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A review on the impact of heat stress on poultry performance

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Abstract
Environmental stress significantly restricts poultry performance, health, and welfare across the globe. Among the various stressors, thermal stress particularly heat stress remains the most critical challenge due to rising global temperatures and the intensification of modern production systems. Such stress induces a range of physiological, biochemical, behavioural, and immune alterations that reduce feed intake, hinder growth, lower egg production, impair fertility, weaken immunity, and increase mortality. This review outlines the major environmental stressors affecting poultry, explains their underlying mechanisms, and highlights their effects on growth, reproduction, immune function, and overall product quality. It also discusses management, nutritional, and genetic interventions to alleviate stress and enhance poultry resilience.

Keywords: Heat stress, poultry welfare, immune response, growth performance, thermoregulation, broiler, layer

Introduction

The poultry industry has gained significant importance worldwide. Among all food-producing animals, chickens provide the most efficient sources of protein through their meat and eggs. In many regions across the world, the poultry industry has emerged as a major contributor to the livestock sector. (Sebho, 2016) [1]. Chickens offer a more affordable and healthier source of food compared to red meat and several other protein options. (Leinonen *et al*., 2014) [2].

Although various climatic factors influence animal farming systems, environmental stress has received particular focus in livestock especially in poultry because of growing public awareness and the wide availability of scientific data (Lara and Rostagno, 2013) [3]. Changes in environmental conditions such as sunlight, temperature, and humidity combined with an animal's metabolic traits and thermoregulatory mechanisms can lead to physiological imbalances in the body (Leinonen *et al*., 2014) [2]. Rising temperatures can increase the survival and activity of pathogens, such as bacteria and parasites in the poultry environment. Heat stress also hampers the growth of crops like cereal grains, leading to lower feed quality, which in turn reduces feed efficiency and slows the growth rate (daily weight gain) of poultry (Gupta *et al*., 2016; Ibtisham *et al*., 2017) [4, 5]. Ayo *et al*. (2011) [6] reported that layer chickens showed a 20% decline in feed intake during periods of high heat and humidity. They also observed reduced egg output and a decrease in hen-day egg production under these conditions.

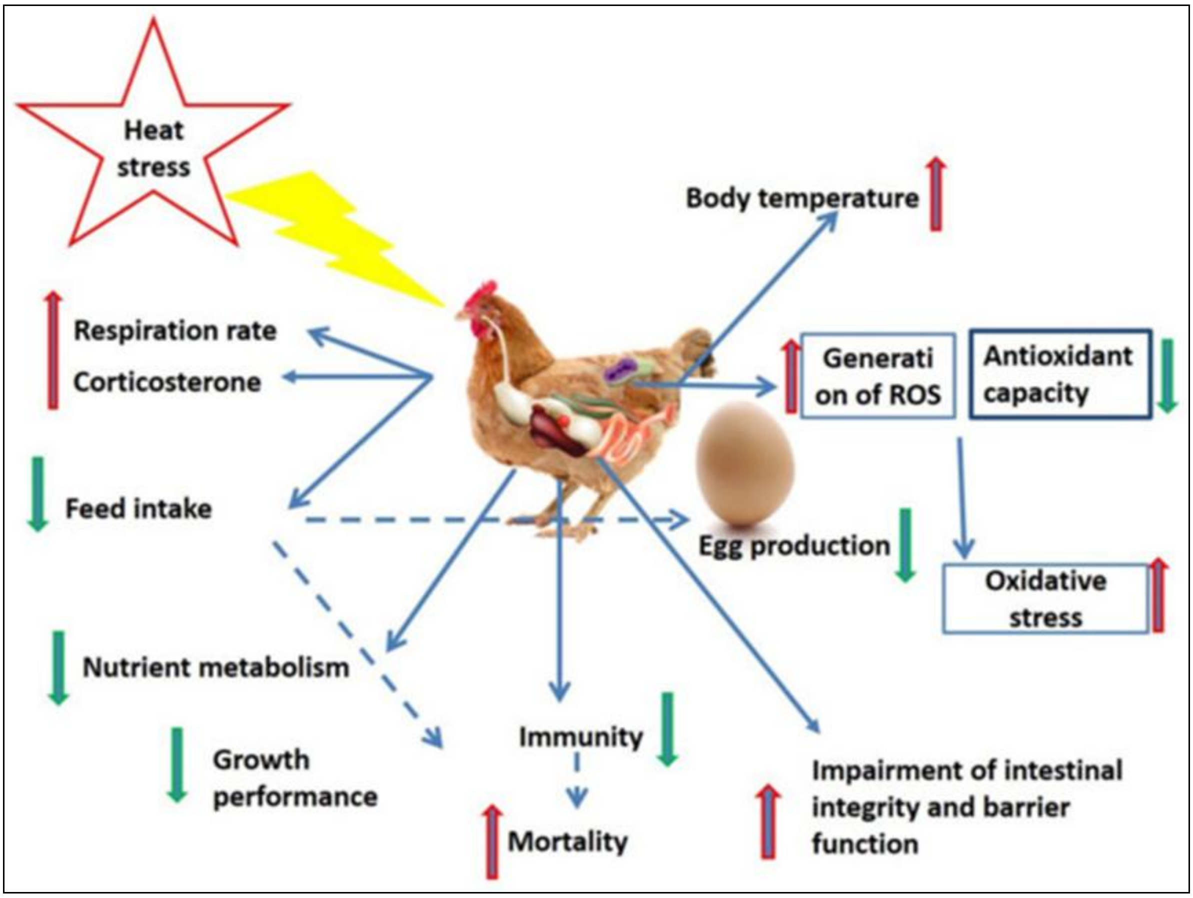
High ambient temperatures adversely affect chickens, leading to increased morbidity and mortality, which ultimately poses a risk to human nutritional security (Nienabar, 2007; Renaudeau *et al*., 2012) [7, 8]. Multiple studies indicate that during heat stress, fast-growing broilers exhibit a greater rise in feed conversion ratio (FCR) compared to slow-growing layers, which negatively impacts overall production costs. (Loyau *et al*., 2013) [9]. Modern commercial poultry generate substantial metabolic heat due to their rapid growth rates, making them highly susceptible to elevated environmental temperatures (Fisinin and Kavtarashvili, 2015; Pawar *et al*., 2016) [10, 11]. Increased ambient temperatures adversely influence the behavioural, physiological, and immune functions of broilers and layers, leading to detrimental outcomes such as immune suppression, hormonal disturbances, and electrolyte imbalance, ultimately reducing profitability (Mazzi *et al*., 2003; Quinteiro-Filho *et al*., 2012) [12, 13]. Consequently, it is essential to investigate the impacts of heat stress on poultry production and to formulate effective mitigation strategies, including the development of heat-tolerant breeds, to sustain efficient poultry production in hot climates.

