STUDY OF NATURAL COLOURS

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in

Chemistry

by

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CANDIDATE’S DECLARATION

I, MANSI MANN (2k22/MSCCHE/20) hereby certify that the work which is being presented in the dissertation entitled STUDY OF NATURAL COLOURS in partial fulfillment of the requirements for the award of the Degree of Masters of Science in Chemistry, submitted in the Department of Applied Chemistry, Delhi Technological University is an authentic record of my own work carried out during the period under the supervision of Prof. Ram Singh.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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CERTIFICATE

Certified that **MANSI MANN** (2k22/MSCCHE/20) has carried out their research work presented in this dissertation entitled **"STUDY OF NATURAL COLOURS"** for the award of **Master of Science in Chemistry** from Department of Applied chemistry, Delhi Technological University, Delhi, under my supervision. The thesis embodies results of original work, and studies are carried out by the student herself and the contents of the dissertation do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Prof. Ram Singh

ACKNOWLEDGMENTS

I wish to express my sincerest gratitude to Prof. Ram Singh for his continuous guidance and mentorship that he provided me during the project. He showed me the path to achieve our targets by explaining all the tasks to be done and explained us the importance of this project as well as its industrial relevance. He was always ready to help and clear doubts regarding any hurdles in this project. Without his constant support and motivation, this dissertation would not have been successful.

I am also thankful to my family members for their continuous support.

Place: Delhi MANSI

STUDY OF NATURAL COLOURS

Historical Background

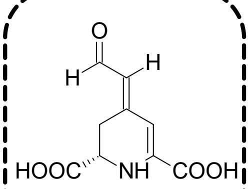
Through the creativity and perseverance of our ancestors, natural bio-colorants have been found for centuries. They can be found hidden in a variety of places, including the secretions of sea snails, insects (*Lacifer lacca*, *Kermes*), rhizomes (*Rheum emodi*, *Curcuma longa*), and plant roots (*Rubia tinctorum*). But in Mediterranean culture, the most prized hues were 6,6'-dibromoindigo for purple, madder for reds, and indigo for blues [1, 2]. Colors have always piqued human attention; dyeing has a lengthy history, and many of the dyes date back to the prehistoric era. Henna plants (*Lawsonia inermis*) were used to tint the nails of Egyptian mummies [3, 4]. Spectroscopic study of ancient Egyptian cuneiform inscriptions revealed that they were dyed with bio-colorants, such as, Murex sp., Tyrian purple, madder, Indigofera sp., and others, that were sold by the resourceful and hardworking artisans [5, 6].

As weaving techniques advanced, several ancient cultures expanded their use of dyes to textiles [7, 8]. While charcoal, limestone, and ochre were significant pigments, other common ancient colors include yellow, blue indigo, and madder made from saffron or turmeric [8]. Animals, minerals, and plants were the main sources of natural colorants; practically every plant part, including seeds, flowers, roots, bark, leaves, and so on, was used to create various hues and their combinations [9]. Colored minerals were the primary pigments used in the Stone Age, but minerals and bio-colorants were also used by the Ancient Egyptians, Phoenicians, , Ancient Romans, Ancient Africans, and Ancient Indians.

Classification of Natural colours

Plant origin

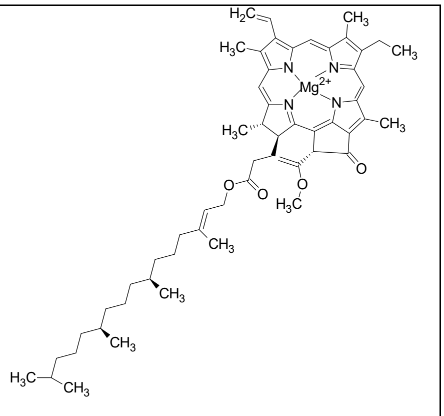
1. Betalains: The pigment betalain is a member of the Caryophyllales group. Based on its chemical structure, it can be separated into yellow betaxanthins or red-violet betacyanins [10]. The chromophoric unit and structural elements are the same betalamic acid for both groups. The molecular weight of betalains is 550.5 g/mol, and their chemical formula is C24H26N2O13. It is present in the plant's edible portion as well as in the bracts, flowers, leaves, and stems [11]. Because betalains are stable over a broad pH range, from 3 to 7, they are primarily utilized in low-corrosive food sources, particularly dairy products [12].

