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Application of Printing and Finishing Cotton Fabrics with Natural Dyes (A Review)

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Abstract

This article is about natural dyes for multifunctional cotton coloration and finishing. Cotton, the king of natural fibers, demands coloring, antimicrobial, and UV protection, without damaging cotton's inherent comfort. Therefore, natural dyeing has become an essential requirement in the coloration and finishing of cotton fabrics because of its natural and environmental properties that do not harm people. Furthermore, most natural dyes also have inherently antimicrobial and UV protection properties. They are made from various microorganisms and plant and marine algae parts that contain pigments like tannin, flavonoids, and quinonoid. Here we review the scientific research on printing, antimicrobial finishing, and UV protection of cotton fabrics using natural dyes.

Key words: cotton fabric, natural dyes; printing; antimicrobial finishing; UV protection.

1. Introduction

Cotton is a low-cost, natural fabric made mainly of cellulose, is essential in the textile industry because of its unique combination of qualities, such as elasticity, softness, strength, permeability, biodegradability, and water affinity [1]. Due to their unique qualities, it is pretty popular among other natural fabrics [2]. Cotton fabrics are often utilized to produce of summer clothing. As a result, cotton has been the subject of the majority of UV-protection research in natural textiles when compared to other types of fabrics, such as silk and wool. The UV protection value of cotton is the lowest [3]. Cotton products are used in various medical and healthcare applications [4] because their porous structure and high moisture absorption provide ideal circumstances for microbe growth, including nutrient sources, temperature, and humidity [5-6]. The rapid expansion of these microbes can be exceedingly hazardous to public health [7]. This contamination is widespread in hospital fabrics, underwear, and athletics, frequently in contact with germs and fungus. Thus, healthcare concerns have sparked an increased interest among researchers in the development of multifunctional cotton fabrics capable of inhibiting the growth of microbes [1].

Natural dyes are colorants derived from natural sources such as plants, marine algae, minerals [8-9], that contain flavonoids, tannin, carotenoids, and quinonoid as coloring ingredients. These dyes can be used not only as a rich and varied supply of dyestuff but also as low-cost treatments and environmentally friendly, with the added benefit of being able to color in one step. Furthermore, the majority of natural dyes contain innate antibacterial characteristics and so may have significant biological activities for cotton fabrics [10], and also Natural dyes can be used to improve the ultraviolet protection of cotton fabrics, making them a viable option for UV protection [11].

Printing is a conventional textile-finishing process that involves the application of dyes to fabric surfaces, and it is a well-known process in the textile industry. Several dyes, as well as various methods, can be used in printing. The most extensively used printing method is screen printing, distinguished by its ease of use, versatility, low cost, and ability to print on virtually any material [12]. However, the synthetic dyes used in the printing process and their

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auxiliaries, may be poisonous and have adverse effects on humans and the environment [13].

In this review, an attempt has been made to give the latest scientific overview of applying natural dyes as effective coloring in printing cotton fabrics and as antibacterial agents, and UV absorbers fabrics.

1. Chemical structure of cotton

Cotton fibers are the finest cellulose source available and the most abundant polymer in nature. Cotton is a linear cellulose polymer, and cellobiose is the repeating unit (Figure 1), consisting of two glucose units [14, 15]. Cotton fabric has become one of the most widely used textile materials because of its wear comfort, hygroscopicity, breathability and softness [16].

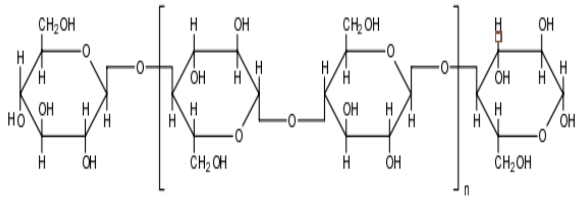


Fig. 1. Chemical structure of cotton

2. Natural dyes

The coloration of textiles can be summarized as simply as applying colorants in the solution medium to the textiles. Typically, the coloring process includes several procedures such as dying, pigmentation, and printing [17]. Synthetic dyes and natural dyes are the two types of dyes. Natural dyes have been used to color fabrics since prehistoric times [18]. Natural ingredients derived from natural sources are natural dyes, such as minerals, vegetables, and animals. Vegetables come in a variety of colors; as a result, they are commonly employed. More than 500 colorants are derived from plant sources such as leaves, trunk, roots, bark, or fruit of plants [19]. Natural dyes have been utilized for various purposes over the centuries, including body painting, decorative art, clothing, and home decoration [20].

