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Original article

Role Of Animal Nutrition To Ameliorate Heat Stress In Chickens

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ABSTRACT

The global poultry sector is expanding rapidly to meet the rising demand for affordable, high-quality animal protein from meat and eggs. However, climate change and escalating environmental temperatures pose significant challenges to poultry production, particularly through heat stress. Chickens, with a high metabolic rate and limited thermoregulatory capacity, are highly susceptible to heat stress, which disrupts the balance between heat production and heat dissipation. Consequently, heat stress induces a wide range of adverse effects, including behavioural alterations, oxidative and acid–base imbalances, suppressed immunity, neuroendocrine disruptions, and substantial reductions in growth, feed efficiency, egg production, and overall bird welfare. Nutritional strategies have emerged as one of the most effective and practical approaches to mitigate the detrimental impacts of heat stress. These include feed restriction, dual feeding regimes, wet feeding, and dietary modification through increased energy density using fats. Supplementation of vitamins (A, E, C), minerals (zinc, selenium, chromium), electrolytes, phytochemicals (lycopene, resveratrol, EGCG, curcumin), and osmolytes (betaine, taurine) has been shown to enhance antioxidant status, maintain acid–base balance, improve immune competence, and support cellular homeostasis in heat-challenged birds. Such dietary interventions significantly improve feed intake, growth performance, egg quality, and survivability during periods of thermal stress. Overall, the integration of targeted nutritional strategies offers a holistic, sustainable, and cost-effective approach to ameliorate heat stress in poultry. Optimizing diets with essential nutrients, bioactive compounds, and osmolytes can effectively counteract physiological disturbances induced by heat stress and enhance the resilience and productivity of chickens under hot climatic conditions.

INTRODUCTION:

The poultry industry is growing across the world to fulfill the increasing demands of poultry meat and eggs. Poultry meat contains a low amount of saturated fatty acids and is rich in protein, vitamins, and minerals. Similarly, poultry eggs are the most affordable source of animal protein. Besides vitamins, minerals, and proteins, eggs are also rich in antioxidants such as lutein and zeaxanthin, which possess major benefits for eye health. Considering these facts, the global consumption of poultry meat and eggs have doubled in the past decade and is expected to be doubled by 2050.Total poultry population in India – 851.8 million and India is ranked as the 3rd largest egg producer and the 4th largest meat producer in the world (Prabakaran et al.,2020). Climate change is one of the major challenges for mankind, with animal Production one of the most affected sectors in the agricultural industry. Heat stress is a major problem in the poultry industry affecting the health and performances of poultry. Heat stress is a condition where chickens are unable to maintain a balance between body heat production and heat loss. This imbalance may be caused by variations of a combination of environmental factors (e.g., sunlight, thermal irradiation, and air temperature, humidity and movement) and characteristics of the animal (e.g., species, metabolism rate, and thermoregulatory mechanisms) (Lara and Rostagno, 2013). The impacts of increasing environmental temperatures on livestock will most likely differ from place to place, depending on latitude, geographical features and local farming systems. The normal body temperature of the chicken is around 41–42°C, and the thermo-neutral temperature for optimum growth is between 18–21°C (Kumari and Nath, 2018). Due to a higher metabolic rate, chicken produce more body heat and are prone to heat stress. Stocking density (SD) can also be a critical stressor in intensive poultry production because high SD is highly related to problems in the performance, health and well-being of poultry (Goo et al., 2019). Several strategies, with a variable degree of effectiveness, have been implemented to attenuate heat stress in poultry. Nutritional strategies such as restricting the feed, wet or dual feeding, adding fat in diets, supplementing vitamins, minerals, osmolytes and phytochemicals have been widely studied and found to reduce the deleterious effects of heat stress.

HEAT PRODUCTION AND HEAT STRESS: The extra heat produced in the course of digestion, excretion and metabolism of nutrients is called the heat increment. It is also well known that within a certain range of ambient temperature with unvarying feed and nutrient intake, the total heat production of the animal remains constant. This temperature range is called the Thermoneutral zone. In a thermo-neutral environment, the heat production of the animal is at the minimum and thus the dietary energy can be used for production (growth and egg production) efficiently. Therefore, whenever the daily amount of energy intake changes, the temperature range of the thermoneutral zone is changed, too. So, if for some reason the animal leaves the thermoneutral zone, this result in an increased heat production by the animal. This means that there is more loss of energy, and in consequence, less energy remains for production and moreover the eciency of energy utilization deteriorates too.

