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Heat stress and vitamin E in diets for broilers as a mitigating measure

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ABSTRACT. This review aimed to identify the importance of vitamin E dietary supplementation to broilers subjected to heat stress in relation to metabolism, growth performance and quality of animal products and its effects on immune system. Vitamin E is the concentration of tocopherol and tocotrienol, which can be found in natural or synthetic form. This vitamin is essential for the integrity of reproductive, muscular, circulatory, nervous and immune systems of the animals. In order to reduce the harmful effects of high temperatures in poultry production, vitamin E supplementation is a viable alternative for the sector. Some studies indicate its potential antioxidant effect able to modulate inflammatory responses and physiological adjustments to mitigate the undesirable effects of exposure of broilers to high temperatures. Moreover, it has been found increased viability of animals due to the greater activation of the immune system, and improved quality of animal products given to the deposition in tissues with consequent nutritional enrichment of meat products.

Keywords: antioxidant, performance, immunity, meat quality, supplementation.

Estresse térmico por calor e vitamina E em rações para frangos de corte como medida atenuante

RESUMO. Objetivou-se, com esta revisão, identificar a importância da suplementação de vitamina E às rações de frangos de corte submetidos a estresse por calor, em relação ao metabolismo, ao desempenho produtivo e à qualidade dos produtos de origem animal, bem como seus efeitos no sistema imune das aves. A vitamina E corresponde à concentração de tocoferol e de tocotrienol, podendo ser encontrada na forma natural ou sintética. É sabido que, essa vitamina, é essencial para a integridade reprodutiva, muscular, circulatória, nervosa e imunológica dos animais. Para reduzir os efeitos prejudiciais das altas temperaturas na produção avícola, a suplementação de vitamina E apresenta-se como alternativa viável para o setor. Alguns estudos indicam seu potencial efeito antioxidante capaz de modular respostas inflamatórias e ajustes fisiológicos para atenuar os efeitos indesejáveis da exposição das aves a elevadas temperaturas. Além disso, tem sido verificado aumento da viabilidade dos animais, pela maior ativação do sistema imune, e melhora na qualidade dos produtos de origem animal, devido à sua capacidade de deposição nos tecidos, com consequente enriquecimento nutricional dos produtos cárneos.

Palavras chave: antioxidante, desempenho, imunidade, qualidade da carne, suplementação.

Introduction

Broiler is increasingly efficient in converting feed into animal protein. However, these animals are often reared under adverse heat stress associated with inadequate levels of relative humidity, typical of tropical countries. Along with this, intensive genetic selection contributed to the emergence of strains more susceptible to heat stress (Brossi et al., 2009). In this sense, broilers have reduced growth capacity and become weakened from the point of view of animal welfare when in environments with high temperatures.

The maximum expression of genetic potential requires a thermoneutral zone for rearing broilers, in which the thermoregulatory system of the poultry is not triggered, whether to produce or dissipate heat (Cassuce et al., 2013). However, the effects of environmental seasonality and the inadequacy of facilities to ensure appropriate temperature ranges expose the broilers to heat, impairing productivity. As a consequence, there are significant economic losses to the poultry sector (Mujahid, 2005). It is estimated annually that the damage to agriculture related to heat stress is of the order of 1.69 to 2.36

billion dollars. Of this amount, 165 million is from poultry production (Khan et al., 2011).

During exposure to heat stress, broilers use mechanisms to dissipate excess heat, and the high temperature is the most important physical factor (Baêta & Souza, 2010). Depletion in feed intake is the first factor used by the animal, aiming to reduce thermogenesis of food metabolism. Concurrently, it is increased the intake of water, gasping, production of glucocorticoids and catecholamines, and the metabolism reduction with decrease in thyroid hormones (Bahrami et al., 2012). Moreover, there is a deficient immune response by atrophy of lymphoid organs, impairing the health and survival of animals, and increased lipid peroxidation (Sahin et al., 2009); affecting the quality of products of animal origin.

Therefore, various practices should be adopted to improve the response of animals to heat stress. The availability of nutritional management has become effective to minimize the deleterious effects of heat in poultry production (Ribeiro et al., 2008). Nutritional methods that are more frequently adopted are: vitamin and mineral handling, modification of the electrolyte balance of the feed, management of drinking water, among others (Borges et al., 2003). The adequacy of facilities, despite being a possibility of significant environmental improvement, may become a costly alternative. Thus, the manipulation of diets is of great relevance to the nutritionist to formulate and provide animals with high quality food with better use of nutrients aiming to mitigate the negative effects of heat (Souza et al., 2011).

