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REVIEW ARTICLE

Impact of Hot Climate on Poultry Production System-A Review

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Abstract

Inspite of the tremendous growth and baffling figures of production in Indian poultry sector, there are several constraints affecting future growth of the poultry industry, among which temperature-associated environmental challenges, especially hot climate imposes severe stress on birds and leads to reduced performance. Therefore, reviewing the impacts of heat stress on poultry productions or its reciprocal effects seems to be the priority research area in the present scenario. The purpose of this article is to review the physiology of birds with respect to hot climate and its detrimental effects on poultry production system.

Keywords: Poultry production, Heat stress, Climate Change, Management.

Introduction

The Indian poultry sector is characterized by its industrialization, faster growth in consumption and trade than any other major agricultural sectors in the world. Today, India is the third largest egg producer in the world after China and USA and the sixth largest broiler producer after USA, China, Eurpopean Union, Brazil and Mexico (FAO, 2014). India's contribution to world's egg and chicken meat production is nearly 5.3% and 2.53%, respectively (FAO, 2010a), whereas poultry sector contributes about 1% to national gross domestic product (GDP) and 11% of total livestock GDP in India. The estimated rate of growth in layers is 6-7% per annum and 10-15% for chicken meat. Thus, poultry development in the country has shown steady progress over the years. Along with this, poultry plays an important economic, nutritional and socio-cultural role in the livelihood of poor rural households in many developing countries, including India. Poultry includes fowl, turkey, duck, goose, ostrich, guinea fowl, etc. which render not only economic services but contribute significantly to human food as a primary supplier of meat, egg, raw materials to industries (feathers and waste products), source of income and employment to people compared to other domestic animals (Avila, 1985; Demeke, 2004). Based on the poultry industry's development during the last two decades and the need for increased animal protein sources in the hot regions of the world, there is general agreement that these areas are going to witness further expansion in the current decade. Although the need for more eggs and poultry meat is obvious and the availability of these products can go a long way to meet the protein needs of several populations in hot regions, there are several constraints to the future development of the poultry industry. The most obvious constraint on poultry production is the climate. Poultry seems to be particularly sensitive to temperature-associated environmental challenges, especially heat stress. High temperature, especially when coupled with high humidity, imposes severe stress on birds and leads to reduced performance. It has been suggested that modern poultry genotypes produce more body heat, due to their greater metabolic activity (Settar, 1999; Deeb and Cahaner, 2002). Seo and Mendelsohn (2006) reported that high environmental temperature will be harmful to commercial poultry owners and warming causes the net revenue from all animals to fall. Pant (2011) also reported that farmers have to bear direct cost of climate change that involves reductions of yield in poultry and indirect costs of adaptation. Understanding and controlling environmental conditions is crucial to successful poultry production and welfare. Therefore, reviewing the impacts of climate changes on poultry productions or its reciprocal effects seems to be the priority research area. Both of the climate change and poultry productions have always negative impacts one over the other. The purpose of this article is to review some of the effects of heat stress on poultry, and to look at methods that can be used by the poultry producer to partially alleviate some of the detrimental effects of heat stress on the poultry productivity.

Thermoregulatory Mechanism of Poultry Birds

The internal body temperature of domesticated gallinaceous birds (chickens) at 106°F to 108°F is measurably higher than that of mammalian livestock

Table 1: General guide to the reaction of adult poultry to various temperatures

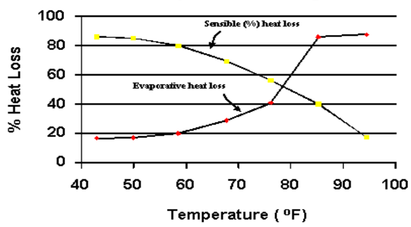
55° to 75°F	Thermal neutral zone. The temperature range in which the bird does not need to alter its basic metabolic rate or behavior to maintain its body temperature.
65° to 75°F	Ideal temperature range.
75° to 85°F	A slight reduction in feed consumption can be expected, but if nutrient intake is adequate, production efficiency is good. Egg size may be reduced and shell quality may suffer as temperatures reach the top of this range.
85° to 90°F	Feed consumption falls further. Weight gains are lower. Egg size and shell quality deteriorate. Egg production usually suffers. Cooling procedures should be started before this temperature range is reached.
90° to 95°F	Feed consumption continues to drop. There is some danger of heat prostration among layers, especially the heavier birds and those in full production. At these temperatures, cooling procedures must be carried out.
95° to 100°F	Heat prostration is probable. Emergency measures may be needed. Egg production and feed consumption are severely reduced. Water consumption is very high.
Over 100°F	Emergency measures are needed to cool birds. Survival is the concern at these temperatures.