IMPACT OF HEAT STRESS ON CHICKENS:

A) Behavioral changes

B) Physiological changes

C) Neuroendocrine changes

D) Production changes

A) Behavioral changes:

When birds are exposed to a higher environmental temperature than their thermoneutral temperature, they try to dissipate excess heat produced inside the body, which is manifested by specific behavioral changes in birds. Chickens in the thermal stress condition spend less time walking and standing, consume less amount of feed and more water, spread wings, and cover their body surface in the litter. Furthermore, the characteristic signs of panting are also observed in heat-stressed birds.

B) Physiological changes

(1) **Oxidative stress:** Reactive oxygen species (ROS) are free radicals and peroxides produced typically within the cells during regular metabolism. They are essential for many cellular processes such as cytokine transcription, immunomodulation and ion transportation. The excess ROS produced within cells are eliminated by physiological detoxifying mechanisms present within the cells. Oxidative stress in the cells/tissues results from an imbalance between free radical production and endogenous antioxidant defense and leads to lipid peroxidation, protein nitration, DNA damage and apoptosis (Mishra and Jha, 2019).

(2) **Acid-Base Imbalance:** Birds lack sweat glands and have feathers throughout the body. Those features impair thermoregulation and as a consequence, they need to release heat via active mechanism (i.e., panting) during higher ambient temperature. Panting is a phenomenon exhibited by the birds by opening their beak to increase respiration rate and evaporative cooling from the respiratory tract. During panting, excretion of CO_2 occurs at a greater rate than the cellular production of CO_2, which alters the standard bicarbonate buffer system in the blood. The reduction of CO_2 leads to a decrease in the concentration of carbonic acids (H_2CO_3) and hydrogen ions (H^+). In contrast, the concentration of the bicarbonate ions (HCO_3^-) is increased; thus, raising the blood pH, i.e., the blood becomes alkaline. To cope with this situation and maintain the normal blood pH, birds will start excreting more amount of HCO_3^- and retain H^+ from the kidney. The elevated H^+ alters the acid-base balance leading to respiratory alkalosis and metabolic acidosis and is associated with the decline in production performances of poultry (Borges et al., 2007).

(3) **Suppressed Immunocompetence:** Heat stress is known to suppress immunity in the chicken. As a result, the prevalence of contagious and infectious poultry diseases, such as Newcastle disease (ND) and Gumboro disease, is relatively higher during the summer season in tropical countries (Badruzzaman et al*.,* 2015). Besides this, the size of immune-related organs such as the spleen, thymus and lymphoid organs are also regressed in the heat-stressed birds. The level of antibodies was also lowered in the heat-stressed birds.

C) Neuroendocrine Changes: The neuroendocrine system plays a crucial role in maintaining homeostasis and normal physiological functioning of birds during heat stress. In birds, the sympathoadrenal medullary (SAM) axis is activated and regulates homeostasis during the early stage of heat stress. The increase in ambient temperature is perceived by the sympathetic nerves, which transmit the impulse to the adrenal medulla. The adrenal medulla increases the secretion of catecholamines which cause a surge of glucose release in the blood, deplete liver glycogen, reduce muscle glycogen, increase respiration rate, vasodilate the peripheral blood vessels and increase neural sensitivity to cope with the stress. As stress persists for a more extended period, the hypothalamic-pituitary-adrenal (HPA) axis is activated. In response to the stress, corticotrophin-releasing hormone (CRH) is secreted from the hypothalamus, which triggers the release of an adrenocorticotrophic hormone (ACTH) from the pituitary. ACTH increases the production and release of corticosteroid by the adrenal glands. Corticosteroid stimulates gluconeogenesis to increase plasma glucose levels. Thyroid hormones, triiodothyronine (T3) and thyroxine (T4), released by the thyroid gland, also play a critical role in maintaining metabolic rate. studies have shown that T3 concentrations were lowered in the heat-stressed birds, whereas T4 concentrations were found inconsistent in different studies (Etches et al., 2008). The reduction of T3 concentration during heat stress is due to a decrease in peripheral deiodination of T4 to T3. Besides this, the secretion of the gonadotrophin-releasing hormone is also found to be impaired in heat-stressed birds. Moreover, sex hormones such as plasma progesterone, testosterone, and estradiol were also found to be lowered in heat-stressed White Leghorns.

