J. Int. Sci. Technol. 2019, 7(2), 29-34 Article

Journal of Integrated
SCIENCE & TECHNOLOGY

Emerging new insights into significance and applications of Plant Pigments

Indu Nashier Gahlawat*

Department of Biology, Aditi Mahavidyalaya, University of Delhi, Bawana, Delhi-110039. India.

Received on: 5-July-2019; Accepted and Published on: 20-Sept-2019.

ABSTRACT

Plant pigments play an important role in plant identification, pollination and visual attraction in nature. They make nature colourful and attractive. Naturally occurring plant pigments include carotenoids, anthocyanins, betacyanins and chlorophyll. Apart from having colour, these pigments provide added properties, therefore they are also known as bioactive compounds. This property has increased the interest to add them to our diet. Recent studies have indicated that they help to prevent chronic degenerative diseases like hypertension, diabetes, cancer and cardiovascular disorders. These pigments possess antioxidative and antimicrobial activities, improve visual and neurological health. Also, there are good perspectives for the inclusion of these plant pigments in other products like cosmetics and dyes.

Keywords: Pigments, Carotenoids, Anthocyanins, Betacyanins, chlorophyll, phytomedicine,

INTRODUCTION

Plants have a fundamental role in supporting life on Earth. Plant pigments are special compounds in plants that have compatibility of absorbing different wavelength of light and appear colourful. Plant pigments are important in controlling photosynthesis, growth and development of plants.[1] Pigments act as visible signals to attract insects, birds and animals for pollination and seed dispersal. Pigments also protect plants from damage caused by UV and visible light.[2] Plant pigments are secondary metabolic compounds which impose specific colouring effects in plant tissues. These are known as biochromes. The main function of these pigments is to capture photons falling in sunlight for photosynthesis so that organic food is produced. Plant pigments not only attract animals needed for pollination and seed dispersal, to ensure the reproductive success and permanence of the species but also participate in the critical biological process for plants, playing essential roles in the maintenance of ecosystems.[2,3]

In recent years, plant pigments have been begun to be recognized as bioactive substances because of their potential health benefits, which has boosted their commercial demand.[4] The biological pigments and plant extracts has been evaluated for the treatment of a number of diseases such as diabetes,[5–7] bacterial infections,[8] inflammation, tuberculosis,[9] and chronic diseases.[10] The combination of these bioactive pigments with nanoparticles has brought about the enhanced biomedical activity with potential in clinical applications.[11–14] Owing to these wide applications of plant pigments in treatment of different ailments, these have a valued recognition in the field of phytomedicine, ayurveda, nutraceuticals and nanomedicine.[15,16]

Many pigment-rich fruits are consumed in the human diet. Plants possess yellow, green, pink, purple and white and red pigments, most of them found in vegetative tissues. Green plants possess green pigment chlorophyll. Pink-coloured pigments are found in onion and leeks. Turmeric contains yellow pigment derived from curcumin. Beetroot contains a red pigment called betanins. Tomato contains red colour due to the presence of

*Corresponding Author: Dr. Indu Nashier Gahlawat
Associate Professor, Aditi Mahavidyalaya, University of Delhi, Bawana-110039, Delhi, India.
Tel:
Email: induingahlawat@gmail.com

Cite as: *J. Int. Sci. Technol., 2019, 7(2), 29-34.*

©IS Publications ISSN: 2321-4635 http://pubs.iscience.in/jist

lycopene. Fruits and other plant parts contain little amount of pigments along with other important components such as protein, lipids, carbohydrates, dietary fibers. These pigments are to be extracted from the plants. Numerous epidemiological evidence has shown that the consumption of these pigments lowers the risk of chronic diseases including various types of cancer and cardiovascular diseases.[10] The inclusion of a variety of colourful plant foods in our diet is a good suggestion to remain healthy. This paper intends to study various plant pigments available in nature and how they can be beneficial to human beings.

