



Repercussions and Mitigation of Heat Stress in Poultry: A review

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Abstract

To achieve successful poultry production and welfare, it is critical to understand and control environmental variables. Heat stress is one of the most important environmental stressors that poultry industries face around the world. Heat stress has a variety of negative impacts on broilers and laying hens, ranging from lower growth and egg production to decreased quality and safety of poultry and eggs. Hence, the harmful effects of heat stress on poultry welfare have recently raised public awareness and concern. Therefore, it is important to focus on intervention strategies to deal with heat stress conditions, which use a variety of approaches, such as environmental management, nutritional manipulation and genetic modifications. This could aid in the development of poultry industry in hotter environmental conditions.

Received: Jul 01, 2021

Accepted: Aug 08, 2021

Published Online: Aug 10, 2021

Journal: Journal of Veterinary Medicine and Animal Sciences

Publisher: MedDocs Publishers LLC

Online edition: <http://meddocsonline.org/>

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Keywords: Heat stress; Poultry farming; Food safety; Production; Genetic markers.

Introduction

Worldwide poultry production is adversely affected by environmental stress among which the heat stress is the one of leading cause of declining poultry economy. As the heat stress is directly hampers the egg laying capacity and broilers of fowls. Moreover indirectly affects the eggs quality, safety and major concern of poultry welfare. Globally, the poultry industry has risen to the top of all agricultural & related industries [1]. In India, poultry industry contributes about Rs. 125 lakh Crore to the livestock sector which accounting for about 1 per cent of the national GDP and about 14% of the Livestock GDP. The FAO (Food and Agriculture Organization) estimated worldwide chicken meat output at 103.5 million tonnes in 2012, accounting for 34.3 percent of global meat production [2]. Chicken meat and eggs are the most efficient protein sources among food animals [3].

But the animal farming systems is influenced by several climatic conditions which lead to stress in animals. Stress is a response to adverse stimuli. According to Selye, "stress is the nonspecific response of the body to any condition" and stressor is an agent that produces stress at any times [4,5]. Hence, stress represents the reaction of the animal organism stimuli that interrupt its physiological equilibrium or homeostasis. It is a reflex reaction of animals in adverse environments and causes ominous consequences ranges from discomfort to death. Stress may be of different types but environmental stress has gained special attention in livestock, particularly poultry production, as a result of public awareness and concern [6]. Variations in environmental stressors such as sunlight, temperature, humidity, characteristics of animal metabolism and the mechanism of thermo regulation can imbalance the animal's body [7].

Cite this article: Sushma, Sharma P. Repercussions and Mitigation of Heat Stress in Poultry: A review. J Vet Med Animal Sci. 2021; 4(2): 1073.



Amongst the environmental stressors heat stress is a critical form which negatively affects the animal health & whole cycle of a bird's production. A rise in temperature might affect the susceptibility of pathogens in the environment of chickens. Heat stress has a negative impact on plant growth (cereal grains) and causes a decrease in feed quality, resulting in a reduction in poultry growth [8,9]. During hot and humid weather layer chickens reduce their feed intake by about 20% [10]. High ambient temperatures harm hens, resulting in a high rate of sickness and mortality, posing a threat to human nutrition [1,11,12]. So, heat stress emerges as major obstruction for future development of poultry industry specifically in the hot and humid part of the world [13]. The following flow chart depicts the poultry response to heat stress (Figure 1).

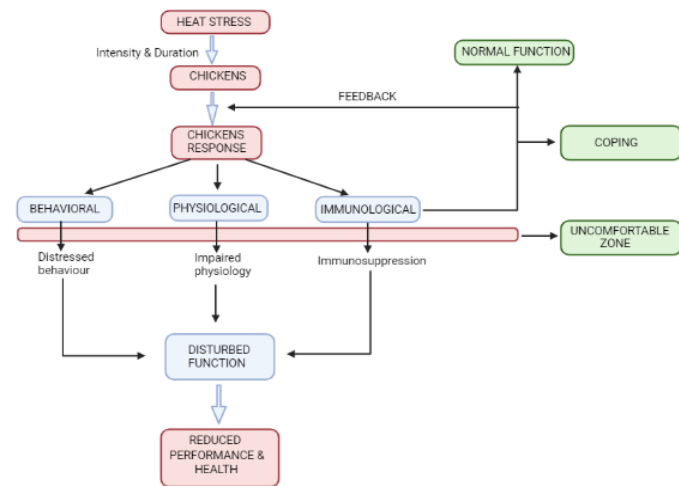


Figure 1: Poultry Response to Heat Stress.

