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Review Article

A review on Antibacterial Coloration Agent's Activity, Implementation & Efficiency to Ensure the Ecofriendly & Green Textiles

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Abstract
Recently antibacterial colorants are most important research topic to the researchers. With high biodegradability, low toxicity, green chemistry and having potential application they exhibit a great impact on the textile dyeing and finishing industry. Natural colorants from plant sources either extraction or synthesis have been recently revealed as novel agents in imparting multifunctional properties to textiles such as antimicrobial, insect repellent, deodorizing, even UV protection. Many colorants, whether natural or synthetic, possess some inherent functions in addition to their coloring attribution. These properties can be utilized in textile dyeing processes to bring the particular functions to textiles in various textile industries. In other words, dyeing textiles with these colorants can combine dyeing with having a functionality finishes, a greener process than current separated wet treatments in terms of reduced generation of waste water and consumption of energy. Recently there has been a revival of interest in the use of natural dyes in textile coloration. This is a result of the stringent environmental standards imposed by many countries in response to the toxic and allergic reactions associated with the use of synthetic dyes. The aim of this review compilation is to give an overview on the main compounds used today for coloration of textile materials seeking for as antibacterial functionalization based on an evaluation of scientific publications, potential perspective of microbes on the environment and human health were considered.

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1. Introduction

Study of coloration technics for numerous functionalize purpose is opening new arena of development to impart color to textiles and other substances which should perform a definite pattern at its applicable moment. Besides reviving the thousands of year's knowledge, antibacterial coloration in Textiles is very much potential & inventive concept. Having the antimicrobial properties, the natural colorants extracted from plants have been widely used both as herbal medicine and dyes for at least 4000 years. For example, black kohl or green malachite were used as cosmetics at the same time to cure or prevent eye diseases as well where Henna (Lawsonia inermis L.) was found to be used for tattoo or hair dyeing and was also used medicinally as an astringent and to cure diarrhea and open wounds.[1, 2] As protective clothing the use of antimicrobial dyes on textiles were found first in 1941 for military purposes. Textile materials from natural fibers are very much amiable to be affected by microbial infections in the warm and humid weather of tropical islands which resulting in certain materials to rapid decomposition.[3] With the increasing advancement in functional textiles along with concerns about outbreaks of various diseases, antimicrobial dyes have attracted more attention in the recent years.[4]

There are a significant number of dyes are obtainable till to date which could be easily applied on textiles alongside these have antibacterial property.[5] These types of dyes could be from natural, synthetic or even from Nano synthesis like silver nanoparticle synthesis along with Sodium alginate or Chitosan. Application of Biosynthesized colorants for both foodstuffs and textiles are receiving increased interests and got substantial popularity in the past decade.[6, 7] Dyes and pigments formulated via fermentation processes which defined as biosynthesized dyes and pigments can serve as major chromophores for further chemical modifications to provide colorants with a broad spectrum of colors.[8, 9] Likewise Anthraquinone type compounds rather than a natural colorants can exhibit outstanding antibacterial activity besides providing bright colors serving as a functional dyes in producing colored antimicrobial textiles.[10] Beside the medicated use with a view to distinguish the detrimental effects on humans and environment the research has been progressed. For example [11] has investigated the toxicity effect of fungal laccase synthesized dyes to ensure non-hazardous influence on human cell and the environment. Years of research also showed some other dyes like Amaranth were found to be carcinogenic and prohibited its industrial use as it possess allergenic properties and also an active source for hyperactivity and histological changes in the thyroid.[12]

Presently used dyestuffs and pigments are entirely prepared from such resources which are nonrenewable, for instance fossil oil or mineral rocks. [13] Though the synthetic colorants can cover the whole color spectrum at the same time affords economic feasibility and grasp the cutting-edge technology, elsewhere they have to face the subsequent challenges of dependency on non-renewable resources, sustainability of existing process, environmental toxicity and human health concerns like as carcinogenic action of some synthetic dyes.[14, 15] Thus, search of biologically viable and technically renewable resources to produce colorants has received considerable attention.[16] Nature is the biggest resource of producing bio colorants including plants, animals, and microorganisms, which are possible alternatives to synthetic dyes and pigments currently employed.[17] In the Primordial ages, the colorants extracted from environment particularly from plants were the main resource until synthetic dyes were invented and flourished.[18] .

2. Types of Antibacterial Colorants

There are a significant amount of different & versatile varieties of antibacterial colorants are available and the increasing attention has led to a rapid development of antimicrobial technologies for textiles and polymers which consequences to antimicrobial textiles.[19] Although most of the processes employ different biocides on fabrics, a significant amount of research efforts have been spent on studying antimicrobial properties of natural and synthetic dyes.[20] Use of antimicrobial dyes could led to the advantage of combining both finishing and dyeing processes together and may yield incorporation of functionalize properties concurrently reducing energy and water usages in wet treatment of textiles providing a green and eco-friendly technology for textile manufacturing processes [21].

Medicinally as an astringent and to cure diarrhea and open wounds. Onion, radish and wine were other well-known antimicrobial agents used in dis-infection or sanitizing objects. Turmeric (Curcuma longa) was applied to close open wounds and was also used to dye skin and cloth [22, 23]. Colorant extracts from rhubarb and aloe have been employed as laxatives for centuries. The main derivatives in the roots of Lithospermum erythrorhizon, shikonin, alkanin and other shikonon derivatives were used as an intensive red colorant [24]. Tannin-based natural dyes from Punica granatum are reported as potent antimicrobial agents[25].

Natural flavonoid compounds such as troxerutin Fig. 1 could be modified to become reactive with polymers and bring both antioxidant and antimicrobial functions to polyamide fabrics. The synthesis of quinine Fig. 2, a valuable natural anti-malarial medicine, led to the accidental synthesis of the first synthetic dye ‘Aniline’.

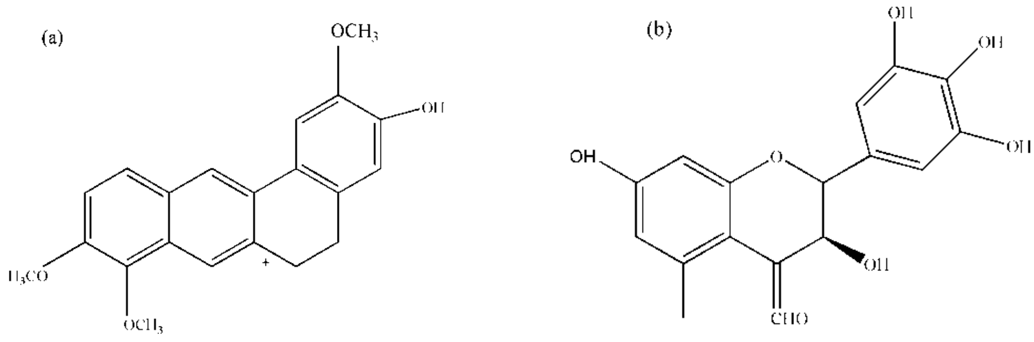


Fig. 1 Chemical structure of (a) berberine and (b) ampelopsin (flavonol).

