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# PHYSIOLOGICAL ASPECTS OF PHYTOCHEMICALS AS ANTIOXIDANTS ON POULTRY: (Article Review)

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**ABSTRACT**

Antioxidants have an important and vital function in preserving animal health and have a special role in animal physiological, reproductive, and productive performance. In general, poultry are subjected to a wide and varied range of stressors, including environmental, biological, nutritional, and productive stresses. These stresses frequently occur in quick and intensive poultry production systems, causing health issues related to their physiological and productive performance that may increase the formation of free radicals, which in turn cause lipid peroxidation, leading to a decline in their physiological and productive performance. Therefore, it requires an antioxidant system that can delay the initiation or slow the going rate of harmful oxidative reactions and prevent cellular and molecular damage that results from the influence of free radicals in the cellular metabolism process. Phytochemicals, which are plant-derived non-vitamin, non-mineral substances such as flavonoids and carotenoids, are considered dietary non-enzymatic antioxidants that play a protective role against oxidative reactions and minimize the effects of the body's oxidative stress, which supports the animal's physiological productive efficiency and health.



## INTRODUCTION

Poultry production in the world has made great progress, especially in the past four decades. Principally, meat and egg production have increased in quantity and quality, mainly improving the growth rate and feed conversion rate (FAO, 2013). The production of commercial poultry has been found to be impacted by a number of stresses, including biological, nutritional, environmental, and technological stress. Actually, it's nearly impossible to escape these stressors. They have emerged as one of the major issues in commercial poultry production that must be avoided because they may result in one of the harmful and dangerous stress factors in poultry production, known as oxidative stress (Surai and Fisinin, 2016 a, b).

The term "oxidative stress" refers to an imbalance between the formation of free radicals such as reactive oxygen species (ROS) and the capacity of biological defense mechanisms to prevent or eliminate them and repair their harmful consequences (Maritim *et al.,* 2003). Also, an imbalance between the body's antioxidant capacity and the harmful effects of reactive oxygen species is another way to describe it (Noguchi *et al.,* 2000; Betteridge, 2000).

**Free Radicals:**

Oxygen is present in many vital compounds due to its vital and essential role in life and in the body. Oxygen possesses oxidizing characteristics that the body's cells use to produce ATP in the mitochondria, which leads to the formation of free radicals as a result of these cellular oxidative activities (Pham-Huy *et al.*, 2008).

Free radical, as a definition, are high-energy compounds, atoms, molecules, or ions whose outer orbit contains one or more single (unpaired) electrons (Papadopoulou *et al.,* 2017), which makes them unstable and excitable and tends to be stable when they gain an electron from surrounding particles (Halliwell and Gutteridge, 2015).

The body produces free radicals rapidly in response to various cellular activities, as byproducts of cellular chemical processes, or when the body is exposed to radiation, chemicals, or environmental toxins (Papadopoulou *et al.,* 2017).

Increased free radical activity may exacerbate intracellular damage, destruction of cellular organelles as well as the cell membrane, and alteration of cell functional efficiency due to oxidative processes (Cheng *et al.*, 2002), and thus the cells degrade and die (Phaniendra *et al.,* 2015). This is due to the oxidation of the fatty acids "polyunsaturated fatty acids" that are found in the cell and its components, the occurrence of lipid peroxidation, and the elevation of malondialdehyde (MDA) level (Ayala *et al.*, 2014).

**Antioxidants:**

Antioxidants are chemical substances found in very low concentrations that act as the body's defense against free radicals, protecting it from their harmful effects by reducing, delaying, or suppressing biomolecule oxidation by donating an electron or scavenging free radicals and converting them to stable compounds unable to interact with the biomolecules in the body (Nimse and Pal, 2015). Hence, it prevents oxidative stress and reduces diseases resulting from it, as well as enhances the body’s immunity (Surai *et al.*, 2019) by adding it as an essential supplement to the poultry diet to lower the severity of oxidative stress that damages the cellular structure and its function (Estévez, 2015).

It is difficult to develop the ideal integrated system to help the growing or productive birds in sustaining redox equilibrium of the body (Surai *et al.*, 2017), but the antioxidant systems in poultry have been developed to survive in an oxidative environment that includes a complex network of endogenous antioxidants (such as glutathione, GSH, and the enzyme Co-Q (CoQ)) and exogenous antioxidants (vitamin E, carotenoids, etc.) (Surai *et al.,* 2019), and let us say that in most cases, they are sufficient to satisfy physiological needs (Surai, 2020).