Mechanism of heat stress

According to intensity and duration of heat stress poultry birds express different types of responses such as more heat stress causes decrease in feeding, moving, walking and more time in panting, drinking, elevating wings and resting. The neuroendocrine system performs the main role in the maintenance of healthy body functions in humans as well as in animals. During stressed conditions, there is alteration in the neuroendocrine system and activate the sympathetic-adrenal medullary axis including the hypothalamic-pituitary-adrenal axis which leads to increase in the glucose synthesis for the longevity of chickens [14,15] (Figure 2).

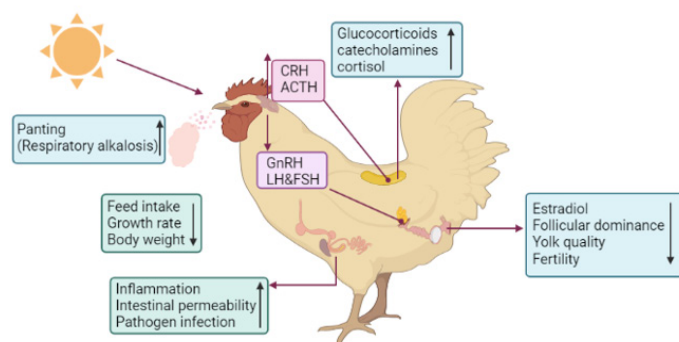


Figure 2: Mechanism of heat stress.

The hypothalamic-pituitary-adrenal axis is the main stressor marker than corticosterone, as corticosterone concentration can increase under positive or negative conditions and the sympathetic-adrenal medullary axis controls the fight or flight response, as it recognizes response and delivers stimuli from the hypothalamus to the adrenal gland [16]. Under stressful conditions, epinephrine is secreted from the sympathetic-adrenal medullary axis, which triggers a fast response in the form of tachycardia and glucose synthesis [17]. Primary glucocorticoids are cortisol and corticosterone, among which cortisol is present in cattle, pigs, sheep, and fish, while corticosterone is present in birds and rodents [18,19]. Corticosterone is secreted from the hypothalamic-pituitary-adrenal axis and the pituitary gland [18,20]. It is produced at a slower rate than adrenaline and has a longer-lasting effect [18]. Therefore, it acts as a good indicator of stress. Long-term secretion of corticosterone may cause sadness, lower immunity, cardiovascular difficulties, muscular breakdown due to gluconeogenesis, and diminished cognition in chickens when they are exposed to chronic stress [20]. Heat stress induces distress in birds and has an impact on the immunological response of hens by causing inflammatory cytokine production [21]. This inhibits the function of the hypothalamic-pituitary-gonadal axis and decreases the defensive system in poultry.

Effect of heat stress on behavioural response

Heat stress alters the behaviour of chickens such as spending less time eating, drinking, and panting, as well as spending more time with their wings raised, moving or walking less, and sleeping more and also showing lethargic behaviour [22]. Due to heat stress, a bird's body heat production and loss are out of balance. By altering their activity inside the thermoneutral zone, birds can lose heat at a controlled rate. At this stage, they are not experiencing any heat stress, and their body temperature remains steady. Birds begin to pant to actively remove body heat when temperatures reach or exceed the upper critical temperature.

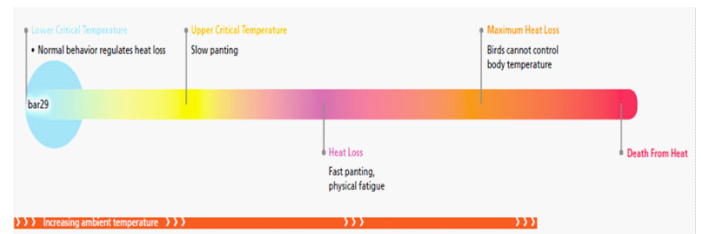


Figure 3: Heat stress on behavioural response.

