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Review

A Review on Colour Fastness of Natural Dyed Textiles

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Abstract. Natural dyes are non-allergic, non-toxic, non-carcinogenic and eco-friendly but their use has been limited since the discovery of synthetic dyes in 1856. These synthetic dyes were gaining importance due to low in cost, giving a variety of shades and being available in abundance. However, excessive use of synthetic dyes can create serious health and environmental problems. To solve these issues, many researchers are being focused on the use of natural dyes in textiles. The purpose of this review is to study the colour fastness of the natural dyes including light, wash and rub fastness, the role and use of mordants in the fixation of natural dyes. The role of different types of fibers and blends in natural dyeing fastness property and role of dyeing methods in the colour fastness of natural dyes. This critical review thus would encourage commercial dyers to focus on the use of natural dyes to overcome the challenges associated with the colour fastness property of the natural dyes and determine a significant direction for aspirational goals of future researchers.

Keywords: natural dyes, colour fastness, mordant

Introduction

Due to the harmful, toxic and carcinogenic effects of synthetic dyes, dyers are moving towards the use of natural dyes which are environment friendly. Dyeing is an ancient art of colouring textiles, its record can be seen back from the Bronze age, when people usually dyed textiles by rubbing any coloured fruit, vegetables or any coloured material on the fabric. In the past few decades, innovative and advanced technologies have evolved new methods and materials for dyeing which are not only less harmful but more environment friendly (Batool *et al*., 2022; Baig *et al*., 2021; Sadeghi-Kiakhani *et al*., 2020; Choudhury, 2018). The some natural dyes found by Abdel-Kareem (2012) which were used in ancient times like madder, red dye taken from Rubiatinctorium plant roots, Indigoferatinctoria plant leaves extract, the blue indigo dye and yellow dye from the Saffron plant. Almost the half of the nineteenth century, the whole dyestuff obtained from natural sources, both vegetable and animal in origin. Ado *et al*. (2014) found natural dyes are non-allergic, non-toxic, non-carcinogenic and eco-friendly but their uses is limited to some extent after the discovery of synthetic dyes in (1856). These synthetic dyes were gaining importance day by day at the beginning of the twentieth century due to their low cost and availability in a variety of shades (Choudhury, 2018; Saravanan and Chandramohan, 2011). Moreover, Samanta and Agarwal (2009) concluded that excessive use of synthetic dyes would create serious health and environmental problems. To address these issues, many types of research are being focused on the use of natural dyes in the textiles industry. Due to the increased environmental issues regarding synthetic dyes, most textile industries looking for all possibilities of using natural dyes. Additionally, they found that people are more conscious of issues related to health and the environment.

In this regard, recently a lot of research has been done on the development and use of natural dyes as well as their medicinal properties like antibacterial properties, etc. being explored. Such dyes are extracted from the various parts of the plant which not only contain the colouring material but also have additional antimicrobial and antioxidant properties e.g., tannin, flavonoids and quinoids (Chakraborty *et al*., 2020; Manicketh and Francis, 2020; Jiang *et al*., 2019; Sheikh *et al*., 2019). Previously, Prabhu *et al*. (2011) found that *Emblica officials* G. plant extract was applied as mordant with natural dye on silk and cotton fabrics to develop good antimicrobial enhanced fabrics which are active for 20 washes. Moreover, water can be recycled as less amount of residues in wastewater results in less water pollution (Amutha and Sudhapriya, 2020; Fröse *et al*., 2019).

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According to Samanta and Agarwal (2009), the colour fastness of dye is related to the change in colour depth of the original material or it may be referring to the staining of the adjacent white material. It is being measured by using greyscale which notices any changes in the original colour of the material after exposure to sunlight, washing and rubbing. Some natural dyes, either of animal or plant origin and have moderate to average colour fastness to light and washing, while some have very limited fastness, these dyes require mordants (fixatives) (Yasukawa *et al*., 2017). Mordant serves as a binder between the dye and fiber, some of them are found naturally like wood ash, alkali mordant and acidic fruits, acid mordant is used. However, some chemicals are being used as mordant as copper sulphate, chrome etc. but their use is kept limited due to their toxic nature.

