Impact of heat stress and strategies for its melioration in poultry production

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ABSTRACT

Poultry production is one of the rapidly growing sectors in the livestock industry. The major affecting factor for the poultry industry is heat stress. It occurs when the temperature of animals increases beyond a specific limit. It is found to be a significant cause of low productivity, reproductive performance, and economic losses in poultry. Several strategies have been adopted to alleviate the harmful impact of HS on poultry farming. Feeding management, water availability, thermal manipulation, and proper ventilation may prevent the poultry sector from heat stress.

1. Introduction:

Poultry production has become one of the rapidly thriving industries of the livestock sector across the globe. In tropical climates, environmental variation is a key contributor that influences the enduring viability of poultry production systems [1]. Poultry meat is a source of limited content of saturated fatty acids, but it is abundant in vitamins, minerals, and proteins. Likewise, the cheap source of animal protein is poultry eggs. One of the main reasons for the decrease in the productivity of the poultry industry is heat stress (HS), particularly in humid and hot tropical regions [2]. The optimal temperature range for peak laying hen performance is 19-22 °C; for growing broilers, the range lies between 18-22 °C. HS is one of the leading causes of decreased reproductive performance, stunted growth, increased mortality, reduced meat and egg production and quality. Prolonged exposure to HS can result in production losses and mortality in birds [3].

2. Effects of HS on Poultry birds

2.1. Biological Changes in Poultry Due to HS

HS in poultry can be a cause of several physiological, neuroendocrine, and behavioral changes that influence their overall health and performance.

2.1.1. Physiological changes

Due to the lack of sweat glands, thermoregulation is very strenuous for birds in hot weather, which leads to a reduction in production efficacy. When the body temperature of a bird is more than the air temperature, the metabolic heat is dissipated to the surrounding environment by radiation, evaporation, conduction, and convection. In contrast, when air temperature exceeds body temperature, the single way to attain thermal regulation is by high rectal temperature. It is indicated by evaporative heat loss that the bird is incapable of that balance. Poultry birds have been seen panting, gasping, closing their eyes, spreading their wings, engaging in cannibalism, and lying down when the environmental temperature is high [4]. Recent research has shown that a decrease in feed intake occurs during HS because the buccal cavity cannot accommodate both panting and feeding simultaneously [5]. These physiological changes in poultry are associated with reduced growth rates and economic losses.

2.1.2. Neuroendocrine changes

The neuroendocrine system is very essential in regulating the typical physiological functioning and homeostasis of chickens during HS. During the initial phases of HS in chickens, the sympathoadrenal medullary (SAM) axis is activated to control homeostasis. Sympathetic nerves recognize the increase in environmental temperature that enhances the secretion of catecholamines which is propagated by the signal to the adrenal medulla, in this way it reduces muscle glycogen, releases glucose in the blood, dilates the peripheral blood vessels, depletes liver glycogen, enhances neural sensitivity and increases the respiration rate to deal with the HS [6]. Corticotrophin-releasing hormone (CRH) is excreted out of the hypothalamus to cope with the stress as it boosts the synthesis and secretion of corticosteroid by the adrenal glands which is stimulated by the emission of an adrenocorticotrophic hormone (ACTH) out of the pituitary gland. Plasma glucose levels are uplifted by corticosteroids as it triggers gluconeogenesis whereas thyroid hormones, triiodothyronine (T3) and thyroxine (T4), excreted by the thyroid gland are crucial in managing metabolic rate [7]. These hormonal changes cause a reduction in growth performance and reproductive efficacy of heat-stressed birds.

2.1.3. Behavioral changes

Birds try to alleviate surplus heat produced inside the body when they are subjected to a temperature exceeding their thermoneutral temperature, revealed by particular behavioral variations in birds. Under heat stress conditions, chickens spend less time standing and walking, their body surface covered in litter, they take more water and less feed, and spread their wings. These behavioral changes result in high mortality, low final body weight, reduced meat and egg production, and less feed intake in poultry.

2.2. Effect of HS on reproduction

Reproductive efficiency and egg quality of birds are crucially affected by HS. HS causes a decrease in the reproductive efficacy of domestic birds due to a decline in hypothalamic gonadotropin-releasing hormone-I content and luteinizing hormone levels. The decrease in reproductive efficiency of poultry during HS due to disruption in the thermoregulatory mechanisms might be regulated at the hypothalamus and pituitary levels. Reduced reproductive activity in White Leghorn hens exposed to high ambient temperature results in reproductive failure and poor egg quality [8].

2.3. Effect of HS on gut health

The gut is renowned significantly for being the place of digestion and nutrient absorption. Previous research proposed that gut health is negatively impacted by HS as it damages the intestinal morphology by increased crypt depth (CD), decreased villus height (VH), and VH to CD ratio. Further, the junctional gene expression that adheres to the epithelial cells was also enhanced. HS reduces the expression of claudin-1, ZO-1, E-cadherin, and occluding genes in birds. Consequently, the permeability of the intestinal barrier results in 'leaky gut syndrome' [9].

Thus, considering the economic losses and reduction in productivity of poultry birds HS is regarded as one of the most significant factors which negatively affects the poultry industry. Different strategies and approaches have been implemented by researchers and farmers to deal with this situation.

