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Natural Colorants: Eco Friendly Alternatves to Synthetic Colorants

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ABSTRACT
Color plays a vital role in marketing a wide range of products, including cosmetics, food additives, and pharmaceuticals, by enhancing their appeal and capturing consumer attention. The shift from synthetic to natural dyes, sourced from microorganisms and plant phytochemicals, is driven by the numerous benefits of natural colorants. These benefits include skin-friendliness, non-toxicity, antioxidant and anti-inflammatory properties, and environmental sustainability. Natural dyes, such as anthocyanins, not only serve as colorants but also offer health benefits, including anticancer properties. However, natural colorants face challenges such as limited color range, stability issues, and color variability. Despite these challenges, they find applications across diverse industries, including cosmetics, pharmaceuticals, food and beverages, and textile dyeing. This paper provides a comprehensive overview of natural colorants, detailing their advantages, disadvantages, applications, and the classification of colorants from plant, animal, microbial, and mineral sources. Various extraction methods for obtaining these natural dyes are also discussed, highlighting their relevance in contemporary industry practices. The global demand for sustainable and environmentally friendly products has led to a resurgence of natural colorants. This study explores various sources, applications, evaluation tests, and medical properties of these colorants. Derived from plants, animals, microorganisms, and minerals, natural colorants have diverse uses in the pharmaceutical and cosmetic industries. They offer a renewable and biodegradable solution with a lower environmental impact. Through a comprehensive review of historical and contemporary uses and extraction methods, this research highlights the potential of natural colorants across various industries, including pharmaceuticals, cosmetics, textiles, and the food industry.

Key words: Natural colorants, Cosmetics, Plant pigments

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I. INTRODUCTION

In recent years, there has been a significant shift towards sustainable and eco-friendly products across various industries, including cosmetics, food, pharmaceuticals, and textiles. This movement is driven by increasing consumer awareness of environmental issues and a growing preference for natural and organic products. A key component of this shift is the use of natural colorants as alternatives to synthetic dyes. Derived from plants, fruits, minerals, and microorganisms, natural colorants offer several benefits that synthetic colorants often lack, such as non-toxicity, biodegradability, and additional health benefits. The transition from synthetic to natural dyes is not merely a trend but a necessity due to the environmental and health concerns associated with synthetic colorants. Synthetic dyes, often produced from petrochemical sources, involve processes that can result in harmful by-products. These dyes have been linked to environmental pollution and health risks, including skin irritations and potential carcinogenic effects. In contrast, natural colorants are generally safer for both humans and the environment. They possess intrinsic properties like antioxidant, anti-inflammatory, and antimicrobial activities, which add value beyond their coloring capabilities. Color plays a vital role in marketing various products such as cosmetics, food additives, and pharmaceuticals, enhancing their appeal and capturing consumer attention. Natural dyes, obtained from pigments produced by microorganisms and phytochemicals from plants, are increasingly replacing synthetic colorants in the cosmetic industry. These natural sources not only provide vibrant colors but also offer health benefits. For example, phytochemicals like anthocyanins are used as colorants and antioxidants, contributing to overall health and well-being. Despite their advantages, natural colorants face challenges such as limited color ranges, stability issues, and variability in shades. These challenges necessitate ongoing research and development to improve extraction methods, enhance color stability, and expand the palette of available hues. Advances in these areas are crucial for increasing the competitiveness and applicability of natural colorants across various sectors. This review provides a comprehensive overview of natural colorants, exploring their sources, benefits, and applications. It delves into the classification of colorants from plant, animal, microbial, and mineral origins, and discusses the various extraction methods used to obtain these dyes. By highlighting the potential and addressing the challenges of natural colorants, this paper underscores their relevance in modern industry practices and advocates for their broader adoption as sustainable and health-conscious alternatives to synthetic colorants.

ADVANTAGES OF NATURAL COLOURANTS

1. Skin-Friendly
2. Non-Toxic
3. Antioxidant Properties
4. Anti-Inflammatory Effects
5. Nutrient-Rich
6. Environmentally Friendly
7. Versatile Range of Colours.
8. Compatibility with Different Formulations

DISADVANTAGES OF NATURAL COLOURANTS

1. Limited Colour Range
2. Colour Variability
3. Stability Issues
4. Sensitivity to pH
5. Masking Flavour and Aroma
6. Limited Solubility
7. Sensitivity to Processing
8. Availability and Sourcing

APPLICATIONS

1. Cosmetics
2. Pharmaceuticals
3. Histological Staining
4. pH Indicator
5. Dye Sensitized Solar Cells
6. Food and Beverages
7. Leather Industry

CLASSIFICATION OF NATURAL COLORANTS

PLANT PIGMENTS

Plant pigments are natural compounds responsible for the vivid colors found in various parts of plants, such as leaves, flowers, fruits, and stems. These pigments, which include anthocyanins, carotenoids, betalains, flavones, chlorophylls, and lycopene, play crucial roles in photosynthesis, protection against UV radiation, and attracting pollinators. Beyond their biological functions, plant pigments are valuable in various industries. In the food industry, they are used as natural colorants, while in the cosmetics and pharmaceutical industries, they are prized for their antioxidant, anti-inflammatory, and other health-promoting properties. Their natural origin and multifunctional benefits make plant pigments an attractive alternative to synthetic dyes.