and humans (97°F to 102°F). The upper temperature limit beyond which living cells and tissues progressively fail to operate is governed by the temperature at which enzymic proteins are destroyed by loss of shape and chemical activity. This starts to occur in the region of 46°C and thus poultry have considerably less leeway than other animals when suffering from heat stress and quickly succumb to higher temperature. In comparison, actual body temperature of poultry may fall as much as 20°C below the normal range with birds still making full recovery if carefully re-warmed. Poultry are not well adapted and disposed to high ambient air temperatures as they lack sweat glands in their skin and are therefore unable to gain much from natural evaporative cooling, although there is some direct diffusion of water through the skin tissue. Only the head appendages (e.g. comb) are very rich in blood vessels and able to act as sites for direct loss of heat, so poultry appears to have few limited options for heat loss in warm conditions. Domestic poultry is clearly less tolerant of heat than cold and much more likely to die from heat stress (hyperthermia) than succumb to stress associated with low temperature (hypothermia).

Methods of Heat Loss in Poultry

During the summer months, when daily temperatures reach at their extremes, it becomes critical for the birds to dissipate body heat to the surrounding environment. Poultry do not sweat and therefore must dissipate heat in other ways to maintain their body temperature at approximately 105°F. Body heat is dissipated to the surrounding environment through radiation, conduction, convection and evaporation (Mustaf *et al*., 2009) (Table 2). The first three avenues are known as sensible heat loss; these methods are effective when the environmental temperature is below or within the thermoneutral zone of the bird (55° to 75°F). The proportion of heat lost through radiation, conduction, and convection depends upon the temperature difference between the bird and its environment. The bird loses heat from surfaces such as wattles, shanks and un-feathered areas under wings. To maintain body temperature by sensible heat loss, the bird does not need to drastically alter its normal behavioral patterns, feed intake, or metabolism (Mack *et al*., 2013). The purpose of poultry house ventilation is to maintain a high air velocity or a low temperature in the house that the birds can maintain body temperature by sensible heat loss. Once the environmental temperature reaches approximately 77°F, the method of heat loss begins shifting from sensible to evaporative heat loss ((Fedde, 1998; Fig 1).

Figure 1. Method of heat loss from birds as temperature changes.



Dissipation of body heat by the evaporative process requires the bird to expend energy by panting (hyperventilation), which begins to occur at about -

Table 2: Methods of sensible and latent body heat loss in poultry

Heat Loss Method	**Direction of Heat Flow**
Sensible Heat Loss Methods	
Radiation Flow of thermal energy without the aid of a material medium between two surfaces	All surfaces radiate heat and receive radiation back; the net radiation heat flow is from higher to lower temperature surfaces.
Conduction Thermal energy flow through a medium or between objects in physical contact.	Direction of energy transfer depends on a temperature gradient; heat moves from areas of higher to lower temperature.
Convection Heat flow through a fluid medium such as air; thermal energy moves by conduction between a solid surface and the layer of air next to the surface, and the thermal energy is carried away by the flow of air over the surface.	Energy transfer to the air depends on temperature and movement of air across the skin surface; heat is transferred to air moving across the skin surface if the air is at a lower temperature than the skin.
Latent Heat Loss Method	
Evaporation The transfer of heat when a liquid is converted to a gas; when water is converted from a liquid to a vapor, heat is utilized.	Energy transfer is influenced by the relative humidity, temperature, and air movement; heat is transferred from the animal's body to water, turning it to water vapor.

