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REVIEW

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Broiler production challenges in the tropics: A review

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Abstract

Under tropical climate, broiler production is encumbered by several constraints which make it difficult for them to attain their genetic potential. The scarcity and high price of poultry feed and veterinary services and the harsh environmental conditions with respect to thermal stress are some of the challenges that hinder optimal growth of the birds. Limited availability of feedstuffs, including crucial feed ingredients like maize and oil seedcakes, is an important challenge to the sector, since feed still represents a major cost of producing broiler chickens. Additionally, the problem of climate change, which has become a global concern, is the main problem in broiler production under hot and humid climate. Under high ambient temperature, feed intake decreases, carbohydrates metabolism and protein synthesis efficiency are disturbed. Lipid utilization is lower and glucose or insulin homeostasis is altered while fat deposition and oxidative stress increases. Several strategies are used to ameliorate the effect of heat stress in poultry. The objective of this review was to summarize the challenge in broiler production under hot and humid climate and different approaches to fight heat stress in poultry.

KEYWORDS

broilers, metabolism, stress, tropical climate

1 | INTRODUCTION

There has been an unprecedented increase in global animal production, especially in subtropical and tropical areas in the last two decades (Renaudeau et al., 2012). The increase in the demand for food is due to a rise in human population (Godfray et al., 2010). Due to its potential role to provide food and livelihood securities (Paswan et al., 2014), poultry production, especially broiler production, are expected to meet the critical shortage in animal protein needed by Africa (Hatab et al., 2019).

There has been growing concerns on the impacts of climate change on livestock production. For example, in West Africa, the expected increase in average temperature by 2°C–6°C by the year 2100 (Sylla et al., 2016) portends a serious challenge to sustainable broiler production. Due to the climatic challenge, heat stress events are expected to become more frequent in livestock species (Rahimi et al., 2020). A study by Tawfeek et al. (2014) showed that high ambient temperature adversely affected the performance of broiler chickens under high ambient temperature. However, the authors indicated that supplementation of antioxidants ameliorated the effects of thermal stress on the birds. Therefore, the diets of the birds are required to be adjusted to the climatic conditions (Attia & Hassan, 2017; Nir, 1992; Suganya et al., 2015) and also to the prevailing economic status of the countries where they are produced. The fast rate of development of the poultry production in tropical countries has also engendered a situation of overdependence on the conventional feedstuffs (Picard et al., 1993). Sometimes, a situation of competition exists between man and livestock on some grains, especially maize (Suganya et al., 2015). It is well known that feed is the most crucial cost of production as it represents the largest part of the cost of production of broiler chickens (Omole et al., 2005).

The growth rate of commercial broiler chickens is fast and they are able to reach market weight of two kilogram and above at about seven weeks of age or less (Smith, 1990; Tallentire et al., 2016). However, optimal growth of the birds can only take place when the birds are reared under a thermoneutral zone of 18°C–24°C (Charles, 2002; Oke et al., 2020; Olanrewaju et al., 2010). Indeed, harsh environmental conditions circumscribe the growth potential of the birds (De Basilio et al., 2001; Sohail et al., 2012). Also, Ahaotu et al. (2019) emphasized the negative influence of seasonal fluctuations on poultry production in different parts of Africa. Liverpool-Tasie et al. (2019) suggested that farmers who had been confronted to economic losses due to heat stress adopt adequate strategies.

This paper reviews the challenges that are averse to production of broiler chickens under the tropical conditions and describes solutions that can be used to combat heat stress.

