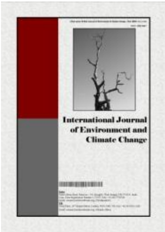

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Impact of Heat Stress on Chicken Performance, Welfare, and Probable Mitigation Strategies

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

The poultry industry globally provides chicken meat and eggs, the most significant protein sources among animal foods. The industry is grappling with the effect of climate change which causes heat stress and harms the performance and welfare of the chicken. Heat stress has been the most significant environmental stress challenging the global poultry industry, as chickens only tolerate a narrow range of temperatures during heat stress. This review aims to assess the impact of heat stress on chicken performance, welfare, and probable mitigation strategies to ameliorate its hazard. The study reviewed research papers of different authors and revealed that heat stress affects the chicken's performance, nutrition, and health. Heat stress reduces feed efficiency, body weight, feed intake, and egg production, as well as an increase chicken mortality. Some mitigation strategies farmers have employed include modifying the environment by providing adequate ventilation and cooling systems and adjusting their nutrition to help lower the body's metabolic heat output and keep electrolyte levels stable under high-stress, high-temperature circumstances. Therefore, there is a pressing need to study the extent of the resilience of native chicken breeds to the effects of climate change. Moreover, it is necessary to develop newer varieties of chicken, especially heat-tolerant breed lines, in response to climate change and the diverse need of the farmers and consumers.

Keywords: Climate change; heat stress; mitigation; poultry production; thermoneutral zone.

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1. INTRODUCTION

The poultry industry globally provides chicken meat and eggs, the most significant protein sources among animal foods [1,2]. In some areas of the world, poultry farming has a more significant impact on the livestock industry than other sectors [3,4]. Global chicken meat output increased 1.3% in 2018 to 123.9 million tonnes, while global poultry meat exports increased by 1.0% to 13.3 million tonnes in 2018 [5]. The demand for more excellent chicken protein sources around the globe is increasing due to the fast growth of the global human population over the past two decades, during which the poultry industry has experienced significant growth [6,7]. Climate change is hurting chicken performance and welfare, and the industry is struggling to adapt [8,9]. Heat stress, in particular, appears to be very dangerous for poultry in hot climates [3,10]. Stress from the combination of high temperature and high humidity is particularly detrimental to birds and results in poor performance [11,12].

Heat stress is the most significant environmental stress impacting global poultry production [11,13]. Due to the low heat tolerance of chicken genotypes, heat stress significantly impacts poultry birds' physiological, immunological, and gastrointestinal health, resulting in substantial economic losses [3,14]. Poultry production can be negatively impacted by the birds' exposure to high temperatures, as this can reduce egg output, diminish egg quality, and reduce bird weight [15,16]. Heat stress is responsible for several alterations in the body's physiology, such as oxidative stress, acid-base imbalance, and diminished immune function [8,5,17]. These changes contribute to a reduction in feed efficiency, body weight, feed intake, and egg production and an increase in chicken mortality [7,18]. Heat stress can also affect the quality of meat and eggs [19,7,1]. This makes climate changes a significant threat to the chicken's performance, health, and well-being, which may lead to a high economic loss for the poultry industry in the world [20,21]. Therefore, this review aims to assess the impact of heat stress on chicken performance, welfare, and probable mitigation strategies to ameliorate its hazard.

2. THERMONEUTRAL ZONE OF CHICKEN AND TEMPERATURE TOLERANCE RANGE

Similar to mammals, poultry is homeothermic, which means that their outer comfort zone (thermoneutral zone) ranges between l8ºC and 36^{o}C, but their interior environment (body temperature) remains generally constant [22]. The optimal temperature for the health and performance of chickens is within their thermoneutral zone [23]. The term "thermoneutral zone" describes the range of temperatures where birds can maintain a steady body temperature with the least effort [24]. The chicken has the least stress when the ambient temperature is within the thermoneutral zone [25,23]. When kept in this temperature range, birds don't have to work hard to maintain a consistent body temperature [26]. Birds' normal behavior varies when temperatures exceed their comfort zone, causing them to pant and shift their posture [27]. The lowest critical temperature (LCT) is the coldest point in the thermoneutral zone. Whenever the temperature drops below that threshold, the bird will begin to use its food as a heat source. The highest critical temperature (HCT) is the highest temperature in the thermoneutral zone. The birds will perish if the temperature climbs above that point because their bodies will overheat [28,29]. Between 36^{o}C and 37^{o}C is the highest critical temperature for broilers [30].