What is Stress?

Stress has been examined extensively in animal science, yet a universally accepted definition remains elusive. Broadly, stress can be understood as any internal or external stimulus that challenges the normal physiological equilibrium of an organism (Virden and Kidd, 2009; Cirule *et al*., 2012) [14, 15]. When such stimuli interfere with biological processes or alter thermal balance, the resulting strain can progress into distress, particularly when coping mechanisms become overwhelmed (Moberg, 2000) [16]. Stress responses may arise from specific challenges, such as acute temperature changes, or from nonspecific adaptive reactions that occur when birds attempt to maintain homeostasis under varying environmental pressures (Virden and Kidd, 2009) [14]. The physiological response typically unfolds through three phases: an initial alert phase when the threat is perceived, a resistance phase during which the animal attempts to cope, and an exhaustion phase that develops if the stressor persists beyond the body's adaptive capacity. Among the different environmental pressures encountered by poultry, heat load is particularly damaging because it affects virtually every aspect of the production cycle.

Mechanism of heat stress in poultry

Heat stress in poultry occurs when ambient temperature and humidity rise beyond the bird's ability to eliminate internal heat, disrupting normal thermoregulation and homeostasis. Since chickens lack sweat glands, they depend mainly on panting to dissipate excess heat; however, intensified panting promotes excessive CO_2 exhalation, resulting in respiratory alkalosis and an imbalance in acid-base status (Yahav *et al*., 1997) [17]. To limit metabolic heat production, birds voluntarily reduce feed intake, which lowers nutrient supply and overall metabolic efficiency (Lara & Rostagno, 2013) [3]. Birds also undergo peripheral vasodilation to increase heat loss from the body surface, but this shift in blood flow away from visceral organs compromises gut integrity, reduces digestive capacity, and contributes to intestinal permeability (Quinteiro-Filho *et al*., 2010) [14]. Activation of the hypothalamic-pituitary-adrenal (HPA) axis during heat load elevates corticosterone levels, suppressing immune responsiveness and increasing muscle protein breakdown (Star *et al*., 2009) [18]. Prolonged exposure further enhances the formation of reactive oxygen species (ROS) while weakening antioxidant defenses, leading to oxidative stress and cellular injury (Mujahid *et al*., 2007) [19]. These combined thermoregulatory, metabolic, hormonal, and oxidative disturbances explain how heat stress severely limits poultry growth, immunity, and overall productivity.