Algae are a rich source of photosynthetic pigments such as chlorophylls, carotenoids, phycobilins, phycocyanin, and phycoerythrin, found in fresh and saline water [21-23], and utilized in a variety of applications, including cosmetics, medicines, and food coloring [24]. They provide color pigments and dyes for many purposes, such as cosmetic products, pharmaceutical products, paints, etc. [25], and the textile industry for printing and dying, as the anti-microbial and antioxidant effects of these pigments are diverse. In addition, these may be utilized to manufacture medical textiles for usage in hospitals due to the antibacterial qualities of the pigments [26]. Almost all synthetic dyes are made from petrochemical sources and are produced using dangerous chemical processes, posing a threat to the environment and human health, especially when produced in higher than usual concentrations that reduce the quality of our environment. Although academics have long argued that there is a symbiotic relationship between countries' environmental policies and the degree to which companies pollute, global concern about pollution has resulted in stricter regulations for high-polluting industries [27-41]. Textile industries use many synthetic dyes, such as reactive dyes, for various types of fabric dyeing, particularly cotton fabric. It demands a considerable amount of water, resulting in a large volume of effluent, which pollutes the environment. Synthetic dyes have been discovered to have dangerous properties in numerous circumstances. Therefore, it is critical to consider synthetic dye alternatives that are safe for the environment and human health. Natural dyes, in this case, could be a viable option for the textile industry [42].

2.1. The advantages of natural dyes are:

- Production of soft and lustrous colors
- Production of rare colors
- Extraction from renewable sources
- Nonhazardous nature
- Biodegradable
- Ease of disposal
- Lack of environmental threat
- Reduced carbon emissions
- Apart from coloration, they have other potential applications, as shown in figure (2) [43, 44].

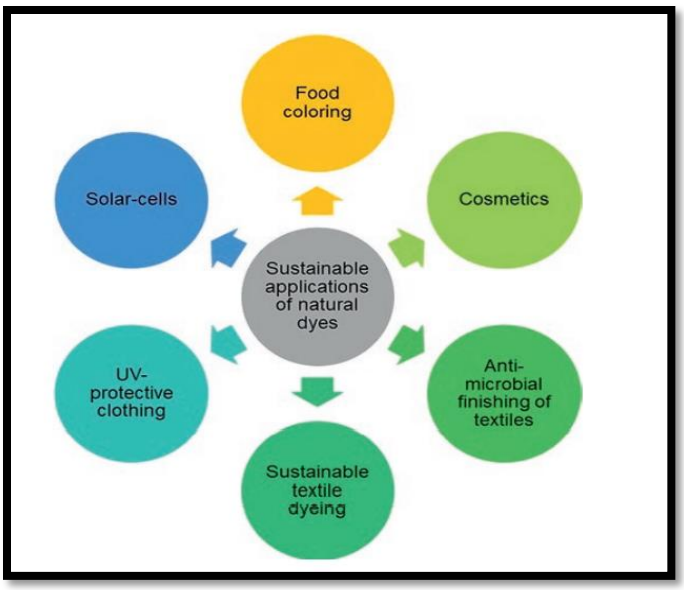


Fig.2. Important sustainable application of natural dyes (i.e., without the addition of any chemicals).

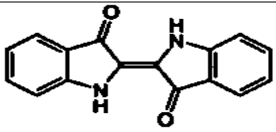
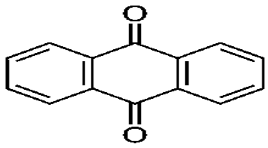
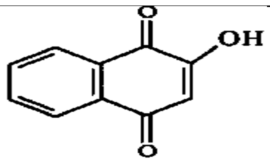
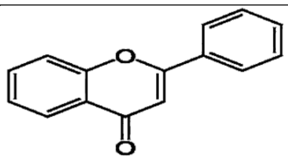
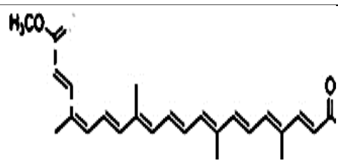
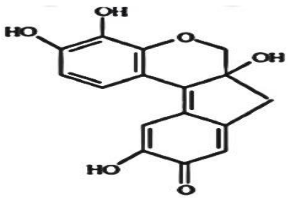
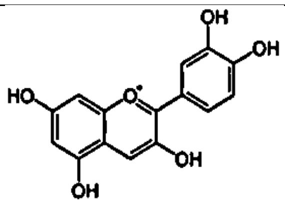
2.2. The disadvantages of natural dyes are:

- Less availability
- Colors and hues are less repeatable.
- Mordants are required (with the majority of natural dyes)
- If synthetic mordants are applied, heavy metals may be present

2.3. Classification of natural dyes

Natural dyes are classified using their chemical structure, which is the most appropriate and widely accepted approach. It quickly differentiates colors that belong to the same chemical group but has different properties [45-46], as shown in Table (1).