A LIST OF PLANT SOURCES FOR POTETIAL NATURAL COLOURANTS

Sno	***Species***	***Family***	***Commonname***	***Partused***	***Colourobtained***	***ColourApplication***
1	*Acacia catechu*	Mimosaceae	Cutch tree	Heart wood	Red	Textile
2	*Aegle marmelos*	Rutaceae	Brel tree	Fruit	Yellow	Food colourant
3	*Alcea rosea*	Malvaceae	Hollyhock	Flower	Red	Food colourant
4	*Alkanna tinctoria*	Boraginaceae	Dyer's alkanet	Root	Purple	Pharmaceutical Colourant
5	*Allium cepa*	Liliaceae	Onion	Skin	Orange	Textile dyeing
6	*Alnus sieboldiana*	Betulaceae	Alnus	Fruit	Red	Textile dyeing
7	*Alpinia flabellata*	Zingiberaceae	Ginger lily	Leaf	Yellow	Medicinal
8	*Amaranthus*	Amaranthaceae	Garden amaranth	Inflorescence	Red-violet	Nutritive pigment

	tricolor			and leaf		
9	*Annona reticulata*	Annonaceae	Bullock heart	Unripe fruit	Black	Textile dye
10	*Anthemis tinctoria*	Asteraceae	Dyer's chamomile	Flower	Yellowish	Textile dyeing
11	*Ardisia humilis*	Mysrinaceae	Jet berry	Fruit	Yellowish	Textile dye
12	*Arnebia densiflora*	Boraginaceae	Macrotomia cephalotes	Root	Red	Pharmaceutical
13	*Arnebia euchroma*	Boraginaceae	Pink Arnebia	Root	Red	Pharmaceutical
14	*Aronia melanocarpa*	Rosaceae	Black chokeberry	Fruits	Blue	Food colourant
15	*Artocarpus heterophyllus syn.A.integrifa*	Moraeceae	Jackfruit	Stem,Root	Yellow	Textile dyeing
16	*Baptisia australis*	Fabaceae	Baptisia	Flower	Yellowish	Textile dye
17	*Bauhinia variegata*	Fabaceae	Orchid tree	Flower	Violet pink	Medicinal (astringent)
18	*Berberis vulgaris*	Berberidaceae	Comon barberry	Root,Bark	Yellowish	Food and textile colourant
19	*Beta vulgaris*	Chenopodiaceae	Red beet	Root	Red,Yellow	Industrial food colourant
20	*Bidens pilosa*	Asteraceae	Hitch hikers	Leaf	Yellow	Textile dye
21	*Bixa orellana*	Bixaceae	Annatto	Seed	Orange	Food colourant
22	*Butea monosperma syn.B.frondosa*	Fabaceae	Bastard teak	Flower	Yellow	Medicinal colourant
23	*Caesalpinia sappan*	Fabaceae	Sappan	Wood	Red	Textile dyeing
24	*Caesulia axillaris*	Asteraceae	Pink node flower	Plant	Yellow	Textile dye
25	*Calendula officinalis*	Asteraceae	Calendula	Inflorescence	Orange	Food colourant
26	*Capsicum annum*	Solanaceae	Chilli	Fruit	Red	Food colourant
27	*Carthamus tinctorius*	Asteraceae	Safflower	Flower	Red	Food colourant
28	*Cassia aurriculata*	Fabaceae	Senn	Flower	Yellow	
29	*Casuarinaequisetafolia*	Casuarinaceae	Tanners	Bark	Brown	Textile dye
30	*Ceriops tagal syn.C. Candolleana*	Rhizophorace	Yellow Mangrove	Bark	Brown	Dye
31	*Cheiranthus cheiri*	Brassicaceae	Wallflower	Leaf,petal	Yellow	Textile dye
32	*Chlorophpora tincoria*	Moraceae	Fustic	Wood	Yellow	Textile dye
33	*Chloroxylon swietenia*	Rutaceae	Sweet orange	Peel	Yellow	Textile dye
34	*Citrus sinensis syn.C.aurantium*	Rutaceae	Satin wood	Bark	Yellow	Colouring fortified drinks
35	*Clitoria ternatea*	Fabaceae	Butterfly pea	Flower	Blue	Food colourant
36	*Coccus cacti*	Coccidae	carmine	Dried Insect body	Red	Textile dye
37	*Coccus ilicis*	Coccidae	Kermes	Insect body	Red	Textile dye
38	*Coreopsis tinctoria*	Asteraceae	Coreopsis	Flower	Yellowish	Textile dye
39	*Coriaria nepalensis*	Coriariaceae	Makola	Wood	Red	Textile dye
40	*Cotinuscoggygria syn. Rhus cotinus*	Anacardiaceae	Young fustic	Wood, leaf	Yellowish orange	Textile dye
41	*Crocus sativa*	Iridaceae	Saffron	Flower	Yellow	Cosmetic and food colourant
42	*Curcuma longa*	Zingiberaceae	Turmeric	Rhizome	Yellow	Food, cosmetic, Texutile and medicinal colorant