When the ambient temperature is within the thermoneutral range, the chicken is most at ease and operates at its best; if the temperature is above or below their thermoneutral, they get anxious [32]. The condition known as heat stress occurs when an organism, whether it be a person, a plant, or an animal, absorbs an excessive amount of heat, which can lead to anxiety, disease, or even death [33]. An animal feels heat stress when the quantity of heat energy it creates exceeds the amount of heat energy it loses to its surroundings [11]. This energy imbalance is affected by environmental elements such as sunshine, thermal irradiation, air temperature, humidity, and stocking density, as well as animal-related parameters such as body mass, feather distribution, dehydration status, metabolic rate, and thermoregulatory processes [11,34]. When the environment is above the thermoneutral zone, animals employ their thermoregulatory systems to release heat through behavioral, biochemical, and physiological responses [35,36]. Acute and chronic heat stress are the two basic kinds of heat stress. Acute heat stress refers to a brief and rapid increase in environmental temperature (a few hours), whereas chronic heat stress is characterized by prolonged exposure to high temperatures (several days) [37,26].

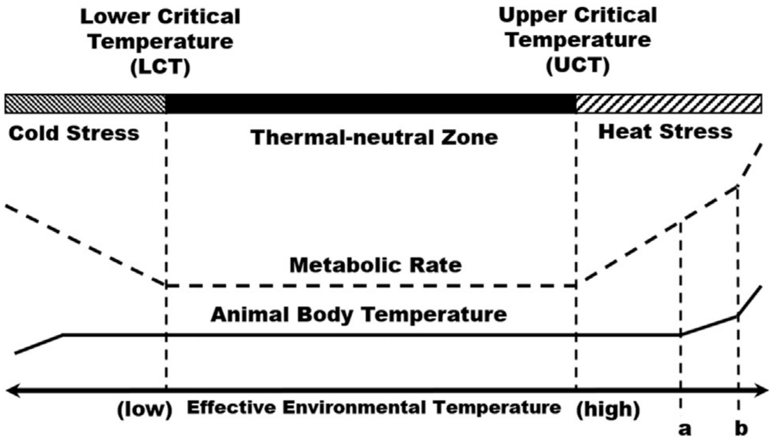

Fig. 1. Relationships between environment, body temperature, and metabolic rate. EET combines air temperature, humidity, airflow, conduction, and radiant heat. When the EET drops below the LCT, the animal shivers to create heat. When EET exceeds UCT, the animal pants, which boosts its metabolism. The thermal neutral zone is between the LCT and UCT. Above the UCT, panting can maintain body temperature until EET rises (a). At some point, EET and body temperature rise too much, causing spiraling hyperthermia (b) and mortality if EET is not decreased. Effective ambient temperature; lower critical temperature; upper critical temperature [31]

Symptoms of heat stress include a high core body temperature, lack of perspiration, and the onset of neurological conditions like paralysis, headache, vertigo, and unconsciousness [33].

During high ambient temperature of about 35.5^{o}C and relative humidity of 50-70%, the chicken starts to develop a panting mechanism to maintain homeothermy as this would allow a high rate of cooling from the respiratory tract through evaporation [30,22]. The animal dissipates heat primarily through conduction, convection, radiation, and evaporation [38]. The amount of heat a birds loses by radiation is proportional to its size [39]. When the external temperature matches or exceeds the body temperature, evaporation is the principal method by which chickens can cool themselves [40]. When moisture evaporates away from the respiratory tract of chickens, evaporative cooling occurs [40,39]. Evaporative cooling is required to stabilize the chicken's body temperature for efficient production [41].

