UTILIZATION OF NATURAL CAROTENOID SOURCES TO ENHANCE MEAT COLOR IN BROILER CHICKENS

I. Ungureanu, M.-G. Usturoi*

"Ion Ionescu de la Brad" Iasi University of Life Sciences, Romania

Abstract

Carotenoids are naturally occurring pigments that have bioactive properties. They are very important for poultry nutrition because they make broiler meat and eggs healthier, more marketable, and of higher quality. This paper provides a comprehensive overview including the chemical structure of carotenoids, biological functions and potential dietary applications including enhancement of meat color as well as antioxidant and immune functions in poultry. Most important natural sources, such as yellow corn, algae meal, marigold extract and dehydrated alfalfa meal, are evaluated for their potential to supply xanthophylls and beta-carotene, which are necessary for the pigmentation desired by consumers. The review's scope also includes the role in pigmentation that carotenoid bioavailability plays as well as their cost-effectiveness and efficacy when given to birds' skin, meat, and nutritional composition. Other synergistic effects, like the effects of combining carotenoids with vitamin E or other antioxidants are also highlighted. New studies hint at sustainable ways in which natural carotenoid sources can be combined to achieve efficient pigmentation in poultry. This paper offers strategies to chicken feed composition to make it more market oriented and poultry products more appealing to consumers.

Key words: *carotenoids, meat color, natural pigments, yellow colorants*

INTRODUCTION

Carotenoids are chemical molecules with yellow, orange, or red hues that are found naturally in plants, algae, and certain microorganisms.

To improve the visual appeal and marketability of poultry products, one crucial component of poultry nutrition is the use of natural carotenoid sources to improve the color of the meat in broiler chickens.

When added to a chicken's diet, carotenoids-natural pigments present in a variety of plants, microalgae, and bacteria-give its flesh and skin vivid red, yellow, and orange colors [1,2]. This improvement is especially important since consumers are increasingly choosing poultry meat with vibrant coloring because they believe it to be fresh and high-quality [3]. In addition to increasing pigmentation, the addition of carotenoids like lutein, zeaxanthin, and canthaxanthin also improves immunological function and meat's ability to withstand oxidation [4,5]. Common feed items like paprika, marigold flowers, and yellow maize can provide these pigments, which have been demonstrated to improve the nutritional value and visual appeal of poultry products [6,7] (fig. 1).

Consuming carotenoids is linked to several health advantages, such as support for eye health and defense against oxidative stress. In chickens and most other organisms, including humans, carotenoids have a variety of biological functions that contribute to several therapeutic effects, such as immunomodulatory, anti-inflammatory, antibacterial, antidiabetic, neuroprotective, and anticarcinogenic [8,9,10].

* Corresponding author: marius.usturoi@iuls.ro

The manuscript was received: 07.10.2025
Accepted for publication: 17.11.2025

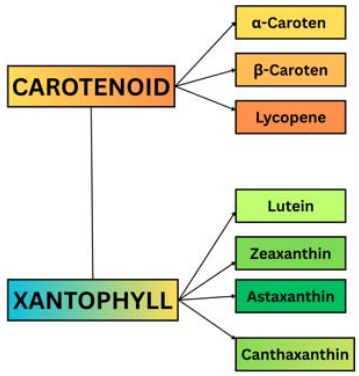

Fig. 1 Classification of carotenoids

The bioavailability of carotenoids is influenced by dietary factors, including the kind and quantity of carotenoid consumed, the type of feed and food that contains carotenoids, post-harvest processing, storage, and the methods used for processing and preparing the feed and food [11].

Less than 10% of the 600 carotenoids found in natural sources have been identified by studies as vitamin A precursors [10]. Both with and without provitamin A activity, human blood and tissues contain a variety of dietary carotenoids [9,11]. Between 15 and 30 percent of the carotenoids in blood serum are beta-carotene, the carotenoid with the highest nutritional activity.

Numerous carotenoids protect cells, tissues, and entire animals from a variety of neoplastic processes, boost the immune system, inhibit mutagenesis, and reduce caused nuclear damage. As a result, carotenoids shield tissues from photons. In some situations, carotene and other carotenoids can neutralize extremely reactive singlet oxygen and stop reactions caused by free radicals.

Consuming fruits and vegetables high in carotenoids have been associated in epidemiological research with protection against several cancers, especially lung cancer [12].

MATERIAL AND METHOD

To carry out this review, scientific articles, specialized books and official reports published between 1990 and 2025 were consulted, available in databases such as Google Scholar, Scopus and on the websites of recognized institutions (EFSA, USDA, ISO). The keywords used in the search included: "carotenoids", "broiler", "additives".

