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Nutritional Strategies to Mitigate Heat Stress in Broilers Birds

Anuj Bishnoi,[1] Manju Lata,[2] Bidhan C. Mondal,[3] and Nisha Noor[4]
M.VSc. Scholar[1,4], Assistant Professor[2], Professor & Head[3]
[1,2,3,4] Department of Animal Nutrition, College of Veterinary and Animal Sciences, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, Udham Singh Nagar, Uttarakhand, India.
***Corresponding Author:** Manju Lata, Assistant Professor, Department of Animal Nutrition, College of Veterinary and Animal Sciences, G.B. Pant University of Agriculture and Technology, Pantnagar-263145, Udham Singh Nagar, Uttarakhand, India.
E-mail: manjundri1@gmail.com ; contact no: 8936978001
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INTRODUCTION:

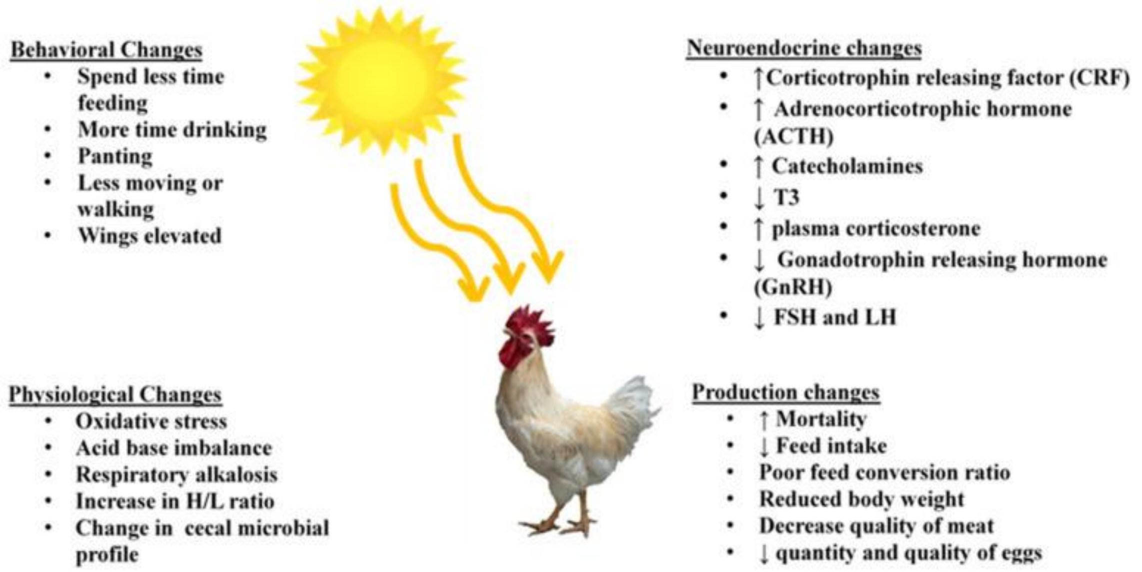
The poultry industry is growing across the world to fulfill the increasing demands of poultry meat and eggs. Poultry meat contains a low amount of saturated fatty acids and is rich in protein, vitamins, and minerals. Similarly, poultry eggs are the most affordable source of animal protein. Besides vitamins, 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. To fulfill the demands, there has been an immense improvement in chicken genetics in the past decade. Broiler chickens, which weighed around 900 g in 56 days in the 1950s, were around 4202 g in 2005. Due to a higher metabolic rate, they produce more body heat and are prone to heat stress. High stocking density of birds, along with the high ambient temperature, increases the propensity of heat stress. 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. Heat stress results from the interaction of different factors such as high environmental temperature, humidity, radiant heat, and airspeed; among them, high ambient temperature plays a significant role. The normal body temperature of the chicken is around 41–42 ◦C, and the thermoneutral temperature to maximize growth is between 18–

21◦C. Studies have shown that any environmental temperature higher than 25◦C elicits heat stress in poultry.

Changes In Poultry Due to Heat Stress:

Heat stress in poultry results in several behavioural, physiological, and neuroendocrine changes that influence health and performances.



