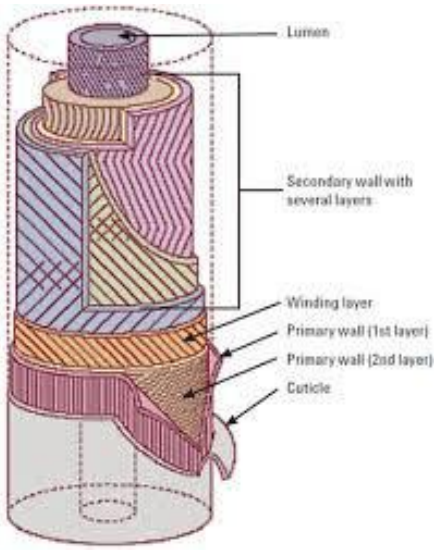


Figure (1) Morphological Structure of Cotton Fiber [24]

Cellulose ($C_6H_{10}O_5$), is one of the most widely distributed organic polymers in the world. Among the many natural raw materials used in industry, cellulose has long held a prominent role [23, 25, 26]. Wool, a notable natural protein fiber, is most commonly used in technical and fashion textiles due to its unique properties. Wool microfiber are increasingly being utilized in the production of carpets, other floor coverings, and various specialized textile applications [27]. The primary chemical component of pure wool is alpha-keratin, the same structural protein found in horns, hooves, and feathers. Keratin is a resilient protein that is not easily hydrolyzed by strong acid. its elemental composition includes approximately 50% carbon, 25% oxygen 20% nitrogen, 6% hydrogen, 3% sulfur, and 0.5% ash [28]. Keratin is composed of more than thirteen types of amino acids which are linked by peptide bonds. Among these amino acids, arginine, cysteine, glutamine, and lysine are particularly significant [29].

In this investigation, Cotton fabric and a combination of powders (turmeric root and pomegranate peel) were exposed to radiation for one to five minutes. It was found that Exposing cellulosic fabric to radiation for three minutes enhanced its dye uptake. When the fabric was dyed in a pH-6 dye bath at 65°C for 40 minutes, good color strength was achieved. An optional concentration of 4% copper as a precursor and 8% chromium as a post-treatment was determined to improve color fastness. Using a dissolved aqueous extract made from irradiated pomegranate peel and powdered turmeric rhizome, it was shown that microwave treatment enhanced both the color strength and color fastness of irradiated cotton. natural dyes offer Additional benefits including non-toxicity, potential medicinal applications, and eco-friendly coatings [9]. Several studies have also reported that natural dyes possess strong antimicrobials properties. For instance, tannin-rich Quercus infectoria extract demonstrated significant antibacterial activity against both Gram-positive and Gram-negative bacteria [14]. In another part of the study, cotton fabric pre-mordanted with three metallic salts—alum, ferrous sulfate, and copper sulfate—was dyed using the colorants madder and weld. Researchers examined the influence of electrolyte concentration, dyeing temperature, dyeing duration, and mordant concentration on the color intensity of the dyed samples. Additionally, low temperature plasma treatment—an environmentally friendly method—was used as a pretreatment to improve dye exhaustion into cotton fibers. To determine the optimal level of each variable for achieving maximum color strength and fastness properties, cotton samples dyed under different conditions were evaluated [30].

The integration of dyeing and finishing processes using antibacterial dyes makes the textile process more efficient, reducing water and energy consumption [31]. Using aluminum sulfate, five different natural dyes were derived from green tea. The results indicated that each dye showed some antibacterial properties. Henna, turmeric, and saffron petals were also applied to wool fabric [32]. And their antibacterial activity as well as dyeing characteristics, such as colorimetric values, light fastness, and wash fastness were examined [33]. Since natural dyes generally have low fastness, Pre-mordanting wool fabric was necessary to provide protection against *Staphylococcus aureus, Escherichia coli*, and *Aspergillus flavus*. Furthermore, aluminum sulfate pretreatment showed improved and more durable antibacterial effects, even after five washing cycles and 300 minutes of light exposure [31].

In this study, turmeric and madder dyes were used to protect cotton and wool threads from the growth of bacteria and fungi. The work was conducted in two stages. First, the powder was boiled in water for an hour to extract the dyes. The extract was then filtered to obtain a tincture. Ferrous sulfate was added to part of the extract as a mordant. Three separate dye extracts were prepared for use in the dyeing (curing) process: madder, turmeric, and turmeric-madder mixture. The second stage involved the dyeing (or treatment) process. The four extracts were used to dye four thread samples made from cotton and an equivalent amount of wool. This resulted in four differently colored cotton thread samples and a matching set of wool threads, each intended for use in producing children's clothing.

