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Antioxidant effects of Vitamin E, Vitamin C and Selenium yeast on Poultry Health, Immunity and Performance

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Abstract

Commercial poultry are constantly exposed to environmental, technological, nutritional, and biological stresses that impair health, reproduction, and production performance. Antioxidants are substances that prevent damaging caused by oxidative molecules and radicals to cells. Antioxidant strategies include **reducing radical production** by lowering oxygen availability, inhibiting reactive oxygen and nitrogen species (ROS/RNS)enzymes production, and binding iron and copper to proteins while **maintaining mitochondrial integrity** as the main ROS source. Vitamin e is recognized as efficient lipid-soluble antioxidant by quenching free radicals, protecting cell membranes from lipid peroxidation, synergizing with vitamin C and glutathione for regeneration, and enhancing antioxidant enzyme activity. Vitamin C supplementation in poultry diets can alleviate heat-stress challenges, enhance immune function, reduce oxidative stress, improve growth performance, and lower mortality. Selenium yeast had a great role in regulating the cellular antioxidant defense mechanism. In addition, selenium yeast can improve antioxidant effects in broilers by increasing of superoxide dismutase, reducing glutathione and mitigate lipid peroxidation by decreasing the level of malondialdehyde. This review evaluates vitamin E, vitamin C, and selenium yeast as potent antioxidants in reducing oxidative stress, supporting immune function, and enhancing the overall performance of poultry under environmental, physiological, and pathological challenges.

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Introduction

Poultry is essential for human nutrition as it offers high-quality protein, vital vitamins, and minerals at a reasonable price. Beyond being a crucial source of animal protein it has a fostering rural economic growth, attributed to its rapid production cycle, efficient feed conversion, and comparatively low production expenses. Nevertheless, poultry are persistently subjected to a variety of stressors such as heat stress, overcrowding, nutritional deficiencies, and disease challenges, which induce oxidative stress, leading to health deterioration, diminished reproductive capabilities, and lower production efficiency. Oxidative reactions can generate free radicals that initiate chain reactions damaging cellular structures **(Hamid *et al.,* 2010).** Redox reactions (reduction-oxidation) involve the transfer of an electron or hydrogen atom from one cell to another (**Pamplona and Costantini, 2011**). The irregular generation of free radicals increases stress on cellular components and alters molecular pathways associated with numerous diseases (**Lushchak, 2011**). Poultry exposed to numerous bad factors (external or internal stressors) which that hinder their production and health (**Surai *et al.,* 2016).**

The antioxidant defense system maintains basal ROS levels, allowing their role in redox signaling (oxidative eustress) through regulation of stress adaptation, homeostasis, and health. Excess ROS, due to impaired antioxidant defenses or high stress, causes oxidative distress by damaging lipids, proteins, and DNA. This disrupts redox signaling, weakens immunity, and reduces poultry productivity and reproduction. To counter oxidative stress, regulatory systems such as Nuclear factor-erythroid 2 (Nrf2/Keap1) and nuclear factor kappa-light-chain-enhancer of activated B cells / Inhibitor of kappa B pathway (NF-κB/IκB) are activated. These transcription factors translocate to the nucleus and regulate protective genes, though often with opposing effects.

The stress response involves multiple pathways, including heat shock, unfolded protein, and hypoxia responses, as well as autophagy, mitophagy, apoptosis, and other cell death or repair mechanisms essential for redox homeostasis (**Sies, 2019**).

Redox-active compounds (antioxidants) are crucial in preventing oxidation and allevating oxidative damage in the living cell **(Masood *et al.*, 2013)**. Antioxidant can postpone / prevent the irreversible cellular damage (**Mendonça *et al.,* 2022).**

Natural primary antioxidants prevent chain propagation through reaction with lipid radical and converted them to more stable products; they were phenolic in structure as antioxidant minerals (selenium, copper, iron, zinc, and manganese), and the absence of these elements led to defective carbohydrate metabolism. Antioxidant vitamins such as vitamin E, vitamin C, and vitamin B are very important for body metabolism. Phytochemicals are phenolic components such as flavonoids, catechins, carotenoids, beta-carotene, lycopene, and herbs. In addition, they reported that secondary (synthetic) antioxidants were the phenolic component that inhibited the damage effect of free radicals, such as butylated hydroxyltoluene and tertiary butyl hydroquinone, **(Hurrell, 2003)**. Natural (biological) antioxidants were categorized as hydrophilic antioxidants (vitamin C, lipoic acid, and glutathione) and hydrophobic antioxidants (carotenoids, vitamin E, and coenzyme Q). Water-soluble antioxidants catch free radicals present in the blood plasma and cell cytosol, while lipid-soluble antioxidants prevent lipid peroxidation to protect cell membranes **(Surai, 2007)**.