43	*Dahlia indica*	Asteraceae	Dahlia	Petals	Peechgold	Textile dye
44	*Datisca cannabina*	Datiscaceae	Hemp	Root	Yellow	Textile dye
45	*Delonix regia*	Fabaceae	Gul Mohar	Flower	Deep crimson	Textile dye
46	*Delphinium zalil*	Ranunculaceae	Larkspur	Flower	Yellow	Textile dye
47	*Diospyros malabarica syn.D.perigrina*	Ebenaceae	Coromandel Ebony	Unripe fruit	Brown	Textile dye and tanning
48	*Embellia ribes*	Myrsinaceae	False pepper	Fruit	Red	Textile dye
49	*Euterpeoleraceae*	Palmae	Acai	Fruit	Red	Food colourant
50	*Euterpe edulis*	Palmae	Assai palm	Fruit	Red	Food colourant
51	*Fagopyrum esculentum*	Polygonaceae	Buckwheet	Grain	Yellow	Textile dye
52	*Galium verum*	Rubiaceae	Lady's Bedstraw	Root	Red	Food and textile dye
53	*Garcinia xanthochymus*	Guttiferae	Dephal	Unripe fruit	Yellow	Food colourant
54	*Gardenia jasminoides*	Rubiaceae	Cape jasmine	Fruit	Yellow	Textile and food colourant
55	*Garuga pinnata*	Burseraceae	Chogar	Leaf	Red	Textile dye
56	*Genipa americana*	Rubiaceae	Jagua	Fruit	Blue	Food colourant
57	*Genista tinctoria*	Fabaceae	Dyer's greenweed	Flower	Yellow	Textile dye
58	*Gentiana pneumonanthe*	Gentianaceae	Gentiana	Flower	Blue	Non commercial
59	*Girardinia diversifolia*	Urticaceae	Girardinia	Fiber	Blue	Textile dye
60	*Gossypium herbaceum*	Malvaceae	Cotton	Flower	Yellow	Textile dye
61	*Haematoxylum campechianum*	Fabaceae	Logwood	Heart wood	Violet-purple	Textile dye and in inks
62	*Hedera nepalensis syn.*	Araliaceae	Ivy	Bark	Yellow	Textile dye
63	*Hibiscus rosasinensis*	Malvaceae	China rose	Flower	Purple	Food and cosmetic colourant
64	*Hibiscus sabdariffa*	Malvaceae	Red sorrel	Flower	Yellow	Food colourant
65	*Hyptyis suaveolens*	Labiatae	Mint weed	Plant	Yellow	Textile dye
66	*Impatiens balsamina*	Balsaminaceae	Garden Balsom	Leaf	Red	Hair dye and colouring fingernails. Henna substitute
67	*Indigofera tinctoria*	Fabaceae	Neel	Leaf	Blue	Textile, cosmetic and medicinal colourant
68	*Ipomoea asarifolia*	Convolvulaceae	Sweet potato	Grain	Pink	Food colourant
69	*Ipomoea batatas*	Convolvulaceae	Sweet potato	Flower	Purple	Colouring beverages
70	*Isatis tinctoria*	Fabaceae	Woad	Leaf	Blue	Textile dye
71	*Jatropha curcas*	Euphorbiaceae	Barbados nut	Bark	Blue	Textile dye
72	*Juglans regia*	Juglandacea	Walnut	Walnut shell bark and leaf	Red	Textile dyeing and supporter for hair dye
73	*Kigelia pinnata*	Bignoniaceae	Sausage tree	Wood, Roots	Greyish brown	Textile dye
74	*Laccifer lacca*	Coccidae	Lac dye	Insect deposit	Red	Textile dye
75	*Lannea microcarpa*	Anacardiaceae	Microcarpa	Fruits	Yellow	Alternative to synthetic