Supplementation of vitamins, at higher levels than the commonly recommended, in traditional vitamin supplements can be a useful tool for favoring the poultry performance under heat stress. This because high environmental temperatures decrease the concentrations of vitamins and minerals in the blood serum, and increase their excretion (Khan et al., 2012).

Vitamin E is one of the vitamins supplemented in the diets, at different levels, as it is essential for the integrity of reproductive, muscular, circulatory, nervous and immune systems of the animals (Habibian et al., 2014). The inclusion of vitamin E in feed for broiler has resulted in positive effects on growth performance when supplemented at higher levels during heat stress (Bou et al., 2004; Souza et al., 2011). In addition, it can be demonstrated an improvement in carcass and cuts yield, quality of meat products, reducing the peroxidation of membrane lipids, and increased activation of the immune system (Hashizawa et al., 2013). For being of soluble nature, vitamin E participates actively in the structure of organic compounds because it is situated at the membrane level, minimizing the peroxidation of fatty acids and phospholipid components. Thus, the fat soluble vitamins are called as growth vitamins (Bou et al., 2009).

Given the above, this review aimed to identify the importance of supplementing vitamin E in feed to broilers reared under heat stress, in relation to metabolism, growth performance and quality of animal products and its effects on improving responses to increased activation of the immune system of broiler chickens.

Thermal environment and heat on broilers

The thermal conditions represented by temperature, relative humidity and air movement, are those which directly affect the broiler chickens because they negatively affect the maintenance of homeothermy (Baêta & Souza, 2010). In poultry, thermal comfort is required for both the use of minimum energy to keep body temperature and of maximum energy for production. Thus, the environment in which the broilers are is considered a key factor for success in the activity and consequently, from the economic point of view, it is capable of generating profit or loss.

Among the environmental factors that influence the homeothermy, the ambient temperature has an important role. In most cases, poultry are under intensive production system, confined, with limited range for behavioral adjustments necessary for maintaining the thermal homeostasis. This also implies difficulty of expression of ethological behaviors inherent to the species, affecting the welfare of broilers.

Broiler chickens are homeothermic animals with internal temperature around 41.5ºC with a body covered with feathers, which favors thermal insulation but makes difficult heat exchange with the environment. Moreover, the broilers do not have sweat glands and have reduced ability for heat exchange, in the latent form. This is justified by their thermoregulatory system best suited to retain the endogenous heat than to dissipate it (Yahav et al., 2005). In the hypothalamus is located in the thermoregulatory center, able to control body temperature, such as a thermostat, using physiological mechanisms and behavioral responses, through production and release of heat (Ferreira, 2011). This fact aims at maintaining body temperature within the proper range for the development of broiler chickens.

Broilers can lose heat through sensitive mechanisms such as radiation, conduction and convection, or by a latent way, through evaporative losses (Baêta & Souza, 2010). Peripheral vasodilation, non-evaporative heat loss, is an attempt to increase the endogenous heat dissipation. The broiler can increase the surface area, keeping the wings away from the body, ruffling the feathers and intensifying peripheral circulation to tissues not covered by feathers as the feet, crest and dewlap.

Broilers also use the latent heat loss by increasing the respiration rate, which is very efficient under stress by high temperatures. However, the increase in this mechanism generates more energy by means of contraction of the muscles, producing more heat, and may determine severe hyperthermia for broilers (Yahav et al., 2005). Added to this, heat production in these animals is particularly high because their growth rate is sustained by high food intake.

Reduction in growth is also a consequence of endocrine and metabolic adjustments of animals in response to stressful thermal environment (Quinteiro-Filho et al., 2010). It is known that plasma levels of triiodothyronine (T3) and thyroxine (T4), important growth promoter in broilers, are reduced with increasing environmental temperature, while others hormones such as corticosterone, for example, increase (Sahin et al., 2009). Considering also the importance of vitamin E for growth, the structural formation of organs and membranes, for reproductive, muscle and immune integrity of animals, the reduction in growth triggered by endocrine factors sensitive to heat can be enhanced by the lack of this vitamin in diet.