Table 1. The chemical structure of natural dyes.

class	structure	Natural day source and colors
Indigoid		Indigo (blue), Tyrian (purple), Woad (blue)
Anthraquinone class		Kermes Purple and red), Madder Brown (orange, and red) Cochineal (Red), Lac (Brown, red), Kermes (Purple and red), Manjit (Brown, red)
Alpha naphthoquinone		Henna (Brown, yellow), Juglone (Brown)
Flavonoids		Weld (Orange and Yellow)
Carotenoids		Bixin (yellow), crocin (yellow to orange)
Di-Hydropyrans		Brazilwood (Black), Sappanwood (Black)
Anthocyanidins		Awobanin (Blue), Carajurin (Orange)

2.4. Extraction of natural dyes:

Extraction of dyes/antimicrobials from natural sources may be one of the essential processes in treating cotton fabrics to achieve desired dyeing qualities and/or antimicrobial activities [10]. One of the most significant unit operations in industries is extraction. Extraction is the typical process for separating active components and pigments of plants using selected solvents. Any extraction separates the plant's soluble metabolites from the insoluble residue. Natural dyes are found in minimal amounts in natural goods. To remove dye from its source, they need a specialized process. There are some methods for extracting natural dyes from their source materials that are suitable for the different types of natural dyes. Many factors influence the extraction efficiency of active agents and colorant components found in natural plant/animal/mineral sources [47-48], including:

- The kind of media (aqueous/ organic solvent or acids/ alkali) and pH of the media.
- Extraction conditions, such as time, temperature, substrate particle size.
- Material-to-liquor ratio.
- Some physiological elements, such as shaking and ultrasound use.

2.4.1 Extraction methods:

a. Aqueous extraction:

The dye-containing compounds are employed in this process to extract active components from plants. The plant is first dried and ground into small pieces or powder and sieved for better extraction. Then it's soaked in water and brought to a boil, producing a solution that's filtered to eliminate any remaining plant matter [49]. To eliminate fine contaminants, trickling filters are sometimes utilized. One of the drawbacks of this method is that some of the dye decomposes during the boiling process. As a result, only colors that do not break-down at boiling temperatures are acceptable for this procedure [50].

b. Acid and alkali extraction:

The majority of natural colors are glycosides, which can be extracted in either acidic or alkaline circumstances. Alkaline solutions are appropriate for dyes with phenolic groups in their structure [51].

c. Solvent extraction:

Natural coloring substances, depending on their nature, are usually extracted using organic solvents such as petroleum ether, acetone, chloroform, methanol, ethanol, or a mixture of solvents such as a mixture of ethanol and methanol, a mixture of water and alcohol, and so. Water-soluble and water-insoluble compounds can be extracted from plant resources using the water/alcohol extraction method. As a result, the extraction yield is higher than with the aqueous approach because more chemicals and coloring ingredients can be extracted. Alcoholic solvents can also be mixed with acid or alkali to aid in the hydrolysis of glycosides and the release of coloring pigment. Purification of extracted color is simplified because solvents can be easily removed and reused by distillation. Because extraction takes place at a lower temperature, there is a decreased risk of deterioration. However, the existence of poisonous residuals in some solvents and their greenhouse effect are drawbacks of this method [50].

d. Enzymatic Extraction:

Because plant tissues contain cellulose, starches, and pectin’s as binding molecules, a few researchers have used inexpensive enzymes like cellulase, amylase, and pectinase to break down the surrounding material, allowing for the extraction of colorant particles in a cost-effective manner. This method could effectively extract colorants from hard plant materials like bark, roots, and so on [52].

2.4.2. Extraction techniques:

Below are some of the different extraction processes that can be applied:

a. Ultrasound-assisted extraction:

Ultrasound-assisted extraction is a technique that extracts target compounds from various plant matrices using sonic energy and solvents. The propagation of ultrasound pressure waves and resulting cavitation phenomena, whereby the collapse of cavitation bubbles breaks cell walls and releases the cell's contents into the extraction medium, is the generally accepted explanation for solvent extraction enhancement by ultrasound [53]. In addition, some reactions become faster with lower temperatures when subjected to ultrasonic energy, which is the most favorable result since it decreases processing time and energy consumption while improving product quality in the coloration of textiles [49].

b. Supercritical fluid extraction:

Today, any new product or procedure must ensure the safety of both producers and consumers. Accordingly, the natural extract industries' expansion has been limited by stringent laws on the use of dangerous, carcinogenic, or poisonous solvents and high energy costs for solvent regeneration. Supercritical fluid extraction techniques are key technologies that have emerged in the last two decades as an alternative to traditional solvent extraction of natural materials. It makes use of CO_2, which is a clean, safe, low-cost, non-flammable, non-toxic, environmentally friendly, and non-polluting solvent. As a result, supercritical fluid extraction technology gains attraction as a viable alternative to traditional extracting natural compounds. The improved separation technology of supercritical fluid extraction is based on the enhanced solvating power of gases above their critical point. CO_2 is an excellent solvent in the food, dye, pharmaceutical, and cosmetic sectors, where high purity final products are required [51].

c. Soxhlet extraction technique:
The Soxhlet extraction process was invented before the turn of the twentieth century; this is one of the most widely used extraction procedures today. This technology has been enhanced to reduce the waste formation and increase the extraction methodology's eco-efficiency. In this method, a specific piece of glassware is placed between a condenser and a flask. The plant is repeatedly washed in the flask by the refluxing solvent, extracting the active chemicals into the flask. [54]

2.5. Characterization of natural dyes:

A standardized dyeing procedure is required for successful commercial usage of natural dyes, for which natural dye characterization is critical. The wavelength of maximum absorption and dominant hue of a color can be determined using UV-visible spectroscopy. UV-characterization is used to determine the ability of dye molecules to absorb UV wavelengths and the fading characteristics of dyes. The wavelength of maximum absorption for a specific dye is determined by the chemical composition of the dye molecules, which is variable and dependent on the natural dye's growing environment [46].