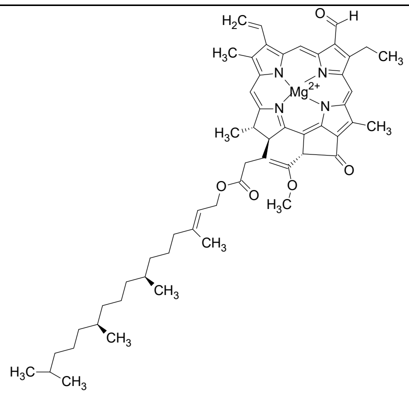


Betalamic acid

The rhizomes of the turmeric rant plant are also used to make turmeric, a bright yellow material. Turmeric contains 2.5–6% curcuminoids and 3–5% unstable oil [13]. In addition to being high in nutrients, betalains exhibit anti-inflammatory, antioxidant, antibacterial, and antifungal properties [14]. It has been demonstrated that red beets use the betalain molecule to boost their resistance to pathogens and improve their important defenses [15].

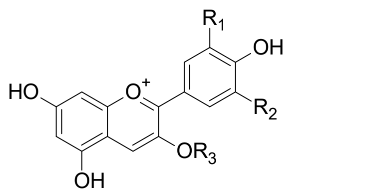
2. Chlorophyll: Since the natural eye's green color area is considered to be sensitive, it can easily discern between the many different shades of green [16]. By absorbing light energy and transforming it into chemical energy, chlorophyll, a complex green pigment present in plants, algae, and some bacteria, is essential to the process of photosynthesis [17]. The structure of the chlorophyll molecule is composed of a linked magnesium molecule in the center of the cyclic tetrapyrrole. This wide variety of greens is based on two pigments: chlorophyll a and chlorophyll b.

Chlorophyll a	

Chlorophyll b	

Furthermore, these hues provide plant-based foods that humans consume—like flavors, spices, veggies, and certain natural products—a green tint [18]. Because of their sensitivity to heat, chlorophyll was removed from food plants, irritable grass or hay, mulberry leaves, and silkworm droppings [19]. Heat is another important factor that indirectly modifies the structure of chlorophyll and causes color changes. Antacids normally have a pH between 7 and 9. Chlorophyll's hue changes under an acidic pH. The cell membrane of the plant deteriorates when exposed to elements that lower pH, such as light, heat, and releasing acids [20]. Chlorophyllin was employed by Paskeviciute et al. (2019) to lower the microbial burden in basil. They stated that one way to extend the safety and shelf life of basil would be to soak it in chlorophyllin and expose it to light at 405 nm [21].

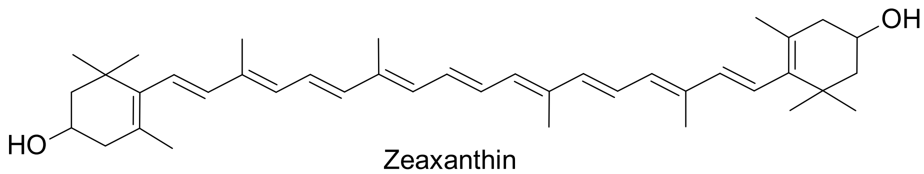
3. Anthocyanins: The majority of vascular plants have water-soluble pigments called anthocyanins. Anthocyanins are a subclass of flavonoids, which are significant secondary plant metabolites [22]. The glycoside of anthocyanidins, anthocyanin, is more abundant in plants than its parent anthocyanidin [23]. Normal, cyanidin, delphinidin, and malvidin are a few important aglycone anthocyanidins that are widely distributed and essential to the human diet [24]. Some natural items, such as apples, cherries, figs, and so on, contain only one type of anthocyanin, such as cyanidin, whereas others, like cherries and cranberries, may include both cyanidin and peonidin [25].