## 2. Materials and methods

### 2.1 Materials

Cotton threads, No. 8/20, were purchased from Misr for Spinning and Weaving Company, Mahalla El-Kobra, Egypt through Ahmed Abdel-Rady store in Al-Sandakia, Al-Azhar Street. Wool yarn was also purchased from Misr Spinning and Weaving Company, Mahalla El-Kobra, Egypt. Commercial-grade turmeric and madder dyes were sourced from a local supplier in Egypt. Ferrous sulfate ( $FeSO_4$) used as a mordant was obtained from Sigma-Aldrich(USA), while high molecular weight chitosan was purchased from Sigma,( Germany).

### 2.2. Method:

#### 2.2.1. Turmeric extract

Seventy grams of turmeric powder were weighed and added to one liter of water at 90 °C, for 60 minutes. After cooling, the liquid was filtered to obtain the extract used for dyeing (Figure 2 A, B, C).

#### 2.2.2. Madder extract and Mixture of dye extract

Weigh 70 grams of madder and add it to one liter of water. Heat the mixture at 90 °C for 60 minutes, then filter it to obtain the extract. To Prepare a mixture of the two dyes (turmeric and madder), proceed as follows: Weigh 40 grams of turmeric and 40 grams of madder, then add them to one liter of water in a dedicated pot. Heat the mixture at 90 °C, for 60 minutes, then filter it to obtain the combined extract (Figure 2A, B, C).


Fig. 2. Preparing the extracts. A. Heating the mixture solution. B. Filtering the mixture. C. Combined extract.

### 2.3. Threads Scouring

Cotton fibers contain numerous contaminants that must be removed to ensure uniform dye uptake, rapid color development and the achievement of desired shades [16]. Proper preparation of the yarns before dying and/or printed is therefore essential. Before use, the yarn was treated for 30 min at 50 °C in a solution containing 5 g $L^{-1}$ of a non-ionic detergent (Hostapal CV, Clariant). After treatment, the yarn was thoroughly rinsed with water and allowed to air dry at room temperature. Auxiliary chemicals including the detergent and leveling agent, were obtained from Clariant, Bangladesh, and utilized as received, Analytical- grades of soda ash ($Na_2CO_3$) and acetic acid ($CH_3COOH$) were sourced from Merck, India. To further clean the threads, bush materials were removed, and the threads were soaked in a solution composed of 1500 milliliters of water, 5 grams per liter of sodium carbonate, and 2 grams per liter of detergent., this solution was heated to 50 °C and maintained for 60 minutes.

### 2.4. Treatment of Cotton Threads with Chitosan (Cationaization)

Cotton thread samples were treated with 1.5% chitosan in 2% acetic acid at 60 °C for 60 minutes prior to dyeing.

### 2.5. Cotton Dyeing and Post Mordanting with $FeSO_4$

Wool and cotton yarns were dyed by conventional heating at pH 5 for 60 minutes at 95°C in a dye bath containing dyes (turmeric and madder) with liquor ratio 1:40. After dyeing, the samples were rinsed with cold water; then immersed in a bath with a liquor ratio of 1:50 and cleaned for 30 minutes at 50 °C using 3 g $L^{-1}$ non-ionic detergent (Hostapal CV, Clariant). Afterward, the samples were rinsed again and allowed to air dry at room temperature. A Hanna pH meter was used to measure the pH, which was adjusted using diluted solution of sodium carbonate and acetic acid. The modified threads were dyed with turmeric, madder, and their mixture then post- mordent with ferrous sulfate at 5% of the thread's weight. Figure (3A, B) display the colors of the dyed threads.

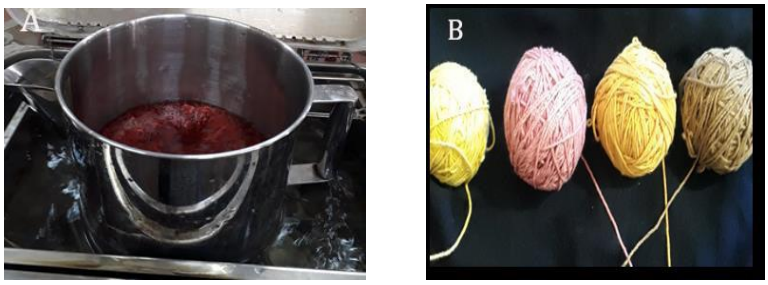


Figure (3) dyeing wool and cotton yarns. A. *dying bath. B. The dyed Cotton threads Samples colors*

2.6. Wool Dyeing and Post- Mordanting with $FeSO_4$

The wool yarn was divided into four samples and dyed following the same procedure used for the cotton threads, using turmeric, madder, and their mixture, the samples were then post-mordented with ferrous sulfate at 5% of the thread's weight. Figure (4) show the colors of the dyed threads.