3. EFFECT OF HEAT STRESS ON THE PERFORMANCE AND HEALTH OF THE CHICKEN

Chicken is highly vulnerable to climate change due to its low heat tolerance, affecting behavioral and physiological activities [42]. Birds try to dissipate heat during extreme heat and conserve heat during freezing temperatures; however, in both cases, birds need to expend much energy to maintain their bodies within their comfort zone [43]. To keep its internal temperature from rising above its external temperature, a bird experiencing heat stress will lower its food intake [42,44]. Heat stress in the chickens leads to a decrease in their feed intake due to the birds being outside their comfort zone as the birds tend to adjust to the changes in the environment [45]. The most damaging consequences of heat stress on chicken performance are likely to begin with, lower feed intake, which then result in decrease body weight, feed efficiency, egg output and quality [46,43].

According to research by Lara and Rostagno [11], feed consumption drops by 5% for every 1^{o}C increase in temperature between 32^{o}C and 38^{o}C. When the ambient temperature increases to 34^{o}C, the mortality due to heat stress would be very high in broilers by 8.4%, and the feed intake of the chicken decreases from 108.3g/bird/day at 31.6^{o}C to 68.9g/bird/day at 37.9^{o}C, the egg production would reduce by 6.4% [47]. Feed intake in broilers is reduced by 16.4% when they are subjected to chronic heat stress, and body weight is lowered by 32.64% [48,47]. Laying hens exposed to heat stress during 8-14 days, 30-42 days, and 43-56 days saw a decrease in egg production of 13.2%, 26.4%, and 57%, respectively [11]. Related research by Mashaly et al. [49] shows that laying hens exposed to chronic heat stress for five weeks have significant drops in egg production (28.8%), feed intake (34.7%), and body weight (19.3%). Deng et al. [46] found that after 12 days of heat stress, daily feed intake dropped by 28.58 g/bird, which led to a 28.8% drop in egg production. Heat stress in laying hens decreased feed conversion by 31.6%, egg production by 36.4%, and egg weight by 3.45%, as found by Star et al. [50]. According to a different set of researchers, Lin et al. [51] found that heat stress led to poorer production performance, thinner eggshells, and more egg breaking. Ebeid et al. [52] also found a drastic decrease in the egg weight (-3.24%), eggshell thickness (-1.2%), eggshell weight (-9.93%), and eggshell percent (-0.66%) when birds are exposed to high temperatures. As previously mentioned, Mack et al. [53] found that heat stress caused a reduction in egg output, egg weight, and eggshell thickness in laying hens. Since chickens drink more water and eat less feed when temperatures and sunshine are high, heat stress can hurt the quantity and quality of eggs and meat produced by chickens [54].

Thyroid hormones (3,5,30-triiodothyronine and thyroxine) play an essential function in regulating the metabolic rates of birds during the development and egg-laying periods [55]. The synchronization of thyroid gland activity is essential for regulating body temperature and maintaining homeostasis in poultry via energy metabolism [56]. Due to heat stress, the thyroid hormones of broiler chickens are negatively impacted. The drop in thyroxine concentrations leads to a decrease in protein synthesis, which reduces body weight and daily growth [57]. Due to a loss of appetite and a drop in feed consumption, birds exposed to high ambient temperatures have a decline in growth [58]. Corticosterone, the primary glucocorticoid hormone in chickens, regulates appetite and thermogenesis [59]. Increased amounts promote brown tissue aggregation and white tissue lipogenesis, impairing metabolism [59]. Under heat stress conditions, an increase in blood serum cortisol levels stimulates the gluconeogenesis pathway, leading to a rise in blood glucose concentration [60].

