Bio. Res. Today 2023, 5(12):827-830

Biotica Research Today

e-ISSN: 2582-6654

December, 2023

Article ID: RT1524

Popular Article

Plant Pigments in Vegetables and their Impact on Human Health

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Open Access

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Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Sushmitha *et al*., 2023. Plant Pigments in Vegetables and their Impact on Human Health. *Biotica Research Today* 5(12), 827-830.

Abstract

Naturally occurring plant pigments, such as chlorophylls, carotenoids, betalains and flavonoids, contribute vibrant colours to plants or their organs. While not deemed essential for survival like vitamins and minerals, these pigments possess properties that can enhance overall human health. Incorporating pigment-rich fruits and vegetables into one's daily diet can fortify the immune system against various diseases. Vegetables, in particular, serve as abundant sources of all major pigment classes and regular consumption may help prevent significant ailments like cancer, cardiovascular diseases and diabetes. This article provides insights into plant pigments, their origins and their crucial role in promoting human health.

Keywords: Betalains, Carotenoids, Flavonoids, Human health

Introduction

Pigments refer to chemical compounds that absorb light within the visible wavelength range, resulting in the exhibition of specific colours due to the unique structure of the molecule, known as a chromophore. When an electron in the outer orbital of the molecule is elevated to a higher orbital, the chromophore captures this energy. The unabsorbed energy, whether reflected or refracted, is then detected by the human eye. Neural impulses generated by these signals are subsequently transmitted to the brain, where they are interpreted as distinct colours.

Among the major and well-recognized classes of plant pigments are chlorophylls, carotenoids, flavonoids and betalains. Each of these classes encompasses various subgroups, exhibiting unique structures and functions. Incorporating pigment-rich fruits and vegetables into the human diet is of paramount importance. Some pigments not only serve as essential nutrients but also act as nutraceuticals, providing additional medical benefits, including the prevention and treatment of specific diseases. Gaining a comprehensive understanding of plant pigments, identifying vegetables rich in these compounds and acknowledging their significant influence on human health are valuable pursuits. This knowledge not only deepens our appreciation for the vivid colours found in nature but also emphasizes the essential role of including vegetables abundant in pigments in our diet for overall well-being.

Major Plant Pigments

Plant pigments play a crucial role in physiological processes and contribute to the vibrant colors observed in various plant tissues. The major pigments include, chlorophylls, carotenoids, flavonoids and betalains. Chlorophylls, which give leaves their green colour, are essential to photosynthetic processes. Carotenoids are antioxidants that aid in the absorption of light and give colours like yellow, orange and red. Flavonoids give rise to red, blue and purple hues and are associated with antioxidant and plant defence mechanisms. Betalains, found in plants, provide them with their distinctive red and yellow hues as well as act as antioxidants and maybe having health advantages (Chen, 2015). Grasping the schematic illustration of key pigments present in vegetables, emphasized in figure 1 and table 1, is a crucial preliminary step before delving into the extensive variety of plant pigments.

1. Chlorophyll

Chlorophylls are green pigments and are found in diverse plants, algae and cyanobacteria, residing within the thylakoid membrane of chloroplasts. These pigments, characterized by their green colour, are water-soluble owing

Article History

RECEIVED on 16th December 2023 RECEIVED in revised form 24th December 2023 ACCEPTED in final form 25th December 2023

to the existence of a hydrophobic chain. Different forms of chlorophylls are available in nature, with chlorophyll a and chlorophyll b being abundantly present in higher plants. Protochlorophyll, on the other hand, is identified in the yellow leaves of seedlings and the seed coat of pumpkins.

