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Exploring the Health Benefits and Nutrient-Rich Qualities of Antioxidant Pigments in Avian Species: A Comprehensive Review

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Abstract

A class of lipid-soluble pigments known as carotenoids is found in many different types of plants, microalgae, bacteria, and fungi. They create a wide range of colors. Because of the health-promoting and bioactive qualities of carotenoids, there has been a noticeable surge in interest in their use as feed additives recently. This review aims to highlight the benefits of carotenoids for the poultry industry in terms of health and medicine by gathering the most recent information on their bioactive properties. Applications-wise, carotenoid-rich goods are widely accessible as natural colorants, vitamins, and additives for food and feed. Carotenoids have a variety of biological functions that support several medical advantages, including immune modulatory, anti-inflammatory, antibacterial, antidiabetic, and neuroprotective effects. Chickens' production, health, and the quality of their eggs and meat can be improved by adding carotenoids to meals. Pre- and post-hatched birds have less oxidative stress due to carotenoids, which also block free radicals, activate antioxidant enzymes, and interfere with signaling pathways, among other processes. Utilizing carotenoids as a supplement to promote bird health and enhance product quality in poultry feed. The coloration of egg yolks, skin, legs, beaks, combs, feathers, and fat is mostly dependent on carotenoids. The diet lacking in carotenoids caused the birds' pale skin and egg yolk colors.

Keywords: Carotenoids, Bioactive properties, Poultry, Health benefits

INTRODUCTION

A green seaweed species called *Ulva Lactuca* has drawn a lot of interest because of its potential to be a valuable source of bioactive chemicals. These large algae have enormous promise for a wide range of industrial uses. The field of algal biotechnology has gained popularity in recent years, with a particular emphasis on employing different macroalgae species to create a range of goods for the food, cosmetics, and pharmaceutical industries (1). Swiftlets are little birds of the Aerodramus genus, and their nests are used to make edible bird's nests (EBN), a rare and valuable food item. These swiftlets create a gel-like nesting structure using their hardened saliva. EBN has a lengthy history of consumed and important in culture (2). Interest in the relationship between diet, nutrition and human health has grown recently. Consuming vegetables can lower the chance of developing several diseases, including cancer and atherosclerosis, according to several epidemiological studies (3). Healthy eating is becoming more popular as people become more conscious of the advantages of leading a healthy lifestyle. Eating more fruits and vegetables is one way to promote healthy eating. Including nutrient-dense fruits in the diet can lower the risk of acute or chronic illnesses and give protection against some diseases. The global market for these fruits is predicted to expand by 41% by 2027, as consumer demand increases due to their perceived health benefits. In 2021, the market was valued at USD 152 billion (4). In a society where wellbeing and health have taken center stage, the idea of functional meals has drawn a lot of interest. They offer a potential means of improving human health and averting

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many illnesses through the power of food (5). "Good food, good health" has many meanings. People's hectic schedules these days cause them a great deal of worry. Extreme stress causes the body to produce free radicals, which hastens the aging process. We can practice yoga, meditate, eat well, exercise, and so on to reduce stress (6). Pseudocereals are dicotyledonous plants that are structurally and functionally distinct from cereals. They are not utilized very well, are free of gluten, high in proteins, and contain a variety of vital nutrients and saponins that have significant applications in agro-pharmaceuticals and agro-industrial products. In addition, as the number of people with celiac disease increases globally, there is a growing need for gluten-free flour alternatives (7). Arthrospira platensis, another name for spirulina algae, is a type of cyanobacteria, or blue-green algae, which belongs to the phylum of multicellular creatures. These filaments have a helical form are unbranched. A varied group of aquatic organisms with the capacity for photosynthesis are called algae (8). Rich in nutrients and containing a range of flavonoids that have different benefits like whitening, decreasing blood fat, increasing immunity, and stimulating digestion, this wild plant resource has both medicinal and food purposes in addition to abundant reserves (9). Marine macroalgae, or seaweed, could be extremely important for food security in a time of climate change as they navigate the world's mounting problems. Creating biomass from seaweed has several benefits. In contrast to terrestrial aquaculture, seaweed aquaculture doesn't necessitate an abundance of arable land, freshwater, or substantial quantities of pesticides or fertilizers (10).