Beckford et al. [31] reported that heat stress reduced feed intake, body weight, bicarbonate, potassium, carbon dioxide, and triiodothyronine while increasing mortality, glucose, pH, plasma thyroxine, and corticosterone. In birds experiencing heat stress, expression of corticotropin-releasing hormone receptor 1 was downregulated, but corticotropin-releasing hormone receptor 2 mRNA levels were elevated. Heat stress elevated the expression of thyroid hormone receptor β (2.8-fold) and thyroid stimulating hormone β (1.4-fold) [31]. Heat stress generates unfavorable physiological reactions and adverse effects on blood biochemical parameters, the immune system, oxidative state, thyroid hormones, mineral balance and osmoregulation, and intestinal and ileal microbiome [36]. According to Lin et al. [61], acute heat exposure (32°C, 6h) produces oxidative stress in 5-week-old broiler chicks. Increased body temperature can generate metabolic alterations associated with oxidative stress [36,61]. Oxidative stress happens when the number of reactive oxygen species (ROS) in the body exceeds the antioxidant capacity of the cells [26]. As a defense mechanism against many stresses, oxidative stress has become a significant factor in poultry production [26,36]. The efficiency with which cells generate energy is decreased, and proteins, lipids, and DNA are all damaged by oxidative stress [26]. Oxidative stress causes an increased intestinal permeability due to tissue damage in the digestive tract causing toxins and infections to enter more easily into the bloodstream from the intestines [61]. The liver is more vulnerable to oxidative stress than the heart in broiler chickens [61].

4. INTERACTION OF HEAT STRESS WITH COCCIDIOSIS AND NECROTIC ENTERITIS

Climate change alters the global disease distribution and the emergence of poultry diseases [54,62]. Typically, birds reduce feed intake in hot environments to reduce heat production from metabolism, but reduced feed intake leads to watery droppings and diarrhea, significantly reducing body weight [11]. Heat stress affects the feed intake of the chicken and lowers the immune system of the chicken, which makes the chicken vulnerable to many poultry diseases [63]. Heat stress increases corticosterone release in hens, reducing the birds' resistance to other diseases like coccidia and putting them at risk for necrotic enteritis [64]. Both the quantity and activity of commensal bacteria may be altered due to decreased feed intake and weakened intestinal function [54]. Beneficial microbe populations can decrease under the stress of heat [47]. It can also promote the growth of latent pathogens and lead to dysbiosis, augmented intestinal penetrability, and immune and metabolic disorders [65]. Clostridia, Salmonella, and coliform bacteria populations rise in heat-stressed chicken, whereas Lactobacilli and Bifidobacterial populations decrease [66,67]. Coccidiosis, hemorrhagic syndrome, fowl pox, and bronchitis are only some diseases that can spread rapidly in chicken flocks due to changes in temperature and humidity [68]. High winds can further disperse airborne diseases in poultry flocks [69].

Oviedo-Rondón et al. [70] reported that intestinal health significantly impacts poultry productivity, animal welfare, and food safety. Immunosuppression and damage to the gut microbiota, intestinal integrity, and villus shape are caused by heat stress, and consequently, digestion and absorption of feed decrease [71,35]. These variables enhance the likelihood of epidemics of necrotic enteritis, which is one of the most troublesome bacterial infections in contemporary chicken farming [72]. In broilers challenged with C. perfringens, researchers Tsiouris et al. [73] discovered that cyclical acute heat stress enhanced the incidence and severity of necrotic enteritis and induced the disease in birds not exposed to the bacteria. Heat stress manifested itself in a variety of ways in the birds, including delayed development and a drop in the pH of the intestinal digesta [35,3]. Heat stress increases the need for antibiotics because it reduces feed digestibility, increases gut permeability, and decreases immunity, all of which increases the risk of gastrointestinal diseases such as dysbacteriosis and nectrotic enteritis in chickens [54,44,47].

