Application of Natural Dyes in the Textile Industry

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Abstract

Natural dyes in the textile industry are obtained from plant, animal, mineral origin and microorganisms. The main purpose of the scientific article is to present application of natural dyes in the textile industry. The methods used in writing the scientific article are descriptive-analytical method, systematic approach, study of the works of authors, comparative analysis, method of observation, induction, deduction. In the study regarding the application of natural dyes for the textile industry, it was established that they have been successfully applied to various textile fabrics of natural origin - cotton, silk, wool, linen. The scientific article highlights the advantages and disadvantages of natural dyes for the textile industry, which are important for their real implementation in practice. Some of the main disadvantages of natural dyes for the textile industry create difficulty in their use, which is an opportunity for new scientific research to help overcome the indicated disadvantages.

Keywords: dyes, natural dyes, textile industry

JEL Code: Q19

Introduction

The use of natural dyes for textile dyeing purpose decreased to a large extent after the discovery of synthetic dyes in 1856. As a result with a distinct lowering in synthetic dyestuff costs, the natural dyes were virtually neglected at the beginning of twentieth century presently there is an excessive use of synthetic dyes estimated at around 10,000,000.00 tons per annum, the production and application of which releases large amount of wastes and unfixed colorants to the environment thereby causing serious health hazards and disturbing the eco-balance of nature (Ado, et al., 2014).

The textile industry is considered one of the major environment polluting sectors, with an estimated 20% of all water pollution caused by textile treatments, such as coloration processes. In conventional textile dyeing, 1 tonne of fabric could result in the pollution of up to 200 tonnes of water. The wastewater produced in textile processes is highly colored and contains complex concentrations of chemicals, such as salt, dye, detergents, peroxides, and heavy metals. In addition to water pollution, other environmental issues emerge from the burning of fossil fuels, which result in atmospheric emissions and contribute to climate change and greenhouse gases. The United Nations' 2030 Agenda for Sustainable Development presents a broad and ambitious vision of the dimensions for social, economic, and environmental development. The goals of this vision extend to the advancement of sustainability in the textile industry, making urgent the need to rethink conventional dyeing processes and searching of ways to introduce natural dyes into the textile industry (Lara, et al., 2022).

Colour is one of the natural factors that enhances the aesthetic and exciting aspects of human life. Plants, animals, and minerals have been utilised as primary sources of dyes, colours, and pigments since ancient times. Man is always struck by the beauty of nature, which is existed with wonderful and enchanting colours. A person cannot picture his existence without colour (Alaskar and Hassabo, 2021).

Natural dyes are known to be used since historic times for coloring of textile fibers like cotton, wool and silk. However due to the advent of synthetic dyes and their good fastness properties in comparison to natural dyes, the use of natural dyes have suffered drastically. In the present time there has been a rise in concern of eco-friendliness and sustainability of the products used by the consumers for which natural dyes are again starting to experience rise in popularity (Samanta, 2020).

The main purpose of the scientific article is to present application of natural dyes in the textile industry.

The methods used in writing the scientific article are descriptive-analytical method, systematic approach, study of the works of authors, comparative analysis, method of observation, induction, deduction.

1. Definition and types of natural dyes for the textile industry

Natural dyes are multi component extracts of unknown concentrations out of which structure of only main component is determined. Natural dyes have better biodegradability and generally higher compatibility with the environment. They are non-toxic, non-allergic and non-carcinogenic as these are obtained from animals or vegetable matters without chemical processing. The main source of natural dyes are vegetables, animals and minerals. Natural dyes are colourants which can be derived from *plants*, *animals* and *minerals*; capable to dye textile and other goods (material, leather, food, medicine etc.) (Chungkrang and Bhuyan, 2020).