2.6. Fastness properties of natural dyes

Fastness qualities are one of the quality parameters in dyeing or printing. To determine colorfastness, several test procedures are described such as washing, rubbing, and lightfastness. The fastness qualities of natural dyes are highly influenced by the fabric type and mordant employed for dyestuff fixing. Natural dyes have a weak to medium washing fastness. Most natural dyes have a moderate to good rubbing fastness. Natural dyes have a weak to moderate lightfastness. The dye structure undergoes chromophoric changes following light absorption, resulting in poor lightfastness. [55].

2.7. Fixation of natural dyes

In water, cellulosic materials acquire a negative charge; this results in a repellent interaction with the dye molecules; cellulosic fibers do not have a high affinity for most natural dyes, so they must go through a mordanting process [56]. Mordants, commonly known as dye fixatives, helps to make a bond between a natural dye and a fabric, resulting in better fastness properties [57-59]. Metallic salts such as sulfates (aluminum, magnesium, zinc, copper, nickel, cobalt, manganese, or tin), chlorides (ferric, stannic, copper, aluminum, zinc, and even neodymium or zirconium), hydroxides (calcium), and oxides (ferric or lanthanum) can be used to make mordants [60]. Alum and iron are environmentally safe metal mordants used in natural dyes that have not been limited by environmental regulations [61]. On the other hand, chrome-based mordants and copper are examples of harmful mordants. Because of environmental concerns, it is vital to utilize environmentally friendly coloring procedures [19].

During the dyeing or printing process with natural dyes and mordants, some amounts of the dye and mordant may be unexhausted and discharged into the environment resulting in major environmental and health risks [62]; as a result, the use of bio-mordants could be a viable alternative to the use of hazardous metallic mordants. Therefore, numerous researchers are due to their potential for long-term use [63, 64]. The most common non-metallic bio-mordants are citric acid (CA) or 1, 2,3,4 butane tetracarboxylic acid (BTCA).

Certain polycarboxylic acids (PCAs), mainly citric acid (CA) or 1,2,3,4 butane tetracarboxylic acid (BTCA) (Figure 3), have shown the most promise as formaldehyde-releasing crosslinking agent alternatives when combined with phosphorus-containing catalyst [65].

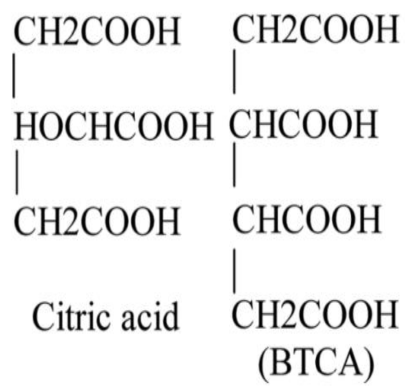


Fig. 3. Structures of citric acid and butane tetracarboxylic acid

The citric acid ($C_6H_8O_7$) is a weak tricarboxylic acid found in citrus fruits, such as lemons, oranges, tomatoes, beets, etc. [66]. According to their research, the crosslinking mechanism of polycarboxylic acid and cellulose is that the two neighboring carboxyl groups produce a five-membered cyclic anhydride intermediate. The ester bond is subsequently formed by reacting with the hydroxyl group on the cellulose chain [67-68].

Among the several polycarboxylic acids, 1,2,3,4-butane tetracarboxylic acid (BTCA) is the most efficient cross-linking agent [69]. However, the extremely high cost of BTCA's has limited its application [70]. For cotton fabrics, citric acid (CA) is a low-cost, environmentally friendly finishing chemical [71].

2.7.1. Mordanting Methods:

Based on the time of application, there are three types of mordant application methods. They are pre-mordanting, post-mordanting, and meta-mordanting or simultaneous mordanting [72].

a. Pre-mordanting: The fabric is initially immersed in the mordant solution for 30 to 60 minutes at room temperature or higher temperature with a liquor ratio of 1:5 to 1:20 in this method [73]. Cotton and cellulosic are the most commonly used fabrics for this process. Standing baths can be used for mordanting, which is an advantage of this technique; after replenishing the mordants, the bath can be utilized multiple times. This makes the process more cost-effective while lowering pollution levels, suitable for large-scale applications [50].
b. Post-mordanting: After dyeing or printing, the fabric is treated with mordant in a separate bath in the post-mordanting procedure. The final color is created during the last stages [72].
c. Meta-mordanting or simultaneous mordanting: In this method, both printing and mordanting procedures are carried out in the same bath. Usually, mordant is also added to the printing past [50].

2.8. Printing of cotton fabrics with natural dyes:

Printing, like dyeing, is a method of transferring color to the fabric surface. However, as compared to the dyeing process, which colors the entire substrate (yarn, fabric, garment, or carpet), only certain areas of the printing are colored, it's essentially a-localized-application-of-colorants-on-substrates-to-obtain-the-desired-pattern [74-75].