						dye
76	*Lawsonia inermis*	Lythraceae	Henna	Leaf	Red	Textile dye and Hair dye
77	*Lotus corniculatus*	Fabaceae	Birds foot trefoil	Flower ,Leaf	Orange,Yellow	Textile dye
78	*Maclura pomifera syn*	Moraceae	Osage-orange	Wood ,Bark ,Root	Yellow	Textile dyeing and tanning
79	*Mahonia aquifolium*	Berberidaceae	Holly Barberry	Fruit	Red	Food colourant
80	*Mallotus phillippensis*	Euphorbiaceae	Kamala tree	Fruit, Seed	Orange	Food textile and medicinal colourant
81	*Mangifera indica*	Anacardiaceae	mango	Bark, Root	Yellow	Textile dye
82	*Melastoma malabathricum*	Melastomataceae	Indian rhododendron	Fruit,Flower,Petal	Black Purple	In manufacturing,inks
83	*Memecylon umbellatum*	Melastomataceae	Iron wood tree	Flower, Leaf	Yellow	Colouring mats
84	*Mimusops elengi*	Sapotaceae	Spanish cherry	Bark	Brown	Textile dye
85	*Morinda citrifolia*	Rubiaceae	Mulberry	Root, Bark	Red, Yellow	Textile dye
86	*Myrica esculenta syn. M. nagi*	Myricaceae	Spanish cherry	Bark	Yellow	Medicinal
87	*Myrtillocactus geometrizans*	Cactaceae	Blue	Fruit	Red	Food colourant
88	*Nyctanthes arbor-tristis*	Oleaceae	Night Jasmine	Flower	Bright orange	Textile dye
89	*Perilla frutescens*	Lamiaceae	Beefsteak Plant	Leaf	Purple	Food colourant
90	*Pfaffia iresinoides*	Amaranthaceae	Brazilian ginseng-E	Roots	Yellow	Textile dye
91	*Phyllanthus emblica syn.Emblica officinalis*	Euphorbiacea	the Indian gooseberry	Bark	Brown red	Textile dye
92	*Phytolacca americana syn. P. decandra*	Phytolaccaceae	Poke weed	Berries	Red	Colouring wine and food stuffs
93	*Plecospermum spinosum*	Moraceae	Gumbenfong	Bark, Wood	Yellow	Textile dyeing
94	*Polygonum tinctorium*	Polygonaceae	Chinese indigo	Flower	Yellow	Textile dye
95	*Prunus cerasus*	Rosaceae	Tart cherry	Fruit	Pink	Food colourant
96	*Pterocarpus santalinus*	Fabaceae	Red sandal wood	Wood	Red	Textile and cosmetic colourant
97	*Punica granatum*	Lythraceae	Pomegranate	Rind	Yellowish Brown	Textile dye
98	*Quercus infectoria*	Fagaceae	Gallnut	Oak gal	Khaki, Yellowish	Textile dyeing and in making inks
99	*Reseda luteola*	Resedaceae	Dyer’s rocket	Whole plant	Deep yellow	Textile dye
100	*Rheum emodi syn.R. australe*	Polygonaceae	HimalayanRhubarb	Rhizome	Reddish	Textile dye
101	*Rhizophora mucronata*	Rhizophoraceae	True Mangroove	Bark	Chocolate	Textile dye
102	*Rosa mosqueta*	Rosaceae	Musk	Fruits	Yellowish	Food colourant
103	*Rubia cordifolia*	Rubiaceae	Indian madder	Root	Brick red	Textile dye
104	*Rubia tinctorium*	Rubiaceae	European madder	Root	Red	Textile dye
105	*Salix caprea*	Salicaceae	Goat willow	Bark	Pink	Textile dye

106	*Sarothamnus scoparius*	Fabaceae	Broom	Flower	Yellow	Textile dye
107	*Scutellaria comosa*	Labiatae	Comosa	Roots	Yellow	Textile dye
108	*Semecarpus anacardium*	Anacardiaceae	Marking nut tree	Bark,nut	black	Textile dye
109	*Serratula tinctoria*	Asteraceae	Sawwort	Whole plant except root	Yellow	Textile dye
110	*Shorea robusta*	Dipterocarpaceae	sal	Bark	Red,Black	Textile dye
111	*Solidago canadensis*	Asteraceae	Goldenrod	Plant	Golden, yellow	Textile dye
112	*Sorghum caudatum*	Poaceae	Caudatum	Leaf Sheaths	Yellow, Orange	Medicinal (fungal growth inhibitor)
113	*Symplocos racemosa*	Symplocaceae	Lodh	Leaf, bark,	Yellow	Textile dye (Silk)
114	*Tagetes erecta*	Asteraceae	Marigold	Petal	Yellow	Food colourant
115	*Tagetes patula*	Asteraceae	French Marigold	Petal	Yellow	Food colourant
116	*Tectona grandis*	Verbenaceae	Teak	Leaf	Yellow	Textile dye
117	*Terminalia catappa*	Combretaceae	Indian almond	Bark	Pinkish Red	Textile dye
118	*Terminaliachebula*	Combretaceae	Chebulic Myrobolan	Bark ripe and unripe fruit	Pink,yllow ,brown	Textile dye
119	*Toona ciliate syn.Cedrela toona*	Meliaceae	Red cedar	Flower	Red, pink	Textile dye
120	*Tradescantia pallida*	Commelinaceae	Purple heart	Leaf	Pink	Food colourant
121	*Ventilago denticulate syn. V calyculata*	Rhamnaceae	Ventilago denticulate	Bark, Root	Red	Textile dye
122	*Ventilago madraspatna*	Rhamnaceae	Red creeper-	Bark, Root	Red	Textile dye
123	*Woodfordia fruticosa*	Lythraceae	Fire Flame Bush	Flower	Pink red	Mordantin
124	*Wrightia tomentosa*	Apocynaceae	Woolly Dyeing Rosebay	Bark	Yellow	Textile dye,
125	*Zingiber officinale*	Zingiberaceae	Ginger	Rhizome	Brown	Textile dye(cotton)

