

EFFECTS OF *DUNALIELLA SALINA* AS A FEED SUPPLEMENT ON PERFORMANCE, ANTIOXIDANTS, AND IMMUNITY OF POULTRY

MAHMOUD H. METWALLY; ZENAT A. IBRAHIM; ISMAIL E. ISMAIL; MAHMOUD ALAGAWANY AND MOHAMED S. EL-KHOLY*

Poultry Department, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt

Received: 10 March 2025; **Accepted:** 13 July 2025

ABSTRACT

Algae have become a prominent topic of discussion due to their rich content of polyunsaturated fatty acids (PUFA) and antioxidant pigments, such as β -carotene. Research indicates that incorporating microalgae into animal feed could help in lowering blood cholesterol, enhancing immunity function, improving the quantity and quality of poultry products, and enhancing resistance against diseases through antimicrobial attributes. Additionally, microalgae contribute to the better digestive system condition and function, promote microflora colonization, and improve nutrient absorption. Among the most important carotenoid-producing microalgae species, *Dunaliella salina* stands out as a primary natural source of β -carotene, making it highly valuable in nutrition, medicine, and cosmetics. β -carotene accounts for approximately 10–14% of its dry weight. Moreover, *Dunaliella salina* is packed with essential nutrients, including minerals, antioxidants, vitamins, pigments lipids, and proteins. It also contains all essential amino acids, along with several non-essential ones, further enhancing its nutritional and functional significance. Studies have demonstrated that diets enriched with *D. salina* improve blood lipid profiles by reducing cholesterol synthesis and absorption in the digestive system. This leads to lower levels of triglycerides, cholesterol, and LD, while increasing HDL levels in animals. Additionally, *D. salina* may function as a digestive enzyme activator, particularly by stimulating pancreatic lipase, which is crucial for breaking down triglycerides and releasing fatty acids into the intestine. The cholesterol-lowering effect of *D. salina* may be attributed to its ability to either reduce dietary cholesterol absorption in the gut or interfere with cholesterol biosynthesis pathways. In this review, we will discuss the biochemical content of *Dunaliella salina* and its uses as antioxidants, immunostimulant and growth promoters in poultry nutrition.

Keywords: *Dunaliella salina*, chemical composition, antioxidants, immunostimulant, growth promoter

List of abbreviations

PUFA: polyunsaturated fatty acids, *D. salina*: *Dunaliella salina*, GPDH: glycerol-3-phosphate dehydrogenase, BC: Beta-carotene, ROS: reactive oxygen species, HPLC: high-performance liquid chromatography, DS: *Dunaliella salina*, VEGF: Vascular endothelial growth factor, TNF- α : Tumor necrosis factor alpha, DSLP: *Dunaliella salina* powder, WEDS: water extract of *Dunaliella salina*, EPS: exopolysaccharides.

Corresponding author: Mohamed S. El-Kholy

E-mail address: elkolymohamed1980@gmail.com

Present address: Poultry Department, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt

INTRODUCTION

By 2050, the global population is projected to reach approximately 9.8 billion. This population surge, along with socio-economical transformations, such as urbanization, shifting demographics, and rising income levels, is expected to double the demand for poultry products. Given their efficiency in converting nutrients into consumable protein, poultry plays a crucial role in meeting the increasing need for nutrient-dense food (Kleyn and Ciacciariello, 2021). The increasing demand for animal protein is directly related to the ever-increasing world population, making efficient poultry production more important (Tona, 2018). Recent years have seen a drastic reduction in the time it takes for chickens to reach market weight, thanks to improvements in production methods made possible by breakthroughs in breeding techniques in response to the worldwide surge in demand for chicken meat (Al-Abdullatif and Azzam, 2023). Feeding mode is very important factor in meat quality since the feed composition can affect or change strongly the characteristics of chicken meat (Jaturasitha *et al.*, 2008). Additionally, waterfowl, particularly ducks and geese, represent an important source of animal protein, with the potential to expand within the livestock industry (El Sabry *et al.*, 2023). The demands for safe and effective feed supplements have risen significantly in recent years as producers seek to enhance animal health and improve meat quality (Reuben *et al.*, 2021, Emam *et al.*, 2023). Natural feed supplements are increasingly used in poultry diets due to their ability to improve production and overall health (Abd El-Hack *et al.*, 2020). Among these supplements, microalgae, bacteria, fungi, yeasts, and insects are widely utilized. Microalgae, in particular, are rich in bioactive compounds, including PUFAs (Liu *et al.*, 2022), antioxidants, sterols, which have antimicrobial effects, pigments, sulfated polysaccharides, with antiviral properties, and β -carotene (Xue *et al.*, 2002).

It was reported that incorporating microalgae into poultry diets can reduce blood cholesterol levels, strengthen the immune system, and enhance meat and egg production and quality (Madeira *et al.*, 2017). Additionally, it possesses anti-microbial capabilities, supports gastro-intestinal health and function, promotes probiotic microflora colonization, and improves feed efficiency (Camacho *et al.*, 2019; Abdel-Wahab *et al.*, 2023).

Recently, attention has been given to *D. salina* as a promising feed additive (Mohammed, 2018). Currently, 28 species of *Dunaliella* have been identified, with five thriving in freshwater environments and the remaining 23 found in saline conditions (Shariati and Hadi, 2011). The alga was first observed in 1838 in salt evaporation ponds in southern France by Michel Félix Dunal and was later named in his honor by Teodoresco in 1905 (Oren, 2005). *D. salina* is highly adaptable to extreme salinity and can accumulate commercially valuable compounds, such as carotenoids, lipids, and glycerol (Al-naghmani and Sayegh, 2023). According to the National Center for Biotechnology Information, the algae belong to the class Chlorophyceae, order Chlamydomonadales, and family Dunaliellaceae (Jin *et al.*, 2003).

