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Adverse effects of tropical climatic conditions on broiler chickens, and possible measures to mitigate them: A review

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Abstract

There is a growing need for animal protein, in order to meet the nutritional demands of people in various parts of the world. This has led to an increase in the level of poultry production, as domesticated birds, such as chickens, are an excellent source of eggs and meat. However, while these birds have been genetically improved for better growth and performance, they are highly vulnerable to extreme climatic/weather conditions, particularly in tropical regions. Broiler chickens may often be raised in hot and humid environments and during the dry season. When the ambient temperature and relative humidity levels are high, broiler chickens can become heat-stressed, and this can adversely affect their health and productivity. Heat stress is commonly associated with oxidative stress due to the over-production of reactive oxygen species and lipid peroxides. To mitigate the negative effects of tropical climatic conditions, various strategies such as anti-oxidant supplementation, certain management techniques, early age conditioning and gene manipulation can be employed. Over a long period, farmers have supplemented the diets of broiler chickens with anti-oxidants, such as ascorbic acid and betaine. It has been shown that dietary manipulation is an affordable means to ameliorate heat stress in broiler chickens. Additionally, other management practices are being employed to mitigate the adverse effects of heat stress induced by tropical climatic conditions. Modifying the design of housing systems and provision of ventilators has contributed to improvements in heat stress management. Scientists have also been able to improve the genes, which enhance thermotolerance in broiler chickens. The present review article documents the adverse impacts of tropical environmental conditions on broiler chickens, and also highlights the various approaches utilized in poultry management to ameliorate these adverse environmental conditions.

Keywords: Tropical climate; Broiler chickens; Adverse environmental conditions; Heat stress; Amelioration.

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Introduction

Over the past two decades, there has been a significant increase in the level of broiler production in countries with hot climates (Vandana *et al*., 2021). The rapid growth of commercial broiler chickens is associated with decreased ability to tolerate high ambient temperatures (heat stress) (Khan *et al*., 2023). Heat stress negatively impacts on the production performance of poultry, and results in decreased feed intake, growth rate and feed efficiency, poor immunity, and increased economic losses due to bird mortality (Wasti *et al*., 2020). Therefore, it is essential to improve the thermotolerance of broiler chickens produced in hot climates. Maintaining homeostasis is crucial for broiler survival under harsh conditions (Nawaz *et al*., 2021). To mitigate the adverse effects of tropical climatic conditions on the growth and performance of broiler chickens, it is necessary to understand and control environmental conditions (Nawab *et al*., 2018). This review article evaluated the effects of tropical climatic conditions on broiler chicken production and suggested solutions to minimize the negative impact on the birds.

Significance of Broiler Chicken Production

The global livestock production, which also includes broiler chicken production, is constantly changing (Mottet and Tempio, 2017). In developing countries, it is evolving to meet the increasing demand for livestock products (Herrero *et al*., 2013). The demand for these products has been driven by factors such as human population growth, income growth, and urbanization (Thornton, 2010).

Broiler production has advantages over the production of other livestock, because of the ease with which broilers can be managed, the high turnover, and their wide acceptance for consumption (Haque *et al*., 2020). Poultry meat is affordable (Martínez Michel *et al*., 2011), and production of broiler chicken is profitable due to its positive net return on investment (Gbigbi, 2021). The major factors that make it attractive are its relatively low and competitive price compared to other meats, the absence of cultural or religious obstacles, and its dietary and nutritional (protein) composition (Magdelaine *et al*., 2008). Broiler production is a valuable asset to local populations as it contributes significantly to food security, poverty alleviation and the promotion of gender equality (Alabi *et al*., 2020).

