Climate Change Impact on Immune Status and Productivity of Poultry as Well as the Quality of Meat and Egg Products

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Abstract The potential impacts of climate change on poultry may include changes in production, reproduction, quality of their products (meat or eggs) and diseases. It is noted that high temperature during the summer season or in regions with hot weather and high relative humidity prevent broiler chicks and laying hens to express their high genotypes, especially when they are raised in an open production system. Current poultry production systems comprise large numbers of birds being housed together making them more susceptible to heat stress. Heat stress not only causes inconvenience and high mortality rate for birds, but results also in lower or lost production which therefore reduces the profitability. Both of production performance and feed conversion ratio are affected by heat stress conditions, which affect the production rate. Other effects associated with heat stress include immunity reduction and weak immune response to vaccines that decrease the resistance of birds to many infectious diseases. In laying hens the production is markedly decrease and does not reach to the peak with declining egg quality (e.g. thin and breakable eggshell) in addition to lower egg weight with small size. This chapter discusses some of the key principles (nutritional or managerial practices) that could be used in order to alleviate the adverse effects resulting from heat stress.

Keywords Climate change · Heat stress · Poultry production · Feeding strategies

1 Introduction

In the current decades, many countries of the world (mainly in tropical and sub-tropical regions) are affected by climate change and global worming which resulted from emitting greenhouse gases (GHG) such as water vapor (H_2O), Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). The negative effects of increased

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environmental temperature due to climate change on poultry production representing lower feed intake, reduction of weight gain and meat quality in broilers, in addition to low egg production rate and egg quality, increasing feed conversion ratio and high mortality rate in laying hens.

An increase in global average surface temperature by 2100, between 0.3 and 4.8 °C, is reported in the IPCC Fifth Assessment Report [1]. That could have several impacts on livestock production including variation in production and quality of feed crops and forage, and biodiversity, water availability and animal health, growth, production and reproduction. Therefore, effective procedures must be taken to challenge this potential risk of high temperature and its impact on livestock in general and on poultry in particular through the implementation of effective strategies in order to protect poultry survival and increase their productivity during hot weather.

2 Response of Heat Stress in Poultry Herds

2.1 Maintenance of Body Temperature

Chicken is a homeothermic animal, which has the ability to maintain a relatively constant temperature of its internal organs. But this ability is highly efficient only when the thermoneutral zone about 21–28 °C which called the temperature range or comfortable zone, through balancing between the body amounts of heat produced and the amount of heat lose. The large part of the heat produced through the body metabolism, which increases the need to increase the elimination of heat to maintain the body temperature at the normal limit of 41.4–42.9 °C. Therefore, the high temperature of the surrounding environment to the direction of a large part of the production capacity in order to maintain the body temperature at the natural limits through a series of physiological changes that work on the stability of body temperature. These changes have direct and indirect negative effects in efficient bird production.

The loss of heat in poultry when exposed to high environment temperature is not through sweating due to lack of sweat glands in the body of poultry and the process of controlling the mechanism of regulating the temperature of the birds by hypothalamus in two ways: The first is sensible heat loss through conduction, convection, fecal excretion, egg production. This system works efficiently in the thermal range, here the size of the comb and wattles plays an important role by providing the body with sufficient space bare skin which provides blood, which transfers the heat from the body to the head to be lost in concrete form, we found that the bird loses about 40% of the heat who wants to get rid by this way. The second is an insensible heat loss, which includes exhaustion and increased evaporative cooling due to increased heart rate, blood flow to the skin and expansion of peripheral blood vessels. Evaporation occurs mainly in the lungs, air sacs, and mucous area between the nasal openings and the tracheal base.

2.2 Behavioral Response

The birds begin to change their behavior to facilitate heat exchange or to get rid of excess heat, which affects the productivity. The birds are exhausted and lose appetite and begin to remove their wings from the body, and increase the speed of breath and exhaustion to get rid of excess heat through water vapor, look for isolated places with the lowest temperature as they stick to cold joints. This is worse if the temperature increases with the increase in humidity as in our country now. Therefore, the ability of the bird to evaporate is reduced, thus increasing the risk of warming. The birds also take some physiological pathways, such as conversion and flow of blood from internal organs to skin [2].

When the temperature rises below 29 °C the thermal capacity of the bird decreases, leading to deterioration of the feed conversion efficiency. This results in a negative effect on production. Large and overweight birds are more prone to stress and mortality than small ones. The ideal range of the bird begins to perform several mechanical procedures to make its temperature constant can be explained as follows:

- Birds try to move away from each other.
- Move to cold surfaces, such as walls or places with air masses and cold currents.
- Remove the wings from the body to reduce the insulation and stripping any areas of the skin without feathers.
- Reduce the temperature of the fatty cover under the skin.
- The flow of blood to the skin of the limbs, especially comb and wattles.
- Reduce movement and reduce food consumption.
- Increasing water consumption.
- Eliminate excess heat through intense panting.

2.3 Physiological Response

The optimum temperature degree of production performance ranging between 20 and 24 °C for laying hens and 18–20 °C for broilers. Body temperature of chickens began increasing when the ambient temperature rose above 30 °C if the rate of increase in ambient temperature was rapid. Physiological response to heat stress in birds involve the functional integration of several organs to meet the metabolic needs of birds that are trying to dissipate heat and maintain homeostasis. The chicken response occurs through increased activity of hypothalamus, pituitary gland and adrenal gland. A series of physiological measures to counter this stress begin by increasing the rate of respiration from 25 times/min. to 260 times/min., resulting in large amounts of carbon dioxide and thus bicarbonate, in blood plasma [3]. In turn, the lowered concentration of hydrogen ions causes a rise in plasma pH, a condition generally referred to as alkalosis.