**Antioxidant Mechanisms and Systems**:

Interestingly, the body's antioxidants collaborate to keep the body's cells and tissues in an ideal state of redox equilibrium (Surai *et al.*, 2019). Antioxidants prevent or delay the oxidation of biological molecules via their interactions with free radicals, converting them to less reactive molecules (Pham-Huy *et al.,* 2008), and because they neutralize free radicals, they oxidize. As a result, the body has to routinely replenish its antioxidant reserves in a variety of ways (Lobo *et al.,* 2010).

Some antioxidants work by scavenging free radicals, preventing their reactions, or neutralizing them and converting them to harmless products, such as vitamin E and C. (Abdul-Majeed, 2013). They can also work by inhibiting the oxidation of molecules by glutathione peroxidase, superoxide dismutase, and catalase enzymes (Young and Woodside, 2001).

The cell's antioxidant defense system consists of three levels (stages) of protection:

1- The first level (a direct enzymatic pathway to neutralize free radicals) is achieved through three main antioxidant enzymes that remove radical effects at the beginning of the process of their formation: SOD, GSH-Px, and CAT (Ighodaro and Akinloye, 2018).
2- The second level mainly includes free radical scavenging antioxidants that detoxify and regenerate small antioxidant molecules that work simultaneously with the 1$^{st}$ level, such as glutathione and vitamin E, A, C (Irshad and Chaudhuri, 2002).
3- The third level is activated when damaged biomolecules, such as methionine sulfoxide reductase, DNA-repair enzymes, proteosomes, and phospholipases, are removed or repaired (Surai *et al.,* 2019; Ighodaro and Akinloye, 2018).

**Classification of Antioxidants:**

Natural sources of antioxidants include vegetables, fruits, cereals, nuts, poultry meat, ruminant meat, fish, and others. They are classified into several classes depending on whether their source is natural or synthetic, or on their chemical nature, being enzymatic or non-enzymatic, or according to the nature of antioxidant reactions (Rasheed and Azeez, 2019).

Natural antioxidants are cheaper, safer, and more effective alternatives to synthetic pharmaceuticals in the production of poultry since they can prevent nutritional oxidation processes during storage, don't cause metabolic disorders in birds and are free of side effects (Pashtetsky *et al.,* 2019). Plant feed additives with high natural antioxidant content can boost chicken production effectiveness without affecting the product's quality due to their ability to shield birds from harmful microorganisms and prevent diseases brought on by oxidative stress (Pashtetsky *et al.,* 2019). Therefore, they can be classified as follows:

**1- <u>Natural Antioxidants:</u>**

The body either produces them during metabolism or they are obtained as supplements from various natural sources. Their actions, which include breaking the chain reaction and converting them into more stable molecules, are greatly impacted by their physical and chemical properties (Hurrell, 2003). Natural antioxidants can be divided into two categories: enzymatic and non-enzymatic.

A- <u>Enzymatic Antioxidants:</u>

Animals have an antioxidant system that includes a variety of antioxidant enzymes that neutralize free radicals created by the body's metabolic reactions (Chen *et al.,* 2011), for instance, CAT, SOD, and GSH-Px (Surai, 2016). They are created by the body and act by oxidizing metabolic waste products into hydrogen peroxide, which, in the presence of cofactors such as Zn, Fe, Cu, and Mn, converts the $H_2O_2$ into water (Lobo *et al.,* 2010). These include primary and secondary enzymes:

a) Primary enzymatic antioxidants such as CAT (Catalase), GSH-Px (Glutathione peroxidase) and SOD (Superoxide dismutase).
b) Secondary enzymatic antioxidants such as GSH-rd (Glutathione reductase), and G6PDH (Glucose-6-dehyrogenase).

B- Non-enzymatic Antioxidants:

They must be supplied for metabolism because they are not naturally available in the body and cannot be produced spontaneously (Moussa *et al.*, 2019). They are also called synthetic or dietary supplements. They increase the body's capacity to neutralize the effects of the ROS by obstructing also ending the reactions of free radicals, either directly by suppressing reactive oxygen species or indirectly by boosting the process of radical scavenging (Irshad & Chaudhary, 2002).