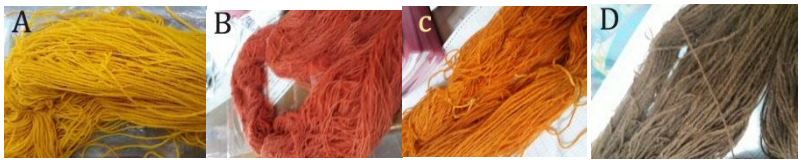


Figure (4) The dyed wool threads samples colors. A. Yellow color. B. Red color. C. Orange color. D. Brown color.

2.7. Data Analysis

The Duncan multiple range test was used to compare means after performing a one-way ANOVA on the data.

## 3. Results

### 3.1 Color strength (Color measurements)

Colorimetric analysis of the dyed fibers was carried out using a spectrophotometer (Ultra Scan Pro, Hunter Lab, USA) with pulsed xenon lamps as the light source. The instrument was set with a 10° observer, D65 illuminant, *d/2* viewing geometry, and a 2 mm measurement area, all measurements were taken at $\lambda_{425}$, the corresponding color strength value (K/S) was determined using the Kubelkae-Munk's equation (34).

$$k/S = \frac{(1-R)}{2R} - \frac{(1-R_0)}{2R_0}$$

Where, R is the decimal percentage of the dyed threads' reflectance. $R_0$ is the decimal portion of the undyed threads' reflectance. K is the coefficient of absorption. S = Scattering coefficient.

The dyed threads' colorimetric characteristics were acquired using a Hunter Lab DP-9000 Color- Spectrophotometer.
Colorimetric data in the CIE Lab, the entire disparity with the Hunter-Lab spectrophotometer (model: Hunter Lab DP-9000), CIE (L*, a*, and b*) was measured. The CIE (L*, a*, b*) between two colors is computed from, where each color is given in terms of L*, a*, and b*.

$$\Delta E = L^2 + \sqrt{a^2 + b^2}$$

Where a* is a red (+)/green (−) ratio, b* is a yellow (+)/blue (−) ratio, L is the lightness from black (0) to white (100), and ΔE is the total difference between the sample and the standard.

It is possible to calculate the color difference using the CIE Lab color space data. The color space *(L, a*, b*)* of colored samples was measured by the same spectrophotometer used for measuring of color strength at the same set up and then the color difference was calculated using (2)

$$\Delta E = L^2 + \sqrt{a^2 + b^2}$$

Where a* is a red (+)/green (−) ratio, b* is a yellow (+)/blue (−) ratio, L is the lightness from black (0) to white (100), and ΔE is the total difference between the sample and the standard. .,. The L* value: indicates lightness, (+) if sample is lighter than standard, (-) if darker. a* & b* values: indicate the relative positions in CIE Lab space of the sample and the standard, from which some indication of the nature of the difference can be seen. [ 35].

**Table 1**: Display the color strength of the dyed cotton yarns.

| Sample | Dye used | $\lambda_{max}$ | K/S | L | a* | b* | $\Delta E$ |
|---|---|---|---|---|---|---|---|
| 1 | Turmeric | 415 | 19,44 | 71.38 | 9.55 | 70,44 | 57,50 |
| 2 | Madder | 420 | 3,92 | 47,43 | 30.72 | 18,12 | 46,29 |
| 3 | madder + Turmeric | 413 | 13,03 | 56,10 | 23,79 | 52,62 | 51,61 |
| 4 | Turmeric +madder+ ferrous sulfate | 430 | 10,28 | 43,22 | 10,55 | 27,12 | 42,21 |

*Color coefficient values for dyed cotton yarn color*

**Table 2:** The color strength for the dyed wool yarns

| sample | Dye used | $\lambda_{max}$ | K/S | L | a* | b* | $\Delta E$ |
|---|---|---|---|---|---|---|---|
| 1 | Turmeric | 410 | 25,89 | 67,25 | 17,93 | 76,69 | 66,14 |
| 2 | Turmeric+ madder +ferrous sulfate | 440 | 23,71 | 43,22 | 10,55 | 27,12 | 42,21 |
| 3 | Turmeric+ madder | 420 | 19,31 | 52,30 | 29,08 | 54,74 | 57,62 |
| 4 | Madder | 420 | 6,73 | 46,77 | 33.89 | 27,15 | 50,43 |

Color coefficient values for dyed wool yarn color

It is clear from tables No 1 and 2 that the color depth values for samples treated with natural dyes (turmeric and madder), with the highest being sample No1, and the lowest being sample No 6.

### 3.2. Fastness properties

3.2.1. Color fastness to washing

Color fastness to washing was evaluated according to the ISO 105-C02 (1989) method. After sewing the composite specimens between two pieces of wool and cotton fabric that had been bleached, they were submerged in an aqueous solution containing 5 g/l non-ionic detergents at a liquor ratio of 1:50. For thirty minutes, the bath's temperature was kept at sixty degrees Celsius. Samples were taken out after the allotted time, rinsed twice with the occasional hand squeeze, and then dried. The grey-scale was used to establish the wash fastness evaluation for color change table (3) shows the color fastness test t to washing values.