2. Carotenoids

Carotenoids, regarded as secondary plant metabolites, are lipid-soluble pigments present in all photosynthetic organisms. Acting as the primary accessory pigments, they play a crucial role in capturing light during photosynthesis. The vast array of carotenoids in nature surpasses 600, with approximately 40 dietary carotenoids commonly included in our everyday consumption. Carotenoids are divided into two main structural groups:

a) Carotenes: This group consists of hydrocarbons, such as beta-carotene, lycopene and alpha-carotene. These pigments contribute to the orange, red and yellow colours observed in various fruits and vegetables.

b) Xanthophylls: These carotenoids contain oxygen in addition to carbon and hydrogen. Examples include lutein, zeaxanthin and beta-cryptoxanthin. Xanthophylls often contribute to the yellow, brown and green colours in plants.

3. Flavonoids

Flavonoids, a group of water-soluble polyphenolic compounds, are housed in the vacuoles of epidermal cells, comprising an extensive family with nearly 9000 members. Within the realm of flavonoids, only anthocyanins possess the ability to produce a complete spectrum of visible colours, playing a pivotal role in the diverse colouration of flowers, fruits, seeds and leaves in angiosperms. Common anthocyanidins distributed in plants encompass cyanidin, delphinidin, pelargonidin, peonidin, malvidin and petunidin. Notably, cyanidin-3-glucoside stands out as the primary anthocyanin in many plants, with rich sources found in red sweet potatoes and purple corn.

4. Betalains

Betalains are water-soluble pigments derived from indole glycosides and are exclusively found in the order Caryophyllales, including plants like beets, cacti and amaranths. Notably, they never coexist with anthocyanins in plants, indicating a mutually exclusive presence. While betalains differ from anthocyanins in chemical structures and some properties, they share similarities in terms of color spectra, biological functions and other characteristics. Structurally, betalains can be divided into two categories: a) betacyanins, which impart a red-violet color and b) betaxanthins, which contribute a yellow-orange hue.

Pigments as a Source of Dietary Supplements

Incorporating major plant pigments as dietary supplements is a valuable strategy to enhance nutritional intake and it offers a spectrum of health benefits. Carotenoids, found in vibrant fruits and vegetables, contribute to eye health and immune function. Flavonoids, abundant in various plant foods, possess antioxidant and anti-inflammatory properties. Anthocyanins, are associated with cardiovascular health. Chlorophyll, prevalent in leafy greens, aids in detoxification

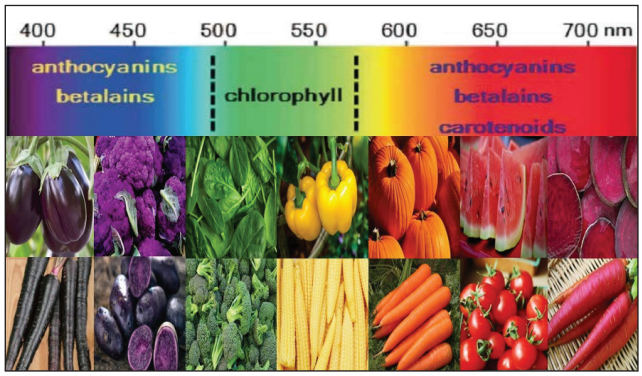

Figure 1: A schematic representation of the colour spectrum showcasing major pigments along with examples of vegetables rich in these pigments

and provides essential nutrients. Incorporating a diverse range of pigments through dietary supplements supports overall well-being and addresses potential nutritional gaps.

Ill-Effects of Pigments as a Source of Dietary Supplements

While plant pigments can offer various health benefits as dietary supplements, excessive intake or improper use may lead to adverse effects. Overconsumption of certain pigments, such as beta-carotene, can result in a condition known as carotenoderma, causing skin discolouration. Additionally, high doses of certain flavonoids and anthocyanins may lead to allergic reactions in some individuals. Therefore, careful consideration of recommended dosage levels and consultation with healthcare professionals is essential to prevent negative consequences and ensure safe supplementation. Enlisted below are some of the potential drawbacks of using pigments as dietary supplements:

- Single purified compounds may not effectively replace the complex mixture of secondary plant metabolites.
- Excessive supplement intake can reduce the bioavailability of trace elements.
- Overdosing may result in poisoning.
- Allergic reactions may occur.
- Increased risk of lung cancer with high intake of carotenoid supplements (beta-carotene).
- Supplementation with high levels of carotene and lycopene can cause skin yellowing.