Types of Plant Pigments

There are four major categories of plant pigments that give colour to the foods. They are:

- Carotenoids (Yellow, Orange, Red)
- Anthocyanins (Red, Blue, Purple)
- Betacyanins (Red)
- Chlorophylls (Green)

Each pigment category has a family of compounds within them, each with a unique name, specific chemical structure, well-defined chemical properties, and unique colour.

Carotenoids

“Carotenoids” is a generic term used to designate the majority of pigments naturally found in animal and plant kingdoms. Carotenoids are hydrophobic compounds, lipophilic, insoluble in water, and soluble in solvents such as acetone, alcohol, and chloroform.[17] Most carotenoids are hydrocarbons containing 40 carbon atoms and two terminal rings.[18] This group of fat-soluble pigments comprises more than 700 compounds responsible for the red, orange, and yellow colours. They are present abundantly in nature. Carotenoids are found in most fruits and vegetables, plants, algae, and photosynthetic bacteria.They have important role for plants. They contribute to photosynthesis by transfering some of the light energy they absorb to chlorophyll to carry on photosynthesis. Also, they protect the plants if they are over exposed to the sunlight by dissipating excess light energy as heat. If this function is not performed then the extra lighy energy could destroy proteins, membranes, and other important molecules. Humans are not able to synthesize carotenoids and therefore they must ingest them in their food or via supplements.

Due to the high unsaturation rate, factors such as heat, light, and acids cause trans-isomerization of carotenoids that promote a slight loss of colour and provitamin activity. Carotenoids are also susceptible to enzymatic or nonenzymatic oxidation, which depends on the carotenoid structure, the oxygen availability, enzymes, metals, prooxidants and antioxidants, high temperature, and light exposure.[19]

Due to the colouring properties present in carotenoids, they are mostly used in food, pharmaceuticals, cosmetic industry, and animal feed industries. In food industries, the carotenoids are mainly used as restoring the natural colour lost during processing or in order to standardize the colour in products like fruit juices, pasta, beverages, candies, margarine, cheeses, and sausages. They also serve as precursors of many important chemical compounds that are responsible for the flavour of some foods, such as alkaloids and volatile compounds, and fragrances of some flowers.

Few important carotenoids are beta carotene, lycopene, lutein, zeaxanthin, also called terpenoids, are essential pigments for plant life, contributing to photosynthesis machinery and providing photoprotection against excess light damage to the photosynthetic reaction centre by quenching excited species such as singlet oxygen and free radicals.[17]

Health Benefits of Carotenoids

Apart from their role as natural pigments, carotenoids have other important aspects also. A broad spectrum of health-promoting effects is associated with carotenoids.[20,21]

The main established health-promoting function of carotenoids is to be an important dietary source of vitamin A, and this is mainly found in beta-carotene. From several hundred naturally occurring carotenoids, few have been reported with significant biological activity. So, carotenoids can be divided into two groups, with and without the provitamin A. The carotenoids that are precursors of vitamin A should have at least one ring of β-ionone and side polienic chain with at least 11 carbons.[22] Carotenoids are converted to vitamin A as the body needs, with varying degrees of conversion efficiency. Carotene are found in dark green and yellow-orange fruits and vegetables. Darker colours are associated with higher levels of this provitamin.

Vitamin A is important for growth, development, maintenance of epithelial tissues, reproduction, immune system,[23] and, in particular, visual cycle acting in the regeneration of photoreceptors.[24] Its deficiency is a serious problem of public health, being the major cause of infant mortality in developing countries. A prolonged deficiency can produce changes in the skin, night blindness, and corneal ulcers. Besides, it leads to blindness, growth disorders, and learning difficulties in childhood.[25]

Studies have shown the inverse relationship between increased consumption of foods rich in carotenoids and the risk of various diseases. According to Olson (1999), carotenoids quench singlet oxygen, remove peroxy radicals, modulate carcinogen metabolism, inhibit cell proliferation, stimulate communication between cells (gap junctions), and increase the immune response.[26] The antioxidant activity of carotenoids involved in the processes of inhibition or reduction of oxidative stress seems to be the main mechanism of action of these pigments to be called as anticarcinogenic agents.[27]