**Table 3:** the color fastness test to washing

| Samples | $St_1$ | St* | Alt | samples | $St_1$ | St* | Alt |
|---|---|---|---|---|---|---|---|
| Cotton | | | | Wool | | | |
| 1 turmeric | 2 | 2 | 3 | 5- turmeric | 4 | 4 | 4 |
| 2 madder | 3 | 3 | 3-4 | 6- madder | 4 | 4 | 4 |
| 3 madder+turmeric | 2 | 2 | 3 | 7- turmeric+madder | 1-2 | 2 | 2-3 |
| 4 turmeric+madder+ ferrous sulfate | 2-3 | 3 | 3 | 8- turmeric+madder+ferrous sulfate | 2-3 | 3-4 | 3-4 |

St=staining. The color fastness test values to washing

3.2.2 Color fastness to perspiration

The test method ISO 105-E04 (1989) was used to prepare two artificial perspiration solutions: acidic and alkaline. One liter of distilled water was used to dissolve (0.5 g.) of L-histidine monohydrochloride monohydrate, (5 g.) of sodium chloride, and (2.2 g.) of sodium dihydrogen orthophosphate dihydrate to create an acidic solution finally 0.1N NaOH was used to the pH to 5.5. One liter of distilled water was used to dissolve L-histidine monohydrochloride (0.5 g.), sodium chloride (5 g.), and disodium hydrogen orthophosphate dihydrate (2.5 g.) in order to create the alkaline solution. 0.1N NaOH was used to bring the pH to 8. This is how the fastness test was carried out. To create a composite specimen, a colored specimen measuring 5 cm × 4 cm was sewn between two pieces of uncolored specimen. To ensure thorough wetting, the composite samples were submerged in both solutions for 15 to 30 minutes while being properly shaken and squeezed. With a force of roughly 4-5 kg, the test specimens were sandwiched between two glass or plastic plates. After that, the plates with the composite specimens were kept vertically in an oven at 37 °C (±2 °C) for four hours. The impact of this temperature change on the tested specimens' color was defined and expressed using a grey-scale scale. Table (4) shows the values of Color fastness test to perspiration for yarns. The color fastness values to (Alkaline) perspiration yarns. It is clear from the Tables 4 and 5 that the values of the Color fastness test to perspiration for yarns are all good.

**Table 4:** Color fastness test to perspiration for yarns (acidic solution)

| | *St* | *St** | *Alt* | *wool* | *St* | *St** | *Alt* | *St* | *St** | *Alt* | *wool* | *St* | *St** | *Alt* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acidic solution | | | | | | | Alkaline solution | | | | | | |
| *1* | 3 | 3 | 3-4 | 5 | 4 | 3 | 4 | 2 | 3-4 | 3-4 | 5 | 4 | 4 | 4 |
| *2* | 4 | 4 | 4 | 6 | 4 | 4 | 4 | 2-3 | 4 | 4 | 6 | 4 | 4 | 4 |
| *3* | 3-4 | 3-4 | 4 | 7 | 1-2 | 3-4 | 2 | 3 | 3-4 | 4-4 | 7 | 2 | 2 | 3 |
| *4* | 4 | 3 | 3-4 | 8 | 4 | 4 | 4 | 3 | 3-4 | 3-4 | 8 | 3-4 | 3-4 | 3-4 |

3.2.3. Color fastness to light

In accordance with ISO 105-B02 (1988), a carbon arc lamp was used for a continuous 35-hour exposure during the light fastness test. The impact on the color of the tested samples was noted using the blue-scale method of color change (36). The color fastness values for the light test. It is evident from Table 5 that, when the samples were exposed to light, the results showed that most of the samples stained with both dyes madder and turmeric had good resistance to light, and the least of them was sample number 3.

**Table 5:** the color fastness to light test

| Cotton | Alt | Wool | Alt |
|---|---|---|---|
| 1-turmeric | 3-4 | 5-turmeric | 5 |
| 2- turmeric +madder +ferrous sulfate | 5 | 6-madder | 4 |
| 3- Turmeric +madder | 5 | 7-turmeric+madder | 4 |
| 4-madder | 3 | 8-turmeric +madder +ferrous sulfate | 5 |

3.3 Determination of the Relative Antimicrobial Activities

To insure valid comparisons, it is crucial that the same microbial load is used in each antimicrobial susceptibility Test (AST). Every strain has a different incubation period before getting immunized. Microorganisms are typically advised to be logarithmically grown when they are initially cultured. This investigation maintained the incubation and vaccination protocols while modifying the bacterial load. McFarland values

for well-inoculated cultures were used to confirm the bacterial load on each occasion. The colony counting method is used to determine the specific bacterial count (CFU/ml).