The study (11) assessed how aquaculture's use of microalgal molecules has evolved and increased the utilization of these valuable substances in the creation of aquaculture meals. A potential replacement for aquafeed production that has positive health impacts is functional chemicals made from microalgae. The study (12) offered the scientific underpinnings for the creation of novel health foods and suggested a fresh approach to the application of seaweed chlorophyll in the culinary and medicinal sectors. The study (13) synthesized and compiles existing knowledge on the physicochemical composition, bioactive components, and ethnobotany of these native fruits, highlighting the promise of the underappreciated biodiversity in the area. The study (14) included an overview of the categories of agro-industrial by-products, together with information on their qualities, nutritional worth, and possible health advantages. The study (15)determined the effects of supplying laying hens with artificial (carmoisine) and natural (paprika) colorants on their blood components, performance, and characteristics related to the quality of their eggs. The research (16) investigates the process by which Black Vultures (Coragyps atratus) and Turkey Vultures (Cathartes aura) generate pigment on their exposed skin. The study (17) looked at the immune stimulating properties, biological activity, and potential use of spirulina as a dietary supplement in hens to enhance growth, intestinal health, and disease resistance. Fat liver syndrome is brought on the liver's inability to metabolize and reseal processed fatty acids as a result of lipolysis or an abundance of ingested fatty acids (18).

This part of the paper follows an identical format as the rest: In part 2, the Methods are discussed in detail. Part 3 discusses the results and the conclusion and recommendations for additional research were covered in Part 4.

MATERIALS AND METHODS

This section covers the investigation of the nutrient-rich characteristics and health benefits of antioxidant pigments in avian species. Plant carotenoids' basic chemical structure is shown in Figure (1).

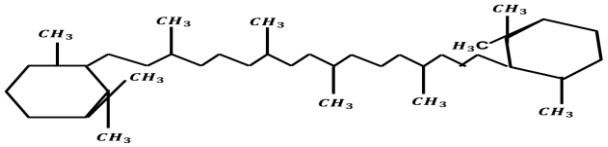

Figure (1). The composition of plant carotenoids
(Source: https://www.researchgate.net/figure/Chemical-structure-of-beta-carotene_fig2_327981139)

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Categorization and molecular makeup of carotenoids

Carotenoids are classified into two groups according to their chemical composition: primary and secondary. Primary carotenoids are the pigments involved in photosynthetic pigmentation are essential to photosynthesis. β-carotene, Lycopene, and α-carotene are examples of carotenes, which, according to their chemical structure, are classified as carotenoids that exist as pure hydrocarbons. Zeaxanthin, Lutein, and β-cryptoxanthin are examples of carotenoids called xanthophylls, which have oxygen as a functional group in their structures. The polarity and biological activity of the carotenoid compounds are determined by the presence of polar groups in their structure (19). Figure (2) displays the biological characteristics of the carotenoids.

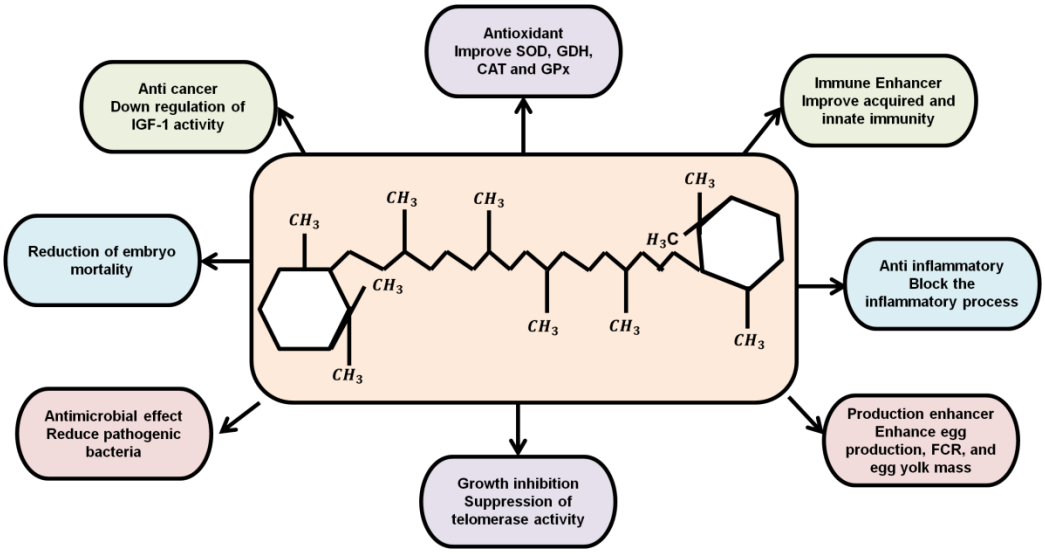

Figure (2). Biological properties of the carotenoids

(Source: https://onlinelibrary.wiley.com/doi/full/10.1111/jpn.13375)

Carotenoids' Antioxidant Properties

Oxidative stress is a result of the body producing unstable molecules in response to external stimuli and reactive oxygen species (ROS), which antioxidants can inhibit or downregulate. Antioxidants are physiologically active chemicals that work as effective agents against a range of diseases. Antioxidants come in two primary varieties for feed supplementation: natural and synthetic. Natural antioxidants can be found in a wide range of photosynthetic organisms and their byproducts, including fruits, vegetables, and herbs (20).