The objectives of this critical review are, the colour fastness of the natural dyes on textiles and the role and use of mordant in the fixation of natural dyes, the role of textiles fibers and their blends and the role of dyeing methods in the colour fastness of natural dyes.

Natural dyes, resources and classification. Natural dyes are obtained from natural resources like animals, plants and minerals. List of important sources of natural dyes and their application are given in Table 1. Samanta and Konar (2011) concluded that natural dyes require a mordant to fix with the fibers, some of these mordants are metallic salts that act as a binder between the dye and the fiber. Recently, the use of natural dyeing has gained so much importance because synthetic dyes are chemical, toxic and caused environmental pollution whereas natural dyes producing, eye appealing colours which attract the human eye, in a wide range of shades, they are usually renewable, environment friendly bio-compatible and biodegradable (Vadwala and Kola, 2017; Samanta and Konar, 2011). Some natural dyes prove to be anti-allergens, safe for the skin, mothproof and enrich in colour within age. On the other hand, some disadvantages of natural dyes are same shade is difficult to reproduce, a little bit expensive as required, more dye stuff, excessive dyeing time and more cost of adding. However, despite all these still, natural dyes are in demand because of their friendly aspects (Werede *et al*., 2021; Choudhury, 2018).

Natural dyes can be classified based on hues like red colour dyes, hidden in barks and roots of plants or insects and have colour fastness to light and washing. Another example of yellow dyes derived from turmeric, tesu and Kapila, have moderate to excellent colour fastness. Blue dyes like indigo have excellent washing and light fastness. Later these dyes were classified as vegetables, animal and mineral origin, almost all vegetable dyes were obtained from bark (sandalwood, purple bark), roots (turmeric, beetroot, onion, madder), trunk, leaves (indigo, coral jasmine, henna, tea, lemon grass,) flowers (Kusum, Marigold) and fruits cochineal, animal origin dye derived from insects (Čorak *et al.*, 2022; Prabhu and Bhute, 2012). Moreover, natural dyes are also developed from the algal-based pigments from marine algal species, mineral dyes taken from the mineral sources which are organic like Larkin-yellow, manganese-brown. Additionally, these dyes are also classified based on methods of application e.g. mordant dyes (applied with the help of mordant) like fustic, berries, cochineal etc. vat dyes (converted into water-soluble form and then applied) like indigo direct dyes (applied in boiling dye bath) like turmeric, pomegranate etc. acid dyes (applied in an acid bath) like saffron etc. disperse dyes (applied on hydrophobic synthetic fibers, silk and wool) e.g. lawsone etc. basic dyes (applied from neutral to mildly acidic pH) do not have strong colour fastness e.g. berberine (Azeem *et al.,* 2019; Yin *et al*., 2018).

Colourfastness of natural dyes. Colour fastness is referred to as the change in the original colour of the fabric or staining of the adjacent material during washing, dry cleaning, light exposure etc. Fading is associated with changes in original colour depth from exposure to light, washing, dry cleaning etc. Bleeding is done when the colour transfer to the material accompanies the other material of the same nature or different. The dyeing of natural dyes is measured by wash, rub and light tests standards. The most common types of colour fastness are the light fastness wash fastness and rub fastness, especially perspiration is the most common problem in apparel (Samanta and Konar, 2011; Zarkogianni *et al.*, 2011; Samanta and Agarwal, 2009).

Light fastness. Prior studies indicated that extensive work has been done in improving the light fastness of natural dyes in the world of textiles. Kennedy (2014) claims that the light fastness of a dyed fabric can be increased if the dye concentration increases due to an increase in the average size of sub-microscopic particles created by the dye in the fiber. The chemical structure and physical properties of the fiber are strongly linked