80°F. Panting removes heat by the evaporation of water from the moist lining of the respiratory tract. However, panting itself generates body heat and it causes poultry to eliminate water from the body. It can induce respiratory alkalosis, which occurs because the bird "blows off" excessive carbon dioxide (CO_2) when it pants. As a result, body fluids become more alkaline, causing the kidneys to excrete excessive amounts of several electrolytes. As the shift in body fluid pH occurs, feed intake is increasingly depressed, adversely affecting growth, production, and overall performance of the bird (Marder and Arad, 1989). During the hot summer months, evaporative heat loss typically becomes the primary method by which birds regulate their body temperature unless proper ventilation is provided and other steps are taken to reduce heat stress

Heat Stress

Heat stress is a worldwide problem in poultry production, especially in broiler and layer lines. Heat stress begins when the ambient temperature climbs above 80^{o}F and is readily apparent above 85^{o}F. When a bird begins to pant, physiological changes have already started within its body to dissipate excess heat. Even before the bird reaches this point, anything that you do to help birds remain comfortable will help maintain optimum growth rates, hatchability, egg size, egg shell quality and egg production. High ambient temperatures can be devastating to commercial broilers; coupled with high humidity they can have an even more harmful effect. Heat stress interferes with the broilers comfort and suppresses productive efficiency, growth rate, feed conversion and live weight gain (Etches *et al*., 1995; Yalcin *et al*., 1997). In poultry production, heat stress can be described as acute or chronic. Acute heat stress refers to short and sudden periods of extremely high temperature, whereas chronic heat stress refers to extended periods of elevated temperature. Chronic stress has deleterious effects on birds reared in open-sided houses mainly through reducing feed consumption and increasing water consumption. Most of the reduction in feed consumption is due to reduced maintenance requirement. In broilers, growth rates, feed efficiency and carcass quality are negatively affected. Again, prolonged periods of elevated ambient temperature increase the broilers' time to reach market weight and increase mortality. In laying hens, heat stress leads to a decline in egg production and egg quality, as well as shelf life of eggs is shortened. In breeders, high ambient temperature coupled with high humidity decreases fertility resulting in low hatchability. During the heat stress period the increase in body temperature has a negative effect on gamete formation and the fertilization process. During periods of heat stress the hens have to make major thermo-regulatory adaptations to prevent death from heat exhaustion. As a result, the full genetic potential of the layer is often not achieved.

Clinical Signs and Symptoms of Heat Stress

Poultry subject to high environmental temperatures exhibit many behavioral and physiological changes which allow them to re-establish heat balance with their surroundings. As ambient temperature increases above comfort zone, chicken spend less time in feeding, more time in drinking and panting, as well as more time with their wings elevated, less time moving or walking and more time in resting (Mack *et al*., 2013). Usually, their wings are spread away from the body to promote cooling by reducing body insulation and they splash water on their combs and wattles in order to increase evaporative cooling from these surfaces (Fedde, 1998). Heat stressed birds also spend relatively less time engaging in social behavior and in changing posture. In a natural environment, birds will look for a shady and cool area. Within the bird, blood flow is diverted from certain internal body organs such as the liver, kidneys and intestines to dilated blood vessels of the peripheral tissue (skin) in order to facilitate heat loss (Mustaf *et al*., 2009).

Effect of Climate Change on Poultry Production System

As previously seen, exposure of birds to high environmental temperature generates behavioral, physiological and immunological responses, which impose detrimental consequences to their performance and productivity. Hot climate can have a severe impact on poultry performance. It inflicts heavy economic losses on poultry production as a result of stunted growth (Sahin *et al*., 2001), decrease in hen-day production (Njoku, 1989; Khan *et al*., 2003; Ayo *et al*., 2011), increased cost of production, high rate of mortality due to depressed immunity, and reproductive failure (Morsy, 1998; Obidi *et al*., 2008; Ayo *et al*., 2011).