5. STRESS RESPONSE BY CHICKEN DUE TO HEAT STRESS

Birds are homeothermic, meaning their internal temperatures stay within a relatively constant range [39]. High temperatures reduce the bird's ability to disperse heat. It happens when heat is brutal to evaporate quickly [74]. The optimum temperature range differs significantly among bird types and age ranges [75]. Observable differences can be attributed to natural factors and avian diversity [39,76]. The bird and its surroundings can undergo radiant heat transfer if its surface temperature differs from the surface it is resting on or the ambient air temperature [39,76,75]. The comb, wattles, face, legs, toes, neck, torso, and wings produce convection by radiating heat into the ambient air [39,75]. The comb and wattles contribute 34% of the total Sensible heat loss at 35°C [77]. Heat loss by convection and radiation can also rise dramatically with wind speed [39]. The increased air velocity further exposes the skin, which may enhance radiation losses [39,78]. Changes in heat dissipation from non-evaporation to increased evaporation occur as the surrounding temperature rises [79]. To a large extent, birds cool themselves by increasing their breath rate, a process known as panting; in fact, this form of enhanced respiration can account for as much as 60% of the total heat loss in some species [78,77]. Dehydration can develop due to the loss of water that occurs during the evaporation process. Thermo-tolerance at greater ambient temperatures is enhanced by drinking enough water, which aids in heat loss [39,75].

When temperatures soar, birds attempt thermoregulation by adjusting their behavior and physiological balance [79,80]. When faced with high environmental temperatures, animals employ various strategies for thermoregulation and homeostasis, including enhancing radiative, convective, and evaporative heat loss through vasodilation and perspiration [11]. Most bird species respond equally to heat stress, while there is some individual disparity in the severity and length of responses [39,11]. Mack et al. [53] stated that birds in heat stress eat less, drink and pant more, stand still or rest with their wings raised more often, and move or walk less frequently. Air sacs are an additional means through which birds facilitate heat exchange with their surroundings [39]. During panting, air sacs are helpful because they increase the surface area exposed to air, which increases gas exchanges with the air and, in turn, increases the rate at which heat is lost by evaporation [81]. Local chickens displayed a behavioral coping mechanism during heat stress by moving into the shade [82,43]. Although this considerably reduces radiant heat load, actively seeking shade during the day may imply poor feed intake, especially for rural poultry, which relies primarily on scavenging around homesteads [82].

6. EFFECT OF HEAT STRESS ON THE NUTRITION AND PHYSIOLOGY OF THE CHICKENS

Since different species have different thermal comfort zones, defining what constitutes a "high" environment temperature is a matter of degree [83]. An animal will feel heat stress if the environmental temperature exceeds its thermo-neutral zone [84,83]. When this occurs depends not just on the relative humidity and air speed but also the surrounding temperature [84]. As the birds' thermal stress rises at higher temperatures, their appetite and metabolism are negatively impacted, limiting the temperature range in which their output is at its peak [44]. Increased environmental heat causes changes in hydration and nutrition intake, metabolic rate, core temperature, heterophil/lymphocyte (H/L) ratio, and gastrointestinal tract (GIT) maturation. Some enzymes, for instance, wouldn't work as effectively in hotter temperatures, limiting birds' ability to eat and digest [54].

When the temperature increased from 32.2^{o}C to 37.8^{o}C, feed intake decreased by 9.9% per bird per day compared to the intake at 21.1^{o}C, and the chicken will drink four times as much water at 38^{o}C as it does at 21^{o}C due to the higher ambient temperature [85]. Chickens drink roughly 7% more water for every degree over 21°C [86]. Increasing the bird's water intake may help it by increasing the efficiency of its cooling system, which relies on evaporation [77]. Thus, water plays a vital role in the metabolism of chickens by helping regulate body temperature, digestion, feed absorption, and nutrient delivery [87]. Heat stress is associated with decreased feed intake, which may lead to less overall body weight gain if water intake is also reduced [88]. Gains in weight were lower in the high-temperature group of chickens compared to the average-temperature group [88,87]. Heat stress negatively impacts the nutrition of chicken which is a severe problem for the poultry industry as optimal nutrition intake and use are crucial to weight gain and egg production, which drive poultry enterprise productivity and profitability [89].