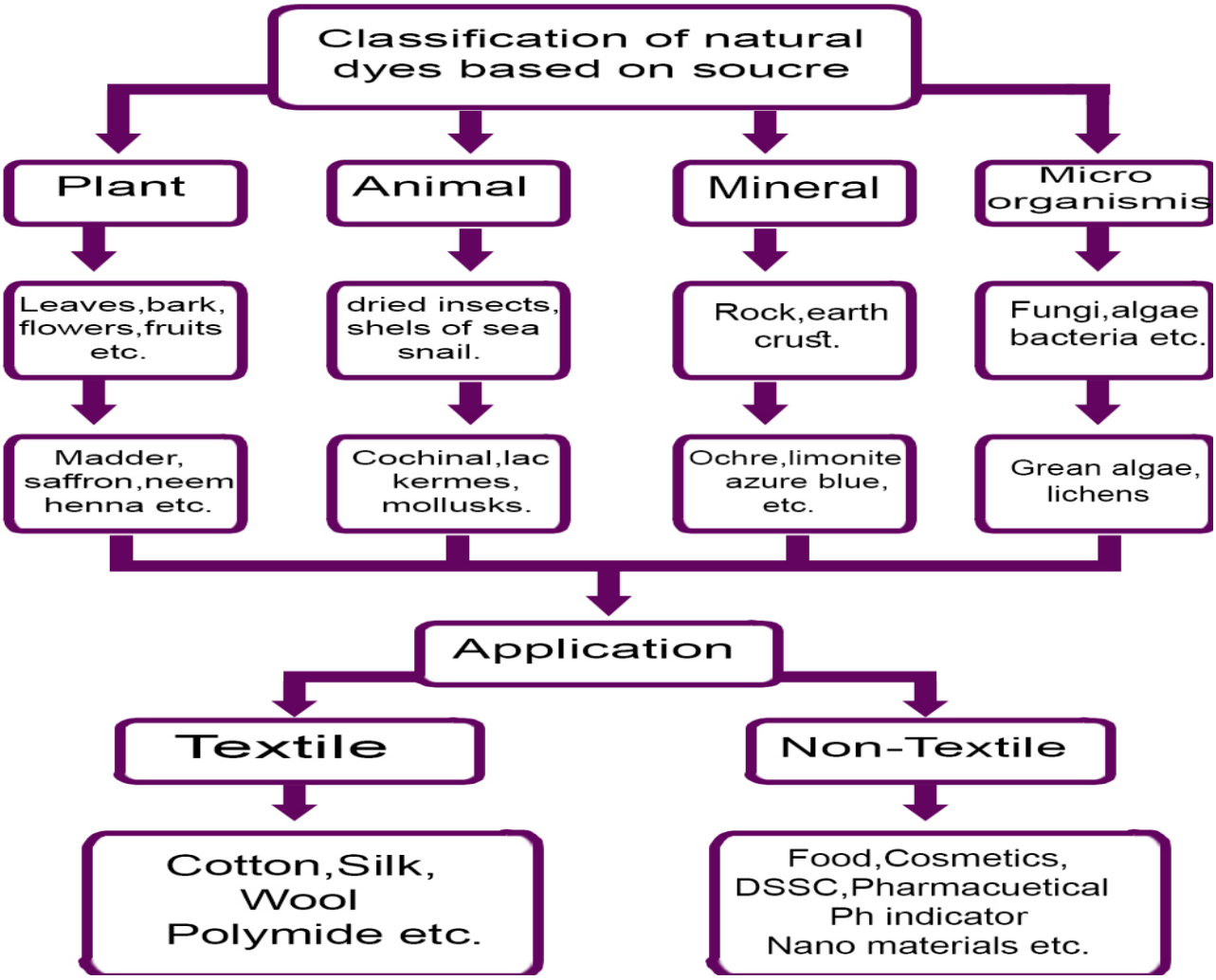

Figure 1. Classification of natural dyes based on source (Alaskar and Hassabo, 2021)

Plant dyes for textile industry

The earliest dyes were of vegetable origin, discovered by accidentally staining garments with juices of fruits or plants. Vegetable dyes are obtained from different parts of plants such as leaves, flowers, fruits, pods, bark, etc. These vegetable dyes can be applied directly or with different

mordants.

Henna: The dye is extracted from the dried leaves of the Henna plant, Lawsonia inermis. It produces yellowish-orange color. It is suitable for dyeing wool and silk fibers.

Indigo: Indigo (blue dye) is called the king of all-natural dyestuffs. It imparts blue color. It is extracted from the leaves of the leguminous plant, Indigofera tinctoria. It is suitable for dyeing cotton and wool.

Indian Madder: It produces shades of red on textile fabrics. It is used for dyeing cotton and woolen fabrics. It is extracted from the roots of Rubia tinctoria.

