The Pharma Innovation Journal 2018; 7(1): 580-581

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2018; 7(1): 580-581

www.thepharmajournal.com
Received: 28-11-2017
Accepted: 29-12-2017

T Rama
Phd Scholar, Indian Veterinary Research Institute, Bareilly, Uttar Pradesh, India

K Sukandhiya
Senior Research Fellow, Department Of Poultry Science, Hosur, Tamil Nadu, India

Correspondence
T Rama
Phd Scholar, Indian Veterinary Research Institute, Bareilly, Uttar Pradesh, India

Physiological response of poultry to heat stress

T Rama and K Sukandhiya

Abstract
Understanding and controlling environmental conditions is crucial to successful poultry production and welfare. Heat stress is one of the most important environmental stressors challenging poultry production worldwide. The detrimental effects of heat stress on broilers and laying hens range from reduced growth and egg production to decreased poultry and egg quality and safety. Moreover, the negative impact of heat stress on poultry welfare has recently attracted increasing public awareness and concern. Much information has been published on the effects of heat stress on productivity and immune response in poultry. However, our knowledge of basic mechanisms associated to the reported effects, as well as related to poultry behavior and welfare under heat stress conditions is in fact scarce. Intervention strategies to deal with heat stress conditions have been the focus of many published studies. Nevertheless, effectiveness of most of the interventions has been variable or inconsistent. This review focuses on the scientific evidence available on the importance and impact of heat stress in poultry production, with emphasis on broilers and laying hens.

Keywords: Broilers, laying hens, heat stress, poultry, welfare

Introduction
Stress is any situation that elicits the biological stress mechanisms. In other words, stress is a biological response elicited when an animal perceives a threat to its homeostasis or normal physiological equilibrium. Heat stress is one of the most important environmental stressors challenging poultry production worldwide. Heat stress results from a negative balance between the net amount of energy flowing from the animal's body to its surrounding environment and the amount of heat energy produced by the animal. The detrimental effects of heat stress on broilers and laying hens range from reduced growth and egg production to decreased poultry and egg quality and safety.

Classification of stress response
Stress responses can be categorized as specific or nonspecific. Specific stressors are typically short-term, such as a sudden increase in environmental temperature. Animals typically react to specific stressors by trying to combat the stressor. Long-term or nonspecific stress, however, results in the animal taking measures to adapt the stressor, rather than dealing with it directly.

Short term regulation of stress
When a bird first encounters a stressor, the neurogenic system is activated. The neurogenic system is composed of the sympathetic postganglionic neurons and adrenal medullary tissue. Activation of the neurogenic system leads to marked increase in blood pressure, muscle tone, nerve sensitivity, blood sugar, and respiration. This is brought about by secretion of the neurogenic amines - epinephrine and norepinephrine.

Failed attempts to combat from the stressor immediately result in the activation of the hypothalamic-pituitary-adrenal cortical system. When this system is activated, the hypothalamus produces corticotrophin-releasing factor, which in turn stimulates the pituitary to release adrenocorticotropic hormone (ACTH). Secretion of ACTH causes the cells of the adrenal cortical tissue to proliferate and to secrete corticosteroids. Corticosterone (CS) is the primary corticosteroid in birds. This hormonal cascade is probably facilitated by the action of catecholamines because catecholamines stimulate corticotrophin releasing factor release from the hypothalamus, ACTH release from the pituitary, and corticosteroid release from the adrenal cortex. If corticosteroids remain at elevated levels in circulation, there are many possible effects, including, but not limited to, changes in glucose and mineral metabolism, cardiovascular diseases, hypercholesterolemia, gastrointestinal lesions, and alterations in immune system function. The distribution of corticosteroids and the delivery of corticosteroids to the tissues are controlled, at least partially, by corticosteroid-binding globulins. The role of corticosteroid-binding globulins is to restrict the absorption of CS by remaining bound to CS until in the presence of the specific target tissue because only unbound CS can pass through the cell membrane.

Long term regulation of stress

Long term physiological stress can be categorized as immunological or metabolic.

