

## Plant Pigments as Drugs

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### ABSTRACT

Plant pigments that are responsible for their yellow, bright red, and orange color are carotenoids that play a key role in plant health. Therefore, consumption of foods that have carotenoids provide various health benefits to the human body. Different vegetables and fruits in which carotenoids are present: yams, carrots, sweet potatoes, watermelon, papaya, cantaloupe, spinach, mangos, kale, tomatoes, oranges, bell peppers, etc. There are over 600 known carotenoids in nature, found in plant cells, bacteria, and algae, and that belongs to a class of phytonutrients (“plant chemicals”). Xanthophyll is the molecules known as hydrocarbons and found in orange and yellow fruits and vegetables, for example, pumpkin, cantaloupe, sweet potatoes, apricots and carrots. Association of word carrot with carotene will certainly relate the color of these pigments. Later class is oxygen-containing molecules, found in dark leafy greens such as kale, spinach, and broccoli.

Plant pigments, a generic term used to designate a large number of colored molecules, can be classified into tetrapyrroles (e.g., chlorophyll) and carotenoids (e.g.,  $\beta$ -carotene and xanthophyll). Of the pigments, carotenoids are fat-soluble (lipophilic) natural pigments which are synthesized by plants and some microbes. These pigments not only play a key role in photosynthesis but are also responsible for the bright colors of various plants, fruits, flowers, and vegetables.

**KEYWORDS:** *plant pigments, drugs, medicinal values, chemicals, color, natural, photosynthesis, health*

### INTRODUCTION

Plant pigments and therapeutic effects against cancer. Important plant pigments such as anthocyanins, lycopene, carotenoids, chlorophyll, and betalains are explained for their anticancer effects. Plant pigments are secondary metabolites which obstruct cancer cell proliferation; stop growth and cell division in cancer cells. These inhibit cellular processes in cancer cells such as signaling pathways, cell cycle, induce apoptosis, and autophagy. Besides, anticancer activity these also assist in controlling high blood pressure, obesity, hyperglycemia, hypercholesterolemia, and restore cardiovascular problems. [1,2] A full series of pigments is available in various plants families which might show protective effects against cancer. Plant pigments are edible, nutritionally rich and therapeutically suitable. Due to their health-promoting effects there is a growing public interest to consume green vegetables, fruits, sprouted seeds, pigmented cereals, and processed low energy antioxidative functional food. For widening their use,

these could be harvested using recombinant gene technology to add to processed foods as a coloring agent.[3,4] Plant pigments as natural plant products or its by-products are highly useful for the development of a large variety of functional foods, digestive ingredients, additives, as well as cosmetic products. These could be naturally added to genetically suitable modified foods by applying genomic tools. No doubt plant secondary metabolites will also fulfill needs of present-day medicine and show great promise for the future.[5,6]

Naturally occurring pigments in plants are responsible for giving eye capturing colors to them. The major groups of plant pigments like chlorophylls, carotenoids, betalains and flavonoids not only impart colors which attract pollinators but also have beneficial health effects when consumed in diet. Plant pigments have been used as impeccable natural source of color. A remarkable work has been done to

**How to cite this paper:** Sheikh Ayyan Ahad "Plant Pigments as Drugs" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-6, October 2022, pp.1740-1746, URL: [www.ijtsrd.com/papers/ijtsrd52160.pdf](http://www.ijtsrd.com/papers/ijtsrd52160.pdf)



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understand the chemical and technological aspects of natural plant pigments, mainly anthocyanins, betalains, chlorophylls, and carotenoids. These plant pigments are related to a broad spectrum of health-promoting benefits. These natural compounds are also used as indispensable components in many pharmaceutical, medicinal and cosmetic product manufacturing industries. The wide range of biological usage of these pigments demand further confirmation by performing cell culture, animal model research supported by human studies.[7,8]