Table 1: A list of plant sources for potential natural colorants

ANIMAL PIGMENTS

Animal pigments play a crucial role in the vibrant spectrum of colors found across the animal kingdom. From the dazzling plumage of birds to the striking patterns of fish and the camouflage of insects, pigments imbue creatures with hues that serve various purposes, including communication, camouflage, and protection from harmful UV radiation. Melanin, carotenoids, and porphyrins are among the primary pigments responsible for these vivid displays. Melanin provides protection against ultraviolet radiation and determines skin and hair color in mammals, while carotenoids produce the vibrant yellows, oranges, and reds seen in many birds, fish, and crustaceans. Porphyrins contribute to the green and red colors observed in some reptiles and amphibians. Understanding these pigments not only sheds light on the aesthetics of the animal world but also offers insights into their ecological interactions and evolutionary adaptations.

COCHINEAL: It is a red dye derived from crushed female cochineal insects.Carmine is the pigment which give red colour.

KERMES: The red dye is present in the dried bodies of female scale insects of the genus Kermes.

LAC INSECT: It is a type of scale insect that produces a resinous substance known as lac.

SEA SNAILS: It contains purple dye as well as blue dye which is obtained from marine mollusks.

MICROBIAL PIGMENTS

Microbial pigments, synthesized by a diverse array of microorganisms, hold significant scientific and industrial importance. These pigments, ranging from carotenoids to flavins and prodigiosins, serve various functions, including photoprotection, antioxidation, and nutrient acquisition. Moreover, their applications span multiple industries, including food, pharmaceuticals, cosmetics, and textiles. Carotenoids, for instance, not only contribute to microbial survival in harsh environments but also find utility as natural colorants and antioxidants in food products. Similarly, prodigiosins exhibit promising antimicrobial and anticancer properties, driving research into their therapeutic potential. Understanding microbial pigment biosynthesis pathways and their regulatory mechanisms is critical for optimizing pigment production and harnessing their biotechnological applications effectively. Consequently, microbial pigments represent not only intriguing facets of microbial physiology but also valuable resources for various industrial and biomedical purposes.

Colour	Utilization	Pigment	Microbes	Biological activities
Red-orange	Cheese, Pastry, ice cream,	β-carotene	Dunaliella salina	Anticancer, antioxidants.
Red	Feed of poultry	canthaxanthin	Hematococcus	Antioxidant
blue	Neutraceuticals, biotechnology, cosmetic & food industries	Phycocyanin	Arthrospira sp.	Antioxidants, antitumors, and immunoregulatory.
Purple	Medicinal, cosmetic & food industry	Violacein	Janthinobacterium lividum, Chromobacterium violaceum	Antioxidant.
orange	Feed of poultry	Canthaxanthin	Lactobacillus pluvalis, Bradyrhizobium sp.	Antioxidants, anticancer.
Blue, green	Food, cosmetic & Neutraceuticals industries	Phycocyanin	Pseudomonas spp.	Cytotoxicity, Proinflammatory
Red	Cosmetic and food products	Prodigiosin	*Serratia marcescens* Pseudoalteromonas rubra	DNA cleavage, anticancer& immune suppressant
Pink -Red	Cosmetic, fish, and animal food products	Astaxanthin	Agrobacterium aurantiacum, Paracoccus, carotinifaciens, Xanthophyllomyces dendrorhous	Anti-inflammatory, anticancer& antioxidants
Dark - Red	Poultry's food	Canthaxanthin	Haloferax alexandrines	Antioxidant, anticancer.
Yellow- Orange	Pastry, cream, cheese & ice cream	β-carotene	Mucor circinelloides, Neurospora crassa, and Phycomyces blakesleeanus	Anticancer, antioxidant.
Red	Meat coloring agent	Lycopene	Blakeslee trispora, Fusarium sporotrichioides	Anticancer& antioxidant
Orange, pink	Poultry feed	Canthaxanthin	Monascus spp.	Antioxidant & anticancer
Yellow	Energy drinks, infant food, sauces, cereal products, &Food products	Riboflavin	Ashbya gossip	Protection of cardiovascular, antioxidant & anticancer
Black	Cosmetic, medical &food industries	Melanin	Saccharomyces, Neoformans	Antibiofilm, antioxidant & anti-microbial.
Pink -Red	Fish & animal products, foods & cosmetic industry	Astaxanthin	Xanthophyllomyces diandrous, Phaffia rhodozyma	Anti-inflammatory, photo protectant, anticancer
Red	Astaxanthin, carbonated drink, milk, yogurt, cereal,	Prodigiosin	Streptoverticillium rubrireticuli	Antioxidant and anticancer.