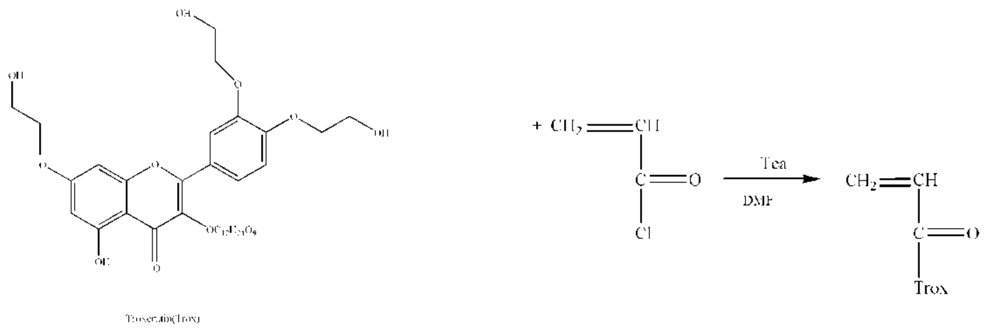


Fig. 2 Converting troxerutin to vinyl monomer

2.1. Synthetic or artificial antibacterial colorants

2.1.1. Quaternary ammonium antibacterial colorants

Quaternary ammonium salts (QAS) are water soluble cationic compounds contains long chain alkyl groups where number of Carbon in the chain length is 8–18 and are membrane active agents can work as disinfectants by destroying cell walls of gram-positive bacteria. Rather the damaged membrane may cause cytolysis by leaking of intracellular constituents [26]. QAS possess durable and powerful antibacterial activity on wool and nylon fabrics.

Two series of dyes containing both anthraquinone and QAS groups were reported, with a long alkyl chain varying from C4 to C12. The dyes with alkyl chain length longer than C8 showed good antimicrobial activities against both E. coli and S. aureus [27, 28]. However, the washing durability and hydrolytic stability of the dyes were very limited since the anthraquinone and QAS were connected by an amide bond, which could be hydrolyzed in alkaline solution [29]. To overcome the low hydrolytic stability of the amide bond Fig. 3, two new series of dyes were synthesized using amine bond as a new connection between the anthraquinone and QAS groups. These dyes are very stable under both alkaline and acidic conditions [30], and have different alkyl chains with different lengths varying from C4 to C16[30].

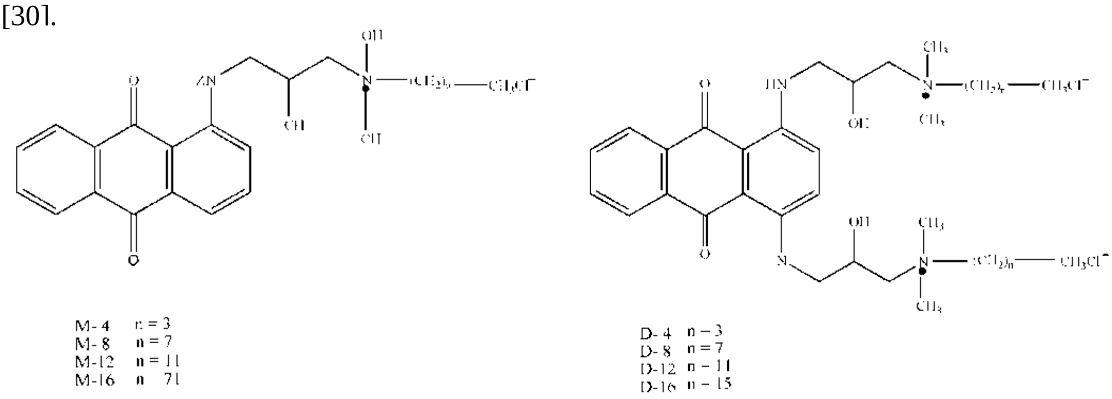


Fig. 3 Chemical structures of antibacterial cationic dyes

An antimicrobial reactive dye that can work on cellulosic fabrics as well as nylon, silk and wool fabrics was produced with QAS as biocidal site [31]. The dye showed the desired antimicrobial functions in solutions, but when it was incorporated to fabrics, the antimicrobial functions were unexpectedly lost. No matter what process, reactive or basic dyeing, was employed the dyed fabrics lost antimicrobial

functions even though the dyes are strong biocides in vitro. Several factors could cause this effect. Most QAS exhibit the functions in dissociated ionic form in solutions. Anionic surfactants could form precipitates with QAS in solutions and could thus reduce the antimicrobial efficacy.
However, if the anionic surfactant concentration is higher than its CMC (critical micelle concentration) the biocidal functions of the QAS will not be affected [32]. It was also found that the immobilized QAS on substrates still demonstrated the functions [33]. In addition, some cationic species such as calcium and magnesium could also affect antimicrobial properties of the dyes [32]. The comparison of antibacterial efficacy of Pyridinium structures revealed that more hydrophobic moieties could increase antimicrobial power of the substrates.

2.1.2. Sulfonamide-based colorants

Prontocil is the first synthetic sulfonamides discovered by Gerhart Domagk in 1932, an early day's antibacterial chromophore which could destroy streptococci. Subsequently a widespread variety of active derivatives of Prontocil Fig. 4 were synthesized, which were effective to treatment of scarlet fever, cellulite and wound infections. The drug also cured Franklin D. Roosevelt Jr. of an infection, which was an important step in its acceptance as a drug and Domagk received Nobel Prize for his discovery in 1939 [34]. Sulfonamides have vast Clinical Uses for example Toxoplasmosis, malaria, ulcerative colitis, inflammatory bowel disease, bacterial conjunctivitis, trachoma, burns, infrequent use of resistance by most pathogenic bacteria. Due to their excellent antimicrobial activity, several attempts were made to bind Sulfonamide dyes to fabric surfaces to enhance their functional properties [35].

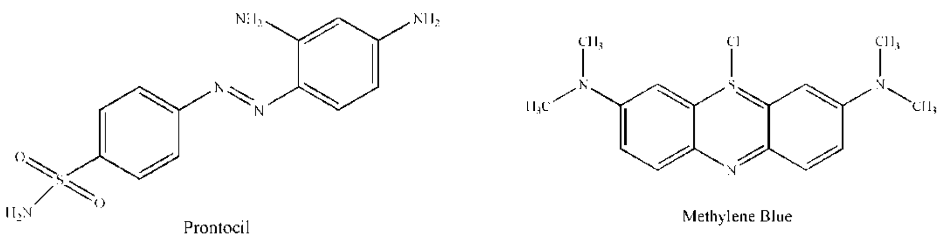


Fig. 4 Chemical structures of prontocil and methylene blue

Besides acridines and sulfonamide dyes, some other dyes such as triphenyl methane, brilliant green and crystal violet are also used as skin disinfectants or in wounds and burns treatments. To demolish the bactericidal activity on the umbilical cord stump in newborn babies a combination of these dyes was applied [36]. A newly reported synthetic dye Phloxine B can significantly inhibit the growth of Staphylococcus aureus as an acid dye and a color additive in food, drugs and cosmetics. [37].

2.1.3. Acridines

As an antimicrobial agents acridines were the first synthetic dye proposed by Ehrlich and Benda in 1912, and the first recognized clinical use occurred in 1917. Till then, a large number of acridine chromophore containing compounds were synthesized and tested for antibacterial functionality. Among them aminoacridines Fig. 5 found to be widespread use of both as antibacterial agent and as antimalarials from the time of World War II.[38].

