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Vitamin E and Its Impact on Poultry Health and Production: An Update

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ABSTRACT: The main goals of recent poultry production sectors are to enhance the immune response of the birds, improve the performance, reduce mortalities and reduce stressors. These goals are achievable with dietary supplementation of vitamins. Vitamin E is one of the fat-soluble vitamin that has been used from last decades for different poultry production types. The inoculation level of vitamin E in the diet of poultry depends on several factors. Low or high level of vitamin E can induce severe adverse economic losses in poultry industry. Vitamin E has been regarded as a potent chain-breaking antioxidant as well as immuno-stimulator for both cell-mediated and humoral immunity. Vitamin E is added to the diet of broilers, layers and breeders especially those under heat stress conditions. In broilers, vitamin E can improve the health conditions, feed efficiency and immunity. However, in layers and breeders, it enhances the egg's quantity and quality as well as the fertility; respectively. Moreover, vitamin E proves its efficacy in modifying the carcass trait or meat quality of broilers. Therefore, this review article aimed to investigate the forms and inoculation levels vitamin E, the role of this vitamin in the biological process as well as its effect on different poultry production types, carcass quality and hematological parameters.

Keywords: Birds, vitamin E, antioxidant, immunity, carcass quality

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INTRODUCTION

The best and efficient strategy to enhance the production performance, disease resistance and the immune response of poultry is the nutrients modification of poultry farming (Liu et al., 2014). Vitamins are organic substances with a complex nature that are found in a very small amount in feed. They are very important for the performance and body's physiological functions. Vitamins supplied to poultry ration to improve the viability, reduce stressors and enhance the growth performance parameters and antioxidant properties (Attia et al., 2017; Surai, 2020). Vitamins are divided into fat and water soluble types.

Vitamin E is considered as a fat-soluble vitamin that has been discovered in 1920s (Evans and Bishop, 1922). It is crucial for humans and animals and poultry species. The natural form of vitamin E (D α -tocopherol) is the most common and superior form in being retained in serum and tissues (Yang et al., 2009). The inoculation levels of vitamin E in poultry diets is recommended by NRC (NRC, 1994), however, the ideal levels are still controversial due to several factors (Kuttappan et al., 2012). Either deficiency or excess level of vitamin E is associated with severe adverse economic losses in poultry industry.

Vitamin E is necessary for the functions of immune, reproductive, nervous, respiratory, muscular and circulatory systems. Moreover, dietary supplementation of this vitamin is a common in poultry practice to improve both cell-mediated and humoral immunity (Konieczka et al., 2017; Pompeu et al., 2018) as well as counteract the deteriorative effects of oxidative stress (Surai et al., 2019; Pirgozliev et al., 2020). It has been recorded that vitamin E plays an important role for broilers production (Pal, 2017; Pitargue et al., 2019) as well as for layers and breeders production and reproduction (Asl et al., 2018; Nawab et al., 2018; Aamir et al., 2019). The carcass trait and meat quality are also positively affected by inoculation of vitamin E in broiler diet during rearing (Fellenberg and Speisky, 2006; Rey et al., 2015; Pitargue et al., 2019).

Accordingly, the objectives of the current review article were to investigate the forms and inoculation levels vitamin E, the role of this vitamin in the biological process as well as its effect on different poultry production types, carcass quality and hematological parameters.

Forms of vitamin E

Chroman-6-ols collectively tocopherols (tocopherols and tocotrienols) are emerged as vitamin E molecules. However, 8 substances have been detected to have the activity of vitamin including 4 tocopherols (α -, β -, γ - and δ -tocopherols) and 4 tocotrienols (α -, β -, γ - and δ -tocotrienols) (Panda and Cherian, 2014); only tocopherol can meet the requirements of animals to vitamin E. They present in the fat sources of the diet as they absorbed in the intestine after ingestion and transformed into non-esterified form (Colombo et al., 1998). The form α -tocopherol is considered as the most common studied form of vitamin E, while tocotrienols form is still under investigations. Vitamin E is commonly added to poultry diet in the natural form (D α -tocopherol) that being retained in the blood and tissue (Yang et al., 2009). The form of vitamin E determines its bioavailability. Vitamin E is measured in international units by defining one mg of all-rac- α -tocopherol acetate as 1 IU, as D- α -tocopherol has a bioactivity of 1.49 IU (Machlin, 1991).

Recommended vitamin E levels in poultry diets

Several factors as bird's physiological and metabolic functions as well as the environmental stressors can control the actual requirements for vitamin E. The fatty acid contents, pelleting and storage conditions of the diets can mainly affect on the required amount of vitamin E. In addition, genetic variations among birds that lead to differences in vitamin E absorbability and degradation in the intestinal tract. Therefore, the ideal inclusion levels of vitamin E in poultry diets are still controversial (Kuttappan et al., 2012).

Poultry cannot synthesize vitamin E. Birds can obtain their requirements for this vitamin from fat sources and then stored by the body, so there is no need to be consumed daily (Colombo, 2010). Vitamin E is regarded as one of the most expensive vitamins for poultry. Under normal conditions, the standard recommended dose of vitamin E for poultry according to NRC ranges from 5-25 IU/kg of feed (NRC, 1994). To meet the poultry requirements, 10 IU/kg of the ration is also suitable. Studies of Rebolé et al. (2006); Singh et al. (2006); Hashizawa et al. (2013); Habibian et al. (2014) and Ismail et al. (2014) successfully used the basal level of vitamin E as adequate or to marginally exceed the minimum requirements of broilers. However, vitamin E requirements may increase especially in broilers to alleviate the negative effects of high temperature condition that affects on feed efficiency (Guo et al., 2003; Niu et al., 2009). Liu et al. (2014)

suggested that using of vitamin E as 25 times up to NRC requirement to enhance the antibody titer in turkeys. It has been suggested that poultry fed on 100 mg vitamin E/kg diet may prevent vitamin E deficiency (Aamir et al., 2019). The recommended dietary level of vitamin E to maintain bird's fertility differs according to the age, breed and the health of the bird as well as the composition of vitamin E. However, a concentration of 10 mg /kg of diet vitamin E is beneficial to maintain the fertility (Biswas et al., 2007; Hooda et al., 2007; Pekmezci, 2011; Khan et al., 2012b).

Deficiency of vitamin E in poultry

Vitamin E deficiency produces severe adverse economic losses in the poultry industry. There are some interaction of vitamin E and other nutritional elements as polyunsaturated fatty acids (PUFAs), sulfur-containing amino acids and selenium. The deficiency of vitamin E with PUFAs is associated with nutritional encephalomalacia in chicks, while with selenium and sulfur-containing amino acids deficiencies induce exudative diathesis and enzootic muscle dystrophy; respectively (Beck, 2007; Guetchomet et al., 2012; Michalczuk et al., 2016). Reproductive disorders, hock disorders and retardation of growth are also forms of vitamin E deficiency in poultry (Niu et al., 2009). Besides, depletion of lymphocytes (Dietert et al., 1983) and growth depressant effect of thymus, bursa and spleen (Marsh et al., 1986) have been recorded as a result of vitamin E deficiency.

Hypervitaminosis with vitamin E in poultry

High dietary levels of vitamin E resulting in reticulocytosis, decreased hematocrit value, lowered thyroid activity and increased vitamins D and K requirement in chicks (March et al., 1973). Also, supplementation with high levels of tocopherol alleviated hypervitaminosis with vitamin A in chicks (Mc Cuaig and Motzok, 1970; Sklan and Donoghue, 1982). Though, decreases the level of vitamin A in the blood and liver may adversely affect on the bone ash and plasma calcium level of birds (Aburto and Britton, 1998).