The continued universal application of synthetic colorants for decades have caused environmental pollutions and human health vulnerabilities. So, it was indispensable to discover novel natural colorants such as microbial colorants which were safer and better than synthetic colorants. The potential of bacterial pigments for mass production of diversified coloring properties was first prospective and is now getting the notable importance and attention of both the researchers and industries. Literature establishes that the natural colorants produced from microbes were applied in food and pharma products successfully. Apart from serving as food colorants, bacterial pigments have several pharmacological activities like anti-microbial, anti-cancer, anti-oxidant, anti-inflammatory and anti-allergic properties with large economic potential. And, there is vast scope for easy and cheap production of natural colorants in all seasons from bacterial sources, compared to plant sources. Tactics in strain improvement, fermentation conditions, metabolic engineering, and easy extraction techniques are needed to produce high end products. [9,10]

Owing to the hazardous nature of synthetic colorants, the current exploitations and the prospective of microbial pigments as natural colorants in the food industry are promising. Food and Drug Administration (FDA) already approved pigments existing in the market such as riboflavin (*Ashbya gossypii*),  $\beta$ -carotene and lycopene (*Blakeslea trispora*), Arpink Red (*Penicillium oxalicum*), astaxanthin (*Xanthophyllomyces dendrorhous*), and *Monascus* pigments FDA and EFSA (European Food Safety Authority) assess the safety of food additives through international guidelines and codes of practice. During the assessment process, the need for color requirement must be described with strict toxicity testing prior to inclusion for assessment. Also, when there are changes in the manufacturing conditions for food applications, safety of additives have to be reexamined [11,12]

The worldwide carotenoid (astaxanthin, beta-carotene, canthaxanthin, lutein, lycopene, zeaxanthin)

platform is evaluated to be at USD 1.53 billion by 2021. The important carotenoid-containing biomass from *Haematococcus* sp. and *Chlorella* sp. are sold at a cost of 40–50 USD per kg in the open market.  $\beta$ -carotene acts as an antioxidant and destroys the impact of free radicals in the human assimilation up to numerous folds

### Discussion

Microbial pigments include astaxanthin, canthaxanthin, carotenoids, melanins, granadaene, indigoidine, flavins, quinones and more specifically monascins, prodigiosin, pyocyanin, rubrolene, scytonemin, violacein, phycocyanin possessing various activities like anti-oxidant, anti-carcinogenic, anti-inflammatory and anti-obesity properties.[39]

The medicinal plants are being therapeutically exploited throughout the world for treating various ailments and it is the oldest and the safest method to manage or cure illness. The use of herbal drug is as old as human beings [1]. In recent times, focus on plant research has increased all over the world to highlight the immense potential of medicinal plants used in various traditional system of medicine. A recommended and regular intake of natural plant pigments in the form of herbal extract can keep the digestive system much healthier. It also provides nutrients to the human body. Plant pigments not only impart a characteristic color to the particular tissue or organ of leaves or stem but also involved in trapping light for photosynthesis and several other physiological processes.[36] Various pigments are found in plants of which chlorophylls are the most important and take part in the light induced metabolic activities of the plants. Chlorophyll benefits the body in a unique and distinctive ways. [13] In fact, the potential health benefit of a diet rich in chlorophylls have been indicated in recent studies reporting their role as agents preventing some diseases. Therapeutic properties of chlorophylls have been well documented [21]. Chlorophyll Stimulates immune system, benefits against sinusitis, fluid buildup, skin rashes and ability to help combat anemia. It also eliminates molds in the body by purifying the blood and detoxifies the liver. It cleans the intestines and rejuvenates and energizes the body. Chlorophyll is an asymmetric molecule having a hydrophilic head (porphyrin) made up of four substituted pyrrolic rings located around a divalent magnesium ( $Mg^{++}$ ) which is complexed with four nitrogen atoms of pyrrole rings (one nitrogen atom from each ring) and a long tail formed by a hydrophobic isoprenoid chain (phytol tail) with a phytol alcohol and 20 carbon atoms. Two types of chlorophyll; chlorophyll- a and chlorophyll- b are present in terrestrial plants. [37] The difference