Table 1. List of natural dyes, source, application, and colour fastness property

Natural dye source	Species	Common name	Parts of plants	Colour obtained	Mordant (chemical /bio)	Application in textiles	Colourfastness properties	References
Plant	*Momordica charantia* L.	Bitter gourd	Leaves (residue)	Skin to brown	Chemical mordants: Salts of iron and tannins Bio-mordants: Onion, Henna, Turmeric, Pomegranate, Golden shower bark	Cotton	Light: Good Rubbing: Good Wash: Good	(Batool *et al*., 2022)
Plant	*Cocos nucifera*	Coconut coir	Fruit	Brown	Chemical Mordants: iron Bio-mordants: Turmeric	Silk	Light: Excellent Rubbing: Excellent Wash: Excellent	(Adeel *et al*., 2022)
Plant	*Ficus religiosa*	Peepal	Bark	Reddish brown	Chemical Mordants: salts of Iron, Aluminium and Tannic acid Bio-mordants: *Acacia*, Turmeric, Pomegranate	Silk	Light: Good Rubbing: Good Wash: Good	(Habib *et al*., 2022)
Plant	*Dactylopius coccus*	Cochineal	Whole Plant	Purple	Chemical mordants: Iron Sulphate, Aluminum and Tannic acid Bio-mordants: *Acacia*, Turmeric, Pomegranate	Modified Cotton	Light: Good Rubbing: Good Wash: Good	(Corak *et al*., 2022)
Plant	*Triadica sebifera*	Tallow tree	Bark	Reddish brown	Aluminum Potassium Sulphate, Acetic acid, Ferrous sulphate, Cupric sulphate	Viscose	Light: Good Rubbing: Good Wash: Good	(Mia *et al*., 2021)
Plant	Tagetes	Marigold	Flower	Yellow	Alum	Cotton	Light: Excellent Rubbing: Good Wash: Excellent	(Baig *et al*., 2021)
Plant	*Citrus sinensis*	Gunda Gundo Orange	Peel	Yellow to green shades	Sodium Carbonate	Cotton	Light: --- Rubbing: Good Wash: Good	(Werede *et al*., 2021)
Plant	*Croton urucurana* baill	Rush Croton	Bark	Beige Reddish Brown	Aluminum, Potassium Sulphate and Ferrous sulphate	Cotton Wool	Light: Good Rubbing: Poor Wash: Good	(Silva *et al*., 2020)
Plant	*Terminalia arjuna* *Thespesia populnea*	Arjun tree Indian tulip tree	Tree	Bright pale-yellow	Alum and Ferrous sulphate	Silk Cotton Nylon	Light: Poor Rubbing: Fair Wash: Good	(Amutha and Sudhapriya, 2020)

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Natural dye source	Species	Common name	Parts of plants	Colour obtained	Mordant (chemical /bio)	Application in textiles	Colourfastness properties	References
Plant	*Acacia auriculiformis*	Earpod wattle		Red yellow	Increased concentration of dye	Silk Wool	Light: Good Rubbing: -- Wash: Excellent	(Chakraborty *et al.,* 2020)
Plant	*Araucaria columnaris Macaranga peltata*, *Averrhoa bilimbi*	Cook pine Chandada Cucumber tree	Barks and Leaves	Brown green Light yellow	Alum, Acetic acid, $CuSO_4$ and Lemon juice	Cotton Silk Polyester	Light: --- Rubbing: Good Wash: Excellent	(Manicketh and Francis, 2020)
Plant	*Mangifera indica*	Mango	Leaves and Peel	Deep yellow pale yellow	Alum, Aluminium sulphate, Ferrous sulphate and Copper sulphate	Cotton	Light: Good Rubbing: Excellent Wash: Fair	(Ayele *et al*., 2020)
Plant	*Terminalia catappa*	Ketapang	Leaves	Light yellow, Brownish -yellow, and Gray near black	Alum, Kapur Tohor and Tunjung	Cotton	Light: ---- Rubbing: Good Wash: Good	(Faisal and Chafidz, 2019)
Plant	*Butea monosperma*	Palas	Flower	Deep brown, Olive green, Dark brown Burgundy and Yellowish	Pomegranate Peel, Gallnut, and Catechu	Wool	Light: Good Rubbing: Fair Wash: Excellent	(Shahid-ul-Islam *et al*., 2019)
Plant	*Azadirachta indica*	Neem	Bark	Brown	Turmeric, Henna, Pomegranate, and *Acacia*	Silk	Light: Excellent Rubbing: Excellent Wash: Excellent	(Zuber *et al*., 2019)
Plant	*Kigelia africana*	Sausage tree	Flower	Yellow, Red green, Red Yellow	Alum, Ferrous sulphate and Copper sulphate	Linen	Light: --- Rubbing: Excellent Wash: Excellent	(Sheikh *et al*., 2019)
Plant	*Caulis spatholobi* (herb)	Spatholobus Stem	Stem	Redness–greenness, and Yellowness–blueness	Aluminum sulphate, Ferrous sulphate, Copper sulphate and Zinc sulphate	Wool	Light: Good Rubbing: Fair Wash: Good	(Jiang *et al*., 2019)
Plant	*Peganum harmala*	Harmel	Seeds	Yellowish - red	Turmeric, Henna, *Acacia* and Pomegranate	Cotton	Light: Excellent Rubbing: Excellent Wash: Excellent	(Adeel *et al*., 2018)
Plant	*Lawsonia inermis*	Henna	Leaves	Red-orange	---	Polyester	Light: Excellent Rubbing: Excellent Wash: Excellent	(Bhuiyan *et al.,* 2018)
Plant	*Cinnamomum camphora*	Camphor Laurel	Leaf	Yellow (pale to dark) Reddish	Potash alum, Ferrous sulphate, and Zinc sulphate	Silk	Light: Fair Rubbing: Excellent Wash: Good	(Khan *et al*., 2018)
Plant	*Crataegus elbursensis*	Thornapple	Fruit	red, Green yellow, Blue	Aluminum sulphate, Copper sulphate and Tin chloride	Wool	Light: Excellent Rubbing: Good Wash: Excellent	(Safapour *et al*., 2018)