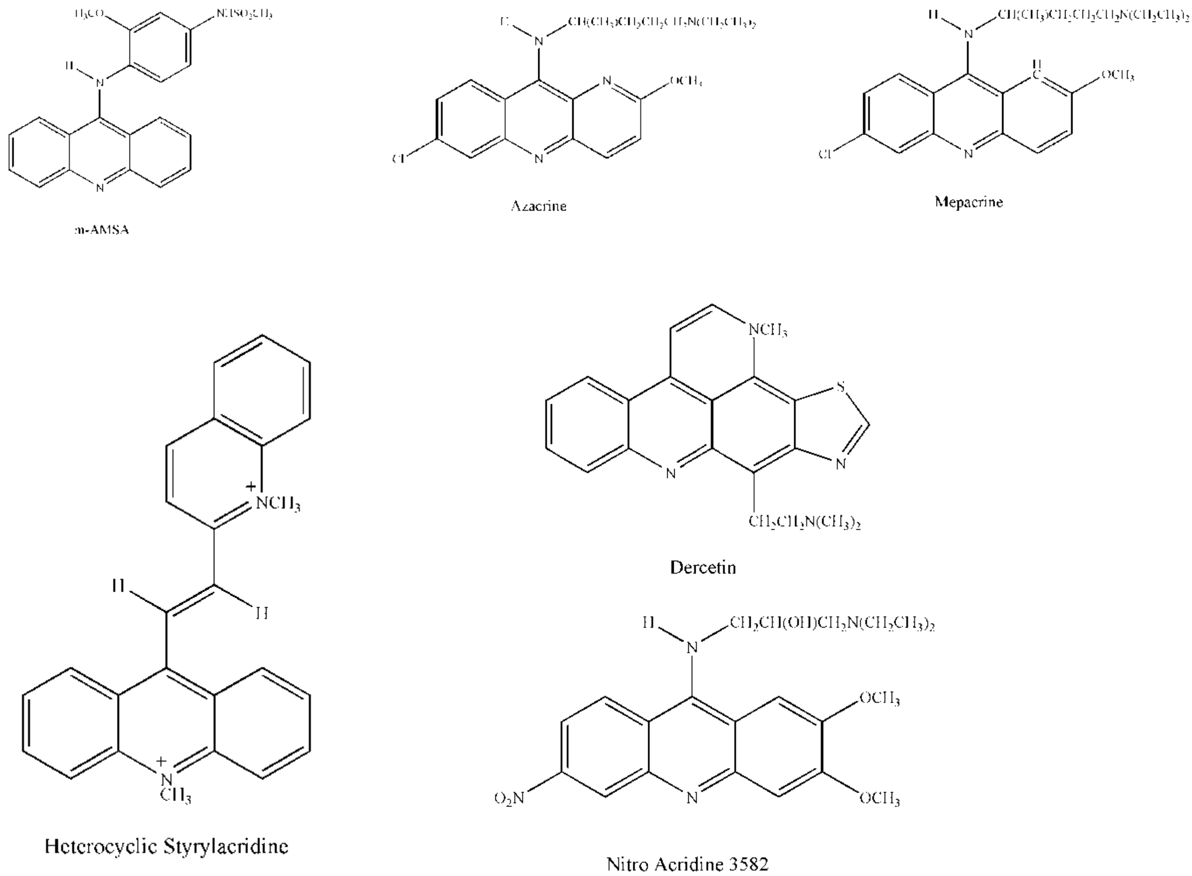


Fig. 5 Chemical structures of Azacrine, Mepacrine, m-AMSA, Heterocyclic Styrylacridine, Dercetin and Nitro Acridine 3582

Antimicrobial activity of acridine-based compounds depends on the structure which shows cationic type character particularly in neutral pH is a key parameter. This strong cationic unit of acridine could easily bonded with anionic sites on the surface of micro-organism cells. As an intercalating agent Acridines can binds with DNA to prohibit synthesis of DNA. Some of the dyes are photo-sensitizers and capable to produce free radical oxygen at presents of the light source to immobilize the bacterial activity. [39] Shows that dyeing with Acridine, acroflavin, acridine yellow G, anthracine derivatives and anthraquinones as photo-induced antimicrobial agents on Nylon fabric prior to coated with poly acrylic acid (PAA) as an intermediate polymer. Among them Acridine yellow G demonstrated supreme efficacy to inactivate the viruses and bacteria.

2.2. Natural Antibacterial Coloration agents

Natural colorants Fig. 6 are typically phenolic compounds and can be categorized according to their sources, methods of application, colors and chemical structures. These compounds are essential for growth and reproduction of plants and can be functionalize for protective organism from pathogens, predators and parasites also act as coloring ingredient of plants.[40] Most of them are effective antioxidant and react as anti-cancer or anti-carcinogenic/anti-mutagenic, anti-atherosclerotic, antibacterial, antiviral, and anti-inflammatory activities more or less.[41-43]

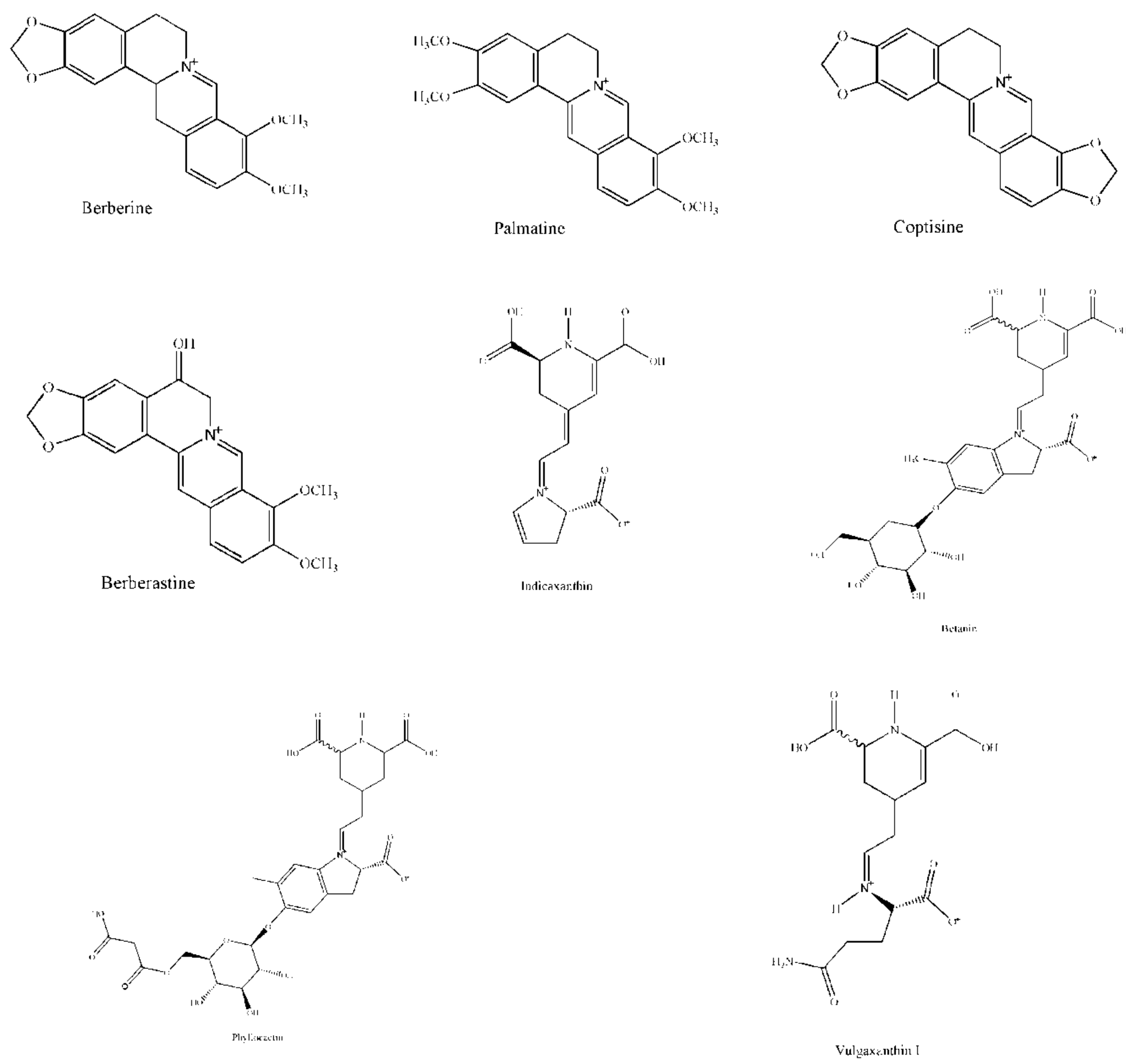
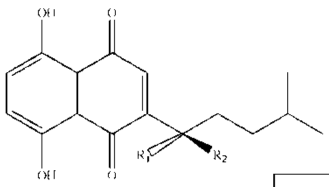