1- Dietary non-enzymatic antioxidants:

These act by inhibiting the chain of the free radicals and must be supplemented in the diet as complements because the body cannot produce them. These include:

a- Vitamins: they are fat soluble (A, E, D, and K) or water soluble (B complex and C) (Rahawi *et al.*, 2022).

b- Minerals: their function as cofactors for the antioxidant enzymes that protect against oxidative damage. Such as iron, copper, manganese, selenium, and zinc.

c- Essential amino acids, such as methionine, which contain sulfur (Kim *et al.*, 2020)

d- Phytochemicals: These are non-vitamin and non-mineral polyphenolic substances as food ingredients of plant origin (medicinal plants) (Engwa, 2018). Phenolic compounds (the major dietary phenolic types are flavonoids, phenolic acids, and polyphenols) and carotenoids are the most typical kinds of phytochemicals (Makhaik *et al.*, 2021). There are hundreds of carotenoids and thousands of flavonoids (Weng and Yen, 2012) responsible for giving fruits, vegetables, teas, and herbs their beautiful colors such as red, orange, yellow, and purple (Benzie, 2005). Here are some of the phytochemicals:

**1) Flavonoids:** are polyphenolic substances found in major plants that give color to vegetables, fruits, grains, seeds, flowers, leaves, and bark (Iskender *et al.*, 2016). According to the structure of their chemical components, more than 4,000 types of flavonoids are classified (Tanwar and Modgil, 2012). Flavonoids' favorable effects on animal health are mostly attributable to their strong antioxidant capacity. (Panche *et al.*, 2016). Green tea, grapes, apples, broccoli, soybeans, turmeric, raspberry, and onions are all natural sources of flavonoids (Panche *et al.*, 2016). Green and black tea, as well as sesamol, contain the most powerful antioxidants (Engwa, 2018).

**2) Carotenoids:** are the colors of fruits and vegetables (yellow, orange, and red). They are natural pigments that dissolve in body fat, which can be converted to vitamin A. They act as antioxidants and combat toxic free radicals that cause tissue damage throughout the body (Engwa, 2018). Description of over 700 types of natural carotenoids, categorized into two classes based on their structures: hydrocarbon carotenoids and xanthophylls. The hydrocarbon carotenoids are also called carotenes, which include α-carotene, β-carotene, γ-carotene, lycopene, phytoene, and phytofluene. Xanthophyll carotenoids include lutein, zeaxanthin, β-cryptoxanthin, astaxanthin, and fucoxanthin (Merhan, 2017).

2- Non-dietary non-enzymatic antioxidants:

These antioxidants help to decompose free radicals and minimize the oxidation of low-density lipoprotein. This class of antioxidant rarely enters cells but is synthesized within them from essential amino acids (Prenzler *et al.,* 2021).

Glutathione is an essential water soluble non-enzymatic antioxidant containing a thiol group (sulfhydryl group). It differs from non-enzymatic food antioxidants in that it can be synthesized in the body, mainly in the liver (Moussa *et al.,* 2019).

Other non-enzymatic, non-dietary antioxidants include proteins that bind to metals, including ceruloplasmin, haptoglobin, hemoglobin, and albumin, as well as non-protein antioxidants that prevent oxidation by removing (scavenging) the free radicals like uric acid, ubiquinol and bilirubin (Surai, 2016).

**2- Synthetic Antioxidants:**

which are polyphenolic substances that inhibit the production of free radicals and block chain reactions, and are manufactured by utilizing different technologies (Hurrell, 2003), commonly used in pharmaceuticals (Lobo *et al.,* 2010), such as (Lourenço *et al.,* 2019):

1-Butylated hydroxyanisole is a kind of butylated hydroxyanisole (BHA).
2-Butylated hydroxytoluene is a kind of butylated hydroxytoluene (BHT).
3-A metal chelating agent with propyl gallate (PG) (EDTA).
4-Butylhydroquinone (tertiary) (TBHQ).
5-Guaiaretic acid (nordihydroguaiaretic acid) (NDGA).
6-Ethoxy quinine (Agashe and Manwar, 2021).

**The Physiological Effects of Phytochemicals in Poultry:**

Antioxidants in general enhance various body functions in several ways based on the kind and dosage of the antioxidant and the method of its administration, as well as the synergistic effects of one type with another type of antioxidant (Kurutas, 2015). The significance of a diet high in plant-based antioxidants is due to the complex combination of phytochemicals that produce synergistic reactions that are responsible for its powerful antioxidant properties (Zhang *et al.,* 2015b). The degree of antioxidant effect in the body varies according to the type of antioxidant as well as the affected organ or the performance to be improved and to raise its functional efficiency (Hermund, 2018).