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Natural dye source	Species	Common name	Parts of plants	Colour obtained	Mordant (chemical /bio)	Application in textiles	Colourfastness properties		References
Plant	*Phytolaccaceae*	Berries	Fruit	Rose-red	$SnCl_2$	Silk	Light: Rubbing: Wash:	--- Excellent Good	(Yin *et al*., 2018)
Plant	*Saccharum bengalense* Retz.	Munj Sweetcane	Stem	Grey pale yellow	Copper, Iron, *Moringa*, and Turmeric	Viscose	Light: Rubbing: Wash:	Excellent --- Good	(Raza *et al*., 2018)
Plant	*Terminalia chebula*	Chebulic Myrobalan/ Harda	Whole plant	Grey yellow	Alum, Ferrous sulphate, and Stannous chloride	Wool	Light: Rubbing: Wash:	Excellent Good Excellent	(Shabbir *et al*., 2017)
Plant	*Opuntia ficus-indica*	Red Prickly Pear	Fruit	Red	Myrobalan Copper sulphate	Silk	Light: Rubbing: Wash:	Excellent Good Good	(Ganesan and Karthik, 2017)
Plant	*Sorghum bicolour*	Sorghum	Husk	Light brown to reddish	Aluminum, Potassium sulphate and Ferrous sulphate	Wool	Light: Rubbing: Wash:	Fair Good Good	(Hou *et al*., 2017)
Plant	*Ribes nigrum*	Blackcurrant	fruit	Light purplish pink	Copper sulphate Ferrous sulphate	Silk Cotton	Light: Rubbing: Wash:	Poor --- Poor	(Yasukawa *et al*., 2017)

to the light fastness of a dye. However, Chakraborty *et al.* (2020) found the light fastness of the natural dye extracted from *Acacia auriculiformis* associated with the presence of tannin in the dye. Moreover, Cheung *et al*. (2013) and Błyskal (2016) naturally dyed fabrics that are subject to fading are due to an oxidative process in cellulose, whereas in protein the fibers have a reductive effect as indigo is more light resistant on wool than on cotton.

Prior literature has indicated tannin-related after treatments for improving the light fastness of dyes on cotton, concerning some specific to natural dyes only. Silva *et al*. (2020) developed reddish brown dye from the bark of *Croton urucurana* Baill which showed excellent light fastness in the presence of mordant such as aluminum, potassium sulphate and ferrous sulphate on cotton and wool fabrics. Most natural dyes have poor light stability as compared to synthetic dyes, hence the colours in museum textiles are different from their original colours. Whereas (Saravanan and Chandramohan, 2011) reported the dyeing of silk fabric with natural dyes extracted from the barks of *Ficus religious* L. with chemicals and natural mordants exhibits good light fastness.