To apply dyes to fabrics, a variety of printing procedures are available; one of the most famous of these methods is the direct style [76, 77], where the dyes are applied in the form of a print paste containing thickeners and auxiliaries and then transferred on the fabric surface using a variety of techniques (screen, block, stencil,…etc.) [78]. The most commonly used process for textile prints in the textile industry is screen printing and it accounts for roughly half of all printing production on the world a traditional textile-finishing method in which dyes or pigments are applied on the fabric surface [79].

Flat-screen printing involves laying a screen onto a piece of fabric that has been coated with the print paste. The print paste is forced through the screen and into the fabric by a squeezer moving across it [80]. The fabrics then move on to the stage of fixing. Printed fabrics are generally washed after the fixation process, and unfixed dyestuffs are removed [78]. A viscous liquid containing dyes and other required ingredients is known as a printing paste. Thickeners play a crucial role in the formulation of printing paste because they control the consistency of the paste and guarantee that it flows evenly during the printing process. Successful printing relies on the right color, design definition, evenness, and softness, all of which are influenced by the thickener used [81]. Many traditional natural thickeners can now be utilized in textile printing processes [82] such as algae, plants, seeds, and microorganisms [81, 83]. Polysaccharides are the most often utilized natural polymers as thickeners in printing [84, 85]. Guar gum, alginate, plant gums, Arabic gum, jhinguh gum, tragacanth gum (tragacanth), goat horn gum, and so on are examples of polysaccharide and plant seed sources [43].

Although, ecological awareness among the public has led to a renewed investigation of natural dyes, there is limited research on printing using natural dyes on cotton fabrics.They have certain advantages over synthetic dyes such as non-toxicity, medicinal properties (e.g., antibacterial activity), UV protective effects, biodegradability,…etc. [43]. This necessitates the use of natural resources for textile printing, which will reduce effluent. An unlimited number of natural resources may add natural color pigments to textiles to improve their practical and aesthetic features. Development of shades and fixation of natural dyes on natural fibers like cotton depends on the use of mordants. Mordants provide specific colors and improved wash and light fastness [78]. Few studies that investigated printing cotton fabrics with natural dyes; some of these studies are listed in (Table 2).

Table 2. Studies of printing cotton fabrics with natural dyes

Natural dye	Mordanting	Fixation	Type of thickener	References
Marigold	Aluminum sulfate, copper sulfate,	steam-fixed at 100 °C for 45 minutes	Guar gum	[86]
Neem tree (Azadirachta indica)	copper sulfate	Steaming for 90 minutes	sodium alginate	[87]
(alkanet) dye	tannic acid	steaming for 30 min at temperature of 120° C	Meypro gum	[88]
Pseudoacacia (Acacia catechu Willd)	Aluminum potassium sulfate dodecahydrate	superheated steam at 100 °C for 10 min	sodium alginate	[89]
annatto plant	alum	thermosetting was done at 150 °C for 4 minutes	annatto printing paste	[90]
turmeric, and (marigold)	Chitosan, alum , Copper sulphate	steamed at 102∘C for 10 mins	Guar gum	[91]
kachnar bark dye	Copper sulphate and ferrous	steaming at 100^{o}C for 30 minutes	Cassia tora gum guar gum	[92]
Nanoparticles of pomegranate peel dye	Alum and tannic acid	steaming at 115˚C for 20 min	synthetic thickening agent, namely Printofix thickener MTB 01 EG liq.	[93]
Nanoparticles of Curcuma	Alum, and tannic Acid	steaming at 115˚C for 20 min	synthetic thickening agent, namely Printofix thickener MTB 01 EG liq.	[94]
Propolis	Without mordant	Thermo fixation at 150 °C for 4 min	Synthetic thickener,	[95]
Melia Azedarach	tannic Acid	steaming at 120 °C for 30 min	Carboxyl Methyl Tamarind 8 (CMT)	[96]
alkanet dye nanoparticles	tartaric acid	steaming at 115 for 15 min	carboxymethyl cellulose (CMC)	[97]
Gallotannin	Without mordant	hot-pressed at 160 °C for 30 s	Hanisol 130 N, acrylic copolymer	[98]

3. Textile Finishes

As a broad range of value-added qualities that could be achieved through finishing processes, functionality has become a new driver of competition in the textile market. [99] Anti-microbial fabrics, anti-mite textiles, stain-resistant treatments, flame retardants and UV-protective fabrics are all examples of performance garment technology.

3.1. Antibacterial finishing

Antimicrobials have been employed since ancient Egypt used to manufacture mummies. Lister invented the first antibacterial textile substance in modern history in 1867. The antimicrobial finishing of cotton fabrics has been increasingly popular in recent years [100].

Microbes are the tiniest organisms that are invisible to the naked eye. Microorganisms such as bacteria, fungus, and viruses are among them. Some bacteria are pathogenic, which means they can cause cross-infection. Fungi, molds, and mildew are complicated organisms that grow slowly. As a result, they stain the fabric and impair its performance. In touch with the human body, cotton textiles provide excellent habitat for microbial growth [101-102].