2 | CONSTRAINTS TO THE DEVELOPMENT OF POULTRY MEAT INDUSTRY UNDER HOT AND HUMID ENVIRONMENTS

Beside the challenges of feed quality (Bastianelli et al., 2005; Houndonougbo et al., 2012) and feed costs (Leeson & Summers, 2005; Omole et al., 2005), there is serious challenge of negative effect of high ambient temperature (Attia, Al-Harthi, et al., 2020; Attia, Bovera, et al., 2020; Fathi et al., 2013; Khan et al., 2011; Mashaly et al., 2004; Muiruri & Harrison, 1991) which has posed a serious constraint to a profitable and sustainable broiler chicken production under hot and humid tropical climate. In fact, tropical conditions limit growth and performance of broiler chickens (Gordon & Charles, 2002; Renaudeau et al., 2012). Thus, high ambient temperature in the tropics constitutes thermal stress on the birds and this remains a major constraint in poultry production, particularly, broiler chickens (Ahaotu et al., 2019; Ayo-Enwerem et al., 2017). Two major issues will be x-rayed here, viz: the problem of thermal stress and of its influence on broiler strains raised under hot and humid environments.

2.1 | Impact of tropical conditions on poultry industry

The challenges posed by climate change has become a global concern and this is not sparing the poultry sector either. The increase in ambient temperature and relative humidity are causing serious disruption to the poultry industry, particularly in opened-sided poultry house in tropical environments. Due to fast growth of commercial broiler chickens, they are particularly susceptible to these climatic extremes.

2.2 | Understanding of the concept of heat stress

There is no universal definition for stress. It refers to any situation that elicits the biological stress mechanisms of an animal (Selye, 1970). It is also defined as a biological response elicited when the homeostasis of an animal is interrupted (Moberg, 2000) or responses to external stimuli that make an animal adapt to a new or abnormal situation (Puron et al., 1994; Virden & Kidd, 2009). Broadly, stress is the sum of defence mechanisms or non-specific responses of an organism when it is faced with abnormal situation or extreme demands (McEwen & Akil, 2020; Sahin et al., 2009). The negative impacts of heat stress on poultry have been reported (Marchini et al., 2016; Oke, 2018; Oke et al., 2020; Olanrewaju et al., 2010; Wan et al., 2018; Yahav et al., 1997). The responses of birds to high ambient temperature includes high body temperature; lower feed intake, feed efficiency, live weight and growth and performance (Ozbey & Ozcelik, 2004).

In poultry farm, heat stress sets in when the ambient temperature exceeds 25°C (Merat, 1990), and cold temperature is temperature less than 20°C on average, the optimum is being located mostly between 22°C and 25°C. High relative humidity could modify the perception of the heat by animals (Yahav et al., 2000). Then, temperature must be associated with relative humidity in order to properly assess heat stress.

2.2.1 | Differents types of heat stress

The concept of heat stress or the exposure to high ambient temperature can be broadly categorized into two:

- The acute heat, which refers to exposure to stress with a very high temperature during short period. Its main effect on broiler chickens is an increase in mortality, often by suffocation;
- The chronic heat, which refers to the exposure of an animal to a prolonged high temperature for several weeks. The resultant consequence of this is a decrease in performance of the birds.

Both continuous and cyclical heat stress affects broiler performance by decreasing weight gain by 36% and 21%, respectively (de Souza et al., 2016). Several studies have been conducted on the responses of broiler chicken to different heat stress durations as shown in Table 1. The trials were generally conducted from a few minutes (45 min, Washburn et al., 1992) to several days (de Souza et al., 2016; Park & Zammit, 2019) when the thermotolerance of birds to heat stress was assessed. To assess the capacities of the animal to maintain good performances in hot climate, the length of trials was longer, varying from few days (3–10 days, Yamada & Tanaka, 1992) to some weeks (de Souza et al., 2016;

TABLE 1 Examples of duration and temperatures used for animals' exposure according to studies

References	Species	Exposure temperature	Exposure duration
Kheir Eldin and Shaffner (1954)	Chicks	43.3°C	6 hr
Wilson et al. (1975)	Chickens (Broiler and layer)	40.8°C + 3.0°C	3 hr
Washburn et al. (1980)	Broiler chickens	50.0°C	4 hr
Washburn et al. (1992)	Broiler chickens	40.6°C	45 min
Donker et al. (1990)	Broiler chickens	42.0°C	30 min
de Souza et al. (2016)	Broiler chickens	32°C	Continuous and cyclical (8 hr)
Park and Zammit (2019)	Meat ducks	34°C	5 hr per day during 20 days

Park & Zammit, 2019).The exposure temperature can be as high as 50°C–54°C for chronic heat stress (Kheir Eldin & Shaffner, 1957; Washburn et al., 1980).