A major challenge of the 21st century is ensuring food security for the rapidly growing population despite finite natural resources. Currently, around one in nine people worldwide suffer from under-nutrition, with protein-energy malnutrition being a leading concern (Torres-Tiji *et al.*, 2020). Researchers are increasingly exploring feed additives that can be safely used to promote healthier diets (Reuben *et al.*, 2021, Emam *et al.*, 2023). It is anticipated that supplementing duck diets with *D. salina* could positively influence performance, carcass traits, renal and hepatic functions, blood lipid panel, immunity, and antioxidant status. The present review provides detailed information about the use

of *D. salina* in poultry diets and focuses on its beneficial role in the promotion of the physiological and productive performance of poultry, through its impact as a potential natural immuno-stimulant and antioxidant.

Components of *D. salina*

The chemical composition of *D. salina* consists of 36.4% crude protein, 33% carbohydrates, 7.8% lipids, 5% chlorophyll, 158 mg/100g phosphorus, 210 mg/100g calcium, 4.5% carotenoids, 4.5 mg/100g iron, and 102 mg/100g ascorbic acid (Tertychnaya *et al.*, 2020). Additionally, *D. salina* possesses three isoforms of glycerol-3-phosphate dehydrogenase (GPDH)—GPDH-1, GPDH-2, and GPDH-3—critical for glycerol accumulation. *D. salina* is the most significant natural source of β -carotene, producing it in various commercially viable forms, including oil suspensions, beadlets, and water-soluble powders, which are widely used in the medical and nutraceutical purposes. Additionally, dried *Dunaliella* is incorporated into animal feed (Borowitzka and biotechnology, 2013). Many anti-cancer drugs originate from natural products, and *D. salina*, known for its high β -carotene content, has been studied for its potential role in treating fibrosarcoma (Raja *et al.*, 2007). This unicellular, biflagellate microalga is commercially exploited for its production of β -carotene, glycerol, and other valuable bioactive compounds. *Dunaliella bardawil*, a related species, has been found to promote normal mammary cell growth while inhibiting cancerous cells (Fujii *et al.*, 1993). β -carotene is well-documented for its antioxidant and anti-cancer properties (Krinsky, 1988). Studies indicate that individuals with higher β -carotene levels in their bloodstream have a lower risk of developing cancer (Williams, *et al.*, 2000). Furthermore, β -carotene exhibits strong free radical-scavenging abilities and plays a role in lipid oxidation prevention (Bitterman *et al.*, 1994). Its applications range from dietary supplements to cancer treatment (Simpson and Chichester, 1981). Notably,

the 9-cis- β -carotene variant has been identified for its role in preventing cardiovascular diseases and malignancies due to its antioxidant properties (Levin *et al.*, 1997). Research on sarcoma-afflicted rats has shown that administering *D. salina* powder led to a marked reduction in hepatic and renal RNA and DNA levels, with tumor tissue analysis revealing significant regenerative effects (Raja *et al.*, 2007).

Microalgae like *D. salina* have been classified as non-toxic and safe for human consumption (El-Baz *et al.*, 2019). Algae serve as valuable sources of bioactive compounds, making them a promising resource for developing innovative food products (Lordan *et al.*, 2011, Draaisma *et al.*, 2013). As the primary commercial source of β -carotene, *D. salina* finds extensive use in cosmetics, pharmaceuticals, and nutrition (Al-naghri and Sayegh, 2023). With β -carotene comprising 10–14% of its dry weight (Sathasivam and Juntawong, 2013), it is a key component in many dietary supplements due to its numerous health benefits (Baker, *et al.*, 2004).

Beyond β -carotene, *D. salina* contains an array of beneficial nutrients, including carbohydrates, proteins, lipids, minerals, vitamins, and antioxidants. Its amino acid profile includes glutamic acid, aspartic acid, histidine, serine, lysine, glycine, alanine, tyrosine, methionine, valine, isoleucine, leucine, threonine, arginine, and phenylalanine (Darsi *et al.*, 2012). As a rich source of pro-vitamin A (Tsai *et al.*, 2012), *D. salina* also contains essential fatty acids, including linolenic acid, linoleic acid, stearic acid, palmitic acid, myristic acid, margaric acid, oleic acid, erucic acid, and arachidonic acid (Molino *et al.*, 2018). Furthermore, it produces lycopene and lutein, making it a valuable source of enzymes (Bharamurugan *et al.*, 2018). Due to its high protein (57%), vitamin C, and B12 content, *D. salina* is widely used as a pro-vitamin A supplement (Machado Sierra *et al.*, 2021). The microalga

Dunaliella salina is recognized as a rich source of bioactive compounds, including β -carotene, chlorophyll, and polyphenols, which contribute to its significant biological properties (Salim *et al.*, 2021). This microalga is particularly known for its high production of zeaxanthin and β -carotene, both of which act as potent natural antioxidants, enhancing its potential in various health-related applications (El-Baz *et al.*, 2022). Additionally, research has shown that violaxanthin, a carotenoid derived from *D. salina*, exhibits strong anti-inflammatory and antioxidant properties, making it highly valuable for therapeutic purposes (Ferdous and Yusof, 2021). Numerous studies have highlighted *D. salina*'s functional activities, particularly its antioxidant and immunostimulatory effects (Hyrslava *et al.*, 2022). This microalga is also highly beneficial in animal nutrition due to its high β -carotene content, which has been shown to provide neuroprotective effects by safeguarding against central nervous system oxygen toxicity (Bitterman *et al.*, 1994). Moreover, *D. salina* plays a role in alleviating gut inflammation through its antioxidant and immunomodulatory mechanisms (Abdelwahab *et al.*, 2020).