As mentioned earlier, phytochemicals (plant chemicals) or phytonutrients are natural polyphenolic compounds found in plant diets (medicinal plants) (Shahidi and Ambigaipalan, 2015), as non-vitamin and non-mineral nutritional supplements (Engwa, 2018), must be supplemented in the diet because the body cannot produce them (Makhaik *et al.,* 2021). Their phytochemical compounds may be existing in plant-based foods like vegetables, fruits, whole cereals, nuts, herbs, leaves, roots, legumes, seeds, and spices (Makhaik *et al.,* 2021), which could contain several compounds, including flavonoids, polyphenols, stilbenes, carotenoids, and anthocyanins (Kamboh *et al.,* 2015; Engwa, 2018).

Phytochemicals are bioactive plant molecules composed of thousands of chemicals, pigments, and natural antioxidants that are physiologically active in the body (Makhaik *et al.,* 2021). Polyphenols and carotenoids are the most important phytochemicals (Weng and Yen, 2012), that act by inhibiting the free radical chain (Shahidi and Ambigaipalan, 2015), and provide the initial defense mechanism for cells against excessive ROS generation (Lipinski *et al.,* 2017; Zhong and Zhou, 2013).

In folk medicine, plant seeds and herbs are used to enhance physiological performance and treat some diseases, as well as phytochemicals are utilized as nutritional supplements to enhance the performance and health of animals due to their properties as antioxidants (Hashemipour *et al.*, 2013), antistress and antimicrobial (Al-Mnaser *et al.,* 2022), as well as their capacity to alter gut microbiota (Hashemi and Davoodi, 2010), and increase immunological responses (Chowdhury *et al.*, 2018). Among these substances that were given to birds with their food were fenugreek (Al-Nuaimmi and Abdul-Rahman, 2018), turmeric and thyme (Fallah and Mirzaei, 2016), and ginger (Abdul-Majeed and Abdul-Rahman, 2022).

In order to fulfill the many functions of the avian body's cells and organs, phytochemicals (whether they are plants, grains, seeds, roots, or chemical compounds) have a variety of impacts, **some of which are listed of them below:**

Alkatan *et al.* (2009) indicated that feeding sesame seeds orally (250 and 500 mg/kg diet daily) to breeder hens (Cobb 500) significantly increased the RBC count, PCV, Hb, and a significant increase in WBC counts and observed that sesame seeds improved erythropoiesis as well as some productive characteristics at 40 weeks of age.

Abd El-Hack and Alagawany (2015) found that the immunological and lipid profile parameters of laying hens reared from 36 to 52 weeks significantly improved when dietary thyme at doses of 3, 6, and 9 g/kg diet were added. Furthermore, the researcher reported that malondialdehyde levels were significantly reduced in the thyme-fed animals and that serum superoxide dismutase activity and glutathione concentration were both significantly elevated compared to the control group. Finally, it was found that thyme addition up to a 9 g/kg diet may be utilized as a productive feed addition (phytogenic feed) to enhance laying hen productivity, the activity of antioxidant enzymes, and blood constituents because thyme contains the most important essential phenolic substances in its oil, like thymol, γ-terpinene, carvacrol, and linalool (Satyal *et al.*, 2016), and it contains a high concentration of flavonoids, which makes its action an antioxidant, antibacterial, antifungal, and anti-inflammatory (Hossain *et al.*, 2013).

Abdul-Majeed (2016) found that giving thyme's crushed leaves (*Thymus vulgaris*) to female quail at 91 days of age dramatically boosted the blood glutathione levels and decreased MDA values, demonstrating that the birds' antioxidant status had been improved. Additionally, compared to the control group, it led to a significant reduction in levels of triglycerides, cholesterol, blood glucose, and AST and ALT activity.

In their study, Iskender *et al.* (2016) reported that 96 Lohmann hens were raised at 28 weeks of age for 8 weeks to assess the antioxidant properties of the flavonoids (0.5 g for each of hesperidin, naringin, and quercetin/kg diet), and they discovered that all flavonoids reduced MDA concentration while the SOD, GSH, GSH-rd, and

Glutathione-s-transferase activities increased, with quercetin superior to hesperidin and naringin. They also stated that flavonoids may assist in promoting the health of laying hens when stressed.

Kamboh *et al.* (2018) stated that both genistein (a soy flavonoid) and hesperidin (a citrus flavonoid) positively impacted the immunological indices (all phytochemical treatment groups showed an increase in antibody titers against Newcastle disease and antibody titers against Avian Influenza virus (compared to the control group) and hematological profile (the WBC counts and hemoglobin were significantly increased) of growing broilers (Arbor Acres).

