Section A-Research paper
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Natural dyes: Its Origin, Categories and Application on Textile Fabrics in brief

Amlan Bishal[1*], Kazi Asraf Ali[2], Somnath Ghosh[1], Pijus Parua[1], Bratati Bandyopadhyay[1], Souvon Mondal[3], Mayukh Jana[1], Aveek Datta[1], Karan Kumar Das[1], Biplab Debnath[1]*

[1] Department of Pharmaceutical Technology, Bharat Technology, Jadurberia, Uluberia, Howrah, West Bengal-711316, India

[2] Department of Pharmaceutical Technology, Maulana Abul Kalam Azad University of Technology, Haringhata, Nadia, West Bengal-741249, India

[3] Department of Pharmaceutical Technology, Bengal College of Pharmaceutical Science & Research, Bidhannagar, Durgapur, Purba Bardhhaman, West Bengal-713212, India

*Corresponding author
Dr. Biplab Debnath
Bharat Technology, Jadurberia, Uluberia, Howrah, West Bengal-711316, India
Email address: biplab.d86@gmail.com

ABSTRACT: -

Natural dyes and their application play an important role in different purposes like in textiles, cosmetics, food products etc. Initially natural dyes were the only option to the people for coloring of different fabrics, butafter the discovery of first synthetic dye in1856, it has altered the dependency on natural dye. Synthetic dyes have gently reduced the production cost & certain applications but have raised a question mark on environmental issues and health safety. On the other hand, natural dyes can be derived from natural sources like roots, leaves and bark of trees, secretion of animal, insects, invertebrates, fungi, minerals etc. They are environment friendly, have less side effect and more effective. Natural dyes encounter some inherent difficulties of uniform use and the uniformity of the dye itself. But they have gained the industry's attention since they have greater environmental compatibility and improved biodegradability. So, instead of having some drawbacks, the textile industries have started a huge amount of use of natural dyes on coloring of different fabrics. People have started to utilize the natural dyes for their beneficiarypurposes. This study attempts to review on different sources, classification, and various applications of natural dye on textile fabrics.

KEYWORDS: - Synthetic and Natural dyes, Biodegradable dye, Synthetic fibers, Eco- friendly textiles, Textile fabrics

I. INTRODUCTION: -

Dye is basically a color which is usually used to stain different materials. The first natural dye was found in and around 2600BC. Originally, dyes were made with natural pigments mixed with water or oil as a base. The art of dying fabrics has been an integral part of human civilization. Over 4000 years, since ancient Egypt to the present, people have been using various dyes to brighten clothes. As civilization continue to flowish and the development of research and studies in synthetic chemistry discovered the synthetic dyes. And these synthetic dyes bring a plethora of color choice. It made the dying of fabrics easier and more cost effective. People became attracted to synthetic dyes because of different varieties, color options and long-lasting use. But the main problem come when they understand different environmental problems and health issues caused by different synthetic dyes. Because of nonbiodegradability and carcinogenicity, synthetic substances used to dye textiles, pollute water and create disposal issues. Today, as the world embraces eco- consciousness and seeks sustainable alternatives, the use of natural dyes for coloring of different fabrics has become a relevant subject. Our country's abundant biodiversity has given us access to several different types of basic ingredients, but there must be a sustainable connection established between their cultivation, gathering, and utilization. Natural dyes have unique aesthetic properties. The ethical importance of an environmentally sustainable product, when combined with its craftmanship, adds value to textile manufacture. The natural dyes are non- toxic, non-allergic, and eco-friendly (1). So, the textile industry has recently been under pressure to utilize natural colorants due to the growing consumer demand. Consequently, the usage of these dyes in order to reduce the use of harmful synthetic materials in textiles have become a serious issue. Natural colorants are not only used for the coloring of different fabrics but also coloring of food substrates, medicines, paper, leather, cosmetics, paint, ink etc.

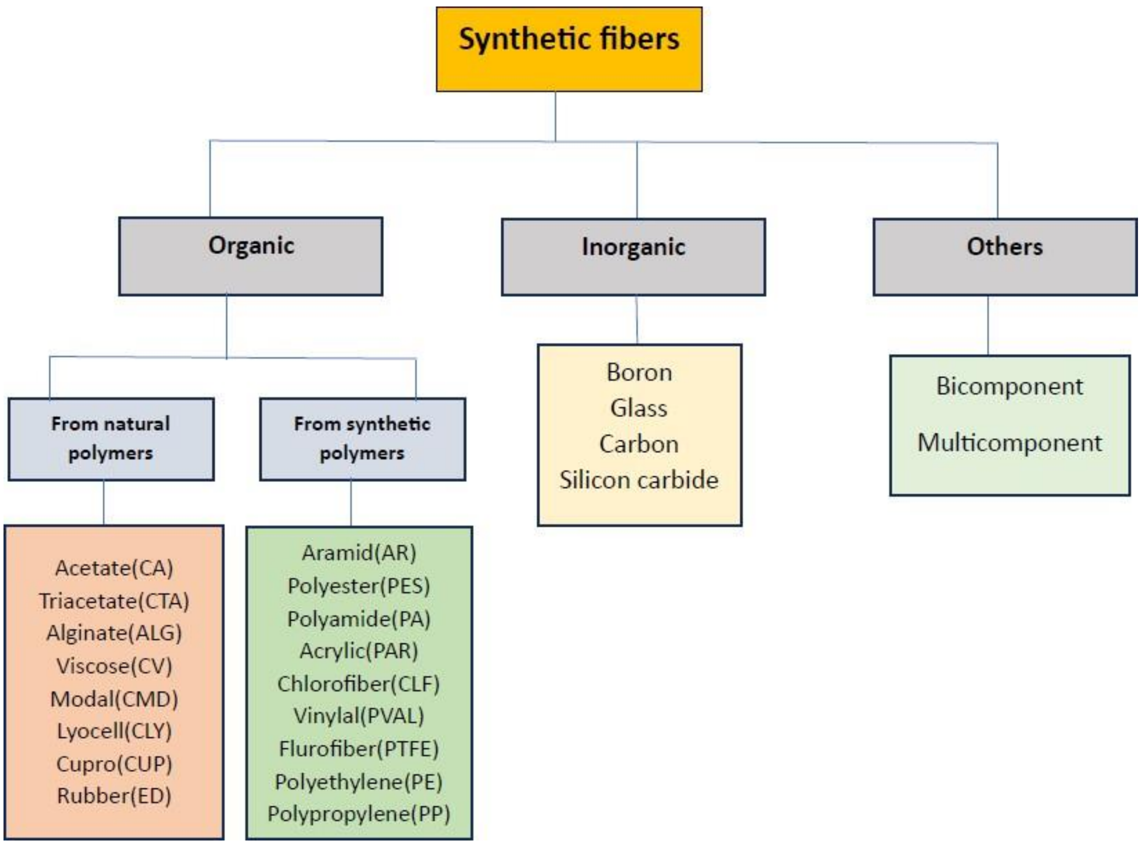
Natural dyes are derived without the use of chemicals from a variety of substances found in nature, including plants (such as indigo and saffron), insects (such as cochineal beetles and lac scale insects), animals (such as some species of mollusks or shellfish), microbes (such as pseudomonas, bacillus, rhodococcus) and minerals (such as ferrous sulfate, ochre, and clay) (1). A lot of the plants which are used to extract dyes are considered as medicinal plants, and recent research has shown that some of these plants have an antibacterial effect (2). The antibacterial characteristics of these plant dyes help the textile materials last longer when they are applied to textiles. However, the issue of sustainability is raised when different plant/tree components are used to make dyes, especially when the dyestuff source must be regenerated and rendered viable for repeated use. And the Plant material cultivation for the extraction of natural colorants can bot compete with crop farming for the production of food. Additionally, at the moment, the direct farming method used to produce natural dyes results in significantly higher specific costs per kg of plant components and, consequently, per kg of dyed material (3). So, to reduce the cost use of the by-products from the food and agriculture industries as well as forestry waste. Peels, shells, seeds, and other agricultural waste are abundant sources of pigments and can be used to make natural colors (4). Thus, an encouraging idea of identification, classification of different natural dyes and their applications on textile fabrics have been arrived.
To know about different types of dyes in textile industries and to fulfil our aim of giving an apt appropriate and succinct review on natural dyes derived from different sources and their application in different textile fabrics, we have to know about different textile fabrics. Fabrics are generally categorized as natural fabrics and synthetic fabrics. Natural fabrics are originated from natural origin. Synthetic fabrics are made up of artificial or man-made. There are mainly five kinds of natural fibers, that can be originated from plant, such as **i**) Bast fibers or Skin fibers (e.g., kenaf, flax, ramie, jute and cannabis) **ii**) Leaf fibers (e.g., agave, pineapple and sisal) **iii**) Seed fibers (e.g., kapok and cotton) **iv**) Stalk fibers (e.g., rice, bamboo and grass) **v**) Fruit fibers (e.g., coir fiber) and all additional varieties, including wood and roots (5,6). Some plants can produce multiple types of fiber. Agave, coconut, and oil palm consist of both fruit and stem fibers. Similarly, both bast and core fibers contain jute, flax, hemp, and kenaf. Additionally, cereal grains include distinct stem and hull fibers (7). Natural fibers are also originated from animal source like silk, wool, hair etc. and there are also some mineral fiber like asbestos, ceramic etc.
Table- Different natural fibers, their biological sources and their uses.