3.3.1. Extraction by micro-dilution assay

The lowest concentration of an antimicrobial that will prevent a microorganism from growing visibly is known as the minimum inhibition concentration, or MIC. Minimum inhibition concentrations are crucial for tracking the effectiveness of novel antimicrobials (37). To ascertain the minimum inhibitory concentration (MIC) for fibers (threads), the study [38] employed *E. coli, Staphylococcus aureus,* and *Aspergillus,* with both tests conducted according to a standard methodology. The process began with the preparation of test samples, which were thereafter serially diluted three times using sterile deionized water to reach a final concentration of 50 mg/mL, Afterward, each Petri plate was filled with 95 µL of nutritional broth and 100 µL of each generated concentration. For every strain, positive and negative controls were also run. Negative controls were prepared by serial dilutions of samples in sterile distilled water (50%), and growth kinetics assays were performed using the bacterial cell counting device.

3.3.2. Microbiological Analysis

In order to obtain the MIC (Minimum inhibition concentration assays) values of samples against different pathogens and virulent microorganisms where the MIC values for *E. coli, Staphylococcus aureus, and Aspergillus* samples are shown in Tables 6 and 7.

Table 6: The total bacterial numbers of the different samples

| Control | | Microorganism | | |
|---|---|---|---|---|
| | | *E.coli* | *Staphylococcus aureus* | *Aspergillus flavus* |
| Madder (Rubiatinctorum) | | $18x10^3$ | $15 x10^3$ | $20 x10^3$ |
| Curcuma longa (Turmeric) | | $16 x10^3$ | $14 x10^3$ | $18 x10^3$ |
| samples | 1-(Cotton+Turmeric) | $6 x10^3$ | $6 x10^3$ | $8 x10^3$ |
| | 2-(cotton+ madder) | $9 x10^3$ | $10 x10^3$ | $12 x10^3$ |
| | 3(cotton+ turmeric+ madder) | $6 x10^3$ | $6 x10^3$ | $4 x10^3$ |
| | 4-(cotton+turmeric+madder +ferrous sulfate | $2 x10^3$ | $2 x10^3$ | $9 x10^3$ |
| | 5(wool +turmeric) | $7 x10^3$ | $7 x10^3$ | $3 x10^3$ |
| | 6-(wool +madder) | $9 x10^3$ | $9 x10^3$ | $6 x10^3$ |
| | 7-wool+turmeric +madder+) | $12 x10^3$ | $12 x10^3$ | $9 x10^3$ |
| | 8-(wool+turmeric +madder+ferrous sulfate | $2 x10^3$ | $2 x10^3$ | $9 x10^3$ |

Concentrations were examined after their preparation.

The treated thread samples were cut into approximately 1.5 cm pieces and divided into 3 batches according to the microbial cells, with different concentrations. Differences between the control samples and the treated samples were detected. The observed microbial count values increased in *Aspergellus flavus* samples compared to the other treated samples. The effect of fiber pretreatment on total viable TVCs (TVCs) from the samples was determined. The microbial load is greater than that of *E. Coli, Staphylococcus aureus*. All samples are significantly lower than the control group treated samples.

It is clear from the data that the primary microorganisms examined for the control samples were higher than the other samples treated with different concentrations of turmeric and madder. A high percentage of *E. coli* was detected in the control samples compared to the other treated samples. Strong inhibition was observed in sample No. 4. The results indicated that there were no statistically significant differences for *Staphylococcus aureus* among the treated samples; only sample 4 was more resistant. It was observed that the microbial count of all microorganisms examined was lower than that of the control samples.

**Table 7:** Antimicrobial activity of samples, solid diffusion test: total inhibition (clear zone, mm*.

| Bacteria and fungi | | *Control* | water extract concentrations for samples | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Gram-negative | *E. coli* | $0^{D}$ | $8^{B}$ | $9^{A}$ | $9^{A}$ | $10^{A}$ | $11^{A}$ | $11^{A}$ | $11^{A}$ | $9^{A}$ |
| | | $0^{D}$ | $8^{AB}$ | $9^{B}$ | $9^{A}$ | $9^{A}$ | $9^{A}$ | $10^{A}$ | $10^{A}$ | $9^{A}$ |
| Gram-Positive | *S. aureus* | $0^{D}$ | $8^{C}$ | $9^{B}$ | $9^{B}$ | $9^{A}$ | $10^{A}$ | $10^{A}$ | $10^{A}$ | $9^{B}$ |
| | | $0^{D}$ | $8^{C}$ | $9^{C}$ | $9^{B}$ | $9^{A}$ | $9^{A}$ | $9^{A}$ | $9^{A}$ | $9^{B}$ |
| Fungi | *Aspergellus flavus* | $0^{D}$ | 8 | 8 | 8 | 9 | 10 | 10 | 10 | 8 |
| | | $0^{D}$ | 0 | 0 | 0 | 8 | 8 | 9 | 9 | 0 |

* A clear zone or total inhibition indicates that no microorganisms are growing. Complete inhibition is indicated by an inhibition of 90 mm. The average of three distinct observations from three different experiments is the inhibition diameter. Data in the row that are denoted by different letters differ statistically significantly.