Mechanism of action of antioxidants:

There are two main techniques for antioxidant action. Firstly, the antioxidants donate electrons to unstable molecules, and this is called the chain-breaking mechanism. The other technique of antioxidants includes the elimination of the causes of oxidation by quenching chain initiator catalysts **(Hamid *et al.*, 2010)**. Polyphenols had an antioxidant effect. These phenols prevented the oxidation of membrane lipids and helped maintain glutathione at an accurate level in the cells **(Ognik *et al.*, 2016).** Nuclear factor-erythroid 2-related factor 2 (Nrf2) signaling was stimulated in oxidative stress animals to regulate the expression of downstream genes and resist oxidative stress damage (**Albarakati *et al.*, 2020**).

Antioxidant Defense Systems:

Systemic antioxidants fall into two types. The first one is enzymatic, which includes superoxide dismutase, glutathione peroxidase and catalase. The other type is non-enzymatic antioxidants, which includes the lipid-soluble vitamins, vitamin E and vitamin A or provitamin A (beta-carotene), and the water-soluble vitamin C **(Hamid *et al*., 2010).**

Several antioxidant mechanisms play vital roles in maintaining cellular balance and protecting against oxidative stress. These mechanisms can be classified into four main categories. Firstly, the prevention of oxidative damage involves reducing oxygen availability to minimize oxidative risk, binding or chelating metals to prevent their pro-oxidant effects, and down-regulating pro-oxidant enzymes to limit the formation of reactive species. Secondly, direct antioxidant defense includes scavenging free radicals to stop lipid and protein oxidation chain reactions, detoxifying and decomposing peroxides to avoid the accumulation of oxidants, and recycling antioxidant molecules like vitamin E to restore their protective function. Thirdly, genetic and redox regulation plays a key role through the activation of vitagenes that stimulate the production of endogenous antioxidants, the involvement of ARE-related pathways in promoting antioxidant enzyme synthesis, and redox signaling that activates transcription factors responsible for antioxidant responses. Lastly, repair and removal systems maintain cellular homeostasis by repairing or eliminating damaged molecules, preserving mitochondrial integrity to sustain energy metabolism, and initiating programmed cell death (apoptosis) to remove irreparably damaged cells, thereby protecting the organism as a whole (**Surai *et al*., 2017**).

Antioxidant strategies:

First, antioxidant defenses aim to reduce production of radicals through limiting oxygen Availability, decreasing Activity of enzymes which generate ROS and RNS (such as xanthine oxidase and Nicotinamide adenine dinucleotide phosphate oxidase), keeping iron and copper bound to proteins, and preventing their participation in the formation of new radicals. Second, it is crucial to preserve structural and functional integrity of mitochondria. Third, free radicals are scavenged by molecules such as coenzyme Q, vitamin E, vitamin C, and glutathione (GSH). Fourth, the biological antioxidant effectiveness can be increased by the mechanism of vitamin E recycling (ascorbic acid, thioredoxin reductase (TrxR), and vitamins B1 and B2), which keeps vitamin E in an active state. In addition (Nrf2) transcription factor and vitamin activation are the first components of the anti-stress., enzymatic systems such as (phospholipases, phospholipid hydroperoxide glutathione peroxidase, proteasomes) remove the collecting molecules in the cells and repair (heat shock proteins, HSP; methionine sulfoxide reductase, Msr; DNA-repair enzymes **Surai *et al*., 2019)**. Lastly the main parts of defense network comprise apoptosis, autophagy, and additional mechanisms that eradicate terminally impaired cells, thereby preventing the propagation of damage to neighboring cells or tissues, while safeguarding proteostasis and cellular macromolecules **Korovila *et al*., 2017).**

There is growing evidence that the body's antioxidants function as a "team" to provide the conditions necessary for adaptive homeostasis. When one team member assists another in being more productive, there are cooperative exchanges. Antioxidant defense systems, which include biosynthetically, derived antioxidant (AO enzymes, GSH, CoQ, uric acid, carnitine, and taurine) and diet derived antioxidant (vitamin E, carotenoids, synthetic antioxidants, carnitine, and silymarin), are actually present in all cell compartments (e.g., mitochondria, nucleus, and cytoplasm) and to be expressed tissue-specifically. Stress severity affects the expression and activity of several antioxidant enzymes, including SOD, GPx, and other selenium proteins (**Surai., 2018).**

Natural Antioxidant:

Exogenous natural antioxidant, selectively obtained from foods and medicinal plants—including fruits, vegetables, cereals, spices, and traditional herbs—can be considered bioactive compounds **(Xu *et al.*, 2017). P**henolic phytochemicals are alimentary derived antioxidants which confer metabolic advantages, and mitigate the risk of multiple pathological conditions (**Cömert *and* Gökmen 2018**). In addition**, C**arotenoids, phenolic compounds, and vitamins constitute three key dietary antioxidants health-promoting properties **(Thaipong *et al.,* 2006)**.