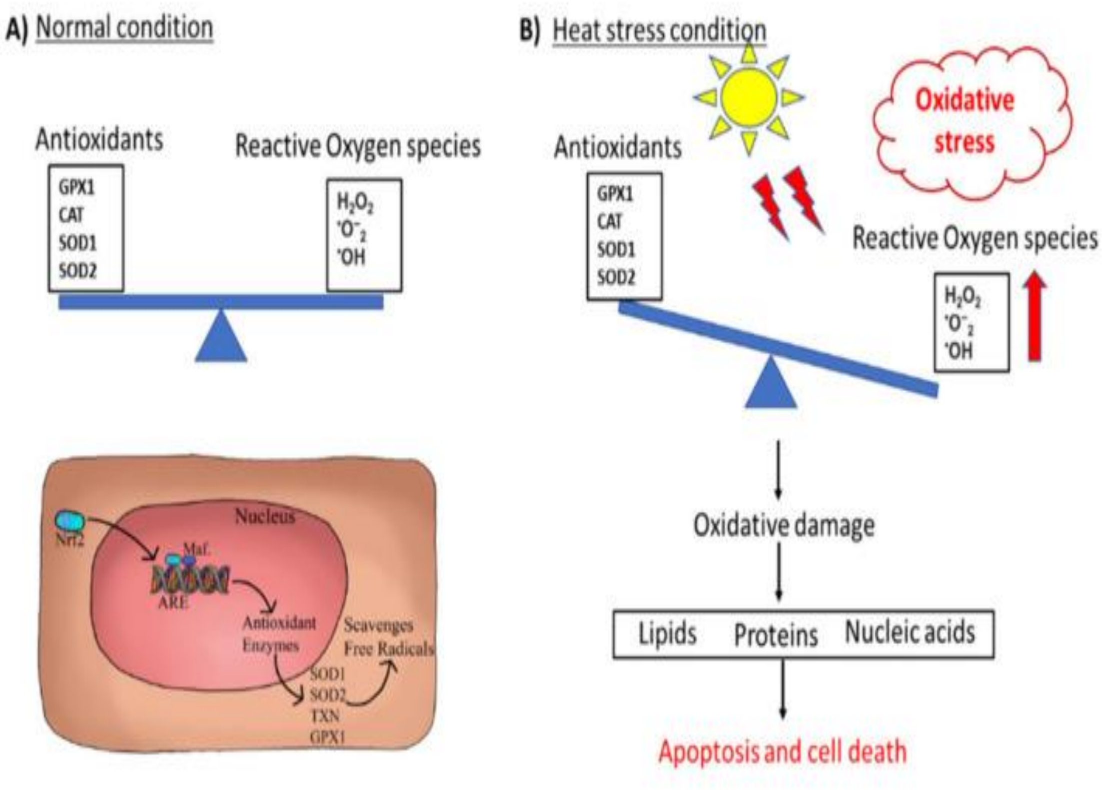
Effects of heat stress on behavioral, physiological, neuroendocrine, and production traits.

1. PHYSIOLOGICAL CHANGES:

Major physiological changes that take place in the heat-stressed birds are:

A) OXIDATIVE STRESS:

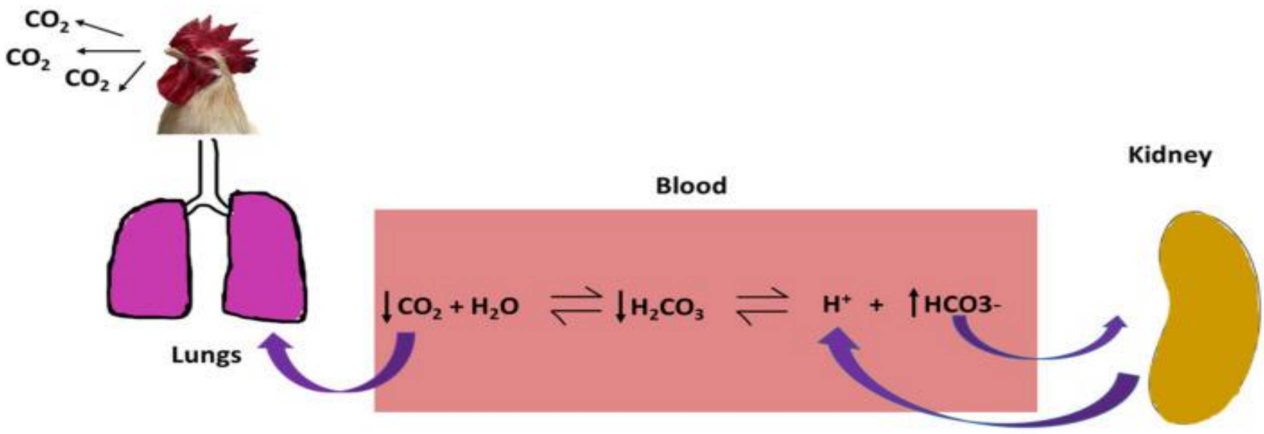
Reactive oxygen species (ROS) are free radicals and peroxides produced typically within the cells during regular metabolism. They are essential for many cellular processes such as cytokine transcription, immunomodulation, and ion transportation. The excess ROS produced within cells are eliminated by physiological detoxifying mechanisms present within the cells. During the thermoneutral condition, activation of transcriptional factor Nrf2 causes the additional synthesis of a group of antioxidant molecules, which deals with increased ROS produced inside the cell. However, due to the imbalance between these systems, either by higher production of ROS or by a decrease in the effectiveness of the antioxidant defense system, the cells are exposed to stress conditions commonly known as oxidative stress. Excess free radicals produced during oxidative stress damage all the components of the cells including proteins, lipids, and DNA. The oxidative stress in poultry is associated with biological damage, severe health disorders, lower growth rates, and economic losses.



