Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(2): 1872-1877

Received: 26-01-2020
Accepted: 27-02-2020

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Nutritional ways to reduce heat stress in broilers

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Abstract
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. Much information has been published on the effects of heat stress on productivity and immune response in poultry. A number of methods to reduce heat stress on poultry production are presented along with various management considerations, including water management, dietary adjustments, increasing heat tolerance through the process of acclimation, designing mineral drinking water supplementation and designing rations for correcting the acid-base imbalance. The beneficial effects of supplemental anti-stress agents (e.g., ascorbic acid) in reducing heat stress are also noted. Nutritional approaches like use of proper concentration of energy, protein, amino acid, electrolyte and vitamin-A, E and C can minimize detrimental effect of heat stress.

Keywords: Heat stress, broiler, feeding management, watering management, vitamins

Introduction

In the world, the poultry industry occupies a leading role among agricultural industries - main supplier of animal protein. Stress is a big factor in determining the overall health of poultry. Stress comes in many forms and seems to affect the performance of birds.

The term "stress" is used to describe the detrimental effect of variety of factors on the health and performance of poultry (Rosales, 1994) [33]. Or "Stress is the nonspecific response of the body to any demand", whereas stressor can be defined as "an agent that produces stress at any time". Therefore, stress represents the reaction of the animal organism (i.e., a biological response) to stimuli that disturb its normal physiological equilibrium or homeostasis (Selye, 1976) [35]. The commercial high yielding breeds are more susceptible to stress and diseases. Stress represents the reaction of the animal organism (i.e., a biological response) to stimuli that disturb its normal physiological equilibrium or homeostasis. The importance of animal responses to environmental challenges applies to all species. However, poultry seems to be particularly sensitive to temperature-associated environmental challenges, especially heat stress. Understanding and controlling environmental conditions is crucial to successful poultry production and welfare. Heat Stress not only causes suffering and death in the birds, but also results in reduced or lost production that adversely affects the profit from the enterprise. Feed consumption is reduced by 5% for every 1^0C rise in temperature between 32-38ºC (John *et al.*, 2008) [20]. Stress response is mainly associated with the activation of hypothalamo-pituitary-adrenal (HPA) axis and orthosympathic nervous system, which aggravates the detrimental effect of high body temperature. The adverse effects of heat stress include high mortality, decreased feed consumption, and poor body weight gain and meat quality in broiler chickens, and poor laying rate and egg weight and shell quality in laying hens (Yahav, 2000) [41].

Behavioral and Physiological Effects of Heat Stress

- Spend less time feeding, more time drinking and panting, as well as more time with their wings elevated, less time moving or walking and more time resting (Mack *et al.*, 2013) [26].
- Increased panting under heat stress conditions leads to increased carbon dioxide levels and higher blood pH (i.e. alkalosis). It affects egg shell quality (Marder *et.al.*, 1989) [27].
- In females, heat stress can disrupt the normal status of reproductive hormones at the hypothalamus, and at the ovary, leading to reduced systemic levels and functions (Elnagar *et. al.*, 2010) [11].
- Also, negative effects caused by heat stress in males, Semen volume, sperm concentration, number of live sperm cells and motility decreased when males were subjected to heat stress (McDaniel *et.al.*, 2004) [28].

- High environmental temperatures alter the activity of the neuroendocrine system of poultry, resulting in activation of the hypothalamic-pituitary-adrenal (HPA) axis, and elevated plasma corticosterone concentrations (Star *et. al*., 2008 and Quinteiro –Filho *et. al*., 2012) [36, 32].