Vitamin E

A naturally occurring fat-soluble antioxidant, vitamin E (D-α tocopherol) stops the creation of reactive oxygen species and gives free radicals electrons to transform cell membranes into their reduced state by generating tocopherol radicals **(Traber and Stevens, 2011).** Under stress, the concentration of vitamin E in poultry is typically lower than normal because the birds' bodies are unable to produce it. Therefore, it acts as the foremost protective agent against heat-induced lipid peroxidation (**Horváth and Babinszky, 2018**).

Vitamin E, a naturally occurring antioxidant, is regarded as significant due to its function in preserving the health of birds as well as their ability to reproduce and be productive. It can stop the onset of oxidative processes and preserve the structural and functional integrity of subcellular organelles by preventing oxidative damage to polyunsaturated fatty acids (PUFAs), thiol-rich protein components of cellular membranes, the cytoskeleton, and nucleic acid (**Panda and Cherian., 2014**).

Addition of vitamin E to layer diets at 250 mg per kilogram of feed alleviates the detrimental effects of heat stress, enhancing egg production and yolk content **(Yardibi and Hostürk, 2008).** Boilers receiving dietary inclusion of vitamin E (250 mg / kg feed) exhibited diminished malondialdehyde concentrations in both serum and liver (**Sahin and Kucuk, 2001).**Vitamin E has been demonstrated to augment macrophage phagocytic function, control the synthesis of prostaglandins, cytokines, and leukotrienes, and modify inflammatory signaling **(Dalólio *et al.,* 2015).** Poultry receiving diets augmented with vitamin E exhibited improved feed consumption and feed efficiency **(Hashizawa *et al***.**, 2013** and **Habibian *et al.,* 2014).**

Dietary vitamin E supplementation to broilers enhances immune response by increasing total immunoglobulins and improving antioxidant properties by decreasing the oxidative degradation of lipids (**Pompeu *et al.,* 2018).** In addition, Vitamin E contributes significantly to health by augmenting cellular and humoral immunity (**Rizvi *et al.,* 2014**).

Vitamin E has a great role in enhancing antioxidant defense mechanisms in poultry. Evidence from breeders, males, and chicken embryo models demonstrates that dietary vitamin E supplementation increases resistance to stressors such as mycotoxins, and heat load. Elevated vitamin E improves α-tocopherol levels in semen, enhances antioxidant capacity in embryos and newly hatched chicks, and reduces lipid peroxidation. Moreover, its carryover from diet to yolk and later into the embryo associated with upregulation of antioxidant enzymes, reflecting regulatory adaptation of the antioxidant system. Subsequent studies are warranted to elucidate involvement of vitamin/ E in cellular signaling pathways, gene expression, microbiota interaction, and gut health in poultry **(Surai *et al.,* 2019).**

Vitamin C

One of the most significant antioxidants is vitamin C, which is essential for the regeneration of vitamin E **(Traber and Stevens, 2011).** Vitamin C functions chemically as an electron donor (reducing agent). Ascorbate can neutralize oxidized molecules; in addition, it’s able to reduce transition metals such as copper and iron.Vitamin C is recognized for its important role in strengthening the immune system, acting as a potential modulator of phagocyte activity, lymphocyte responses, cytokine secretion, and monocyte activity (**Preedy *et al.,* 2010).**

Vitamin C can function both as an antioxidant and, under certain conditions, as a pro-oxidant **(Padayatty and Levine, 2016).** Although the bodies of birds can generate vitamin C, in stressful conditions this synthesis is insufficient; hence, it is advised that broiler diets be supplemented with vitamin C **(Rafiee *et al.,* 2016).** The provision of vitamin C alleviates of heat load and enhances the immune response in broilers. Vitamin C nutrient fortification has been evidenced to mitigate thermal stress–induced detriments in chickens, including compromised immunity,, reduced feed consumption, decreased gain, oxidative stress, elevated core temperature, reduced fertility and semen quality, lower carcass yeild, and increased death rate **(Abidin and Khatoon, 2013)**. Vitamin C is crucial for the endogenous synthesis of Corticosterone, a hormone that sustains energy availability under stressful conditions. It is actively transported into body tissues, and both its utilization and requirement rise under heat-stress conditions, while its endogenous synthesis remains limited **(Ahmadu *et al.,* 2016).** According to **Min *et al.* (2018),** dietary fortification with vitamin C at 300 mg / kg roosters enhanced antioxidant activity and improved immunological responses under oxidative stress, mainly through the upregulation of GSH-Px gene expression. Vitamin C delivered during embryogenesis at day 15 has been shown to enhance antioxidant capacity and immunological function in serum of recently hatched chicks, while concurrently reducing pro-inflammatory cytokines activity in spleen (**Zhu *et al.,* 2019).**