Jothi (2008) found that cotton and silk fabrics dyed with African Marigold showed good light fastness and iron and copper mordants were used in dyeing, due to these mordants, a complex is formed with the transition of metals hence stopping the photolytic degradation, thus saving the dye. Later (Kumaresan *et al*., 2011) reported that good colour fastness exhibited by the silk fabric dyed with natural dye *Cordia sebestena* with the help of mordants using Shirley MBTF microcell fade-o-meter for testing the light fastness. The same results have been reported by Saravanan and Chandramohan in (2011) on the good light fastness of silk dyed with natural dyes. Good light fastness was also reported by (Vankar, 2002), with Henna, Catechu and Babool. Numerous attempts have been made to improve the light fastness of textiles fabric dyed with natural dyes by effects of various additives on the photofading of carthamin in cellulose acetate film, critically examining the process of fading of natural dyes. The rate of photofading decreases substantively in the presence of nickel hydroxy-aryl sulphonates, while the addition of UV absorbers made little impact on the rate of fading (Samanta and Konar, 2011; Cristea and Vilarem, 2006).

The nature of the incident light is of significance during the photofading process, fugitive dyes fade mainly by visible radiation, while dyes of high light fastness fade mainly by UV radiation and this radiation is a major contributing factor in the fading of light fastness of dyes. As by Little and Christie (2010) claimed that UV filter renders some protection to natural dyes. Cristea and Vilarem (2006) found that temperature and humidity affect the rate of fading of dyed textile material in normal exposure to light conditions. They found that a 65 to 45% drop in humidity had very little effect on the rate of fading, but there was a significant effect when it dropped another 25%. Atmospheric contaminants like sulphur dioxide and oxides of nitrogen and ozone react with dyes even in the absence of light. Substances other than colourants affect fastness properties. For example, after treatment of silk with tannic acid, before and after the dyeing process, improves the fastness properties of most natural dyes. Moreover, the presence of starch and gums might accelerate the fading process (Gaur and Bhagat, 2016; Swamy *et al.*, 2016).

Wash fastness. Numerous studies have reported that colour fastness to washing of natural dyes was considered moderate. Dye concentration and its absorption in the fiber determine the wash fastness of natural dyes in textiles. Jothi *et al.* (2008) is found that natural dyes extracted from mehndi/henna, turmeric and tea leaf exhibited strong colour wash fastness. Included in this, Shariful *et al*. (2020) extracted dye from pomegranate showed a highly strong colour wash fastness property. Moreover, Silva *et al.* (2020) developed reddish brown colour dye from the bark of *Croton urucurana* Baill which showed excellent light fastness on cotton and wool fabrics in the presence of aluminum potassium sulphate and ferrous sulphate mordants. Tamarind seeds extracted dye was used to dye the cotton, bombyx, Mori-silk and Eri-silk fabrics results showed that colour fastness to washing was excellent, even after five washes, the colour strength was denser and no change in colour shade. Natural dyes (extracted from the marigold flower) exhibited good and excellent wash colour fastness, which is attributed to the tendency of the dye to aggregate inside the fibers. However, when the treated samples were exposed to washing by using soap colour faded to some extent, this is due to the weaker bonding between the fiber and dye. In this regard, Kumaresan *et al*. (2011) also found that silk fabric exhibits excellent colour fastness to washing if it was treated with Sandofix HCF by 1% followed by 2% treatment with CTAB (Ado *et al.*, 2014; Samanta *et al.*, 2011). Combination of mordant like myrobolan and nickel sulphate, myrobolan and aluminum sulphate, myrobolan and potassium dichromate, myrobolan and ferrous sulphate, myrobolan and stannous chloride with the ratio of 1:3, 1:1, 3:1 improves the colour fastness to washing from good to excellent such as silk dyed with natural dyes extracted from the flower of *Cordia sebestena* in the presence of above mentioned mordants (Kumaresan *et al.*, 2011). Cotton and polyester fabrics dyed with extract of Kola nuts (red, white and brown) exhibited excellent fastness to wash and perspiration on the simultaneously mordanting method. Saravanan and Chandramohan (2011) found that dyeing of silk with natural dyes extracted from the barks of *Ficus religious* L with chemicals and natural mordants exhibits good washing fastness property.