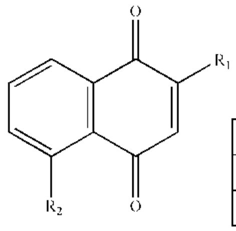
Fig. 6 Chemical structures of some alkaloid natural dyes

It's one of the most important colorant. Shikonin is the first natural colorant that has been commercially produced by a plant cell culture method to supply the cosmetic industry in Japan since 1983[44]. Shikonin was loaded into PCL/PTMC (poly (epsilon-caprolactone)/poly (trimethylene carbonate)) nanofibers via electrospinning method. The fibers showed a sustained release of shikonin over a 48 h period with no sign of losing activity, thus ideal for drug delivery or in pads for wound healing.

Lawsone, a major colorant component extracted from Lawsonia inermis (Henna), and Juglone, Fig. 7 extracted from walnut (Juglans), are the two most prominent members of naphthoquinone-type dyes. This compound is well known for its cosmetic use to dye hair, nails and skin while it is been used to color textiles including leather, wool and silk [45].



	R_1	R_2
Shikonin	OH	H
Alkanin	H	OH



	R_1	R_2
Lawsone	OH	H
Juglone	H	OH

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Fig. 7 Chemical structures of lawsone and juglone.

Lawsone and juglone as members of the quinone-type Fig. 8 compound family are found to possess antibacterial, antifun-gal, antiviral and antineoplastic activities. They could also inhibit tumor cell growth[46].

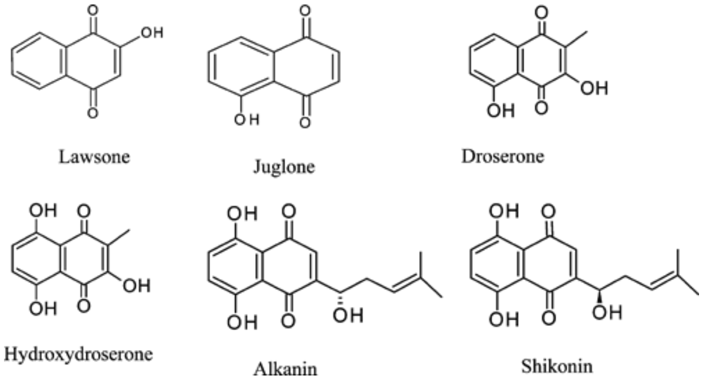


Fig. 8 Chemical structures of some alpha naphthoquinone dyes.

2.2.2. Benzoquinones

Carthamin (Natural Red 26) is a benzoquinone-based metabolite of safflower with the botanical name of Carthamus tinctorius L. Flower petals of the plant contains two main colors, the water-insoluble red Carthamin and a water-soluble yellow dye carthamidin. At the beginning the base com-pound in plant is yellow and as the flower grows, the yellow color oxidizes to a red oil soluble colorant. The yield of Carthamin is about 0.4% of the flower petals while safflower yellow content is 26–36%. Safflower has been widely cultivated for its oil seed in industry but traditionally its petals have been used as a dye for textiles, cosmetics, coloring and flavoring of foods and drinks[47].

Its extract is used as a harmless colorant in the cosmetic industry and shows a good light and washing fastness on dyed cotton and silk fabrics [47] . In recent years, the traditional medicinal aspect of Carthamin Fig. 9 has received attention as a cure for menstrual Problems, cardiovascular disease and pain and swelling associated with trauma.

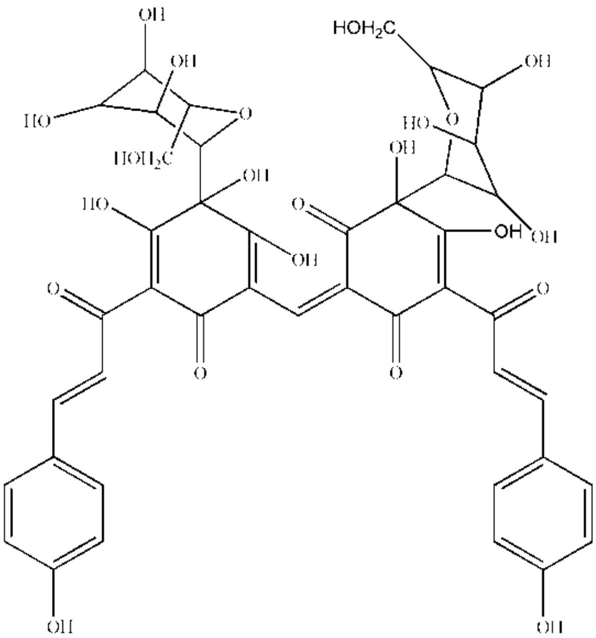


Fig. 9 Chemical structure of carthamin.

Experimental results have shown that, Carthamin has free radical scavenging activity against superoxide, hydroxyl and 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radicals and singlet oxygen which inhibits oxidative damage to lipids, proteins and nucleic acids. Quenching the free radicals involved in aging can result in a neuroprotective effect against neuron loss in forms of dementia including Alzheimer's Carthamin is unstable in water and irreversibly changes to an unknown yellow-brown component. It is also unstable upon exposure to visible and ultraviolet (UV) light, oxygen and in the pH conditions out of 1.5–5.5.Quinolones have been identified as rapid biocidal compounds. They can change the cell membrane permeability which leads to cytoplasmic leak-age and cell death[46].

2.2.3. Quinones

Quinone-type compounds including anthraquinones, naphthoquinones, phenanthraquinones and benzoquinones are naturally occurring in plants with remarkable therapeutic applications. These compounds are the basis of many of the ancient natural dyes. In addition, they have been used as medicines due to their antibacterial, antiviral or antifungal activities [48].

2.2.4. Anthraquinones

Anthraquinones are the largest class of naturally occurring quinones and contain some of the most important natural colorants such as alizarin, purpurin, munjistin, emodin, chrysophanol, aloeemodin, physcion, rhein, etc. They exist in the form of hydroxyanthraquinones and usually have 1–3 hydroxyl groups. These quinone dyes could form complexes with different metal salts resulting in very good color fastness [48, 49].Alizarin and purpurin Fig. 10 are two main anthraquinone-type colorants found in the root and tubers of Rubia tinctorum (Common Madder), R. peregrine (Wild Madder), R. cordifolia (Indian Madder), and R. mun-jista.