2.2.2 | The influence of strain in broiler chickens

The intensive selection on broiler chickens has paid much attention on fast posthatch growth rate and improved feed conversion in the past decades (Tona et al., 2010). The progress made on the improvement of some important production traits had contributed immensely to the advancement of poultry industry (Tavárez & Solis de los Santos, 2016). Today, chicken weighing 1.8 kg can now be produced by the broiler industry in 6–7 weeks (Maurer, 2003; Oke et al., 2020). As a result of this advances, several strains of broilers with different physiology or growth trajectories, or both, have been developed (Tona et al., 2003). Among the broiler strains used for meat production, Cobb and Ross are actually the most widely produced globally (Tona et al., 2010). Studies (Jana, 1989; Oke et al., 2015) have shown that even though broiler chickens generally had fast growth across the strains, there were significant differences in their growth trajectories. For instance, Cobb strain grows better with a better feed conversion ratio than the Ross strain (Sterling et al., 2006). This observation was confirmed by Tona et al. (2010) who found that Cobb strain chicks were bigger than Ross chicks. Furthermore, Iqbal et al. (2012) reported a significant difference in the performance of four internationally reputed broiler strains (Hubbard, Arbor Acres, Ross 308 and Hybro PN) under the tropical conditions of Pakistan. The overall performance of Hubbard strain was better than the other strains. This underscores the importance of adaptation of strains to different rearing conditions, as their thermotolerance may differ. Through genetic selection, geneticists have achieved great feat in producing fast growing broilers and a large number of the birds are being imported and reared under different environmental and production conditions. However, as a result of great differences in growth rate trajectories of the different strains of broiler chickens (Oke et al., 2015; Tona et al., 2003), they have similar post-hatch challenges such as metabolic disorder, leg weakness, among other challenges (De Smit et al., 2005).

Certain genes have been implicated in the thermotolerance of chickens. For instance, frizzle feather gene divert feathers away from body centre, dwarfism gene (dw) is implicated in reducing heat load from metabolism and reduction of body size while naked neck (Na) is involved in reduction of feather around the neck of birds (Cahaner et al., 1992). The findings of Patra et al. (2002) indicated that homozygous/heterozygous naked neck chickens had a better thermotolerance and growth performance than fully feathered broiler chickens. The earlier study of Deeb and Cahaner (1999) showed an improved thermotolerance in birds exposed to thermal challenge while Yahav et al. (1998) showed that loss of heat was enhanced due to reduced feathers around the neck. There is a paucity of information on the exploitation of frizzle and naked neck genes in broiler under the tropical conditions.

2.2.3 | Broiler chicken's behaviour and responses to heat stress

It has been shown that fast growth rate in broilers is linked with increased appetite and accelerated rate of voluntary intake with the digestive capacity of the gastrointestinal tract almost being used to the fullest (McCarthy & Siegel, 1983). Additionally, studies have shown that broiler conserve energy through reduced activity but spend more time in sitting/resting as they grow older (Newberry et al., 1988). The resultant effect of this is metabolic disorders leading to lameness and abnormal gait (Bradshaw et al., 2002; De Smit et al., 2005). Metabolic disorders are associated with a failure in one of the body hormone or enzyme systems, storage disease related to lack of metabolism of secretory products because of the lack of production of a specific enzyme, or the failure or reduced activity of some metabolic function (Khan et al., 2012; Stanbury et al., 1983). Basal metabolism of broiler chickens has been reported to reduce under chronic heat stress with an increase in additional heat from metabolizable energy (Sayed & Downing, 2015; Tesseraud et al., 1999). Also, the proportion of energy retained in the form of fat is higher and protein retention is lower. Thus, changes that occur in the metabolism of the birds should be further investigated and exploited.