The role of vitamin E in the biological process

Antioxidant

Vitamin E plays a major antioxidant role by prevention of lipid peroxidation of PUFAs in plasma membranes of cells and sub-capsular organs (Fusco et al., 2007; Khan et al., 2012a; Surai and Kochish, 2019), therefore protecting cells from free radicals

toxicity (free radicals scavenger) during normal metabolic status and inflammation (Colombo, 2010; Khan, 2011; Rizvi et al., 2014). Vitamin E can mediate free radicals signal transduction and finally modulates the genes expression that are regulated by free radical signaling (Packer and Suzuki, 1993). In addition, it has a negative effect on the production of reactive oxygen species (ROS) which activate unsaturated phospholipids and critical sulfhydryl group oxidation (Traber and Atkinson, 2007). Particularly, phospholipid membranes are more prone to oxidative stress, being positively correlated with the degree of PUFAs. Vitamin E has been classified as a reducing agent for ROS molecules. Nowadays, the bioactive contents of some phytobiotics plant react synergistically with vitamin E to enhance the antioxidant potential of vitamin E (Sonam and Guleria, 2017).

Immunity

It has been documented that vitamin E is essential for the ontogeny of the bird's immune response (Gore and Qureshi, 1997; Silva et al., 2011). Vitamin E significantly increased Sephadex-elicited inflammatory exudate cells as well as the macrophages percentage of chickens in a dose of 10 IU (Gore and Qureshi, 1997). Dietary vitamin E increases the T helper cells, and in turn improves responsiveness to immunologic stimuli (Erf et al., 1998). The dietary level of vitamin E may alter the innate cellular oxidative immunity (Perez-Carbajal et al., 2010). Besides, vitamin E is regarded as immuno-potentiator via delaying the production of ROS in lipid membranes (Pekmezci, 2011; Tufarelli and Laudadio, 2016; Aslet et al., 2018). It has been shown that vitamin E reduces the generation of MDA, decreases the total antioxidant capacity levels in the liver which is consistent with enhancing hepatic α -tocopherol content; resulting in improvement of the antioxidant capacity (inhibit lipid peroxidation) of immunosuppressed broilers (Cheng et al., 2017).

Vitamin E acts on the immune organs either directly or indirectly through the affection of metabolic and endocrine parameters (Gershwin et al., 1985; Marsh et al., 1986; Leshchinsky and Klasing, 2001; Lohakare et al., 2005; Pompeu et al., 2018). As an antioxidant, vitamin E may reduce plasma concentrations of corticosterone (Puthongsiriporn et al., 2001). It can modulate cyclooxygenase and lipoxygenase pathways which reflects on the synthesis of leukotrienes and prostaglandins (Leshchinsky and Klasing, 2001, 2003).

It is not exactly known whether vitamin E directly increases production of antibodies by altering B cells or indirectly through T cells (Lee and Han, 2018).

As vitamin E acts as an antioxidant, it may prevent the oxidation of arachidonic acid involved in the biosynthesis pathway of prostaglandins which has immunosuppressive effects at elevated levels (Sheffy and Schultz, 1979). Modulation of arachidonic acid metabolism via cyclo-oxygenase and lipoxygenase pathways lead to synthesis of prostaglandins and leukotriens, respectively (Leshchinsky and Klasing, 2001). The inhibition of lipid peroxidation and protection of mitochondria and microsomes of the liver against oxidative stress may be another possible immunomodulatory role of vitamin E (Leshchinsky and Klasing, 2001). In addition, Gore and Qureshi (1997) suggested that higher levels of vitamin E may maintain the integrity of macrophage membrane that needed for phagocytosis. Broilers fed on excess vitamin E showed an increase in the phagocytosis process of peritoneal macrophages as a result of increasing the expression of Fc receptors of antibodies on macrophages membranes (Konjufca et al., 2004). Elevated numbers of macrophages displayed an increased ability to opsonize sheep red blood cells (SRRCS). Khan et al. (2014) suggested that vitamin E may affect macrophage cell viability and function by regulating levels of free radicals to maintain normal cell functions.

It has been appeared that vitamin E can boost both cell mediated and humoral immune response to various antigens. It enhances IFN- γ production, induces proliferation of immune cells and modulates chemotaxis and bactericidal properties of polymorphonuclear cells (Boxer, 1986). Quantitatively and qualitatively augments of lymphocyte and monocyte mediated responses have been shown after dietary supplementation with vitamin E. For instance, feeding of broiler chickens with 80 IU/kg or 40 IU/kg of vitamin E following vaccination with infectious bursal disease virus (IBDV) vaccination induced significant increase in peripheral blood CD4⁺ and CD8⁺ T cells (Abdukalykova et al., 2008). Similarly, an increase in lymphocytes populations of the thymus as well as the number of plasma cells in spleen, cecal tonsils and ileum of broiler chickens have been observed following feeding on higher levels of vitamin E (Khan et al., 2008). Dalia et al. (2018) detected that inclusion of vitamin E (100 mg/kg) along with inorganic selenium (0.3 mg/kg) effectively improved the immune system through regulation of some cytokines expression and

immunoglobulin levels.

Vitamin E can benefit the immune response of poultry via anti-inflammatory effects. It has an essential role in balancing cytokine responses, which could be critical in cases of inflammation. It has been found that broiler chickens fed on 220 IU/kg of vitamin E showed significant decrease in the level of IL-6 mRNA in spleen (Kaiser et al., 2012) as vitamin E controls inflammatory responses when pro-inflammatory cytokine production is elevated. Broilers fed on vitamin E supplemented feed (100 mg/kg) and kept under heat stress showed significant decrease in liver expression IL-6 and heat shock protein 70 (Jang et al., 2014). Recent study of Pitargue et al. (2019) revealed that broiler chickens received vitamin E showed decrease in inflammatory (IFN- γ , IL-1 β and IL-6) and anti-inflammatory (IL-4, IL-10 and TGF- β) cytokines in the intestine. Inclusion of arginine in a vitamin E-supplemented diet in broiler chickens enhanced responses to phytohemagglutinin as assessed by the cutaneous basophil hypersensitivity test (Abdukalykova and Ruiz-Feria, 2006).

The findings of Lin and Chang (2006) suggested that moderate supplementation of vitamin E may enhance immune responses to selective antigens in breeders. Supplementation with vitamin E at level of (100IU/kg) to the diet of broilers breeders resulting in enhancing the immune response to bronchitis virus vaccine (Khan et al., 2014). In the same context, broiler chickens supplemented with 200IU/kg of vitamin E and 0.2 mg/kg of selenium and vaccinated with Newcastle disease virus (NDV) vaccine developed significant higher vaccine-specific antibodies when compared with control (Singh et al., 2006). Similarly, Ismail et al. (2014) demonstrated significant increase in the titers of antibodies against NDV and avian influenza disease virus in the plasma of vitamin E supplemented broiler chickens (300 mg/ kg diet). Significant elevation of antibody titers was observed in broilers after primary and secondary immunization with SRBCS and feeding on vitamin E (Niu et al., 2009; Habibian et al., 2014). Chickens infected with IBDV and fed on vitamin E (178 IU/kg) showed reduced mortalities and high body weight gain (McIlroy et al., 1993).

Broiler chickens received a diet containing 100 IU/kg of vitamin E and infested with *E. tenella* oocysts revealed significant resistance indicated by decreasing in mortalities and increasing in body weight gain (Colnago et al., 1984). Perez-Carbajal et al. (2010)

demonstrated that supplementation of chickens with vitamin E and arginine improved the phagocytic activity of heterophils and monocytes. Similar effects were also seen when chickens were challenged with *Salmonella enterica* serovar Typhimurium (Liu et al., 2014). Recently, Liu et al. (2019) assessed the effects of feeding laying hens on 30 IU/kg of vitamin E on antibody levels, pro-inflammatory cytokines and mortalities after challenge with *Salmonella enteritidis*. The results proved increasing IgA, IgM and IgY levels, while decreasing in IL-1 β , IL-6 and mortalities at 2 weeks post-challenge.