between these two chlorophyll is a methyl moiety in chlorophyll- a replaced by formyl group in chlorophyll- b. The ratio of chlorophyll- a to chlorophyll- b in higher plants is approximately 3:1. Chlorophyll absorbs the light mainly in the red (650-700nm) and the blue violet (400-500nm) regions of the visible spectrum. Green light (550nm) is not absorbed but reflected giving chlorophyll its characteristic color. Chlorophyll a possesses a green-yellow color [2]. The phytochemical analysis of the plants is very important commercially and has great interest in pharmaceutical companies for the production of the new drugs for curing of various diseases[23]. In Assam, some medicinal plants are generally used to cure digestive problems, out of which *Alteranathera sessilis*, *Centella asiatica*, *Eclipta alba*, *Houttuynia cordata*, *Leucas aspera*, *Mentha arvensis*, *Paederia foetida*, *Phyllanthus niruri*, *Pogostemon benghalensis*, *Psidium guajava*, *Punica granatum* and *Oxalis corniculata* were selected for the present studies. *Alteranathera sessilis* commonly called as Sessile Joyweed and Dwarf Copperleaf belonging to the family Amaranthaceae. As an herbal medicine, the plant has diuretic, cooling, tonic and laxative properties. [38] It is used to treat some diseases such as dysuria and haemorrhoids [3]. Different communities of Utrakhannada district of Karnataka use the plant to treat ulcers, cuts and wounds. The trula tribals of kalavai,[14] Vellore district, Tamilnadu, India, use this plant to treat headache, hepatitis A, asthma [4]. *Centella asiatica* is a very important medicinal herb used in the orient [5], commonly known as Gotu kola, Mandukpanni or Indian Pennywort or Jalbrahmi. It has been used as a medicine in the Ayurvedic traditions of India for thousands of the years and listed in the historic “Sushruta Samhita” an ancient Indian medical Text [6, 7]. *Centella asiatica* was recommended for the treatment of wound, leprosy, lupus, varicose ulcers, eczema, psoriasis, diarrhea, fever, amenorrhea and diseases of female genitourinary tract [8]. *Eclipta Alba Hassk* is belonging to the family Asteraceae, [15,16]commonly available throughout India, common in areas of upper Gangetic plains, in pasture lands, roadsides in Chota, Nagpur, all districts of Bihar and Orissa, Punjab, western India, south India [9]. *Eclipta Alba* plays an important role in the traditional Ayurvedic, Unani systems of holistic health an herbal medicine of the east. It is reported that *Eclipta Alba Hassk* possesses hepatoprotective, antimicrobial, antiinflammatory, analgesic, immunomodulatory, antiviral and promoter for blackening and growth of hair [10]. *Houttuynia cordata* Thumb is belonging to the Saururaceae family, is a flowering and perennial plant. *Houttuynia*

*cordata* is a well-known traditionally used medicinal plant in the indigenous system of medicine of Southeast Asia.[35] Recently several studies reported that *Houttuynia cordata* is having anti- inflammatory, anti-allergic, virucidal, antilukemic, anti-oxidative and anti- cancer activities.[17,18] In India, the shoot is used for the freshness, good sleep, heart disorders by Apatani, who have traditionally settled in seven villages in the Ziro Valley of lower Subansiri district of Arunachal Pradesh in the Eastern Himalayan region of India [11]. *Leucas aspera* commonly known as Thumbai, Gumma is found all over India. The plant is used for the treatment of many diseases such as cough, cold, diarrhea, inflammatory diseases. It is reported that the plant is having anti-inflammatory, analgesic, ant diarrheal, antimicrobial, antioxidant, insecticidal activities [12]. *Mentha arvensis* Linn is one such herb belonging to the family Lamiaceae that is a common edible and aromatic perennial herb cultivated throughout India. It is widely used in pharmaceutical, cosmetic and flavoring industries [9]. *Paederia foetida* is commonly known as “Gandhavadulia” belonging to the family Rubiaceae. The whole plant is traditionally used in Ayurveda medicine for the treatment of various diseases such as asthma,[17] bowel complaints, diarrhea, diabetes, seminal weakness etc. It is also reported that the plant is used in gout, vesical calculi, diarrhea, dysentery, piles, inflammation of the liver and emetic [13]. *Phyllanthus niruri* is a small erect annual herb belonging to the family Euphorbiaceae. It is about 30-40 cm in height [20]. It is basically found in Amazon rainforest and other tropical areas including Southeast Asia, southern India and China [14]. *P. niruri* has an important role in herbal medicine system such as Indian Ayurveda, Traditional Chinese medicine. The plant has been used in dystentery, influenza, vaginitis, tumor, diabetes, diuretics, jaundice, kidney stones and dyspepsia and it is also useful for treating hepatotoxicity, hepatitis B, hyperglycemias[18] and viral and bacterial diseases [6]. It is also an important medicinal plant used as antiviral and hepatoprotective agent. The diuretic, hypotensive and hypoglycaemic effect of *P. niruri* were documented in a human study, showed a significant diuretic effect [15] .