Lycopene, a naturally occurring red carotenoid pigment found in tomatoes, pink grapefruit, watermelon, papaya, guava, and other fruits, is recognized as one of the best biological suppressors of free radicals due to its chemical structure.[28,29] Among the carotenoids, lycopene was shown to be one of the most effective antioxidants and may donate electrons to neutralize the singlet oxygen molecules and other oxidizing molecules before they affect the cells.[30] It has twice the antioxidant activity when compared to beta-carotene.[31] Dietary lycopene consumption is associated with a reduced risk of prostate cancer[32] while beta carotene and other carotenoids are reversibly linked to immune activation and inflammatory biomarkers in the patients with coronary artery disease.[33] However lycopene's effects may vary from person to person based on dietary lycopene and fat intake, genetic differences in metabolism, and other factors.

Carotenoids also have role protection of the skin against UV light-induced damage. This effect is associated with the high potential of carotenoids to scavenge reactive oxygen species as peroxide radicals or singlet oxygen molecules.[34]

Lutein and zeaxanthin are only carotenoids that accumulate in the retina, particularly the macula region, which is located at the back of your eye. Due to presence of these pigments in higher amounts in the macula, they are also known as macular pigments. Our eyes are constantly exposed to oxygen and light which in turn leads to the production of harmful free radicals.These pigments cancel out these free radicals so that our eye cells are saved from damage. Some studies have shown that high lutein and zeaxanthin intake, particularly from foods rich in xanthophylls such as spinach, broccoli, and eggs, are related to over 20% reduction of cataract and over 40% macular degeneration related to age.[35] Lutein and zeaxanthin also act as a natural sunblock by absorbing excess light energy. Also, their antioxidant effects help them to protect our skin from the sun's damaging ultraviolet (UV) rays. Green leafy vegetables like spinach, parsley, kale, broccoli and peas are their good dietary sources. Orange juice kiwis, red peppers, grapes have moderate amount of these pigments. In addition, egg yolk may be an important source of lutein and zeaxanthin, as the high fat content of the yolk may improve absorption of these pigments. Lutein and zeaxanthin are widely recommended as dietary supplements to prevent visual loss or eye disease. These supplements are very popular among older adults who are concerned about falling eye health.

Anthocyanins

Anthocyanins are blue, red, or purple pigments found in plants, especially flowers, fruits, and tubers. Anthocyanins are the largest group of pigments. The color of anthocyanins depends on the pH of the solution. This is because of the molecular structure of anthocyanins having an ionic nature.[36] In acidic conditions, the anthocyanins appear red. Anthocyanins have a purple hue in neutral pH while the colour changes to blue on increasing pH conditions. These pigments are present in strawberries, raspberries, blackberries, grapes, cherries, red onion, red cabbage, red lettuce, roses. These are found in almost all vegetative tissues of higher plants. More than 500 anthocyanin variants have been identified in nature until now. They belong to a family of compounds known as flavonoids.

The use of natural colorants and additives in processed foods and beverages increases consumer acceptability. Anthocyanins are some of the natural coloured pigments which are extracted from plants. They have an attractive hue. Anthocyanins extracted from plants are red, blue, and purple pigments. These pigments are natural colorants and have no toxicity. Natural colorants are considered safe to be consumed even at higher doses compared to synthetic colorants. Anthocyanins extracted from plants have been used as food additives. These days, the use of anthocyanin-based colorants in yogurts and some mixed fruit juice is becoming more popular Anthocyanins, as natural colorants, also have value-added properties.