Ascorbic acid (vitamin C) is an essential nutrient in poultry that enhances bird health, growth, and overall productivity. Its supplementation in feed or drinking water boosts disease resistance, reduces stress effects, and improves egg quality and shell strength, especially during the concluding stage of egg production.

Vitamin C additionally functions as an antioxidant, anti-inflammatory agent beside interacting alongside vitamin E and other nutrients to support optimal poultry performance (**Hieu *et al.,* 2022).**

Vitamin C is recommended as an effective growth promoter in poultry under heat load because it enhances body gain, improves feed efficiency, and augments antioxidant activity (**Tavakolinasab and Hashemi**, **2025).**

Selenium yeast:

Selenium is a minor yet vital elements sustain growth and physiological maintenance in poultry (**Sevcikova *et al.,* 2006).** The suggested dietary inclusion level for broilers ranges from 0.1–0.15 mg / kg of feed **(Mahan, 1995; NRC, 1994).** Selenium was one of the trace minerals that sustain health for animals and humans; insufficient level led to exudative diathesis and pancreatic lesions (**Toghyani *et al.,* 2008).** Glutathione peroxidase was an enzyme activated by selenium to a modified enzyme (glutathione peroxidase 4), which occurred by substituting sulfur in the glutathione molecule. This modified enzyme transform-ed hydrogen perox-ide into harmless water and oxygen. Body oxidation resistance was enhanced more by organic selenium than inorganic selenium (**Suchy *et al***., **2014)**. Selenium yeast improved Nrf2, which had a great role in regulating the cellular antioxidant defense mechanism and its target genes of HO-1, GSH-px, GLRX2, MnSOD, and CAT, so it prevented oxidative damage from ochratoxin (**Li *et al***., **2020).** Chickens receiving 0.3 ppm of organic selenium (Sel-Plex) in their diet exhibited enhanced body weight and superior feed efficiency (**Djordjevic *et al.,* 2016).**

In laying ducks, dietary selenium yeast was shown to strengthen antioxidant defense mechanisms, reflected by higher Glutathione peroxidase, Catalase activities and lower Malondialdehyde levels serum (**Zhang *et al***., **2020).**

Selenium yeast can improve antioxidant effects in through upregulation the level of superoxide dismutase (SOD), reduced glutathione (GSH) and mitigate lipid peroxidation by decreasing the level of malondialdehyde (MDA) **(Ibrahim *et al***., **2021).**

Broilers supplemented with different dosages of selenium yeast exhibited enhanced antioxidant activity (glutathione peroxidase, SOD, and catalase) with decreasing levels of MDA by decreasing the amount of oxidized products produced **(Liu *et al***., **2023).**

Selenium and vitamin E work together to boost antioxidant and immune functions in poultry. Supplementing feed with bacterial organic selenium produced by Enterobacter cloacae strain and Vit E increased immunoglobulin levels, regulated cytokine expression and improved gut health by Promoting commensal bacteria while suppressing pathogenic bacteria. Vitamin E alone lowered TNF-α but had little effect on gut microbes. Overall, combining ADS18-Se with Vit E gave the strongest immune response **(Dalia *et al.,* 2018).** The supplementation of selenium in combination with vitamins E /C has been established to markedly optimize performance of chickens facing an acute thermal challenge. Compared with their individual supplementation, the synergistic interaction among these antioxidants provides superior protection by activating multiple physiological and biochemical defense mechanisms. Collectively, selenium and vitamins E and C enhance immune competence and maintain cellular macromolecules particularly proteins and lipids from oxidative degradation induced by heat stress (**Shakeri *et al.,* 2020).**

Conclusion

Commercial poultry production is challenged by multiple environmental, nutritional, and physiological stressors that trigger oxidative stress, impairing health, immunity, and productivity. Incorporation of vitamin E, vitamin C, and selenium yeast into poultry feed provides an effective strategy to combat oxidative damage. These antioxidants act synergistically to scavenge reactive oxygen species, enhance endogenous defense systems, and maintain cellular homeostasis. Integrating these micronutrients into poultry rations not only mitigates oxidative damage but also enhances growth metrics and reproductive outcomes, and overall flock resilience, offering a practical approach to sustaining productivity under modern intensive production conditions.

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