Turmeric: It produces shades of yellow on fabrics. It is suitable for dyeing cotton, silk, and wool. The yellow dye is extracted from the ground root (rhizome) of the turmeric plant (Curcuma longa).

Marigold: It is extracted from lemon or orange-colored marigold (Calendula officinalis) flower. It is suitable for dyeing both silk and wool fibers.

Tea: Leaves of tea plants (Camellia sinensis) or tea powder is used to extract the dye. It produces different shades of brown.

Onion: The dye is extracted from the outermost skin or peel of the onion (Allium cepa). The onion skins if properly dried can be used for one year.

Senegalia catechu: The dye is extracted from the resin. The sticky substance from the plant of the acacia tree. It produces shades of brown.

Fustic: Old fustic, or yellowwood, is derived from the heartwood of dyer's mulberry, a large, tropical American tree (Chlorophora tinctoria, or Maclura tinctoria) of the mulberry family, Moraceae. The dye produces yellows on wool mordanted (fixed) with chromium salts.

Logwood: It may also refer to members of the genus Xylosma, part of the willow family. The dye is extracted from the core heart of the logwood tree, it creates black color.

Saffron: It is a spice derived from the flower of Crocus sativus, commonly known as the "saffron crocus". The dye is extracted from stigmas of the common crocus.it produces from yellow color (Tamilarasi and Banuchitra, 2021).

Animal dyes for textile industry

The red-mouthed rock shell was one of the main sources of Tyrian purple and the study blames its collapse on rising sea temperature. Phoenician purples and BIBLICAL BLUES are the most royal and sacred of all ancient dyeing were produced from Levantine sea snails of the family Muricidae. These mollusks may have been in use for the production of the royal purple pigment.

Cochineal: Cochineal dye is extracted from the dried bodies of the female red bug (Dactylopius coccus). It produces crimson and scarlet colors with mordants aluminum and tin oxide. This dyestuff was mostly used for dyeing wool and silk. These dyes exhibit excellent fastness properties.

Tyrian Purple: This dye is extracted from the sea snails found in the Mediterranean Sea. The amount of dye produced was very limited and therefore very expensive. Hence, it is called Royal purple.

Lac Dye: This dye is extracted from the fluid secreted by the lac insect (Lauifer lacca), which lives on the twigs of the banyan trees and other varieties (Tamilarasi and Banuchitra, 2021).

Mineral dyes for textile industry

Mineral dyes are obtained from an impure earthy ore of iron or ferruginous clay, usually red or yellow. Some natural dyes is present in nature as natural form like *cinnabar, red ochre, yellow ochre, raw sienna, malachite, ultramarine blue, azurite, gypsum, talc, charcoal black* etc. *Red Pigments Cinnabar*, *Red Ochre*, *Red lead* and *Realgar* are some of the examples of red pigments originate from minerals. *Red Ochre (Geru)* is a natural earth pigment. *Red lead (Sindur)* is a bright red or orange crystalline or amorphous pigment has been used in Indian paintings in abundance.

Yellow Pigments Yellow Ochre (Ram Raj), Raw Sienna, Orpiment and *Litharge (Massicot)* are classified in yellow pigments due to their yellow color range (Singh, et al., 2020).

Microbial dyes for textile industry

Some bacteria produce coloured substances as secondary metabolites. *Bacillus, Brevibacterium, Flavobacterium, Achromobacter, Pseudomonas, Rhodococcus spp*. are some of the pigment-producing bacteria. Microbes as a dye source offer an advantage as these can be easily grown on cheap substrates under controlled conditions. The dyeing of nylon with prodigiosin pigment extracted from *Serratia marcescens* was attempted. Pigments from the fungus *Monascus purpureus* are used for coloration of some traditional oriental food items. It has been used for fabric coloration also. *Trichoderma sp*. has been used for coloration of silk and wool with excellent washing fastness. Orchil dye from lichens was used to create violet and purple shades as a cheap alternative to costly purple dye from molluscs. They have also been used to dye wool to shades of yellow, brown, and reddish brown (Singh, et al., 2020).