The selection of papers was based on their relevance to the proposed theme, considering both experimental studies and synthesis articles. Only materials that directly analysed the importance of carotenoids and their effect on chickens (health effects, effects on meat and egg quality, general welfare) and food safety aspects were included. The extracted information was then grouped and synthesized according to the categories of factors presented in the text, to provide a clearer and more accessible picture of the main conclusions in the literature.

RESULTS AND DISCUSSIONS

Likewise, serum beta-carotene levels are associated with a decreased risk of lung cancer. It is important to note, though, that since long-term intervention studies using beta-carotene supplements are still being conducted, such epidemiological links do not prove causation. Notwithstanding the findings of these investigations, carotenoids exhibit unique biological activities in animals in addition to their function as vitamin A precursors [13].

The primary aim of this study is to investigate the critical role of carotenoids as functional and bioactive components in poultry feed, with a particular emphasis on their capacity to enhance production performance, promote bird health, and improve the overall quality of poultry products. Carotenoids, as naturally occurring compounds, are recognized for their dual functionality: not only do they possess significant bioactive properties that

contribute to the physiological health of animals, but they also serve as natural pigments that influence the aesthetic and sensory qualities of meat and eggs.

Special attention is given to their role in meat coloration, a vital quality parameter that directly affects consumer acceptance and marketability. Poultry carcasses exhibit a range of external colors, from white and varying shades of yellow to darker hues such as black. Similarly, the internal color of meat varies, with pectoral muscles typically appearing white and thigh meat characterized by a red-pink hue [12].

The influence of carotenoids on these color attributes is particularly significant, as studies have shown that dietary carotenoids can effectively modulate skin and meat pigmentation, thereby aligning with consumer preferences in diverse cultural and geographical markets (*Fig.2*).

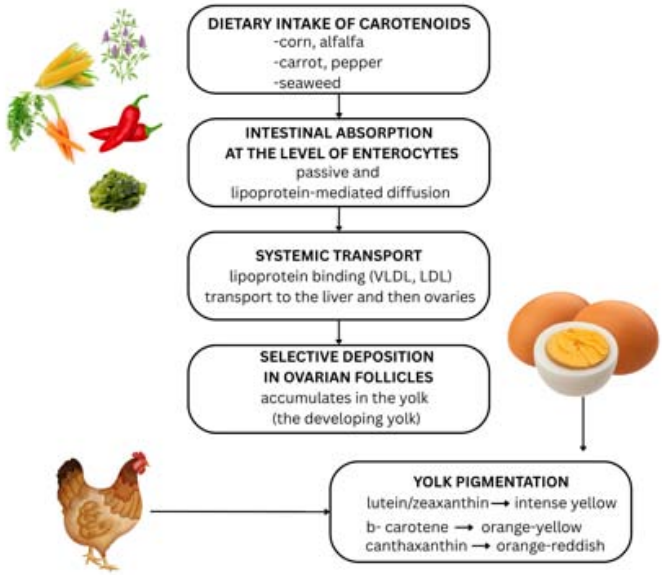

Fig. 2 Dietary intake of carotenoids

Furthermore, the study explores the broader functional benefits of carotenoids in poultry production. These compounds not only contribute to improved visual aesthetics but also enhance the nutritional quality of eggs and meat. Their bioactive properties support the health and well-being of poultry, leading to better growth performance, immune function, and overall productivity. As such, carotenoids represent a key element in sustainable poultry nutrition strategies, addressing both industry demands and consumer expectations for high-quality, visually appealing, and nutritionally enriched products.

This study highlights the significance of natural carotenoid sources in poultry feed formulations to accomplish these goals. Carotenoids can be effectively and sustainably transported by ingredients such yellow maize, corn gluten meal, algal meal, and dehydrated alfalfa meal, which facilitates their incorporation into animal diets [14,15]. This study's exploration of these natural sources emphasizes how they can offer a workable and environmentally responsible response to the growing need for poultry feed enhanced with carotenoids. The work seeks to bridge the gap between scientific research and real-world

applications in animal husbandry by highlighting the complex role of carotenoids in poultry nutrition through this thorough examination. In the end, this investigation advances our knowledge of how carotenoids might improve the biological and commercial value of poultry products [1], which in turn aids in the creation of creative and sustainable feeding practices [16].

BIOLOGICAL FUNCTIONS OF CAROTENOIDS

Antioxidants: Carotenoid help neutralize free radicals in the body, thereby reducing oxidative stress and protecting cells from damage. This helps in preventing chronic diseases such as cardiovascular diseases and cancer [17] (Fig. 3).