*Pogostemon benghalensis* is a aromatic plant which belongs to the Lamiaceae. It occurs in open riverine forest and also cultivated in almost all the parts of India, Bangladesh, Sri Lanka, Nepal, Myanmar, Thailand and China [22]. It is reported that the plant possesses antibacterial, antifungal, antitubercular, anti-rheumatic etc activities [21]. *Psidium guajava* is an important medicinal plant basically found in tropical and subtropical countries. It is widely used as food and in folk medicine [34] around the world.[19]

It is reported that *Psidium guajava* is mainly known for its antispasmodic and antimicrobial properties in the treatment of diarrhea and dysentery. This plant is also used extensively as a hypoglycaemic agent. Many studies have demonstrated the ability of this plant to exhibit antioxidant, hepatoprotective, anti-allergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antinociceptive, activities [16]. *Punica granatum* commonly known as pomegranate is a member of the family Punicaceae, mainly found in Iran, the Himalayas in the northern India, China, USA and throughout the Mediterranean region extensively [17]. The fruit of *Punica granatum* has been used extensively as a traditional remedy against acidosis, helminth infection, dysentery, microbial infections, diarrhea, hemorrhage and respiratory pathologies. The seed contains estrogenic compounds, estrone and estradiol [18]. *Punica granatum* possesses inhibitory effects on different types of cancer such as prostate, breast, [20] colon, lung cancers. It inhibits angiogenesis [33] which is an important process for the development of new blood vessels that supply oxygen and nutrition for tumor growth and progression of cancer [17]. *Oxalis corriculata* Linn, Commonly known as creeping wood sorrel belonging to the family Oxalidaceae is one of the most focus plant species in India. [21] The plant has been used in Indian System of Medicine (ISM) for the treatment of diseases and ailments of human beings. It has been reported that the plant contains anti-inflammatory, anticonvulsant, antifungal, antiulcer, anti-diabetic, hepatoprotective, antioxidant and diuretic, antimicrobial and wound healing properties [19].

## Results

Carotenoids are fat-soluble compounds, meaning they are best absorbed with fat. Unlike some protein-rich foods and vegetables, cooking and chopping carotenoid-rich foods increase the strength of the nutrients when they enter the bloodstream. [22] Carotenoids are classified into two main groups: xanthophylls and carotenes. Both types of carotenoids have antioxidant properties. In addition, some carotenoids can be converted into vitamin A, an essential component for human health and growth. These provitamin A carotenoids include alpha carotene, beta carotene, and beta cryptoxanthin. Non-provitamin A [32] carotenoids include lutein, zeaxanthin, and lycopene. Carotenoids are beneficial antioxidants that can protect you from disease and enhance your immune system. Provitamin A carotenoids can be converted into vitamin A, which is essential for growth, immune system function, and eye health. Eating carotenoid-rich foods can protect

the healthy cells in the eye and prevent the growth of cancerous cells. One of the leading causes of blindness is macular degeneration, or the degeneration of the center of the retina. Long-term blue light exposure can cause this and negatively affect the delicate parts of the eye. However, the carotenoids lutein and zeaxanthin found in the retina can help to absorb blue light. [22]