Effects of *Dunaliella salina* on poultry performance

Algae, including various types, such as brown, green, and red macro (Figure 1) and microalgae, are being explored as a promising nutrient source for poultry. Packed with beneficial components like polyphenols, polysaccharides, fatty acids, and amino acids, they offer significant advantages. Research shows that integrating algae into chicken diets can lead to notable improvements. Laying hens experience increased egg production (4.0-8.6%) and heavier eggs (1.3-1.5 g), while broiler chickens show enhanced growth performance (5-22% increased body weight) and improved feed conversion ratio (4-15% improvement). Optimal amounts vary depending on the algae type, with microalgae suggested at around 2% and macroalgae ranging from 1-5%. Considering the specific algae type and desired benefits is crucial for optimal outcomes. These findings underscore algae's substantial potential as a valuable addition to poultry feed, promoting better health, enhanced performance, and improved product quality (Coudert *et al.*, 2020).

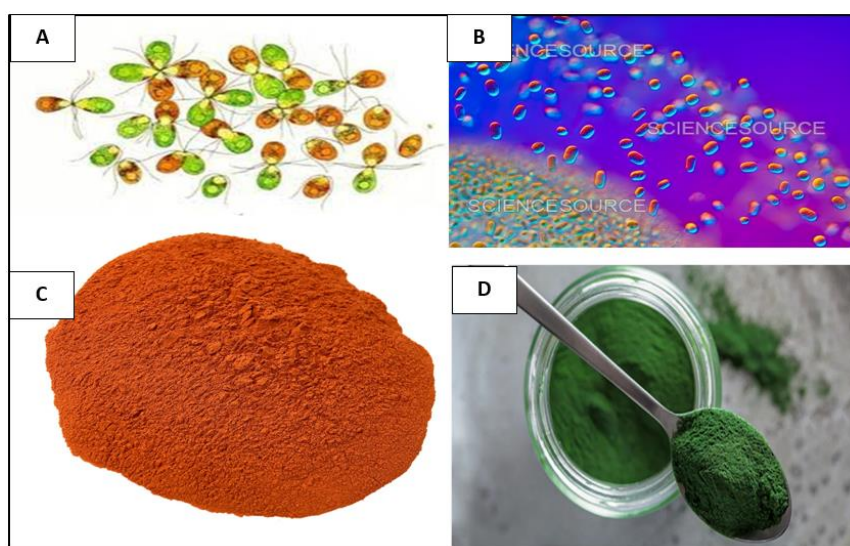


Figure 1. *Dunaliella salina*: **A:** Green and orange cells, **B:** Light micrograph, **C:** Orange powder, and **D:** Green powder.

D. salina shows promise as a valuable feed additive for young quail chicks. Quail fed diets containing 0.5 or 1.0 g DS/kg exhibited

significantly improved growth performance compared to chicks on a control diet or one with a lower DS concentration. These

benefits include increased growth, in terms of birds' weight and weight gain, and a better feed utilization, indicating the chicks efficiently converted their feed into body mass. Overall, this study suggests that incorporating *Dunaliella salina* into the diet of growing quail at these specific levels has the potential to be a beneficial strategy for promoting better overall growth (Alagawany *et al.*, 2024).

D. salina thrives with bicarbonate for β -carotene production. Researchers optimized culturing with bicarbonate (a cheaper carbon source) and achieved a significantly higher β -carotene yield compared to previous methods. However, high bicarbonate concentrations might stress the algae, suggesting a trade-off between cost-effectiveness and optimal β -carotene output (Xi *et al.*, 2020). Beta-carotene (BC), a vital nutrient for poultry, gets converted to vitamin A and contributes to vision, immunity, and overall health. Poultry relies on dietary sources like corn, marigold, and alfalfa for BC, which not only pigments egg yolks but also acts as an antioxidant in eggs and meat. Studies suggest BC strengthens the immune system and may even benefit cardiovascular health and reduce inflammation. Interestingly, wild birds have eggs richer in BC than chickens, and hens can keep depositing BC in eggs despite their own liver stores decreasing. Overall, BC is essential for poultry nutrition, impacting their health, product quality, and immune function (Çalışlar, 2019).

Leftover biomass after extracting carotenoids from *Dunaliella salina* has a high essential amino acid crude protein and n-3 PUFAs. Studies using defatted *Dunaliella salina* powder (made after scCO₂ extraction) as a feed additive for broiler chickens showed promise at low inclusion levels (0.1-1% of feed weight). Chicks fed with 0.1% defatted powder gained more weight and had a better feed conversion ratio. However, these benefits disappeared or became negative at the greater inclusion

doses. Overall, this suggests leftover biomass from *Dunaliella salina* can be valuable and the defatted powder has potential as a low-dose antibiotic alternative in animal feed (Harvey and Ben-Amotz, 2020).