2. Advantages and disadvantages of natural dyes for textile industry

Advantages of natural dyes for the textile industry are the following:

1. *Minimal impact on environment*: As of natural origin, natural dyes are not harmful to the environment. Natural dyes are biodegradable and disposing them do not create pollution.

2. *Renewable*: Natural dyes are obtained from renewable sources assuring no harm to the environment.

3. *Chemical reactions*: No or little chemical reactions are involved during dye preparation.

4. *Easy to extract and purify.*

5. *Disposal*: No disposal problems.

6. *Natural shades*: If you're going for a soft hue or soothing shade, natural dyes can help you achieve that look. Colours produced by natural dyes are usually soft, lustrous and soothing to the eyes

7. *Safe*: Non-toxic, non-allergic and non-carcinogenic natural dyes as these are obtained from animals or plants without any chemical processing (Affat, 2021; Chungkrang, et al., 2021).

Disadvantages of natural dyes for the textile industry are the following:

1. *Cost*: A larger amount of natural dyes may be needed in order to dye a specific amount of fabric as opposed to synthetic dyes. Using natural dyes is more expensive than synthetic dyes.

2. *Standardization*: Difficult to standardize and to blend. Non-standardized color recipes and methods

3. *Poor brightness and fastness properties*: Color pay-off from natural dyes tends to fade quickly. The quality may not be as consistent as what synthetic dyes can deliver.

4. *Availability*: Another issue with natural dyes is their availability. It can be difficult to produce because the availability of raw materials can vary from season to season, place, and species, whereas synthetic dyes can be produced in laboratories all year round.

5. *Fixation*: Inadequate degree of fixation.

6. *Lengthy dyeing procedure*.

7. *Reproducibility*: Poor reproducibility of shade

8. *Solubility*: Poor solubility in water and tedious extraction procedure may be necessary.

9. *Harmful Effects*: Natural dyes can also be harmful to some extent. Natural dyes may need mordants for application. While these substances help the dye stick to fabrics, they can also be toxic

10. *Application*: Applicable to natural fibers only (cotton, wool, silk and linen) (Affat, 2021; Chungkrang, et al., 2021).

For better systematization and visualization, the advantages and disadvantages of natural dyes for the textile industry are presented in Table 1.

Table 1. Advantages and disadvantages of natural dyes for textile industry

№	Advantages (+)	Disadvantages (-)
1	Minimal impact on environment	Using natural dyes is more expensive than synthetic dyes.
2	Renewable	Difficult to standardize and to blend. Non-standardized color recipes and methods
3	No or little chemical reactions are involved during dye preparation.	Poor brightness and fastness properties
4	Easy to extract and purify	Absence of their permanent availability
5	No disposal problems.	Inadequate degree of fixation
6	Colours produced by natural dyes are usually soft, lustrous and soothing to the eyes	Lengthy dyeing procedure
7	Safe (Non-toxic, non-allergic and non-carcinogenic)	Poor reproducibility of shade
8		Poor solubility in water and tedious extraction procedure
9		Natural dyes may need mordants for application. These substances help the dye stick to fabrics, they can also be toxic.
10		Applicable natural fibers only (cotton, wool, silk and linen)

Important advantages of natural dyes for the textile industry is that they are renewable, have no disposal problems and have a minimal impact on the environment, which is in the direction of the environmental policies of the textile industry. In addition, natural textile dyes are safe, easy to extract and purify. Little or no chemical reactions are involved in the preparation of the dyes. Colors produced from natural dyes are usually soft, shiny and soothing to the eyes, which is good for consumers.

The disadvantages of natural dyes used in the textile industry are expressed in the fact that using natural dyes is more expensive than synthetic dyes, which will create difficulty and impossibility in their implementation. In addition, the use of natural dyes in the textile industry is difficult to implement in practice due to the fact that they are non-standardized color recipes and methods, poor brightness and fastness properties, absence of their permanent availability, inadequate degree of fixation, lengthy dyeing procedure, poor reproducibility of shade and poor solubility in water and tedious extraction procedure. The indicated disadvantages make it extremely difficult to implement technologies for dyeing textile goods with natural dyes. Natural dyes may require tweezers to apply. These substances help the dye stick to the fabrics, they can also be toxic. Another disadvantage regarding the application of natural dyes is that they are applicable natural fibers only (cotton, wool, silk and linen), which further limits their use for chemical fibers.