Sl. no	Name of fibres	Type of natural source	Biological source	Uses	References
1	Silk	Animal	Bombyx mori	Making of composites, livestock, agriculture, silk cloth, silk yarn etc.	(8–10)
2	Wool	Animal	Ovis aries	Making of Cotillion, wool yarn blankets, carpets, upholstery, winter cloths and different types ofinsulations.	(10)
3	Jute	Plant	Corchorus capsularis	Tarpaulins, wrapping, furniture materials, fabric, carpets, carpet upholstery, geotextiles for transportation, electrical insulation, and ropes.	(5,11,12)
4	Flax	Plant	Linum usitatissimum	These fibers are utilized in bed linens, clothing, furniture materials,textiles, home design accents, etc.	(13–15)
5	Hemp	Plant	*Cannabis sativa*	In Industry sectors, include boxes, carpets, yarn, furnitures, fabric, textiles garden mulch, fleeces, and needle felts, as well as light weight composites and geotextile/geotextile insulation.	(16)
6	Remine	Plant	Boehmeria nivea	Textile, paper, pulp, yarn, biofuel, fabric, seed food, composites, livestock, gas mantle, fishing net, marine packaging.	(10,17,18)
7	Kenaf	Plant	Hibiscus cannabinus	Pulp, paper product and rope production.	(10,19)
8	Sisal	Plant	Agave sisalana	Used in the automotive & shipping industry, civil engineering, utilized as the fiber core for baler twine, agricultural twine, and steel wire cables for elevators, among otherthings.	(20–22)
9	Date palm	Plant	*Phoenix dactylifera*	As prospective sources of cellulosicfiber. The reinforcing for	(23,24)

				thermoplastic and thermosetting polymers comes from rachis and leaf fibers. Some researchers have the automotive application.	
10	Cotton	Plant	*Gossypium*	Furniture, clothing, and yarnindustries. composites are utilized.	(25,26)
11	Kapok	Plant	*Ceiba pentandra*	Utilized to create biofuel, reinforcing materials, buoyancy materials, oil-absorbing materials, and other materials.	(27,28)
12	Banana	Plant	*Musa acuminata*	Used to make Rope, placemats, cardboard, thread yarn, tea bags, premium fabric and textiles, currency note paper, mushrooms, crafts, and art.	(29,30)
13	Rice	Plant	*Oryza sativa*	Making of cellulose fiber,adsorbent, paper product, rope etc.	(14)
14	Bamboo	Plant	*Bambusoideae*	To get ready bioenergy sources, shoes, food, clothing, pulp and paper manufacturing, andreinforcement.	(31)
15	Pineapple	Plant	*Ananas comosus*	Making handbags, tablecloths, mats, ropes, cutting material, lightweight duck cloth, composites, and conveyor belt cord.	(32)
16	Coir	Plant	*Cocos nucifera*	To make lightweight composites, fillers, and reinforcement for composite materials.	(29)
17	Abaca		*Musa textulis*	Used to make Clothing, textiles, valuable papers like check, journal,and money. Used as composites.	(25)
18	Nettle	Plant	*Urtica dioica*	Used for animal housing, biofuels production, textile industry, etc. In the modern era, efforts have been undertaken to utilise nettle fibers on a large scale.	(33,34)
19	Asbestos	Mineral	*Hydrated silicate*	Manufacturing paper goods, heat-resistant textiles, gaskets, and other building components (such as roofing shingles, ceiling and floor tiles).	(10)
20	Glass	Mineral	*silica*	Provides superior thermal insulation and exceptional acoustic performance, is lightweight andsimple to install.	(10)

The three main categories of synthetic fibers—organic, inorganic, and others, are further divided into subcategories on the basis of origin of the fibers. They are sub classified into different sub classes. They are synthesized in the laboratory from polymers, which is a by-product of petroleum. Synthetic fibers can be processed via spinning, polymerization, and filament processing. To produce filaments from synthetic polymers, a further spinning process is divided into three subcategories: melt spinning method, wet spinning method, and dry spinning method (35).

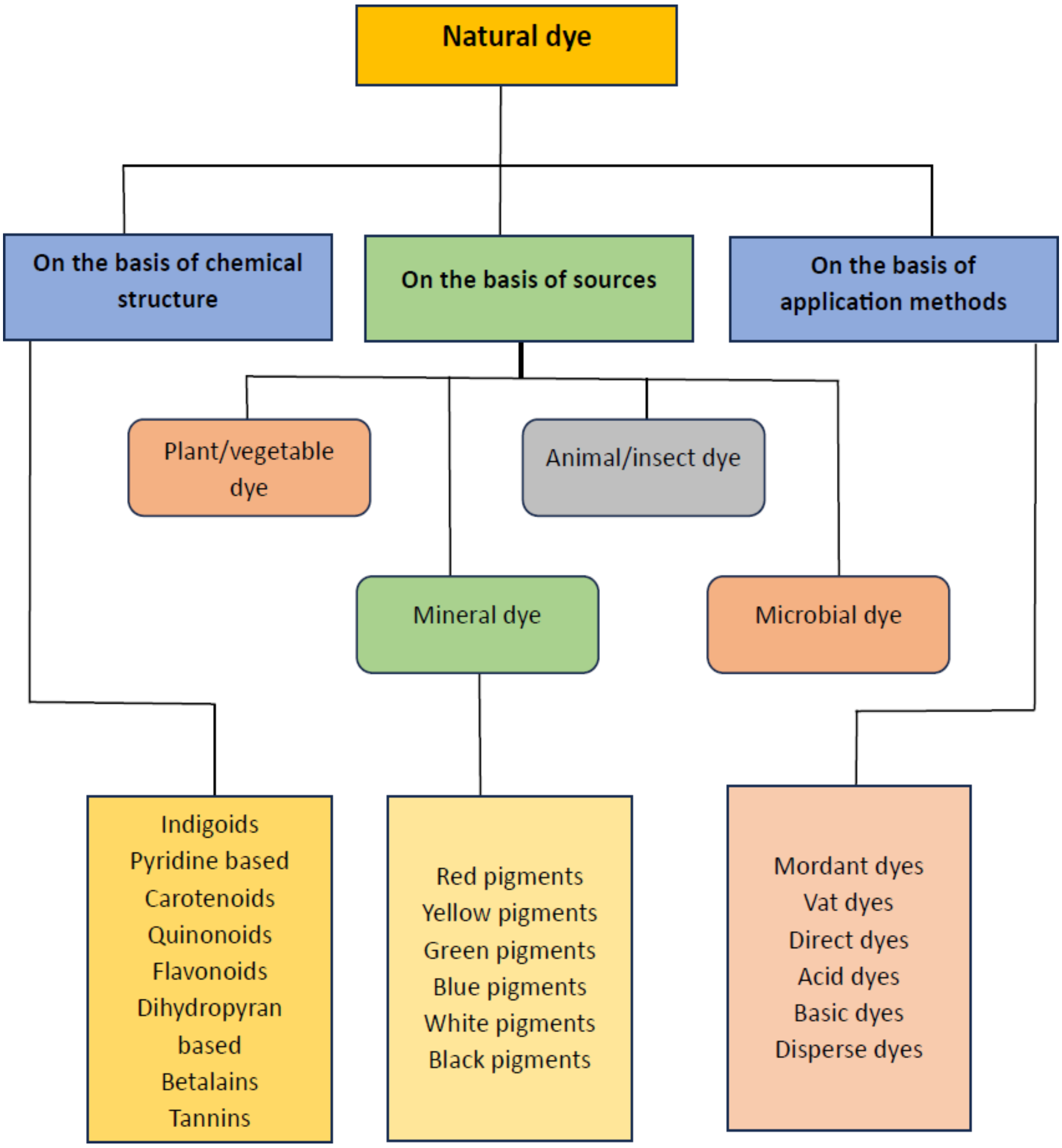
II. CLASSIFICATION OF SYNTHETIC FIBRES.



Thoughts about the usage of renewable resources began to arise as a result of the rise in environmental awareness, community interest, new environmental restrictions, and the unsustainable use of synthetic fiber. Due to its superior characteristics over synthetic fiber, natural fiber is regarded as one of the most environmentally friendly materials (36). The many forms of Composites made of natural fiber-reinforced polymers have received a lot of interest by many automotive companies including Cambridge industry, Proton company, and German automotives (Volkswagen, Opel, Ford, Mercedes, BMW, Audi Group, and Daimler Chrysler). Composites made of natural fibers have various uses besides the automotive business, including the civil sector, athletics, aerospace, and more (37). Given the rate at which natural fiber is being used, it can be predicted that in the near future, natural fiber composites will experience greater growth than synthetic fiber composites (38).

III.CLASSIFICATION OF NATURAL DYES

Different natural sources can be used to produce natural dyes. Different plant parts, such as the roots, bark, leaves, flowers, and fruit, can produce a broad variety of hues (39). They can alsobe originated from insect source, mineral sources, and different waste sources. Multidisciplinary research using spectroscopic techniques, micro-analytical chemistry, history, archaeology, botany, and other fields is utilized to study the colorants employed by ancient peoples. The development of different natural dyes and colourants developed through microchemical testing. UV-Visible spectroscopy, FT-IR spectroscopy, X-ray fluorescence and EDX (energy dispersive X-ray) spectroscopic techniques are a few examples (40–42). Different categories exist for natural dyes. The primary factors used to categorize natural dyes are the places where they are produced, how they are applied to fabrics, and their chemical structure.



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- **Based on chemical structure: -**

The most common classification scheme for natural dyes is based on their chemical structure. It is simple to determine the specific chemical group the color belongs to.