Precursor of Vitamin A: Beta-carotene is a precursor of vitamin A, essential for eye health, the immune system and skin health. Vitamin A is crucial for normal vision and cellular development [17,18].

Natural Pigments: Carotenoids give color to plants (from yellow to red), helping to attract pollinators and other animals that contribute to plant reproduction [18].

Gene Regulation: Certain carotenoids can influence the expression of genes involved in metabolic processes and inflammatory responses, contributing to overall health [18,19].

Eye Health: Carotenoids, such as lutein and zeaxanthin, accumulate in the eye's retina and help filter blue light, thereby protecting the the eyes from oxidative damage and age-related macular degeneration [19].

Anti-Inflammatory Properties: Carotenoids can have anti-inflammatory effects, thereby contributing to the reduction of risks associated with inflammatory diseases [14,17].

Role in Fat Metabolism: Certain carotenoids are involved in fat metabolism, influencing lipid balance and cardiovascular health. These functions underscore the importance of carotenoids in the diet and their impact on overall health [17,18].

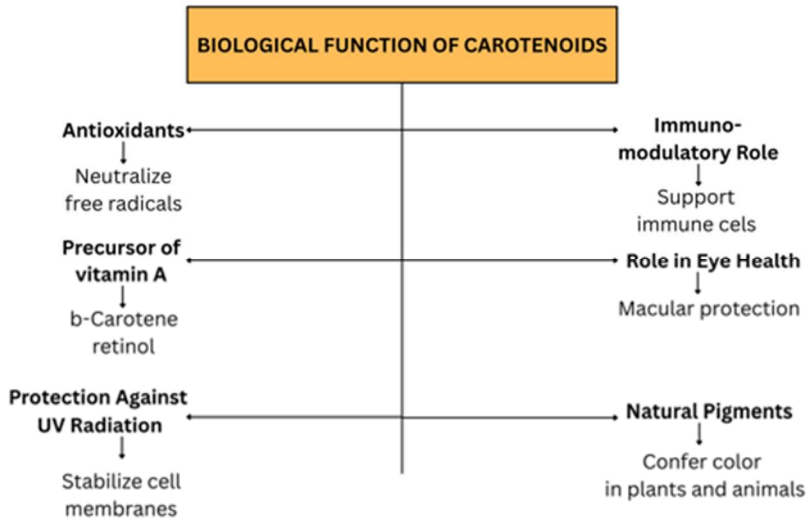

Fig.3 The biological function of carotenoids

SKIN AND FLESH PIGMENTATION

Research indicates that there is a connection between product safety, pricing, and quality [20]. Every production chain is aimed at consumers, and every production line has flaws if the needs of the customers are not carefully considered beforehand, even though it is well known that satisfying customer expectations influences purchasing behavior [21, 22]. Regional and cultural preferences for fowl skin color differ. Regional and cultural preferences for fowl skin color differ. Compared to American consumers, European consumers are content with substantially less pigment [23].

In the UK and Ireland, poultry typically has a brown-to-grey color when cooked and a light bronze or pink color while raw [24]. According to research, people's perceptions of poultry color were different more than ten years ago [25]. Although corn can be used to color poultry goods, its restricted output in many nations means that feed formulation must only include rice and wheat. However, according to [16] the meals on the list typically don't yield the appropriate yellow color for poultry eggs or meat. Skin color was seen as a significant quality concern for the ultimate customer assessment of the product during the time when most consumers bought poultry meat as a complete carcass [17, 26]. Genotype, the amount and dietary source of pigments, and the health of the birds are other factors that affect skin pigmentation [27].

Poultry flesh is colored by the carotenoid pigments in the feed, which accumulate in the skin and subcutaneous fat [27, 28]. Thus, the color of poultry skin is guaranteed by carotenoid pigments, which are fed to broiler chickens and then deposited in their skin and fat [28]. To get the desired amount of skin pigmentation, the chicken industry can add natural or synthetic pigments to feed, however doing so raises production costs [29]. The amount of xanthophyll in the feed is the primary determinant of the amount of yellow color deposited in the skin. Researchers discovered that the amount of xanthophyll in the feed affected the color of the skin of birds with yellow skin [30].

CONCLUSION

Although the consumption of poultry meat is rising, maximizing its quality is a significant concern for the sustainable production of poultry. This calls for fine-tuning farming factors, such as nutrition, to partially adjust tissue metabolism to meet a number of quality criteria pertaining to body composition and meat properties. This study demonstrated that adding antioxidants to commercial broiler diets greatly enhanced both hepatic antioxidant concentrations and immunological response. Carotenoids improve the color of meat and skin.