Health Benefits of Anthocyanins

Anthocyanins is one of the bioactive components popularly known as a nutraceutical and used in traditional medicines for a long time. The health benefits of anthocyanins are attributed to its high antioxidant capacity. The health and therapeutic effects of anthocyanins are mainly attributed to its antioxidative activities.[37] Epidemiological studies show inverse relationships between anthocyanin-rich foods and the development of coronary heart disease.[38,39] Anthocyanins have also proved to be effective in inhibiting the initiation, promotion, and progression of multiple types of cancers. Anthocyanins, as the well-known antioxidants and free radical scavengers, are able to act as reducing agents in the electron-transfer reaction pathway. The antioxidative compounds are able to donate electrons to the free radicals with unpaired electrons.[40] Anthocyanins have been associated with reduced incidence of major chronic diseases such as cancer, heart disease, diabetes, stroke, cataracts, Alzheimer's disease, and deterioration of age-related functions.[20,41] Anthocyanins possess antimicrobial activity against a wide range of microorganisms, thereby inhibiting the growth of food-borne pathogens.[42] They exhibit antimicrobial activity through several mechanisms, such as induced cell damage by destroying the cell wall, membrane, and intercellular matrix.[43] The pharmaceutical development from Anthocyanins and other plant pigments have emerged due to understanding of their complex receptors identification and relative binding affinities.

Also, anti-inflammatory activity of anthocyanins to overcome inflammation-related diseases such as periodontal diseases, colitis have been been reported.[44] Anthocyanin pigments are also important nutraceuticals in maintaining good vision. Anthocyanin-rich berries are well known for the goodness to eyes. These health effects which are described above emphasizes the potential of these pigments to be used as functional health-enhancing ingredients.

Betacyanins

Betacyanins are water-soluble nitrogen-containing pigments that impart red pigmentation in fruits, vegetables, and flowers. They occur in a few plant families, and are always independently of anthocyanins. They are established food colorants which are widely used. Betacyanins (red-violet pigments) and betaxanthins (Yellow, orange pigments) constitute the family of plant pigments which is known as betalains. The composition of different betalain pigments can vary, thus giving rise to different breeds of beetroot that have yellow or any other colour apart from the familiar deep red. Betalains are water-soluble pigments found in the vacuoles of plant cells. Betacyanins as colorants have certain advantages over other natural red pigments. Being water-soluble they are easily incorporated into the foods as most foods are hydrophilic in nature.

Health Benefits of Betacyanins

Betacyanins have a number of health-related properties. Betalains are beneficial pigments and antioxidant that is beneficial in lowering inflammation, detoxifying body and prevents the chances of premature aging. The betalain pigments in beets have repeatedly been shown to help in neutralizing toxins by making them sufficiently water-soluble for excretion in the urine. Betacyanins play a protective role against diseases like cancer, diabetes, cardiovascular diseases, and autoimmune disorders as they have radical-scavenging activity.[45] They behave like bioactive pigments thus have positive health effects. Betacyanins also have antilipidemic effects.[46] Beetroot has been studied extensively and found to lower blood pressure.. Animal studies have indicated that these substances lower amount of inflammation in blood vessels which further prevent formation of clots. It lowers levels of harmful cholesterol in blood that is formation of plaque and blocked arteries. Betalains have been reported to exhibit antimalarial and antimicrobial effects also, but their effects are dependent on the dose and type of betalains present. Food sources of betacyanins are red beetroots, prickly pears, and amaranth.

CHLOROPHYLL

The name chlorophyll is derived from the Greek words “chloros” meaning green and “phyllon” meaning leaf. Chlorophyll is the primary pigment in the plants and it is chlorin that absorbs yellow and blue wavelength of light while reflecting green. Chlorophyll is found in chloroplasts There are different forms of chlorophyll. Chlorophyll-a is present in higher plants, algae, cyanobacteria, and chloroxybacteria. Higher plants and few groups of algae have chlorophyll-b. Other groups of algae have chlorophyll-c or chlorophyll-d. Chlorophyll is decomposed by heat and an olive-green colour is produced. Chlorophyll is a vital component for photosynthetic process and rich source of antioxidants.[47] Good sources of chlorophylls are spinach, mustard leaves, broccoli, alfalfa. Green plants have got high chlorophyll content and it shows free radical scavenging and anticancer activities.[48] It is reported that the chemo preventive effects of chlorophyll are most likely due to their potential to trap carcinogens within the intestinal lumen.[49] Chlorophyll is chemically similar to haemoglobin, a protein essential in red blood cells to carry oxygen in the human body. Researchers have suggested that wheatgrass juice, rich in chlorophyll is helpful in improving haemoglobin levels. Chlorophyll shows medicinal properties since they improve human metabolism being a source of magnesium.[50] Other applications of chlorophyll are in wound healing, germ-killing, treatment of infections, materials used against inflammation, and in use of bandages, antiseptic ointments, and surgical dressings.[51] Although chlorophyll has a variety of potential health benefits, there are few adequate scientific studies to back them up, hence it requires further investigation.