Effects of *Dunaliella salina* as antioxidant

Increased interest in assessing antioxidant capacity across food, pharmaceuticals, and clinical research stems from the recognized involvement of reactive oxygen species (ROS) in aging and disease progression, leading to cellular damage through lipid peroxidation. *D. salina* green microalgae renowned for its exceptional ability to accumulate carotenoids, stands out for its antioxidant properties. The antioxidative action of β -carotene primarily involves radical trapping, attributed to its ability to prevent various cancers and modulate immune response and cellular communication. Carotenoids, including β -carotene, neutralize singlet oxygen through physical mechanisms, shielding lipids, proteins, and DNA from further oxidative harm. The superior antioxidant efficacy of natural carotenoid blends, characterized by their isomeric diversity, outperforms synthetic counterparts. Collectively, carotenoids offer diverse protective mechanisms against free radicals, thus proving invaluable in mitigating oxidative stress (Murthy *et al.*, 2005).

The study presents a novel HPLC method for analyzing and separating carotenoids in DS algae developed in Taiwan. The method efficiently separates seven carotenoids, with β -carotene being the most prevalent. Interestingly, the combined carotenoid extract displayed significantly stronger antioxidant activity in various assays compared to individual, purified carotenoids like β -carotene, lutein, and zeaxanthin. This suggests that *D. salina* holds promise due to its high content of antioxidants and cis-carotenoids that might be crucial contributors to their overall antioxidant capacity (Hu *et al.*, 2008).

Obesity and high-fat diets hurt the heart. A study by El-Baz *et al* (2020) tested a substance (crf-DS) from *Dunaliella salina* algae in obese rats. The rats that got crf-DS showed signs of better heart health compared to obese rats that didn't. This suggests crf-DS may protect hearts from obesity damage. The study evaluated the hepatic protective effects and antioxidant properties of *Dunaliella salina* methanolic extract in mitigating liver damage induced by paracetamol overdose in rats. Rats overdosed with paracetamol exhibited liver damage and oxidative stress, characterized by elevated serum levels of liver damage markers, malondialdehyde, cholesterol, and nitric oxide, alongside reduced activities of antioxidant enzymes. Treatment with the extract of *D. salina* at 500 and 1000 ppm or silymarin significantly mitigated liver damage markers, reduced oxidative stress indicators, and induced antioxidant enzyme activities in comparison to the paracetamol-intoxicated group. Liver histopathology also revealed reduced necrosis, congestion, and inflammatory cell infiltration in rats treated with *D. salina*. These findings indicate that DS possesses potent hepatic protective properties against the damage that is induced by paracetamol, likely by enhancing the activities antioxidant enzymes and inhibiting the process of lipid oxidation (Madkour and Abdel-Daim, 2013).

Dunaliella salina, shows promising source of natural antimicrobials and antioxidants. Extracts and oil from *Dunaliella salina* fought disease-causing microbes and exhibited antioxidant activity in lab tests. This suggests they could act as natural preservatives in food, animal feed, and pharmaceuticals. Additionally, the high content of unsaturated fatty acids in *D. salina* makes it a potential candidate for biodiesel production. Overall, it was reported that *Dunaliella salina's* potential for various beneficial applications (Cakmak *et al.*, 2014).

Dunaliella species can accumulate a wide variety of bioactive molecules, making them highly valuable in the global food, aquaculture, animal feed, pharmaceutical, and nutraceutical industries. Currently, the commercial production of β -carotene from *D. salina* is economically viable. However, several challenges hinder the large-scale commercialization of *Dunaliella*-based antioxidant enzymes. These include the high costs of biomass production, suboptimal cultivation conditions, technical difficulties in scaling up production, and the absence of cost-effective downstream processing technologies. Additionally, the instability of antioxidant enzymes at room temperature further limits their commercial applications. To overcome these limitations, optimizing abiotic stress factors during cultivation can enhance the antioxidant systems in *Dunaliella*. Implementing a multi-factor stress strategy proves to be more effective than relying on a single stress factor. Moreover, using a photobioreactor-based monoculture system provides greater flexibility in design and better control overgrowth conditions, leading to improved productivity and higher-quality bioactive compounds (Roy *et al.*, 2021).

Scientists investigated the use of nanoparticles loaded with *Dunaliella salina* algae, renowned for its antioxidant-rich content including zeaxanthin and β -carotene, to enhance wound healing. Their study revealed that extracts from *Dunaliella salina* contained substantial amounts of these beneficial compounds. Through the creation of two types of nanoparticles-high-efficiency and medium-efficiency, the researchers demonstrated significant wound healing properties, with the high-efficiency variant proving most effective. This efficacy was attributed to the antioxidant properties of *Dunaliella salina's* carotenoids. These nanoparticles not only reduced levels of TNF- α , a molecule linked to inflammation, but also elevated levels of VEGF and collagen, essential for blood vessel growth and skin regeneration, respectively. Microscopic examination confirmed the

nanoparticles' effectiveness in promoting healing, marking a notable advancement in wound treatment research (El-Baz *et al.*, 2023).

Effects of *Dunaliella salina* on immunity

Microalgae are among the richest natural sources of carotenoids, particularly green microalgae such as *Dunaliella salina*, *Haematococcus pluvialis*, and various *Chlorella* species (Zhang *et al.*, 2014). For example, while the lutein content in marigold flowers is typically reported to be around 0.3 mg/g, microalgae can contain lutein levels exceeding 4 mg/g (Ho *et al.*, 2014). *Dunaliella* strains are well known for their high content of lutein, zeaxanthin, and β -carotene (Jin and Melis, 2003). Among these strains, *D. salina* is one of the most extensively studied due to its status as the richest natural source of β -carotene (Hosseini Tafreshi and Shariati, 2009). Notably, approximately 50% of the total β -carotene in *D. salina* exists in the 9-cis isomeric form, which has unique biological benefits (Khoo *et al.*, 2011). Furthermore, *D. salina* contains other valuable carotenoids with potential medical applications, including violaxanthin, antheraxanthin, zeaxanthin, α -carotene, and lycopene (Fu *et al.*, 2013). The *Dunaliella* genus encompasses multiple species, and even within the same species, different strains exhibit varying carotenoid production capabilities and compositions. This diversity presents opportunities for selecting and developing strains with enhanced carotenogenic properties to meet specific industrial and medical demands (Borowitzka and Siva, 2007).