D) Production Changes:

- ✓ Increase Mortality
- ✓ Decrease feed intake
- ✓ Poor FCR
- ✓ Reduced body weight
- ✓ Decrease quality of meat
- ✓ Decrease quantity and quality of eggs

ROLE OF ANIMAL NUTRITION IN HEAT STRESS:

1) **Feed Restriction:** Restricting the feed during the hotter period of the day has been a common practice in poultry production. In this practice, feed intake is reduced by withdrawing feed for a certain period (generally 8 a.m. to 5 p.m.) to reduce the metabolic rate of birds. Feed restriction is found to reduce rectal temperature, minimize mortality and decrease abdominal fat in heat-stressed broilers (Mohamed et al*.,* 2019). Yet, this approach is not widely used in the poultry industry, as it results in reduced growth rate and delayed marketing age of the birds.

2) **Dual Feeding Regime:** Practical observations have shown that feed restriction results in overcrowding and rush at a re-feeding time resulting in some additional mortality. Thus, the dual feeding regime has been devised to ensure birds have access to feed throughout the day. The thermic effects of proteins are higher than carbohydrates and produce higher metabolic heat. Taking this into account, the protein-rich diet is provided during cooler times and the energy-rich diet during the warmer period of the day (Westerterp, 2004). Studies have shown that providing a protein-rich diet from 4 p.m. to 9 a.m. and an energy-rich diet

during the 9 a.m. to 4 p.m. heat stress period was found to reduce the body temperature and mortality in the heat-stressed broilers (Basilio et al., 2001)

3) **Wet Feeding:** During heat stress, birds lose a high amount of water through the respiratory tract, and there is a marked increase in water intake to restore thermoregulatory balance**.** Adding water in the feed helps increase water intake and reduces viscosity in the gut resulting in the faster passage of the feed. Wet feeding stimulates pre-digestion, improves absorption of the nutrients from the gut, and accelerates the action of the digestive enzyme on the feed (Syafwan and Kwakkel, 2011).

4) **Adding Fat in the Diet:** Higher energy diets were effective in partially mitigating the effects of heat stress in poultry. During metabolism, fat produces lower heat increment as compared to protein and carbohydrates. Considering this fact, supplementation of fat in the diet has been a general practice in the hot climatic regions to increase the energy level and diminish the detrimental effects of heat stress. Adding fat at the level of 5% to the diet in heat-stressed laying hens was found to increase feed intake by 17% (Daghir, 2008). Supplementation of fat in the poultry diet not only helps to increase the nutrient utilization in the GI tract by lowering the rate of food passage but also helps to increase the energy value of the other feed constituents.

5) **Supplementation Of Vitamins, Minerals And Electrolytes :-**

Vitamin E: is a fat-soluble vitamin that has antioxidant activity and helps to scavenge free radicals produced inside the cell. Vitamin E is found to modulate inflammatory signaling, regulate the production of prostaglandins, cytokines, and leukotrienes, and also improve the phagocytic activity of macrophages in broiler chickens (Dalolio et al., 2015). Furthermore, Vitamin E also helps to improve immunity by inducing proliferation of lymphocytes. Dietary supplementation of vitamin E in heat-stressed laying hens is found to improve egg production, egg weight, eggshell thickness, egg specific gravity, and Haugh unit (Khan et al., 2011).

Vitamin A: associated with antibody production and T cell proliferation. Vitamin A is the most effective antioxidant at low oxygen tensions, which is found to quench singlet oxygen, neutralize thiyl radicals and combine with and stabilize peroxyl radicals. level of vitamin A supplementation (9,000 IU/kg) had a beneficial effect on the feed intake and laying rate of heat-stressed hen ($P<0.05$), compared with the control group (3,000 IU/kg) (Lin et al., 2002). They also reported that hens exposed to heat stress immediately after NDV (Newcastle disease virus) vaccination require a higher amount of vitamin A for an adequate level of antibody production.