Table 2 : Colour obtained from microorganisms

MINERAL PIGMENTS

Mineral pigments, hailing from the earth's diverse geological makeup, have been fundamental to human creativity and expression for millennia. Ranging from the warm ochres to the vibrant ultramarines, these inorganic compounds offer a kaleidoscope of colors that have adorned cave walls, illuminated manuscripts, and modern canvases alike. Their enduring appeal lies not only in their rich hues but also in their permanence and stability, standing the test of time against fading and degradation. From the terracotta tones of iron oxide to the striking blues of azurite, mineral pigments continue to inspire artists, craftsmen, and technologists across myriad applications, from fine art to industrial coatings. As we navigate towards sustainable practices, a renewed appreciation for the earth's natural palette drives innovation in sourcing and processing, ensuring that the legacy of mineral pigments endures while respecting the planet that provides them.

OCHRE - A kind of iron ore, also called limonite which is an earth mineral oxide. It is used for yellow, brown, and red nuances.

CHARCOAL BLACK- Charcoal is used as black pigment. It is produced from woods after burning in a closed container.

CLAY- Clay has been widely used as a natural colorant for various applications. Different types of clay offer a spectrum of colors due to their mineral content. It is used in Pottery and ceramics, construction purposes, cosmetics and as natural dyes.

MALACHITE - An intense green mineral, actually copper carbonate mixed with copper hydroxide. Breaks from time to time as copper ore. Used for green nuances.

MANGANESE - A metallic element. Used for black nuances.

CINNABAR - A heavy reddish mineral, with a metallic adamantine luster. It is made from quick silversulfide. Used for red nuances.

AZURITE - A blue/dark blue copper mineral. It is crystallized and often found together with the green mineral malachite. Both are products of erosion and oxidation from copper minerals. Used for blue nuances.

LEAD - Used for red nuances.

ARAGONITE - Usually colourless or white mineral. Used for white nuances.

SIENNA- This is another common mineral-based pigment. It is a form of limonite clay that is derived from ferric oxides to produce a rich, earthy red. It produces darker shades from creams to browns.

COBALT-It is a shiny gray brittle metal that is known for creating an intense blue colour in glass and paints. The pigments are made by heating aluminium silicates with cobalt and heating to 1200 °C.

ULTRAMARINE-Ultramarine was obtained from lapis lazuli and commonly used in Europe for jewellery and paint. The expensive blue pigment was artificially manufactured beginning in the 19th century.

SPINELS- These hard, crystalline minerals generate colours by exchanging certain ions that heat and combine with other minerals. They're available in yellow, orange, turquoise, and blue.

EXTRACTION OF NATURAL COLOURANTS

Extraction Methods

- Aqueous extraction
- Alkali or acid extraction
- Microwave and ultrasonic assisted extraction
- Solvent extraction
- Super critical fluid extraction
- Soxhlet extraction

Aqueous Extraction

Traditionally employed for extracting dyes from plants and other materials, aqueous extraction involves initially breaking down the sample material into small pieces or powder, which is then sieved to enhance extraction efficacy. Subsequently, the material is soaked in water within earthen, wooden, or metal vessels, typically left overnight to facilitate the loosening of cell structures. Following this, the mixture is boiled to release the dye solution, which is subsequently filtered. This boiling and filtering process is iterated to ensure maximal extraction of the dye.

Acid and Alkali Extraction Process

Given that numerous dyes exist in glycoside form, their extraction can be achieved under mild acidic or alkaline conditions. The inclusion of acid or alkali aids in the hydrolysis of glycosides, thereby enhancing extraction efficiency and increasing the yield of coloring agents. Alkaline extraction proves beneficial for dyes containing phenolic groups, as these compounds readily dissolve in alkali, thereby augmenting dye yield. Subsequently, the dyes can be precipitated through acidification. This technique is applicable for extracting dye from sources such as annatto seeds, safflower petals, and lac insects.