7. POTENTIAL PREVENTIVE MEASURES OF HEAT STRESS IN CHICKEN

7.1 Feeding Approaches

Climate change's impact on chicken production is just one more difficulty that poultry farmers face in an already challenging sector [90]. Heat stress can be reduced through several measures related to environmental control, dietary modification, feed additive use, and electrolyte additions to drinking water [11,90]. In high-temperature stressful settings, it may be possible to lower metabolic heat generation and maintain electrolyte balance by modifying the chickens' surroundings with the addition of ventilation, cooling devices, and dietary changes [11]. In contrast, chicks can improve their thermo-tolerance and thus their survival rate under heat stress through early-age heat conditioning and regulated fasting in the first few days of life [3].

Changes in energy-to-protein ratio, wet feeding, electrolyte supplementation, feeding time, drinker type, and height are only some feeding management methods shown to boost performance in the face of heat stress [91]. Based on their findings that heat stress can cause hyperthermia in poultry, Syafwan et al. [77] advise free-choice feeding with high-protein or high-energy diet options. The bird's free-choice food must contain a variety of particle sizes or shapes. A big particle size aids in the maturation of the GIT, particularly the gizzard and the caeca. The amount of heat generated by digestion could be reduced if birds had large gizzards, as this would allow for more efficient grinding and possibly better digestion further down the GIT [77,3]. The chicken may be able to self-select its diet in such a way that it optimizes the heat load associated with the metabolism of the nutrients it consumes [92,77].

The local poultry farmers employ traditional procedures, such as early stocking of birds, increased litter changes during the hot period, and the maintenance of native bird breeds [93,94]. Rajkumar et al. [94] suggested that the naked neck birds fared much better in terms of growth, carcass, and metabolic markers at high ambient temperatures. The lower feather bulk of the naked-necked birds allows for more efficient heat dissipation, making them more resistant to the effects of heat stress. Nyoni et al. [82] also stated that using genetics and adaptation, and native breeds may do better than foreign ones in a warmer world.

7.2 Supplementation of Vitamins, Minerals, and Electrolytes in the Chicken Diet

Nutritional solutions have been extensively examined and proven to mitigate the adverse effects of heat stress. These include limiting feed intake, wet or dual feeding, increasing fat intake, and supplementing with vitamins, minerals, osmolytes, and phytochemicals [89]. Alpha-tocopherol, often known as vitamin E, is a fat-soluble vitamin with antioxidant characteristics that aid in the detoxification of harmful free radicals produced inside cells [95]. Adding vitamin E to the diets of laying hens under heat stress increases egg production, eggshell thickness, egg-specific gravity, and the Haugh unit [96]. As it aids in creating and releasing protein-vitellogenin, the liver is a crucial organ for egg development [97]. In heat stress circumstances, supplementation with vitamin E (250 mg/kg of feed) decreases liver and serum malondialdehyde (MDA) concentration and increases serum and liver vitamin E and A concentration [98]. At low oxygen pressures, vitamin A is the most efficient antioxidant, quenching singlet oxygen and neutralizing thiyl radicals [99]. Treatment with vitamin A (IU/kg of feed) in heat-stressed broilers increased live weight growth, improved feed efficiency, and decreased blood MDA levels [89].

Vitamin C, an antioxidant, prevents damage to cells caused by oxidative stress by scavenging reactive oxygen species (ROS), neutralizing hydroperoxyl radicals that are vitamin E dependent, and protecting proteins from alkylation and electrophilic lipid peroxidation products [100]. Vitamin C (250 mg/kg of feed) improved growth rate, food utilization, egg production and quality, immune response, and antioxidant status in birds exposed to heat stress [101]. Supplementing broiler feed with 200 mg of ascorbic acid per kg boosted growth and FCR [102]. According to Sahin et al. [103], supplementing with either vitamin C or chromium led to better live weight gain, feed efficiency, and carcass traits and reduced blood corticosterone and MDA concentrations. According to Mahmoud et al. [104], supplementing broilers' diets with 250 mg/kg of propolis, vitamin E, or vitamin C helps mitigate the oxidative damage caused by heat stress. Sujatha et al. [105] found that oxidative stress in broilers might be alleviated throughout the summer by employing antioxidant synthetic vitamin C and the polyherbal anti-stressor, immunomodulator, and adaptogenic feed premix. According to Selvam et al. [106], Phytocee supplementation has an anti-stress impact on hens by bringing their serum corticosterone levels and thermoregulatory systems back to normal.