Rub fastness. Recently many studies have been conducted on the development of natural dyes having good rub fastness both on cellulosic and protein fibers. As many studies indicated that natural dyes have moderate to good rub fastness e.g. red sandalwood, manjistha, babool, marigold, jackfruit wood etc. showed good rub fastness, especially on cotton and jute fabrics (Silva *et al.*, 2020; Samanta and Konar, 2011; Samanta and Agarwal, 2009). The natural dye extracted from marigold flowers showed good rub fastness on wool, cotton and silk (Samanta and Konar, 2011; Samanta and Agarwal, 2009). Kumaresan *et al*., (2011) found that the rub fastness of natural dyes in both conditions, wet and dry is excellent on dyed silk with *Cordia subestena*. However, the colour fastness of the natural dyes does not rely only on the chemical composition of the fiber and the dye but also on the mordant being used. Ado *et al.* (2014) observed that to achieve the best colour fastness, the dyers must know the best combination of fiber and the mordants as cutch and ratan jot natural dyes have average rub fastness in wet conditions whereas moderate to good in dry conditions. Additionally, Saravanan and Chandramohan (2011) emphasized that the combination of mordant like myrobolan and nickel sulphate, myrobolan and aluminum sulphate, myrobolan and potassium dichromate, myrobolan and ferrous sulphate, myrobolan and stannous chloride with the ratio of 1:3, 1:1, 3:1 improves the colour fastness to rubbing from good to excellent as dyed silk with natural dyes extracted from the flower of *Cordia sebestena* e.g. dyeing of silk with natural dyes extracted from the barks of *Ficus religious* L. with chemicals and natural mordants exhibits good rub fastness property.

Mordants used in natural dyeing of textile. Very few natural dyes showed good colour fastness. The word mordant comes from the Latin word order, which means to bite. All types of mordants, whether they are bio or chemical, have positive powers. effect on the light, rub and wash fastness properties of dyed textiles are the elements used to fix the dye on the fiber, so mordants play a major role in the colour fastness of the dyes (Ayele *et al.*, 2020; Prabhu and Bhute, 2012). Moreover, different shades were obtained by using different mordants. Some natural dyes do not require mordant to fix with the fiber e.g. indigo, while most of the dyes require the presence of mordant to fix. Otherwise, the dye will fade when exposed to light and washing because of poor fixation of the dye to the fibers of the fabrics. Islam *et al.* (2016) observed that many types of mordants are used in textiles some of them found in nature may be alkali and acidic in nature urine and wood ash were alkali in nature, while rhubarb is acidic. However, some dyers still use chemical mordants like copper, alum, iron and chrome. Additionally, Faisal and Chafidz (2019) developed natural dye from the mango peel and leaves which was applied on cotton fabric using three mordants i.e., Tawas, Kapur tohor and Tanjung to fix the dye and found that alum and Tanjung strongly fix the dye to the cotton resulting in excellent colour fastness. Mordants are applied in a solution form that helps in the fiber's fixation. According to Saravanan and Chandramohan (2011) mordants are usually applied to the textiles by three methods, pre-mordanting (chemical and natural mordants were used to pretreat the samples), and post mordanting (samples were treated with the natural and chemical mordants after dyeing with natural dyes) and while simultaneous mordanting (simultaneously samples were treated with the dyed extract and natural and chemical mordant. Recently, researchers are increasingly focusing on eco-friendly and sustainable procedures and materials in the colouration of textiles, they are more biodegradable and bio-compatible (Adeel *et al*., 2022; Batool *et al*., 2022; Mia *et al*., 2022; Raza *et al*., 2018). As Shahid-ul-Islam *et al.* (2019) used pomegranate peel (*Punica granatum* L), catechu (*Acacia catechu*) and gallnut (*Quercus infectoria* L) as bio mordant for dyeing wool fiber from *Butea monosperma* (palas) flower dye extract. Results indicated that all mordanted wool samples exhibited a variety of shades and excellent colour fastness. Similarly, Zuber *et al.* (2019) used eco-friendly dye extracted from neem bark to dye silk fiber using biomradants i.e. turmeric (*Curcuma longa*), henna (*Lawsonia inermis*), pomegranate (*Punica granatum*) and acacia (*Acacia nilotica*) samples showed excellent colour fastness and a range of shades.