Indigoids (43–45)**;** Indigo is the most significant class of natural dye, which has been utilized by human civilizations for the longest time. The king of all-natural dyestuffs, as the name implies. It gives off a blue tint. *Perisicaria tinctoria*, *Isatis tinctoria*, *and Indigofera tinctoria* (a leguminous plant) are the sources of indigo (46). It works well for dying wool and cotton.
Pyridine based dye; Berberine is one and only natural dye that belongs to this class (47). It has a vivid yellow color and is an isoquinoline alkaloid. It is derived from plants like *Berberis aristata*, *Rhizoma coptidis*, *Phellodendron amurense* and *Berberis vulgaris* (48–50). They are used for dying of synthetic fibers, blended polyesters and wool fibers.
Carotenoids; Carotenoids, a tetraterpene pigments which exhibit yellow, red, orange and purole color (51). In photosynthetic bacteria, a few species of archaea, fungi, algae, mammals, and plants, they can be present within the chloroplast and chromoplast. Source of some carotenoids plants are *Crocus sativus, Curcuma longa, Cedrela toona, Nyctanthesarbor-tristis,* and *Bixa orellana* (52).
Quinonoids; Quinonoids are naturally occurring substances. They exhibit yellow to red colour (53). They are further divided into three groups like anthraquinones, benzoquinones, and a-naphthoquinones. The natural sources for quinonoids include *Juglans regia* (Walnut), *Plumbago capensis* (Chitraka/Chita), *Tabebuia avellanedae* (Taigu/Lapachol), *Choloraphora tinctoria* (Gaudich), *Alkanna tinctoria* (Ratanjot/Alkanet), *Carthamus tinctorius* (Safflower), *Lithospermum erythrorhizon* (Tokyo Violet/Shikone), *Dactylopius coccus* (Cochineal), *Laccifer lacca/Kerria lacca/Coccus lacca*, *Rubia tinctorum*, *Drosera whittakeri* (Sundew), *Rheum emodi* (Himalayan rhubarb), *Rubia cordifolia* (Indian Madder), *Oldenlandia umbellat* (54,55).
Flavonoids; Flavonoids are originated from different plant sources. It provides orange, red, yellow to blue colors (56). There are many plant sources of flavonoid dyes, including *Allium cepa* (Onion), *Myrica esculenta* (Kaiphal), *Datisca cannabina* (Hemp), *Delphinium zalil* (Yellow Larksur), *Gossypium herbaceum*, *Artocarpus heterophyllus/Artocarpus integrifolia* (Jackfruit), *Sophora japonica/Styphnolobium japonicum*, *Reseda luteola* (Weld), *Butea monosperma/Butea frondosa* (Flame of the forest/Palas), *Mallotus philippinensis* (Kamala) etc (57,58).
Dihydropyran Based Dyes; These pigments are made up of haematoxylin (C.I. 75290) from logwood (*Haematoxylon campechianum*) and brazilin (C.I. 75280) from brazilwood (*Caesalpinia sappan*).
Betalains; Betailains are a group of plant pigments that include water-soluble nitrogen. The violet betacyanins and yellow betaxanthins are main component of this dye. Common natural resources for the betalains class of dyeds include *Opuntia lasiacantha* and *Beta vulgaris* (59,60).
Tannins; It comes from a variety of plant parts, including fruit, leaves, plant galls, bark, roots, wood etc. They are astringent in nature and water-soluble phenolic compound. By increasing the affinity of fibers for various dyes, tannins play a significant role in natural dyeing. It can be mixed with various natural dyes to produce hues like brown, grey, yellow and black. Sources of plants for tannins include *Punica granatum* and *Quercus infectoria* (61,62).

- **Based on origin or Production Sources**: -

Based on origin or occurring, natural dyes are classified into plant dye or vegetable, animal dye, insect dye, minerals dye (63), waste dye.

Plant/vegetable dyes: -

The process of dying of fabrics with plant dyes/vegetable dyes is ancient. It was unintentionally discovered by staining clothing with plant or fruit extracts. Various plant parts, including flowers, fruits, seeds, leaves, bark, trunks, and roots, among others, can be used to extract it. There are already more than 450 dye-producing plants or vegetables in India.

Turmeric; Turmeric is basically the root of turmeric plant (*Curcuma longa*). It produces yellow colour on clothing. It is useful for dying cotton, wool, silk etc. It is having medicinal value so it does not produce any health hazards (54).
Henna; We can extract the dye from leaves of the Henna plant (*Lawsonia inermis)*. It is also called as the Egyptian privet, mignonette tree. It imparts orange-red color. It works well for dying silk and wool fibers (64).
Indigo; The king of all-natural dyestuffs is referred to as indigo. It gives off a blue tint. Indigo is extracted from *Indigofera tinctoria* (leguminous plant), *Isatis tinctoria* (woad), *Polygonam tinctorium* (dyer's knotweed) and *Perisicaria tinctoria* (46). The substance that gives indigo plant leaves their distinctive hue is known as indican (1H-indol-3yl b-D-glucoside). It works well for dying wool and cotton.
Indian Madder; It imparts red colour from its roots on textile fabrics. It is isolated from the roots of *Rubia cordifolia*. It is also called manjistha. In addition to the roots, the plant also has dye in the stems and other sections. It is a type of flowering plant belonging to the coffee family. It is employed to color cotton and wool textiles (2).
Marigold; The dye can be isolated from yellow or orange colored marigold flower. Its biological sources are *Tagetus erecta* and *Calendula officinalis*, from Asteraceae family. The main coloring agent in marigold flowers is lutein, a fat-soluble carotenoid that gives the pigment its yellow to orange hue (65). It gives optimum result in dyeing both wool and silk fibers.
Pomegranate; It is extracted from *Punica granatum* plant. It belongs to the family Punicacea. It imparts orange to yellow colour. With pelletierine, pomegranates contain around 19% of their total tannin content. Granatonine, which is present as the alkaloid N-methyl granatonine, is the primary coloring ingredient in the pomegranate peel and grains (66). It can be additionally added in conjunction with turmeric to increase the dyed fabrics' light resistance. It is suitable for dying cotton/synthetic fabrics.
Tea; The dye is extracted from tea plant (Camellia sinensis), leaves or tea powder. It generates various brown hues. Used for dying of natural fibers like silk, wool, wool and linan. It won't work on synthetic fabric, such as polyester (67,68).
Onion; The onion's (*Allium cepa*) outermost skin or peel is used to extract the colour**.** It imparts golden/yellow and redish-brown tones on fabrics. Its simple and easy process of dying. Useful for dying of natural fabrics. In Anatolia, this dye resource is frequently employed (69).
Brazil Wood or Sappan Wood; The source of the dye is the sappan wood (*Caesalpina* sappan) and Brazil wood *(Caesalpinia echinate*). Basically, we can get a red dye from this due to the vivid red color of the wood. Textile fabrics can be dyed with or without the use of an alum mordant to get the red hue. When combined with turmeric, this dye yields orange hues, and when combined with catechu, it yields a deep maroon color (70).

Senegalia catechu; It comes under family Fabaceae. The resin, a gooey material found in acacia tree plants, is where the dye is produced. It generates various brown shades. Useful for dying cotton, silk and wool (71).

Morinda; Dye can be got from the bark and root of the Morinda tree (*Morinda citrifolia).* It grows in India and Sri Lanka. It usually gives red colors. The tree, which is between three and four years old, provides the most coloring matter. A first wash to get rid of free acids is done before extracting the dye with water from the chipped material. Mordants are substances that can be used to create a variety of colors, such as chocolate and purple. Used for coloring of cotton, silk and wool in shades of red, chocolate or purple color (72).

Fustic; Old fustic is made from the heartwood of the huge, tropical American tree dyer's mulberry (*Chlorophora tinctoria*, or *Maclura tinctoria*). It comes under Moraceae family. On wool that has been mordanted (fixed) with chromium salts, the dye causes yellowing . And the young fustic (zante fustic, or Venetian sumac) can be get from the wood of smoke tree (*Cotinus coggygria*, or *Rhus cotinus*), a southern European and Asian shrub fall under cashew family, Anacardiaceae (73).

Safflower; Safflower florets were formerly used to make a dye that was prized for its vivid cherry-red hue. It had two coloring components: a water-soluble yellow that was present in large amounts (26-36%), but wasn't used as a dye, and a crimson red colorant called carthamin that was only present in little amounts (0.3-0.6%). Safflower has been used to give silk and cotton cherry-red direct dyeings (74).

Logwood: It comes under genus Xylosma and a part of the willow family. The dye is obtained from the core heart of the logwood trees (Haematoxylum or *Haematoxylon campechianum*). It comes from central America. It creates blues and purple on wool, black color on cotton and wool and black and violet on silk (75).

Saffron; The dye is produced from dry stigmas of the *Crocus sativus* plant. It is commonly known as the "saffron crocus" and belongs to the family Iridaceae. It gives the materials a vivid yellow color. It may color cotton, silk, and wool directly (64)

Annatto; The Bixaceae family includes the little tree known as annatto (*Bixa Orellana*), from which the dye is obtained. Its seeds can be used to make a yellow-orange dye. The pulp is rich in tannin. It results in colors of reddish orange on wool, cotton, and silk (76).

Barberry; The bark, roots and stems of *Berberis aristate* can be used to make dye. Berberine, an alkaloid, is the dye's primary ingredient. The dye yields a vivid yellow hue with average lightfastness and good washing fastness. After regulating, it can be used to dye cotton, silk, and wool directly (77).

