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Vitamin C the 'Magic Bullet' for Poultry Production during Heat Stress: A Review

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Abstract

Domesticated animals are homeothermic animals, including poultry. This means they are warm-blooded animals and usually maintains their relatively constant internal body temperature. This means that they have a relatively uniform temperature maintained almost independent of the environmental temperature. Therefore, they are usually productive when they are within their comfortable thermo-neutral zone of ambient temperature ranges. Consequently, maintenance of the relative constancies of poultry of their internal environment depends on behavioural interactions with the external environment as well as automatic adjustments within the body. Nutrient, fluid and thermal balance cannot be maintained in the long run without appropriate control of the behavioural activities of eating, drinking and selection of a favourable thermal environment. In each case, these behavioural activities contribute to homeostasis by adjusting the rate of exchange of the regulated quantity of nutrients, fluid or heat between the external environment and the interior of the body in such a way as to favour the constancy of the body's content of each quantity. In the tropics, particularly during the dry seasons or summer periods birds usually find themselves outside the comfortable environmental temperature resulting in heat stress. During heat stress, heat increment emanating from nutrient digestion surges resulting to birds going off feed as a physiological response that significantly results in poor performance and other productive indices. In this circumstance, vitamin C has been shown to be the 'magic bullet' of importance in managing heat stress in poultry production. This is very important, especially in the tropic where heat stress is endemic.

Keywords: Vitamin C, Productivity, Heat Stress and Poultry

Introduction

Vitamins are groups of organic compounds that animals require at micro-levels to improve their growth as they are essential for normal body functions, growth and reproduction. Therefore, a deficiency of one or more vitamins can lead to disease conditions (Harsh, 2015) [10]. The sources of vitamins are mostly from food because the body either does not produce them or produces them in very little quantities that may not be sufficient for metabolic and other physiological functions. All vitamins have their individual functions which are very important and a deficiency in any of the vitamins can cause severe health problems such as heart diseases, cancer and poor bone health (Comb, 2008) [8]. One of the well-known vitamins playing these critical functions is vitamin C also known as ascorbic acid.

Prior to the discovery of vitamin C, scurvy has for a long time been the scourge of sailors who sailed for very long distances without supplies of fresh foods. This led to the death of many sailors. It was towards the end of the 15th century that the major cause of the mortality and disability among sailors on long sea journeys was discovered to be scurvy. In 1753, scurvy became recognized as directly related to dietary deficiency in the British medical community (James, 2002) [12].

Since the discovery of vitamin C, apart from the fore-stated roles it has also been found to have many essential functions. For instances, Vitamin C serves as a cofactor for some oxygenase which are involved in the synthesis of catecholamine and carnitine and also in the metabolism of cholesterol, xenobiotic and tyrosine (Comb, 2008) [8]. Vitamin C also functions in the recycling of Vitamin E (May *et al*., 1998; NRC, 2012) [18, 23]. Vitamin C protects the immune system and facilitates the conversion of cholesterol into bile acids and thus lowers blood cholesterol levels; in this way serves as an antidote in atherosclerosis (Comb, 2008) [8]. It also increases gut absorption of iron by reducing ferric iron to ferrous iron thereby functioning as a blood-builder (Comb, 2008: Matsui, 2012) [8, 17].

In poultry, vitamin C has been used to improve the carcass and meat quality characteristics (NRC, 1993; NRC, 2012) [22, 23]; improve performance in laying hens (Oruwari *et al*., 1995) [25] and alleviate heat stress in poultry (Ahmadu *et al*., 2015) [2]

leading to improved production indices. These are indicators to the fact that vitamin C functions in alleviating the negative impacts of heat stress in poultry.

Thermal stress is a fundamental feature in poultry management, especially in the tropics; this partly forms the basis of the differences between the temperate regions and the tropics in poultry management. Heat stress is a great economic threat to the poultry industry. Heat waves result in huge losses through heat prostration. This paper was not intended to cover all studies in the literature where vitamin C was implicated in alleviating impacts of heat stress in birds; it would nevertheless focus on four important areas vitamin C influences positively in poultry production, during heat stress. These are: birds' productivity and performance during heat stress, activation of the immune response during heat stress enabling birds' overcome the drawbacks of heat stress, egg laying performance in layers during heat stress as well as reproductive performance of birds during heat stress.