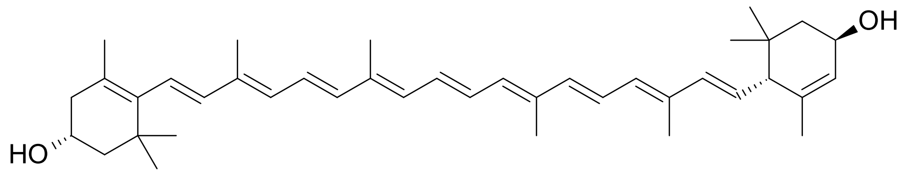
Compound	R_1	R_2	R_3
Cyanidin	OH	H	Glucose,
Delphinidin	OH	OH	galactose,
Malvidine	OCH_3	OCH_3	or arabinose

Anthocyanins serve a variety of ecological purposes for plants, including photoprotection, defense mechanisms, and antioxidants. Additionally, it supports reproductive processes such seed dispersal, pollination, and antifeedant [26]. Butterfly pea anthocyanins microencapsulation is a sustainable method of makeup application that can be used in pharmaceutics and cosmetics, particularly powder dosage forms. An accelerated stability test revealed that the red shade rouges that were created with 2–8% microencapsulated butterfly pea anthocyanins and 6% maize starch were stable [27].

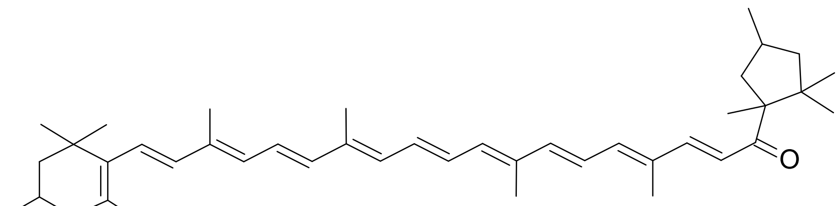
4. Carotenoids: Brightly colored natural organic pigments called carotenoids, also known as tetraterpenoids, are present in the chromoplast and chloroplast of almost every plant family as well as certain other photosynthetic species. Carotenoids can only be synthesized by prokaryotes, fungi, and plants [28]. Long conjugated double bonds are what give the carotenoids their color. They produce the colors yellow, orange, and red by absorbing light in the 400–500 nm band of the spectrum [29]. Carotenoids, which are formed as part of the xanthophyll cycle and have a photoprotective function, are primarily red and yellow in color and include lutein, zeaxanthin, capsanthin, violaxanthin, and neoxanthin. An excellent example of lutein's natural supply is the marigold flower [30].



Zeaxanthin



Lutein



Capsanthin

According to research, carotenoids can prevent cancer by preventing radiation damage, serving as antimutagens and enemies of molecules that cause cancer, and reversing the harmful effects of photosensitizers [31]. Carotenoids [32] and other bioactive antioxidants with potential health benefits [33] are plentiful in the trash produced by the tomato canning and citrus juice industries. One of the biggest environmental concerns is how to dispose of such waste. By recovering economically significant compounds from fruit and vegetable waste, this issue can be resolved. Many studies are being conducted to extract commercially significant carotenoids from the waste of fruits and vegetables [34].

Animal Origin

Colorants made from animal parts such as scales, bones, shells, and secretions are known as animal-based dyes. Many cultures have been using them for thousands of years to color ceramics, textiles, and other items [35].

Cochineal (carmine): The dried carcasses of female insects, Dactylopius coccus, which feed on cactus plants, mainly Opuntia, are used to make cochineal, a red dye [36]. The red pigment is extracted by crushing, drying, and harvesting the insects [37]. Cochineal was a major export during colonial times and has been used for generations throughout Central and South America. This natural food and fabric dye is still in use [38]. The cochineal bug, which makes red pigments, is native to South Africa. Carminic acid, the primary anthraquinone colorant, dissolves in water. The color variations of carminic acid are violet, but the hue of lowering acidity is red [39].

Tyrian Purple: Tyrian Purple, also known as royal purple, is made from the secretions of certain sea snails, including the Murex Trunculus and Murex brandaris [40]. A purple pigment is created by a chemical reaction that occurs when the snails are crushed [41]. Tyrian Purple was highly prized in ancient societies, particularly in Greece and Rome. Royalty is associated with this expensive coloring [35].

Lac Insect: Lacquer is a red pigment that has been used as one of the earliest insect dyes since prehistoric times. The word "lac" comes from the Indian word "lakh," suggesting that a small quantity of pigment can yield hundreds of thousands of insects [42]. It is also utilized as a coloring agent in the production of food, medicine, and solar cells [43].

Sepia and shellfish purple: The ink sac of the cuttlefish, Sepia officinalis, is the source of sepia coloring [44]. To produce brown pigment, the ink sac is extracted and treated [37]. Historically, sepia has been used as a dye and an ink. Shellfish Hexaplex trunculus is one of the mollusk species from which purple color is extracted [38]. Made from the mollusk's secretions, it was prized as a luxury commodity by the ancient Greeks and Phoenicians [35].