Other Uses of Plant Pigments

The extraction of pigments and minerals from plant products vary from source to source and also the the extraction procedures affect the final constituents of the extract. The extracted pigments and phytochemicals find use in number of other applications. Natural pigments found in plants also give colour to the food products.[52,53] They are used as additives in the form of pigments to deepen the colour or to renew the colour of the food products after processing. These pigments also help to make the identification of the product easier. Nowadays, many consumers demand food products that are coloured using natural pigments.[54] Artificial pigments can be harmful to our health. These natural pigments are used to colour frozen food, ice-creams, flavoured milk drinks, yogurts, powdered desserts, gels, sauces, jams, jellies, candies.[55] Betalains have been used as food colorants and as dietary supplements.[45] Anthocyanins also change colour depending on the pH of the food product. Carotenoids are resistant to heating, sterilization, and freezing processes. They are well soluble in oils but insoluble in water. They are used in the production of butter, margarine, oils and fats, cheese spreads, non-alcoholic drinks, fruit juices, confectionery baked goods, ice-creams, yogurts, desserts, jams, creams, pastries, and jellies.[56] Commercial products comprising of chlorophyll included diapers, chewing gum, bedsheets, toothpaste, and other products which we use daily. Nowadays there is a shift in the trend of using natural colours in the form of pigments in cosmetics also. Plant extracted pigments[57] are mixed in dermatological products to transfer colour to the skin or lips, hair, etc. Due to the antimicrobial properties and radical scavenging activities, plant pigments have been beneficially used in cosmetics.[58–60] Henna or mehndi has been used as an agent to cover gray hair without adverse effects on hair and also for making temporary tattoos for decoration purposes on the skin Natural pigments are also used in paintings. Even the prehistoric people used these pigments for painting the walls of the caves in which they used to live.

CONCLUSION

These days consumer demands on food quality are increasing. Carotenoids, anthocyanins, betacyanins, and chlorophyll are known as bioactive pigments and by including them in our diet could help to prevent certain degenerative diseases such as hypertension, diabetes, cancer, and cardiovascular disorders. The biological activity of these pigments is mainly attributed to their antioxidant and anti-inflammatory properties. These properties strengthen the importance of carotenoids, anthocyanins, betacyanins, and chlorophyll in our diet. Thus, we can conclude that many health benefits are hidden under the colour mark of natural pigments. Moreover, these pigments have other important uses also.

REFERENCES

1. P. Sudhakar, P. Latha, P. V. Reddy. Phenotyping Crop Plants for Physiological and Biochemical Traits. *Phenotyping Crop Plants Physiol. Biochem. Trait.* **2016**, 1–172.
2. Y. Tanaka, N. Sasaki, A. Ohmiya. Biosynthesis of plant pigments: anthocyanins, betalains and carotenoids. *Plant J.* **2008**, 54 (4), 733–749.
3. R.F. Carvalho, M. Takaki, R.A. Azevedo. Plant pigments: The many faces of light perception. *Acta Physiol. Plant.* **2011**, 33 (2), 241–248.
4. R. Hai Liu. Health-Promoting Components of Fruits and Vegetables in

the Diet. *Adv. Nutr.* **2013**, 4 (3), 384–392.