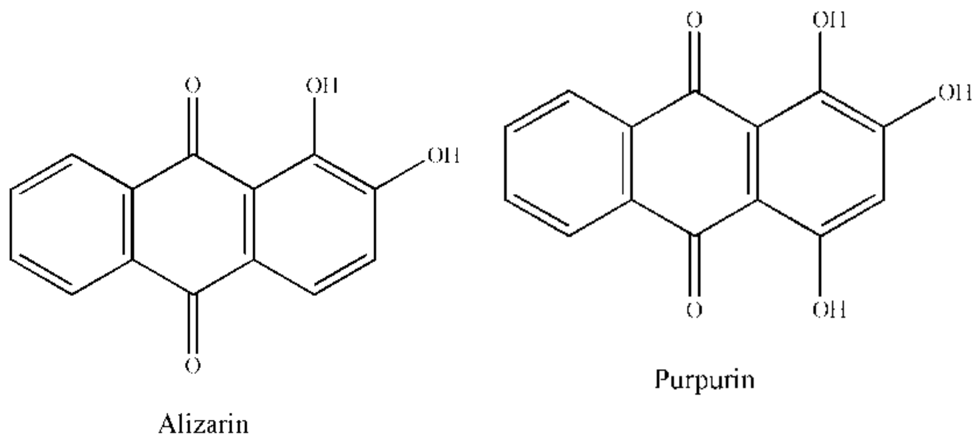


Fig. 10 Chemical structure of (a) alizarin and (b) purpurin.

In fermentation process particles stick together and form a solid mass called lake. The enzymatic process is con-sidered the best since acidic or basic hydrolysis leads to the formation of a mutagenic compound called lucidin. Alizarin and purpurin Fig. 12have antimicrobial and antifungal activity against different pathogenic bacteria[50, 51].

Carminic acid is another important hydroxyanthraquinone-based colorant, which is derived from cochineal and has been used to dye wool, silk and cotton fabrics. Its brilliant red color with great light fastness could suppress many similar synthetic ones used in textiles. In alkaline conditions carmine Fig. 11 provides a blue-red shade [52].

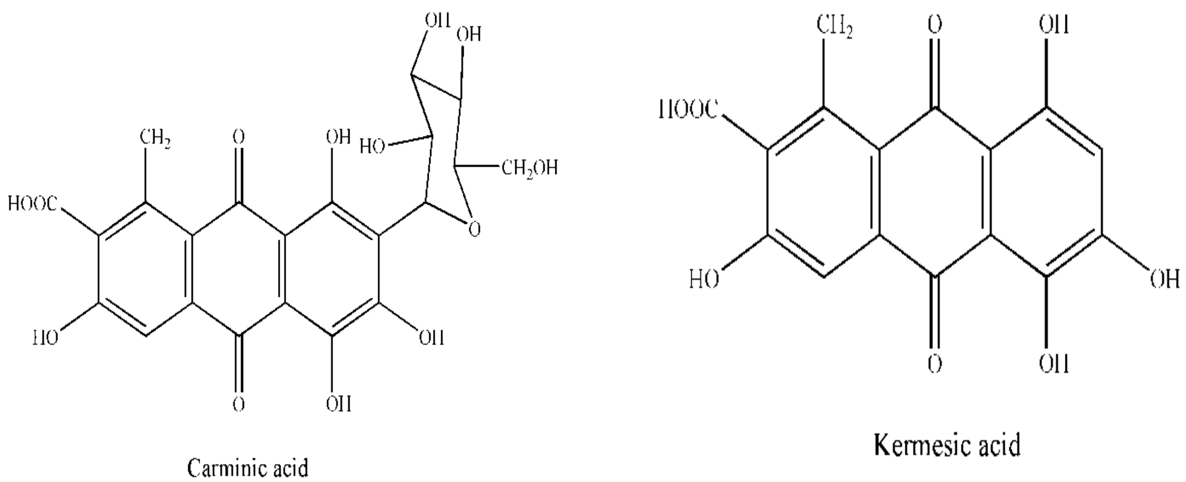


Fig. 11 Chemical structures of (a) carminic acid and (b) kermesic acid

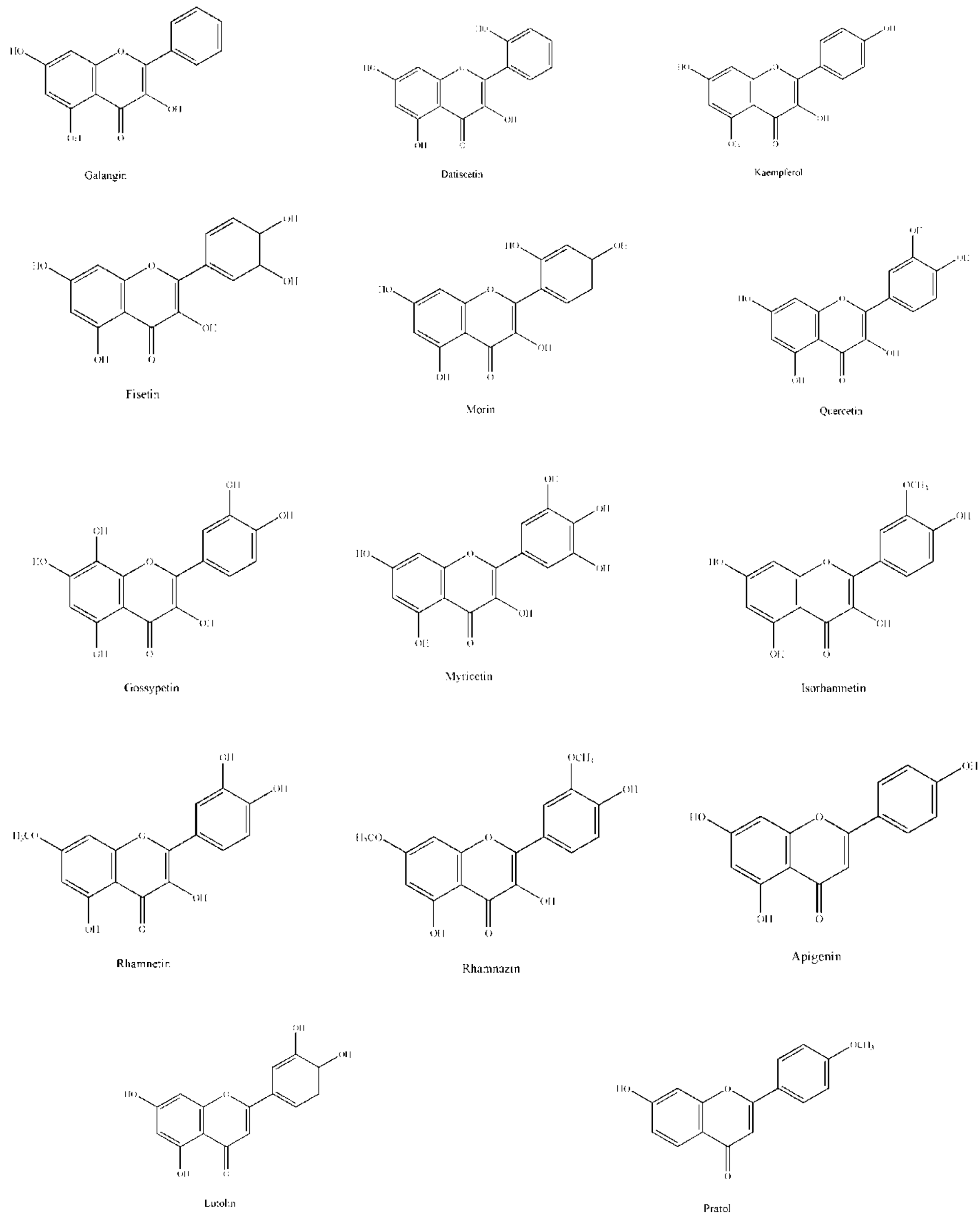


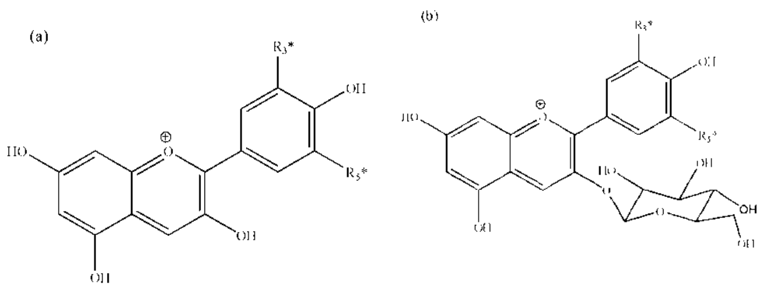
Fig. 12 Chemical structure of Anthraquinones