Mordants should be handled with care and poisonous, protective overalls and safety masks (from inhaling fumes) should be used, while working in the dyeing-house. Tepparin *et al.* (2012) mentioned that the use of mordants in dyeing can be at any pre, post and simultaneously stage. Natural dyes, extracted from tamarind seeds were used to dye the cotton, bombyx. Mori-silk and Eri-silk fabrics results showed that colour fastness to washing was excellent, even after five washes, the colour strength was denser and no change in colour shade. Then they used the three mordants such as zinc oxide, potassium chromium oxide and ferrous sulphate, it has been observed that the uptake quality of the dye was increased by adding the mordant e.g. zinc oxide mordant enhance the fastness of colour to washing whereas potassium chromium oxide bring some changes in the colour shade but stabilize the dye into the fiber, while ferrous sulphate provides excellent wash fastness to the dyed fabrics but the colour change to gray shade.

Previously, Prabhu *et al.* (2011) proved that mordants can enhance the washing and light fastness of the cotton and silk fabrics dyed with natural dyes as well as an anti-microbial activity up to 20 washes, the researcher used the *Emblica official*, G. Dewed fruits tannies as a natural mordant along with the metal mordant as copper sulphate.

Similarly, Kumerasan *et al.* (2011) also observed that silk dyed with the eco-friendly natural dyes using plant extracts in a combination of mordants showed excellent washing, rub and preparation (in both acidic and alkaline solutions) fastness and good fastness towards the light. Sometimes mordant and mordanting methods are more important than the dye itself, especially when metal is used as mordant come dye complexes are formed which is difficult for the dye to remain fixed with the fabric. According to Safapour *et al.* (2018) reported that Cu mordant gave excellent results in colour fastness, while dyeing wool yarns from *C. elbursensis* fruit, whereas Sn mordant lowers the colour fastness and chroma of the dye. The ratio of the mordant also affects the colour shade of natural dyes. Silk fabric dyed with natural dyes using a pre-mordanting technique with potassium calcium sulphate, showed higher colour strength, while optimal dye colour was achieved when 10 g/L potassium, aluminum and sulphate, at PH 6 for 20 min dying was used.

Role of fibers and blends in the colour fastness of naturally dyed textiles. Almost all types of textiles can be dyed with natural dyes. However, Gürses *et al*. (2016) found that achieving an excellent level of fastness and richness in colour depth varies considerably. Dyers mostly used natural dyes on natural fibers (Hou *et al*., 2017). Many studies indicated that natural fibers of both animal and plant origin; animal fibers (protein in nature) like silk, wool, alpaca and mohair exhibit a higher affinity to natural dyes than plant fibers (flax, hemp, jute, ramie, linen, etc.) (Fröse *et al*., 2019) observed that some natural dyes from different sources do not require any mordant, while applying to the wool fabrics but in the case of cotton fabric, some shades require mordant, while others do not. As Chakraborty *et al.* (2020) proved from their study the colourfastness of the dye extracted from *Acacia auriculiformis* showed better wash and light fastness on protein fibers rather than cellulosic fibers.

Previously, Bhuiyan *et al*. (2018) found that the polyester synthetic fabric was successfully dyed with *Araucaria columbaria*, *Macaranga peltate* and *Averrhoa bilimbi* plants dyes without any pre and post-treatment. Another application on polyester fabric was of henna dye at a high-temperature dye bath and pressure without any use of mordant exhibited excellent colourfastness.

Role of methods of dyeing with natural dyes in textiles. Alkaline, acids or natural baths can be used for dyeing textiles with natural dyes, based on the chemical composition of the dye and fibers. Dyeing of cotton and silk with different mordants and natural dyes. Clothes must be scoured, bleached or treated chemically before applying dye and different mordants to obtain shades like black to brown and green to yellow. Various artesian dyers have developed special techniques and processes to get a shade. One of the most used methods for applying natural dyes is the vast method. Some techniques also allow the incorporation of patterns in the process of dying, however, the skill required to incorporate the patterns is learned over years (Ado *et al*., 2014; Shahid and Mohammad, 2013).