Agriculture contributes 35% to Nigeria's gross domestic product (GDP), with the poultry sub-sector contributing about 25% of the total livestock and fisheries share (Adeyonu *et al*., 2021). Poultry production is more established in the south-west, but investments are increasing in the North West and North Central (Adeyonu *et al*., 2021). Nigeria's per capita consumption of chicken meat is low, with an average of 1.9 kg per year, compared to other countries (Akpan and Nkanta, 2022). However, it is anticipated that economic growth will lead to an increase in consumption. The competition among animal protein sources is high, but there is a large market for poultry products (Mottet and Tempio, 2017). Nigeria's current per capita consumption is 65 eggs and 1.9 kg of poultry meat per year, which is low compared to the global average (Ayojimi *et al*., 2020). However, it is expected that poultry meat consumption will increase due to the growing middle class. The consumption of eggs however, is not expected to change significantly (Henchion *et al*., 2021).

Climatic Conditions in the Tropics and Broiler Production

The tropical climate is distinct for two reasons. Firstly, the sun shines more directly on the tropics than at higher latitudes, making the tropics warmer (Parkes *et al*., 2022). Secondly, the vertical direction at the equator is perpendicular to the earth's axis of rotation, while the axis of rotation and the vertical are the same at the pole (Halilovic *et al.*, 2022). This results in the earth's rotation influencing the atmospheric circulation more strongly at high latitudes (Hammond and Lewis, 2021). As the temperature rises, the amount of water vapor that the air can hold without condensing also increases (Al-Ghussain, 2019). Since the sun shines strongly on the tropics, particularly on warm oceans, which have an infinite amount of water to evaporate into the air, the overlying atmosphere becomes very humid (Al-Ghussain, 2019). The wind patterns move from west to east, taking a month or two to complete a cycle. The cycles are not entirely regular, and within a rainy or dry period, the weather may differ from what is prevalent during that period (Ogunrinde *et al*., 2020).

Livestock production, including broiler chicken production, in tropical countries faces the challenge of heat stress, especially during the warmer periods of the year (Vandana *et al*., 2021). The tropical climate may affect broiler production, especially where there are heat waves, which may induce heat stress and lead to high mortality (Nyoni *et al*., 2019). Heat wave prediction and characterization may, however, allow actions to be taken to mitigate the adverse effects early (Baldwin *et al*., 2019). In the tropics, the diurnal fluctuations in ambient temperature usually exceed the thermoneutral zone of chickens. Thermal comfort indices such as the temperature-humidity index (THI) integrate the effects of temperature and humidity and may offer a means to predict the effects of thermal conditions on performance (Omomowo and Falayi, 2021). The influence of thermal environmental factors, especially during transportation and lairage at slaughterhouses in hot regions, is due to high ambient temperature and relative humidity (Dos Santos *et al*., 2020). These negatively impact the survival of broiler chickens. Although, birds may tolerate narrow temperature ranges, they are vulnerable to climate changes (Pollock *et al*., 2021).

Thermoneutral Zone for Broiler Chickens

It has been reported that it is important to take into account the microclimate within broiler houses and monitor the rearing environment data to ensure better environmental control during broiler grow-out (Martinez *et al*., 2021). Values beyond the recommended ranges can indicate that broilers are experiencing thermal distress (Dedousi *et al*., 2023). High temperatures can result in reduced feed intake, leading to impaired live performance as the dietary energy is used to maintain the birds' body temperature rather than converting feed into meat (Nawaz *et al*., 2021). Studies by Hassanzadeh *et al*. (2019) have shown that broilers reared above the temperature of thermal comfort during the first week of their lives may experience metabolic disorders such as ascites syndrome and sudden death syndrome.

The thermoneutral zone is the range of ambient temperature that does not affect regulatory changes in metabolic heat production or evaporative heat loss in birds (McKechnie, 2021). The thermoneutral zone for poultry in the tropics is between 18 – 24°C (Ribeiro *et al*., 2020), while the ideal temperature range for poultry is between 19 – 26°C (Kic, 2016). Al-Fataftah and Abu-Dieyeh (2007) reported that ambient temperatures above 25°C can adversely affect the performance of 4 – 8-week-old broilers reared in open-sided poultry houses, and Purswell *et al*. (2012) have further reported that if the temperature-humidity index (THI) exceeds approximately 21°C, bird performance significantly declines, and their body temperature can increase up to 1.7 °C above the normal body temperature for broilers (41°C).