Myrobolan; The dye is obtained from dried myrobolan (Terminalia chebula) fruits. Myrobolan is a component in the well-known Ayurvedic remedy triphala. It is having a high tannin content. It produces bright yellow colors for all textile fabrics (78)

Flame of the forest; A bright orange colour dye can be extracted from the flower of flame of the forest (*Butea monosperma*) tree. In India, it is referred to as tesu locally. Any natural textile can be dyed with the dye. With the proper mordant, bright yellow to brown and orange hues can be developed (75).

Himalayan rhubarb; The rhizomes and roots from Himalayan rhubarb (Rheum emodi) can be used to make an orange-golden dye. A little bit of rhubarb will dye a lot of fabric. The are basically used for dying of wool. Also used on cotton, hemp, linen etc plant fibers (78).

Weld; A yellow dye is extracted from the weld plant (Reseda luteola). Ancient tapestry wavers in central Asia, Turkey and Europe used the dye. The coloring matter is a flavonoid. Widely used in natural fiber textile, leather and paper (75).

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Grape; Grapes (*Vitis vinifera*) are a member of the Vitaceae family. It is mostly grown in the Mediterranean region, south-western Asia, central Europe, north and south Germany, and eastern and northern Iran. Procyanidin, prodelphinidin, glucosylated procyanidin, and gallated procyanidin are the tannins that give it its color (79). It produces red-purple color. It's employed to color fibers made of cationized cotton, wool, silk, acrylic and polyamid (80).
Kamala; kamala is a powdery substance obtained from dried kamala fruit (*Mallotus phillipensis*). It is also called as the monkey face tree. It yields a red-orange colour. It can be used to create vibrant orange-yellow and golden-yellow dyes for wool and silk. Colors on cotton don't have great fastness qualities (75).
Red sandalwood; A typical red color is obtained from the mature tree (wood) of *Pterocarpus santalinus*, a species of pterocarpus. They are basically found in Southern Eastern Ghats Mountain range of South India. It has a good affinity for all protein fibers, and gives light strawberry shades on cotton (81)
Siam weeds; the dye can be extracted from the whole body of *Eupatorium odoratum*. Yellow to brown colour is obtained. The leaves, twigs and roots are reach in tannin. Used as textile dye (75).
Amla; The dried fruits of *Emblica officinalis* is used to make the dye. It is the reach source of tannin. Utilized alone or in combination with other mordants. It imparts grey color. Useful for dying cotton and silk fabrics.
Gulmohar; The dye can be obtained from the flowers of gulmohar plant (*Delonix regia*). In the presence of alum, it gives off an olive-green tint. It gives a dark tan in the presence of turmeric.
Drumstick; Dye is extracted from the leaf and seeds of *Moringa pterygosperma*. Basically, yellow colored dye is extracted and used for colorin g of fabrics (75).
Sausage tree; *Kigelia Africana*, belonging to family Bignoniaceae. The is extracted from flower. Used for dying silk and wool fabrics. Addition of different mordants during dying impart very fastness properties on the fabrics.

Animal/insect dyes: -

Natural dyes can come from a variety of sources, but those derived from animals are special. The majority of animal dyes came from insects, which were the primary source of red hues. There are so much different animal dyes, which are discussed below.

Tyrian purple; Tyrian purple was the oldest animal dye. Levantine Sea snails of the Muricidae family are used to make this dye (82). Other names for tyramine purple include royal purple, imperial purple, and imperial dye. Since a gram of the color required thousands of mollusks, it is highly expensive. It produces deep violet color on fabrics. It was used to dye the royal family's clothing and was regarded as an emblem of royalty. It is basically used in wool cotton and silk.
Cochineal; The Aztecs and then the Spaniards employed the ancient natural color cochineal. It is taken out of the dried-out bodies of female *Dactylopius coccus* red bugs. It occurs mainly in Central and South America, primarily in Mexico and Brazil, and is also referred to as nopal, opuntia, or the Indian fig (83). Cochineal (cochineal wax) is used as a coloring agent and includes 9–10% carminic acid in the form of fat called glyceryl myristate. Using the mordants aluminum and tin oxide, it creates the colors crimson red and scarlet (84). Carminic acid is widely used in natural animal fibre due to its strong firming properties and exhibit excellent fastness properties (85). The majority of the time, this dye was used to color wool and silk.

Polish cochineal; In the Palearctic, Eurasia, and Central Europe, Polish cochineal (*Phor phyrophorapolonica*) is widespread. It is sometimes referred to as Saint John's blood or polish vermilion scales. kermesic acid and flavocermesic acid are found in higher quantity in Polish cochineal and imparts red colour to the substratum (86). Their applications are, however, rejected at the turn of the century because it was listed as endangered species (87).
Armenian Cochineal; Because of its beginnings in the plain and the valley of the same name in Armenia, it is also called to be the Armenian River. it is also called Ara or Ararat cochineal (88). kermesic acid and flavocermesic acid is found in them in small quantity. One of the first sources of red coloring, it dates to 714 BC. It has been utilized in silk and wool fabrics in the Middle East of Europe (89).
Lac Dye; The liquid released by the lac bug (Lauifer lacca), which inhabits the twigs of various types of plants including banyan trees, is used to make this color. They impart a red pigment because of laccaic acid, the main chemical component (90,91). In recent studies it has shown that it has affinity for cotton fabric (92). Additionally, a number of research have demonstrated the functional and antioxidant qualities of lacquer (93).
Kermes; Kermes is a red dye from an animal source that comes from the bug *Kermes licis*. In South France, Spain, England, Turkey, and Scotland, this dye has been used for centuries, to dye animal fibers (94). The coloring component, which is soluble in hot water, uses kermesic acid, an aglycon of carmine acid and flavocermesic acid, to create a red and yellowish dye (95,96). Compared to purple, it is a cheaper color.
Octopus/Cuttlefish; A dark black to sepia brown is produced from octopus. They are basically used to produce inks like octopus ink(black), cuttlefish ink(brown), squid ink(blue-black). They are no toxic in nature. They are also used in fabric industry.
Hexaplex trunculus; Between 3.6 and 0.012 million years ago, this snail species were identified on the Mediterranean and Atlantic coasts. The snail is historically important because of its hypobronchial gland secrets a mucus used to create a distinctive purple-blue indigo dye. Hexaplex trunculus is also known as *Murex trunculus, Dye Murex banded* and *Phyllonotus trunculus* (97).
Bolinas Brandaris; Originally known as the Murex brandaries, the Bolinas Brandaris is also referred to as the branders or purple dye murex. 3.6–2.6 million years ago, it was classified as a medium-sized meal. It was used by the Phoenicians in ancient times to extract imperial Tyrian purple (98)

Mineral dyes: -

Mineral dyes are dyes that have a mineral origin. These natural dyes include several colours derived from inorganic metal salts and metal oxides. The classification of mineral dye can be done based on color obtained. The most important mineral dyes are as follows (99,100)-

Red pigment- The name of some red pigments and their sources are listed below-
Cinnabar; It is also known as vermillion, a heavy reddish mineral, with a metallic adamantine luster. It is obtained from mercury sulphide (HgS). Used for red nuances.
Red Ochre; It is a naturally occuring earth pigment, also called limonite containing anhydrous and hydrated iron oxide ($Fe_2O_3.nH_2O$). Light, acids, and alkalies have little effect on the stability of ochre. Red ocher, which the monks used to dye their robes, was mostly employed in paintings and murals coupled with gum as a binding agent.
Red lead; It is called sindur. Red lead (Pb_3O_4 or 2[PbO].[PbO_2]). Indian art frequently employs this vivid red or orange crystalline or amorphous color, using this pigment. It is composed primarily of lead tetroxide (85-98%) and litharge (2-15%). Used for red nuances.

Yellow Pigments- The name of some yellow pigments and their sources are listed below-

Yellow Ochre; Different hydrated varieties of iron oxide being present, particularly the mineral limonite ($Fe_2O_3.H_2O$), is what gives yellow ochre its color. They are used in painting in fabrics like sails, natural fibers and even in synthetic polyacrylonitrile.

Raw Sienna; Raw sienna is an earth pigment that is a member of the Siena earth class and contains iron oxide and manganese oxide. It was the first pigment utilized in human cave drawings, along with ochre. Due to its high degree of transparency, it is employed as a glaze in paintings.

Orpiment; It is an arsenic sulfide mineral with a rich, vivid color that is deep orange-yellow. It is yellow sulphide of arsenic (As_2S_3) chemically. Along with being a pigment in the paper industry.

Litharge; White leads are besically roasted to create litharge (Massicot), a natural secondary mineral form of lead oxide (galena). White lead, which is actually lead carbonate ($2PbCO_3.Pb(OH)_2$) chemically, is transformed into pale yellow lead monoxide (PbO) powder during decarboxylation and dehydration at a temperature of roughly 300°C.

Green Pigments- The name of some green pigments and their sources are listed below-

Malachite; Malachite ($Cu_2(OH)_2CO_3$) is a material occurs naturally along with azurite, an intense green mineral, copper carbonate mixed with copper hydroxide. The pigment produced is a vivid, deep green. Used for green nuances (101).

Terre-Verte; Since ancient times, terre-verte has proven to be the most often utilized. It goes by the name "green earth." Other minerals are probably present as well. It is a combination of hydrosilicates of iron, magnesium, aluminum, and Potassium (gluconite and celadenite). Depending on the source, the hue of the earth is different everywhere.

Vedgiris; During the Mugal era and afterwards in miniature paintings, vedgiris was a frequently employed color in paintings. It is the typical copper acetate [$Cu(CH_3COO)_2$], and it is made by rubbing copper foils with vinegar. The pigment produced is a vivid, deep green. However, if not used cautiously, it has the drawback of charring paper or textiles (102).