Feeding of vitamin E to breeder hens can passively transferred antibody-mediated response against diseases in their progeny. When broiler breeder hens supplemented with vitamin E (150 IU/kg) or (450 IU/kg) in feed before inoculation with *Brucella abortus* antigens, their chicks that received more vitamin E showed higher antigen-specific antibody titers (Jackson et al., 1978). Supplementation of breeders on 0.03% total vitamin E in their diet for 3 weeks prior to immunization with Newcastle disease virus vaccine induce high antibody levels in their progeny at 1 and 7 days old as compared with controls (Haq et al., 1996). Inoculation of 10 mg of vitamin E in embryonated chicken eggs increased cellular and humoral immunity in newly hatched chickens with (Gore and Qureshi, 1997). In addition, these chicks showed higher phagocytic activity when inoculated with sheep red blood cells at 7 days of age as well as higher antibody titers to SRBC were also detected at 14 and 21 days of age. The same research also tested the effect of inoculating three doses of vitamin E into embryonated turkey eggs 3 days prior hatching. The results revealed that inoculation of 20 and 30 IU of vitamin E resulting in significant reduction of hatchability, while 10 IU induced slight higher hatchability. Furthermore, 7 days old turkey poults showed higher level of IgM antibodies against sheep red blood cells than controls at 7 and 14 days post-inoculation. The number of phagocytic macrophages at 7 weeks post hatch were also significantly higher in the group inoculated with 10 IU of vitamin E.

The effect of vitamin E supplementation in poultry production

Broilers

Improvement in feed efficiency has been recorded in broilers after feeding on vitamin E at levels of 60, 90 and 120 IU/kg of diet (Serman et al., 1992). Addi-

tion of both vitamins E and C at levels of 150 mg/kg and 200 mg/kg ration, respectively enhanced chicken's growth and immune response to vaccination (Rajmane and Ranade, 1994). Moreover, improvement in broilers feed efficiency has been observed after addition of 75 ppm of vitamin E/kg in diet (Aravind et al., 2001). Villar-Patino et al. (2002) recorded an enhancement of the live body weight of broilers supplemented by 75 mg of vitamin E/kg of diet.

Erf et al. (1998) reported that inoculation of vitamin E at levels beyond those needed to enhance the optimal growth is efficient for increasing the immuno-competence of growing broilers. It has been documented that supplementation of vitamin E induced significant increase in the relative weight of spleen which indirectly has a benefit for the broilers' immune system (BasmacioğluMalayoğlu et al., 2009). Konieczka et al. (2017) detected an increase in the relative weight of bursa Fabricius of chickens supplemented with dietary 300 IU/kg vitamin E as compared to those fed diets containing 50 IU/kg. Moreover, vitamin E at 100 and 200 mg/kg of the diet could improve the performances and have immune potentiating effect in broiler chickens (Desoky, 2018). Vitamin E has a significant role in enhancing the health conditions through the positive influence on both humoral and cell-mediated immune response of birds (Zhao et al., 2011; Lu et al., 2014; Rizvi et al., 2014). Moreover, it can induce protective immunity in broiler chickens through amelioration of the immuno-suppressive effect of lipopolysaccharide (Zhang et al., 2010), *Escherichia coli*, *Eimeriatenella*, T2 toxins (Jaradat et al., 2006), as well as heat stress (Niu et al., 2009).

It has been documented that heat stress increases the serum and liver concentrations of malondialdehyde (MDA), while vitamin E decreases the production of MDA in the liver by acting against lipid peroxidation and cell damage (McDowell, 2012) and results in the enhancement of the bird's performance (Sahin and Kucuk, 2001; Sahin et al., 2001). Several reports showed the positive effect of vitamin E supplementation alone or with other elements on broiler performance under heat stress condition. Both vitamin E and vitamin C at levels of 250 mg/kg of the diet induced the highest productive performance of Japanese quails reared under heat stress (Sahin and Kucuk 2001; Sahin et al., 2003). Habibian et al. (2014) confirmed that heat stressed broiler chickens supplemented with combined levels of vitamin E and selenium at 250 mg/kg and 0.5 mg/kg, respectively

showed an improvement of both health and immune response to sheep red blood cells (SRBCs). Broiler chickens fed on dietary vitamin E at 30-50mg/kg under heat stress pressure showed reduced lipid peroxidation that can be detected by reduced levels of MDA (Dalólio et al., 2015). Furthermore, dietary concentration of zinc at 30-60 mg/kg has synergistic positive action with vitamin E on the productive performance of broilers under heat stress climate (Kim et al., 1998; Salgueiro et al., 2000).

Other literatures revealed no effect of vitamin E on broiler performance. Sosnowka-Czajka et al. (2005) found that dietary supplementation of broilers with both 40 mg/kg of vitamin C and 70 mg/kg of vitamin E failed to increase the resistance of birds to high temperature stressor. This result may be due to low doses of the vitamins or presence of factor interfere with the vitamins bioavailability. Feeding of dihydroquercetin (antioxidant) or vitamin E improved different parameters of antioxidant status of broiler chickens, although it did not affect growth performance parameters and energy or nutrient availability (Pirgozliev et al., 2020).

Layers

Laying hens supplemented by 6% semi-refined sunflower oil and 150 mg/kg vitamin E showed significant increase in egg production performance (Narimany-Rad et al., 2011). A concentration of 60 IU vitamin E /kg feed revealed an increase in egg production, yolk and albumin weights, and vitelline membrane strength of layer chickens (Parolini et al., 2015). In addition, vitamin E at levels 125-300 mg/kg has been found to minimize the egg production losses, eggshell density and feed efficiency (Cherian, 2015). Dietary supplementation of 125 to 300 mg vitamin E /kg feed improved the feed efficiency rate, egg production and egg shell thickness of layers (Karadas et al., 2017).

It has been observed that addition of vitamin E to the diets of layer hens appeared to be beneficial especially during the heat stress, probably, due to its concurrent function as fertility factor (Bollingier-Lee et al., 1999; Sahin et al., 2002a; Attia et al., 2016). Numerous studies have investigated the beneficial effects of vitamin E supplementation in laying hens under heat stressed conditions. For example, Kirunda and Scheideler (2001) found that vitamin E supplementation in the diet of heat stressed hens was able to alleviate egg quality deterioration. Ciftci et al. (2005) found that vitamin E can improve the egg quantity

and quality of laying chickens reared under heat stress conditions. It has been demonstrated that vitamin E at 250 mg/ fed of layer hens may decrease the harmful stress effects of high temperature (Chung et al., 2005). Besides, dietary concentration of zinc at 30-60 mg/kg has synergistic positive action with vitamin E on the health and egg production of laying hens (Onderci et al., 2003; Sahin and Kucuk, 2003; Kucuk et al., 2008). Sahin and Kucuk (2001) observed a greatest performance of Japanese quails after supplementation with a combined treatment with vitamin C (200 mg) and vitamin E (250 mg) under chronic heat stress. Also, supplementation with 150 mg vitamin C and/or 150 mg vitamin E to the diet improved the production performance in heat stressed layer chickens (Joachim Ajakaiye et al., 2011). Dietary vitamin E and vitamin C at levels of 65 IU/kg and 1, 000 ppm; respectively enhanced the *in vitro* lymphocyte proliferations of layer hens under bad environmental conditions (Jiang et al., 2013).

The role of vitamin E in improving the egg production under heat stress may be through the protection of liver from lipid peroxidation and damage of cell membrane that resulted in increasing in plasma egg yolk precursors as very low density lipoprotein and vitellogenin (Bollingier-Lee et al., 1999). Addition of vitamin E to diets containing high levels of PUFAs may prevent feed oxidation as well as may contribute to egg formation as these evidenced by increasing in the egg/bird/day and improving the feed intake and efficiency. Moreover, vitamin E protects the tissue from lipid peroxidation due to production of ROS and consequently affects the egg quality in layers (Lin et al., 2004; Khan et al., 2017).