Responses of Broiler Chickens to Heat Stress

Heat stress can lead to various adverse effects on broiler chickens. It can elicit physiological, behavioral and thermoregulatory responses, with increased oxidative damage and alterations in amino acid concentrations in the diencephalon (Bohler *et al*., 2021). High temperatures can lead to decreased feed consumption and increased water consumption. Heat stress also influences some gastrointestinal tract peptides, such as ghrelin and cholecystokinin (CCK), which may regulate appetite (Mazzoni *et al*. 2022). The reduction in broiler weight gain, and consequently decreased productivity, is another consequence of high temperatures. Heat stress can also lead to the deterioration of meat quality, and lead to paleness and softness of broiler carcass (Nawaz *et al*., 2021).

Heat stress has been reported to have detrimental effects on the microstructure of the gut of broiler chickens (Rostagno, 2020). It (heat stress) reduces villus height, crypt depth, and surface area in the duodenum and ileum, and increases crypt depth in the ileum (Bogusławska-Tryk *et al*., 2020).

High ambient temperatures increase the endogenous production of free radicals, leading to oxidative stress and a reduction and exhaustion of antioxidant enzymes, which can result in cellular injury or death (Engwa *et al*., 2022). During heat stress, mitochondrial reactive oxygen species (ROS) production may increase, due to changes in respiratory chain activity, as well as avian uncoupling protein (avUCP) expression in skeletal muscle mitochondria (Toyomizu *et al*., 2019). The incidence and subjective degree of myodegeneration characterized by loss of cross striations, myocyte hyper-refractility, sarcoplasmic vacuolation, and nuclear pyknosis or loss has also been reported to increase in hot conditions (Joiner *et al*., 2014).

Furthermore, heat stress can lead to a weakening of the defense mechanisms of birds, resulting in immune suppression. Elevated ambient temperature negatively affects production, reproductive potentials, immune responses, and health status of livestock, including broilers (Wasti *et al*., 2020). The hypothalamic-pituitary-adrenocortical axis is a major neuroendocrine system involved in the regulation of numerous physiological processes and in adaptation to stress (Herman *et al*., 2016). It has been posited that stress-induced hypothalamic-pituitary-adrenal axis activation is responsible for the negative effects observed on chicken performance and immune function, as well as for changes in the intestinal mucosa (Ahmad *et al*., 2022).

Thermoregulation and Mechanisms for Heat Dissipation/Exchange

Broiler chickens respond differently to various durations of acute heat stress, leading to distinct physiological changes over time (Gogoi *et al*., 2021). Heat stress can cause hyperthermia in poultry, which can be reduced by increasing the chances of heat dissipation, decreasing heat production or changing the thermal production pattern throughout the day (Chen *et al*., 2021). Brain nitric oxide can modulate heat stress-induced hyperthermia in poultry (Uyanga *et al*., 2021). However, poultry is particularly susceptible to heat stress due to their inability to sweat, with convection and respiration being key methods of heat dissipation (Vandana *et al*., 2021). The ability of broiler chickens to regulate their temperature through convection and radiation decreases as they mature (Tickle and Codd, 2019).

Broiler chickens adjust their behavior in response to daily temperature variations. Wing-spreading and beak-opening are crucial adaptations to thermal environments (Gonçalves *et al*., 2020). Panting and drooping of wings are effective methods of heat loss, with panting being the dominant method as air temperature approaches or exceeds body temperature in birds (McKechnie, 2021). Heat stress exposure in broiler chickens also results in sitting or lying down, and a decrease in feed intake (Khan *et al*., 2023). Plasma levels of triiodothyronine (T3) and triglycerides decrease in broiler chickens as part of their thermoregulation mechanisms (Badakhshan *et al*., 2021). Glucocorticoid hormones released by the adrenal cortex play a vital role in stress responses, including protein catabolism for energy production and storage, as well as affecting metabolism, the cardiovascular system, inflammatory processes, and brain function, to promote adaptation and survival under strong environmental pressure (Lin *et al*., 2021).