Effect of Heat Stress on the Immune Response

- In general, all studies show an immunosuppressing effect of heat stress on broilers and laying hens, although using different measurements. For instance, lower relative weights of thymus and spleen has been found in laying hens subjected to heat stress (Gazi *et. al*., 2012) [12]; reduced lymphoid organ weights have also been reported in broilers under heat stress conditions (Nui *et. al*., 2009) [30].
- Reduced liver weights in laying hens subjected to chronic heat stress conditions (Felver-Gant *et al*., 2012) [13]. The decreased liver weight can be attributed to multiple negative consequences of heat stress (HS). Under HS, capillary blood flow in the hen will be redirected from inner organs to outer body parts, such as the epidermis, wattle, comb, and upper respiratory tract, to aid in body heat loss. Capillary blood flow was found to significantly decrease in the liver given the lack of capillary blood flow; the organ may become compromised during this period, resulting in limited function. Furthermore, hens exhibit hyperventilation and maintain proper thermoregulation through evaporative cooling, which can result in dehydration. This can lead to a decrease of fluids in multiple organs of the hen and ultimately reveal itself in decreased weight.
- Bartlett and Smith (2003) [4] observed that broilers subjected to heat stress had lower levels of total circulating antibodies, as well as lower specific IgM and IgG levels, both during primary and secondary humoral responses. Moreover, they observed significantly reduced thymus, bursa, spleen, and liver weights.
- The occurrence of reduced bursa weight in broilers subjected to heat stress, as well as decreased numbers of lymphocytes in the cortex and medulla areas of the bursa (Aengwanich, 2008) [2].
- Reduced antibody response, as well as reduced phagocytic ability of macrophages, in broilers under heat stress. Moreover, reduced macrophages performing phagocytosis, as well as reduced macrophage basal and induced oxidative burst were observed in heat-stressed broilers (Quinteiro –Filho *et. al*., 2012) [32].
- Heat stress can alter levels of circulating cells. It has been shown that heat stress causes an increase in heterophil:lymphocyte ratio, due to reduced numbers of circulating lymphocytes and higher numbers of heterophils (Felver-Gant *et. al*., 2012) [13].

Impact of Heat Stress on Poultry Production

- In broilers subjected to chronic heat stress had significantly reduced feed intake (16.4%), lower body weight (32.6%), and higher feed conversion ratio (+25.6%) at 42 days of age (Ghazi *et. al*., 2012 and Imik *et. al*., 2012) [16] [19].
- However, even though the detrimental effects of heat stress in broilers seem to be very consistent, it is important to consider that stocking density has a major role as a potential compounding factor, both from the standpoint of productivity as well as welfare (Estevez, 2007) [12].
- The chronic heat exposure negatively affects fat deposition and meat quality in broilers, in a breed-dependent manner (Lu Q. *et. al*., 2007) [25].
- The heat stress is associated with depression of meat chemical composition and quality in broilers (Dai *et. al*., 2012) [9].
- The chronic heat stress decreased the proportion of breast muscle, while increasing the proportion of thigh muscle in broilers. Moreover, the study also showed that protein content was lower and fat deposition higher in birds subjected to heat stress (Zhag *et. al*., 2012) [42].
- Heat stress during transport has been associated with higher mortality rate, decreased meat quality and reduced welfare status (Mitchell and Kettlewell, 1998) [29].
- (Warriss *et. al*., 2005) [40] Demonstrated a seasonal impact with peak mortality rates occurring in the summer months.
- Decreased feed intake is very likely the starting point of most detrimental effects of heat stress on production, leading to decreased body weight, feed efficiency, egg production and quality (Deng *et. al*., 2012) [10].
- It has been shown that heat stress leads to reduced dietary digestibility and decreased plasma protein and calcium levels (Zhou *et. al*., 1998) [43].
- (Deng *et. al*., 2012) [10] Reported a 12-day heat stress period caused a daily feed intake reduction of 28.58 g/bird, resulting in a 28.8% decrease in egg production.
- (Star *et al*., 2009) reported a reduction of 31.6% in feed conversion, 36.4% in egg production, and 3.41% in egg weight in laying hens subjected to heat stress.

Heat Stress Impact Food Safety

- Heat stress during the growth period of broilers has been associated with undesirable meat characteristics and quality loss (Zhang *et. al*., 2012) [42].
- Additionally, transportation of broilers from farms to processing facilities under high temperature conditions have also been shown to cause meat quality losses (Dadgar *et. al*., 2010) [8].
- In laying hens, heat stress has been shown to negatively affect egg production and quality (Bozkurt *et. al*., 2012) [6].
- Environmental stress has been shown to be a factor that can lead to colonization of farm animals by pathogens, increased fecal shedding and horizontal transmission, and consequently, increased contamination risk of animal products (Verbrugghe *et al*., 2012) [39].
- Many recent studies have demonstrated that bacteria, such as *Salmonella* and *Campylobacter*, are capable of exploiting the neuroendocrine alterations due to the stress response in the host to promote growth and pathogenicity (Freestone *et al*., 2008) [15].
- In ex vivo approach, the study showed that mucosal attachment of *Salmonella enteritidis* increased when tissues originated from heat-stressed birds (Burkholder *et al*., 2008) [7].