Breeders

There are several factors that have a great hazardous effect on the semen and sperm quality (Rengarajet al., 2015; Nawabet al., 2018). Antioxidant feed supplementation reduces these effects by lipid peroxidation (Richard et al., 2008). As a result of neutralization of free radicals and inhibition of lipids membranes oxidation, vitamin E is regarded as chain-breaking antioxidant (Raederstorff et al., 2015). Vitamin E reduces the production of ROS molecules in the cells at their initial phase with destruction of thousands of PUFAs molecules (Anwar et al., 2016). It has been found that ROS damages hydroxyl radical, superoxide anion radical, singlet oxygen and hydrogen peroxide that produced during aerobic cellular metabolism (Anwar et al., 2016). Nevertheless, these oxidative

radicals induced destruction of healthy cells if they are not eliminated. Thus, it is necessary to add vitamin E to poultry ration to increase antioxidant metabolites in sperms and semen and consequently helps in improving the quality and motility of sperms (Khan et al., 2017). Vitamin E reduces the defects in the DNA of sperm through decreasing free radicals production and consequently increase the semen volume, sperm motility and sperm capacity in fertilizing eggs (Anwar et al., 2016). Biswas et al. (2009) demonstrated that birds supplemented with high doses of vitamin E (100 mg/kg diet) showed good quality semen and spermatozoa in comparison with those received 10 mg/kg of the vitamin. At a level of 20 mg/kg diet of breeder chickens, vitamin E significantly enhanced the immune response of SRBCs in comparison with levels of 0, 80 and 160 mg/kg diet (Lin and Chang, 2006).

Carcass trait

Lipid oxidation is very important process by which deterioration of meat products can occur as it is initiated at the membrane level in the intracellular phospholipid fractions (Buckley et al., 1995; Cortinas et al., 2005). Generally, supplementing birds with high levels of antioxidants in the diets enhances the oxidative stability, sensory quality, shelf life and consequently acceptability of meat (Buckley and Morrissey, 1992). It has been demonstrated that the peroxidation process begins just after slaughter, so the rate of meat spoilage is dependent on the concentration of vitamin E in the tissue (Morrissey et al., 1994). Vitamin E, in the form of α tocopheryl, is regarded as the major antioxidant defense and the lipid-soluble antioxidant that delays and breaks the lipid peroxidation chain in cell membranes, prevents hydroperoxides formation (Halliwell, 1987) and improves the quality of poultry meat (Pompeu et al., 2018). The level of dietary α -tocopheryl acetate in the poultry feed determines its level in the muscle and consequently the oxidative stability of meat (Carreras et al., 2004; Goñi et al., 2007). Previous studies of Gao et al. (2010) and Rey et al. (2015) have suggested that α tocopherol retained in serum and tissues and improved the meat quality of broiler chickens. Increasing the levels of α tocopherol levels in poultry diets significantly improved the feed conversion rate, average body weights, and net income/bird (Kennedy et al., 1992). In addition, the higher levels of α tocopherol resulting in high tissue concentrations, improvement of the cells membranes structure as well as an increase the oxidative stability

of meat and meat products (Bartov and Frigg, 1992; Sheehy et al., 1993). It has been found that addition of α tocopherol to turkey's ration can improve meat oxidative stability leading to improving the flavour and colour (Sheldon et al., 1997). Supplementing chickens with 20 mg vitamin E/kg diet doubled the storage time in freezer, however 40 mg vitamin E/kg diet extended storage time by one day in refrigerated broiler carcasses (Coetzee and Hoffman, 2001). The MDA production in the broilers muscles decreased by addition of vitamin E to the ration, which reflects on the lipid peroxidation during the storage of chicken meat (Yesilbag et al., 2011). Brandon et al. (1993) suggested that feeding on 200 mg α tocopheryl acetate/kg of ration (i.e. 20 times higher than the NRC requirement) for at least 4-5 weeks, is essential to obtain the protective benefit of the vitamin in processed meat. However, Nobakht (2012) demonstrated that inclusion of broilers fat until 6% has no adverse effects on performance and carcass percent while, supplementing diet with 150 mg/kg of vitamin E is not recommended.

Hematology

Vitamin E significantly protected erythrocytes against high levels of hydrogen peroxide (Calabrese et al., 1985). In addition, vitamin E prevents oxidation of unsaturated fatty acids as linoleic acid on the membranes of erythrocytes (Bast et al., 1991) so, the deficiency of this vitamin increases erythrocytes' hemolysis (Levander et al., 1977). The effect of different dietary levels of vitamin E (100, 200 and 300) ppm on erythrocyte osmotic fragility and some biochemical parameters were studied in broiler chickens for 7 weeks observation period and the results showed significant decrease in erythrocyte osmotic fragility (Arslan et al., 2001).

Excessive supplementation of vitamin E decreases the plasma cholesterol (Bell, 1971; Clegg et al., 1976) and triglyceride levels and consequently inhibits atherosclerosis in poultry (Donaldson, 1982; Smith et al., 1989). Francini et al. (1988) demonstrated that the addition of vitamin E at level of 325 ppm in the diet of broilers resulting in decrease in cholesterol and triglyceride levels till 49 days of age. Decreasing the level of cholesterol was also found in turkeys fed with vitamin E on the 42nd day (Francini et al., 1990). Ismail et al. (2014) found no effects on T4, total lipids, total cholesterol and high density lipoprotein cholesterol after inoculation of high levels vitamin E (200, 300 and 400 mg/kg diet) in the diets of broiler

chickens. However, plasma level of T3 increased significantly in response to high level of vitamin E (400 mg/kg diet). Serum concentration levels of T3 and T4 were higher in birds treated with dietary vitamin E (Sahin et al., 2001, 2002b).

It has been declared that dietary supplementation of birds with vitamin E in high levels increased alkaline phosphatase (ALP) levels. Arslan et al. (2001) demonstrated statistical significant decrease in ALP level by the 7th week after treatment of broilers with 100, 200 and 300 ppm of vitamin E. In the same line, no significant difference was also found in the plasma ALP levels of turkeys supplemented with 30, 90, 180, 360 ppm of vitamin E/kg of ration, however, an increase in plasma ALP levels were increased with increasing the bird's age (Francini et al., 1990).

In addition, the total protein, calcium (Ca), phosphorus (P), aspartate aminotransferase (AST) or alanin aminotransferase (ALT) was not affected by the treatment with vitamin E by the 5th and 7th weeks of age (Arslan et al., 2001). In the same context, no significant differences were found in Ca and P in broilers treatment with 100 and 200 mg/kg of vitamin E (Desoky, 2018). One hundred, day old broilers fed on 25 and 10, 000 IU of vitamin E/kg of the diet showed decrease in plasma P and Ca levels (Murphy et al., 1981). But Francini et al. (1988) found an increase in the levels of ALP, Ca and P in birds treated with excess vitamin E and proposed this result to the osteoblastic activity (Francini et al., 1988).

Although AST level has been increased with the increase in the dietary level of vitamin E in turkey

poult, but decreased in older birds (140 days old) (Francini et al., 1990). Desoky (2018) observed significant decline in AST and ALT activities in the group of broilers fed with vitamin E at 200 mg/kg.

Dietary supplementation with vitamin E (250 mg/kg) for Japanese quails under heat stress induce significant increase in lymphocytes (L) numbers and white blood cells counts, whereas, heterophils (H) numbers and H/L ratio was decreased (Abdel Maksoud, 1999; Ipek et al., 2007).

It has been shown that broilers fed on vitamin E at levels of 100 and 200 mg/kg had significant increase in hemoglobin, total proteins and albumin, significant decrease in the level of glucose and while no significant differences were found in globulin (Desoky, 2018)

CONCLUSION

As can be seen, vitamins E has measurable effects as an efficient antioxidant and immuno-stimulant agent. Addition of vitamin E in poultry diet is essential for growth and health parameters as well as maintenance and enhancement of immune system function in broilers. In addition, supplementing layers and breeders with vitamin E has positive effects on the quantity and quality of eggs as well as fertility and hatchability. Improvement of carcass trait and blood parameters are also the other beneficial aspects of vitamin E.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest.