The blood system is particularly sensitive to changes in temperature and an important indicator of physiological responses of broilers to stressors. Quantitative and morphological changes in blood cells are associated with heat stress, reflected in variations in hematocrit values, number of circulating white blood cells, content of erythrocytes and hemoglobin in the red blood cell (Roll et al., 2010). According to Virden and Kidd (2009), under stressful situations with release of adrenocorticotropic hormone (ACTH), there is a reduction in the number of circulating lymphocytes, contributing to the increase of the heterophil/lymphocyte ratio. In addition to that, the release of corticosterone may cause involution of lymphoid tissue (thymus, spleen and cloacal bursa) and the suppression of humoral immunity and the cell-mediated immunity (Laganá et al., 2007). Consequently, the broiler becomes more susceptible to acquiring secondary illnesses, a consequence of heat stress. Still, the heat stress promotes decrease in phagocytic activity of macrophages, which negatively affects the development of animals and the immune response (Quinteiro-Filho et al., 2010).

Heat stress is still considered an important factor that influences the quality of meat products, as it increases the incidence of PSE meat (pale, soft and exudative) and favors the oxidation of meat after slaughter. The PSE meat is characterized by undesirable functional properties, such as pale color and low water holding capacity. These characteristics reflect in meat with low yield in industrial production of animal products and low consumer acceptance. In this sense, addition of vitamin E at the meat processing increases the stability of the product color and decreases the rancidity. But its action is most effective when incorporated into the diet of animals (Olivo et al., 2001), emphasizing the importance of supplementation at levels higher than those adopted.

Thus, considering the problems caused by heat stress, measures must be taken to reduce the losses and damages that may occur to the supply chain. Among them, supplementation with vitamins above levels commonly used may be a useful tool for the increase in productivity of broilers reared under stress conditions promoted by heat.

Vitamin in the feed for broilers and ways of supply

Vitamins are essential organic nutrients to animals and participate as cofactors in many metabolic processes acting in more than 30 cellular metabolic reactions (Asensi-Fabado & Munné-Bosch, 2010). In this way, they are essential for growth, productive performance, health, survival and reproduction of broiler chickens. Because they are not produced in adequate amounts, it is recommended to provide them in the diet. However, depending on the animal species and the environment, some can be synthesized. Vitamin D, for example, can be synthesized when the animal is exposed to the sun, while vitamin C may have its guaranteed levels if the animal has the gulonolactone oxidase. In turn, niacin is derived from tryptophan, and choline from methionine (Bertechini, 2012). Therefore, the vitamins should be supplemented in the diet at small amounts compared to other ingredients, and their deficiency cause several problems for the development of animals.

Vitamins also act as immunomodulators in the endogenous metabolism for improving immune function and resistance to infection in poultry and other domestic animals (Kraemer et al., 2008). To meet the physiological needs of the organism, vitamins are provided by vitamin supplements, commonly called premix. These represent a small percentage of the feed formula, about 0.1 to 0.5% on average though correspond from 1 to 3% of the total cost of feed, and the vitamins E and A may amount to 50% of the total cost of the vitamin supplement (Toledo et al., 2006).

The requirements of fat-soluble vitamins (A, D, E and K) are those that vary most between recommended and adopted commercial levels. This is because these vitamins are particularly involved with the development and maintenance of tissue structures, cellular immunity and improvement of meat quality (Zingg, 2007). In practice, nutritionists provide minimum levels required for maximum performance and profit, plus a safety margin to ensure the effectiveness of supplementation.

Besides the signs of deficiency and loss in performance, currently, new variables have been evaluated to determine the requirements of vitamins for broilers. These variables include immune response, welfare of the animals, enrichment of vitamins in the carcass and the consequent improvement in meat quality parameters. The purpose is to obtain better visual appearance, higher nutritional value and preserve the natural characteristics of meat products to consumers, as they are increasingly demanding about the quality and suitability of products of animal origin.

Vitamin E: source, role in the organism and use in feed for broilers under heat stress to improve the immune system, increase antioxidant activity and effects on growth performance

Vitamin E is a term used to describe two types of compounds, tocopherols and tocotrienols, each of which has four presentations. The basic structural difference between them is the number of double bonds of the side chain. This results in a change in biological activity of vitamin E. In general, α-tocopherol is considered as a standard of comparison for determining the activity of other forms of vitamin E (Açıkgöz et al., 2011). Vitamin E can be found in natural or synthetic form, and is present in vegetable oils, egg, liver, and some vegetables and in general in green leaves.