Studies show that incorporating at least six milligrams of lutein in your diet a day can decrease your risk of developing macular degeneration by 43 percent. Increasing the amount of lutein and zeaxanthin in your diet can also help to slow or halt current eye damage, and prevent your current condition from progressing. [23]

Carotenoids are antioxidants, lowering inflammation in the body. Though it's still being researched, carotenoid anti-inflammatory properties have been associated with improving cardiovascular health. [31] Reducing inflammation helps to protect against heart disease and prevents arterial walls from being blocked. Antioxidants protect cells from free radicals, or substances that destroy or damage cell membranes. Increasing carotenoids via your diet can increase the amount of antioxidants and protective cells in your body. This is significant when battling cancer and may be able to prevent cancer growth. [24]

Carotenoids have been associated with lowering cancer risk, specifically lung cancer. When you smoke cigarettes, you ingest harmful chemicals that destroy healthy cells. Though mixed in results, one study showed a small decrease in risk from lung cancer when incorporating carotenoids into your diet. It is even healthier to stop smoking and increase carotenoids in your diet to help your lungs heal as you move past the addiction.

Similarly, carotenoids have been associated with reducing the risk of skin cancer. Some carotenoids can break down into vitamin A, a nutrient that protects against premature skin damage from sun exposure. Both are risks for melanoma, premature wrinkles, and unhealthy skin. [25]

## Conclusions

Proanthocyanidins typically comprise flavan-3-ol units in a simple catechin polymer. However, it is thought that they may undergo several modifications and conversions during the ripening period to produce more irregularity.

Since proanthocyanidins are chemically stable, it is unclear how the transformations during ripening may arise. One hypothesis to explain the conundrum is that proanthocyanidins contain chromophores that have yet to be identified. [26]

Researchers have recently conducted a full structural analysis of the pigments in adzuki bean seed coats to determine whether or not there are chromophores present in proanthocyanidins<sup>4</sup>.

The methanol extract of the seed coats and the extraction residue were analysed by high-performance liquid chromatography–electron spray ionization mass spectrometry (HPLC-ESI-MS), and a number of new peaks were detected with NMR Spectroscopy, using the Bruker Biospin AVANCE III 600 spectrometer.[27]

The methanol extract was found to contain two types of polymeric red pigments. One was a simple proanthocyanidin, whereas the other was a complicated polyphenol produced by several modifications and conversions.

Spectral data suggested that the chromophores of the two compounds differed in structure. The chemical structures of the three products of direct thiolysis indicated that the structure of adzuki bean pigments includes a glyoxylic acid-bridged catechin skeleton.

The compound in which this structure was identified may represent the link to elucidating the mechanism of action of the proanthocyanidin transformation to achieve the color changes observed during ripening.[28]

In addition, the compounds identified in this study may also be important bioactive components in adzuki beans, and justify further investigation to determine the structure–activity relationship.

Carotenoids, such as carotene and lycopene, are powerful antioxidants that provide protection against the signs of aging and a range of chronic conditions by mopping up the free radicals produced as by-products of essential metabolic processes.

In addition, dietary carotene is an important source of vitamin A. Anthocyanins and proanthocyanidins improve vision and protect against heart disease[29]

The red adzuki bean is a legume commonly used in Asian cuisine, most notably as the key ingredient of red bean paste. The high protein and antioxidant content of the adzuki bean mean that it is associated with several health benefits, including slower aging, improved heart health, cancer prevention, cholesterol lowering, increased energy and increased muscle mass. For this reason, it is also included in various traditional Chinese herbal remedies.[30]

The red pigment giving the red adzuki bean its color include polyphenols, flavonol glycosides and catechins. Key components are proanthocyanidins, oligomeric or polymeric phenolic compounds, which

are thought to provide many of the properties advantageous to human health, ie, antioxidant, antimicrobial, hypolipidemic, and cardioprotective properties.[40]

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