REFERENCES

- Aamir N, Shuyan T, Wenchoo L, Jiang W, Fahar I, Kai K, Muhammad WG, Muhammad WB, Guanghui L, Chenyu S, Yi Z, Mei X, Lilong A (2019) Vitamin E and fertility in the poultry birds; deficiency of vitamin E and its hazardous effects. *Approaches Poult Dairy VetSci* 6: 501-506.
- Abdel Maksoud AM (1999) Influence of ascorbic acid supplementation on some hormonal and hematological responses in Japanese quail exposed to acute heat stress. *Egypt J Nutr Feeds* 2: 729-742.
- Abdukalykova ST, Ruiz-Feria CA (2006). Arginine and vitamin E improve the cellular and humoral immune response of broiler chickens. *Int J PoultSci* 5: 121-127.
- Abdukalykova ST, Zhao X, Ruiz-Feria CA (2008) Arginine and vitamin E modulate the subpopulations of T lymphocytes in broiler chickens. *PoultSci* 87: 50-55.
- Aburto A, Britton WM (1998) Effects and interactions of dietary levels of vitamins A and E and cholecalciferol in broiler chickens. *PoultSci* 77: 666-673.
- Anwar H, Iftikhar A, Sohail MU, Hussain G, Faisal MN, Khan J, Bukhari SA, Iqbal Z (2016) Efficacy of various post-moult feed supplementations in poultry: an empirical review. *World's PoultSci J* 72: 619-627.
- Aravind KL, Gowda CV, ManjunathBP, RajendraAY, GanpuleSP (2001) Influence of dietary level of selenium and vitamin E on growth, immunity and carcass traits in broiler chickens. *Ind J PoultSci* 36: 58-62.
- Arslan M, Özcan M, Matur E, Çöteloglu, Ergül E (2001) The effects of vitamin E on some blood parameters in broilers. *Turk J Vet AnimSci* 25: 711-716.
- Asl SR, Shariatmadari F, Sharafi M, Torshizi KMA, Shahverdi A (2018) Dietary fish oil supplemented with vitamin E improves quality indicators of rooster cold-stored semen through reducing lipid peroxidation. *Cryobiology* 84: 15-19.
- Attia YA, Al-HarathiMA, ElShafeyAS, Rehab YA, Kyun Kim W (2017) Enhancing tolerance of broiler chickens to heat stress by supplementation with vitamin E, vitamin C and/ or probiotics. *Ann AnimSci* 17: 1155-1169.
- Attia YA, Abd El-Hamid AE, Abedalla AA, Berika MA, Al-Harathi MA, Kucuk O, Sahin K, Abou-Shehema BM (2016) Laying performance, digestibility and plasma hormones in laying hens exposed to chronic heat stress as affected by betaine, vitamin C, and/or vitamin E supplementation. *SpringerPlus* 5: 1619.
- Bartov I, Frigg M (1992) Effect of high concentrations of dietary vitamin E during various age periods on performance, plasma vitamin E and meat stability of broiler chicks at 7 weeks of age. *Br Poultry Sci* 33: 393-402.
- Basmacioğlu Malayoğlu H, Özkan S, Koçtürk S, Oktay G, Ergül M (2009) Dietary vitamin E (α -tocopheryl acetate) and organic selenium supplementation: performance and antioxidant status of broilers fed n-3 PUFA-enriched feeds. *S Afr J AnimSci* 39: 274-285.
- Bast A, Haenen GR, Doelman, CJA (1991) Oxidants and antioxidants: State of the art. *Am J Med* 91: 1-10.
- Beck MA (2007) Selenium and vitamin E status: Impact on viral pathogenicity. *J Nutr* 137: 1338-1340.
- Bell DJ (1971) Plasma enzyme in physiology and biochemistry of the domestic fowl. II ed, 964-971.
- Biswas A, Mohan J, Sastry KV (2009) Effect of higher dietary vitamin E concentrations on physical and biochemical characteristics of semen in Kadaknath cockerels. *Br PoultSci* 50: 733-738.
- Biswas A, Mohan J, Sastry KV, Tyagi JS (2007). Effect of dietary vitamin E on the cloacal gland, foam and semen characteristics of male Japanese quail. *Theriogenology* 67: 259-263.
- Bollingier-Lee S, Williams PEV, Whitehead CC (1999) Optimal dietary concentration of vitamin E for alleviating the effect of heat stress on egg production in laying hens. *Br PoultSci* 40:102-107.
- Boxer LA (1986) Regulation of phagocyte function by alpha-tocopherol. *Proc NutrSoc* 45: 333-338.
- Brandon S, Morrissey PA, Buckley DJ, Frigg M (1993) Influence of dietary a-tocopherol acetate on the oxidative stability of chicken tissues. In: *Proceedings of the 11th European Symposium on the Quality of Poultry Meat*, (Eds. P. Colin, J. Culioli and F. H. Ricard), pp. 397-403.
- Buckley DJ, Morrissey PA (1992) Animal production highlights. In: *Vitamin E and Meat Quality*, Hoffmann-La Roche Ltd., Basel, Switzerland, pp. 24-27.
- Buckley DJ, Morrissey PA, Gray JI (1995) Influence of dietary vitamin E on the oxidative stability and quality of pig meat. *J AnimSci* 73:3122-3130.
- Calabrese EJ, Victor J, Stoddard MA (1985) Influence of dietary vitamin E on susceptibility to ozone exposure. *Bull Environ ContamToxicol* 34: 417-422.
- Carreras I, Guerrero L, Guardia MD, Esteve-GarcíaE, Garcia JA, RegueiroJA, SárragaC (2004) Vitamin E levels, thiobarbituric acid test and sensory evaluation of breast muscles from broilers fed α -tocopheryl acetate and β -carotene-supplemented diets. *J AnimSci Food Agric* 84: 313-317.
- Cheng K, Song ZH, Zheng XC, Zhang H, Zhang JF, Zhang LL, Zhou YM, Wang T (2017) Effects of dietary vitamin E type on the growth performance and antioxidant capacity in cyclophosphamide immunosuppressed broilers. *PoultSci* 96:1159-1166.
- Cherian G (2015) Nutrition and metabolism in poultry: role of lipids in early diet. *J AnimSciBiotechnol* 6: 28.
- Chung MK, Choi JH, Chung YK, Chee KM (2005) Effects of dietary vitamins C and E on egg shell quality of broiler breeder hens exposed to heat stress. *Asian-Aust J AnimSci* 18: 545-551.
- Ciftci M, NihatErtas O, Guler T (2005) Effects of vitamin E and vitamin C dietary supplementation on egg production and egg quality of laying hens exposed to a chronic heat stress. *Revue Med Vet* 156:107-111.
- Clegg RE, Klopfenstein CF, Klopfenstein WE (1976) Effects of diethylstilbestrol, ascorbic acid and vitamin E on serum lipid patterns. *PoultSci* 55: 1104-1111.
- Coetzee GJM, Hoffman LC (2001) Effect of dietary vitamin E on the performance of broilers and quality of broiler meat during refrigerated and frozen storage. *S Afr J AnimSci* 31:158-173.
- Colnago GL, Jensen LS, Long PL (1984) Effect of selenium and vitamin E on the 744 development of immunity to coccidiosis in chickens. *PoultSci* 63: 1136-1143.
- Colombo ML (2010) An update on vitamin E, tocopherol and tocotrienol-perspectives. *Molecules* 15: 2103-2113.
- Colombo ML, Corsini A, Mossa A, Sala L, Stanca M (1998) Extraction of the fat-soluble vitamin E from *Hordeum vulgare* L. fruits by supercritical fluid carbon dioxide. *Phytochem Anal* 9: 192-195.
- CortinasL, BarroetaA, VillaverdeC, GalobartJ, Guardiola F, BaucellsMD (2005) Influence of the dietary polyunsaturation level on chicken meat quality: lipid oxidation. *PoultSci* 84: 48-55.
- Dalia AM, Loh TC, Sazili AQ, Jahromi MF, Samsudin AA (2018) Effects of vitamin E, inorganic selenium, bacterial organic selenium, and their combinations on immunity response in broiler chickens. *BMC Vet Res* 14: 249.
- Dalólio FS, Albino LFT, Lima HJD, Silva JN, Moreira J (2015) Heat stress and vitamin E in diets for broilers as a mitigating measure. *ActaSciAnimSci* 37: 419-427.
- Desoky AA (2018) Growth performance and immune response of broiler chickens reared under high stocking density and vitamin E supplementation. *Egypt PoultSci* 38: 607-620.
- Dietert RR, Marsh JA, Combs JR (1983) Influence of dietary selenium and vitamin E on the activity of chicken blood phagocytes. *PoultSci* 62: 1412.
- Donaldson WE (1982) Atherosclerosis in cholesterol fed Japanese quail: Evidence for amelioration by dietary vitamin E. *PoultSci* 61: 2097-2102.
- Erf GF, BottjeWG, BersiTK, HeadrickMD, FrittsCA (1998) Effects of dietary vitamin E on the immune system in broilers: altered proportions of CD4 T cells in the thymus and spleen. *PoultSci* 77: 529-537.
- Evans HM, Bishop KS (1922) On the existence of a hitherto unrecognized dietary factor essential for reproduction. *Science* 56: 650-651.
- Fellenberg MA, Speisky H (2006) Antioxidants: their effects on broiler oxidative stress and its meat oxidative stability. *WorldsPoultSci J* 62:

- 53-70.
- Franchini A, Meluzzi A, Bertuzzi S, Giordani G (1988) High doses of vitamin E in the broilers diets. *Arch Gefügelk* 52: 12-16.
- Franchini, A, Giordani G, Meluzzi A, Manfreda G (1990) High doses of vitamin E in the turkey diet. *Arch Gefügelk* 54: 6-10.
- Fusco D, Colloca G, Monaco MRL, Cesari M (2007) Effects of antioxidant supplementation on the aging process. *ClinInterv Aging* 2: 377-387.
- Gao, J, Lin H, Wang XJ, Song ZG, Jiao HC (2010) Vitamin E supplementation alleviates the oxidative stress induced by dexamethasone treatment and improves meat quality in broiler chickens. *PoultSci* 89:318-327.
- Gershwin M, Beach R, Hurley L (1985) The potent impact of nutritional factors on immune response. Pages 1-7 in: *Nutrition and Immunity*. Academic Press, New York, NY.
- Goñi I, BrenesA, Centeno C, ViverosA, Saura-CalixtoF, ReboléA, Arijal, Estevez R (2007) Effect of dietary grape pomace and vitamin E on growth Performance, nutrient digestibility, and susceptibility to meat lipid oxidation in chickens. *PoultSci* 86:508-516.
- Gore AB, Qureshi V (1997) Enhancement of humoral and cellular immunity by vitamin E after embryonic exposure. *PoultSci* 76: 984-991.
- Guetchom B, Venne D, Chénier S, Chorfi Y (2012) Effect of extra dietary vitamin E on preventing nutritional myopathy in broiler chickens. *J ApplPoult Res* 21: 548-555.
- Guo Y, Zhang G, Yuan J, Nie W (2003) Effects of source and level of magnesium and vitamin E on prevention of hepatic peroxidation and oxidative deterioration of broiler meat. *Anim Feed SciTechnol* 107:143-150.
- Habibian M, Ghazi S, Moeini MM, Abdolmohammadi A (2014) Effects of dietary selenium and vitamin E on immune response and biological blood parameters of broilers reared under thermoneutral or heat stress conditions. *Int J Biometeorol* 58:741-752.
- HalliwellB (1987) Oxidants and disease: some new concepts. *FASEB J* 1: 358-364.
- Hashizawa Y, Kubota M, Kadowaki M, Fujimura S (2013) Effect of dietary vitamin E on broiler meat qualities, color, water-holding capacity and shear force value, under heat stress conditions. *AnimSci J* 84: 732-736.
- Haq A, Bailey CA, China A (1996) Effect of carotene, canthaxanthin, lutein, and vitamin E on neonatal immunity of chicks when supplemented in the broiler breeder diets. *PoultSci* 75: 1092-1097.
- Hooda S, Tyagi PK, Mohan J, Mandal AB, Elangovan AV, Pramod KT (2007) Effects of supplemental vitamin E in diet of Japanese quail on male reproduction, fertility and hatchability. *Br PoultSci* 48: 104-110.
- Ipek H, Avci M., Yerturk M, Iriadam M, Aydılek N (2007) Effects of ascorbic acid and vitamin E on performance and hematological parameters of Japanese quails under high ambient temperature in Sanlıurfa. *Arch Gefügelk* 71:130- 134.
- Ismail FSA, El-GogaryMr, El-Nadi MI (2014) Influence of vitamin E supplementation and stocking density on performance, thyroid status, some blood parameters, immunity and antioxidant status in broiler chickens. *Asian J Anim VetAdv* 9:702-712.
- Jackson DW, Law GRJ, Nockels CE (1978) Maternal vitamin E alters passively acquired immunity of chicks. *PoultSci* 57: 70-73.
- Jang IS, Ko YH, Moon YS, Sohn SH (2014) Effects of vitamin C or E on the pro-inflammatory cytokines, heat shock protein and antioxidant status in broiler chicks under summer conditions. *Asian-Aust J AnimSci* 27: 749-756.
- Jaradat ZW, Vil' aB, Marquardt RR (2006) Adverse effects of T-2 toxin on chicken lymphocytes blastogenesis and its protection with Vitamin E. *Toxicology* 225:90-96.
- Jiang W, Zhang L, Shan A (2013) The effect of vitamin E on laying performance and egg quality in laying hens fed corn dried distillers grains with solubles. *PoultSci* 92: 2956-2964.
- Joachim Ajakaiye J, Alcides Pérez B, Angel Mollineda T (2011). Effects of high temperature on production in layer chickens supplemented with vitamins C and E. *Rev MVZ Córdoba* 16:2283-2291
- Kaiser MG, Block SS, Ciraci C, Fang W, Sifri M, Lamont SJ (2012). Effects of dietary vitamin E type and level on lipopolysaccharide-induced cytokine mRNA expression in broiler chicks. *PoultSci* 91: 1893-1898.
- Karadas F, Møller AP, Karageçili MR (2017) A comparison of fat-soluble antioxidants in wild and farm-reared chukar partridges (*Alectoris chukar*). *Comp BiochemPhysiolMolIntegrPhysiol* 208: 89-94.
- Kennedy DG, Rice DA, Bruce EA, Goodall EA, McIlroy SG (1992) Economic effects of increased vitamin E supplementation of broiler diets on commercial broiler production. *Br PoultSci* 33: 1015-1023.
- Khan RU (2011) Antioxidants and poultry semen quality. *World's PoultSci J* 67: 297-308.
- Khan MZ, Akter SH, Islam MN, Karim MR, Islam MR, Kon Y (2008) The effect of selenium and vitamin E on the lymphocytes and immunoglobulin-containing plasma cells in the lymphoid organ and mucosa-associated lymphatic tissues of broiler chickens. *AnatHistolEmbryol* 37: 52-59.
- Khan RU, Rahman ZU, NikousefatZ, JavdaniM, TufarelliV, Dario C, Selvaggi, M, LaudadioV (2012a) Immunomodulating effects of vitamin E in broilers. *World's PoultSci J* 68:31-40.
- Khan RU, Rahman ZU, Javed I, Muhammad F (2012b) Effect of vitamins, probiotics and protein on semen traits in post-molt male broiler breeders. *AnimReprodSci* 135: 85-90.
- Khan RU, Rahman ZU, Javed I, Muhammad F (2014) Effect of vitamins, protein level and probiotics on immune response of moulted male broiler breeders. *J AnimPhysiolAnimNutr* 98: 620-627.
- Khan SA, Khan A, Khan SA, Beg MA, Ali A, Damanhourig (2017) Comparative study of fatty-acid composition of table eggs from the jeddah food market and effect of value addition in omega-3 bio-fortified eggs. *Saudi J BiolSci* 24: 929-935.
- Kim ES, Noh SK, Koo SI (1998) Marginal zinc deficiency lowers the lymphatic absorption of α -tocopherol in rats. *J Nutr* 128: 265-270.
- Kirunda D, Scheideler S (2001) The efficacy of vitamin E (DL- α -tocopheryl acetate) supplementation in hen diets to alleviate egg quality deterioration associated with high temperature exposure. *PoultSci* 80: 1378-1383.
- Koniczka P, Barszcz M, Chmielewska N, Cieślak M, Szlis M, Smulikowska S (2017) Interactive effects of dietary lipids and vitamin E level on performance, blood eicosanoids, and response to mitogen stimulation in broiler chickens of different ages. *PoultSci* 96: 359-369.
- Konjufca VK, Bottje WG, Bersi TK, Erf GF (2004) Influence of dietary vitamin E on phagocytic functions of macrophages in broilers. *PoultSci* 83: 1530-1534.
- Kucuk O, Kahraman A, Kurt I, Yildiz N, Onmaz A (2008) A combination of zinc and pyridoxine supplementation to the diet of laying hens improves performance and egg quality. *BiolTrace Elem Res* 126: 165-175.
- Kuttappan VA, Goodgame SD, Bradley CD, MauromoustakosA, Hargis BM, WaldroupPW, Owens CM (2012) Effect of different levels of dietary vitamin E (dl- α -tocopherol acetate) on the occurrence of various degrees of white striping on broiler breast fillets. *PoultSci* 91: 3230-3235.
- Lee GY, Han SN (2018) The role of vitamin E in immunity. *Nutrients* 10: 1614.
- Leshchinsky TV, Klasing KC (2001) Relationship between the level of dietary vitamin E and the immune response of broiler chickens. *PoultSci* 80: 1590-1599.
- Leshchinsky TV, Klasing KC (2003) Profile of chicken cytokines induced by lipopolysaccharide is modulated by dietary alpha-tocopheryl acetate. *PoultSci* 82 (8) : 1266-1273.
- Levander OA, Morris VC, Ferretti RJ (1977) Comparative effects of selenium and vitamin E in lead-poisoned rats. *J Nutr* 107: 378-382.
- Lin YF, Chang SJ (2006) Effect of dietary vitamin E on growth performance and immune response of breeder chickens. *Asian-Aust J AnimSci* 19: 884-891.
- Lin YF, Chang SJ, Hsu AL (2004) Effects of supplemental vitamin E during the laying period on the reproductive performance of Taiwan native chickens. *Br PoultSci* 45: 807-814.
- Liu X, Byrd JA, Farnell M, Feria RCA (2014) Arginine and vitamin E improve the immune response after a Salmonella challenge in broiler chicks. *PoultSci* 93: 882-890.
- Liu YJ, Zhao LH, Mosenthin R, Zhang JY, Ji C, Ma QG (2019) Protective effect of vitamin E on laying performance, antioxidant capacity, and immunity in laying hens challenged with Salmonella enteritidis. *PoultSci* 98: 5847-5854.