α-tocopherol has the greatest biological activity when compared to other forms of vitamin E, because it has higher absorption, higher deposition in tissues and low fecal excretion (Cortinas et al., 2005). Excess of α-tocopherol and its analogs are extensively metabolized before excretion. This suggests that the organism tries to maintain a certain level of vitamin E by selective retention of certain amounts of α-tocopherol (Zingg, 2007).

Vitamin E is a component and natural antioxidant of cell membranes and has been considered almost exclusively associated only with the reproductive system of animals. However, currently, it is known that this vitamin modulates inflammatory signaling, regulates the production of prostaglandins and leukotrienes, minimizes damage resulting from cytotoxic action caused by free radicals in the organism, and improves the phagocytic activity of macrophages in broiler chickens (Leshchinsky & Klasing, 2001).

In poultry, the absorption of vitamin E occurs in the non-esterified form in the small intestine attached to chylomicrons and released via the hepatic-portal system associated with very low density lipoproteins (VLDL), which subsequently dissociate up into low density protein (LDL) (Liebler, 1993), similar to the lipid digestion. Esters are extensively hydrolyzed in the gut wall, and the free alcohol is absorbed by intestinal vessels and transported via the lymph to the circulation (McDowell, 2000). Only the alcoholic part is assimilated by the animal. The LDL molecule carries the major portion of vitamin E, and then performs its exchange with high density lipoprotein (HDL) until the latter reach the other tissues, such as liver, muscle, and especially the adipose tissue (Burton, 1994).

It is estimated that diets based on corn and soybean meal provide an average of 10 mg/kg vitamin E (Khan et al., 2011). Usually, supplementation of vitamin E is in the form of DL-α-tocopherol, commercially available, being the most stable in processing and storage of food and feed (Silva et al., 2009). Table 1 presents the variability between some recommendations for vitamin E inclusion according to the rearing phase of broilers.

Table 1. Vitamin E inclusion levels recommended for broilers according to rearing phase.

References	Inclusion levels (mg kg^{-1})	Rearing phase (days)
NRC (1994)	10	1-42
Rostagno et al. (2005)	$35^1/28^2/14^3$	$1\text{-}7^1/8\text{-}21^2/22\text{-}42^3$
BASF (2009)	30-50	1-42
Rostagno et al. (2011)	$35^1/31^2/28^3/21^4$	$1\text{-}7^1/8\text{-}21^2/22\text{-}35^3/36\text{-}42^4$
Bertechini (2012)	$150\text{-}360^1/50\text{-}100^2$	$1\text{-}10^1/11\text{-}42^2$
Pompeu et al. (2015)	10	1-42

$^{1,2,3 \text{ and } 4}$= level respective to each phase according to each inclusion recommended.

The recommendation of the practical level of this vitamin varies according to age and level of the animal production. Young and breeder animals require greater amounts in the diet. The requirements of vitamin E are not fixed, since establishing optimal requirements and efficacy, according to the production phase and with the age of the poultry, depends on several factors. Among these, we can mention: the concentration of vitamin E in the feed, the processing temperature in the manufacturing of animal feed, light, moisture, concentration of polyunsaturated fatty acids in the diet, sulfur amino acid content, and possible interactions with other elements such as selenium, vitamins A and C and the mineral zinc.

In this regard, aiming to evaluate the synergistic effects of supplementation of vitamins C and E in the diets of broilers kept at high temperatures, Souza et al. (2011) observed that the plasma concentration of triiodothyronine (T3), the percentage of blood cells, heterophil/lymphocyte ratio and absolute and relative weights of the spleen, at 21 and at 42 days of age, were not affected by vitamin supplementation. Meantime, in the same study, combinations of vitamins C and E promoted improvement in absolute and relative weights of breast in broilers subjected to high temperatures.

According to Hosseini-Mansoub et al. (2010), the combination of 100 mg kg^{-1} of vitamin E + 50 mg kg^{-1} zinc is a strategy for broilers reared under heat stress, as it favors the growth performance. Nevertheless, Lopes et al. (2015) claimed that levels of zinc and vitamin E above the commonly used do not improve the feed intake, weight gain, feed conversion, production viability and the production efficiency index of broilers kept under high temperatures reared on reused litter.