According to Al-Nuaimmi and Abdul-Rahman (2018), treatment with fenugreek seeds alone (10 g/kg of feed) or with $H_2O_2$ 0.5% (which causes oxidative stress) in quail females from 7–42 days of age resulted in a significant decrease in glucose and triglyceride levels as well as a reduction in the activity of AST and ALT, but an increase in the level of heart tissue glutathione. This is in line with the conclusions of Salah (2008) after giving fenugreek to a male Arber Acer breeder.

All fruits and vegetables contain lycopene, a common carotenoid pigment, although the largest sources of it are tomatoes and tomato-related products (Arain *et al.,* 2018). It has a high ability to preserve oxidative equilibrium by a variety of actions like scavenging ROS or increasing the synthesis of enzymatic antioxidants like glutathione peroxidase, superoxide dismutase, and catalase enzymes. It has a strong capacity to maintain oxidative equilibrium (Blokhina *et al.,* 2003). Lycopene protects cells and tissues against ROS-induced damage (Palozza *et al.,* 2011).

The antioxidant characteristics of lycopene showed that it reduced heat stress by decreasing MDA levels in the blood and liver (Sahin *et al.,* 2008). With increasing dietary lycopene supplementation, MDA levels in the quail heart, liver, and serum were linearly lowered (Sahin *et al.,* 2006).

The findings of the study by Al-Chlabi and Abdul-Rahman (2019) confirmed that the dietary addition of chamomile flower powder (5 g/kg ration), which contained flavone glycosides, and oak leaf powder (10 g/kg ration), which contained ellagic and gallic acid (as a polyphenol) from 10 to 90 days of age, led to an improvement in the antioxidant status, represented by a reduction in MDA and an elevation in glutathione levels in the blood serum. The treatment also significantly lowered the blood serum levels of cholesterol and TG, LDL-C, and VLDL-C of heat-stressed quail, compared with the control group.

According to Abdul-Majeed and Taha (2019), crushed rocket salad (*Eruca sativa*) seeds at 77 days of age improved the serum lipid profile of quail (males and females), raised HDL-C levels, and improved the risk index (LDL/HDL). Additionally, they reduced the effects of stress as seen by a considerable reduction in AST and ALT activity when seeds were administered throughout the growth stage and before sexual maturity as compared to the control group.

Abdul-Majeed (2019) indicated that licorice roots have the ability to improve the antioxidant status of quail. This was demonstrated by significantly increasing glutathione and significantly decreasing the blood serum levels of MDA, cholesterol, and triglycerides of quail females at 91 days of age.

Nawab *et al.* (2019) indicated the laying hens that received 200 and 250 mg/kg of dietary curcumin from 22 to 31 weeks of age had better heat tolerance than the control group, which was demonstrated by increased CAT, SOD, T-AOC, and GSH-

Px activities as well as a reduction in MDA levels in blood and tissue samples, in comparison with the control group of heat stress, which suggests that turmeric may help prevent lipid peroxidation in cells and tissues. The findings of this study also demonstrated that curcumin, a natural antioxidant, can be used as a dietary supplement instead of synthetic antioxidants in chicken feed to increase the resistance of birds to stressful environmental conditions. This is consistent with Zhang *et al.* (2015a) and Zhang *et al.* (2018a, b) when they stated that curcumin can increase chicken growth performance under heat stress and reduce ROS generation in broilers during heat stress by enhancing mitochondrial Mn-SOD activity. Also stated, curcumin has the ability to repair heat-stressed broiler growth performance by reducing mitochondrial dysfunction (lower mitochondrial malondialdehyde level) and enhancing mitochondrial biogenesis (increasing glutathione content). That is because curcumin (feruloyl methane) is a yellow polyphenol derived from the zingiber plant, and it is one of the most extensively used natural pigments and acts as an efficient antioxidant (Hu *et al.* 2019).

Reda *et al.* (2020) found that dietary supplementation with red pepper oil (diffident concentrations) led to an improvement in the health status of Japanese quail after 5 weeks of age, especially the dose (0.8 g/kg ration), which caused the quail's live body weight to grow, their body weight to gain, their feed conversion ratio to improve, and an improvement in the plasma lipid profile of quail, compared with the control group.

Also, red pepper oil was found to improve the performance and antioxidant status when added to the ration of quail (the value of glutathione increased and the values of MDA and CAT values decreased in the blood serum). These results agree with those of Tayeb *et al.* (2015), who fed crushed red pepper (5g/kg ration) to quail.