3 | METABOLISM DISTURBANCE IN HEAT-STRESSED BROILERS

3.1 | Metabolism of carbohydrates

Carbohydrates are the main source of energy in chickens. Fat deposition is the net result of energy intake and expenditure and is controlled by multiple regulatory mechanisms. The lipids deposited are therefore essentially derived from dietary carbohydrates. The poor growth and high fat deposition observed in broiler chickens (Park & Kim, 2017) in warm tropical conditions suggests alteration in glucose utilization and its regulation by insulin (Tesseraud & Temim, 1999). Chickens exposed to hot conditions have been reported to show an insulin resistance leading to a difficulty in capturing glucose by muscle cells (Bray & York, 1979; Quinteiro-Filho et al., 2012). This may cause tissue sensitivity to insulin and degradation of insulin secretion. Moreover prolonged exposure to heat causes a rise in the plasma corticosterone but reduces plasma triiodothyronine (T_3) concentrations in growing broiler chickens (Geraert et al., 1996; Xie et al., 2015). These physiological changes may stimulate lipid deposition as altered thyroid hormone metabolism plays a crucial role in the development of obesity (Leclercq et al., 1988).

3.2 | Lipid metabolism

Broiler chickens accumulate higher fat under hot tropical condition due to the fact that exposure to heat stress causes an increase in the proportion of adipose tissue (Ain Baziz et al., 1996; Habashy et al., 2017). Prolonged exposure to heat stress also alters the composition of fatty acids in fatty tissues by increasing the level of saturated fatty acids. Higher fat content, particularly at the subcutaneous level, reduces the quality of the carcasses of broiler chickens (Tesseraud & Temim, 1999). This portends a loss of profit to the farmers. In broilers, fat is localized as: abdominal fat (including fat surrounding proventriculus, gizzard, bursa of fabricius, adjacent muscles and cloaca), sartorial fat (subcuticular fat in cranial thigh), fat located in the neck (subcuticular fat in ventro-caudal neck region) and mesenteric fat (fat attached to mesentery, along the intestine). Abdominal fat is about 20% of total body fat, skeleton fat 15%, subcutaneous fat 18%, liver and feather 2.5%. (Crespo & Esteve-Garcia, 2001; Haro, 2005). However, abdominal fat is the main part of body fat in broiler chicken. The high lipogenesis of broiler chickens under hot environment is associated to the dietary carbohydrates, the main components of the diets. There is a higher conversion of dietary lipids to body fat in chickens reared in such environments, especially with high energy diets, indicating a lower use of lipid reserves to meet the energy needs of the birds (Tesseraud & Temim, 1999).

3.3 | Protein metabolism

Generally, diets containing high energy content or a high ratio of energy to protein promote energy retention as fat. Under hot conditions, protein utilization and its efficiency are reduced in broiler chickens, indicating alteration in the metabolism of the birds (Tesseraud et al., 1999). Temim et al. (2000) showed that broiler chickens fed high-protein diet and reared under 32°C did not alter protein synthesis since heat production was highly associated to protein accretion (Macleod, 1992). The lower protein deposition can be associated to a decrease in the capacities of protein synthesis (Temim et al., 2000), but also to an altered insulin signalling in muscles (Boussaid-Om Ezzine et al., 2010). Nutritional practices to alleviate heat stress effects which suggest the decrease of crude protein levels (Attia, Al-Harthi, et al., 2020; Attia, Bovera, et al., 2020; Awad et al., 2014; Cheng et al., 1999) resulted into a poor performance of broiler chickens in tropical environments (Awad et al., 2020).