Methods to alleviate the adverse effects of heat stress

Feeding management

Ensure good physical quality of feed (crumb, pellets or mash) to encourage appetite. If there is enough floor space, extra feeders should be added. Feed should not be stored for longer than two months, especially in summer to reduce the possibility of mycotoxin build up. Encourage eating at cooler times of the day, i.e., early morning or in the evening. Feeding birds at cool times enables birds to make up for what they have not eaten during the day. Laying hens increase their calcium intake during the evening as eggshells are normally formed during this time. Remove feed 4 to 6 hours prior to an anticipated heat stress period. Birds should not be fed or disturbed during the hottest part of the day. Dim the lights while feeding – using low light intensity during periodic feeding reduces activity that reduces heat load.

Feed Restriction

- Zulkifili *et al.*, (2000) [44] reported that, the survivability of female broilers restricted at an early age to 60% of ad libitum consumption was significantly ($p< 0.05$) higher than ad libitum broilers when exposed to heat tolerance test at 38ºC.
- Feed restriction of broilers kept at high ambient temperature (35ºC) reduced significantly the mortality rate. The total mortality rates at 35ºC were 12.19, 5.0 and 0.0% for broilers fed ad libitum, 75 % and 50 %, respectively. (Abu-Dieyeh, 2006) [1].
- (Koh and Macleod, 1999) [21] Who found that, rectal temperature of broilers was increased significantly when feed intake level was increased

Nutritional strategies

Energy Requirement

- ME Requirement decrease with increase in temperature. Lowest at 28-30ºC followed by increase up to 36ºC (Hurwitz, 1980) [18] Reduced energy intake is associated with reduced growth rate in heat stress. Feeding of high energy rations can overcome this growth rate depression.
- Necessary to reduce energy level by 10% and provide an addition of 1 or 2 % protein and slightly increase level of vitamins, minerals, essential amino acids and coccidiostat.
- Nearly 10-15% of calories in feed of carbohydrate and protein origin may be replaced by fat/oil energy.
- Digestion of fat produces less heat than the digestion of CHO and protein. Fat has also been shown to slow down feed passage through GI tract and increases nutrient utilization.

Protein & Amino acid Requirement:

- Protein requirement is decreased because of suppression in Production performance. High protein diet during heat stress decrease growth rate & meat yield. Protein has high heat increment. Diets containing lower protein levels & supplemented with limited amino acids, methionine and lysine gave better results.
- To ensure that layers do not suffer nutritional stress of hot weather, it is recommended that protein content of feed should be increased from 16% to 17-18%.
- It is contended that increasing dietary protein content would cover the requirements for isoleucine and tryptophan, while methionine and lysine can be supplemented with synthetic compounds provided that they are cheaper than natural sources.

Vitamin Requirement

- Decreased nutrient intake at high temperature decreases intake of micro nutrients. Supplementation of these nutrients is helpful for maintenance of performance & immune function (Ferket *et al.*, 1992) [14].

Vitamin C

- Under heat stress, birds are not able to synthesize enough vitamin C to meet physiological demands, hence the need for mineral and vitamin supplementation. Chicken require Vitamin C for amino acid and mineral metabolism as well as for synthesis of hormone. Vitamin C is also involved in the synthesis of the sex hormones such as testosterone, which is essential to the reproductive performance of males. Vitamin C @ 250-400 mg/kg of feed. Act as antioxidant reduce oxidative injuries. Reduce mortality.
- Supplemental dietary vitamin C limits and alleviates the metabolic sign of stress and improves performance, immunological status and the behavior of birds. Optimum response in growth, feed efficiency and/or livability in broilers under heat stress seems to occur with supplements of about 250 mg vitamin C/kg feed. Laying hens have also shown responses to supplemental vitamin C at 200-400 mg/kg in terms of improvement in livability, feed intake, egg production and egg quality (Panda, 2011) [11].

Vitamin A

- Detrimental effect on egg Production by heat stress can be alleviated by dietary supplement of Vitamin A @ (8000 IU/Kg diet) for optimal egg production. For immunity of heat stressed hen. Alleviate the oxidative injuries induced by heat Exposure.
- Vitamin A has an effect on the immune function of birds. It has been reported that conversion of carotene to vitamin A reduces under stress. In broiler chickens, Vitamin A (15,000IU) supplementation resulted in an improved live weight gain, feed efficiency, and carcass traits, as well as a decrease in serum MDA concentrations (Kucuk *et al.*, 2003) [22].
- Vitamin A supplementation is favourable for the immunity of heat-stressed hens. Hens suffering heat-stress immediately after NDV vaccination need higher dietary Vitamin A intake to obtain the maximal level of antibody production (Lin *et al.*, 2002) [24].