Birds' Productivity and Performance during Heat Stress

Stress is one of the major factors negatively affecting animal production, including poultry. Stress as used here implies the detrimental effects of varying environmental temperature conditions surrounding animals in respect to their health and thus performance (Ahmadu *et al*., 2015) [2]. Heat stress is a major stress-factor in the poultry industry and this occurs especially when birds are raised under high density conditions, especially during the summer months. Many independent studies have demonstrated that vitamin C could palliate the effects of heat stress in poultry birds. Thermal stress poses several issues relating to growth, feed intake, immune function, nutrient utilization and antioxidant system in the body of chickens (Sugiharto, 2020) [30]. In these conditions birds' performance is significantly reduced or compromised (Ahmadu *et al*., 2015) [2]. Abidin and Khatoon (2013) [1] reported that vitamin C ameliorates heat stress induced problems such as poor immunity, feed intake, weight gain, oxidative stress, rectal and body temperature, fertility and semen quality, carcass weight and mortality in birds.

Ahmadu *et al*. (2015) [2] reported that dietary inclusion of 100 to 200mg vitamin C/Kg of feed inhibited stress factors in poultry and thereby improved their productivity. Lin *et al*. (2006) [16], reported that vitamin C improved the performance of birds under heat stress by lowering plasma levels of corticosterone and adrenocorticotropic hormones. These hormones are used to measure stress levels in animals. In an earlier study (Lin *et al*., 2003) [15] vitamin C was shown to improve immune response and weight gain of birds whose diet were supplemented with ascorbic acid during heat stress.

Khan *et al*. (2012) [14] reported a supplementation of 250 mg/kg of feed has been found to be optimum in improving feed intake, body weight gain, feed efficiency, egg production and quality, nutrient digestibility, immune response and antioxidant status in poultry birds. Attia *et al*. (2016) [4] also reported that supplemental diets with vitamin C at 200mg/kg of diet enhanced egg laying performance of laying hens during heat stress.

Alaeldein *et al*. (2018) [3] studied the effects of natural vitamin C on performance and certain hematological and biochemical values in broiler chicken exposed to heat stress. One hundred and forty-four unsexed broiler chicks were used in the study. In that study, vitamin C was supplemented at 100 and 200mg/Kg of feed at two temperature levels of 22oC (normal) and 32oC (high) to induce heat stress. At the end of the study, it was observed that supplemental vitamin C at 100mg/Kg of feed had no major impact on cumulative performance and plasma mineral status as feed intake was only positively affected in the first week of the experiment but by the end of the second week the demonstrated marginal positive effect of the vitamin had disappeared, suggesting that the 100mg/kg of diet was not optimal compared to the 200mg/kg of diet. However, the birds that were in the supplemented level of 200mg/kg of feed had optimal performance indices in the presence of the induced heat stress, suggesting that lower levels of supplemental might be inadequate in maintaining performance in heat stress.

Vitamin C also works in synergy with vitamin E as antioxidants in combating heat stress. This synergy has been documented in pullets (Sinkalu and Ayo, 2008) [29] and in Japanese quails (Ciftci *et al*., 2005) [7]. Attia *et al*. (2017) [5] reported that dietary supplementation of vitamins C and E increased body weight gain, feed intake, feed conversion ratio and dressing percentage while abdominal fat was significantly decreased in chronic heat stressed broilers. Sahin *et al*. (2002) [27] reported that vitamin C and E had synergetic effects for reducing the adverse effect of chronic heat stress in chickens. Furthermore, Ipek *et al*. (2007) [11] reported that vitamin E, vitamin C, and a combination of vitamins E and C supplementation equally increased lymphocytes numbers and white blood cells but decreased heterophil/lymphocyte ratio in quails, suggesting that supplementation increased lymphocyte levels that are implicated in better protection of the animal from the detrimental effects of heat, thereby avoiding impeding the bird performance.

Vitamin C and Immune Response of the Bird during Stress

On immune response of broilers on vitamin C supplementation, Chand *et al*. (2014) [6] investigated the effect of supplementation of Zinc and vitamin C during heat stress in broilers. In the study, birds were fed supplemented zinc diet, ascorbic acid (AA) diet and a combination of zinc and ascorbic acid diet. Their findings showed that feed intake, body weight gain and burda of fabricius were significantly improved in the treatment group of birds that received supplemented zinc and ascorbic acid diets. Preedy *et al*. (2010) [26] reported that high concentrations of AA are found in immune cells and are readily used during infections and heat stress. Nevertheless, the mode of interaction between AA and the immune system is not well understood at present. However, it has been postulated to regulate the production of cytokines and lymphocytes, the activities of phagocytes and cell adhesion molecules in monocytes (Preedy *et al*., 2010) [26]. Furthermore, antibody titer against Newcastle disease infectious bursal disease and infectious bronchitis increased significantly in birds on the supplemented diet with zinc, AA or both. Again, lymphocytes, leucocytes and monocytes counts increased in all birds on supplemented diets compared to the control. From their findings, they concluded that supplementation of birds' diets with Zinc or ascorbic acid alone or in combination could improve performance and immune status of broilers reared under heat stress.