4 | EFFECTS OF HEAT STRESS ON BROILER CHICKENS

Broiler production in the sub-Saharan region of Africa is encumbered by a problem of high temperature and relative humidity (Ayo-Enwerem et al., 2017). The increase in temperature coupled with high humidity usually becomes critical (Pragya et al., 2014). Farmers are faced with serious thermal challenge, particularly during the dry season, when daily temperatures reach their extremes (Ahaotu et al., 2019). A peculiar challenge of broilers in hot climate is that the birds are selected for greater growth rate and generate more heat (Sandercock et al., 1995) and thus need lower ambient temperature to maintain normal body temperature in order to attain genetic potential for rapid growth (Emmans & Kyriazakis, 2000). There has been a rapid increase and expansion in commercial broiler production in tropical countries where climatic control of broiler houses is lacking (Cahaner et al., 2008). Most farmers cannot afford a controlled housing system for the birds and in most cases, there is no adequate power supply to support this, especially, in the developing countries. Lower feed intake, growth and protein deposition combined with an increase of fat deposition in broiler chickens has been reported under chronic hot ambient temperatures in poultry houses (Geraert, 1991). In broilers, feed intake is depressed when ambient temperature rises. However, the reduction of growth in broilers is often greater than the reduction in feed intake, resulting in a lower feed efficiency (Al-Fataftah & Abu-Dieyeh, 2007; Geraert et al., 1993). The fasting heat production is the main component being affected by high temperature in chickens (Geraert et al., 1996). Broilers chickens exposed to thermal stress has been reported to gain less protein (Temim & Tesseraud, 1999) but retain more fat, especially in subcutaneous fat tissues (Ain Baziz et al., 1996). Also, meat quality of chickens is adversely affected by thermal stress through alteration in the glucose metabolism (Ain Baziz et al., 1996).

Birds make physiological and behavioural changes when they are exposed to thermal stress (Farag & Alagawany, 2018). Thermal stress has been shown to have immunosuppression effect on the immunity of birds (Quinteiro-Filho et al., 2017). Different segment of intestine can be adversely affected (Varasteh et al., 2015; Wu et al., 2018) thereby affecting intestinal integrity (Karl et al., 2018). Alteration in different levels of biomarkers such as heat shock protein has been reported (Arnal & Lalles, 2016). Additionally, alteration in the glucocorticoids (corticosterone) concentration has been reported in birds (Scanes, 2016).

5 | MECHANISMS OF BODY HEAT REGULATION IN POULTRY

Environmental stressor is one of the main limiting factors of broiler production efficiency in hot and humid areas (Renaudeau et al., 2012). Production performance, health and product quality of broiler chickens are influence by climatic conditions including temperature, relative humidity and ventilation influence (Lin et al., 2006; Yahav et al., 2000). It increases panting and mortality in birds (Abidin & Khatoon, 2013). Generally, the severity of the effect of environmental temperatures in thinner animals is lower than in the larger ones (Ozbey & Ozcelik, 2004). Poultry birds are more susceptible to climate change because birds can only tolerate narrow temperature range of 18°C–24°C as their thermoneutral zone (Weaver, 2002). According to Charles (2002), the optimum temperature of (thermoneutral zone) for performance is between 18°C and 22°C for growing broilers. Broiler chickens do not experience heat stress when they reared under thermoneutral zone, as their body temperature is held constant and the birds lose heat at a controlled rate without discomfort. However, under high ambient temperature, the birds need to regulate their body temperature. Thermoregulation is the balance between heat production and heat loss, mechanisms that occur to maintain a relatively constant body temperature (Khan et al., 2011). Thus, when birds' temperature exceeds the upper critical limit of thermo-neutral zone, it is considered to be heat stressed. Five mechanisms of thermoregulation have been identified in birds, namely, radiation, conduction, convection, evaporation and excretion (Defra, 2005; Ruvio et al., 2017). Some of the adjustments make under stressful conditions include dilation of the blood vessels of the skin, wattles and comb to bring internal body heat to the skin surface, to facilitate conductive, convective and radiative heat loss. The absence of sweat glands makes broiler chickens susceptible to high ambient temperatures (Fathi et al., 2013), as sweating is not possible. To compensate for this, they try to lose heat by evaporative heat loss mechanism such as panting. When the use of such mechanism get exhausted and the cooling becomes insufficient, then death occurs (Al-Fataftah & Abu-Dieyeh, 2007; Sahin et al., 2009). Under heat stressed conditions, birds usually have limited nutrients for growth, reproduction, thermoregulation and defence mechanisms (Khan et al., 2011; Quinteiro-Filho et al., 2012). In order to cope with heat stress challenge, they redistribute body reserves of energy and protein at a cost of decreased reproductive efficiency and growth performance (Park & Kim, 2017; Puron et al., 1994). Continuous stress causes fatigue and weakness (Sayed & Downing, 2015). Birds are more likely to succumb to starvation and infectious diseases (Quinteiro-Filho et al., 2012) if the condition becomes protracted (Khan et al., 2011).