- Lohakare JD, Choi JY, Kim JK, Yong JS, Shim YH, Hahn TW, ChaeBJ (2005) Effects of dietary combinations of vitamin A, E and methionine on growth performance, meat quality and immunity in commercial broilers. *Asian-Aust J AnimSci* 18: 516-523.
- Lu T, Harper AF, Zhao J, Dalloul RA (2014) Effects of a dietary antioxidant blend and vitamin E on growth performance, oxidative status, and meat quality in broiler chickens fed a diet high in oxidants. *PoultSci* 93: 1649-1657.
- Machlin LJ (1991) Vitamin E. Pages 99-144 in *Handbook of Vitamins*. L. J. Machlin, ed. Marcel Dekker, New York, NY.
- March BE, Wong E, Seier L, Sim J, Biely J (1973) Hypervitaminosis E in the chick. *JNutr* 103: 371-377.
- Marsh JA, Combs JR, Whitacre ME, Dietert RR (1986) Effect of selenium and vitamin E dietary deficiencies on chick lymphoid organ development. *ProcSociExperimBiolMed* 182: 425-436.
- McCuaig LW, Motzok I (1970) Excessive dietary vitamin E: Its alleviation of hypervitaminosis A and lack of toxicity. *PoultSci* 49:1050-1052.
- McDowell LR (2012) *Vitamins in Animal Nutrition: Comparative Aspects to Human Nutrition*; Elsevier: Amsterdam, The Netherlands.
- McIlroy SG, Goodall EA, Rice DA, McNulty MS, Kennedy DG (1993) Improved performance in commercial broiler flocks with subclinical infectious bursal disease when fed diets containing increased concentrations of vitamin E. *Avian Pathol* 22: 81-94.
- Michalczuk M, Damaziak K, Niemiec J (2016) Dietary vitamin E supplementation on cholesterol, vitamin E content, and fatty acid profile in chicken muscles. *Can J AnimSci* 120: 114-120.
- Morrissey PA, Buckley DJ, Sheehy PJ, Monahan FJ (1994) Vitamin E and meat quality. *Proc NutrSoc* 53:289-295.
- Murphy TP, Wright KE, PudelKiewicz WJ (1981) An apparent effect of excessive vitamin E in the chick. *PoultSci* 60: 1873-1878.
- Narimany-Rad M, Nobakht A, Aghdam-shahyarH, Lotfi AR (2011) The effects of dietary National Research Council (1994). Nutrient requirements of poultry. National Academic Press, Washington, DC. USA.
- Nawab A, Ibtisham F, Li G, Kieser B, Wu J, Liu W, Zhao Y, Nawab Y, Li K, Xiao M, An L (2018) Heat stress in poultry production: mitigation strategies to overcome the future challenges facing the global poultry industry. *J ThermBiol* 78: 131-139.
- Niu ZY, Liu FZ, Yan QL, Li WC (2009) Effects of different levels of vitamin E on growth performance and immune responses of broilers under heat stress. *PoultSci* 88: 2101-2107.
- Nobakht A (2012) The effects of different levels of poultry fat with vitamin E on performance and carcass traits of broilers. *Afr J AgricRes* 7: 1420-1424.
- National Research Council (NRC) (1994) *Nutrient requirements of domestic animals*. 9th ed. Washington, DC.
- Onderci M, Sahin N, SahinK, Kilic N (2003) Antioxidant properties of chromium and zinc. *Biol Trace Elem Res* 92: 139-149.
- Packer L, Suzuki YJ (1993) Vitamin E and alpha-lipoate: role in antioxidant recycling and activation of the NF-kappa B transcription factor. *Mol Aspects Med* 14: 229-239.
- Pal M (2017) The role of minerals and vitamins in poultry production. *Agric World*, 3.
- Panda AK, Cherian G (2014) Role of vitamin E in counteracting oxidative stress in poultry. *JPoultSci* 51:109-117.
- Parolini M, Romano M, Caprioli M, Rubolini D, Saino N (2015) Vitamin E deficiency in last-laid eggs limits growth of yellow-legged gull chicks. *FunctEcol* 29: 1070-1077.
- Pekmezci D (2011) Vitamin E and immunity. *VitamHorm* 86: 179-215.
- Perez-Carbajal C, Caldwell D, Farnell M, StringfellowK, Pohl S, Casco G, Pro-Martinez A, Ruiz-Feria CA (2010). Immune response of broiler chickens fed different levels of arginine and vitamin E to a coccidiosis vaccine and *Eimeria* challenge. *PoultSci* 89: 1870-1877.
- PitargueFM, Kim JH, Goo D, Reyes JBD, KiDY (2019) Effect of vitamin E sources and inclusion levels in diets on growth performance, meat quality, alpha-tocopherol retention, and intestinal inflammatory cytokine expression in broiler chickens. *PoultSci* 98: 4584-4594.
- PirgozlievVR, MansbridgeSC, Westbrook CA, Woods SL, Rose SP, Whiting IM, YovchevDG, AtanasovAG, KljakK, StaykovaGP, IvanovaSG, KarakeçiliMR, KaradaşF, Stringhini JH (2020) Feeding dihydroquercetin and vitamin E to broiler chickens reared at standard and high ambient temperatures. *Arch AnimNutr* 74: 96-511.
- Pompeu MA, Cavalcanti LFL, ToralFLB (2018) Effect of vitamin E supplementation on growth performance, meat quality, and immune response of male broiler chickens: A meta-analysis. *LivestSci*208: 5-13.
- Puthongsiriporn U, ScheidelerSE, Sell JL, Beck MM (2001) Effects of vitamin E and C supplementation on performance, *in vitro* lymphocyte proliferation, and antioxidant status of laying hens during heat stress. *PoultSci*80: 1190-1200.
- Raederstorff D, Wyss A, Calder PC, Weber P, Eggersdorfer M (2015) Vitamin E function and requirements in relation to PUFA. *Br J Nutr* 114: 1113-1122.
- Rajmane BV, RanadeAS (1994) Effect of dietary vitamin E and C on growth and immune response of broilers. *Ind J PoultSci*29: 78.
- ReboléA, Rodri'guezML, Ortiz LT, AlzuetaC, Centeno C, ViverosA, BrenesA, Arijal (2006) Effect of dietary high-oleic acid sunflower seed, palm oil and vitamin E supplementation on broiler performance, fatty acid composition and oxidation susceptibility of meat. *Br PoultSci*47: 581-591.
- Rengaraj D, Kwon WS, Pang MG (2015) Effects of motor vehicle exhaust on male reproductive function and associated proteins. *J Proteome Res* 14: 22-37.
- Rey AI, Segura J, Olivares A, CerisueloA, PiñeiroC, L'opez-BoteCJ (2015) Effect of micellized natural (D- α -tocopherol) vs. synthetic (DL- α -tocopheryl acetate) vitamin E supplementation given to turkeys on oxidative status and breast meat quality characteristic. *PoultSci* 94:1259-1269.
- Richard D, Kefi K, Barbe U, Bausero P, Visioli F (2008) Polyunsaturated fatty acids as antioxidants. *Pharmacol Res* 57: 451-455.
- Rizvi S, Raza ST, Ahmed F, Ahmad A, Abbas S, Mahdi F (2014) The role of vitamin e in human health and some diseases. *Sultan QaboosUniv Med J* 14: e157-165.
- Sahin K, Kucuk O (2001) Effects of vitamin C and vitamin E on performance, digestion of nutrients and carcass characteristics of Japanese quails reared under chronic heat stress (34°C). *J AnimPhysiolAnim-Nutr* 85:335-341.
- Sahin K, Kucuk O (2003) Zinc supplementation alleviates heat stress in laying Japanese quail. *J Nutr* 133: 2808-2811.
- Sahin K, Sahin N, Yaralioglu S (2002a) Effects of vitamin C and vitamin E on lipid peroxidation, blood serum metabolites and mineral concentrations of laying hens reared at high ambient temperature. *Biol Trace Elem Res* 85:35-45.
- Sahin K, Kucuk O, Sahin N, Gursu MF (2002b) Optimal dietary concentration of vitamin E for alleviating the effect of heat stress on performance, thyroid status, ACTH and some serum metabolite and mineral concentrations in broilers. *Vet Med* 47: 110-116.
- Sahin K, Sahin N, Onderci M, Yaralioglu S, Kucuk O (2001) Protective role of supplemental vitamin E on lipid peroxidation, vitamins E, A and some mineral concentrations of broilers reared under heat stress. *Vet Med (Praha)* 46: 140-144.
- Sahin K, Sahin N, Onderci M, Gursu MF, Issi M (2003) Vitamin C and E can alleviate negative effects of heat stress in Japanese quails. *Food Agric Environ* 1: 244-249.
- Salgueiro MJ, Zubillaga M, Lysionek A, Sarabia MI, Caro R, De Paoli T, Hager A, Weill R, Bocci J (2000) Zinc as an essential micronutrient: A review. *Nutr Res* 20: 737-755.
- SermanV, Mas N, Mazija H, Mikulec Z (1992) Immune response as a marker of needs for vitamin E in chickens. 2.The influence of Vitamin E on fattening chicks productivity. *Krimva* 34: 65-69.
- Sheehy PJA, Morrissey PA, Flynn A (1993) Influence of heated vegetable oils and alpha-tocopherol acetate supplementation on alpha-tocopherol, fatty acids and lipid peroxidation in chicken muscle. *BrPoultSci* 34: 367-381.
- Sheffy BE, Schultz RD (1979) Influence of vitamin E and selenium on immune response mechanisms. *Feed Processing* 38: 2139-2143.
- Sheldon BW, Curtis PA, Dawson PL, Ferket PR (1997) Effect of dietary vitamin E on the oxidative stability, flavour, colour and volatile profiles of refrigerated and frozen turkey breast meat. *PoultSci* 76: 634-641.
- Singh H, Sodhi S, Kaur R (2006) Effects of dietary supplements of selenium, vitamin E or combinations of the two on antibody responses of broilers. *Br PoultSci* 47:714-719.
- Silva ICM, Ribeiro AML, Canal CW, Vieira MM, Pinheiro CC, Gonçalves