The study of the advantages and disadvantages of natural dyes for the textile industry makes it possible to assess the extent to which new technologies, application methods can be created to increase their application to textile fibers and goods. An important point is the search for economic efficiency from the use of natural dyes for the textile industry.

3. Application of natural dyes in the textile industry

In recent years, consumer requirements have increased regarding the functionality and safety of textile materials, and it was observed the growing movement in our society towards sustainability, green and ecofriendly products. With this move, a return to natural dyes was welcome because of their properties (insect repellent, deodorizing, flame retardant, UV protection, fluorescence, antimicrobial activity, biocompatibility, biodegradability, and non-toxicity) which revolutionized the textile industry for producing ecologically and value-added textiles (Danila, et al., 2021).

In a scientific study is extract natural dye from fresh bluish purple grapes by aqueous extraction method. To get the maximum yield of natural dye from bluish grape, variation in temperatures and time was explored. The dyeing is perform on wool and cotton textile material without, with a single and a mixed mordant system. Color strength; build up properties, CIE Lab coordinates and fastness properties were measured. The results indicated the potential of extractable natural dye on both textile materials, especially on wool. It is observed that mordant dosage and dyeing temperature were the key factors for good dyeing conditions with the natural dye. Regarding fastness, washing was good on all dyeing fabrics but light fastness was not up to the mark with respect to commercial dyeing requirements (Iqbal, et al., 2022).

In article, the natural dyes are extracted and fabric dyeing is analyzed by applying dye on 100% pure cotton. At first stage extracted dye from Butea Monosperma. This dye is extracted (yellow color from Butea monosperma) with the help of boiling method. The fabric dyed with extracted dye by using alum as a mordant. The dyed fabric tested for rubbing fastness, washing fastness, perspiration fastness, etc.In conclucions established that the natural dyes along with mordant are giving better result on 100% cotton fabric for given natural dye (Daberao, et al., 2016).

Figure 2. Extraction of Dye From Butea Monosperma (Daberao, et al., 2016)

In a study, natural staining procedures have been evaluated using hybrid dyes of mango and turmeric leaves. To get rich color shades with high strength and color fastness, coloring is done by involving a number of preparation stages which include washing using Turkish Red Oil (TRO), mordanting using alum, and staining which ends with fixation using iron material (II) sulfate (tunjung), alum and lime. The results showed the appearance of dark blue (dark), greenish yellow and yellow from the staining results using mango leaf extract as a single dye, each of which was fixed using tunjung, alum and lime, while in natural coloring with turmeric extract as a single dye with all three types of fixer the same each produces shades of brown, bright yellow and cream (Samik, et al., 2018).

The colour fastness properties of the flowers of Erythrina suberosa dyed on wool were studied using combination of mordants such as lemon juice: copper sulphate, lemon juice: potassium dichromate, lemon juice: ferrous sulphate and lemon juice: stannous chloride in the ratio of 1:3, 1:2 and 3:1. Dyeing along with mordanting techniques which included pre-mordanting, simultaneous mordanting and post mordanting was carried out. Study about fastness tests of dyed clothes was undertaken. Large range of shades was obtained because of varying mordant ratios and combinations. The washing, rubbing, light and perspiration fastness of the dyed samples was also evaluated, giving fair to excellent fastness grades and this evaluation also useful for textile industries (Singh and Purohit, 2012).

In the study evaluated the effect of color and fastness properties of wool fibers dyed with R. cordifolia as a natural dye and A. catechu as an anchoring agent. The colorimetric (CIE L*a*b*) and fastness properties were considerably improved using A. catechu as a biomordant and R. cordifolia as a natural dye which may be profitably acceptable in industrial and commercial spheres. The pre-mordanting method found more overdriven effects than the meta-mordanting and post-mordanting methods overall. In order to obtain more eco-friendly and biocompatible dyeing, the current study demonstrated a cleaner approach by using A. catechu as a biomordant to minimize the pollution with substitution of metallic salts to fulfill the demand of the world in contemporary scenario. Auxochromic groups responsible for interaction of dye and wool were studied by Fourier transform infrared (FTIR) analysis of R. cordifolia extract. The surface morphology of dyed wool fiber was investigated by scanning electron microscopy (SEM) for any changes on fiber after dyeing (Yusuf, et al., 2016).