3. Strategies to reduce heat stress in poultry

To diminish the effects of HS there is dire a need to promote the use of different strategies as environmental temperature is increasing steadily worldwide. Several strategies have been tested with limited progress and these are discussed below.

3.1. Feeding Strategies

3.1.1. Feed Restriction

In poultry production, restricting the feed during the warmer duration of the day has been a routine practice. This approach is used to lower the metabolic rate of birds, feed intake is lowered by withholding feed for a specific period (generally 8 a.m. to 5 p.m.). It is observed that in the heat-stressed broiler, feed restriction plays a crucial role in minimizing mortality and decreasing abdominal fat and rectal temperature. It is determined that there is an increase in feed efficacy and reduction in tonic immobility when restricting the access to feed for 8 hours a day during the warmer duration in broilers [10].

3.1.2. Dual Feeding Regime

Practical experiences have demonstrated that feed restriction leads to additional mortality due to crowded conditions and rush at a refeeding time. Thus, to ensure that birds have an approach to feed throughout the day, a strategy has been introduced which is a dual feeding regime. Protein has greater thermal effects than carbohydrates, so it generates higher metabolic heat. During cooler durations, the protein-rich diet is given and during the warmer duration of the day, the energy-rich diet is given as proteins have greater thermal effects than carbohydrates, so they generate higher metabolic heat [11].

3.1.3. Wet Feeding

A significant amount of water is lost by birds via the respiratory tract and a significant rise in water intake occurs to restore thermoregulation during HS.

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The addition of water in the feed plays a role in promoting an increased intake of water and lowering viscosity which leads to the quicker passage of the feed in the gut. Due to pre-digestion as a result of wet feeding, there is an improvement in nutrient absorption from the gut and quickness in the gut enzyme activity on the feed. Wet feeding is found to enhance the intake of feed, weight of the GI tract, and body weight in boilers. Due to the possibility of growth of fungus in the feed that can cause mycotoxicosis in the birds, this strategy is uncommon among poultry farmers. Although it is found to have positive effects in heat-stressed birds [12]

3.1.4. Adding Fat in the Diet

To partially alleviate the effects of HS in poultry, higher energy diets were found very effective. Fat yields lower heat in comparison to protein and carbohydrates during metabolism. Fat added to the poultry diet aids in boosting the absorption of nutrients in the gastrointestinal tract by reducing the passage speed of food and also enhances the energy content of the other feed components [13].

3.2. Genetic Approach

Enhanced broiler lines are more prone to HS as they exhibit a higher metabolic rate. Therefore, integrating certain genes that aid in reducing HS in developing poultry lines can be pivotal in further enhancement of the production of these breeds in arid and hot regions. Under HS the primary concern with meat-type birds has been linked with the lack of feed intake. Successive selection over the past few decades aimed for rapid broiler growth. However, because of reduced heat tolerance in contrast to slow growing broilers fast growing broilers are noticeably more impacted by HS. Fine mapping with quantitative attributes loci (QTL) is efficient as well for the identification of birds with high HS tolerance. Identification of QTL regarding crucial traits like weight and body temperature is the key objective for such investigations. Previous research proposed that QTL supports the selection of heat-bearing chickens for enhanced growth performances in birds [14].

3.3. Early age thermal conditioning

The poultry sector demands rapidly growing birds to attain the highest weight in the least time. Due to their elevated metabolic rate, rapidly growing birds are more prone to HS. During fluctuating temperature conditions, birds experience challenges in keeping stable inner body temperature. Panting and other mechanisms employed by birds are inadequate to sustain body temperature. Under high-temperature conditions, it is vital to bring down the body temperature to increase the bird's resilience to HS. Previous investigations proposed that 24-hour thermal conditioning at 40°C of a 5-day-old chick led to a decline in the body temperature in broilers. For example, when chicks are kept for the first 4 days at 35°C, they exhibit more suitable rectal temperature and glucose levels unlike birds kept at a consistent temperature for 2 days [15,16].

3.4. Thermal manipulation

In a developing embryo modulation in the temperature during incubation is termed as thermal manipulation (TM). Several aspects encompassing the incubation phase, exposure time, and temperature play a role in the effectiveness of TM. Recent investigations proposed that TM can be adequately utilized for optimizing hatchability by reducing the rectal temperature and chick weight at the hatch. Further, TM improves heat tolerance capability by stimulating the antioxidant enzyme-related genes such as catalase and nicotinamide adenine dinucleotide phosphate oxidase 4, Superoxide dismutase, HSP70, and immunity-related genes (IL-6, IL-1β, TNF-α, NFκB50) in the birds affected by heat stress [17].

4. Conclusion

The poultry sector is the major revenue generator for many countries and different factors are affecting it negatively. Heat stress is one of the leading causes of mortality in the poultry sector. It adversely impacts the production and feed intake of birds. It affects both meat and egg-producing birds. It reduces the growth and lowers the egg and meat quality. Different strategies need to be addressed for the prevention of HS such as feeding management, genetic approach, early-age thermal conditioning, and thermal manipulation.

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