5. R. Dabur, B. Sharma, A. Mittal. Mechanistic approach of anti-diabetic compounds identified from natural sources. *Chem. Biol. Lett.* **2018**, 5 (2), 63–99.
6. R. Singh, T. Arif, I. Khan, P. Sharma. Phytochemicals in antidiabetic drug discovery. *J. Biomed. Ther. Sci.* **2014**, 1 (1), 1–33.
7. V. Mehra, M. Khatri, S. Mishra, et al. Assessment of Anti-diabetic and Anti-oxidant activity of Murraya Koenigii extracts using in-vitro assays. *J. Biomed. Ther. Sci.* **2018**, 5 (1), 1–8.
8. I. Singh. Antimicrobials in Higher Plants: classification, mode of action and bioactivities. *Chem. Biol. Lett.* **2017**, 4 (1), 48–62.
9. S. Mishra, M. Khatri, V. Mehra. Trials and tribulations in tuberculosis research: Can plant based drug(s) be the solution? *Chem. Biol. Lett.* **2017**, 4 (1), 33–47.
10. P. Lakra, I. Nashier Gahlawat. Prospective Phytochemicals for alleviation of different chronic ailments. *Integr. J. Soc. Sci.* **2015**, 2 (1), 36–39.
11. J. Singh, S. Kumar, B. Rathi, K. Bhrara, B.S. Chhikara. Therapeutic analysis of Terminalia arjuna plant extracts in combinations with different metal nanoparticles. *J. Mater. Nanosci.* **2015**, 2 (1), 1–7.
12. N. Gupta, C. Gupta, S. Sharma, R.K. Sharma, H.B. Bohidar. Comparative study of antibacterial activity of standard antibiotic with silver nanoparticles synthesized using ocimum tenuiflorum and garcinia mangostana leaves. *Chem. Biol. Lett.* **2015**, 2 (2), 41–44.
13. A.K. Mittal, K. Thanki, S. Jain, U.C. Banerjee. Comparative studies of anticancer and antimicrobial potential of bioinspired silver and silver-selenium nanoparticles. *J. Mater. Nanosci.* **2016**, 3 (1), 22–27.
14. N.L. Naveena, R. Pratap, R. Naik, S.A. Shivashankar. Microwave assisted greener synthesis of silver nanoparticles using Karanjin and their antifungal activity. *J. Mater. Nanosci.* **2018**, 5 (1), 23–28.
15. B.S. Chhikara, R. Kumar, B. Rathi, S. Krishnamoorthy, A. Kumar. Prospects of Applied Nanomedicine: potential clinical and (bio)medical interventions via nanoscale research advances. *J. Mater. Nanosci.* **2016**, 3 (1), 50–56.
16. B.S. Chhikara. Current trends in nanomedicine and nanobiotechnology research. *J. Mater. Nanosci.* **2017**, 4 (1), 19–24.
17. L. Almela, J.M. López-Roca, M.E. Candela, M.D. Alcázar. Carotenoid Composition of New Cultivars of Red Pepper for Paprika. *J. Agric. Food Chem.* **1991**, 39 (9), 1606–1609.
18. J.G. Bell, J. McEvoy, D.R. Tocher, J.R. Sargent. Depletion of α-tocopherol and astaxanthin in Atlantic salmon (Salmo salar) affects autoxidative defense and fatty acid metabolism. *J. Nutr.* **2000**, 130 (7), 1800–1808.
19. W.A. Schroeder, E.A. Johnson. Singlet oxygen and peroxyl radicals regulate carotenoid biosynthesis in Phaffia rhodozyma. *J. Biol. Chem.* **1995**, 270 (31), 18374–18379.
20. D. McCann, A. Barrett, A. Cooper, et al. Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial. *Lancet* **2007**, 370 (9598), 1560–1567.
21. P.D. Fraser, P.M. Bramley. The biosynthesis and nutritional uses of carotenoids. *Prog. Lipid Res.* **2004**, 43 (3), 228–265.
22. C.L.B. Ambrósio, F. de A.C. e S. Campos, Z.P. de Faro. Carotenóides como alternativa contra a hipovitaminose A. *Rev. Nutr.* **2006**, 19 (2), 233–243.
23. P. Lakra, I. Nashier Gahlawat. The role of Nutrition in the Immune system functions. *Integr. J. Soc. Sci.* **2016**, 3 (1), 30–33.
