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Chromium: Pharmacological Applications in Heat-Stressed Poultry

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Abstract: Heat stress has been associated with depressed growth in meat-type birds and a decline in egg production and quality in laying hens. During heat stress, feed intake tends to decrease, thus the availability of certain important minerals is reduced. Chromium (Cr) is one such mineral which is required for maintaining growth performance in poultry due to its role in growth, metabolism and alleviation of lipid peroxidation. The available scientific literature on Cr has documented the beneficial effects of this essential mineral in improving poultry performance under conditions of environmental heat stress. In the present study, past and present information about the specific role of Cr in heat-stressed poultry is presented.

Key words: Chromium, heat stress, poultry

INTRODUCTION

High ambient temperature has been reported to negatively affect the performance of animals through reduced feed intake, weight gain, egg quality and feed efficiency (Babe, 2011; Khan *et al*., 2011). Heat stress impairs antioxidant status and increases mineral and vitamin excretion (Sahin *et al*., 2002a). Furthermore, it is the principal cause of mortality and economic losses in the modern poultry industry (Babe, 2011). According to Khan *et al*. (2011) the term 'heat stress' has many connotations, however, birds are considered to be heat-stressed when the environmental temperature exceeds the thermoneutral zone (18-22°C). Birds have a remarkable ability to adapt to their environment, however, death may occur when the body's defence mechanism is exhausted due to continuous heat stress (Puron *et al*., 1994). High ambient temperatures have detrimental effects on poultry performance in terms of reduced egg production and egg quality in laying hens and depressed growth rates in broilers (Sahin *et al*., 2002a; Zha *et al*., 2009).

Several methods have been proposed to alleviate the detrimental effects of heat stress, encompassing environmental strategies (i.e. keeping birds in open cages, increasing ventilation and lowering stock density), genetics and feeding management (Khan *et al*., 2011). In recent years, alternative feeding strategies, especially the use of feed additives, have gained importance to alleviate the negative effects of heat stress and increase the bird's performance under thermo-neutral conditions (Al-Shami *et al*., 2011; Diarra *et al*., 2011; Mohammed and Kheravii, 2011; Manesh *et al*., 2012). Nowadays, various growth promoters, feed additives and immuno modulators are available for boosting production and safeguarding health of animals including poultry (Dhama *et al*., 2011, 2013, 2014a, b; Mahima *et al*., 2012, 2013; Rahal *et al*., 2014).

The objective of the present study is to review the published literature dealing with the effect of Cr supplementation in heat-stressed poultry with respect to its role in performance and productivity, antioxidant status and metabolism. The postulated mechanism of Cr in preventing and alleviating the negative effects of heat stress are also discussed.

CHROMIUM: AN ESSENTIAL NUTRIENT

In the last few decades, there has been considerable research interest in the utilisation of Cr in animal feeds. Chromium is essential for the metabolism of carbohydrates, proteins and lipids (Anderson, 1987). In poultry, Cr intake is often negligible and its absorption is poor (Prasad, 1978; Anderson, 1993). Additionally, Cr levels are low in the grain used in the formulation of poultry rations (Uyanik *et al*., 2005). Under stressful

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conditions, the mobilisation of Cr is increased from tissue and its excretion is increased, thus the demand for this mineral is further exacerbated (Sahin *et al*., 2005). Heat stress adversely affects Cr status in poultry (NRC, 1997) by decreasing its retention in serum and increasing its excretion (Sahin *et al*., 2010). In addition, organic Cr has been found to have more beneficial effects in heat-stress birds as compared to inorganic forms due to its increased absorption and bioavailability (Moeini *et al*., 2011). A considerable body of evidence indicates that environmental stress may be alleviated by supplementing antioxidant vitamins and minerals (Babe, 2011).

GROWTH AND FEED EFFICIENCY

Reductions in feed intakes and weight gain in broilers with increasing ambient temperature above the thermoneutral zone have been well documented (Sahin *et al*., 2010). Several published trials have demonstrated that protein digestibility is reduced by high environmental temperatures (Wallis and Balnave, 1984; Larbier *et al*., 1993; Bonnet *et al*., 1997). Heat stress decreases the flow of nutrients from the crop down into the intestines and deactivates some important digestive enzymes like trypsin, chymotrypsin and amylase (Hai *et al*., 2000). Under high ambient temperatures, feed intake and growth rate are affected through arrested thyroid activity and oxygen consumption (Hurwitz *et al*., 1983). Heat-exposed birds reduce their feed intake to alleviate the thermogenic effect associated with impaired nutrient absorption, assimilation and utilisation (Mckee *et al*., 1997), leading to depressed productive performance in poultry.