Growth and Production Efficiency

Heat stress depresses growth rate and production as a result of a down-turn in voluntary feed intake in birds (Sahin *et al*., 2001). It is apparent that the inhibition of growth and production in heat-stressed broiler birds is mediated via the stress hormones, especially the corticosteroids. Sahin *et al*. (2001) also showed that body weight in heat-stressed broilers was significantly lower than in birds administered with antioxidant vitamins A and E. Plasma triiodothyronine and thyroxine, which are important growth promoters in animals, were adversely affected in heat-stressed broiler chickens. Heat stress results in decreased feed consumption and increased water consumption. As temperature rises, the bird has to maintain the balance between heat production and heat loss and so will reduce its feed consumption to reduce heat from metabolism. Research demonstrated that feed consumption is reduced by 5% for every 1ºC rise in temperature between 32-38ºC. In a recent study (Sohail *et al*., 2012) 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. Many additional studies have shown impaired growth performance in broilers subjected to heat stress (Niu *et al*., 2009; Attia *et al*., 2011; Imik *et al*., 2012). However, in addition to decreased feed intake, it has been shown that heat stress leads to reduced dietary digestibility, and decreased plasma protein and calcium levels (Bonnet *et al*., 1997; Zhou *et al*., 1998).

Egg Quality

Heat stress limits the productivity of laying hens, as reflected by egg production and egg quality, as the bird diverts feed metabolic energy to maintain its body temperature constant, resulting in lower egg production, and particularly in lower egg quality (Esmay 1982; Teeter and Belay, 1993; Hsu *et al*., 1998; Tinoco, 2001). Under high environmental temperatures, layer respiratory rate increases from eases from approximately 29 cycles per minute (mild environmental temperatures) to more than 100 cycles per minute (environmental temperatures above the thermoneutral zone). The resulting hyperventilation decreases CO_2 blood levels, which may decrease eggshell thickness in approximately 12% (Campos, 2000). CO_2 is responsible for eggshell quality improvement, as it may promote acidosis, which is subsequently compensated by kidney uptake of bicarbonate. Therefore, heat stress causes losses in egg weight, egg shell percentage, egg shell weight, and egg specific gravity (Macari *et al*., 1994; Naas, 1992). Hsu *et al*. (1998) found that temperature increase significantly decreases feed intake, egg production, mean egg weight, and live weight, and also influence some egg quality traits, such as eggshell thickness and egg specific gravity. Muiruri and Harison (1991) studied the performance of layers maintained under thermoneutral (25°C) or hot (35°C) temperatures, and concluded that environmental temperature did not influence egg weight or feed conversion ratio, but egg production and feed intake significantly decreased. As to environmental ammonia concentration, Naas *et al*. (2007) and Wathes *et al*. (2002) found that ammonia concentrations higher than 20 ppm may cause respiratory disease and affect egg production. Studying the effects of light intensity on egg quality, Renema *et al*. (2001) observed a 12% incidence of eggs below 55g when light intensity was 500 lux, whereas no differences in egg weight were detected when light intensity was below 50 lux. Due to the importance of the environment on layer productivity, this study evaluated the correlations between egg quality parameters and environmental variables recorded at the time of lay of two layer genetic strains housed in battery cages in a commercial layer house.

Meat Quality

Climate change could affect meat quality in two ways. First, there are direct effects on organ and muscle metabolism during heat exposure which can persist after slaughter. For example heat stress can increase the risks of pale-soft-exudative meat in turkeys, heat shortening in broilers and dehydration in most species. Second, changes in poultry management practices in response to hazards that stem from climate change could indirectly lead to changes in meat quality. Also, pre-conditioning broilers to heat stress to encourage better survival during transport could lead to more variable breast meat pH. The impacts that short term climate change could have will vary between regions (Gregory, 2010). It has been reported that chronic heat exposure negatively affects fat deposition and meat quality in broilers, in a breed-dependent manner (Lu *et al*., 2007). In fact, recent studies demonstrated that heat stress is associated with depression of meat chemical composition and quality in broilers (Dai *et al*., 2012; Imik *et al*., 2012). Another recent study (Zhang *et al*., 2012) demonstrated that 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 hot climate.