Blue Pigments- The name of some blue pigments and their sources are listed below-

Ultramarine Blue; Ultramarine blue is a rich blue dye obtained from the mineral lapis lazuli. The stone is semi-precious. In India, it has been employed in textiles and miniature art.

Lapis lazuli; Also known as lapis, a blue rock consisting a mixture of azurite and calcite, pyroxenite, and other silicate minerals besides pyrite. Used for blue nuances.

Azurite; Azurite [$Cu_3(CO_3)_2(OH)_2$] is a soft, blue/dark blue copper mineral. It is produced by weathering of copper ore deposits and often found together with the green mineral malachite. Used for blue nuances in Chinese paintings and Indian paintings.

White Pigments- The name of some white pigments and their sources are listed below-

Chalk; One of the varieties of calcium carbonate ($CaCO_3$) is chalk. It is frequently utilized in paintings. Chalk has been widely used as a pigment since very ancient times and is typically found with quantities of limestone. Conch shell white is favored by artists in India and is thought to have unique qualities.

White lead; The complex salt known as white lead ($PbCO_3$) contains both carbonate and hydroxide. It occurs in nature as the mineral Cerussite. It was previously a component of lead paint. White lead is typically made artificially.

Aragonite; It is Usually colorless or white mineral. Used for white nuances.

Zinc White; Zinc white (ZnO) is another important color used in painting. Talc, Barium White, and Titanium White are other white pigments. Titanium White, also known as titanium dioxide (TiO2), is a delustrant used in textiles.

Black Pigments- The name of some black pigments and their sources are listed below-
Manganese; Manganese is a metallic element. Used for black nuances.
Charcoal Black; charcoal is used as black pigment. It is produced from woods after burning in a closed container.
Ivory Black; A closed earthen pot is used to roast ivory shavings, which are subsequently ground, washed, and dried to produce ivory black. The black is very intensely prepared. Due to environmental and animal rights concerns, it is currently unpopular.
Bone Black; Animal bones are charred in covered earthen pots to create bone black. It serves as a replacement for ivory black despite not being as vivid.
Graphite; Writing implements have historically been made of powdered graphite, a mineral that may be found across India. The pigment is a dull grey. However, drawing has been the primary use rather than painting.
Black Chalk; Black clay used in pottery and paintings is referred to as "black chalk."
Terre-noire; Terre-noire is the same as black clay. It contains clay along with calcium, iron, and manganese carbonates.

Microbial dyes: -

With the increasing demand of natural dye and the scarcity of natural sources like plant and animal, various microbial sources are used to extract dyes. Specially fungi and bacteria (103) have received particular attention for their ability to produce natural hues because of their color, stability and sustainable supply (104). Some of the sources are listed below.
Pseudomonas; It is a pigment-producing bacteria. They are responsible for producing soluble pigments like pyocyanin, pyoverdine, pyorubin and pyomelanin.
Achromobacter; They are gram negative bacteria. When the organism is cultivated in a medium that contains yeast extract and tryptophan, a red pigment is produced.
Bacillus; It is a pigment-producing gram-positive bacteria. The most commonly found pigments are yellow, brown, orange and pink.
Rhodococcus; This species has application in bioprocess technology, bioremediation, pigment synthesis and probiotics in aquaculture. Carotenoids are the pigments ranging yellow to orange color, obtained from this species.
Flavobacterium; they are the rod-shaped bacteria. Flexirubin is the main pigment found in them.
Amygdalaria panaeola**;** It is a Fungal/lichen species. It produces pigments Panaefluorolines A,B,C, which are a Isoquinoline class of compounds. Yellowish green color is obtained (105).
Aspergillus sulphureus; It is a Fungal/lichen species. It produces pigments Viopurpurin and Rubrosulfin, napthaquinone class of compounds. The imparts purple and red color.
Aspergillus glaucus; Catenarin, Erythroglaucin and Rubrocristin are the Hydroxyanthraquinone class of compounds and main component pigment in these fungi. They impart red color.
Aspergillus variecolor; the main pigment Variecolorquinone A, a quinone class of compound is found in this species. Imparts yellow color.
Aspergillus niger; Azanigerones B and Azanigerones C are the dying pigments. Comes under Azaphilones category of compounds. Pigments color is yellow (106).

Trichoderma harzianum; It is a Fungal/lichen species. Emodin and Pachybasin are the pigments found in them which are the yellow pigments (107).
Fusarium fujikuroi; Norbikaverin, Bikaverin, 8-O-methylfusarubin and b-carotene are the pigments found in thin fungi. They impart red color.
Monascus purpureus; Monapilol A, B, C, D are the pigments, Azaphilone class of compound.The color of the pigment is orange (108).
Trypethelium eluteriae; Trypethelonamide A, 5′-hydroxytrypethelone, (–)-trypethelone, (+)-trypethelone and (+)-8-hydroxy-7-Methoxytrypethelone pigments are found in this species. The pigments are Naphthoquinone class of compound. Produce violet red color (109)

- **Based on methods of application: -**

The following classes of natural dyes have been identified based on their method of application

Mordant Dyes; In an effort to boost the interaction between the dye and the fiber, mordant dyes can be bonded to materials for which they have little to no affinity. Alizarin is an important example of such a dye. Most of these types of dyes produce a variety of hues or colors depending on the mordant used.
Vat Dyes; Based on the techniques used to apply them, they are categorized. This procedure is carried out in a bucket or vat. In their colorful form, they cannot be dissolved. The category of vat dyes only includes three natural dyes, including indigo, tyrian purple and wood.
Direct Dyes; Direct dyes are organic compounds that are soluble in water that are simple to use and produce bright colors. Cellulosic, Fibres, cotton etc. Turmeric, annatto, pomegranate, safflower is example of direct dyes.
Acid Dyes; Another category of direct dyes used in an acidic media is acid dyes. Mainly carboxylic acid groups are present in them. Saffron is an example of acid dye. They ate used for polyamide fibres like silk, wool and cotton.
Basic Dyes; The salts of organic bases are basic dyes. They go by the name "cationic Dyes" as well. These colors are applied in conditions that range from mild acidic to neutral. One example of a simple dye is berberine. They are used on fabrics such as wool, silk, cotton, and modified acrylic.
Disperse Dyes; Water is not soluble in disperse dyes. Lawson, Juglone, Lapachol, and Shikonin, among other natural colors, can be categorized as disperse dyes. They are employed to color fibers made of acetate and polyester.

- **Natural dyes from waste sources**: -

With the increasing demand of natural dye and the scarcity of natural sources like plant, animal, insects, mineral and microbes various wastes materials are used to extract dyes. Different waste sources like agricultural sources, forestry sources and industrial sources are used. The environment is seriously threatened by the disposal of garbage produced as byproducts of forestry, agriculture, and industry. They are also reused by this dye yielding process.

Waste from agriculture-
Harvest-wastes such as barks, fruits, leaves, flowers, roots, woods, and seeds that provide dyes are examples of agro-wastes.
Pumpkin skin; The yellow pumpkin vegetable was collected and peel the skin of Pumpkin is isolated. The skin was then divided into small pieces, allowed to dry in the shade for 7 to 10

days, and then ground into a fine powder using a mixer grinder. This sample, which is powdered, was used in the dyeing process before being placed in an airtight container. Cotton fabric was coloured using a fixed volume of a chosen aqueous extract in each set of experiments (110).

Mango leaves; Mango leaves were gathered for the extraction process. Mangiferin (1,3,6,7-tetrahydroxyxanthone-C-2-D-glucoside) is the substance that gives mango leaves their color (111).

Almond shell; Almond (*Prunus dulcis*), a shrub belongs to the family Rosaceae. The main flavonoids in almond shells, which are also high in lignin and other phenolic compounds, include (+)-catechin, ()-epicatechin, kaempferol, and isohamnetin (112). With the metallic mordants, rose, cinnamon, brown and burgundy/reddish colors were produced in the wool fiber, whereas the bio-mordants produced entirely distinct hues (113). Silk has been dyed using an almond shell aqueous extract (114).

Groundnut/Peanut skin; Groundnut/ Peanut skin (*Arachis hypogaea*), comes under Fabaceae family. Vanillin, catechin, and epicatechin (polyphenolic chemicals) are the three primary coloring agents found in peanut skin (115). Aqueous extract of peanut skin has been used to dye silk, cotton and wool (116).

Banana; The plant *Musa acuminata* is evergreen. Tetrahydroxyflavone (flavonoids), also referred to as luteolin, and certain tannins are present as coloring agents (117). Used for dying natural fibers.

Waste from forestry-

Forestry operations can produce enormous amounts of waste that can be used for textile coloring, including bark, fallen branches, fruits, and leaves.

Tamarind seeds; The leaves and seeds of tamarind (*Tamarindus indica*) are used to extract dye. They yield Yellow, brown color. This water soluble dye can be used to dye the cotton and silk fabrics.

Walnut shells; Walnut (*Juglans regia*) comes under family Juglandaceae. Juglone (CI 75500), a napthoquinone (5hydroxy-1, 4-napthoquinone) that gives textile substrates a brown tint, is the coloring agent found in walnut shell (118).

Jack fruit tree; Jack fruit tree (*Atrocarpus heterophyllus*) bark is used to get yellow color.

Eucalyptus; Bark of eucalyptus (Eucalyptus Camaldulensis) tree is used to get Yellow and brown color and has been used for the coloring purposes of cotton (119).

Waste from industry-

It is necessary to look into fresh sources of natural dyes because of the rising demand for natural colorants. The food business generates significant amounts of solid and liquid waste that could be contaminants and have disposal issues, but could also be a source of natural color. A source for natural coloring wool fibers could be found in a few studies on how to make the utilization of plant waste from the food and beverage sector (120).