Effect of heat stress on physiological response

Heat stress adversely affects the physiology of poultry birds at every stage of life, which ultimately affects growth, production, and performance [23,24]. Day-old chicks have a quick metabolism and growth rate, hence they have a limited ability to react to changes in the environment and are extremely vulnerable to heat stress. Under stress, the first neurogenic system is met. Blood sugar, respiration, muscle tone, and nerve sensitivity are all increased by the neurogenic system. By the activation of the neurogenic system, epinephrine and nor-epinephrine are secreted.

Heat stress influences the hypothalamic-pituitary-adrenal cortical system and produces a corticotrophin-releasing factor from the hypothalamus. Corticotrophin-releasing factor sends a signal to the pituitary to secrete an adrenocorticotropic hormone [25]. Adrenocorticotropic hormone is secreted from the pituitary while corticosteroid is released from the adrenal cortex.

cal tissue. Glucose synthesis and mineral metabolism alter due to elevation in levels of corticosteroids. This increased level of corticosteroids responsible for hypercholesterolemia, cardiovascular diseases, gastrointestinal lesions, and variations in immune functions [26]. Under high temperature animals maintain their homeostasis by conduction, convection, and evaporative heat loss by vasodilatation and perspiration [2]. For exchange of gases Air sacs play main role that increase the circulation of air toward the surface. In stress increased panting expire more carbon dioxide and increases pH of blood, this phenomenon is called as respiratory alkalosis and this disrupts the bicarbonate and free calcium availability for the mineralization of the egg shell. This is significant in the poultry that needs to avoid poor egg production [27,28].

Effect of heat stress on reproduction

In livestock production system reproductive capability is main factor which affects profitability [29]. In males, heat stress negatively affect all phases production of semen, testes weight, concentration of sperm, sperm count and motility [30]. McDaniel et al., [31] reported that when hen inseminated with semen collected from heat-stressed roosters, reduced the % of fertilised eggs.

Under heat stress release of GnRH decreases which in turn reduces the concentration of FSH & LH leads to infertility in laying birds. Through inhibition of intracellular ion exchange stress shows harmful effects on testicular functions [32,33]. It reduces the development of reproductive organs, thus suppresses the reproductive ability of poultry [10]. By reducing development of reproductive organ, concentration of estradiol, expression of LH receptor delay the process of ovulation [34].

Under exposure of heat reactive oxidative species increases that induces lipid peroxidation of cytochrome-membranes which results in reduction of yolk quality and the maturation rate of yolk may be decreases due to change in composition of fatty acid, heat shock proteins & level of antioxidant in layer birds [10,35]. Noiva and Peleteiro [36], observed that a long term exposure of heat stress debilitate the growth & development of embryo in poultry and cause teratogenic defects in chicks.

Effect of heat stress on digestion

Digestive health is very important as it plays significant role in digestion, absorption, electrolyte balance as well as in development of immune system [37]. But heat stress leads to change in morphology of intestine and different intestinal segments i.e. duodenum, jejunum and ileum. It causes abrasion in these segments. In addition, it declines the production of digestive enzymes i.e. trypsin, chemotrypsin, amylase, sucrose and malase due rise in level of reactive oxygen species which increase lipid peroxidation of cell walls of the intestine and pancreas. Hence it adversely affects the digestion and absorption of nutrient while positively affects the sensitivity of intestine to pathogens [38-46].

Abdelqader and Al-Fataftah, [45] reported increase in harmful while decrease in beneficial bacteria in intestine which adversely affects gut health, nutrient digestion and absorption. Due to these changes there is reduction in meat yield, egg yield, immune activity and production performance.

Intestinal epithelial cells are connected by intercellular junctions like adherent junctions, tight junction, gap junctions and desmosomes [47]. Among these tight junction forms trans-

membrane protein channels that permit transport of different substances but in stressed condition tight junction barrier disturb & luminal contents enter into the circulation result in leaky gut that promotes chronic systemic inflammation which decreases the disease resistance ability of birds [48,49].