Reproductive Performance

Heat stress caused decreased production performance, as well as reduced eggshell thickness, and increased egg breakage (Lin *et al*., 2004). Additionally, heat stress has been shown to cause a significant reduction of egg weight (3.24%), egg shell thickness (1.2%), eggshell weight (9.93%), and eggshell percent (0.66%) (Ebeid *et al*., 2012). Heat stress affects all phases of semen production in breeder cocks (Banks *et al*., 2005). Although limited high temperature stimulates testicular growth in the early phase and promotes increased semen volume and concentration, a subsequent rise suppresses reproductive capacity as a result of a decrease in seminiferous epithelial cell differentiation, which is manifested in decreased semen quality and quantity with time (Obidi *et al*., 2008; McDaniel *et al*., 1996). McDaniel *et al*. (1996) showed that the broiler male broiler breeder was exposed to a temperature of 32°C, male fertility declined to 42% and in vivo sperm-egg penetration declined to 52%, compared to values obtained from males that were maintained at 21°C, it may be concluded that heat stress has deleterious multiple effects on testicular function through inhibition of intracellular ion exchange. Report of McDaniel *et al*. (1996) showed that semen characteristics such as consistency, spermatozoa concentration, and seminal volume were depressed by environmental temperatures outside the zone of thermal comfort. In the study in which breeder hens were inseminated in the morning hours had a significantly higher fertility and hatchability than those obtained in inseminated hens during the afternoon hours (Obidi *et al*., 2008).

Embryonic Development

The incidence of adverse effects of heat stress on embryonic growth has been reported by various workers. Yalcin and Siegel (2003 and 2005) showed that over-heating fertile eggs during incubation resulted in differential tissue growth at different stages of incubation. The finding further showed asymmetries in skeletal development during the early and late stages of embryo development. Heat-stressed embryos, showed shorter face length and low lung weight, resulting in weaker chicks with high incidence of culled-out birds due to unsteady gait. A greater number of culled chicks as a result of unthrifty behaviour. All the anomalies were due to heat stress suffered by embryo during the incubation process, induced by poorly controlled machine and environmental temperature due to frequent incubator electrical power failure. Findings of Deeming and Ferguson (1991) and Lourens *et al*. (2001 and 2007), showed that retarded embryonic and post-hatch chick developments are due to consistent heat stress.

Immunity

In poultry, several studies have investigated the effects of hot climate on the immune response in recent years. In general, all studies show an immunosuppressing effect of heat stress on broilers and laying hens. For instance, lower relative weights of thymus and spleen has been found in laying hens subjected to heat stress (Ghazi *et al*., 2012) reduced lymphoid organ weights have also been reported in broilers under heat stress conditions (Bartlett and Smith, 2003; Niu *et al*., 2009). Additionally, Felver-Gant *et al*. (2012) observed reduced liver weights in laying hens subjected to chronic heat stress conditions. Bartlett and Smith (2003) observed that broilers subjected to heat stress had lower levels of total circulating antibodies, as well as lower specific IgM and IgG levels.

Disease Incidence

According to Guis *et al*. (2011) reports, climate change will alter global disease distribution. High temperature has tremendous effect on prevalence of zoonotic diseases as well. The changes in climate may increase the insect vectors, prolong transmission cycles or increase the importation of vectors or animal reservoirs. It may also have an adverse effect on biodiversity, distribution and migratory pattern of birds which may lead to emergence of disease outbreaks. Climate change would almost certainly alter bird migration, influence the avian influenza virus transmission cycle and directly affect virus survival outside the host. In domestic poultry, too little is known about the direct effect of environmental factors on highly pathogenic avian influenza transmission and persistence to allow inference about the possible effect of climate change. However, possible indirect links through changes in the distribution of duck-crop farming are there, as reported by Gilbert *et al*. (2008).

Conclusion

Both of the hot climate change and poultry productions have always negative impacts one over the other. Heat stress is one of the most important environmental stressors challenging poultry production worldwide. The negative effects of heat stress on broilers and laying hens range from reduced growth and egg production to decreased poultry and egg quality and safety. However, a major concern should be the negative impact of heat stress on poultry welfare. However, these potential opportunities, although promising (particularly, for poultry production in hot climatic regions), still require further research and development.

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