Supplementing with selenium and vitamin E also raised total plasma carotenoid levels, demonstrating the complementary actions of antioxidants. The highest dietary inclusion levels and digestive uptake rates in poultry must be addressed, nevertheless, as high dosages of β-carotene have also been linked to higher death rates. Carotenoids are a great class A nutritious pigment that can be used as a food additive or dietary supplement. The Food and Agriculture Organization of the United Nations has approved their usage in 52 nations. Pomegranate peel polyphenols at 50 mg/kg have been shown in studies to enhance performance, biochemical characteristics, and pigmentation; this may increase consumer preference for unpigmented grain-fed broilers.

REFERENCES

1. Nabi, Fazul; Arain, M. A.; Rajput, N.; Alagawany, M.; Soomro, J.; Umer, M.; Soomro, F.; Wang, Z.; Ye, R. & Liu, J; Health benefits of carotenoids and potential application in poultry industry: A review. *Journal of Animal Physiology and Animal Nutrition*, **2020**, 104(6), 1809–1818.
2. Yunitasari, F.; Jayanegara, A. & Ulupi, N; Performance, egg quality, and immunity of

laying hens due to natural carotenoid supplementation: A meta-analysis. *Food Science of Animal Resources*, **2023**, 43(2), 282–304.
3. Cervantes-Paz, B.; Victoria-Campos, C. I. & Ornelas-Paz, J. de J; Absorption of carotenoids and mechanisms involved in their health-related properties. *Sub-Cellular Biochemistry*, **2016**, 79, 415–454.
4. Kojima, S.; Koizumi, S.; Kawami, Y.; Shigeta, Y. & Osawa, A; Effect of Dietary Carotenoid on Egg Yolk Color and Singlet Oxygen Quenching Activity of Laying Hens. *J. Poult. Sci*, **2022,** 2022(2), 137–142.
5. Neta, M. S. P., Doi, A. C. B., Vieira, V. I., Souza, R. B. M., Felix, A. P., & de Oliveira, S. G. Impact of poultry feed on egg yolk color and quality. Appec-h.com, (n.d.). Retrieved February 19, **2025.**
6. Jlali, M., Graulet, B., Chauveau-Duriot, B., Godet, E., Praud, C., Nunes, C. S., Le Bihan-Duval, E., Berri, C., & Duclos, M. J. Nutri-genetics of carotenoid metabolism in the chicken: A polymorphism at the β,β-carotene 15,15'-monooxygenase 1 (BCMO1) locus affects the response to dietary β-carotene. *British Journal of Nutrition*, **2014,** 111(12), 2079–2088.
7. Kojima, S., Koizumi, S., Kawami, Y., Shigeta, Y., & Osawa, A. (n.d.). Effect of Dietary Carotenoid on Egg Yolk Color and Singlet Oxy-gen Quenching Activity of Laying Hens. *J. Poult. Sci*, **2022** (2), 137–142.
8. Bennedsen, M., Wang, X., Willén, R., Wadström, T., & Andersen, L. P. Treatment of H. pylori infected mice with antioxidant astaxanthin reduces gastric inflammation, bacterial load and modulates cytokine release by splenocytes. *Immunology Letters*, **1999,** *70*(3), 185–189.
9. Guerin, M., Huntley, M. E., & Olaizola, M. Haematococcus astaxanthin: applications for human health and nutrition. *Trends in Biotechnology*, **2003**, *21*(5), 210–216.
10. Arain, M. A., Mei, Z., Hassan, F. U., Saeed, M., Alagawany, M., Shar, A. H., & Rajput, I. R. Lycopene: a natural antioxidant for prevention of heat-induced oxidative stress in poultry. *World's Poultry Science Journal*, **2020**, *74*(1), 89–100.
11. Pugliese, A., Loizzo, M. R., Tundis, R., O'Callaghan, Y., Galvin, K., Menichini, F., & O'Brien, N. The effect of domestic processing on the content and bioaccessibility of carotenoids from chili peppers (Capsicum species). *Food Chemistry*, **2013**, *141*(3), 2606–2613.
12. Kumar, S., Dar, A. H., Srivastava, S., Dash, K. K., & Pandey, V. K. (n.d.). Based Smart Packaging: A Comprehensive Re-view. *Measurement: Food*, ***2024.***
13. Bendich, A., & Olson, J. A. Biological actions of carotenoids. *FASEB Journal: Official Publication of the Federation of American Societies for Experimental Biology*, **1989,** *3*(8), 1927–1932.
14. Castañeda, M. P., Hirschler, E. M., & Sams, A. R. Skin pigmentation evaluation in broilers fed natural and synthetic pigments. *Poultry Science*, **2005**, *84*(1), 143–147.
15. Liu, G.-D., Hou, G.-Y., Wang, D.-J., Lv, S.-J., Zhang, X.-Y., Sun, W.-P., & Yang, Y. Skin pigmentation evaluation in broilers fed different levels of natural okra and synthetic pigments. *The Journal of Applied Poultry Research*, **2008,** *17*(4), 498–504.
16. Rajput, N., Naeem, M., Ali, S., Rui, Y., & Tian, W. Effect of dietary supplementation of marigold pigment on immunity, skin and meat color, and growth performance of broiler chickens. *Revista Brasileira de Ciencia Avicola*, **2012,** *14*(4), 291–295.
17. Jackson, H., Braun, C. L., & Ernst, H. The chemistry of novel xanthophyll carotenoids. *The American Journal of Cardiology*, **2019**, *101*(10A), 50D-57D.
18. Vershinin, A. Biological functions of carotenoids - diversity and evolution. *Journal Biofactors*, **2008**, *10*(2), 99–104.
19. Ernst, H.Recent advances in industrial carotenoid synthesis. *Journal Applied Chemistry*, **2002**, *74*(11), 2213–2226.
20. Vitales, C. A. A thesis Dissertation: Relationship between product quality and customer satisfaction. *Walden Disserta-Tion and Doctoral Studies,* **2015.**
21. Adegoke, A. V., Sanwo, K. A., Egbeyale, L. T., Akinola, O. S., & Oyewolw, O. M. (n.d.). Physio-Chemical, Technological and Sensorial Qualities of Meat and Sausage from Broiler Chickens fed Dietary white and Cayenne Pepper Powders. *Journal of Food Science and Technology*, **2023(**2), 78–93.
22. Usturoi, M. G., Radu-Rusu, R.-M., Usturoi, A., Simeanu, C., Doliș, M. G., Rațu, R. N., & Simeanu, D. Impact of different levels of crude protein on production performance and meat