Effect of vitamin A on feed intake and egg weight in 40 Laying hens reared under 31.5ºc

($P<0.05$)

Vitamin A (IU)	Feed intake (g/day)	Egg weight (g/egg)
3000	79.83±5.95[a]	61.64±4.74[a]
9000	84.47±8.17[a]	62.12±3.32[b]

(Lin et al., 2002)

Vitamin C: is a water-soluble antioxidant that protects against oxidative stress by scavenging ROS, neutralizing vitamin E-dependent hydroperoxyl radicals, and protecting proteins from alkylation and by electrophilic lipid peroxidation products **.**it has been shown to enhance differentiation and proliferation of B and T-cells, likely due to its gene regulating effects. Although poultry can synthesize vitamin C, the amount is limited during heat stress conditions . Thus, dietary supplementation of vitamin C is an effective strategy to reduce the harmful effects of heat stress in poultry. Supplementation of vitamin C (250 mg/kg of feed) improved growth rate, nutrient utilization, egg production, and quality, immune response, and antioxidant status in heat-stressed birds (Khan et al., 2012).

Zinc: Zinc is an essential nutrient required for the enzymatic activity for more than 300 different enzymes. Zinc is associated with the antioxidant defense system, immune function, and skeletal development. Zinc also plays an essential role in the synthesis of metallothionein, which acts as a free radical scavenger. Zn is a Integral component of carbonic anhydrase that catalyzes the formation of carbonates, an essential compound for eggshell mineralization.The supplementation of zinc helped to suppress the free radicals by being part of superoxide dismutase, glutathione, glutathione S-transferase and hemeoxygenase-1 (Lee, 2018). In broilers, supplementation of the organic form of zinc (40 mg/kg of feed) was effective in improving body mass growth, reducing the level of the lipid peroxide, and increasing the activity of superoxide dismutase enzyme during summer (Rao et al., 2016).

Chromium: is an essential mineral,which is an integral component of chromodulin and is also necessary for insulin functioning. Moreover, chromium is also involved in carbohydrate, protein, lipid, and nucleic acid metabolism. They researched the effects of chromium supplementation (chromium picolinate CrPic) at different doses (200, 400, 800 or 1200 μg/kg of feed) in heat-stressed broilers, where they found that increased supplementation of chromium was associated with an increase in body weight, feed intake, and carcass quality. They also observed a decreased level of serum corticosterone, serum glucose, cholesterol, and increased serum insulin level (Sahin et al., 2002).

Selenium: Selenium is a vital component of at least 25 different selenoproteins, most of which are the different parts of the enzymes, such as glutathione peroxidase and thioredoxin reductases. Two different forms of selenium, i.e., inorganic forms (sodium selenite and selenite) and organic forms (selenomethionine and selenium-yeast) are used as supplements for poultry. Associated with Improved live weight and FCR (Rahimi et al., 2011).

Electrolytes : Panting in heat-stressed bird alters the acid-base balance in blood plasma and ultimately leads to respiratory alkalosis. This acid-base imbalance can be recovered by supplementation of electrolytes such as NH_4Cl, $NaHCO_3$, and KCl. During respiratory alkalosis, birds excrete a higher amount of bicarbonate ions from the kidney to restore normal blood pH. These bicarbonates ions are further coupled with Na^+ and K^+ ions before being excreted through the kidney. Ultimately, the loss of ions results in an acid-base imbalance (Ahmad et al., 2008). Thus, sodium and potassium supplementation is preferred in heat-stressed birds to increase the blood pH and blood HCO_3^-, while chloride is supplemented to reduce these parameters.

6) Supplementation Of Phytochemicals :-

Lycopene: Lycopene is a predominant carotenoid mainly found in tomatoes and tomato products, and is known to enhance the production of antioxidant enzymes through activation of antioxidant response element in the DNA**.** Lycopene is found to improve the level of antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) in broilers (Arain et al., 2018).

Resveratrol: Resveratrol is natural bio active polyphenols mainly found in grapes, peanuts, berries and turmeric. Compared with birds in the heat stress group, birds in the heat stress + resveratrol group exhibited decreased ($P < 0.05$) crypt depth (Zhang et al*.,* 2017).

Effect of resveratrol on growth performance in 270 twentyone day-old cobb male broilers reared under 33 ± 1◦c for10 h/d

(P<0.05)

Items	**Control**	**HS 33±1ºc**	**HS+Res. 400mg/kg**
Initial body weight (g)	668.9	670.8	672.2
Final body weight (g)	1966.4^{a}	1784.2^{c}	1854.7^{b}
Average daily gain (g/d)	61.60^{a}	52.32^{b}	55.31^{b}
Average daily feed intake (g/d)	129.7^{a}	116.8^{b}	119.1^{b}
Feed/Gain	2.10	2.24	2.11

(Zhang et al.,2017)

Epigallocatechin Gallate: Epigallocatechin gallate (EGCG) is the polyphenols present in green tea extract that possess high antioxidant and anti-inflammatory properties. Associated with Increase body weight, feed intake and level of serum total protein, glucose and alkaline phosphatase activity in broilers (Luo et al*.,* 2018).