Dunaliella salina algae extract (WEDS) affects the immune system in mice in interesting ways. WEDS can either rev up or calm down the immune response depending on the initial state of the immune system. In mice with weak immunity, WEDS strengthens a specific immune response. In mice with an overactive immune system, WEDS help to tone it down. WEDS also

influences immune cells, promoting their growth and activity. These findings suggest WEDS has potential as a treatment to regulate the immune system, acting as a booster when needed or a calming agent for overactive immune response (Zheng *et al.*, 2004). The findings indicate that *Dunaliella salina* powder (DSLPP) has potential as an immunomodulatory agent against breast cancer. Administering DSLPP at higher doses resulted in a significant reduction in tumor formation in rats. The mechanism of action involves DSLPP slowing cancer cell growth, inducing cancer cell death, and potentially restoring the body's natural defenses against cancer. These results suggest DSLPP could serve as a preventive measure against breast cancer, highlighting its promising role in immune modulation against the disease (Srinivasan *et al.*, 2017).

Researchers investigated an immunomodulatory substance derived from *Dunaliella salina* microalgae. They isolated a particular fraction, known as the ethyl acetate fraction, from the algae's exopolysaccharides (EPS) and examined its effects on human immune cells. This fraction exhibited a complex response dependent on dosage, at lower doses, it inhibited cell growth, while at higher doses, it promoted cell growth, increased cytokine production, and stimulated TNF- α production in immune cells, indicating an immune-boosting effect. Conversely, the ethyl acetate fraction acted differently on macrophages, suppressing their growth and nitric oxide production at higher doses. Chemical analysis identified the presence of a five-sugar molecule, specifically a penta-saccharide, within the active fraction. It was suggested that this particular penta-saccharide from *Dunaliella salina* holds promise as a therapeutic agent for regulating the immune system. Researchers investigated an immunomodulatory substance derived from *Dunaliella salina* microalgae. They isolated a particular fraction, known as the ethyl acetate fraction, from the algae's EPS and examined its effects on human immune

cells. This fraction exhibited a complex response dependent on dosage: at lower doses, it inhibited cell growth, while at higher doses, it promoted cell growth, increased cytokine production, and stimulated TNF- α production in immune cells, indicating an immune-boosting effect. Conversely, the ethyl acetate fraction acted differently on macrophages, suppressing their growth and nitric oxide production at higher doses. Chemical analysis identified the presence of a five-sugar molecule, specifically a penta-saccharide, within the active fraction. This suggests that particular penta-saccharide from *Dunaliella salina* holds promise as a therapeutic agent for regulating the immune system (Goyal *et al.*, 2019).

Dunaliella salina, single-celled green algae, emerges as a potential star in shrimp farming. This review highlights its benefits as a natural shrimp feed. Packed with protein, carbohydrates, and pigments, *Dunaliella salina* not only promotes shrimp growth but also contributes to their health. The high content of β -carotene and phenols in these algae seems to boost the shrimp immune system. This review specifically examined the optimal conditions for growing *Dunaliella salina*, the nutrients it offers, and its positive effects on various commercially important shrimp species. Based on these findings, the review recommends exploring *Dunaliella salina* as a potential feed for a wider range of shrimp, making it a valuable option for shrimp farmers (Pratiwi, 2020).

CONCLUCISON

As a natural source of antioxidants, *D. salina* is considered a promising remedy for oxidative stress-related conditions. Given its ability to positively influence lipid metabolism, it has been identified as an optimal dietary supplement with numerous health benefits. Consequently, incorporating *D. salina* into animal feed or human diets holds great potential for promoting metabolic health and reducing the risk of

lipid-related disorders and inflammatory conditions.

REFERENCES

- Abd El-Hack, M.; Elnesr, S.; Alagawany, M.; Gado, A.; Noreldin, A. and Gabr, A.J.W.S.P.S.J. (2020):* Impact of green tea (*Camellia sinensis*) and epigallocatechin gallate on poultry. *World's Poultry Science Journal*. 76: 49-63.
- Abdelwahab, A.; Al-Madani, A. and Almohsen, I.Y.J.A.A.V.S. (2020):* Growth performance, morphological and chemical characteristics of red tilapia fed diets supplemented with *dunaliella salina*. 8: 536-542.
- Abdel-Wahab, A.; Elnesr, S.S.; Ahmad, E.A. and Abdel-Kader, I.J.A.B. (2023):* Effect of dietary supplementation of *Spirulina platensis* powder on performance, some serum biochemistry, digestive enzymes, microbial content, antioxidant parameters and immune responses of growing Japanese quail. 34: 4869-4877.
- Al-Abdullatif, A. and Azzam, M.M. (2023):* Effects of hot arid environments on the production performance, carcass traits, and fatty acids composition of breast meat in broiler chickens. *Life*, 13(6), 1239.
- Alagawany, M.; Lestingi, A.; Abdelzaher, H.A.; Elnesr, S.S.; Madkour, M.; El-Baz, F.K.; Alfassam, H.E.; Rudayni, H.A.; Allam, A.A. and Abd El Hack, M.E. (2024):* Dietary supplementation with *Dunaliella salina* microalga promotes quail growth by altering lipid profile and immunity. *Poultry Science*: 103591.
- Al-naghрани, M.J. and Sayegh, F.J.J.O.S.I.F.S. (2023):* Extraction of β -carotene from locally *Dunaliella salina* using bacterial lipase enzyme. 10: 1527-1545.
- Baker, R.; C.J.T.I.F.S. Günther and Technology (2004):* The role of