The Antioxidant Activity and Chemistry of Carotenoids

The lipid-soluble tetraterpenoid C40 pigment (15Z)-phytoene is the primary source of carotenoids. This pigment is biosynthesized using the allylic isomers of the C5 isoprenoid precursor, isopentenyl pyrophosphate (IPP), and dimethylallyl pyrophosphate (DMAPP). The pigmentation capabilities of the CAR molecule, which refer to its ability to absorb light in the visible (400–500 nm) region of the electromagnetic spectrum, are ascribed to its chromophore, which is a polyene chain consisting of 8–13 conjugated double bonds situated along its length.

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Furthermore, a resonance-stabilized intermediate is provided by this lengthy polyene chain structure, which effectively quenches ROS (21).

Possibility of improving health

Mechanistically, the antioxidant capacity of carotenoids explains their main health benefits. Certain carotenoids, however, might function through different channels. For instance, the capacity of β-carotene to be transformed into vitamin A confers additional benefits, and the absorption of particular light wavelengths by lutein and zeaxanthin offers eye protection. Carotenoids have the potential to prevent specific forms of cancer by either improving gap-junctional communication or suppressing aberrant cell development. Furthermore, carotenoids can protect against heart disease by preventing low-density lipoprotein from forming and oxidizing (22). Table (1) and Figure (3) show the market growth of carotenoids.

Table (1). Numerical Outcomes of Carotenoids Market Growth (Source: Author)

Year	Beta - Carotene	Lutein	Lycopene
2018	10	20	30
2019	15	17	35
2020	20	25	40
2021	30	36	50
2022	36	40	60
2023	55	60	70

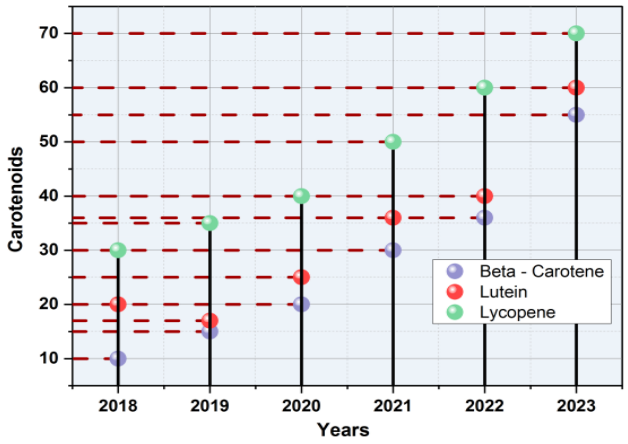

Figure (3). Carotenoids market growth (Source: Author)

The Health Advantages of Carotenoids for Chickens

Numerous environmental conditions and diseases, including viruses, pathogenic bacteria, heat stress, and other pathological causes, might jeopardize commercial chicken production. Poultry birds are faced with significant problems. The potential benefits of carotenoids and other plant-derived compounds for enhancing the therapeutic and health-promoting properties of chickens have been demonstrated (23).

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Carotenoids are potent immunomodulatory and antioxidant agents that scavenge cytotoxic ROS generated during regular physiological processes in birds and other oviparous animals. The therapeutic benefits include oxidation, inflammation, and the prevention of infectious illnesses.Supplementing broiler meat with lycopene pigment and other chemical compounds like fish oil and selenium improves the meat's nutritional value, oxidative stability, and production performance (24).Figure (4) and Table (2) present the numerical results for carotenoids.