According to the current results, in the solid diffusion assay, Gram-negative bacteria and fungi are more resistant to the antibacterial effect than Gram-positive bacteria. This could be because the former peptidoglycan's cell wall was surrounded by an outer lipopolysaccharide [38]. *Origanum marjorana* L. (MIC, 170 µl) demonstrated a potent growth-inhibiting effect against *Aspergillus flavus*, *S. aureus*, and *E. coli*, exhibiting values of 11, 10, 10, 9, 10, and 9 mm, respectively. However, it did not, exhibit strong antimicrobial activity against all of the microorganisms tested when compared to control samples.

## 4. Discussion

Natural dyes are now widely used in the textile industry, with wool, silk, cotton, and other materials being dyed naturally [39]. These dyes are environmentally safe and stable, as they don't irritate human skin. Various plant parts are employed in coloring techniques, and many plants have been provided by nature for us to use in dyeing procedures, promoting healthy living [40]. This study explores the use of recycled tea dust as a coloring for silk fabrics, revealing that tea leaves contain colorants, but dye extraction requires additional effort to achieve the desired color. This research is part of growing movement driven by environmental awareness and concerns about industrial dyes [41].

This study employs eco-friendly natural coloring agents, like pomegranate, curcumin, cutch, red onion peel, and a mixture of red onion peel/curcumin to dye cotton, wool, silk, and nylon fabrics. The dyed are tested for color strength, colorimetric data, and fastness properties. The dyed fabrics exhibit high UV protection and effectiveness against micro-organisms like *Staphylococcus aureus*, *Klebsiella Pneumoniae*, and *Candida albicans*. These dyed fabrics are recommended for use in medical textiles [42,43]. The study also investigated the antimicrobial properties of eleven natural dyes against Gram-negative bacteria, with seven showing activity against one or more species. Kamala, pomegranate, and safflower nut were identified as effective biocides, particularly safflower nut, which reduced *E. coli* and Proteus vulgaris colonies by 99%. Wool fabric dyed with *Rhizoma coptidis* root showed good antibacterial properties, and a color evaluation was conducted [44].

This article investigates the finishing and coloring of natural textiles, including cotton, wool, and silk, using natural functional dye mixtures such as cochineal, madder, and turmeric. It discusses the advantages and disadvantages of different formulations, including improved color fastness, dye absorption, and antibacterial properties. Additionally, it examines the use of chemical and natural additives to enhance dyeing quality. The article concludes that there is significant potential for producing new, environmentally friendly products through the use of natural dyes in the textile industry.

Based on the study, cotton and wool threads treated with turmeric and madder as natural dyes exhibited antibacterial and antifungal activities. A color depth test was conducted on cotton and wool threads, with the highest color yield observed in those dyed with turmeric, followed by those mordanted. In the solid diffusion test, Gram-negative bacteria and fungi showed more resistance to the antibacterial effect compared to Gram-positive bacteria. The minimum inhibitory concentration (MIC) of 170 μM exhibited a strong growth inhibitory effect against *S. aureus*, *E. coli*, and *Aspergillus* at concentrations of 11, 10, 10, 9, 10, and 9 mM, respectively. However, no significant antimicrobial activity was observed against all tested microorganisms compared to the control samples. Thus, the research objective of obtaining high-quality antimicrobial-treated cotton and wool yarns for making children's clothing using crochet techniques was achieved.

## Conclusions

This study successfully demonstrates the potential of natural dyes not only as sustainable alternatives to synthetic dyes but also as functional agents for enhancing the properties of natural threads used in children's apparel. By employing eco-friendly colorants such as turmeric, madder, and other plant-based dyes, cotton and wool threads were effectively functionalized to exhibit desirable antibacterial and antifungal properties. The dyed yarns showed promising results in terms of color strength, UV protection, and microbial resistance, particularly against Gram-positive bacteria. Although the antimicrobial activity varied among microorganisms, the overall findings confirm that natural dyes can be leveraged to produce high-quality, health-conscious, and environmentally sustainable yarns suitable for needlecraft in children's garments. This aligns with the growing trend towards safer, greener textile production and paves the way for further innovations in natural dye applications within the fashion and textile industries. The Further Recommendations are: (1) Use a mordant to enhance color fastness and improve the dyeing process. (2) Experiment with different dye extracts and combinations to create a variety of colors. (3) Analyze results to determine the most effective dye extracts.