2.2.5. Flavones

Flavones are the most popular colorants used as textile dyes due to their often high light fastness. The most common flavones are apigenin, luteolin and their glycosides. Loteolin and its derivatives named luteolin 7-glucoside and 5-deoxyluteolin were identified as yellow colorants in fabrics belonging to pre-Colombian Andes cultures. Usually flavones such as luteolin and its derivatives have higher light and thermal stability compared to other flavonols such as quercetin . Their higher stability might be related to the absence of a hydroxyl group on position 3 compared to presence of OH group in flavonols . The color fading rate on fabric is fast initially, followed by a slower constant rate like most dyes [53].

2.2.6. Anthocyanins

Anthocyanins Fig. 13 are the most important flavonoid colorants in plants and mostly occur in floral tissues. The six main aglycone anthocyanin chromophores and their glycosides are pelargonidin, cyanidin, delphinidin, peonidin, petunidin and malvidin. Some of them are covalently linked to flavonol glycoside co-pigments. This intermolecular co-pigmentation enhances and stabilizes the color. For example, the stable bluish color of Ceanothus and agapanthus praecox flowers is related to the delphinidin glycoside linked to a kaempferol triglycoside. The colorant has a maximum absorption at 680 nm, as well as bands at 536, 576 and 615 nm. Pigment–co-pigment complexes are mostly linked together by hydrogen bonding but rarely via covalent linkage through organic acids[54] .



	R3'	R5'	(a) λ_{max} (nm)	(b) λ_{max} (nm)
Pelargonidin	H	H	520	516
Cyanidin	OH	H	535	530
Delphinidin	OH	OH	546	543
Peonidin	OCH_3	OH	532	536
Malvidin	OCH_3	OCH_3	542	546

Fig. 13 Chemical structure of Anthocyanin

(delphinidin) color of grapes and blueberries . The hydroxylated anthocyanins have bathochromic shift while methylation or glycosidation of OH at position 3 reduces the maximum absorption band and increases the solubility and stability of the color. Aglycone forms of anthocyanins are rarely found in fresh plant materials.Despite the variety of colors and high abundance in nature, they were rarely used as textile colorants due to degradation during processing and storage.

Cotton fabric dyed with anthocyanins extracted from grape pomace using tannic acid as mordant, and the combination of the mordant with anthocya-nins provided different red-violet color with good washing fastness. However, the dyed fabric did not have good light fastness [55].

2.2.7. Flavonoids

Flavonoids are one of the most abundant groups of the natural phenolic compounds in plants, which provide color and protection against UV-B irradiation. They have been found in flowers, leaves, fruit and seeds as well as tea, wine, propolis and honey .They have been widely used to dye fabrics; in fact, they make up almost 50% of all the natural colo-rants listed in the color index, although their light fastness is not high and falls below other classes of natural dyes such as anthraquinones and indi-goids [46]. The core structure of the flavonoid compounds is the 2-phenylbenzo[α] pyrene or flavone nucleus comprising two benzene rings (A and B) linked by a three-carbon bridge that usually forms a heterocyclic pyrane C-ring.

Flavonoids are usually yellow in color, except for anthocyanins, with a spectrum of colors from yellow to red, violet and blue. In addition, many flavonoids possess antibacterial, anti-inflammatory, anticarcinogenic and enzyme inhibition activities and were used for centuries to cure diseases. For exam-ple, propolis containing galanin and pinocembrin has been used for treat-ment of sores and ulcers[56] . Ginkgo biloba extract containing flavonoid compounds has been used in Korea as a natural anti-microbial agent in herbal medicine. In a recent study the extract was applied to bedclothes made from Tencel Jacquard fabrics (cellulosic-based fabric).

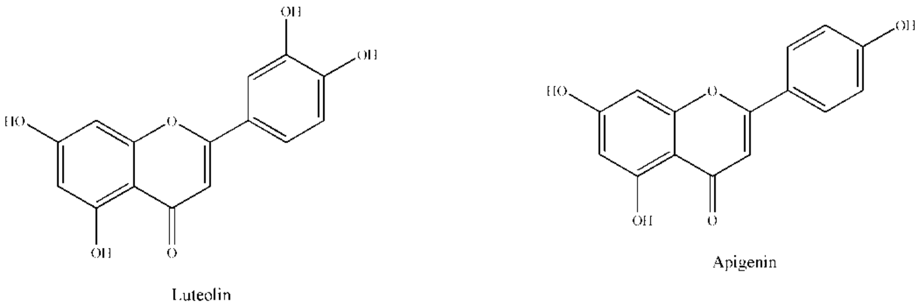
The treated fabric showed 98.2% antimicrobial activity against S. aureus. Adding silicone as a softener to the G. biloba treated fabric increased the antimicrobial activity to 100% and this activity was maintained after 30 consecutive launderings. Chitosan fibers were grafted with flavonoids and the functionalized polymer showed antioxidant activity and higher antimicrobial effect against Bacillus subtilis and Pseudomonas aeruginosa.

2.2.7.1. Antimicrobial functions of flavonoids

Flavonoids have shown antioxidant, anti-inflammatory, anti-allergic, anti-carcinogenic and antimicrobial functions. Flavonols in diet have been reported to reduce the risk of heart disease and cancer .Among flavonoids, flavonols and some of the flavones have shown activity against Methicillin-resistant S. aureus (MRSA), while other compounds such as flavonones, flavonols, isoflavones, chalcones and biflavones were inactive. None of the glycoside forms of the compounds showed any activity against micro-organisms [57]. One study on the relation-ship between flavonoid structure and their antibacterial activity indicated that the active flavonoids were polyhydroxylated. They have common C4 keto group and hydroxyl groups at positions C3, C5 and C7 and contain at least one hydroxyl group on ring B. The higher degree of hydroxylation of the A and B rings result in higher antioxidant and higher radical scavenging activities [46].

2.2.8. Flavonols

Flavonols are the most abundant yellow colorants. There are a variety of different sources of flavonols Fig. 14, but only a few of them produced a sufficient Quantity of dyes with relatively good color fastness. Flavonols Fig. 15 can easily chelate with meal cations due to the presence of neighboring hydroxyl–keto functional groups[25].

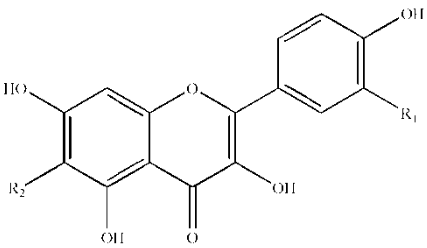


(a) Luteolin (M = 286 Da, λ_{max} = 348 nm) and (b) Apigenin (M = 270 Da, λ_{max} = 337 nm).