Role of Plant Pigments in Human Health

Plant pigments are beneficial for human health in several ways here are some important health benefits they provide.

1. Carotenoids as Provitamin A

Provitamin A carotenoids (β-carotene, α-carotene and β-cryptoxanthin) found in plant foods serve as a source of vitamin A for humans. In the human intestine, these provitamins undergo conversion to Retinoic acid, the biologically active form of vitamin A. The assimilated vitamin A contributes to various health benefits in the human body.

2. Antioxidants

Human exposure to UV radiation, air pollutants and industrial particles induces oxidative stress, associated with 90% of

Table 1: List of vegetables rich in plant pigments

Sl. No.	Plant pigments	Pigment type	Vegetables and carotenoids quantity	References
1	Carotenoids	Lycopene	Tomato (2481 µg/ 100 g)	Longvah *et al*., 2017
			Watermelon (1447 µg/ 100 g)	
			Carrot (871 µg/ 100 g)	
			Chilli (red) (36.44 µg/ 100 g)	
		α-carotene	Carrot(orange) (2654 µg/ 100 g)	
			Carrot (red) (1128 µg/ 100 g)	
			Pumpkin (90.74 µg/ 100 g)	
			Broad bean, Elephant foot yam	
		β-carotene	Drumstick leaves (17,542 µg/ 100 g)	
			Agathi leaves (12582 µg/ 100 g)	
			Fenugreek (9245 µg/ 100 g)	
			Carrot, Amaranthus, Sweet potato, Curry leaves, Colocasia	
		β-cryptoxanthin	Chilli (1599 µg/ 100 g)	
		Lutein	Drumstick leaves (17542 µg/ 100 g)	
			Agathi leaves (12941 µg/ 100 g)	
			Amaranthus (8397 µg/ 100 g)	
			Pumpkin leaves, colocasia leaves, parsley, spinach	
		Zeaxanthin	Agathi leaves (559 µg/ 100 g)	
			Basella (241 µg/ 100 g)	
			Drumstick (235 µg/ 100 g)	
			Beet greens, Amaranthus, Colocasia	
2	Flavonoids	Flavanols (*e.g*., quercetin)	Onions (60.2 mg/ 100 g)	Parihar *et al*., 2015
		Flavones (*e.g*., apigenin)	Celery hearts (green) (22.60 mg/ 100 g)	
			Parsley (18.6-29 mg/ 100 g)	
		Isoflavones	Soybeans, legumes (94.2-97.5 mg/ 100 g)	
		Total Anthocyanins	Cabbage (red) (250 mg/ 100 g)	Horbowicz *et al*., 2008
			Eggplant (7500 mg kg^{-1})	
			Radish (red) (110-600 mg kg^{-1})	
			Onion (red) (up to 250 mg kg^{-1})	
			Rhubarb (up to 2000 mg kg^{-1})	
3	Betalains	Betacyanins	Beetroot, *Ullucus tuberosus*, *Basella rubra*, Amaranthus (both leaves and grain type)	Rodriguez-Amaya, 2019
		Betaxanthins	Yellow varieties of Swiss chard and Beet	

diseases and aging. Antioxidants function as superheroes by neutralizing free radicals, donating electrons to stabilize them and prevent damage. Flavonoids and carotenoids, as potent antioxidants, fortify our body's defense system, guarding against the detrimental effects of free radicals.

3. As Photo Protectants by Screening Harmful Radiation

All plant pigments possess photo-protective abilities. Following absorption, carotenoids accumulate significantly in adipose tissue, the liver and the bloodstream. Human skin harbors carotenoids and their isomers, providing protection against oxidation for living cells. In the eyes, lutein and zeaxanthin filter high-energy wavelengths of visible light and serve as antioxidants, guarding against the formation of reactive oxygen species and subsequent free radicals.