Reduction in lymphocyte numbers and an increase in the ratio of circulating heterophils to lymphocytes, is the most recognizable symptom of stress in poultry. The cause of this decrease in lymphocyte numbers is probably due to the regression of lymphoid tissue caused by the presence of circulating CS for prolonged periods. Regression of the thymus, bursa, and spleen, Inhibition of lymphocyte production by lymphoid tissue atrophy are the alterations in immune system which can result in immunosuppression. Reduction of cytokines and MHC-II antigen presence can cause impaired immune responses and disease resistance because they play important roles in both cellular innate and humoral adaptive immunity.

Probably the most pronounced consequence of chronic stress is the alteration of metabolic function. Primarily, stress-induced metabolic alterations seem to be focused on the mobilization or production of glucose for energy needed to maintain homeostasis in the presence of the stressor. During stress, birds adapt by creating a tissue priority hierarchy by which nutrients are devoted to certain tissues based on their order of importance.

When the bird is initially exposed to stress, the neurogenic system is activated, and the catecholamines, epinephrine and norepinephrine, are released. Of these, epinephrine seems to have the largest role in altering metabolism. Epinephrine binds to β-adrenergic receptors on the cell membrane. When this occurs, the main result is enzyme activation, most notably the activation of certain protein kinases that signal the body to enact glycogenolysis and gluconeogenesis. Probably the chief function of norepinephrine during stress is to induce nonshivering thermogenesis to provide energy from adipose tissue for skeletal muscles because the majority of energy from glucose is being devoted to other tissues. After the activation of the hypothalamic-pituitary- adrenal cortical system and the subsequent secretion of CS, further metabolic alterations occur, which focus on glucose production and mobilization. One of the chief metabolic functions of CS is to promote gluconeogenesis by causing the liberation of substrates from body tissues necessary for endogenous glucose production.

Physiological response to environment

The most important physiological response of poultry to the environment is the constant maintenance of a homoeothermic state during exposure to extreme ambient temperatures. Since birds do not sweat, they must rely on evaporative cooling (panting) to keep themselves cool. Panting produces respiratory alkalosis of the blood. This physiologic response is characterized by an increase in blood pH along with a decrease in blood CO_2 concentration. This upsets the blood acid-base balance. Excess acids in the blood (H+) can combine with bicarbonate ions (HCO3−) to form H2CO3 (carbonic acid), which is converted into CO2 and H2O by the action of carbonic anhydrase. The CO2 resulting from this reaction is removed by the lungs, and the H+ ions are excreted by the kidneys with the HCO3− retained to maintain the acid-base ratio. Therefore, to maintain the acid-base balance, birds have to regulate acid uptake and excretion (Ruiz-Lopez and Austic, 1993). When there is either an excess or deficiency of acid or base in the body, excess bases or alkaline reserves are adjusted. The minerals most essential to acid-base balance are Na, K, and Cl. There is a reduction in plasma levels of K+ and Na+ due to heat stress, probably as a result of hemodilution following increased water consumption.

Synthesis of heat shock proteins

Several cellular events are triggered when cells and organisms are exposed to stress injury. The physiological and molecular mechanisms involved in the stress response have been extensively investigated in a wide variety of species. It has been well characterized that this emergency response is marked by a drastic reduction in cellular protein synthesis, except for a set of proteins named heat shock proteins (Hsps), whose synthesis is perceptibly increased under stressing conditions. These proteins are highly conserved among species and some evidences suggest that their function is to protect stressed cells and organisms, preventing or reversing disorders caused by stress. Other stressing agents besides changes in environment temperature can activate specific heat shock genes, with a consequent increase in synthesis and levels of intracellular Hsps. There is an expression of 70 kDa heat shock protein (Hsp70) which is time - and temperature-dependent in broiler chickens.

Conclusion

Physiological stress is one of many concerns facing the modern poultry producers. Research has yet to reveal mechanisms that would allow the producer to efficiently minimize the detrimental impacts of physiological stress on the performance of poultry.

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