Effect of heat stress on immune response

High temperature disturbs the immune system and performance of poultry. Stress causes immunosuppression and decreases weight of chickens thymus, spleen, liver, bursa of fabricus and lymphoid organ. Heat stress decreases antibodies (IgG & IgM) in circulation and hence lowers both primary as well as secondary humoral response [6,50-52].

Gomes et al, [34] & Sugiharto et al, [35] observed that thermal stress decreases phagocytic capacity of macrophages as well as reduces antibody response in broilers. In addition, heat stress can change the ratio of circulating cells. High temperature increase in ratio of heterophil to lymphocyte due to decreased no of lymphocytes and more no of heterophils [6,53]. The poultry birds try to maintain their homeostasis but under stressful conditions there is increase in production of reactive oxygen species.

During heat stress Toll- like receptors play significant role as they sense different microbial patterns. Different bacteria are sensed by TLR2, TLR4, TLR5 and TLR9 that recognise lipoproteins, lipopolysaccharide, flagellin and DNA respectively [54]. TLR4 pathway activated during heat stress. After activation of TLR, a signalling cascade start which involves adapter proteins My88. As a result of this, there is activation of nuclear transcription factors induce pro-inflammatory cytokines while suppress immunity [55].

Effect of heat stress on production

As previously seen, exposure to high temperature generates behavioral, physiological and immunological responses, which cause detrimental affects to the productivity of poultry birds. chronic heat exposure reduces 16.4% feed intake, 32.6% body weight and a 25.6% higher feed consumption ratio in broilers at 42 days [56] and also adversely affects fat metabolism, growth of muscle and decreases the quality of meat and chemical profile due to imbalance of electrolytes and activation of lipid peroxidation [57-60]. Heat stress causes depression of meat chemical composition and quality in broilers [58,61]. Moreover long exposure to heat stress leads to reduction in the proportion of breast muscle, while increase in the proportion of thigh muscle in broilers [62].

Ayo et al., [10] observed high reduction in protein content while increase in deposition of fat during high temperature in chickens. During transportation, higher mortality and welfare associated with high temperature or heat stress [63] & the death is usually related with weight of chickens as higher weight leads to higher mortality [64].

Zhang et al [65], reported in 12 day trial about 28.58 g/chicken/day reduction in feed intake and 28.8% reduction in egg production in laying hens under stressed condition. Additionally, heat stress causes a significant loss about 3.24%, 1.2%, 9.93%, 0.66% in whole egg weight, egg shell thickness, only eggshell weight and eggshell, respectively [22,66]. The variability is explained by the use of duration and intensity of stress, age of birds as well as physiological condition and genetic background of birds.

Effect of heat stress on food safety

In modern food quality concept, food safety is considered an important part. Globally, due to stressful conditions poultry industry faces a lot of issues related to food safety.

Pawar et al., [2] reported that stress can negatively affect food safety via different possible mechanisms such as due to stress conditions, the shedding of pathogens in farm animals. In broilers, high temperature causes quality loss and undesirable characters in meat [60]. Additionally, meat quality losses occur during transportation from poultry farms to processing units under high temperature [67]. In laying hens, loss in egg production and quality associated with heat stress [2,68]. In poultry and egg production, the colonisation of birds by food-borne pathogens such as Salmonella and Campylobacter, and their subsequent transmission along the human food chain, is a major public health and economic problem. In fact, one of the most regularly implicated sources of foodborne disease is the intake and handling of undercooked poultry items [69-72]. High ambient temperatures are likely to alter not only the bacterial levels in bird faeces, but also the duration and level of contamination in the environment where faeces are deposited, potentially leading to enhanced dispersion. However, heat stress did not lead to increased levels or longer survival of Salmonella shed in faeces [73]. Seasonal effects on the prevalence of Salmonella and Campylobacter in broiler and laying hen flocks, as well as in retail chicken products, have been observed in various epidemiological investigations [74-78].

As a result, due to the vast implications for our understanding of the ecology and epidemiology of diseases in poultry flocks under high temperature or heat stress conditions, this topic represents a crucial knowledge gap that has to be filled.