24. S. Kim, T.Y. Ha, I.K. Hwang. Analysis, bioavailability, and potential healthy effects of capsanthin, natural red pigment from capsicum spp. *Food Rev. Int.* **2009**, 25 (3), 198–213.
25. P.G.B. de Carvalho, C.M.M. Machado, C.L. Moretti, M.E. de N. Fonseca. Hortaliças como alimentos funcionais. *Hortic. Bras.* **2006**, 24 (4), 397–404.
26. J.A. Olson. Carotenoids and human health. *Arch. Latinoam. Nutr.* **1999**, 49 (3 Suppl 1), 7S-11S.
27. J. Erdman. Variable bioavailability of carotenoids from vegetables. *Am. J. Clin. Nutr.* **1999**, 70 (2), 179–180.
28. A.V. Rao, S. Agarwal. Role of Antioxidant Lycopene in Cancer and Heart Disease. *J. Am. Coll. Nutr.* **2000**, 19 (5), 563–569.
29. A. V. Rao. Lycopene, tomatoes, and the prevention of coronary heart disease. *Exp. Biol. Med.* **2002**, 227 (10), 908–913.
30. A. V. Rao, Z. Waseem, S. Agarwal. Lycopene content of tomatoes and tomato products and their contribution to dietary lycopene. *Food Res. Int.* **1998**, 31 (10), 737–741.
31. J. Shi, M. Le Maguer, Y. Kakuda, A. Liptay, F. Niekamp. Lycopene degradation and isomerization in tomato dehydration. *Food Res. Int.* **1999**, 32 (1), 15–21.
32. B.C. Ip, C. Liu, L.M. Ausman, J. Von Lintig, X.D. Wang. Lycopene attenuated hepatic tumorigenesis via differential mechanisms depending on carotenoid cleavage enzyme in mice. *Chest* **2014**, 146 (6), 1219–1227.
33. L. Jonasson, A. Wikby, A.G. Olsson. Low serum β-carotene reflects immune activation in patients with coronary artery disease. *Nutr. Metab. Cardiovasc. Dis.* **2003**, 13 (3), 120–125.
34. W. Köpcke, J. Krutmann. Beta carotene and Skin Health. *Photochem. Photobiol.* **2008**, 84 (84), 284–288.
35. S.M. Moeller, P.F. Jacques, J.B. Blumberg. The Potential Role of Dietary Xanthophylls in Cataract and Age-Related Macular Degeneration. *J. Am. Coll. Nutr.* **2000**, 19, 522S-527S.
36. M. Turturică, A.M. Oancea, G. Râpeanu, G. Bahrim. Anthocyanins: Naturally occuring fruit pigments with functional properties. *Ann. Univ. Dunarea Jos Galati, Fascicle VI Food Technol.* **2015**, 39 (1), 9–24.
37. H. Wang, G. Cao, R.L. Prior. Oxygen Radical Absorbing Capacity of Anthocyanins. *J. Agric. Food Chem.* **1997**, 45 (2), 304–309.
38. A.R. Rechner, C. Kroner. Anthocyanins and colonic metabolites of dietary polyphenols inhibit platelet function. *Thromb. Res.* **2005**, 116 (4), 327–334.
39. D.R. Bell, K. Gochenaur. Direct vasoactive and vasoprotective properties of anthocyanin-rich extracts. *J. Appl. Physiol.* **2006**, 100 (4), 1164–1170.
40. D. Huang, O.U. Boxin, R.L. Prior. The chemistry behind antioxidant capacity assays. *J. Agric. Food Chem.* **2005**, 53 (6), 1841–1856.
41. J. He, M. Monica Giusti. Anthocyanins: Natural colorants with health-promoting properties. *Annu. Rev. Food Sci. Technol.* **2010**, 1 (1), 163–187.
42. T.P.T. Cushnie, A.J. Lamb. Antimicrobial activity of flavonoids. *Int. J. Antimicrob. Agents* **2005**, 26 (5), 343–356.
43. E. Pojer, F. Mattivi, D. Johnson, C.S. Stockley. The case for anthocyanin consumption to promote human health: A review. *Compr. Rev. Food Sci. Food Saf.* **2013**, 12 (5), 483–508.
44. D. Prasad, R. Kunnaiah. Punica granatum: A review on its potential role in treating periodontal disease. *J. Indian Soc. Periodontol.* **2014**, 18 (4), 428–432.