Curcumin: Curcumin is the primary polyphenols extracted from turmeric and possesses antioxidant and anti-inflammatory properties . As animals readily absorb curcumin, its use as a potential compound to mitigate heat stress in poultry has received attention in recent years. It Associated with Decrease mitochondrial MDA level, increase activity of Mn-SOD, GSH-Px in broilers (Zhang et al., 2015).

7) **Supplementation Of Osmolytes :-**

Betaine: Betaine is a small zwitterionic quaternary ammonium compound found in microorganisms, animals, and plants . Betaine is incorporated in the animal diets in different forms; as anhydrous betaine, betaine monohydrate, or betaine hydrochloride. Betaine possesses two fundamental metabolic activities, i.e., methyl donor activity and osmotic activity. Under heat stress, betaine plays a vital role in regulating the cellular osmotic environment, Preventing dehydration by increasing the water-holding capacity of the cells (Ratriyanto and Mosenthin, 2018). Improvement in the feed intake, weight gain, FCR and improvement in the dressing percentage in broilers (Chand et al., 2017).

Effect of betaine supplementation on mean weight gain (g) of 120 chicks for 42 days

(P<0.05)

Group	**Total weight gain (mean±SE)**
Control	1779.9±11.52 [d]
Bet-1.0 g/kg feed	1842.7±17.29 [c]
Bet-1.5 g/kg feed	1905.0±11.19 [b]
Bet-2.0 g/kg feed	2003.9±4.62 [a]

Effect of betaine supplementation on mean feed intake (g) of 120 chicks for 42 days

(P<0.05)

Group	**Total Feed intake (mean±SE)**
Control	3327.7±8.57 [d]
Bet-1.0 g/kg feed	3420.6±9.76 [c]
Bet-1.5 g/kg feed	3488.8±22.0 [b]
Bet-2.0 g/kg feed	3618.0±12.21 [a]

(Chand et al., 2017)

Taurine: 2-aminoethanesulfonic acid, is one of the most abundant amino acids distributed in different parts of animal tissues. Taurine plays a role in antioxidant action, bile acid conjugation, maintenance of calcium homeostasis, osmoregulation, and membrane stabilization. The use of taurine to mitigate heat stress in poultry has gained popularity in recent days under chronic heat stress. It Associated with Improved expression of heat shock proteins and body weight in broilers (Belal et al*.,* 2018). Taurine supplementation was found to reduce fat deposition in the liver of chronic heat-stressed broilers (Lu et al., 2019).

Effect of Taurine on final body weight of 120 one-day-old broilers reared under 34°C heat stress

($P<0.05$)

Items	**Control group**	**Heat stress group**	**Heat stress group + 0.1% Taurine**
Final body weight (g)	2336.50[a]	1881.70[c]	2067.90[b]

(Belal et al*.,* 2018)

CONCLUSION:

With the rising global temperature, heat stress has been a severe challenge to the growth of the poultry industry. Several strategies have been tried and tested to counteract heat stress in poultry. However, only a few of them are widely used in the poultry industry. Heat stress in poultry results from the interplay of several factors, such as high environmental temperature, humidity, radiant heat, and airspeed, and causes several physiological, neuroendocrine, and behavioral changes. So, no single approach alone is enough to negate the impacts of heat-stress on poultry. Therefore, there is a need for a holistic approach to attenuate the negative effect of heat stress in poultry. Vitamins (e.g. A, E and C) are capable of reacting with free radicals, thereby reducing their amounts and lipid peroxidation in the poultry. However, micro minerals (e.g. Zn, Se) are not directly capable of preventing or reducing ROS-formation, but they are essential cofactors for those enzymes which are reacting with free radicals. Several nutritional strategies like feed restriction, dual feeding regime, wet feeding, adding fat in diet along with Supplementation of vitamins, minerals, electrolytes, phyto-chemicals and osmolytes help to reduce impact of heat stress and improve production performance.

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