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CONCLUSION: -

Natural dyes or colorants are one of the best options to the textile industries. This review tries to give a brief detail on natural dyes, their classifications, their resources and their applications. Though there are so many difficulties with natural dyes like poor fastness, less durability etc but intended to be a cheap, biodegradable, renewable, non-toxic and sustainable resource. Moreover, the unique and organic qualities of natural dyes add value and aesthetic appeal to products, fostering a connection to nature and cultural heritage. To improve the quality of natural dye, we need higher research and industrial involvements. The textile industry has witnessed a renewed focus on natural dyes as a means to achieve eco-friendly and socially responsible production processes. Due to the limited industry of natural dyes and their purification process, previously only about 1% of textiles were dyed with them, largely in the cottage industry by traditional artisans, enthusiasts, and small business owners. But now different manufacturer from India, China, United States are cooperating and trying to build this industry. Utilization of natural dyes are steadily earning acceptance on the international market, and the creation of textiles that are eco-friendly and organically dyed is a great method to protect the environment from harmful synthetic dyes. Not only in the textile industry, the applications of natural colorants have strong potential and a promising future in a few applied sectors like leather, food, pharmaceutical, cosmetics and paint industries etc. Dyes from different waste sources have become a source of potential natural dyes. Natural dyes can compete with synthetic dyes as an eco-friendly approach for the environmentally concerned users at the current stage of scientific development. But in future it will cover the small-scale as well as large scale applications.

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References: -

1. Sara Kadolph, Natural Dyes: A Traditional Craft Experiencing New Attention, The Delta Kappa Gamma Bulletin, 2008, page no:14

2. K. Agarwal, Application of natural dyes on textiles, Indian Journal of Fibre & Textile Research, 34, 2009, 384-399,mma Bulletin, 2008, page no:14.

3. Bechtold T, Mussak R, Mahmud-Ali A, Ganglberger E, Geissler S. Extraction of natural dyes for textile dyeing from coloured plant wastes released from the food and beverage industry. Journal of the Science of Food and Agriculture. 2006;86:233-242

4. Adeel S, Ali S, Bhatti I, Zsila F. Dyeing of cotton fabric using pomegranate (Punica granatum) aqueous extract. Asian Journal of Chemistry. 2009;21(5):3493-3499

5. Rowell RM. The use of biomass to produce bio-based composites and building materials. Woodhead Publishing Limited; 2014.

6. Singh, Y., Paswan, S. K., Kumar, R., Otia, M. K., Acharya, S., Kumar, D., & Keshamma, E. (2022). Plant & Its Derivative Shows Therapeutic Activity on Neuroprotective Effect. *Journal for Research in Applied Sciences and Biotechnology*, *1*(2), 10-24.

7. Gunti R and Atluri RP. Study on Effect of Chemical Treatments and Concentration of Jute on Tensile

Properties of Long and Continuous Twisted Jute/Polypropylene Composite. Advanced Materials Manufacturing and Characterization, 2013, 3: 395-398.

8. Das, S., and Natarajan, G. (2019). "Silk fiber composites in biomedical applications," in Materials for Biomedical Engineering, eds V. Grumezescu and A. Mihai Grumezescu (Elsevier), 309-338. doi: 10.1016/B978-0-12-816872-1.00011-X

9. Yuan, Q., Yao, J., Chen, X., Huang, L., and Shao, Z. (2010). The preparation of high-performance silk fiber/fibroin composite. Polymer (Guildf). 51, 4843–4849. doi: 10.1016/j.polymer.2010.08.042 &sclient=gws-wiz-serp

10. Kumar, R., & Saha, P. (2022). A review on artificial intelligence and machine learning to improve cancer management and drug discovery. *International Journal for Research in Applied Sciences and Biotechnology*, *9*(3), 149-156.

11. Praveenkumar J, Sunder Raj N, Chandan H R, Srivathsa Marathe, Madhu P, "Natural fibres and its composites for engineering applications: An Overview", 2017. -AEB-AECqAIU4gMEGAAgQYgGAboGBggBEAEYCw&sclient=gws-wiz-serp

12. Banik, S., Basak,M. K., Paul,D.,Nayak, P., Sardar,D., Sil, S. C., et al. (2003). Ribbon retting of jute - a prospective and eco-friendly method for improvement of fibre quality. Ind. Crops Prod. 17,183–190. doi: 10.1016/S0926-6690(02)00097-3 &sclient=gws-wiz-serp

13. Behera, A. K., Avancha, S., Basak, R. K., Sen, R., and Adhikari, B. (2012). Fabrication and characterizations of biodegradable jute reinforced soy based green composites. Carbohydr. Polym. 88, 329–335. doi: 10.1016/j.carbpol.2011.12.023

14. Charlet, K., Jernot, J. P., Breard, J., and Gomina, M. (2010). Scattering of morphological and mechanical properties of flax fibres. Ind. Crops Prod. 32, 220–224. doi: 10.1016/j.indcrop.2010.04.015

15. Angelini, L. G., and Tavarini, S. (2013). Ramie [Boehmeria nivea (L.) Gaud.] as a potential new fibre crop for the Mediterranean region: growth, crop yield and fibre quality in a long-term field experiment in Central Italy. Ind. Crops Prod. 51, 138–144. doi: 10.1016/j.indcrop.2013.09.009

16. Ramesh, M. (2019). Flax (Linum usitatissimum L.) fibre reinforced polymer composite materials: a review on preparation, properties and prospects. Prog. Mater. Sci. 102, 109–166. doi: 10.1016/j.pmatsci.2018.12.004

17. Girijappa YG, Rangappa SM, Parameswaranpillai V, Siengchin S. Natural fibers as sustainable and renewable resource for development of Eco-friendly composites: a comprehensive review. Front. Mater 2019;2:226. https:// doi.org/10.3389/fmats.2019.00226.

18. Cengiz, T. G., and Babalik, F. C. (2009). The effects of ramie blended car seat covers on thermal comfort during road trials. Int. J. Ind. Ergon. 39, 287–294. doi: 10.1016/j.ergon.2008.12.002

19. Marsyahyo, E., Jamasri, H. S. B., and Soekrisno (2009). Preliminary investigation on bulletproof panels made from ramie fiber reinforced composites for NIJ Level II, IIA, and IV. J. Ind. Text. 39,13–26. doi: 10.1177/1528083708098913

20. Hamidon, M. H., Sultan, M. T. H., Ariffin, A. H., and Shah, A. U. M. (2019). Effects of fibre treatment on mechanical properties of kenaf fibre reinforced composites: a review. J. Mater. Res. Technol. 8, 3327–3337. doi: 10.1016/j.jmrt.2019.04.012

21. Mihai, M. (2013). Novel polylactide/triticale straw biocomposites : processing, formulation, and properties. Polym. Eng. Sci. 54. doi: 10.1002/pen.23575

22. Ramesh, M., Palanikumar, K., and Reddy, K. H. (2013). Mechanical property evaluation of sisal-jute-glass fiber reinforced polyester composites. Compos. Part B Eng. 48, 1-9. doi: 10.1016/j.compositesb.2012.12.004

23. CHOURASIA, A., & KUMAR, R. Investigation Of Anti-Ulcer Activities By Using Indomethacine Induced & Cold-Water Restraint Procedure In Experimental Rat: Meta Analysis.

24. Kumar, R. S., Singh, A. P., & Singh, A. (2022). A Meta Analysis on Cardiac Vascular Disease with Obesity. *Journal for Research in Applied Sciences and Biotechnology*, *1*(3), 78-85.

25. Arunachalam, V. (2012). Date palm. Genomics Cultiv. Palms, 49–59. doi: 10.1016/B978-0-12- 387736-9.00004-2

26. Dhaliwal JS. Natural fibers: applications. In: Development and modifications of natural fibers. Interchopen; 2020 &sclient=gws-wiz-serp

27. Cheung, H., Ho, M., Lau, K., Cardona, F., and Hui, D. (2009). Natural fibre-reinforced composites for bioengineering and environmental engineering applications. Compos. Part B Eng. 40, 655– 663. doi: 10.1016/j.compositesb.2009.04.014

28. Tye, Y. Y., Lee, K. T., Wan Abdullah, W. N., and Leh, C. P. (2012). Potential of Ceiba pentandra (L.) Gaertn. (Kapok fiber) as a resource for second generation bioethanol: effect of various simple pretreatment methods on sugar production. Bioresour. Technol. 116, 536–539. doi: 10.1016/j.biortech.2012.04.025

29. Dong, T., Xu, G., and Wang, F. (2015). Adsorption and adhesiveness of kapok fiber to differentoils. J. Hazard. Mater. 296, 101–111. doi: 10.1016/j.jhazmat.2015.03.040

30. Oksman K, Aitom€aki Y, Mathew AP, Siqueira G, Zhou Q, Butylina S, et al. Review of the recent developments in cellulose nanocomposite processing. Compos. Part A Appl Sci Manuf 2016;83:2e18. https://doi.org/10.1016/ j.compositesa.2015.10.041

31. Gupta US, Dhamarikar M, Dhakar A, Tiwari S, Namdeo R. Study on the effects of fibre volume percentage on bananareinforced epoxy composite by finite-element method. Adv Compo Hybrid

32. Raj, R., Kumar, A., Sood, P., Kumar, R., & Rana, V. (2023). Randomized Phase III Trial Comparing Epirubicin/Doxorubicin Plus Docetaxel and Epirubicin/Doxorubicin Plus Paclitaxel as First Line Treatment in Women with Advanced Breast Cancer. *Journal for Research in Applied Sciences and Biotechnology*, *2*(3), 55-63.