Fig. 14 Chemical structure of Flavonols

Quercetin and kaempferol are the predominant flavonols followed by morin, fisetin, myricetin, isorhamnetin and their glycoside derivatives. Flavonols usually have brilliant yellow color and have been mainly used to dye wool and silk fabric since ancient times. The characteristic UV-Vis maximum absorption bands of morin are 378 and 261nm. Quercetin-like structures have UV spectrum with maximum absorption at 258, 278, 358 nm [58]

Green tea, red grapes, onion especially red onion and leafy vegetable, and berries are the main source of quercetin. Onion skin contains a mixture of quercetin, kaempferol and quercetin-3-o-glucoside and has been used to dye wool and silk . Tea has been used to dye cotton and jute using copper sulfate or ferrous sulfate as mordants. Marigold (Tagetes patula L.) has been used in European countries to achieve dark yellow colors on cotton- and protein-based fabrics[59] .



	R_1	R_2	M_w (Da)
Quercetin	OH	H	302
Kaempferol	H	H	286
Isorhamnetin	OCH_3	H	319
Patuletin	OCH_3	OH	332

Fig. 15 Chemical structures of main flavonol colorants.

2.2.9. Tannins

Tannins are concentrated in bark, wood, leaves, fruit, roots and seeds of different plants. Their production is increased in plants with sickness so it is assumed to provide protection against infections and insects. Tannins are natural water-soluble polyphenolic compounds with light yellow or white color. In textiles they are well-known mordant dyes for brown and black colors [60]. Tannins are applied on fabric as cationic dyes and have also been used in the production of inks (iron gallate ink).

Tannins Fig. 16 are widely used as tanning agents in preparing leather, herbal medicine, textile dyes and antioxidants in the food industry. They have antiviral, antimicrobial, anti-inflammatory and especially, anti-tumor activity and could be used as astringent, antiseptic and haemostatic agents[61].

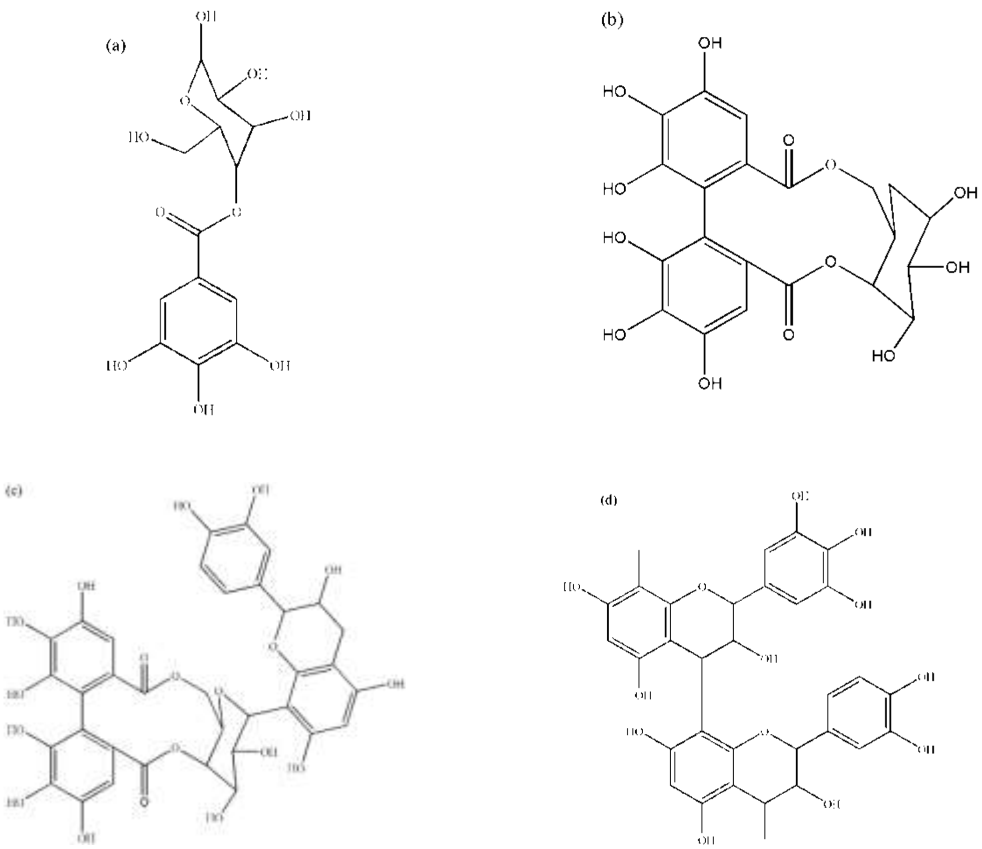


Fig. 16 Chemical structures of (a) gallotannins, (b) ellagitannins, (c) Complex and (d) condensed tannins.

Pomegranate fruit husk/peels have been used in dyeing wool, silk and cot-ton fabrics for 1000 years. In addition it has shown antimicrobial activities on cotton and wool fabrics with good laundry durability and light fastness[62]. The antibacterial activities of pomegranate extract are possibly related to EA and tannin components. EA has been reported as an antioxidant, antimicrobial, anti-inflammatory, antiviral, or anticarcinogen agent and has showed inhibitory effect on the microbes when applied on textile materials.

Quercus infectoria (QI) is another tannin-rich plant which has been used with alum and copper mordants to dye cotton fabrics. The dyed fabric with 12% concentration (owf, on weight of fiber) showed antimicrobial activ-ity (70–90%) against gram-negative bacterium E. coli and gram-positive bacterium B. subtilis. The antibacterial activity of treated cotton fabric with QI was not durable to laundering but the mordanted samples retain 80–100% activity after five launderings [63].

It has also been reported that wool and silk fabrics dyed with extract of black tea, peony, clove, Coptis chinensis and gallnut extracts showed excel-lent antimicrobial activity against S. aureus (96.8–99.9%). All the fabrics dyed, except the one dyed with peony extract, could also kill K. pneumo-nia (95.7–99.9%) [64].The antimicrobial activity of black tea, peony and galls extracts might be due to tannins.

2.3. Photo-activated antimicrobial colorants

Photo-sensitizers and some dyes with special structures can become activated upon exposure to UV or daylight, and the activated (excited) forms of the compounds can react with other substrate and result in very reactive species such as singlet oxygen and radicals. The color is the result of absorption of specific wavelengths of light by the chemical. The molecule absorbs light, and as a result, one or more electrons will be excited to a higher energy, non-bonding or anti-bonding molecular orbital. The excited compound will be in a structure possessing bi-radicals in triplet status. The triplet bi-radicals can collide with another bi-radical-oxygen in the air to produce single oxygen or peroxide and consequently hydroxyl radicals, which could cause bacte-rial cell damage or necrosis. Synthetic positively charged photo-sensitizers such as methylene blue and toluidine blue and natural ones including porphyrins and phthalocyanines have shown antibacterial activity against both gram-positive and gram-negative bacteria. In other application, photo-sensitizer applied on fabrics was used as radical initiator to graft polymer onto the fabrics [65].These antimicrobial colorants are advantageous in medical use textiles for prevention of cross-transmission of infectious diseases through hard and soft surface areas.