Biomarkers of Heat Stress used in Measuring Broiler Chicken Responses to Heat Stress

Heat stress levels can be estimated using the heterophil: lymphocyte ratio (Gogoi *et al*., 2021). This ratio has been reported to be a reliable tool for evaluating the ability of the chickens to cope with stress, making it important for production and selection of good reproduction traits (Perini *et al*., 2020). The cloacal temperature of the chickens is an important parameter to determine their comfort status, and can be used to turn on acclimatization systems (Abioja and Abiona, 2021). Heat shock proteins are associated with acquired and maintained thermoresistance in broiler chickens, while thermography can be considered a useful method in measuring skin temperature as a welfare indicator in poultry production (Reis *et al*., 2022). Broiler chickens exposed to heat stress may experience elevated brain and hepatic levels of heat shock protein 70, as well as brain peptides (Goel *et al*., 2021).

Evaluating body surface temperature can be used to determine thermal equilibrium in animals (Pollock *et al*., 2021). However, as the bodies of broiler chickens are partially covered in feathers, the heat flow at the boundary layer differs between feathered and featherless areas (Kim and Lee, 2023). Exposure to acute heat stress can result in decreased monocyte and lymphocyte proportions, while maintaining water and electrolyte balances are considered important factors affecting the survivability and productivity of broiler chickens (Roushdy *et al*., 2020). When exposed to high temperatures, birds increase their respiratory rates to dissipate heat by evaporation, leading to higher losses of carbon dioxide and increased blood pH (Habibu *et al*., 2019). The acid-base balance is further disrupted by the increased electrolyte excretion through urine and feces (Chen *et al.*, 2022). Blood levels of pCO2, sodium and potassium ions are decreased, but HCO_3 levels are increased (Popoola *et al.*, 2020). Heat-stressed broiler chickens also have higher serum levels malondialdehyde (Egbuniwe *et al*., 2016; 2018).

Measures for Mitigating Thermal Stress in Broiler Chicken Production

Broiler chickens experience an increase in growth rate and heat production, making it necessary to find a cost-effective way to help them adapt to hot climates (Biswal *et al*., 2022). A study by Juiputta *et al*. (2023) suggested that improving the birds' thermotolerance is essential in achieving this goal. To prevent hyperthermia caused by heat stress in poultry, several measures can be taken, including reducing the thermal load by increasing dissipation potentials, lowering heat production levels, or altering the daily heat production pattern (Onagbesan *et al*., 2023). Possible measures to mitigate the negative effects of heat stress include anti-oxidant supplementation, certain management strategies, early age conditioning and gene manipulation.

Anti-oxidant Supplementation: Supplementation with anti-stress agents in poultry is commonly used to reduce the negative effects of stress, particularly heat stress (Abdel-Moneim *et al*., 2021). Anti-oxidants are also used in poultry feed to mitigate the effects of environmental stress, as they are known to have anti-stress benefits (Surai *et al*., 2019). Anti-oxidants can help decrease meat quality deterioration caused by lipid peroxidation and stabilize meat oxidation after slaughter (Amaral *et al*., 2018). Studies have shown that a combination of vitamins C and E provides better protection against heat stress in coloured broiler breeder hens than individual administrations (Egbuniwe *et al*., 2018; Ayo *et al*., 2022). Additionally, the combination of ascorbic acid with glucose in drinking water can alleviate the effects of high ambient temperature on broilers during the grower and finisher stages of growth (Gouda *et al*., 2020). The administration of vitamin C, chromium, and their combination may also prevent heat stress-related depression in broiler chicken performance, protecting them from the adverse effects of heat stress (Al-Sultan *et al*., 2019). Supplementation with dietary vitamin E and vitamin A has been shown to be an effective management practice to reduce heat stress-related decreases in broiler performance (Selvam *et al*., 2017). It has also been reported that supplementation with zinc and vitamin A, either alone or in combination, can prevent heat-stress-related depression in the liveweight of broiler chickens (Akinyemi and Adewole, 2021).