6 | STRATEGIES TO AMELIORATE HEAT STRESS

Heat stress contributes to reduction in feed intake, meat quality (Tang et al., 2013), immuno-suppression (Ohtsu et al., 2015) and hormonal imbalances (Xie et al., 2015). Furthermore, oxidative stress (breaking of the balance of body redox) as a consequence of heat stress is one of the most important disturbances leading to a decrease of the performance of broilers (Quinteiro-Filho et al., 2012; Al-Zghoul et al., 2019; Hu et al., 2019). It is a perturbation in a biological system's defence against reactive oxygen species and affects the capacity of a number of different antioxidant enzymes (Kannan & Jain, 2000; Ray et al., 2012). The unexpected increase in reactive oxygen species levels is the cause of protein denaturation, lipid peroxidation and DNA damage (Ighodaro & Akinloye, 2017). To overcome the detrimental effect of heat stress, nutritional manipulations, genetics approaches and management strategies have been suggested as useful tools (Suganya et al., 2015).

6.1 | Feeding approaches

The increase in protein with energy level of diet had improved the productive performance, meat quality, antioxidants and immunity of broiler chickens (Attia & Hassan, 2017). Also, protein of diet may be reduced from 18% to 15% with an adequate supplementation of only methionine and lysine (Attia, Al-Harthi, et al., 2020; Attia, Bovera, et al., 2020). Moreover beneficial effect of fat has been shown (Zulkifli et al., 2007). Among different types of fat sources such as palm oil, coconut oil, soy oil and fish oil, Htin et al. (2007) suggested the use of palm oil (Table 2). Also, Attia, Al-Harthi, et al. (2020) and Attia, Bovera, et al. (2020) recommended oil supplementation at 1.5% under hot climate.

Short term of early feed restriction for less than two weeks might improve growth performance and economic efficiency of broiler chickens during hot seasons (Shamma et al., 2014). It has also been revealed that feeding crumbled and pelletized diets may increase productive performance in broilers under tropical areas (Hosseini & Afshar, 2017) by reducing the energy necessary for nutrient uptake.

As shown in Table 2, some trace elements (vitamin C, vitamin E and selenium, polyphenols, etc.) which play biological functions and specially antioxidant defence could help to combat heat stress

TABLE 2 Effect of dietary supplements on broiler chickens under hot and humid climate