Mitigation strategies to reduce heat stress in poultry

Environmental measures: Environmental modification is one of the most important variables in reducing the consequences of heat stress. However, if dietary programmes, disease control, and the genetic state of chickens are not appropriate, environmental technical measures will not be able to mitigate heat stress in the poultry farm.

To decompress the heat-stressed birds, a variety of approaches might be used. The key features are house shape, air flow into and out of buildings to remove ammonia, carbon dioxide, and moisture in hot and humid climates, natural or artificial shade and water consumption [2,79-81]. Another thing that can help prevent heat build-up is the roof's condition. Roofs should be rust-free, clean, and dust-free. A sparkling roof reflects more sunlight than a dark or rusted roof. The reflectivity of a roof can be improved by using metallic zinc paint or installing an aluminium roof [2]. Using circulating fans, proper ventilation can promote convective cooling. Heat stress in poultry housing should be handled to reduce the negative effects on chickens. Ventilation technology can help to reduce stress-related health concerns [2]. Ventilation equipment should be properly installed and maintained on a regular basis. In the event of an emergency, additional ventilation fans and generators should be accessible [82]

Installation of an alarm system that notifies to the failure of the ventilation system is required by 1994 legislation for the welfare of livestock, which may protect chickens from unpleasant or stressful situations, especially during periods of hot weather [82]. As a result, emergency equipment should be built

to keep poultry housing temperatures below 5°C above the ambient temperature.

Catching, loading, and transporting birds in high-temperature or high-humidity conditions put them under a lot of stress. As a result, planning should be developed in advance, including daily attention to metrological projections, in order to take the appropriate actions to decrease the risk of overheating. Early in the morning is the best time to catch and transport chickens. During the catching and loading procedures, additional mobile fans or ventilation fans should be provided for the uncaught birds. Water should be supplied to the uncaught birds on a regular basis by lowering the drinkers from time to time, ensuring that the birds have enough water, food, and light.

During the hot summer months, density is one of the most important factors [82]. As a result, the number of birds should be modified based on the crate design and the temperature of the environment.

Feeding measures: To counteract the negative effects of rising environmental temperatures, several successful dietary strategies have been implemented. The goal is to provide water, nutrients, electrolytes, vitamins, and minerals to meet the unique needs of chickens in hot climates. Heat stress has a deleterious impact on broiler growth and immunity, while early feed restriction (EFR) lessens this [12,79,83-85]. In response to heat stress on days 35 to 41 (marketing age), feed restriction (about 60 percent) to chicks on days 4, 5, and 6 increased growth and survival rate.

Fat supplementation in feed improves nutrient utilisation by increasing the nutritious value of other feed components, reducing feed retention time in the digestive tract, and increasing nutrient utilisation [2,86]. During times of extreme stress, the feed should be made up of highly digestible nutrients [82]. As a result, the chicken industry recommends using high-quality protein and amino acids (for example methionine and lysine) to prevent heat accumulation and the detrimental consequences of high temperatures [85,87,88].

Minerals (Fe, Zn, Se and Cr) and vitamins (A, C and E) are expelled from the body of chickens during heat stress, resulting in mineral and vitamin deficit [2,85,89]. Under adverse environmental conditions, nutritional supplementation of vitamins, minerals, and electrolyte balance has been shown to reduce mortality and improve growth rate in poultry [81]. Salts electrolytes ammonium chloride, potassium chloride, and sodium bicarbonate added to broiler feed or drinking water boost performance and prevent broilers from the harmful effects of heat exposure [12,81,90,91]. The addition of sodium bicarbonate (four to ten kilogrammes per tonne of feed) helps to maintain the acid-base balance in the birds, which is caused by panting (respiratory alkalosis). In drinking water and/or feed, potassium chloride 0.25-0.5 percent or 0.5-1.0 percent restores electrolyte salt equilibrium [81].

Elnagar et al, [92] reported that in poultry, adding an electrolyte to drinking water replenishes important nutrients that help balance blood pH levels.