The article reflects that environmental concerns grow up due to accelerated progress in textile wet processing manufacture paved the way for ongoing interest in the progress of green production strategies for making cost-effective value added textile products. There has also been remarkable improvement in extraction techniques of natural colourants such as the invention of ultrasound or microwave assisted extraction techniques where they prove high extraction efficiency over the traditional techniques. The utilization of enzymes in extraction of natural colourants is an example of industrial biotechnology, which allows the progress of environmentally- friendly technologies in fibre processing and strategies to enhance the quality of final product. It has revealed that enzymatic treatment brought about enhancement in colourant uptake in all cases, and credited it to improve shrink-resistance properties of the treated fibers (Helmy, 2020).

Cotton fabric can be padded with natural dyes and a low mordant concentration to yield shades with acceptable rubbing, washing and light fastness. Post-mordanting is a better procedure than pre-mordanting or meta-mordanting when the depth of shade obtained is considered. Copper sulfate and ferrous sulfate as mordants produced beige and grey shades respectively with the same natural dye from the Acacia plant family. Each mordant-dye combination is unique in terms of the optimum amount of mordant required for the same amount of dye. The optimal mordant concentration was determined to be 15 g/l copper sulfate and 5 g/l ferrous sulfate respectively for 10 g/l dye. This study indicates that some natural dyes can be readily applied using padding processes. The research proves that ample scope exists for further research on padding of different natural dyes considering the large variety of dyes and mordants available (Ratnapandian, et al., 2012).

The dyeing of silk and cotton can be achieved using the flower extracts of *Spathodea campanulata* by using natural and metallic mordants. The dyeing of flower extract exhibited excellent fastness to washing/rubbing and fairly good fastness to light. Among the various fibre-mordanting systems, the use of Myrobolan: $SnCl_2$ with alkaline water extract of flower of *Spathodea campanulata* showed maximum K/S values as compared to other selective mordanting systems (Lokesh and Swamy, 2013).

In the study shows that the root of rumex abyssinicuss jaq and eucalyptus leave, dye can be successfully used for dyeing silk to obtain a wide range of soft, pastel and light colors by using natural dyes and metallic mordants .With regards to colourfastness, test samples exhibited excellent fastness to washing (except pre and post mordanting); excellent fastness to rubbing(except

pre,simultaneous and post mordanting$K_2Cr_2O_7$). Among the different fiber-mordanting systems studied, the use of 3% of ferrous sulphate applied bysimultaneously mordanting for subsequent dyeing on cotton and silk with extract of eucalyptus dye 3% of aluminum sulphate applied by simultaneous mordanting for subsequent dyeing on silk with 5% extract of rumex abyssinicuss jaqand 3% of stannous chloride applied by simultaneous mordanting for subsequent dyeing on silk with 5% extract of rumexabisinicuss jaqshow maximum K/S values as compared to other selective pre, simultaneous and post mordanting systems (Jihad, 2014).

From the study, it may be concluded that the selected dye sources namely gulmohar tree leaves are highly suitable for linen material with pomegranate mordant. The pre-mordant techniques are mostly suitable for linen material. These dyes are safe and eco-friendly. Therefore, their use will definitely minimize the health hazards caused by the use of synthetic dyes. These natural dyes give some medicinal properties as well (Sasikala, 2016).

In the study a single-bath dyeing of linen fabric with natural dyes, Curcuma longa, Logwood and Pomegranate has been developed. In this process, one or more enzymes are complexed with tannic acid and a natural dye. On the basis of the developed enzyme complexes of the natural dyes, a comparison was made between the three dyeing methods, exhaustion, pad dry and pad dry cure methods. The effectiveness of the four enzymes neutral cellulose, protease, β-amylase and lipase, and three mixtures of these enzymes, β-amylase + lipase, neutral cellulose + lipase and neutral cellulose + β-amylase, was determined. A broad variation in shade, hue and colour depth can be achieved by applying enzymes and mixtures of enzymes complexes in the three dyeing methods. Colorimetric data shows dyeing improvement using these enzymatic complexes. It was found that each of the four enzymes and their mixtures were very effective, when used in conjunction with tannic acid in improving the washing fastness of the three natural dyes. The use of enzyme/tannic acid/natural dye complexes replaces metal mordants making natural dyeing process more ecofriendly (El-Zawahry, 2009).