- T, de Moraes ML, Ledur VS (2011) Effect of vitamin E levels on the cell-mediated immunity of broilers vaccinated against coccidiosis. *Braz J PoultSci* 13: 53-56.
- Sklan D, Donoghue S (1982) Vitamin E response to high dietary vitamin A in the chick. *J Nutr* 112: 759-765.
- Smith TL, Kummerow FA (1989) Effect of dietary vitamin E and plasma lipids anatherogenesis in restricted ovulation chickens. *Atherosclerosis* 75: 105-109.
- Sonam K, Guleria S (2017) Synergistic antioxidant activity of natural products. *AnnalPharmacol Pharm* 2: 1086.
- Sosnowka-Czajka E, Skomorucha I, Herbut E (2005) Effect of dietary vitamin supplements on productivity and physiological parameters of broiler chickens exposed to elevated ambient temperature. Warsaw, Poland: ISAH; 2005.
- Surai PF (2020) Antioxidants in poultry nutrition and reproduction: An update. *Antioxidants (Basel)* 9:105.
- Surai PF, Kochish II (2019) Nutritional modulation of the antioxidant capacities in poultry: The case of selenium. *PoultSci* 98: 4231-4239.
- Surai PF, Kochish II, Romanov MN, Griffin DK (2019) Nutritional modulation of the antioxidant capacities in poultry: The case of vitamin E. *PoultSci* 98: 4030-4041.
- Traber MG, Atkinson J (2007) Vitamin E, antioxidant and nothing more. *Free RadicBiol Med* 43: 4-15.
- Tufarelli V, Laudadio V (2016) Antioxidant activity of vitamin E and its role in avian reproduction. *J ExperimBiolAgricSci* 4: 267-272.
- Villar-Patino G, Díaz-Cruz A, Avila-González E, Guinzberg R, Pablos JL, Piña E (2002) Effects of dietary supplementation with vitamin C or vitamin E on cardiac lipid peroxidation and growth performance in broilers at risk of developing ascites syndrome. *Am J Vet Res* 63:673-676.
- Yang H, Mahan DC, Hill DA, Shipp TE, Radke TR, Cecava MJ (2009) Effect of vitamin E source, natural versus synthetic, and quantity on serum and tissue {alpha}-tocopherol concentrations in finishing swine. *J AnimSci* 87:4057-4063.
- Yesilbag D, Eren M, Agel H, Kovanlikaya A, Balci F (2011) Effects of dietary rosemary, rosemary volatile oil and vitamin E on broiler performance, meat quality and serum SOD activity. *Br PoultSci* 52:472-482.
- Zhang XH, Zhong X, Zhou YM, Wang GQ, Du HM, Wang T (2010) Dietary RRR- α -tocopherol succinate attenuates lipopolysaccharide-induced inflammatory cytokines secretion in broiler chicks. *Brit J Nutr* 104:1796-1805.
- Zhao GP, Han MJ, Zheng MQ, Zhao JP, Chen JL, Wen J (2011) Effects of dietary vitamin E on immunological stress of layers and their offspring. *J AnimPhysiolAnimNutr (Berl)*. 95: 343-350.