Schematic diagram showing the redox system. (A) Normal condition, and (B) under heat stress.

B) 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 (HCO3−) 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 HCO3− and retain H+ from the kidney. The elevated H+ alters the acid-base balance leading to respiratory alkalosis and metabolic acidosis (Figure 3) and is associated with the decline in production performances of poultry.



Schematic diagram showing an acid-base imbalance in poultry under heat stress

C) Suppressed Immuno-competence

Heat stress is known to suppress immunity in the chicken. 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. Likewise, total white blood cell counts (WBC) are significantly lowered, whereas the heterophils to lymphocytes (H/L) ratio is higher in heat-stressed birds.

2) NEUROENDOCRINE CHANGES:

The neuroendocrine system plays a crucial role in maintaining homeostasis and normal physiological functioning of birds during heat stress. In birds, the sympatho-adrenal 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. The reduction of T3 concentration during heat stress is due to a decrease in peripheral deiodination of T4 to T3. There is also a difference in T3 secretion between selected breeds and native breeds. 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 birds. These hormonal changes are responsible for reduced growth performance and reproductive efficiency of hyperthermic birds.

3) 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.

These major physiological, neuroendocrine, and behavioral changes lead to increased mortality, decreased feed intake, reduced final body weight, decreased quality of meat and increased feed conversion ratio (FCR) in poultry. Thus, heat stress has been of paramount importance in the poultry industry considering global warming and economic losses.

NUTRITIONAL STRATEGIES TO MITIGATE HEAT STRESS IN BROLIERS

1) FEEDING STRATEGIES

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. restricting the availability of feed to 8 h a day during the hot periods in broilers improved feed efficiency and shortened tonic immobility; a measure to determine fearfulness in which birds are placed on its back for observing righting reflex.

a) 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. 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. However, this approach could not enhance growth and feed efficiency in heat-stressed birds.

b) 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. In broilers, wet feeding improved the feed intake, body weight, and weight of the GI tract. In laying hens, feeding of wet feed during the high temperature increased dry matter intake, egg weight, and egg production. Although this approach was found to have beneficial effects in heat-stressed birds, it is less common among poultry farmers, as there is a risk of fungal growth in the feed causing mycotoxicosis in the birds.

c) 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. 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. Adding fat at the level of 5% to the diet in heat-stressed laying hens was found to increase feed intake by 17%. Similarly, significant improvement in the broiler performance was observed when the 5% fat diet was provided.

d) SUPPLEMENTATION OF VITAMINS, MINERALS, AND ELECTROLYTES:

Vitamin E

Vitamin E (alpha-tocopherol) 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. Furthermore, Vitamin E also helps to improve immunity by inducing proliferation of lymphocytes.

Vitamin A

Vitamin A is 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. In broilers,

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supplementation of vitamin A (IU/kg of feed) was found to increase the live weight gain, improve feed efficiency, and decrease the serum MDA concentration in the heat-stressed birds.

Vitamin C

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. Vitamin C is also known to improve immunity by enhancing the differentiation and proliferation of T and B cells. 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. Dietary supplementation of vitamin C lowered the serum concentration of MDA, homocysteine, and adrenal corticotropin hormone in heat-stressed Japanese quail.

Zinc

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. Moreover, zinc is an integral component of carbonic anhydrase, the enzyme 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. 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.