Microbial origin

Although it is typically found in Actinobacteria, the production of pigment varies greatly among bacteria. Numerous colors are produced by a number of species, including *Streptomyces*, *Nocardia*, *Thermomonospora*, *Microbispora*, *Streptosporangium*, *Rhodococcus*, and *Kitasatospora* [45]. It is mostly used as a bio-colorant because of its biological activity, which produces the different shades from microorganisms such as melanin, vioacein, riboflavin, canthaxanthin, prodigiosin, astaxanthin, phycocyanin, β-carotene, carotenoid, lycopene, etc. [46].

Violaceins: When two tryptophan molecules condense, a natural indolocarbazole product called vitexin, a purple color, is created [47]. Raw extracts of a purple pigment made by the strain *Chromobacterium violaceum* combined with bacterial suspensions inhibited the soil amoebas from consuming the bacteria, which would have otherwise been phagocytized, according to the first activity reports on this pigment, which were published in 1942 [48].

In the natural world, several genera can be found in soil, freshwater, and marine habitats. Because of its various biological properties, such as its anticancer, antifungal, antibacterial, and antibiotic properties, it is becoming more and more popular in the pharmaceutical, food, and cosmetics industries [49].

Indigoidines: A non-ribosomal peptide synthetase (NRPS) catalyzes the condensation of two L-glutamine molecules to produce indigoidine, a naturally occurring pigment. Its name is derived from its very unusual blue coloring, which is comparable to indigo [50]. Indigoidines are currently known to exhibit antibacterial action against *Vibrio fischeri* [51].

Melanins: Through fermentative oxidation, eukaryotic organisms and a number of microbes create melanin, a heterogeneous and polymeric pigment [52]. Since melanin is highly stable photochemically and nearly insoluble in the majority of organic solvents, acids, and water, it is a particularly difficult compound from an analytical perspective in microorganisms [53]. Recent years have seen the description of novel melanin-producing strains with a range of biological properties, including the ability to be heat-stable, photostable, antioxidant, and anticancer [54, 55].

Beta carotene: The algae Dunaliella salina has a lot of β carotene, which makes it possible to extract it [56]. Carrots, spinach, tomatoes, and other foods are rich in β-carotene. The food sector uses β carotene to color food products including cheese, milk, pastry, ice cream, etc. [57].

Carotenoids: Carotenoids are lipid-soluble compounds found in nature. Carotenoids are incorporated with a variety of microorganisms, such as bacteria, fungus, and microalgae [58,59]. The red, orange, and yellow hues were produced by carotenoids. Carotenoids are produced for industrial use by a variety of microbes, including *streptomyces*, *penicillium oxylium*, and *Ashbya gossipy*. Because of their pro-vitamin A and antioxidant properties, carotenoids are widely used in the feed industries, food, and cosmetic [60].

Mineral origin

Colorants made from naturally occurring minerals are referred to as mineral-based dyes, inorganic dyes, or mineral pigments. The strong chemical stability and resistance to fading or chemical alteration under various environmental circumstances are characteristics of these pigments, which are made up of inorganic compounds [61]. Ultramarine blue, which comes from the stone lapis lazuli, is among the most well-known instances of a mineral-based dye. Utilized since antiquity, this pigment is prized for its rich blue hue and fading resilience [62].

The longevity and permanence of mineral-based dyes are their main advantages. Mineral pigments are extremely resistant to elements like light, heat, and moisture, in contrast to organic dyes, which are frequently made from plant or animal sources and may fade or degrade with time [63]. In order to produce golden and white coloring, respectively, in liqueurs, chocolate decorations, and the outside coating of confections, gold and silver are permitted as colorants in the European Union [64]. Mineral colorants often disperse in the application media as crystals or powders; they are pigments rather than dyestuffs. As a result, painting uses of colorants derived from minerals are restricted. Moreover, mineral-based colorants are linked to the negative impacts that heavy metals like lead and chromium have on the environment and human health [65]. A study on the synthesis of non-toxic inorganic pigments was published by Yuan et al. (2018). The results showed that the synthesized pigments were brighter, more Near InfraRed (NIR) reflective, and had superior thermal and chemical durability, making them suitable for use as multipurpose pigments in roofing materials or ceramic tiles [66].

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