- carotenoids in consumer choice and the likely benefits from their inclusion into products for human consumption. 15: 484-488.
- Bhalamurugan, G. L., O. Valerie and L. J. E. E. R. Mark (2018).* Valuable bioproducts obtained from microalgal biomass and their commercial applications: A review. 23: 229-241.
- Bitterman, N.; Melamed, Y. and Ben-Amotz, A.J.J.O.A.P. (1994):* Beta-carotene and CNS oxygen toxicity in rats. 76: 1073-1076.
- Borowitzka, M.A. and Siva, C.J. (2007):* The taxonomy of the genus *Dunaliella* (Chlorophyta, Dunaliellales) with emphasis on the marine and halophilic species. *Journal of Applied Phycology* 19: 567-590.
- Borowitzka, M.A.J.H.O.M.C.A.P. and biotechnology (2013).* *Dunaliella*: biology, production, and markets. 359-368.
- Cakmak, Y. S., M. Kaya and M. Asan-Ozusaglam (2014).* Biochemical composition and bioactivity screening of various extracts from *Dunaliella salina*, a green microalga. *Excli j* 13: 679-690.
- Çalışlar, S. (2019):* The Important of Beta Carotene on Poultry Nutrition. *Selcuk Journal of Agriculture and Food Sciences* 33: 252-259.
- Camacho, F.; Macedo, A. and Malcata, F.J.M.D. (2019):* Potential industrial applications and commercialization of microalgae in the functional food and feed industries: A short review. 17: 312.
- Coudert, E.; Baéza, E. and Berri, C. (2020):* Use of algae in poultry production: a review. *World's Poultry Science Journal* 76: 767-786.
- Darsi, R.; Supriadi, A. and Sasanti, A.D.J.J.F. (2012):* Karakteristik Kimiawi dan Potensi Pemanfaatan *Dunaliella salina* dan *Nannochloropsis*. 1: 14-25.
- Draaisma, R.B.; Wijffels, R.H.; Slegers, P.E.; Brentner, L.B.; Roy, A. and Barbosa, M.J.J.C.O.I.B. (2013):* Food commodities from microalgae. 24: 169-177.
- El Sabry, M.I.; O.J.T.A.H. Almasri and production (2023).* Global waterfowl production: stocking rate is a key factor for improving productivity and well-being—a review. 55: 419.
- El-Baz, K.; F., A.M. Aboul-Enein, O.. M. Abdel-Fatah, H. H Abd El-Baky, A. M Hagag, S.I Ali and A.J.E.J.O.C. Salama (2022).* Anti-inflammatory role of *Dunaliella salina* carotenoid enrich fractions in paw oedema via down-regulation of COX-2/PGE2 pathway. 65: 223-233.
- El-Baz, F.K.; Salama, A.; Ali S.I. and El-Hashemy, H.A. (2023):* *Dunaliella salina* chitosan nanoparticles as a promising wound healing vehicles: In-vitro and in-vivo study. *OpenNano* 12: 100165.
- El-Baz, F.K.; Aly, H.F. and Salama, A.A.J.T.R. (2019):* Toxicity assessment of the green *Dunaliella salina* microalgae. 6: 850-861.
- El-Baz, F.K.; Aly, H.F. and Abd-Alla, H.I. (2020):* The ameliorating effect of carotenoid rich fraction extracted from *Dunaliella salina* microalga against inflammation- associated cardiac dysfunction in obese rats. *Toxicology Reports* 7: 118-124.
- Emam, A.M.; Elnesr, S.S.; El-Full, E.A.; Mahmoud, B.Y. and Elwan, H.J.A. (2023):* Influence of improved microclimate conditions on growth and physiological performance of two Japanese quail lines. 13: 1118.
- Ferdous, U.T. and Yusof, Z.N.B.J.F.I.P. (2021):* Medicinal prospects of antioxidants from algal sources in cancer therapy. 12: 593116.
- Fu, W.; Guðmundsson, Ó.; Paglia, G.; Herjólfsson, G.; Andr sson, Ó.S.; Palsson, B. . and Brynj lfsson, S. (2013):* Enhancement of carotenoid