Effect of heat stress on physiological responses in poultry

When birds experience high thermal loads, a series of physiological adjustments occur as they attempt to stabilize body temperature. Respiratory rate increases markedly, driving more rapid CO_2 release and predisposing birds to alkalosis and associated mineral disturbances that can impair eggshell formation (Yahav *et al*., 1997) [17]. Elevated core temperature, accelerated heart rate, and enhanced peripheral circulation help dissipate heat but simultaneously increase cardiovascular strain (Lara & Rostagno, 2013) [3]. Heat exposure also reduces digestive activity and feed passage, which diminishes nutrient breakdown and absorption, ultimately lowering metabolic efficiency (Quinteiro-Filho *et al*., 2010) [13]. Stimulation of the hypothalamic-pituitary-adrenal axis raises corticosterone concentrations, suppressing immune activity and promoting tissue catabolism (Star *et al*., 2009) [18]. Extended periods of heat load intensify oxidative pressure, as higher ROS levels coincide with reduced antioxidant defences, leading to structural and functional damage in various tissues (Mujahid *et al*., 2007) [19]. These combined responses can significantly impair growth, immunity, and overall flock performance.

Effect of heat stress on reproduction in poultry

Heat stress exerts a strong negative influence on poultry reproduction by altering endocrine function, damaging gametes, and compromising embryo development. High temperatures interfere with the hypothalamic-pituitary-gonadal axis, resulting in reduced secretion of reproductive hormones such as LH, FSH, estrogen, and progesterone changes that slow follicular development, impair ovulation, and reduce egg output (Rozenboim *et al*., 2007) [20]. Ovarian follicles may regress prematurely, and disturbances in acid-base and mineral balance can lead to eggs with poor albumen quality or thinner shells (Mashaly *et al*., 2004) [21]. In males, heat disrupts sperm formation and maturation, decreasing motility and viability while increasing abnormalities, effects largely tied to oxidative damage and weakened antioxidant defence systems (Karaca *et al*., 2002; Soleimani *et al*., 2011) [22, 23]. Reduced libido and mating activity also contribute to lower fertility rates. Additionally, hens exposed to heat stress deposit fewer nutrients and antioxidants into the egg, reducing embryo resilience and lowering hatchability (Deeb & Cahaner, 2002) [24]. These cumulative disruptions make heat stress a major limiting factor in poultry breeding efficiency.

Effect of heat stress on immune response in poultry

Heat stress significantly impairs the immune system of poultry by inducing hormonal, cellular, and oxidative alterations that weaken both innate and adaptive immunity. Exposure to high temperatures activates the Hypothalamic-Pituitary-Adrenal (HPA) axis, resulting in elevated corticosterone levels that suppress lymphocyte proliferation and cause thymic and bursal atrophy, thereby compromising T-cell and B-cell-mediated immune responses (Mashaly *et al*., 2004) [21]. Heat stress also reduces macrophage and heterophil activity, limiting phagocytic capacity and weakening the first line of defense against pathogens (Shehata *et al*., 2020) [25]. Additionally, prolonged heat exposure alters cytokine expression, increasing pro-inflammatory cytokines such as IL-1β, IL-6, and TNF-α while downregulating protective immune mediators, leading to systemic inflammation and immune dysregulation (Quinteiro-Filho *et al*., 2012) [13]. Oxidative stress induced by heat further damages immune cells and reduces antioxidant enzyme activity, impairing the structure and function of primary immune organs including the thymus, spleen, and bursa of Fabricius (Sohail *et al*., 2012) [26]. These combined effects reduce vaccine responsiveness and increase susceptibility to bacterial, viral, and parasitic infections, making heat stress one of the major immunosuppressive challenges in poultry production.

Strategies to reduce heat stress in poultry

Mitigating heat stress in poultry requires an integrated approach that combines environmental control, nutritional support, and sound management practices to maintain thermoregulation and reduce physiological burden. Housing modifications such as enhancing airflow through increased ventilation, installing fogging or sprinkler systems, and adopting evaporative cooling technologies, help lower ambient temperature and promote efficient heat dissipation (Yahav *et al*., 1997) [17]. Reducing bird density and ensuring continuous access to cool, clean water further contribute to maintaining optimal body temperature during heat episodes.

Nutritional interventions play a crucial role in improving tolerance to thermal stress. Supplementing diets with antioxidants (vitamins C and E), electrolytes (sodium, potassium, and chloride), selenium, and betaine supports cellular protection, stabilizes acid-base balance, and enhances immune competence under high thermal load (Sohail *et al*., 2012) [26]. Modifying feeding schedules so that most feed is offered during the cooler hours of the day, along with providing energy-rich diets, helps sustain productivity when feed intake declines due to elevated temperatures.

From a management perspective, incorporating heat-tolerant genetic strains, implementing early thermal conditioning of chicks, and maintaining dry, well-managed litter all contribute to improved resilience and reduced mortality (Lara & Rostagno, 2013) [3]. When applied collectively, these environmental, nutritional, and managerial strategies greatly improve bird welfare and maintain production efficiency in hot climates.

Conflict of Interest

Not available

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Reference

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