## Author Contributions

All authors contributed to this work. Samiha Abu El-Ela and Naglaa El-Sayed prepared the samples, conducted the experimental tests and measurements, and complied the results. Nohair Galal and Naglaa El-Sayed participated in performing the microbial tests, analyzing the results, and validating the data. Manal El-Adawy participated collaborated with Naglaa El-Sayed in conducting the experiments, overseeing product development, and contributing to the writing process. Manal El-Adawy, Samiha Abu El-Ela, and Sahar M. Ali were involved in reviewing the manuscript and overseeing its submission for publication.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References

[1] N. Reddy, S. Han, Y. Zhao, Y. Yang, Antimicrobial activity of cotton fabrics treated with curcumin, J. App. Polym. Sci., 127(6) (2013) 2698-2702.
[2] Y. Gao, R. Cranston. Recent advances in antimicrobial treatments of textiles. Textile Res. J. 78(1) (2008) 60-72.
[3] M. M. Hasan, K. Abu Nayem, AM.A. Azim, Dyeing of cotton and silk fabric with purified natural curcumin dye. Int. J. Sci. Eng. Tech. 3(4) (2014) 838-844.
[4] A. Mohammed, M. Majeed, H. Jasim, Extraction of curcumin pigment and study its efficiency in dyeing of scoured cotton fabric and as antibacterial agent. Iraq j. sci. 53 (2) (2012) 308-315.
[5] A. Gurses, M. Acikilidiz, K. Gnes, M. S. Gurses. Gürses. Dyes and pigments. Springer (2016). 1–25
[6] A. A. Alaskar, & A. G. Hassabo, Recent use of natural animal dyes in various fields, J. Textiles, Col. Polym. Sci. 18 (3) (2021) 191-210.
[7] A. K. Samanta, N. S. Awwad & H. M. Algarni, Review on application of natural dyes on textile fabrics and its revival strategy. Chem. Tech. nat. synth. dyes and pigments 3 (1) (2020) 1-25.
[8] V. K. Gupta, Fundamentals of natural dyes and its application on textile substrates. Chem. Tech. nat. synth. dyes and pigments 2(2) (2019) 22-30

[9] R. Naveed, I. A. Bhatti, S Adeel, A. Ashar, I. Sohail, M. Ul . Haq Khan, N. Masood, M. Iqbal, A. Nazi. Microwave assisted extraction and dyeing of cotton fabric with mixed natural dye from pomegranate rind (*Punica granatum* L.) and turmeric rhizome (*Curcuma longa* L.). J. Nat. Fibers. 19(1) (2022) 248-255.

[10] S. Amutha, N. Sudhapriya. Dyeing of textiles with natural dyes extracted from *Terminalia arjuna* and *Thespesia populnea* fruits. Industrial crops and products, 148 (2020) 112303.

[11] R. Mansour, M. Yusuf. Natural dyes and pigments: Extraction and applications. Handbook of renewable materials for coloration and finishing, 9 (2018) 75-102.

[12] H. Křížová. Natural dyes: their past, present, future and sustainability. Recent Developments in Fibrous Material Science. Prague: Kosmas Publishing, (2015) 59-71.

[13] A. K. Samanta, K.Ashis . Adwaita K. Dyeing of textiles with natural dyes. Natural dyes 3 (2011) 30-56.

[14] S, Iqbal, T. N. Ansari. Extraction and application of natural dyes. Sustainable practices in the textile industry, (2021) 1-40.

[15] S. Saxena, A. M. S. Raja. Natural dyes: sources, chemistry, application and sustainability issues. Roadmap to sustainable textiles and clothing: eco-friendly raw materials, technologies, and processing methods, (2014) 37-80.

[16] R. S. Chakrabarti, A. Vignesh, Natural Dyes: Application, Identification and Standardization. Available online: www.fibre2fasion.com. (accessed 14 March 2023).

[17] N. B, U. D. Extraction and evaluation of dyeing quality of natural curcumin. *J. Innov. Appl. Pharm.Sci. (JIAPS)* (2017) 1-3.

[18] I. A. Bhatti, S. Adeel, M. A. Jamal. M. Safdar, M. Abbas. Influence of gamma radiation on the color strength and fastness properties of fabric using turmeric (*Curcuma longa* L.) as natural dye. Radiat. Phys. Chem., 79 (2010) 622-625.

[19] S. M. Abdel-Hafez, R. M. Hathout, O. A. Sammour. Attempts to enhance the anti-cancer activity of curcumin as a magical oncological agent using transdermal delivery. Adv. Tradit. Med., 21 (2021) 15-29.

[20] R. H. Atalla. The structures of cellulose. MRS Online Proc. Libr., 197 (1990) 89-98.

[21] P. J. Wakelyn, N. R. Bertoniere, A. D. French, D. P. Thibodeaux, B. A. Triplett, M. A. Rousselle, G. R. Gamble, Cotton fiber chemistry and technology. CRC Press, (2006) 176.

[22] T. Lindström, C. Aulin, A. Naderi, M. Ankerfors. Microfibrillated cellulose, in: Encyclopedia of Polymer Science and Technology, (2002) 1-34.

[23] Y. L. Hsieh. Chemical structure and properties of cotton. Cotton: Science. and Technology, (2007) 3-34.