2.4. Antimicrobial colorants from micro-organisms

Micro-organisms such as fungi and bacteria are a key source of natural colorants. Colorants are secondary metabolites from micro-organisms which have no effect on the cell growth of fungi but serve different functions based on their structures. For example, they can have a protective function against light or can be used as a cofactor in biochemical reactions. Use of fungi colorant in food stuff is not a novel practice. Different water soluble natural colorants Fig. 17 from fungi such as red pigment from Monascus and yellow caro-tenoids from Dunaliella salina have already been used as food colorants. Many colorants resulting from micro-organisms, such as ones with quinine structures, possess significant antibiotic and antibacterial activity and are used as herbal medicines. Although some of these antimicrobial colorants have been reported, researchers have renewed interest in looking for alternatives to current synthetic dyes Fig. 18 and novel antimicrobial dyes in recent years [66] .
The colorant extracted from Roccella tinctoria was used as an alternative for royal purple from shellfish. The main natural colorants from the lichen extracts, Phycocyanobilin are a colorant from spirulina, blue - green algae, which has been used for many years to dye fabrics. Research on bacterial production of prodigiosin compounds.

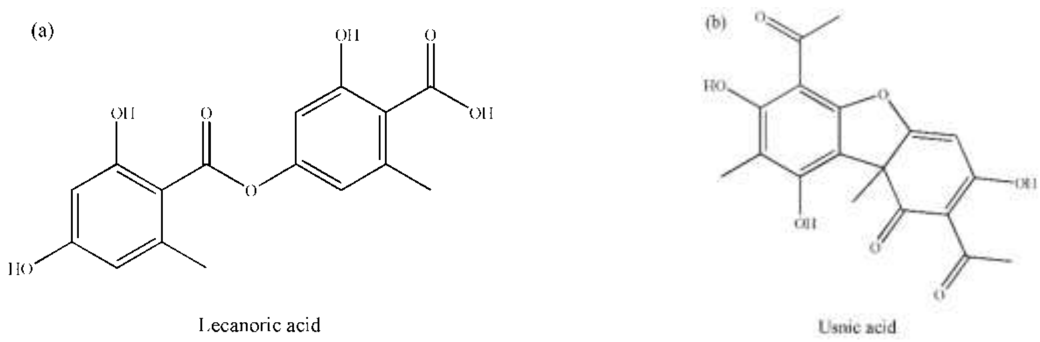


Fig. 17 Chemical structures of (a) Lecanoric acid and (b) Usnic acid

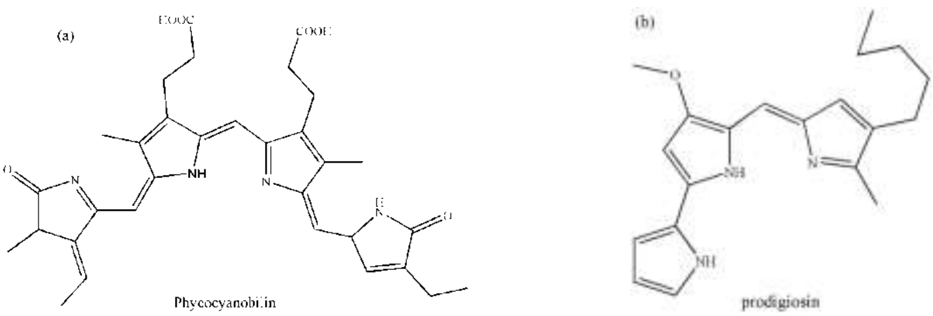


Fig. 18 Chemical structures of (a) Phycocyanobilin and (b) Prodigiosin

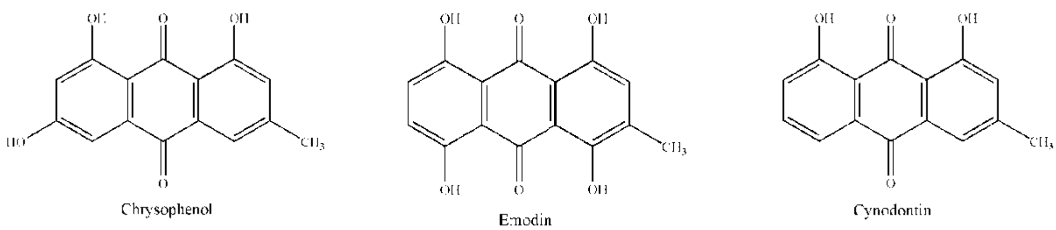


Fig. 19 Anthraquinones produced by C. lunata

The dyed fabrics could kill gram-negative bacterium E. coli which was not reported before. The antimicrobial power of the dyed fabric increased under exposure to UV light, suggesting that photo-induced reactions on the colorant could be a cause of its antimicrobial activity. Genetic modification of the bacterium increased the yields of prodigiosin compounds to 81% and improved selectivity of the pigment production with 97% purity. This result is important to commercial applications as it can simplify the purification step. In another study, colorants resulted from five different fungi were used to dye Fig. 19 cotton and leather fabrics, with the dyed fabrics showing 50%

antibacterial activity with post-mordanting [67].Colorants isolated from fungi and bacteria could be chemically modified to produce new bio-based colorants for textile products. In other words, these chemicals can serve as building blocks for bio-based colorants [68].

2.5. Coloration by synthesizing Nano particle

Through the green synthesizing of silver Nano particle with chitosan or Sodium alginate colored fabric is found along with antibacterial property.Anisotropic silver nanoparticles were assembled on cotton fibers to realize the coloration Fig. 20 of cotton. The assembly of silver nanoparticles on fibers was achieved by linking of poly (diallyldimethylammonium chloride) (PDDA) at room temperature. The silver nanoparticle treated cotton showed different colors because of localized surface plasmon resonance (LSPR) property of silver nanoparticles. The coloration is completed through electrostatic interaction between the PDDA treated cotton surface and the anisotropic silver nanoparticles in the reaction system. Scanning electron microscopy (SEM) characterization demonstrated that the morphologies of silver nanoparticles remained unchanged during the coloration process, so the treated cotton inherited the LSPR optical features of silver nanoparticles. Moreover, the cotton colorated with silver nanoparticles showed reasonably good color fastness to washing, which will facilitate the practical application of this coloration process. It is found that the fabric entails antibacterial property[69, 70].

3. Different Antibacterial Colour

Fig. 20 Various antibacterial colors of dyed fabrics (cotton, silk, and wool fabrics) using peony, pomegranate, clove, Coptis chinensis and Gallnut.

4. Conclusion

There are lots of antibacterial colorants which could be easily applied on the textile fabric both in synthetic & natural textiles fabric. The antibacterial colorants are found from different sources like natural, synthetic even from the green synthesize of silver nanoparticle. The antibacterial colorants exist a very potential application in the coloration of Textiles. The textiles could be easily colored along with the antibacterial application through using such kind of dyes. In some cases antibacterial dyes are very much cheaper than that of traditional dyes used in the textile dyeing industries.

Many colorants, whether natural or synthetic, possess some inherent functions in addition to their colors. These properties can be utilized in textile dyeing processes to bring the particular functions to textiles. In other words, dyeing textiles with these colorants can combine dyeing and functional finishing, a greener process than current separated wet treatments in terms of reduced generation of waste water and consumption of energy. Antimicrobial colorants are one of the functional colorants that have been widely employed in textile applications. This work provides a review on antimicrobial colorants with detailed discussions of synthetic and natural colorants, as well as some colorants produced from micro-organisms and photoactive colorants. Special concentration to develop & synthesize new forms of antibacterial colorants is extremely necessary to ensure the practical application of these dyes in the replace of traditional dyes most effectively. Because it is seen that still there is also huge opportunity for synthesizing most cost effective & harmless antibacterial colorants.

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