quality in broiler selected for slow growth. *Agriculture*, **2023**, *13*(2), 427.
23. Usturoi, A., Simeanu, C., Usturoi, M.G., Dolis, M.G., Ratu, R.N. & Simeanu, D. Influence of Packaging Type on the Dynamics of Powdered Eggs Chemical Composition. Materiale Plastice**, 2017**, 54(2), 380-385.
24. Kennedy, O. B., Stewart-Knox, B. J., Mitchell, P. C., & Thurnham, D. I. Flesh colour dominates consumer preference for chicken. *Appetite*, **2005**, *44*(2), 181–186.
25. Li, B., Vachali, P., Chang, F.-Y., Gorusupudi, A., Arunkumar, R., Shi, L., Rognon, G. T., Frederick, J. M., & Bernstein, P. S. HDL is the primary transporter for carotenoids from liver to retinal pigment epithelium in transgenic ApoA-I-/-/Bco2-/- mice. *Archives of Biochemistry and Biophysics*, 2022, *716*(109111), 109111.
26. Akiba, Y., Sato, K., Takahashi, K., Matsushita, K., Komiyama, H., Tsunekawa, H., & Nagao, H. Meat Color Modification in Broil-er Chickens by Feeding yeast Phaffia Rhodozyma Containing high Concentrations of astaxantin. *Journal of Applied Poultry Reseatch*, **2001**, *10*(2), 154–161.
27. Sirri, F., Petracci, M., Bianchi, M., & Meluzzi, A. Survey of skin pigmentation of yellow-skinned broiler chickens. *Poultry Science*, **2001**, *89*(7), 1556–1561.
28. Perez-Vendrell, A. M., Hernandez, J. M., Llaurado, L., Schierle, J., & Braufau, J. Influence of Source and Ratio of Xanthophyll Pig-ments on Broiler Chicken Pigmentation and Performance. *Poultry of Science*, **2001**, *80*, 320–326.
29. Grashorn, M. Feed additives for influencing chicken meat and egg yolk color. In *Handbook on Natural Pigments in Food and Beverages,* **2016**, (pp. 283–302). Elsevier.
30. Fritz, J. C., Roberts, T., & Boehne, J. W. The chick's response to choline and its application to an assay for choline in feedstuffs. *Poultry Science*, **1967**, *46*(6), 1447–1454.