Many materials-based textiles utilized in hospitals or hotels are conductive to cross-infection or illness transmission caused by microorganisms. Fabrics for hygienic or medicinal use are essential in the textile industry. In general, antimicrobial properties can be imparted to textile materials by chemical procedures or by physically integrating functional agents into fabrics in addition to the use of nanomaterials in textile finishing [103-104].

Cotton products are used in a variety of medical and healthcare applications. [4]. Because of its porous structure and high moisture absorption, provide ideal circumstances for microbe growth, including nutrient sources, temperature, and humidity. [5-6]. However, the rapid expansion of these microbes can be exceedingly hazardous to public health [7], this contamination is widespread in hospital fabrics, underwear, and athletics, which are frequently in contact with germs and fungus. Thus, healthcare concerns have sparked an increased interest among researchers in the development of multifunctional fabrics capable of inhibiting the growth of microbes [1].

3.1.1. Action of antibacterial agents

The selection of an antimicrobial agent is always based on its intended use, needs, and mode of antimicrobial action [105]. Biocidal and biostatic finishes are the two basic types of antimicrobial finishes. Biocidal textiles can kill bacteria, while biostatic textiles can inhibit microbes [106], generally, they act in two ways as follows:

3.1.1a. Bound type antimicrobial agents

This type of molecule can form chemical bonds with the fabric's surface and they only have an effect on microorganisms on the fabric's surface, not on the environment. Because of their adhesion to the fiber, these bound antimicrobials may be abraded or weakened, reducing their long-term fastness properties [107].

3.1.1b. Controlled-release mechanism

This group of antibacterial compounds does not develop a strong fixation with the textile substrate. The biocidal chemical species that are responsible for the fabric's biocidal activity are slowly released from the treated surface; As a result, all microorganisms in the near area of the agent are killed. The enhanced antibacterial activity of leaching antimicrobials over compounds based on other modes of action on the same fabric under similar environmental circumstances is one of its advantages [108-109].

Because they are not chemically linked to the textile surface and because the reservoir of agent to be given is limited, the active agent concentration eventually decreases, it eventually reaches its limit of effectiveness, causing bacteria to develop resistance to these compounds. Furthermore, releasing the agent might cause major health concerns, and the antimicrobial may interact with the microbiota that lives on the skin; this can result in rashes, skin irritations, allergies, and harmful bacteria outgrowing. Finally, controlled-release antimicrobials do not usually endure many washing cycles. Furthermore, their release into the water can harm beneficial microbes needed for effective waste-water treatment [105].

Antimicrobial compounds have a wide range of ways of controlling microbial growth, depending on the type of agent utilized. Antimicrobial agents, in general, stop cells from reproducing, damage cell walls or permeability, denature proteins, block enzymes, and make cell survival difficult [107-109].

3.1.2. Requirements of antimicrobial finish on textiles

In order to get the most out of antimicrobial-functionalized textile products, ideal antimicrobial finishing must meet some criteria. A hygienic antimicrobial treated material must meet the following requirements [110].

- Efficient inhibition of a wide range of bacterial and fungal species.
- Non-toxic to the consumer, the manufacturer, or the environment.
- Compatibility with the resident skin bacteria, as well as other finishing processes.
- Suitability without damaging the textile's quality or appearance.
- The antibacterial finish should be simple to apply and inexpensive.
- Durability of activity to dry cleaning and laundering [111].

4. Natural bioactive compounds

Antibacterial finishing agents, which include inorganic, organic, and natural antibacterial agents, play a critical role in the production of antibacterial textile surfaces [5]. These chemicals range from manufactured chemicals such as metals and metal salts (Silver, Zinc, Copper), cationizing agents (quaternary ammonium salts), amines (biguanides and glucoprotamine), triclosan, oxidizing agents (halogens, aldehydes, and peroxy compounds), naturally derived antimicrobials, such as seaweeds derivatives, and essential oils (Rosemary, Lavender, Pomegranate, Prickly Chaff Flower, Aloe Vera , Clove, Turmeric,…etc.) [100]. A wide range of organic agents, including quaternary ammonium compounds (QACs), N-halamine, and triclosan, are used to provide antibacterial properties. Although N-halamine and triclosan have great antibacterial activity, they are extremely toxic and have harmful effects on the human body [112].

Antibacterial properties of natural bioactive compounds have sparked a lot of interest in the scientific community as an appealing environmentally acceptable alternative to synthetic antibacterial agents for textile applications, especially in medical and health care fabrics, since they are skin-friendly, non-toxic, and safe [113-115].

The investigated natural product-based antimicrobial agents for textile finishing are phenols, polyphenols, quinones, flavonoids, tannins, coumarins, and terpenoids, abundant in natural dyes [116].

4.1. Natural dyes as natural antimicrobial finishing agents for cotton fabrics

Few studies investigated the potential of natural dyes as antimicrobial finishing agents for cotton fabrics by using the dying method (Table 3). But for the printing of cotton fabrics with natural dyes, the study of the antimicrobial activity is very limited, such as the study of printing cotton fabric with *Propolis* [94] and *Melia Azedarach* [95], as mentioned in table (2).