From a practical point of view, the companies producing vitamin supplements adopt a margin of 20 to 50 mg kg^{-1} of vitamin E. However, levels of up to 25 times the recommendation of NRC (1994) can be adopted with the intention of enriching the carcass and protecting the broilers exposed to a challenge, such as exposure to heat and the incidence of diseases, such as Gumboro. According to Emadi et al. (2010), vitamin E enhances immunity of broilers infected with Gumboro at the sub-clinical stage in vaccinated flocks. Such an alternative would be interesting in regions of high incidence of the disease, with inappropriate temperatures for the development of the animals, poultry production at high densities and sites with high bacterial and viral load.

Heat stress promotes the release of catecholamines and corticosteroids that induce lipid peroxidation of membranes, including membranes of T and B lymphocytes. Vitamin E, in turn, stimulates the enzyme glutathione peroxidase activity of circulating neutrophils and macrophages and also promotes increased activity of T lymphocytes (Silva et al., 2011). As a result, there is increased phagocytic activity, and increased production of antibodies, resulting in increased immune activity.

In the immune response of broilers to stressors, one of the most important processes occurs when foreign particles, such as bacteria, bind to heterophils, which are the first line of defense of birds (Silva et al., 2011). Then, it increases the concentration of free radicals such as superoxide (O^{2-}) and hydrogen peroxide ($H_2 0_2$) that are produced at large quantities by NADPH oxidase enzyme for later use in oxygen-dependent mechanisms to eliminate invading pathogens (Burton & Traber, 1990). These free radicals, once present in the extracellular space, start to damage the immune cells and the surrounding tissues.

Vitamin E is the major antioxidant in blood, reacting with the peroxy radicals. This reaction reduces the effects of free radicals, protecting the tissues. This is the mechanism by which it is the vitamin E has immunomodulatory effect (Chew, 1996). Demonstrating the immunomodulatory and antioxidant activity of vitamin E, Silva et al. (2011) found increased duration of cellular reaction when supplemented levels above 65 mg/kg to broilers challenged with vaccine against coccidiosis and New Castle.

The role of vitamin E in the synthesis of eicosanoids, which modulate the production of prostaglandins and leukotrienes, occurs in an alternative mechanism of action of this vitamin by the immune system. This is because prostaglandins are immunosuppressive, and leukotrienes are immunostimulatory (Peters-Golden et al., 2005). Macrophages are the main cell type responsible for producing prostaglandins and vitamin E plays a key role in reducing the production thereof by antagonizing the peroxidation of arachidonic acid, thus limiting the entry of the precursors into the prostaglandins pathway (Ayala et al., 2014).

Still related to the immune system, vitamin E is associated with the synthesis of interferon, which is a glycoprotein that non-specifically inhibits viral replication. When a cell is invaded by a virus, the genetic material triggers the production of interferon, which has the ability to leave the infected cell and lie on neighboring cells, in order to protect it. Thus, it begins to induce an antiviral state and promotes the decrease of nuclear activity that prevents or at least hinders the invasion of surrounding cells by another virus (Stetson & Medzhitov, 2006).

Vitamin E supplemented to diets at a level of 200 mg kg^{-1} diet increases the response of primary and secondary antibodies in broilers subjected to high temperatures (Singh et al., 2006; Niu et al., 2009). Habibian et al. (2014) observed that besides the increase in antibody responses, there was a decrease in the heterophil/lymphocyte ratio, reduced HDL and increased LDL in broiler under heat stress, supplemented with vitamin E at 250 mg/kg feed, with or without the combined addition of organic selenium, showing the pronounced effect of this vitamin.

Due to its soluble nature, vitamin E is deposited at the membrane level, known for its lipoprotein constitution and may perform at this site its best-known action, the antioxidant. Moreover, it can be attached to circulating chylomicrons favoring the immune response to stress in vivo (Voljč et al., 2011). As it is a potent scavenger of free radicals, high doses of vitamin E can provide stability to fat deposits, improving the resistance of fresh meat and meat products to oxidation (Akşit et al., 2006; Dikeman, 2007).