[24] I. Yan, B. Kasal, I. Huang. A review of recent research on the use of cellulosic fibres, their fibre fabric reinforced cementitious, geo-polymer and polymer composites in civil engineering., Compos part B Eng., 92 (2016) 94-132. Available online: Science Direct (accessed 2 Dec. 2023).

[25] P. K. Gupta, S. S. Raghunath, D. V. Prasanna, P. Venkat, V. Shree, C. Chithananthan, K. Geetha. An update on overview of cellulose, its structure and applications. Cellulose, 201 (2019) 84727.

[26] D. D. Fang (Ed.). Cotton Fiber: Physics, Chem. bio. Springer, (2018) 1-11.

[27] F. Allafi, M. S. Hossain, J. Lalung, M.Shaah, A. Salehabadi, M. I.Ahmad, A.Shadi. Advancements in applications of natural wool fiber. J. Nat. Fibers, 19 (2022) 497-512.

[28] P. S. Vankar. Chemistry of natural dyes. Resonance, 5 (2000) 73-80.

[29] U. S. Erdogan, Y. Seki, F. Selli. Wool fibres. In: Handbook of Natural Fibres, Woodhead Publishing, (2020), 257-278.

[30] A. Haji, Dyeing of cotton fabric with natural dyes improved by mordants and plasma treatment. *Prog. Color, Colorants Coat. 12*(3) (2019) 191-201.

[31] F. S. Ghaheh, S. M. Mortazavi, F. Alihosseini, A. Fassihi, A. S. Nateri, D. Abedi, Assessment of antibacterial activity of wool fabrics dyed with natural dyes. J. Clean. Prod., 72 (2014) 139-145.

[32] N. Comlekcioglu, A. Aygan, M. Kutlu, Y. Z. Kocabas, Antimicrobial activities of some natural dyes and dyed wool yarn. *Iran. J. Chem. Chem. Eng. (IJCCE)*, *36*(4) (2017)137-144.

[33] W. Pothitirat, W. Gritsanapan, Quantitative analysis of curcumin, demethoxycurcumin and bisdemethoxycurcumin in the crude curcuminoid extract from Curcuma longa in Thailand by TLC-densitometry. *Mahidol Univ. J. Pharm. Sci.*, *32*(1-2) (2005) 23-30.

[34] M. Menna, A. Ragab, G. Ahmed, B. Hassabo, A. Hanan, A. Othman. An Overview of Natural Dyes Extraction Techniques for Valuable Utilization on Textile Fabrics J. Text. Color. Polym. Sci., 19 (2021) 137-153.

[35] H. E. Emam, S. Mowafi, H. M. Mashaly, M. Rehan. Production of antibacterial colored viscose fibers using in situ prepared spherical Ag nanoparticles. Carbohydr. polym., 110 (2014) 148-155.

[36] J.M. Andrews. Determination of minimum inhibitory concentrations. *J. Antimicrob. Chemother.*, 48 (suppl_1) (2001) 5-16.

[37] R. Metuno, B. Ngameni. A. M. Tsafack, F. Ngandeu, G. W. Fotso, V.P. Beng. Antimicrobial activity of the methanolic extracts and compounds from *Treculia obovoidea* (Moraceae). J. Ethnopharmacol., 112 (2007) 531-536.

[38] O. H. Lee, B. Y. Lee. Antioxidant and antimicrobial activities of individual and combined phenolics in Olea europaea leaf extract, Bioresour. Technol., 101 (2010) 3751-3754.

[39] I. Sanjeeda, A. N. Taiyaba, Natural dyes: Their sources and eco-friendly use as textile materials. *J. Environ. Res. Dev.,8* (3A) (2014). 683.

[40] A. F. Farid, Colour fastness properties of mordants and mordanting methods when dyed with used tea leaves on silk fabric. Int. J. Eng. Sci. Res. Technol.

[41] S. M. Gawish, H. M. Mashaly, H. M Helmy, A. M Ramadan, R. Farouk,.Effect of mordant on UV protection and antimicrobial activity of cotton, wool, silk and nylon fabrics dyed with some natural dyes. *J. Nanomed. Nanotechnol*, *8* (2) (2017).

[42] D. Gupta; S. K. Khare, A. Laha, Antimicrobial properties of natural dyes against Gram- negative bacteria, Color. Technol.,120 (4) (2004)167-171.

[43] G. Ke, W. Yu, W. Xu, Color evaluation of wool fabric dyed with *Rhizoma coptidis* extract, J. Appl. Polym. Sci.101(5) (2006) 3376-3380.

[44] H. M Mashaly, M. M. Eladawy N. M. M. Kamal, N. G. Rashad, Mixtures of natural functional dyes in finishing and coloration of natural fabrics, *Labyrinth: Fayoum J. Sci. and Interdiscip. Stud.*, *2* (2), (2024)35-48.