Studies	Levels of dietary supplements	Findings
Awad et al. (2015)	Low-protein diets fortified with 0.81% of glycine	Improved feed conversion ratio
Attia, Al-Harthi, et al. (2020); Attia, Bovera, et al. (2020)	Low-protein diets supplemented with lysine at 0.19%–0.28% and methionine at 0.08%–0.1%	Increased protein efficiency, decrease nitrogen excretion and positive effect on growth performances and carcass yield
Jiang et al. (2020)	Synbiotic at different levels: 0, 0.5 and 1 g/kg of diet	Improved the health and welfare
Majdeddin et al. (2020)	Guanidinoacetic acid supplementation (the precursor of creatine) at level of 0.6 and 1.2 g/kg of diet	Improved feed conversion and survival
Porto et al. (2015)	Dietary glutamine and glutamic acid supplemented at level of 1%	Enhanced body weight and intestinal integrity
Tawfeek et al. (2014)	Antioxidants: 250 mg of vitamin C + 250 mg of vitamin E/kg diet and 0.50 mg chromium/kg diet.	Decrease of protein and glutathione peroxidase, improvement of oxidative status and blood profile.
Attia et al. (2010); Waseem et al. (2016)	Organic form of Selenium at level of 0.25 mg/kg of diet and 0.3 ppm	Improvement of growth performances
Chand et al. (2014)	Zinc at the rate of 60 mg/kg of diet and ascorbic acid at 300 mg/kg of feed and combination of both supplements.	Enhancement of the production performance and immune status
Laganá et al. (2007)	1.6% soy oil with crude protein reduction of 1%	No influence on production performance
Htin et al. (2007)	Palm oil at 8%	Reduction of mortality by more than 50% and enhancement of production performances

in broilers (Attia et al., 2010; Khan et al., 2012; Waseem et al., 2016). Shakeri et al. (2020) observed that through synergistic effects, the use of combination of vitamin C, vitamin E and selenium is highly recommended than their individual use. Due to their great antioxidant ability, polyphenols, naturally available, are getting increasing attention (Crozier et al., 2009). They could be used to ameliorate performance in heat-stressed bird (Hu et al., 2019; Oke et al., 2016, 2017).

6.2 | Genetics' approaches

Lan et al. (2016) suggested the selection of chickens for resilience to heat stress. In that perspective, these authors were able to identify a certain number of genes using RNA-seq technology. In fact, geneticists have shown great interest in the specific response of organisms under stress. The main characteristic during this specific response to stress is the increased expression of HSPs (Mazzi et al., 2003). High levels of HSPs indicated an increase in heat resistance (Tamzil et al., 2013; Zulkifli et al., 2009). It was proven that through its role in stimulating the activities of antioxidant enzymes and in reducing oxidative damage in intestinal mucosal cells, heat shock proteins (HSP70, a group of highly conserved protective proteins involved in cell protection and repair) may play an essential role during heat stress (Awad et al., 2015). Recently, Sharma et al., (2020) observed that the expression of HspB1 mRNA and protein increased with age of chickens under heat stress. The early heat exposure did not have a positive effect on heat shock protein expression in chickens (Kang et al., 2019).

6.3 | Management strategies

Various management strategies have been adopted to ameliorate the influence of thermal stress on birds. Recent studies (Al-Zghoul et al., 2019; suggested that thermal manipulation of broilers embryos could reduce the system of gene system in relation with heat-induced oxidative stress and give chickens long-lasting thermotolerance. Embryonic thermal manipulation may use to prevent broilers from thermally induced oxidative stress (Saleh et al., 2020). Also, other studies (Meteyake et al., 2020; Oke et al., 2020) indicated that and early age thermal manipulation improved the performance and thermotolerance of broiler under thermal stress.

7 | CONCLUSION

Tropical environments are harsh to the present-day broiler production and thermal stress represents crucial environmental stressor in this region adversely affecting broiler production, resulting in sub-optimal performance of the birds. The frequency of cases of severe heat stress is likely to increase at the end of this decade for almost all livestock species in the tropics, especially, Sub-Saharan Africa. Concerted efforts should be in place to ensure the maintenance of homeostasis of the birds in order to improve their survival and optimal performance under the tropics. This will include looking at feeding, genetic and management approaches.

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CONFLICT OF INTEREST

There is no conflict of interest with me or any of my co-authors with regard to this review article.

AUTHOR CONTRIBUTION

Claude Kpomasse: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing-original draft; Writing-review & editing. **Oyegunle Emmanuel OKE:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Supervision; Visualization; Writing-review & editing. **Frédéric M. HOUNDONOUGBO:** Conceptualization; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing-review & editing. **Kokou TONA:** Conceptualization; Funding acquisition; Methodology; Project administration; Resources; Supervision; Validation; Visualization; Writing-review & editing.

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