Vitamin E is the only antioxidant which, once absorbed, is deposited in the animal body. Because of this, it has been used for nutritional enrichment of animal products, increasing their value and becoming an important functional nutrient to consumer health. On the other hand, Souza et al. (2006) found no improvement in yield of carcass and cuts of broilers slaughtered at 42 days of age with the addition of different levels of vitamin E in the diet. This indicates that although vitamin E contributes to reduce lipid oxidation of meat, it does not act directly on growth and protein deposition. So its influence is more pronounced from a qualitative point of view of animal products.

Maini et al. (2007) supplemented vitamin E (200 mg kg^{-1}) in feed during the summer months and observed that the broilers showed reduced lipid peroxidation and high activity of the glutathione peroxidase, catalase, superoxide dismutase and glutathione reductase in erythrocytes, compared to the control diet. Therefore, vitamin E supplementation improves enzymatic and non-enzymatic antioxidative systems of red blood cells in animals subjected to heat.

By studying the effect of vitamin E supplementation on quality of broiler meat, especially in the incidence of PSE meat (pale, soft and exudative), under conditions of chronic heat stress, Hashizawa et al. (2013) reported that stress effects on meat quality were more significant in the breast meat resistance, and that supplementation with vitamin E (200 mg kg^{-1}) was effective to prevent incidence of PSE meat. Bou et al. (2004) observed that the addition of 140 mg tocopherol acetate to broiler feed possibly increased this element in the meat. However, it did not affect the storage and acceptance by consumers.

Diets for rapid growth broilers, reared under heat, have high levels of polyunsaturated fatty acids to increase the energy available in the diet. However, the diets will have less stability and resistance to rancidity. In this sense, the use of higher levels of vitamin E would be of paramount importance, as it would reduce lipid oxidation of feed and increase the concentration of vitamin E in the feed to be consumed. Furthermore, after slaughter, it would favor the protection of cell membranes, reducing the loss of exudate, and especially would enrich the product from the nutritional point of view. Consequently, there is provision of a healthier product with longer shelf life. Proving this fact, Voljč et al. (2011) verified that vitamin E supplemented at 200 mg/kg diet promoted greater oxidative stability of meat and reduced stress in vivo in animals reared under heat stress receiving high content of polyunsaturated fatty acids in the diet.

Vitamin E is one of the vitamins of higher cost for inclusion in the feed. Thus, its inclusion at higher levels in diets is only justified if this cost is passed on to the final product, and is also restricted to regions with high productive challenge, like high temperature regions. Although higher doses of vitamin E may result in several positive effects, information as to the level of absorption of this vitamin is still scarce. Some authors also suggest that excess vitamin E in the diet can be harmful to animals. Thornton et al. (1995) showed that high levels of vitamin E supplementation in the diet may have cytotoxic effects on chicks, so that the antioxidant role of this vitamin is reversed, contributing to cell oxidation.

Given the improved immune response and the reduction of oxidation processes in the animal organism, vitamin E can have benefits for growth performance or mitigate the negative effects of heat. Based on this, Sahin et al. (2002) supplemented increasing levels of vitamin E for broilers under heat stress, and observed linear increase in performance parameters with consequent increase in metabolically active organs (heart, liver, intestines and gizzard). Khattak et al. (2012) registered improved performance of broilers subjected to heat stress fed diets supplemented with vitamin E at 300 mg kg^{-1} compared to the control group (35 mg kg^{-1} vitamin E). However, Nobakht (2012) and Pompeu et al. (2015) found no effect of increasing levels of vitamin E in broiler feed.

Vitamin E is among the most important natural nutraceuticals. However, for best efficiency it must be administered at higher levels compared to the levels adopted, both before and during stress, including that caused by high temperatures. Thereby, this nutrient works as a preventative added to animal feed, with the purpose to minimize and mitigate the deleterious effects of heat.

At least, there are controversies regarding the inclusion of vitamin E at higher levels than recommended, since the problems triggered by heat stress are mostly of multifactorial origin. Thus, it is evident the need for more detailed studies in order to elucidate issues and to discuss the mechanisms of action and absorption of vitamin E in the organisms of broilers reared under heat stress conditions.

Conclusion

Vitamin E has the potential to reduce the undesirable effects of exposure of broilers to high temperatures. The inclusion of vitamin E at 250 mg kg^{-1} in the feed can be used when the broilers are under hot thermal environment, or in regions with some health challenge, with the possibility of causing an improvement in animal performance, besides the possibility of increasing the nutritional value of the meat.

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