45. H.M.C. Azeredo. Betalains: Properties, sources, applications, and stability - A review. *Int. J. Food Sci. Technol.* **2009**, 44 (12), 2365–2376.
46. A. Colaco e Clemente, P. V. Desai. Evaluation of the hematological, hypoglycemic, hypolipidemic and antioxidant properties of Amaranthus Tricolor leaf extract in rat. *Trop. J. Pharm. Res.* **2011**, 10 (5), 595–602.
47. A.L. İnanç. Chlorophyll: Structural Properties, Health Benefits and Its Occurrence in Virgin Olive Oils. *Akad. Gıdatr (A.L. İnanç)* **2011**, 9 (2), 90–344.
48. W.M. El-Sayed, W.A. Hussin, A.A. Mahmoud, M.A. Alfredan. The conyza triloba extracts with high chlorophyll content and free radical scavenging activity had anticancer activity in cell lines. *Biomed Res. Int.* **2013**, 2013.
49. M.S. Donaldson. Nutrition and cancer: A review of the evidence for an anti-cancer diet. *Nutr. J.* **2004**, 3.
50. K. Solymosi, N. Latruffe, A. Morant-Manceau, B. Schoefs. Food colour additives of natural origin. *Colour Addit. Foods Beverages* **2015**, 4–34.
51. A.A. Ryan, M.O. Senge. How green is green chemistry? Chlorophylls as a bioresource from biorefineries and their commercial potential in medicine and photovoltaics. *Photochem. Photobiol. Sci.* **2015**, 14 (4), 638–660.
52. S. Hazra, S. Chattopadhyay. An overview of lignans with special reference to podophyllotoxin, a cytotoxic lignan. *Chem. Biol. Lett.* **2016**, 3 (1), 1–8.
53. I. Nashier Gahlawat, P. Lakra. Contextual implicit role of PROBIOTICS in improving the Human Health. *J. Integr. Sci. Technol.* **2017**, 5 (2), 50-53.
54. P. Lakra, S. Sehgal, I. Nashier Gahlawat, M. Wadhwa nee Dasbas. Use of products developed from potato flour, defatted soy flour and corn flour in combating malnutrition. *Integr. J. Soc. Sci.* **2018**, 5 (1), 47–50.
55. N. Galaffu, K. Bortlik, M. Michel. An industry perspective on natural food colour stability. *Colour Addit. Foods Beverages* **2015**, 91–130.
56. D.B.R. Amaya. Food Carotenoids: Chemistry, Biology and Technology. *Food Carotenoids Chem. Biol. Technol.* **2015**, 1–310.
57. B. Thorat. Chemical extraction and biomedical importance of secondary organic metabolites from plants – A review. *J. Biomed. Ther. Sci.* **2018**, 5 (1), 9–42.
58. S. Bhardwaj, S. Parashar, K. Verma, R. Arora, B.S. Chhikara. Evaluation of awareness about beauty products composition and proper utilization among college students. *Integr. J. Soc. Sci.* **2019**, 6 (2), 57–64.
59. A. Kotnala, K. Verma, A. Sharma, et al. Indian Medicinal Plants for skin care and cosmeceuticals: A review. *J. Integr. Sci. Technol.* **2019**, 7 (2), 35–70.
60. H.-O. Boo, J.-S. Shin, S.-J. Hwang, C.-S. Bae, S.-H. Park. Antimicrobial Effects and Antioxidative Activities of the Cosmetic Composition Having Natural Plant Pigments. *Korean J. Plant Resour.* **2012**, 25 (1), 80–88.