The gut microbiota changes negatively as a result of heat stress. Supplementing probiotic-based lactobacillus strains to chickens suffering from high temperatures may help to balance the gut microbiota [2,79,93]. Several specialised feed supplements, such as dietary enzymes, baking soda, zinc bacitracin, and osmoprotective supplements, may also help to reduce

heat-stress mortality [6,81]. Feed should not be stored for more than two months, especially during the warmer season, to avoid fungus contamination. Feeding times should be in the morning or evening, or the night feeding concept should be followed. In laying hens, 1/3 of the ration should be given early in the morning and the other 2/3 late in the afternoon.

Kapetanov et al, [82] reported that night feeding can improve the quality of eggshell. The feed mixture should be correctly formulated to meet the specific needs of the chicken breed. Low-energy lights or dimmers should be used during feeding to limit the birds' activity, which reduces the heat load. In hot locations, several writers propose feeding broilers roughly 4 to 6 hours before the daily high in temperatures to prevent the increase in body temperature during feed intake [2].

Genetic measures: Breed improvement initiatives have improved the pace of growth and feed efficiency in chicken, but they have resulted in a reduction in heat tolerance and the genotype responses in high-temperature environments may differ from those in a thermo-neutral environment [2,94]. There are a number of traits in poultry, which favor heat tolerance. Due to a loss of immunity, heat stress reduces bird disease resistance [95,96].

Gwaza et al., 2017 revealed that three broiler, exhibited similar performance at temperature 18°C, but, changes in feed intake, body weight and feed efficiency were seen at temperature 28°C. Protein synthesis is mostly halted during thermal stress, but Heat Shock Proteins (HSP) are rapidly synthesised and bind with heat-sensitive proteins to prevent protein degradation. HSP also prevent proteins from precipitating and affecting cell viability [2,97]. In livestock breeding, genomic selection is used to choose the fittest animals [9].

Nowadays, poultry heat tolerance is determining with genetic markers such as SNPs (single nucleotide polymorphisms) and these markers use chromosomal regions of chickens [2,98,99].

Epigenetics is another possible tool in the animal breeding industry. It causes heritable phenotype change that do not involve alteration in the DNA sequences such as gene expression, transposon imprinting and silencing, histone protein modification, non-coding RNA, DNA sequencing, and DNA methylation and can assist researchers figure out how environmental variables cause heritable differences in gene expression or genomic functions. This can be used to increase the birds' heat tolerance while also increasing chicken output in the future [100,101]. To boost global meat-chicken production, it is vital to concentrate on broiler genotypes, particularly in hotter regions of the world [12].

Conclusion

Heat stress is one of the most important environmental stressors that poultry producers face around the world. Heat stress has a variety of detrimental impacts on broilers and laying hens, ranging from lower growth and egg production to decreased quality and safety of poultry and eggs. However, the harmful impact of heat stress on poultry welfare should be a serious concern. Because of the poor heat tolerance of poultry genotypes, heat stress has a deleterious impact on the physiological, immunological, reproductive, and gastrointestinal health of poultry birds, resulting in significant economic losses in the poultry industry.

In stressful conditions, environmental alterations such as proper ventilation and cooling systems, as well as nutritional adjustments, may aid to lower metabolic heat production and preserve electrolyte balance. Early-age heat conditioning and regulated fasting during the starting days of a chick's life can improve thermo-tolerance and hence increase the survival rate of broilers under heat stress. These methods have different outcomes based on the age, health, breed, sex, management, and geographic location of the birds.

As a result, there is a critical need of various preventive techniques in order to address the poultry industry's future issues. Genetic markers are being investigated in the selection of poultry breeds to promote heat tolerance and disease resistance. Increased heat tolerance in birds can also be achieved through epigenetics (early embryo gene expression and imprinting). Understanding the various biological pathways involved in the physiological, reproductive, and immunological responses of poultry birds to global warming can be aided by cellular and molecular techniques such as RNA extraction, cDNA synthesis, and quantitative PCR, as well as examination of oxidative stress (malondialdehyde and thiobarbituric acid-reactive substances) and antioxidant enzyme activities such as superoxide dismutase, glutathione peroxidase and catalase activities.

This could aid in the development of poultry breeds that perform better in hotter environments. Furthermore, a specific breeding programme should be designed to assess the potentiality of better quality genes under various environmental conditions in order to improve the poultry industry, particularly in hotter climates around the world.

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