Table 3. Studies of finishing cotton fabrics with natural dyes.

Natural dye	Microbial pathogen	mordanting	Reference
Neem leaves, turmeric, tea leaves, pomegranate rind, and myrobalan (harda)	*S.aureus* and *E.coli*	Without mordant	[117]
Curcumin	*E. coli* and *S. aureus*	Without mordant	[118]
Acacia eburnea (L. F.) Willd	*E. coli* and *S. aureus*	ferrous sulphate	[119]
Quercus infectoria (QI) plant	*B.subtilis* and *E. coli*	Alum , copper and ferrous sulphate as	[120]
onion skin	*S. aureus*	Without mordant	[121]
waste peel of banana fruits	*S. aureus, S. pyogenes, E. aerogenes, K. pneumoniae, E. coli, M. catarrhalis,* and *c. albicanis*	ferric sulfate	[122]
barberry root and red onion skin (Alliumcepa L)	*Staphylococcus aureus*	Tannic acid	[123]
Punica Granatum	*S. Aureus* and *E. coli*	alum and copper sulfate	[124]
Green tea	*S. aureus* and *E. coli*	citric acid	[125]
Melia composita leaves	*S. aureus, S. epidermidis ,B. cereus, E. coli, K. pneumonia, S. flexneri, P. Vulgaris*	Without mordant	[126]
pomegranate, curcumin, cutch, red onion peel	*S. aureus, K.Pneumoniae* and *C. Albicans*	ferrous sulfate	[127]
catechu natural	*S. aureus, E. coli*	Without mordant	[128]
Hibiscus sabdariffa L.	*S. aureus , E. coli, P. aeruginosa*	pine cone was used. Tannic acid	[129]
Hematoxylin	*S. aureus B. subtilis E. coli P. aeruginosa C. albicans*	aloe vera and gelatin	[130]

4.2. Evaluation of the antimicrobial activity of treated textile materials:

Antimicrobial testing is typically done using two methods. The first approach uses agar zone inhibition, immersing treated material in an agar culture medium with inoculated microorganisms (fungi or bacteria). It is standardized by EN ISO 20645/2004, which established a method for assessing the effect of antimicrobial treatments applied to woven and knitted textiles, and ISO/DIS 20645. The ISO 11721 standard specifies a burial test. The antibacterial effect is described as a bacterial growth inhibition under favorable conditions. The second approach is based on bacteria number testing and involves determining the fungistatic / bacteriostatic activity of sterilized and inoculation treated material by counting the colonies of bacteria and fungus [131].

4.2.1. Ultraviolet (UV) protection

UV light is electromagnetic radiation with a shorter wavelength than visible light but a greater wavelength than X-rays. The sun emits ultraviolet (UV) radiation, which is a type of radiant energy [132]. Because the ozone barrier is decreased, more UV light reaches the ground [133]. Ultraviolet radiation makes up around 6% of the sun's total energy (UVR) [134]. Wavelength is used to classify different types of energy or radiation. The more intense the radiation is, the shorter the wavelength. [132]. UVR is separated into three major ranges: 320–400 nm, 290–320 nm, and 200–290 nm, UVA, UVB, and UVC [135]. Sunlight contains 95 % UVA and 5% UVB, which may contact human skin [136]. The ozone layer absorbs UV-C light, but UV-A and UV-B radiation reached the earth's surface resulting in major health issues like skin cancer, photo-aging and sunburn. The market's increased demand for lightweight clothes that provide UVR protection while encouraging comfort, significant emphasis has recently been paid to the ultraviolet transmission of textiles [137-138]. As a result, ultraviolet protection finishes are one of the most common chemical finishing agents used on textiles, to protect humans and textiles from the harmful effects of UV radiation [139].

The fiber content determines the ultraviolet protection qualities of textiles, dyes used, weave, finishing methods, and should be between 40 and 50+ to be classified as UV-protective clothing materials [140]. In most cases, a textile material is regarded to provide adequate UV protection if it transmits less than 6% of total incident UVR, a value of less than 2.5 percent, on the other hand, is regarded to be excellent [141]. Therefore, ultraviolet protective clothing should be utilized to limit UV irradiation and potential harm [142], and should be used in any circumstance when UV exposure is expected: outdoor workers, teenagers, sportsmen, people who work with advertising lamps, sterilization equipment, hardening plastics, medical care [143].

Cotton fibers are commonly used in the textile industry because of their great hygroscopicity, biodegradability, air permeability, lack of static electricity, etc. It's an extensive natural fiber made up almost entirely of cellulose. (about 88–96%). Cotton has a global market share of 48 % of total fiber consumption [144]. Because of their hypoallergenic features, cotton fabrics are often utilized in the production of summer clothing. As a result, cotton has been the subject of most UV-protection research in natural textiles compared to other types of fabrics, such as silk and wool. However, UV protection value of cotton is the lowest [3].