33. Kumar, R., Sood, P., Rana, V., & Prajapati, A. K. (2023). Combine Therapy of Gallic Acid and Allicin in Management of Diabetes. *Journal for Research in Applied Sciences and Biotechnology*, *2*(3), 91-99.

34. Bacci, L., Baronti, S., Predieri, S., and di Virgilio, N. (2009). Fiber yield and quality of fiber nettle(Urtica dioica L.) cultivated in Italy. Ind. Crops Prod. 29, 480–484. doi:10.1016/j.indcrop.2008.09.005

35. Mortazavi, S. M., and Moghaddam, M. K. (2010). An analysis of structure and properties of a natural cellulosic fiber (Leafiran). Fibers Polym. 11, 877–882. doi: 10.1007/s12221-010-0877-z

36. Begum, S.; Fawzia, S.; Hashmi, M.S.J. Polymer matrix composite with natural and synthetic fibres. Adv. Mater. Process. Technol. 2020, 6, 547–564.

37. Pat AM, Gonz´alez AV and Franco PJH. Effect of Fiber Surface Treatments on the EssentialWork Offracture of HDPEContinuous Henequen Fiber-Reinforced Composites. Polymer Testing, 2013, 32(6): 1114-1122. https://doi.org/10.1016/j.polymertesting.2013.06.006

38. Shinoj S, Visvanathan R, Panigrahi S, et al. Oil Palm Fiber (OPF) and its Composites: A Review. Industrial Crops and Products, 2011, 33(1): 7-22. https://doi.org/10.1016/j.indcrop.2010.09.009

39. Uddin N. Developments in Fiber-Reinforced Polymer (FRP) Composites for Civil Engineering, inWoodhead Publishing Series in Civil and Structural Engineering, Birmingham, Woodhead Publishing, 2013: 558. https://doi.org/10.1533/9780857098955

40. Saravanan P, Chandramohan G., MariajancyraniJ., Shanmugasundaram P.,Extraction and application of EcoFriendly Natural dye obtained from Leaves of Acalypha indica Linn on Cotton Fabric, International research journal of environment science. Vol 2 (12),1 –5, December (2013).

40. C. Ahn, S.K. Obendorf, Text. Res. J. 74(11), 949–954 (2004)

41. I. Good, Ann. Rev. Anthropol. 30, 209–226 (2001)

42. H. Schweppe, Practical Hints on Dyeing with Natural Dyes: Production of Comparative Dyeings for the Identification of Dyes on Historic Textile Materials (Conservation Analytical Laboratory, Smithsonian Institution, Washington, DC, 1986)

43. A.G. Perkin, A.E. Everest, The Natural Organic Colouring matters (Longmans Green and Co., London, 1918)

44. P. John, L.G. Angelini, Indigo-agricultural, in Handbook of Natural Colorants, ed. by T. Bechtold, R. Mussak (Wiley, Chichester, 2009), pp. 75–103

45. P. John, Indigo-extraction, in Handbook of Natural Colorants, ed. by T. Bechtold, R. Mussak(Wiley, Chichester, 2009), pp. 105–133

46. P. Garcia-Macias, P. John, J. Agric. Food Chem. 52(26), 7891–7896 (2004)

47. S. Dharmananda, New Uses of Berberine, A Valuable Alkaloid from Herbs for '"Damp- Heat"' Syndromes (2005). http://www.itmonline.org/arts/berberine.htm. Accessed 4 Aug 2016

48. M. Leona, J.R. Lombardi, J. Raman Spectroscopy. 38(7), 853–858 (2007) 49.

C. Ahn, X. Zeng, S.K. Obendorf, Text. Res. J. 82(16), 1645–1658 (2012)

50. G. Ke, W. Yu, W. Xu, J. Appl. Polymer Sci. 101(5), 3376–3380 (2006)

51. D.M. Niedzwiedzki, D.J. Sandberg, H. Cong, M.N. Sandberg, G.N. Gibson, R.R. Birge et al., Chem.Phys. 357(1), 4–16 (2009)

52. U.G. Chandrika, Carotenoid dyes-properties, in Handbook of Natural Colorants, ed. by T. Bechtold, R. Mussak (Wiley, Chichester, 2009), pp. 221–236

53. R.H. Thomson, in Chemistry and Biochemistry of Plant Pigments, ed. by T.W. Goodwin (Academic Press, New York, 1976), pp. 527–559

54. S.A. Khan, A. Ahmad, M.I. Khan, M. Yusuf, M. Shahid, N. Manzoor et al., Dyes Pigments. 95(2),206–214 (2012)

55. A.G. Perkin, A.E. Everest, The Natural Organic Colouring matters (Longmans Green and Co., London, 1918)

56. K. Markham, Techniques of Flavonoid Identification (Academic Press, London, 1982)

57. F. Mayer, A.H. Cook, The Chemistry of Natural Coloring Matters: The Constitutions, Properties, and Biological Relations of the Important Natural Pigments (Reinhold Publishing Corp, New York, 1943)

58. M.I. Khan, A. Ahmad, S.A. Khan, M. Yusuf, M. Shahid, N. Manzoor et al., J. Clean. Prod. 19(12), 1385–1394 (2011)

59. N.F. Ali, R.S. El-Mohamedy, J. Saudi Chem. Soc. 15(3), 257–261 (2011)

60. V. Sivakumar, J.L. Anna, J. Vijayeeswarri, G. Swaminathan, Ultrasonics Sonochem. 16(6), 782– 789 (2009)

61. R. Rajendran, C. Balakumar, J. Kalaivani, R. Sivakumar, J. Text. Apparel Technol. Manag. 7(2), 1– 12 (2011)

62. M. Shabbir, S.U. Islam, M.N. Bukhari, L.J. Rather, M.A. Khan, F. Mohammad, Text. Cloth. Sust. 2(1), 1–9 (2016)

63. N. Bhattacharyya, Natural Dyes for Textiles and Their Ecofriendly Applications (IAFL Publications, New Delhi, 2010)

64. O. Korankye, Extraction and Application of plant dyes to serve as colorants for food and textiles, phd thesis, 2010.

65. Chengaiah B, Mallikarjuna Rao K, Mahesh Kumar K, Alagusundaram M, Madhusudhana Chetty C, Medicinal importance of natural dyes a review. Int. J. Pharmtech Research. 2010, 2 (1), 144-154.

66. Goodarzian, H and Ekrami E, Wool Dyeing with Extracted Dye from Pomegranate (Punica Granatum) Peel, World Appl. Sc. Journal, 2010, 8 (11), 1387-1389

67. Bechtold, T., Turcanu, A., Gangberger, E. Geissler S., 2003. Application of natural dye on textiles., journal of cleaner ptoduction , 11,499-509

68. Lal, R.A., 1995. Vegetable dye and its application on textiles. Colourage, 42(1), 55-56.

69. Tezcan, İ. and Suyunu, A. İpek Halılarda Doğal Boyarmaddeler, Tekstil ve Mühendis, 5(26) 88-97(1991)

70. Badami S, Moorkoth S, Suresh B (2004) Caesalpinia sappan, a medicinal and dying plant. Nat. Prod. Rad. 3: 75-82.

71. Ansari, T. N., Iqbal, S. and Barhanpurkar, S., “Eco-friendly Dyeing with Senegalia catechu Using Biomordant”, International Journal of Creative Research Thoughts, 2018: 6(1), 1351- 1354.

72. Abubakar, A., Okogun, J. I., Gbodi, T. A., Kabiru, Y. A., Makun, H. A., & Ogbadoyi, E. O. (2016). Evaluation of the extracts of Morinda lucida and Tridax procumbens for antitrypanosomal activity in mice. African Journal of Pharmacy and Pharmacology, 10, 107-120.

73. Bhattacharyya N (2010) Natural dyes and their eco-friendly application. IAFL, New Delhi

74. Tripathi, G., Yadav, M.K., Padhyay, P., and Mishra, S. (2015). Natural dyes with future aspects in the dyeing of Textiles: A research article. International Journal of Pharm Tech Research, 8 (1): 096-100.

75. Gulrajani ML, Gupta D (eds) (1992) Natural dyes and their application to textiles. Department of Textile Technology, Indian Institute of Technology, New Delhi

76. Mukherji A (1999) Dyeing of cotton fabric with Kigelia Pinnata, Spathodea Companulata and Carissa Congesta. In: Book of papers of the convention on natural dyes. Department of Textile Technology, IIT Delhi, New Delhi. Accessed 9–11 Dec 1999

77. Bansal, A. and Sood, A. (2006). Dyeing of silken yarns with Berberry dye. Tex. Trends, XLVIII (12):39-42.

78. Deveouglu O (2013) Marmara university, natural dye researcher.\ http://mimoza.marmara.edu.tr/*ozan.deveoglu/A13.pdf. Accessed 20 Dec 2013

79. Deng Q, Penner MH, Zhao Y. Chemical composition of dietary fiber and polyphenols of five different varieties of wine grape pomace skins. Food Research International. 2011;44:2712- 2720

80. Baaka N, Ticha MB, Haddar W, Amorim MTP, Mhenni MF. Upgrading of UV protection properties of several textile fabrics by their dyeing with grape pomace colorants. Fibers and Polymers. 2018;19(2):307-312

81. Gulrajani ML, Bhaumik S, Oppermann W, Hardtmann G (2003) Dyeing of red sandal wood on wool and nylon. Ind J Fib Text Res 28(2):221–226

82. Zvi C. Koren, The First Optimal All-Murex All- Natural Purple Dyeing in the Eastern Mediterranean in a Millennium and a Half, Dyes in History and Archaeology 20, pp. 136–149, Color Plates 15.1–15.5(Archetype Publications, London).