In the research about application of natural dye on synthetic fabrics establish that very little information is available on dyeing of synthetic filament like polyester, acrylic, nylon etc. In the paper is a comprehensive review of application of natural dyes on synthetic fabrics. The dyeing of synthetic fabrics with natural dyes requires pre-treatments to generate hydrophilic groups. The paper highlights about the various pre treatment processes used to carry out dyeing with natural dyes on synthetic fabrics. Synthetic fabric requires pretreatment process before dyeing with natural dyes. Among pretreatment process majority of the work is carried out on mordant process. The natural dye along with mordant gives good fastness properties. There is need to carry out more research work to improve the fastness properties of natural dye on synthetic fabrics (Purwar, 2016).

Other examples of natural dyes for the textile industry are presented in tabular form (table 2).

Table 2. Examples of natural dyes for textile industry

Name	Color	Types of goods
Blueberry *Vaccinium myrtillus*	Purple/blue	textile goods
Green tea *Camellia sinensis*	Brown	textile goods
Spinach *Spinacea oleracea*	Green	textile goods
Coffee *Coffea arabica*	Brown	textile goods
Cochineal *Dactylopius coccus*	Crimson red color	textile goods
Kermes *Kermes licis*	Red	textile goods
Orchal *Lichen*	Red and purple	textile goods
Bacteria *Serratia plymuthica*	Pink	textile goods
Mushrooms *Sarcodon imbricatus*	Blue/green	textile goods
Fungi *Fusarium oxysporum*	Pink/purple	textile goods

Sources: Lara, et al., 2022 and Singh, et al., 2020

When researching the application of natural dyes for the textile industry, a wide variety of research was found: extract natural from fresh bluish purple grapes for perform on wool and cotton textile material; dye from Butea Monosperma (yellow color) applied dye on 100% pure cotton give good result; natural staining procedures have been evaluated using hybrid dyes of mango and turmeric leaves; properties of the flowers of Erythrina suberosa dyed on wool were studied using combination of mordants such as lemon juice: copper sulphate, lemon juice: potassium dichromate, lemon juice: ferrous sulphate and lemon juice: stannous chloride in the different ratio; evaluated is the effect of color and fastness properties of wool fibers dyed with R. cordifolia as a natural dye and A. catechu as an anchoring agent; enzymatic treatment lead about enhancement in colourant uptake in all cases, and improve shrink-resistance properties of the treated fibers; cotton fabric can be padded with natural dyes and a low mordant concentration to yield shades with acceptable rubbing, washing and light fastness; the dyeing of silk and cotton can be achieved using the flower extracts of Spathodea campanulata by using natural and metallic mordants; the root of rumex abyssinicuss jaq and eucalyptus leave, dye can be successfully used for dyeing silk and cotton; gulmohar tree leaves are highly suitable for linen material with pomegranate mordant; dyeing of linen fabric with natural dyes, Curcuma longa, Logwood and Pomegranate has been developed and other natural dyes from blueberry, green tea, spinach, coffee, cochineal, kermes, orchal lichen, bacteria Serratia plymuthica, mushrooms Sarcodon imbricatus, fungi Fusarium oxysporum and ect. for textile industry.

Conclusion

Natural dyes in the textile industry are obtained from plant, animal, mineral origin and microorganisms. In the study regarding the application of natural dyes for the textile industry, it was established that they have been successfully applied to various textile fabrics of natural origin - cotton, silk, wool, linen. Application of natural dyes on synthetic fabrics shows that very little information is available on dyeing of synthetic filaments like polyester, acrylic, nylon, which is a prerequisite for future research in the field.

The scientific article highlights the advantages and disadvantages of natural dyes for the textile industry, which are important for their real implementation in practice. Some of the main disadvantages (non-standardized color recipes and methods, poor brightness and fastness properties, absence of their permanent availability, applicable natural fibers only and the fact that natural dyes is more expensive than synthetic dyes) of natural dyes for the textile industry create difficulty in their use, which is an opportunity for new scientific research to help overcome the indicated disadvantages.

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