Vitamin C and Egg Laying Performance

Oruwari *et al*. (1995) [25] investigated the effects of dietary ascorbic acid on the performance of Babcock hens in a tropical condition. The diets of the hens were supplemented at 0, 1, 1.5 and 2g ascorbic acid/Kg of diet, respectively. They found that supplementation at 1.5g AA/Kg of feed was most beneficial in egg production under heat stress condition. The supplementation also improved interior egg and shell qualities such as Haugh units, shell thickness, feed intake, body weight gains and also significantly reduced mortality. Although, there were no effects on egg weight, supplemented AA tended to normalize the physiological status of hens under tropical conditions. From their findings, it was deduced that AA was important for laying hens productivity during heat stress.

Khan and Sardar, (2005) [13] studied the effects of vitamin C supplementation on the performance of Desi, Fayoumi and commercial White Leghorn chicken breeds exposed to heat stress. The drinking water of the birds was supplemented with vitamin C at the rate of 5ml/5 liter. The results from the study indicated that egg production, egg weight and egg shell thickness improved with supplementation of vitamin C in all the layer strains studied. The average feed consumption was also improved with supplementation of vitamin C. The blood picture showed that the concentration of ascorbic acid was higher in layers supplemented with vitamin C. In the same study, it was observed that the concentrations of serum enzymes, such as alkaline phosphatase, serum glutamic pyruvic transaminase and serum glutamic-oxaloacetic transaminase were lower with vitamin C supplementation in all types of layers in the study suggesting that liver integrity was intact. Based on the findings of the trial, it was concluded that vitamin C supplementation was effective in improving performance of layers under heat stress conditions.

In another study, Seven (2008) [28] investigated the effects of propolis and vitamin C supplementation on feed intake, body weight, body weight gain, feed conversion rate, nutrient digestibility and on egg production and qualities (weight, mortality, shell thickness) in laying hens exposed to heat stress and found that supplemental diets with vitamin C increased feed intake, egg shell thickness and egg shell weight and it improved feed conversion ratio, hen day egg and egg weight. Supplemental diets with vitamin C also improved nutrient digestibility and reduced mortality of laying hens under heat stress. The findings of this study again further lay credence to the fact that AA supports productivity of poultry in heat stress conditions.

Vitamin C and Reproduction in Poultry

It had been reported that vitamin C supplementation improved male reproduction characteristics (Ahmadu *et al*., 2015) [2]. Earlier independent studies such as that of Monsi and Onitchi (1991) [19] that supplemented a maize and soybean-based broiler diet with ascorbic acid at 0, 125, 250 and 500mg/Kg respectively, found that vitamin C supplementation significantly increased semen volume, motility of sperm per ejaculate. However, these characteristics were best with the AA supplementation level of 500mg/kg of diet. In other words, the supplementation at the concentration of 500mg/kg of diet showed the highest level of improvement in these parameters. It was thus concluded that dietary AA supplementation at 250mg/Kg was desirable to maintain semen quality during the hot dry months under humid tropical conditions but best at 500mg/kg of diet.

However, some other studies observed positive results at lower concentrations compared to Monsi and Onitchi, (1991) [19]. Dobrescu (1987) [9] found that sperm concentration and semen volume of Tom turkeys increased by 28% when breeder ration was supplemented at 150 mg/kg of diet. Noll (1993) [20] also reported a 16% improvement in semen volume and 18% increase in sperm concentration when 200 mg/kg of AA was supplemented for eight weeks in male breeder turkeys ration. Again, Noll (1997) [21] reported more concentrations of sperm cells in males and more eggs per hen when turkey breeder diets were supplemented with 200 mg/kg of AA. Vitamin C therefore, improved reproductive performance in spite of adverse environmental temperature fluctuations, suggesting that AA supplementation may be the 'magic bullet' for poultry producers during heat stress.

Nowaczewski and Kontecka (2005) [24] studied the effects of three doses of vitamin C: 100, 200 and 300mg/Kg of feed on reproductive pheasants on egg production, egg quality, fertility and hatchability parameters. Their data showed that supplementation of diet with AA at 100 and 200mg/Kg diet significantly improved egg production, egg fertility and hatchability, but these improvements were best at 300mg/kg of feed.

Conclusions

From the reviewed studies on the effect of vitamin C in poultry production during heat stress, it is no more a gainsaying that vitamin C is very essential for birds for optimum performance during heat stress. However, depending on the breed and physiological status of the birds' concentrations of vitamin C supplementation varies. Therefore, its uses in enhancing birds' productivity in the presence of heat stress should be employed based on breed types and physiological conditions, especially in the tropics where heat stress is very prevalent and endemic.

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