Vitamin E

- Vitamin E can be supplemented in broiler diets at 250 mg/kg as a protective management practice to reduce the negative effects of stress and to result in optimum performance in broilers. In layers, vitamin E supplementation at 125-250 mg/kg improves egg production, feed efficiency and immune competence. It also acts as antioxidant. Contribute to integrity of epithelial cells (Panda, 2011) [11].
- Vitamin E (125-250 mg/kg), vitamin C (200-250 mg/kg) and vitamin A (15000IU/kg) are recommended for alleviating summer stress in poultry (Panda, 2011) [11].
- Antioxidant vitamins such as vitamins A (retinol), E (α tocopherol) and C (ascorbic acid) are used in poultry diets because of their anti-stress effects and also because their synthesis is reduced during heat stress. Heat stress stimulates the release of corticosterone and catecholamines and initiates lipid peroxidation in cell membranes. (Panda, 2011) [11].

Mineral Requirement

- Blood acid balance is disturbed by hyperventilation and results in respiratory alkalosis. Respiratory Alkalosis suppress growth rate & egg shell quality. Suppression of growth can be partially alleviated by supplementation of 1% NH_4Cl, 0.15% - 0.6% KCl and 0.2% $NaHCO_3$ (Hayat *et al.*, 1999) [17].
- Supplementing diets with 0.3 or 1.0% Ammonium Chloride (NH_4Cl) significantly improved broiler weight gains by 9.5 and 25%, respectively and decreased blood pH. Also, adding 0.5 % sodium bicarbonate increased body weight gains by 9 %. Moreover, it was observed that both ammonium chloride and sodium bicarbonate had synergetic effect on broiler performance (Teeter *et al.*, 1985) [38].
- Zinc, chromium and folic acid supplementation alleviate heat stress.
- Dietary supplementation of chromium (120 ppb) is favourable to the zootechnical performance of heat-stressed broiler chickens, by increasing feed intake and body weight, improving feed efficiency, and facilitating carcass characteristics (Sahin *et al*., 2002) [34].
- Zinc (4.5 mg/kg) supplementation resulted in an improved live weight gain, feed efficiency, and carcass traits (Kucuk *et al*., 2003) [22].
- Moreover, there is a combination of zinc and Vitamin A effect in preventing heat-stress-related depression in performance of broiler chickens (Kucuk *et al*., 2003) [22].

Water management

- Provide clean, fresh, cold and sanitized water.
- Increase number of drinkers and provide adlib water.
- Water requirement increase during hot periods. 6% water intake increase per degree rise in temperature from that at 20^0C temperature. 25% more drinking space should be provided. Water below body temperature will certainly aid in heat dissipation.
- Water drinkers should be wide & deep enough so that birds face is immersed in it. Earthen pitchers can be used for watering birds.
- Wash and clean the drinkers regularly.
- Water tank and water pipeline should not expose to sun light.
- Maintain proper height of drinkers.

Water Supplements

- **Electrolytes:** Supplementation of electrolytes in water enhances Water consumption. Increase tolerance to heat stress. Improve production performance. (Balnave *et al.*, 1991) [3].
- Borges *et al.*, (2004) [5] reported that a dietary electrolyte balance of 240 m eq/ kg diet increased N, Na and K retention and water consumption and was more favourable under thermoneutral and heat stress temperatures than diets with dietary electrolyte balance of 140 or 340 m eq/ kg diet.
- **Probiotics:** Heat stress can induce unfavorable changes in indigenous bacterial microbionta. Supplementation of probiotic lactobacillus strains may enrich diversity of micro flora in chicken. Restore microbial balance in jejunum & caeca of chicken. Reduce harmful effects of heat stress. (Lan *et al.*, 2004) [23].

Water Supplements

- **Aspirin:** Aspirin in soluble liquid form can be used for its antipyretic (cooling) effect at the rate of 0.3 grams per liter of water.
- **Sodium Bicarbonate:** The addition of Sodium Bicarbonate @ 8gm/100 litre of drinking water (or 35gm per 25 kg of feed) can be useful in heat stressed broiler (Butcher & Miles, 2003).
- **Vitamin C:** Supplementation of vitamin C in drinking water at 40 milligrams per bird per day is reported to give beneficial effects in broilers.

Conclusion

The intervention strategies to deal with heat stress conditions have been the focus to apply different approaches, including environmental management (such as facilities design, ventilation, sprinkling, shading, etc.), nutritional manipulation (i.e., diet formulation according to the metabolic condition of the birds), as well as inclusion of feed additives in the diet (e.g., antioxidants, vitamins, minerals, probiotics, prebiotics, essential oils, etc.), housing design and water supplementation with electrolytes. Nevertheless, effectiveness of most of the interventions has been variable or inconsistent.

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