Prihambodo *et al.* (2021) concluded that increasing flavonoid levels in broiler ration (different types of flavonoids such as: kaempferol, quercetin, catechin, epicatechin, trihydroxy flavone, isoflavone, luteolin, flavanols and anthocyanins) led to an enhancement of growth performance. The mortality rate decreased linearly with increasing flavonoid dose. Cholesterol, triglycerides, MDA, and LDL-C were also decreased, while the level of high-density lipoprotein and activity of superoxide dismutase increased.

Abdul-Majeed *et al.* (2021) stated that adding nettle plants (0.25 and 0.5%) to the broiler ration led to an increase in PCV, hemoglobin, MCHC values, decreased blood clotting time, elevated basophils%, and a decrease in the risk index (LDL/HDL). He suggested the possibility of administering nettle plants to enhance the blood and biochemical indices of broilers because of their antioxidant characteristics. It also led to an improvement in the immune status, so the globulin value increased and the AST and ALT values decreased.

Abdul-Majeed and Abdul-Rahman (2022) added ginger (*Zingiber officinale*) to the male quail diet (1000 mg/kg) because it contains effective antioxidant elements, and it was found that ginger enhanced the serum antioxidant status by increasing the glutathione levels and lowering levels of MDA, corticosterone (stress hormone), and lowering the activity of AST and ALT. As well, ginger decreased the glucose, cholesterol, and triglyceride levels, which prevented the influence of hydrogen peroxide-induced oxidative stress and returned most of the blood parameters to or close to the values of the control group.

## CONCLUSIONS

From this review, it becomes clear to us that it is possible to use phytochemicals as supplements to the basal diet of poultry that act as antioxidants, minimize the negative effects of oxidative stress, and give the best outcome in the physiological and productive performance of poultry.

The antioxidant defense system, which consists of the phenolic and polyphenolic classifications together with carotenoids, represents one of the largest groups of antioxidant properties that are principally found within plants and have the capacity to freely interact with free radicals, lowering their concentrations and preventing their reactions or/and decreasing the incidence of lipid peroxidation in birds.

On the other hand, it was found that there is a synergistic effect of the phytochemical components among them as antioxidants, so the product of the synergistic effect becomes stronger in enhancing the antioxidant status of birds and reducing oxidative stress, thus improving their physiological performance as well as their immunological system against diseases.

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## CONFLICT TO INTEREST

The authors have no conflicting interests in publishing this research.

**الجوانب الفسلجية للمواد الكيمياوية النباتية كمضادات أكسدة في الدواجن: بحث مراجعة**

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**الخلاصة**

تؤدي مضادات الأكسدة دورًا أساسيًا وحيويًا في الحفاظ على صحة الحيوان ولها دور خاص في الأداء الفسيولوجي والإنتاجي والتكاثري للحيوان. بشكل عام ، تتعرض الدواجن لمجموعة واسعة ومتنوعة من الإجهادات بما في ذلك الإجهاد البيئي والبيولوجي والتغذوي والإنتاجي ، والتي تحدث بشكل متكرر في أنظمة إنتاج الدواجن السريعة والمكثفة، مما يتسبب في مشاكل صحية متعلقة بأدائها الفسلجي والإنتاجي والتي قد تزيد من تكوين الجذور الحرة ، والتي بدورها تسبب بير وأكسدة الدهون، مما يؤدي إلى انخفاض في الأداء الفسيولوجي والإنتاجي. لذلك، فإنه يتطلب نظامًا مضادًا للأكسدة يمكنه تأخير بدء أو إبطاء معدل التفاعلات التأكسدية الضارة ويمنع الضرر الخلوي والجزيئي الناتج عن تأثير الجذور الحرة في عملية التمثيل الغذائي الخلوي. المواد الكيمياوية النباتية ، وهي مواد غير فيتامينيه وغير معدنية من أصل نباتي مثل الفلافونويد والكاروتينات، تعد من مضادات الأكسدة الغذائية غير الأنزيمية ، والتي تؤدي دورًا وقائيًا ضد التفاعلات التأكسدية وتقلل من آثار الإجهاد التأكسدي في الجسم ، مما يدعم الكفاءة الإنتاجية الفسيولوجية للحيوان وصحته.

**الكلمات الدالة:** مضادات الأكسدة الغذائية، الإجهاد التأكسدي، المواد الكيمياوية النباتية، البولي فينول.

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