Ultrasonic and Microwave Extraction

These methods utilize microwave and ultrasound assistance to enhance extraction efficiency, thereby reducing the required solvent quantity, extraction time, and temperature. When plant-derived materials containing natural dyes are subjected to water or other solvents in the presence of ultrasound, tiny bubbles or cavitations form within the liquid, facilitating extraction. Moreover, this process can be conducted at lower temperatures, thereby improving the extraction of heat-sensitive dye molecules. In microwave extraction, natural sources are treated with minimal solvent in the presence of microwave energy, accelerating the processes and resulting in shorter extraction times and improved yields.

Solvent Extraction

Natural coloring agents, depending on their characteristics, can also be extracted using organic solvents such as acetone, petroleum ether, chloroform, ethanol, methanol, or combinations thereof, such as ethanol-methanol mixtures or water-alcohol mixtures. The water/alcohol extraction method proves effective in extracting both water-soluble and water-insoluble substances from plant resources.

Supercritical Fluid Extraction

It is highly effective method to extract natural pigments. maintain a gas in the supercritical state. Extraction by supercritical fluid involves the dissolution of the desired component from sample of plant under the controlled condition of temperature and pressure followed by the separation of desired component from the supercritical fluid by a significant drop in solution pressureSupercritical fluid extraction using carbon dioxide (CO_2) is a good alternative to solvent extraction as it is nontoxic, cheap, easily available, and does not leave residues.

Soxhlet Extraction

This method, also known as continuous hot extraction, utilizes a glass apparatus comprising components such as a round-bottom flask (RBF), an extraction chamber, a siphon tube, and a condenser positioned at the top. Finely powdered plant material is enclosed within a porous bag crafted from clean cloth or robust filter paper, tightly sealed. Solvent is then poured into the bottom flask, followed by the placement of the thimble into the extraction chamber. Upon heating, the solvent evaporates and ascends through the condenser, where it condenses and extracts the drug upon contact. Once the solvent level in the extraction chamber reaches the siphon's top, both solvent and extracted plant material flow back into the flask. This cyclic process persists until the drug is completely extracted.

TESTING OF NATURAL COLOURANTS

INVITRO TESTING

In vitro testing of natural colorants typically involves assessing their safety and efficacy outside a living organism.

1. Stability Testing:

Divide each colorant solution into two sets. Expose one set to light, heat, and oxygen for 10 days. Keep the other set in controlled conditions. Measure color intensity using a spectrophotometer at regular intervals.

2. pH Sensitivity Test:

Adjust the pH of colorant solutions using acids/bases over a range of 2 to 10.Monitor color changes at each pH level.

3. Compatibility Test:

Mix colorant solutions with common food matrices (e.g., dairy, oils). Assess stability and color retention over 14 days. It can also determined by FTIR.

4. Microbial Contamination Test:

Inoculate colorant solutions with common foodborne microbes. Monitor microbial growth and assess color changes over 21 days.

5. Solubility Test:

Assess colorant solubility in different solvents. Observe any precipitation or changes in color.

INVIVO TESTING

1. Oral Ingestion Studies:

Administer varying doses of the natural colorant orally to a group of test subjects. Monitor subjects for changes in behavior, signs of distress, or adverse reactions. Conduct regular blood tests to assess metabolic byproducts and potential toxicity. Perform post-mortem examinations to analyze organs for abnormalities.

2. Dermal Application Studies:

Apply the natural colorant to a specific area on the skin of test subjects. Assess skin reactions, including redness, swelling, or irritation, at regular intervals. Collect skin samples for histological analysis to examine cellular changes. Monitor for systemic effects by conducting blood tests over the test period. Conduct post-mortem examinations to examine internal organs for indications of toxicity.

3. Genotoxicity Assessments:

Administer the natural colorant to test subjects. Collect samples of blood, bone marrow, or other tissues.

Conduct assays like the Ames test or Comet assay to assess genetic damage. Evaluate results for DNA mutations, chromosomal aberrations, or other genotoxic effects.

4. Inhalation Studies:

Expose test subjects to aerosolized forms of the natural colorant. Monitor respiratory function and signs of respiratory distress. Collect lung tissue for histological analysis. Conduct blood tests to assess systemic effects.

5. Immunotoxicity Studies:

Administer the colorant to test subjects. Assess immune system function through various immune response assays. Monitor for signs of immunosuppression or hypersensitivity. Conduct blood tests for immune cell counts and cytokine levels.