There is ample evidence supporting the inclusion of Cr in the basal diet of poultry to improve performance characteristics during periods of heat stress. Sahin *et al*. (2002a) reported that increasing Cr (200-1200 μg kg^{-1}) supplementation improved body weight, feed intake and feed efficiency in Japanese quail reared under heat stress (32.5°C) and got the same results at 34°C with 400 μg kg^{-1} chromium picolinate (Cr pic) (Sahin *et al*., 2005). In 2004, the same team observed that chromium supplementation at the rate of 4 and 8 mg kg^{-1} diet increased feed intake and feed efficiency in Japanese quail reared under high ambient temperatures (34°C). Onderci *et al*. (2005) concurred with these findings, showing that Cr pic supplementation increased performance and carcass traits in heat exposed (34°C) Japanese quails. Toghyani *et al*. (2006) found that feeding 1500 ppb Cr to broilers reared under heat stress conditions (33°C) increased weight gain and improved feed efficiency. Recently, Sahin *et al*. (2010) reported that Cr pic (400 and 800 μg kg^{-1}) improved performance again in Japanese quails exposed to high ambient temperatures (34°C). For other poultry, Sahin *et al*. (2002b) reported higher body weights, feed intakes, feed efficiency and carcass characteristics in Cr (299, 400, 800 and 1200 μg kg^{-1}) supplemented broilers reared under heat stress (32.8°C). Zha *et al*. (2009) showed increased average daily gain, feed efficiency, carcass yield and lean muscle and decreased abdominal fat in response to supplementation with 500 μg kg^{-1} chromium nano-composite in heat-stressed (35°C) broilers. Ahmed *et al*. (2005) obtained higher carcass weights and better feed efficiency when chromium chloride was fed to broiler chicks at the rate of 8 mg kg^{-1} during the peak tropical season. In addition, Sands and Smith (1999) reported that supplementation of Cr pic increased weight gain, feed efficiency and carcass characteristics in heat stressed (35°C) broilers.

Sahin *et al*. (2002a) concluded that egg production, egg weight, shell thickness, specific gravity and Haugh units were improved when Japanese quail were supplemented with an inorganic Cr-salt under high ambient temperatures which was in agreement with their later findings (Sahin *et al*., 2002a). It is well known that egg production decreases with high ambient temperature (Kirunda *et al*., 2001; Mashaly *et al*., 2004). It can be hypothesised that decreased feed intakes under high ambient temperatures reduced the availability of essential nutrients necessary for egg production such as plasma protein and calcium (Mashaly *et al*., 2004). Additionally, high ambient temperatures impair the synthesis of vitellogenine, a protein necessary for yolk formation and accelerate the conversion of norepinephrine into epinephrine which induces the degradation of ovarian follicles (Khan *et al*., 2011).

METABOLIC EFFECTS

It has been well documented that Cr stimulates the function of insulin through increasing insulin-sensitive cell receptors (Anderson, 1987; Linder, 1991; Onderci *et al*., 2005). Sahin *et al*. (2002a) observed increased insulin and decreased corticosterone in Japanese quail reared under heat stress. In the same year, Sahin *et al*. (2002b) reported that increased supplemental Cr resulted in decreased serum corticosterone and increased insulin, consequently, serum glucose and cholesterol declined and protein concentration was elevated in heat stressed broilers. Insulin regulates the metabolism of carbohydrates, proteins and fats and stimulates the uptake of amino acids, protein synthesis and glucose utilisation (Linder, 1991; Vincent, 2000). Onderci *et al*. (2005) found that Cr pic supplementation decreased serum cholesterol and glucose concentrations in heat-stressed Japanese quails. The improvement in the cholesterol profile may be due to an augmented insulin action that reduces lipolysis and increases the incorporation of fatty acids in the adipocytes (Anderson, 1987; Vincent, 2000, 2001), or increases liver LDL receptors which results in reduced LDL and increased HDL concentration (Lien *et al.*, 1999). Additionally, Du *et al.* (2005) suggested that Cr may have a role in improving cholesterol levels through facilitating the activity of Lecithin Cholesterol Acyltransferase (LCAT), thus, accelerating the esterification and excretion of cholesterol. Recently, Zha *et al.* (2009) reported increased protein contents in the thigh muscle and decreased fat and cholesterol levels in broilers reared under heat stress conditions. Moeini *et al.* (2011) found that serum glucose in chromium methionine (Cr met) supplemented broilers decreased during exposure to elevated ambient temperature (33°C) and HDL cholesterol concentration improved. The increase in serum protein concentrations may be due to an increased synthesis of amino acids in the liver via insulin which enhances the incorporation of several amino acids into protein (Moeini *et al.*, 2011).

ANTIOXIDANT EFFECTS

Environmental stress has been associated with the increased production of free radicals which damage cells and result in increased morbidity and mortality in poultry (Khan *et al.*, 2011; Khan, 2011). Heat stress causes exhaustion of antioxidant reserves due to an increased level of lipid peroxidation in the serum and liver (Sahin *et al.*, 2005). Sahin *et al.* (2010) reported that heat stress triggers the secretion of inflammatory markers such as interleukin-6, C-reactive protein and tumour necrosis factor-alpha (TNF-á). It has been postulated that lipid peroxidation is influenced by insulin metabolism and, therefore, Cr may function as an antioxidant (Preuss *et al.*, 1997). Sahin *et al.* (2002a) observed that in heat-stressed Japanese quail there was a decrease in serum MDA (malondialdehyde) when Cr was supplemented in the diet. Sahin *et al.* (2005) reported increased serum vitamin C and E and decreased MDA (malondialdehyde) in Japanese quail reared under heat stress. In heat exposed Japanese quails, Onderci *et al.* (2005) found that Cr pic supplementation increased serum vitamin C and E and decreased MDA concentration in the serum, liver and muscle. A reduction in MDA levels is related to inhibition of epinephrine resulting from insulin tropic effect of Cr which consequently thwarts lipid mobilisation (Linder, 1991).

CONCLUSION

In is concluded that chromium restores reduction in performance, productivity, nutrient digestibility, immune status and antioxidant profile as a consequence of exposure to heat stress. Because of significant role in poultry production and performance, chromium is one of the very important components in the poultry feed during times of heat stress.

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