4.2.2. The Ultraviolet protection factor (UPF):

The UV protection factor (UPF) measures UV radiations (UVB & UVA) that are blocked by the textiles. UV rays are filtered more effectively with a higher UPF number [145]. UPF is a global standard for encoding a material's protective ability based on instrumental measurements in the textile and garment industries. As indicated in table (5), it is defined in the Australian/New Zealand standard AS/NZS 4399:1996 [146].

Table 5. Fabric protection categories based on ASTMD6603 and AS/NZS standards [145].

UPF range	Effective UVR transmittance (%)	Protection category
40–50, 50+	≤2.5	Excellent
25–39	4.1–2.6	Very good
15–24	6.7–4.2	Good

4.2.3. Mechanism of UV protection

UVR transmitted by textile materials determines the sun protection effectiveness. When UVR reaches fabrics, part of it is transmitted (Figure 4), some is scattered, and some is absorbed and changed into various forms of energy by the material [138]. A fabric's UPF is determined by various factors, including the fiber type, Dyes, UV absorbents, thickness and weight, clothing design and more [140]. Inorganic and Organic are the two primary types of UV protection agents, depending on their chemical composition. UV protection finishes' primary function is to absorb dangerous UV radiation and transform the energy of excited electrons into safe heat energy. This UV protection technique is applicable to organic substances that can collect UV energy and convert it into kinetic and thermal energy without photo degradation [146]. UV absorbers are the common name for these agents because they are generally used to prevent photo aging and photo-oxidation process in textile fibers, potentializing additives is a term used to describe these substances [149].

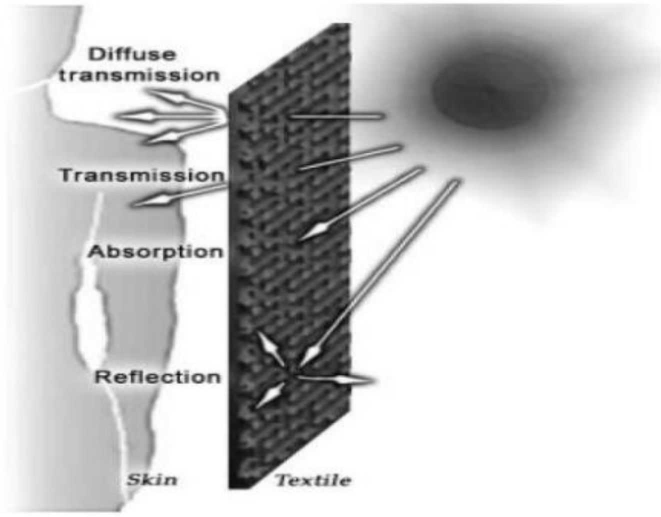


Figure (4). UV-transmittance characteristics of a textile material.

Cotton fabrics (woven or knitted) that have not been colored or treated have a high UV transmission and so provide little protection. This protection is dependent on the type of fabrics, dye types and concentration. Light hues, generally, reflect solar radiation better than dark colors, allowing incoming radiation to pass through the cloth and be reflected (scattering). The darker the shade, the greater the cloth UPF might be obtained with the same fabric composition and dyestuff. Black, navy blues, dark greens, and other dark colors, substantially enhance the fabric UPF. On the other hand, light pastel colors, only make a minor difference. Due to different transmission and absorption qualities, the level of UV protection provided by different hue dyes might vary significantly [150]. Natural dyes can improve the ultraviolet protection of cotton fabrics, making them a viable option for UV protection [11]. Many studies have proven that dyeing cotton fabrics with natural dyes effectively protect against ultraviolet rays. Such as *Barberry root and Red onion skin* [122], *pomegranate*, *curcumin* and *cutch* [126]. *Banana peel*. [124]. But for the printing of cotton fabrics with natural dyes, the study of the protective effect against ultraviolet is minimal, as we found only two studies, such as the use of *Arecanut Slurry* [151] and *Melia Azedarach* [95] in printing cotton fabrics

Conclusion

This review is a brief information about using natural dyes as multifunctional coloring and finishing agents for cotton fabrics. Their extraction fixation methods, printing on cotton fabrics in addition to antimicrobial and UV protection finishing are also covered. As people become more aware of the high-risk impact of synthetic dyes used in the textile industry, natural extracts as colorants or finishing agents are becoming more popular. Cotton fabrics are very popular among other natural materials because of their unique qualities. Due to the elasticity, softness, strength, permeability, bio-degradability, and water affinity of cotton; It is one of the most commonly used materials in the production of summer clothing and medical fabrics that require coloration, antimicrobial and ultraviolet protection finishes. In addition, most natural dyes have antibacterial and UV protection finishing characteristics and may have significant medicinal activity. However, there are several disadvantages to using natural dyes. The papers published in this field show that the time-consuming extraction methods and fastness properties are the main problems in printing and finishing processes. One of the problems regarding the environmental impact of natural dyes is the use of metallic mordants for enhanced fastness properties. As a result, biomordants could be a viable alternative to hazardous metallic mordants.

Conflicts of Interset

The authors dechare no conflict of interst.

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