MEDICINAL PROPERTIES OF NATURAL COLOURANTS

PLANT	BIOLOGICAL NAME	PARTS USED	COLOUR OBTAINED	MEDICINALPROPERTIES
Black catechu	Acacia catechu	Bark	Brown/ black	Used medicinally for sore throat and cough.
Vasaka	Adhatoda vasica Nees.	Leaf	Yellow	Used in bronchial infection
Aloe vera	Aloe barbadensis L.	Whole plant	Red	Fresh juice of leaves is cathartic and refrigerant used in liver and spleen ailments and for eye infections, useful in X-ray burns and other skin disorders.
Neem	Azadirachta indica A.	Bark	Brown	Skin disorders, leaves considered as antiseptic.
Annato	Bixa orellena L.	Seeds	Orange,Red	Antimicrobial, diuretic, digestive stimulant, hepatoprotective, Antipyretic and antiperiodic.
Bastard Teak	Butea monosperma Lam.	Flower	Yellow/Orange	Astringent, antidiarrheal, Antidysenteric, purgative and anthelmintic
Capsicum	Capsicum annuum L.	Fruits	Red	Digestive, carminative, stimulant, cardiotonic, antipyretic and expectorant.
Safflower	Carthamus tinctorious L.	Flower	Yellow, Red	Oil applied to sores and rheumatic swelling; also used in case of jaundice.
Senna	Cassia auriculata L	Flower, Seed	Yellow	Leaves and fruit anthelmintic. Seeds used in eye infection. Roots employed in skin disorders.
Saffron	Crocus sativus L.	Flower	Yellow, Orange	Used as sedative and emmenagogue.
Turmeric	Curcuma longa L.	Rhizomes	Yellow	Anti-oxidant, anti-inflammatory, antiplatelet, anti-cancer, anti -viral, anti -fungal, anti -bacterial effects.
Ceylon tea	Elaeodendron glaucum Pers.	Bark	Red	To cure stomach pain.
Plum	Eugenia jambolana Lam.	Bark, leaf	Red	Decoction of bark and seeds used in diabetes
Mangosteen	Garcinia mangostana L.	Fruit	Black	Used in diarrhoea and dysentery
Indigo	Indigofera tinctoria L.	Leaf	Blue	Extract used in epilepsy and other nervous disorders; in the form of ointment used for sores, old ulcers and piles. Root used in urinary complaints and hepatitis
Henna	Lawsonia inermis L.	Leaf	Orange	Antidiarrheal, antidysenteric, astringent, emmenagogue liver tonic and antifungal.
Night Jasmine	Nyctanthes arbortristis L.	Flower	Yellow	Used in rheumatism, fever and antibacterial.
Pomegranate	Punica granatum L.	Fruits	Yellow	Antibacterial, Antiviral, Astringent, Cardiac, Demulcent, Stomachic Emmenagogue,

				Vermifuge.
Red Sandalwood	Pterocarpus santalinus L.	Wood	Red	Hepatoprotective
Indian madder	Rubia cordifolia L.	Root	Red	Antitussive, Astringent, Diuretic, Emmenagogue, Expectorant and Styptic.
Tomato	Solanum lycopersicum L.	Fruits	Red	Antibacterial, antifungal, anti-mutagenic. Used in prostate cancer, arteriosclerosis and diabetes.
Marigold	Tagetes erecta L.	Flowers	Yellow	Emmenagogue, Anthelminthic, aromatic, digestive, diuretic, sedative, stomachic.

Table 3: Medicinal properties of natural colourants

II. CONCLUSION

The adoption of natural colorants is gaining traction due to their health benefits, environmental sustainability, and consumer preference for natural products. Although they pose challenges like stability and color variability, advancements in extraction techniques and formulation methods are enhancing their applicability. Natural colorants, sourced from plants, animals, microorganisms, and minerals, offer versatile solutions across multiple industries. Ongoing research and development are expected to improve their efficacy and range, reducing reliance on synthetic dyes. Embracing natural colorants aligns with the growing demand for eco-friendly products and leverages their health benefits, making them valuable in modern industrial applications. Natural colorants present a compelling alternative to synthetic ones, offering hues derived from plants, fruits, and minerals. While they may lack the vibrancy of synthetic counterparts, their appeal lies in sustainability and potential health benefits. However, challenges such as stability and consistency necessitate ongoing research and innovation. In the quest for eco-friendly and safe options, natural colorants stand as a promising choice for industries seeking environmentally conscious solutions. Beyond their visual appeal, natural colorants exhibit intriguing medicinal properties that have captured the interest of the cosmetics and pharmaceutical industries. Extracts from plants like turmeric, beetroot, and spirulina, known for their vibrant hues, also boast anti-inflammatory and antioxidant qualities. These bioactive compounds are used in cosmetics not only for pigmentation but also for skincare formulations promoting healthier skin. In pharmaceuticals, the use of natural colorants aligns with a growing preference for plant-based remedies, offering potential benefits like antimicrobial effects and overall wellness promotion. The shift towards natural colorants reflects a broader societal inclination towards sustainable and health-conscious choices. Despite their medicinal properties, challenges like standardization and regulatory considerations persist, requiring continued research to fully unlock their potential in promoting aesthetic and health benefits in cosmetics and pharmaceuticals.

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