Table (2). Comparison of Carotenoids (Source: Author)

Carotenoids	Outcomes		
	SBP	DBP	Hypertension
α - Carotene	15	5	20
β - Cryptoxanthin	5	30	2
Trans - lycopene	10	5	3
Trans β - Carotene	40	10	35

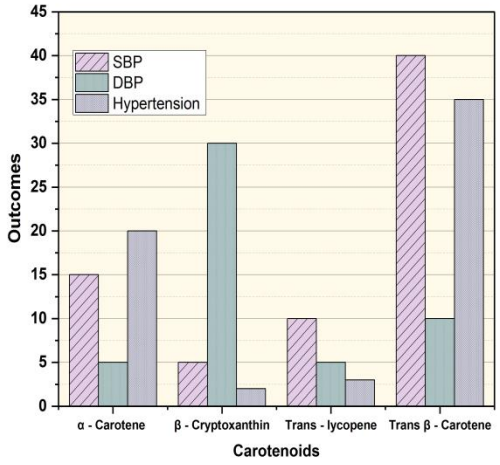

Figure (4). Numerical outcomes of Carotenoids (Source: Author)

Anti-inflammatory properties of carrot oils

A tissue's biological reaction to a variety of damaging stimuli, including pathogens, irritants, and damaged cells, is inflammation. The body's defensive response, which involves the activation of blood vessels, immune cells, and chemical mediators, removes the source of the inflammatory process. Consuming fruits and vegetables is advised by several health organizations to reduce the prevalence of certain chronic illnesses. Fruits and vegetables include phytochemicals called lipophilic carotenoids, which are remarkably rich in antioxidants and anti-inflammatory qualities. Most of these traits have been demonstrated to prevent or lessen oxidative stress and inflammation. It has been reported that giving infants supplements of carotenoids (lycopene, lutein, and β-carotene) reduces inflammation and increases carotenoids' plasma concentration (25).

Carotenoids' influence on health

There is evidence from vitro and animal studies that carotenoids offer protection against many types of cancer. According to epidemiological research, consuming more foods high in carotenoids is linked to a lower risk of

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developing various cancer types. These findings support this theory. Furthermore, h-carotene serum levels have been linked to a lower risk of cancer, as evidenced by studies on lung cancer. However, the majority of intervention trials involving h-carotene as a supplement ingredient revealed no changes in the risk of cancer (26).

Sources of Vitamin A

With the kingdom of plants, carotenoid pigments are extensively spread and can be found in bacteria, yeast, mold, and fungi. Carotenoids are found in human and animal tissue even though their bodies are unable to produce them naturally. This is because they enter the body through food and are absorbed and deposited there (27).

DISCUSSION

Fungus-derived carotenoids

Terpenoids with forty carbons are called carotenoids. They are organic materials. These are organic materials that can fend against photo-oxidation. Their hues range from yellow to orange-red. Light exposure, particularly blue light, is considered to be the main source of carotenogenesis. Conjugated double bonds that absorb light are thought to be the most important structural component of carotenoids since they primarily control their physiochemical properties. For instance, conjugated double bonds give most carotenoids their color (28). Carotenoids can be divided into two groups. Among them oxygen-free carotenes such as torulene, lycopene, and β-carotene.

Anticancer Action and its Capability to trigger an immune response

One of the main diseases that kill people is cancer. This fatal illness is treated using a variety of methods. Nevertheless, their medical care is very expensive and has been demonstrated to have detrimental effects on people. Consuming carotenoids daily can lower the risk of cancer in humans and has numerous anti-cancer properties. The free radicals of oxygen that cause cancer in humans can be decreased by consuming carotenoids (29). According to some sources, exposure to excessive UV radiation can cause photooxidation, which is detrimental to human skin and can result in skin cancer. Consuming carotenoids lowers the risk of skin cancer by reducing photooxidation of the skin. There are numerous medical advantages to carotenoids, and some studies have shown that astaxanthin, a type of carotenoid derived from microalgae, stimulates an immunological response. Tomatoes and their products are major sources of lycopene, a carotenoid that is widely distributed in fruits and vegetables (30). Additionally, lycopene can lower the chance of developing cancer, including liver, breast, prostate, ovarian, and cervical cancer. Conversely was discovered that lycopene concentrations above normal successfully lower the incidence of cardiovascular illnesses.

CONCLUSION

A class of lipid-soluble pigments known as carotenoids is found in many different types of plants, microalgae, bacteria, and fungi. They create a wide range of colors. The proactive and health-promoting properties of carotenoids have led to a notable increase in interest from the poultry industry to employ them as feed elements. Strong antioxidants known as carotenoids can lessen the negative effects of oxidative stress in a variety of ways, including by scavenging free radicals, suppressing signaling pathways, and initiating the phase II cytoprotective response. Feeding trials in chicken have improved the oxidative stability of poultry products, including meat and eggs, as well as their reproductive and productive capabilities. To comprehend the potential of natural carotenoids in terms of therapeutic and health-promoting benefits, more molecular study in diverse chicken models is needed.

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