There are around 300 enzymes that can't function without zinc. Antioxidant defense, immune system health, and proper skeletal growth are all bolstered by zinc's presence in the body [107]. Zinc is necessary for synthesizing the free radical scavenger metallothionein [108]. Zinc supplementation helps to reduce free radical formation since it is a component of antioxidant enzymes such as superoxide dismutase, glutathione, glutathione S-transferase, and hemeoxygenase-1 [109]. Heat-stressed quails given zinc and magnesium significantly increased live weight, feed intake, and hot and chilled dressing percentage [110]. Zinc supplementation in the form of Zn-methionine (80-100 mg/kg of diet) increased eggshell thickness and decreased defects in laying hens [111,112].

Chromium is a vital mineral because it is a constituent of chromodulin and helps insulin work properly [113]. Adding 0.4-2 mg of chromium/kg of feed as CrPic to a laying hen's diet improved her immune response, egg quality, and Haugh unit while lowering her blood sugar, cholesterol, and triglyceride levels [114,115]. Selenium is a component of at least 25 selenoproteins, including glutathione peroxidase and thioredoxin reductases [116]. Inorganic and organic selenium is used as poultry supplements [117]. The organic versions are more absorbable than their inorganic counterparts [118]. Selenium improves laying hens' and quails' fertility [119]. Under heat stress, selenium supplementation (0.15-0.30 mg/kg of feed sodium selenite or selenomethionine) increased feed intake, body weight, and egg production in laying quails [120]. Organic and inorganic selenium increased Haugh units and eggshell weights [89].

When birds are under extreme heat stress, they pant, which alters their blood's acid-base balance and causes them to develop respiratory alkalosis. This can be restored using electrolytes like NH_4Cl, $NaHCO_3$, and KCl [121]. It has been found that heat stress in chickens can be reduced by providing a more variable dietary electrolyte balance (DEB) [122]. Under high temperatures, sodium bicarbonate ($NaHCO_3$) is the salt of choice [123]. Incorporating this salt into the diets of heat-stressed broiler chickens improved their performance [124]. Ingestion of 1.5–2.0% K from KCl improved FCR under conditions of chronic heat stress. In addition to including these salts in the diet, supplementing drinking water with 0.2% NH_4Cl, 0.150% KCl, and carbonated water enhanced chicken performance [61].

The diet helps alleviate heat stress. Diets are supplemented with feed additives to reduce heat stress in poultry [11]. Poultry nutritionists are becoming increasingly interested in probiotics because they can improve the health and productivity of heat-stressed chicken by influencing its physiology, gut shape and structure, and immune function [125]. By supplementing the broiler diet with probiotics, researchers saw dramatic increases in feed consumption, daily growth, total body weight, intestinal absorption, and immunity [46]. By controlling corticosterone levels and the overproduction of pro-inflammatory chemicals that cause intestinal tissue damage and increased tissue permeability in heat-stressed birds, probiotics can aid in repairing villus-crypt structures [126]. Birds grown in high-temperature environments benefit from probiotics because they improve gut microbial ecology and morphology, physiological conditions, the immune system, and overall performance [46].

8. CONCLUSION

Heat stress is responsible for many physiological changes, including oxidative stress, acid-base imbalance, and suppressed immunocompetence. These changes contribute to an increase in mortality and a reduction in feed efficiency, body weight, feed intake, and egg production. Heat stress also has an impact on the quality of meat and eggs.

Therefore, rural poultry may have a higher level of heat tolerance than commercial breeds, but the extent of their tolerance threshold to temperature variation is unknown and requires urgent attention. Breeding projects to improve the climate resilience of native birds should also be promoted. Moreover, it is necessary to develop newer varieties of chicken, especially heat-tolerant breed lines, in response to climate change and the diverse need of the farmers and consumers. Finally, a well-planned and carried-out adaptation response system for the poultry industry will raise enough awareness and adaption to extreme climate circumstances.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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