Chromium

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. The organic form of chromium supplemented as chromium methionine was also found to improve the cellular and humoral immune responses in broilers during heat stress.

Selenium

Selenium is a vital component of atleast 25 different selenoproteins, most of which are the different parts of the enzymes, such as glutathione peroxidase and thioredoxin reductases. Type I deiodinase enzyme is one such enzyme that helps in the conversion of thyroxin into active triiodothyronine. 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. The organic forms are more easily absorbed than inorganic forms. Dietary supplementation of selenium (0.3 mg/kg of feed) is found to improve the live weight and FCR in broilers during heat stress. Similarly, supplementation of sodium selenite at 0.1 or 0.2 mg/kg of feed improved the carcass quality and performance of quails reared under high temperature.

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. 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. A higher range of dietary electrolyte balance (DEB), i.e., 200–300 mEq/kg, has been suggested to be effective in ameliorating the detrimental effects of heat stress in poultry.

e) Supplementation of Phytochemicals

Different types of phytochemicals have been supplemented in the diet to mitigate heat stress in poultry.

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. Supplementation of lycopene (200 or 400 mg/kg of feed) in heat-stressed broilers improved the cumulative feed intake, body weight, and FCR.

Resveratrol

Resveratrol is natural bioactive polyphenols mainly found in grapes, peanuts, berries, and turmeric. Resveratrol also improved different gut health parameters such as microbial profile, villus-crypt structure, and expression of the tight junction and adherence junction related genes in the heat-stressed broilers. Interestingly, resveratrol improved meat quality in the heat-stressed broilers by increasing the muscle total antioxidant capacity (T-AOC) and activity of antioxidant enzymes (catalase, GSH-Px).

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Epigallocatechin Gallate (EGCG):

Epigallocatechin gallate (EGCG) is the polyphenols present in green tea extract that possess high antioxidant and anti-inflammatory properties. Luo *et al.* (2017) used different dosages of EGCG in the feed (0, 300 and 600 mg/kg) of heat-stressed broiler birds where they found a linear increase in body weight, feed intake, and level of serum total protein, glucose and alkaline phosphatase activity in the heat-stressed birds.

Curcumin

Curcumin is the primary polyphenols extracted from turmeric and possesses antioxidant and anti-inflammatory properties. Zhang *et al.* (2018) found that the inclusion of curcumin at 100 mg/kg of feed significantly improved the final body weight in broilers under heat stress conditions. Curcumins fortification reduced the mitochondrial MDA level; reduced the ROS production by increasing the activity of Mn-SOD, GSH-Px, Glutathione S-transferase (GSST) and increased gene expression of thioredoxin-2 and peroxiredoxin-3 during heat stress in broilers.

f) 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 cell. Furthermore, betaine is also found to have anti-inflammatory properties and improves the intestinal function. During heat stress, supplementation of betaine ranging from 0.05–0.20% improved the feed intake, carcass trait, and egg production parameters in broilers, layers, and ducks.

Taurine

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. Supplementation of 0.1% taurine in the drinking water demonstrated significant improvement in the final body weight of chronic heat-stressed broilers. Moreover, expression of heat shock proteins was lowered in the taurine supplemented broilers indicating improved thermotolerance in these birds under heat stress.

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2) GENETIC APPROACH:

Improved broiler lines have a higher metabolic rate; as a result, they are more susceptible to heat stress. Thus, developing poultry lines incorporating some of the genes that help to reduce heat stress can be instrumental in further excelling the production traits of these breeds in the hot and arid areas.

3) HOUSING MANAGEMENT:

Naturally ventilated open-type housing is most common in the tropics, which should be oriented in the east-west direction. It has been observed that farmers used different local materials such as thatched and bamboo to insulate the roof. With the advancement of technologies, there has been a surge in the use of a closed house system for more intensive farming systems recently. Closed housed systems equipped with air conditioning, cooling pads, cool perches, and exhaust fans are found useful in attenuating the negative effects of heat stress in broilers.

4) OTHERS:

Some other strategies have been used to combat heat stress in poultry, such as early heat conditioning (EHC), early feed restriction (EFR), reducing stocking density of birds, and thinning the litter during summer seasons.

CONCLUSION:

With the rising global temperature, heat stress has been a severe challenge to the growth of the broiler industry. Heat stress in broilers 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. The potential use of proper nutrition, housing, and management should be beneficial in mitigating heat stress.

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