- biosynthesis in the green microalga *Dunaliella salina* with light-emitting diodes and adaptive laboratory evolution. *Applied microbiology and biotechnology* 97: 2395-2403.
- Fujii, Y.; Sakamoto, S.; Ben-Amotz, A. and Nagasawa, H.J.A.R. (1993). Effects of beta-carotene-rich algae *Dunaliella bardawil* on the dynamic changes of normal and neoplastic mammary cells and general metabolism in mice. 13: 389-393.
- Goyal, M.; Baranwal, M.; Pandey, S.K. and Reddy, M.S. (2019). Hetero-Polysaccharides Secreted from *Dunaliella salina* Exhibit Immunomodulatory Activity Against Peripheral Blood Mononuclear Cells and RAW 264.7 Macrophages. *Indian Journal of Microbiology* 59: 428-435.
- Harvey, P.J. and Ben-Amotz, A. (2020). Towards a sustainable *Dunaliella salina* microalgal biorefinery for 9-cis β -carotene production. *Algal Research* 50: 102002.
- Ho, S.-H.; Chan, M.-C.; Liu, C.-C.; Chen, C.-Y.; Lee, W.-L.; Lee, D.-J. and Chang, J.-S. (2014). Enhancing lutein productivity of an indigenous microalga *Scenedesmus obliquus* FSP-3 using light-related strategies. *Bioresource technology* 152: 275-282.
- Hosseini Tafreshi, A. and Shariati, M. (2009). *Dunaliella* biotechnology: methods and applications. *Journal of applied microbiology* 107: 14-35.
- Hu, C.-C.; Lin, J.-T.; Lu, F.-J.; Chou, F.-P. and Yang, D.-J. (2008). Determination of carotenoids in *Dunaliella salina* cultivated in Taiwan and antioxidant capacity of the algal carotenoid extract. *Food Chemistry* 109: 439-446.
- Hyršlova, I., G. Krausova, I. Mrvikova, B. Stankova, T. Branyik, H. Malinska, M. Huttel, A. Kana and I. J. M. D. Dorskocil (2022). Functional properties of *Dunaliella salina* and its positive effect on probiotics. 20: 781.
- Jaturasitha, S.; Srikanthai, T.; Kreuzer, M. and Wicke, M. (2008). Differences in carcass and meat characteristics between chicken indigenous to northern Thailand (Black-boned and Thai native) and imported extensive breeds (Bresse and Rhode Island Red). *Poultry science*, 87(1), 160-169.
- Jin, E.S. and A. Melis (2003). Microalgal biotechnology: carotenoid production by the green algae *Dunaliella salina*. *Biotechnology and Bioprocess Engineering* 8: 331-337.
- Jin, E., B. Feth, A.J.B. Melis and bioengineering (2003). A mutant of the green alga *Dunaliella salina* constitutively accumulates zeaxanthin under all growth conditions. 81: 115-124.
- Khoo, H.-E.; Prasad, K.N.; Kong, K.-W.; Jiang, Y. and Ismail, A. (2011). Carotenoids and their isomers: color pigments in fruits and vegetables. *Molecules* 16: 1710-1738.
- Kleyn, F. and Ciacciariello, M.J.W.S.P.S.J. (2021). Future demands of the poultry industry: will we meet our commitments sustainably in developed and developing economies? 77: 267-278.
- Krinsky, N.J.C.N. (1988). The evidence for the role of carotenes in preventive health. 7: 107-114.
- Levin, G.; Yeshurun, M. and Mokady, S. (1997). In vivo antiperoxidative effect of 9-cis β -carotene compared with that of the all-trans isomer.
- Liu, Y.; X. Ren, C. Fan, W. Wu, W. Zhang and Y.J.F. Wang (2022). Health benefits, food applications, and sustainability of microalgae-derived N-3 PUFA. 11: 1883.
- Lordan, S.; Ross, R.P. and Stanton, C.J.M.D. (2011). Marine bioactives as functional food ingredients:

- potential to reduce the incidence of chronic diseases. 9: 1056-1100.
- Machado Sierra, E.; Serrano, M.C.; Manares, A.; Guerra, A. and Aranguren Díaz, Y.J.A.S. (2021):* Microalgae: Potential for bioeconomy in food systems. 11: 11316.
- Madeira, M.S.; Cardoso, C.; Lopes, P.A.; Coelho, D.; Afonso, C.; Bandarra, N.M. and Prates, J.A.J.L.S. (2017).* Microalgae as feed ingredients for livestock production and meat quality: A review. 205: 111-121.
- Madkour, F.F. and Abdel-Daim, M.M. (2013):* Hepatoprotective and Antioxidant Activity of *Dunaliella salina* in Paracetamol-induced Acute Toxicity in Rats. Indian J Pharm Sci 75: 642-648.
- Mohammed, A.E.-N.A.J.P.J.O.Z. (2018):* Ovarian tissue transplantation in mice and rats: Comparison of Ovaries Age. 50.
- Molino, A.; Iovine, A.; Casella, P.; Mehariya, S.; Chianese, S.; Cerbone, A.; Rimauro, J.; Musmarra, D.J.I.j.O.E.R. and Health, P. (2018):* Microalgae characterization for consolidated and new application in human food, animal feed and nutraceuticals. 15: 2436.
- Murthy, K.N.C.; Vanitha, A.; Rajesha, J.; Swamy, M.M.; Sowmya, P.R. and Ravishankar, G.A. (2005):* In vivo antioxidant activity of carotenoids from *Dunaliella salina* — a green microalga. Life Sciences 76: 1381-1390.
- Oren, A.J.S.S. (2005):* A hundred years of *Dunaliella* research: 1905–2005. 1: 1-14.
- Pratiwi, D.Y. (2020):* A mini review-effect of *Dunaliella salina* on growth and health of shrimps. International Journal of Fisheries and Aquatic Studies 8: 317-319.
- Raja, R.; Hemaiswarya, S.; Balasubramanyam, D. and Rengasamy, R.J.M.R. (2007):* Protective effect of *Dunaliella salina* (Volvocales, Chlorophyta) against experimentally induced fibrosarcoma on wistar rats. 162: 177-184.
- Reuben, R.C.; Sarkar, S.L.; Roy, P.C.; Anwar, A.; Hossain, M.A. and Jahid, I.K.J. W.S.P.S.J. (2021):* Prebiotics, probiotics and postbiotics for sustainable poultry production. 77: 825-882.
- Roy, U.K.; Nielsen, B.V. and Milledge, J.J. (2021):* Antioxidant Production in *Dunaliella*. Applied Sciences 11: 3959.
- Salim, M.A.; Subandi, M. and Yuniarti, Y.J.B. (2021):* Neuroprotective efficacy of *Dunaliella salina* against paraquat-induced neurotoxicity in *Drosophila melanogaster*. 2307: 2239.
- Sathasivam, R. and Juntawong, N.J.I.J.C.S. (2013):* Modified medium for enhanced growth of *Dunaliella* strains. 5: 67-73.
- Shariati, M. and M.R. Hadi (2011).* Microalgal biotechnology and bioenergy in *Dunaliella*, Progress in Molecular and Environmental Bioengineering-From Analysis and Modeling to Technology Applications. IntechOpen.
- Simpson, K.L. and Chichester, C.O.J.A.R.O.N. (1981):* Metabolism and nutritional significance of carotenoids. 1: 351-374.
- Srinivasan, R., A. Chaitanyakumar, A. Mageswari, A. Gomathi, J.G.S. Pavan Kumar, M. Jayasindu, G. Bharath, J.S. Shravan and K.M. Gothandam (2017):* Oral administration of lyophilized *Dunaliella salina*, a carotenoid-rich marine alga, reduces tumor progression in mammary cancer induced rats. Food & Function 8: 4517-4527.
- Tertychnaya, T.; Manzhesov, V.; Andrianov, E. and Yakovleva, S. (2020):* New