Conventional method of natural dyeing of textile. According to Samanta and Agarwal (2009) following processes are followed, while preparing a cotton cloth for dyeing, washing, bleaching, steaming, steeping and rinsing. The cotton cloth is soaked in a solution of Barda/Myrobolan and dried. Alum and water were used to pre-mordant the cotton cloth. At times gum or tamarind seed paste is added to make it look sticky. The process of dying involves boiling the cloth in an aqueous solution until all the colour is absorbed by the cloth. The dyed fabric is spanned out to gradually dry with air and sun. The sprinkling of water is carried out at a certain level to brighten the colour. This process is continued for 2-4 days if required; the cloth is starched by dipping it in a paste of rice or wheat flour.

According to Wanyama *et al*. (2011) conventional dyeing of cotton fabric can be carried out using natural dyes which are extracted from native plants in Uganda. The process consists of a 60 min boiling (at 90 °C) treatment of dye and mordant in a mixture. The pH of the dye bath is maintained strictly between 6.5 and 7.5 using acetic acid (40% solution) and a liquor ratio of 1:200 is used in all the dying. Rinsing of the dyed fabrics takes place in warm distilled water for 10 min after removing it from the exhausted dyed solution. The warm distilled water also contains a liquid detergent. After rinsing the cloth in warm water, the rinsing takes place in cold water to see that there is no more colour bleeding, if there is no colour bleeding, the cloth is dried in the air.

Previously, Jothi (2008) is used African marigold flowers for conventional dyeing of cotton and silk fabrics. The cotton was dyed straight using the material to a liquor ration of 1:40; however, a buffer solution was added in the case of silk to maintain the pH value at 4 °C. After then it was washed with cold water and dried at room temperature. Dye fixing is carried out by dipping the cloth in brine and determining the colour strength calorimetrically using colour matching software. The software operates at the maximum wavelength of the natural colourant.

Non-conventional method of natural dyeing of textiles. Now customers wants of eco-friendly textiles dyes which is the revival of eco-friendly dyes for textiles with more energy efficient dyeing and shade producible processes (Corak *et al*., 2022). As Amutha and Sudhapriya (2020) used natural dye from fruits of *Terminalia arjuna* and *Thespesia populnea* to dye cotton, silk and nylon through an ultrasonic bath and found that this method is more effective and eco-friendlier than conventional dyeing in terms of time, water usage, and energy conservation.

Previously, Samanta and Konar (2011) also reported that the ultrasonic energized dyeing technique gives better dye uptake uniform dyeing and better light and wash fastness on cotton fabric. It is always advantageous as it consumes less heat than normal, dying for the same shade. As Samanta and Agarwal (2009) found that the high-pressure and high-temperature technique was more effective. As well as the use of microwave in dyeing textiles with natural dyes is more effective than conventional methods, they dyed silk with neem bark dye with the minimum usage of mordants in the microwave for 2 min giving better results than conventional dyeing such as efficient extraction of colour from the neem bark and excellent colour fastness (Habib *et al*., 2022; Zuber *et al.*, 2019; Adeel *et al.*, 2018).

Recently, Adeel *et al*. (2022) developed more eco-friendly and sustainable dyeing process to dye the silk fabrics in the presence of bio mordants with natural dye (*Cocos nucifera*) extracted through ultrasonic radiations which have excellent colour fastness properties. Previously, Vankar *et al*. (2002) studied and reported that eco-friendly sonicator dyeing of cotton and the use of bio-mordant for dyeing was eco-friendlier. These techniques have still not been commercialized due to the following reasons, no or very little advancement in extraction methodologies, non-availability of technology for the application of natural dyes to cotton silk and wool fibers, and lack of awareness in the small-scale dyers.

Conclusion

Henceforth, it is concluded that present and past studies, executed through experiments and empirical reports on using natural dyes are still not enough for this modern era. To overcome the use of toxic and hazardous synthetic dyes, extensive research into the use of natural dyes is required. Fortunately, people are aware of the environmental issues related to synthetic dyes and they are moving towards natural dyes, they are eco-friendly, non-allergic, non-toxic, non-carcinogenic and abundant. However, the colour fastness of the natural dyes is still a question mark? More detailed scientific studies with natural dyes must be explored in this regard, there is a wealth of natural plants available but extraction of dyes from them still requires much attention. However, the use of both natural and chemical mordants improves the colour fixation of dye to the fibers. Therefore, more research is needed to gear toward producing quality natural dyes with shades and high colour fastness.

Conflict of Interest. The authors declare that they have no conflict of interest.

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