Management strategies: Studies by Soliman and Safwat (2020) have shown that feeding broilers with a diet rich in protein before the hottest hours of the day can help reduce heat production peaks, facilitate evaporative activity and decrease the heat load. This has beneficial effects on the performance and health of birds kept in tropical areas worldwide (Soliman and Safwat, 2020). Also, providing broilers with free access to low-density diets has been suggested as a strategy to improve their performance in tropical environments (Sánchez-Casanova *et al*., 2022). Dietary supplements such as mannan-oligosaccharide and lactobacillus-based probiotics have been used to alleviate cyclic heat stress in broilers (Cheng *et al*., 2019). Feed restriction can enhance birds' thermotolerance, and is one of the most promising management methods for improving the heat resistance of broiler chickens in the short term (Abdel-Moneim *et al*., 2021). Administering electrolytes during the summer has been shown to improve feed conversion in broilers. Supplementation with electrolytes, either through drinking water or feed, has been found to correct blood acid-base balance and had been proven to be beneficial for broilers under different heat stress regimens (Rahman *et al*., 2020). More recent reports by Krishnan *et al*. (2023) have shown that an air velocity of 2.0 m/s within the poultry house enabled broilers to maintain proper performance, thermoregulation, and water balance under harsh environmental conditions.

Early Age conditioning: Studies have shown that acclimation can help protect birds from heat stress induced mortality caused by acute heat waves until they reach marketing age (Madkour *et al*., 2022). Also, recent findings by Goel *et al*. (2023) suggest that thermal manipulation of the embryo can have a long-term effect on the physiology of broilers and may be a possible means of improving their heat tolerance. Robertson *et al*. (2020) had reported that by modifying the central thermoregulation system, bird's responses to subsequent heat exposure can be altered, resulting in an alleviation of heat stress. Reports by Costa *et al*. (2020) have shown that the incubation period is also important in enhancing thermotolerance, as higher temperatures during incubation can lead to an elevation of the thermoregulatory set-point after hatch. Also, broiler chicks exposed to high temperatures during the brooding period had been reported to cope better with heat stress (Khan *et al*., 2023). More recent reports by Onagbesan *et al*. (2023) have shown that chicks that undergo early-age thermal conditioning respond in a similar way to chronic heat stress as birds earlier adapted to it, indicating a protective role of early-age thermal conditioning. Reports by Zaboli *et al*. (2017) have further shown that thermal-manipulated chickens had an improved feed conversion ratio, that was attributed to lower body temperature and lower plasma thyroid hormone levels, which indicated lower heat production rates. Such thermally-manipulated chickens also demonstrated greater muscle growth and a lower relative weight of the abdominal fat pad under hot conditions (Zaboli *et al*., 2017).

Gene Manipulation: Genetic variation among poultry populations can result in adaptation to high temperatures, which can be managed and conserved through selection decisions in tropical climates (Mpenda *et al*., 2019). Recent reports of heat-reactive genes, including mitogen-activated protein kinase activating protein pm20 and 21, suppressors of cytokine signaling box-containing protein 2, ubiquitin-specific proteinase 45, and TRK-fused gene, suggest that several pathways play important roles in heat regulation, including mitogen-activated protein kinase, ubiquitin-proteasome, and nuclear factor κB pathways (Li *et al*., 2011). Genetic selection may possibly be a useful strategy for reducing the heat stress response in poultry (Kumar *et al*., 2021). One possibly effective method is the introduction of the featherless gene to counteract the negative effects of hot climates in normally feathered birds (Hadad *et al.*, 2014). Additionally, earlier reports by Nayak *et al*. (2016) showed that epigenetic regulation of gene expression and thermal imprinting of the genome can improve thermal tolerance. Further, Candido (2019) posited that to develop thermotolerance, three direct responses should be employed: the rapid thermal stress response, acclimation/acclimatization and epigenetic temperature adaptation.

Conclusion

Tropical climatic conditions can lead to heat stress in broiler chickens, which can negatively affect their health and productivity. Measures that can be taken to mitigate these effects include anti-oxidant supplementation, certain management strategies, early age conditioning and gene manipulation.

Conflict of Interest

The authors declare no conflict of interest.

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