4. Anti-Cancerous

The following properties of each pigment help the human

body to fight against different types of cancers:

• *Flavonoids*: Acts as antioxidant, chemo preventive, repairs and protects genomic DNA integrity, antitumor and anti-allergic.

• *Carotenoids*: Acts as apoptosis, anti-angiogenic, anti-metastatic, cytotoxicity to cancer and tumour cells and anti-proliferative.

• *Betalains*: Acts as anti-proliferative and cytotoxic to cancer cells.

• *Chlorophyll*: Acts as cytotoxic to cancer cells and anti-oxidants.

5. Cardiovascular Disease

Cardiovascular diseases (CVD) rank as the leading cause of annual deaths, accounting for approximately 17.5 million (31%) of global fatalities. he various properties of individual plant pigments contribute to the body's defense against cardiovascular disease:

• Lycopene: Acts as anti-atherosclerosis.

• Flavonoids: Acts as anti-oxidants, anti-thrombotic, anti-hypertensive and anti-inflammatory.

6. Cognitive Decline and Alzheimer's Disease

Neurodegenerative disorders primarily impact cognitive functions such as learning, memory, perception and problem-solving. The antioxidant and anti-inflammatory properties of carotenoids play a role in mitigating these disorders.

7. Diabetes Mellitus

Oxidative stress contributes to diabetes by hindering insulin production in pancreatic cells. Increased consumption of β-cryptoxanthin through the diet lowers the risk of type-2 diabetes.

8. Anti-Obesity

Obesity is a significant risk factor for cardiovascular disease, insulin resistance and type 2 diabetes. Flavonoids mitigate this risk by reducing the expression of the gene responsible for adipocyte differentiation.

9. Neuroprotectors

Anthocyanins are regarded as 'neuroprotectors' since they protect nerve cells from oxidative injury and neurotoxicity.

10. Antimicrobial Effect

Anthocyanins exhibit antimicrobial activity against various microorganisms, particularly inhibiting the growth of food-borne pathogens. The mechanism involves inducing cell damage by disrupting the cell wall, membrane and intercellular matrix.

Conclusion

The diverse array of plant pigments in vegetables is a powerhouse of health benefits for humans. From antioxidant properties to disease-fighting capabilities, these pigments contribute to overall well-being and should be incorporated into a balanced and nutritious diet. Understanding and harnessing the benefits of plant pigments offers a natural and holistic approach to enhancing human health and preventing various ailments.

References

Chen, C., 2015. Overview of Plant Pigments. In: *Pigments in Fruits and Vegetables: Genomics and Dietetics*. (Ed.) Chen, C. Springer, New York, NY. pp. 1-7. DOI: https://doi.org/10.1007/978-1-4939-2356-4_1.

Horbowicz, M., Kosson, R., Grzesiuk, A., Dębski, H., 2008. Anthocyanins of fruits and vegetables - Their occurrence, analysis and role in human nutrition. *Journal of Fruit and Ornamental Plant Research* 68(1), 5-22. DOI: https://doi.org/10.2478/v10032-008-0001-8.

Longvah, T., Ananthan, I., Bhaskarachary, K., Venkaiah, K., 2017. *Indian Food Composition Tables*. National Institute of Nutrition, Indian Council of Medical Research, MOHFW, GOI, Hyderabad. pp. 2-58.

Parihar, A., Grotewold, E., Doseff, A.I., 2015. Flavonoid dietetics: Mechanisms and emerging roles of plant nutraceuticals. In: *Pigments in Fruits and Vegetables: Genomics and Dietetics* (Ed.) Chen, C. Springer, New York, NY. pp. 93-126. DOI: https://doi.org/10.1007/978-1-4939-2356-4_5.

Rodriguez-Amaya, D.B., 2019. Update on natural food pigments - A mini-review on carotenoids, anthocyanins and betalains. *Food Research International* 124, 200-205. DOI: https://doi.org/10.1016/j.foodres.2018.05.028.