83. Serrano, A., Sousa, M.M., Hallett, J., Lopes, J.A. and Oliveira, M.C., “Analysis of Natural Red Dyes (Cochineal) in Textiles of Historical Importance Using Hplc and Multivariate Data Analysis”. Anal Bioanal Chem, 401(2) 735-43 (2011)

84. Khan, Z.H., Mamun, R.A. and Hasan, R., “Dye- Sensitized Solar Cell Using Used Semiconductor Glass and Natural Dye: Towards Alternative Energy Challenge”. International Journal of Renewable Energy Research, 5(2) 38-44 (2015)

85. Serrano, A., Sousa, M., Hallett, J., Simmonds, M.S., Nesbitt, M. and Lopes, J.A., “Identification of Dactylopius Cochineal Species with High- Performance Liquid Chromatography and Multivariate Data Analysis”. Analyst, 138(20) 6081-90 (2013)

86. Lech, K. and Jarosz, M., “Identification of Polish Cochineal (Porphyrophora Polonica L.) in Historical Textiles by High-Performance Liquid Chromatography Coupled with Spectrophotometric and Tandem Mass Spectrometric Detection”. Anal Bioanal Chem, 408(12)3349-58 (2016)

87. Maynez-Rojas, M.A., Casanova-Gonzalez, E. and Ruvalcaba-Sil, J.L., “Identification of Natural Red and Purple Dyes on Textiles by Fiber-Optics Reflectance Spectroscopy”. Spectrochim Acta A Mol Biomol Spectrosc, 178 239-250 (2017)

88. Deveoglu, O., Torgan, E. and Karadag, R., “Characterization of Colouring Matters by Hplc- Dad and Colour Measurements, Preparation of Lake Pigments with Ararat Kermes”. Journal of Chemistry, 5 307-316 (2010)

89. Karapanagiotis, I. and Karydis, C., “Identification of Cochineal and Other Dyes in Byzantine Textiles of the 14th Century from Mount Athos”. Mediterranean Archaeology and Archaeometry, 16 7 (2016)

90. Lluveras-Tenorio, A., Parlanti, F., Degano, I., Lorenzetti, G., Demosthenous, D., Colombini, M.P. and Rasmussen, K.L., “Spectroscopic and Mass Spectrometric Approach to Define the Cyprus Orthodox Icon Tradition - the First Known Occurrence of Indian Lac in Greece/Europe”. Microchemical Journal, 131 112-119 (2017)

91. Sharma, K.K., “Lac Insects and Host Plants”, in Industrial Entomology springer. p. 157-180 (2017)

92. Rastogi D, Gulrajani ML, Gupta P (2000) Application of lac dye on cationised cotton. Colorage 47(4):36–40

93. Zhang, H., Fang, G.G., Zheng, H., Guo, Y.H. and Li, K., “Study on the Antioxidation of Lac Dye”. Applied Mechanics and Materials, 140 451-458 (2011)

94. Al-Ghadeer, H.A., “Acute Ocular Complications from Self-Administered Topical Kermes”. Middle East Afr J Ophthalmol, 17(4) 382-386 (2010)

95. Doménech-Carbó, A., Doménech-Carbó, M.T., Calisti, M. and Maiolo, V., “Identification of Naphthoquinonic and Anthraquinonic Dyes Via Sequential Potential Steps Applied to the Voltammetry of Microparticles Methodology”. Journal of Solid State Electrochemistry, 14(3) 465- 477 (2009)

96. Yurdun, T., Karadag, R., Dolen, E. and Mubarak, M.S., “Identification of Natural Yellow, Blue, Green and Black Dyes in 15th–17th Centuries Ottoman Silk and Wool Textiles by Hplc with Diode Array Detection”. Reviews in Analytical Chemistry, 30(3- 4)(2011

97. Oliver, A.V., “An Ancient Fishery of Banded Dye- Murex (Hexaplex Trunculus): Zooarchaeological Evidence from the Roman City of Pollentia (Mallorca, Western Mediterranean)”. Journal of Archaeological Science, 54 1-7 (2015)

98. Mantzouris, D. and Karapanagiotis, I., “Identification of Indirubin and Monobromoindirubins in Murex

Brandaris”. Dyes and Pigments, 104 194-196 (2014)

99. Agarwal OP, Tiwari R (1989) Mineral pigments of India. In: Compendium of the national convention of natural dyes. National Handloom Development Corporation, Lucknow, Jaipur. Accessed 20–21 Oct 1989

100. A volume in Woodhead Publishing Series in Textiles, pp. 141–166. Singh, K. and Parmar, S.S. (1998). Are natural dyes safer than synthetic dyes? Textile Trends XL (11): 23-27.

101. G. otterstatter, Part I, 228-245, Dragoco Report, 1 (1997) 5-27.

102. Rosenberg, Characterization of historic al organic dyestuffs by liquid chromatography –mass spectrometry, Analytical bioanol chemi. Journal, 391, 2008, 33-57.

103. Joshi VK, Attri D, Bala A, Bhushan S (2003) Microbial pigments. Indian J Biotechnol 2:362–369

104. Durán, N., Teixeira, M. F., De Conti, R., and Esposito, E. (2002). Ecological-friendly pigments fromfungi. Crit. Rev. Food Sci. 42, 53–66. doi: 10.1080/10408690290825457

105. Kinoshita, K., Yamamoto, Y., Koyama, K., Takahashi, K., and Yoshimura, I. (2003). Novel fluorescent isoquinoline pigments, panaefluorolines A–C from the cultured mycobiont of a lichen, Amygdalaria panaeola. Tetrahedron. Lett. 44, 8009–8011. doi: 10.1016/j.tetlet.2003.08.109

106. Zabala, A. O., Xu, W., Chooi, Y.-H., and Tang, Y. (2012). Discovery and characterization of a silentgene cluster that produces azaphilones from Aspergillus niger ATCC 1015 reveal a hydroxylation-mediated pyran-ring.

107. Lin, Y.-R., Lo, C.-T., Liu, S.-Y., and Peng, K.-C. (2012). Involvement of pachybasin and emodin inself-regulation of trichoderma harzianummycoparasitic coiling. J. Agr. Food Chem. 60, 2123– 2128. doi: 10.1021/jf202773y

108. Hsu, Y.-W., Hsu, L.-C., Liang, Y.-H., Kuo, Y.-H., and Pan, T.-M. (2011). New bioactive orange pigments with yellow fluorescence from Monascus-fermented dioscorea. J. Agr. Food Chem. 59, 4512–4518. doi: 10.1021/jf1045987

109. Basnet, B.B., Liu, L., Zhao, W., Liu, R., Ma, K., and Bao, L. (2019). New 1, 2-naphthoquinone- derived pigments from the mycobiont of lichen Trypethelium eluteriae Sprengel. Nat. Prod. Res. 33, 2044–2050. doi: 10.1080/14786419.2018.1484458

110. Mr. G. Karthikeyan and Dr. A.K. Vidya.2020, Production and Application of Natural Dye from Skin of Yellow Pumpkin Vegetable. Int J Recent Sci Res. 11(03), pp. 37828-37839. DOI: http://dx.doi.org/10.24327/ijrsr.2020.1103.5188

111. Luo, F, Lv, Q, Zhao, Y, Hu, G, Huang, G, Zhang, J, et al. (2012). Quantification and purification of mangiferin from Chinese mango (Mangifera indica L.) cultivars and its protective effect on human umbilical vein endothelial cells under H2O2-induced stress. Int J Mol Sci, 13, 11260– 11261. doi:10.3390/ijms130911260.

112. Esfahlan AJ, Jamei R, Esfahlan RJ. The importance of almond (Prunus amygdalus L.) and is by-products. Food Chemistry. 2010;120(2):349-360

113. Erdem IO, Leyla Y, Esen O. Use of almond shell extracts plus biomordants as effective textile dye. Journal of Cleaner Production. 2014;70:61-67

114. Deepali S, Shraddha N. A study on dyeing of silk fabric with almond shells (P. amygdalus L.) waste. International Journal of Research. 2017;4(5):921-935

115. Helmy HM, Kamel MM, Hagag K, El-Hawary N, El-Shemy NS. Antimicrobial activity of dyed wool fabrics with peanut red skin extract using different heating techniques. Egyptian Journal of Chemistry. 2017;Special Issue:103-116

116. Pandey R, Shweta P, Pandit P, Shanmugam N, Jose S. Colouration of textiles using roasted peanut skin—An agro processing residue. Journal of Cleaner Production. 2018;172:1319-1326

117. Repon MR, Mamun MA, Islam MT. Eco-friendly cotton coloration using banana (Musa sapientum) waste: Optimization of dyeing temperature. Universal Journal of EngineeringScience. 2016;4(1):14-20

118. Shahmoradi GF, Shams NA, Majid MS, Daryoush A, Javad M. The effect of mordant salts on antibacterial activity of wool fabric dyed with pomegranate and walnut shell extracts. Coloration Technology. 2012;128:473-478

119. Rossi T, Silva PMS, De Moura LF, Araujo MC, Brito JO, Freeman HS. Waste from eucalyptus wood steaming as a natural dye source for textile fibers. Journal of Cleaner Production. 2017;143:303-310

120. Bechtold T, Mahmud-Ali A, Mussak R. Anthocyanin dyes extracted from grape pomace for thepurpose of textile dyeing. Journal of the Science of Food and Agriculture. 2007;87:2589-2595