- aspects of application of microalgae *Dunaliella Salina* in the formula of enriched bread, IOP Conference Series: Earth and Environmental Science. IOP Publishing, p. 012021.
- Tona, G.O. (2018): Current and Future Improvements in Livestock. Animal husbandry and nutrition, 147.
- Torres-Tiji, Y.; Fields, F.J. and Mayfield, S.P.J.B.A. (2020): Microalgae as a future food source. 41: 107536.
- Tsai, C.-F.; Lu, F.-J. and Hsu, Y.-W.J.M.V. (2012): Protective effects of *Dunaliella salina*—a carotenoids-rich alga—against ultraviolet B-induced corneal oxidative damage in mice. 18: 1540.
- Williams, A.W.; Boileau, T. W.-M.; Zhou, J.R.; Clinton, S.K. and Erdman Jr, J.W.J.T.J.O.N. (2000). β -Carotene modulates human prostate cancer cell growth and may undergo intracellular metabolism to retinol. 130: 728-732.
- Xi, Y., J. Wang, S. Xue and Z. Chi (2020). β -Carotene Production from *Dunaliella salina* Cultivated with Bicarbonate as Carbon Source. J Microbiol Biotechnol 30: 868-877.
- Xue, C.; Hu, Y.; Saito, H.; Zhang, Z.; Li, Z.; Cai, Y.; Ou, C.; Lin H. and Imbs A.B.J.F.C. (2002): Molecular species composition of glycolipids from *Spirulina platensis*. 77: 9-13.
- Zhang, J.; Sun, Z.; Sun, P.; Chen, T. and Chen, F. (2014): Microalgal carotenoids: Beneficial effects and potential in human health. Food & Function 5: 413-425.
- Zheng, W.; Wang, L. Shi, F. and Chu, C. (2004): Effects on cell immunity in mice by water extract of *Dunaliella salina*. Chinese Traditional Patent Medicine 26: 1031-1036

تأثير الدوناليليا ساليينا كإضافة علفية على الأداء ومضادات الأكسدة والمناعة في الدواجن

محمود حماده متولي، زينات عبد الجواد إبراهيم، إسماعيل السيد إسماعيل،

محمود محمد العجواني، محمد سليمان الخولي

قسم الدواجن - كلية الزراعة - جامعة الزقازيق - الزقازيق - مصر

Email: elkolymohamed1980@gmail.com Assiut University web-site: www.aun.edu.eg

أصبحت الطحالب موضوعاً مهماً للبحث والنقاش نظراً لمحتواها الغني من الأحماض الدهنية المتعددة غير المشبعة والصبغات المضادة للأكسدة مثل البيتا كاروتين، وتشير الأبحاث إلى أن إدخال الطحالب الدقيقة في علف الحيوانات يمكن أن يساعد في خفض نسبة الكوليسترول في الدم، وتعزيز الوظائف المناعية، وتحسين كمية وجودة منتجات الدواجن، وتعزيز المقاومة للأمراض من خلال خصائصها المضادة للميكروبات، بالإضافة إلى ذلك، تساهم الطحالب الدقيقة في تحسين حالة الجهاز الهضمي ووظائفه، وتعزيز محتواها من الميكروبات النافعة، وتحسين امتصاص العناصر الغذائية. ومن بين أهم أنواع الطحالب الدقيقة المنتجة للكاروتينات، تبرز الدوناليليا ساليينا كمصدر طبيعي رئيسي للبيتا كاروتين، مما يجعلها ذات قيمة عالية في التغذية والطب والتجميل، حيث يشكل البيتا كاروتين حوالي 10-14٪ من وزنها الجاف، علاوة على ذلك، فإن الدوناليليا ساليينا غنية بالعناصر الغذائية الأساسية بما في ذلك المعادن ومضادات الأكسدة والفيتامينات والدهون الصلبة والبروتينات، كما أنها تحتوي على جميع الأحماض الأمينية الأساسية، إلى جانب العديد من الأحماض الأمينية غير الأساسية، مما يعزز أهميتها الغذائية والوظيفية. في هذه المقالة المرجعية سناقش المحتوى الكيميائي الحيوي للدوناليليا ساليينا واستخداماتها في تغذية الدواجن كمضادات للأكسدة، ومحفزات للمناعة والنمو.