The hypothalamus starts to stimulate the secretion of hormones that inhibit urinary incontinence, becoming more watery. Corticosteroids are also released, increasing

losses in electrolytes, sodium, potassium and bicarbonate. Some organs, such as the brain and circulatory system, are also affected and the burden on the heart and blood vessels increases. The rate of urinary incontinence is the result of water consumption. In the end, the immunity of birds is significantly reduced, especially the reduction of immunoglobulin in the blood, and the herds become more susceptible to diseases. All previous manifestations of high temperature affect the herds produced in the form of symptoms such as bird swings with peripheral spasms, low body weight, increased predation disease, decreased egg production, decreased cortex quality, decreased fertility and poor semen quality, and finally in severe cases to death.

Many studies have shown the possibility of adapting birds to the conditions of heat stress and their tolerance to this burden and low mortality if exposed early in the age to high temperature, and this adaptation is reflected in increased rates of fatigue and low body weight and the lack of water lost by evaporation, high on several factors, including: type of strain, average body weight, quantity of drinking water available and quantity of production.

2.4 Immune Response

The immune system functions can be broadly classified into: (i) innate immunity and (ii) adaptive immunity. Innate immunity is the germ line encoded, non-specific, preliminary line of defense against the invading pathogens. The first entry of the pathogens is prevented at body's entry site through antimicrobial components in mucosa, sweat, tears, saliva, etc. Heat stress directly or indirectly favours disease occurrence in animal host. Directly, high temperature favours the survival of organisms outside the host for a long time. Indirectly, chronic heat stress causes immune suppression in birds and makes them susceptible to diseases. Heat stress reduces the relative weights of lymphoid organs like spleen, thymus and cloacal bursa. This might be due to glucocorticoid induced lympholysis and redistribution of lymphocytes from systemic circulation to other organs NK cells are important components of the innate immune system present in systemic circulation and also in lymphoid organs like lymph nodes, spleen and bone marrow. They are involved in destruction of tumour cells and infectious agents like bacteria, fungi and viruses. Chronic heat stress reduced the splenic NK cell cytotoxic functions. The inhibition may be due to increased glucocorticoid influence in the immune cell [4].

Cytokine interactions are responsible for altered immune functions during heat stress. Stress induced glucocorticoids act to inhibit the pro-inflammatory cytokines, which are required to initiate an innate immune response through inhibition pathway.

Heat stress leads to activation of hypothalamic-pituitary adrenal axis and ultimately the release of glucocorticoids. Glucocorticoids, in normal pulsatile release, enhance the pro-inflammatory cytokine release. However, chronic rise in glucocorticoid levels is inhibitory to majority of immune cytokines. The stress related immune responses in poultry species revealed that acute stress is beneficial to the bird as it the immune system. On the other hand, chronic stress shifts the T helper cell response

to T regulatory cell and also TGF-β, a regulatory cytokine production; thereby it suppresses immune response [5].

3 Effect of Heat Stress on Poultry Production

The rapid development of poultry production in many countries of the world with warm climates, such as most countries of the Arab global has, the interest for studying the impact of environment temperature increased as one of the consequences of climate change on poultry production, which is one of the biggest problems can be encountered, because it is the most important needs for poultry. The growth achieved for the quality and quantity production of the bird depends not only on the capabilities of the genetic and the food quality provided to him, but also depends on the environmental factors surrounding it, which negatively affect the ability of productivity and the economic benefits envisaged. Therefore, air temperature is considered one of the most important external environment factors, which directly affect the physiological and productive status on the birds causing constant stress.

Heat stress is the most stressful factor that causes severe losses in poultry farms, especially when high temperatures are accompanied by high humidity, such as some countries due to climatic changes like Egypt. Also, heat stress severely affects the productivity of poultry directly on egg production and growth rates of broilers or indirectly by increasing the probability of growth and reproduction of toxin-producing fungi in feed or by reducing the ability of birds to cope with other stressors. 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.

3.1 Egg Production

The optimal care of the laying hens under the conditions of heat stress is one of the most important criteria that affect productivity efficiency. The factors related to the herd care and management is combined with the provision of the optimal ingredients of balanced nutrition during the growth stage to reach the production of the young layers to the optimal weight, good health and physical condition at sexual maturity. It is known that high temperature contributes significantly to the lack of access to optimal weight, which leads to the deterioration of productive efficiency throughout the cycle of egg production, it was found that the care of herds leaves within the temperature of 35 °C reduces the body weight at sexual maturity by 20–30% compared to the same hens rearing at a temperature of 21 °C.

It is preferable for the breeders during the heat stress to reach laying hens at sexual maturity to a weight slightly higher than the standard weight, which increases the consumption of food later, improve produced of the eggs weight and make them more persistent on production [6].

As soon as laying hens reach sexual maturity, ambient temperature becomes an important factor affecting production. The average feed consumption is 1.6% and the energy consumed is 2.3% for every 1° above the ideal temperature. At temperatures above 30 °C, both food consumption and egg production are reduced by 5% and 1.5%, respectively. The decrease in food consumption (50%) was found when the temperature rises from 21 to 38 °C and most of this decrease is due to the lack of the needs of the preservative body. Treating this decrease by increase the rest of the nutrients in the feed to overcome most of the harmful effects of the heat from an improvement in egg production and the egg weight, but he could not overcome the deterioration of the egg shell quality.

3.1.1 Egg Quality

Several studies have indicated that the bad effect of heat stress on the quality of internal and external eggs. This effect is clearly visible on the egg shell and calcium carbonate deposition. This is reflected in the appearance of the eggshell and its characteristics, with insufficient mineral sources and bicarbonate ions. The decrease in egg weight was estimated at 0.07–0.98 g/egg for each 1° rise. The thickness of the eggshell is reduced by high temperature, and it becomes more complicated at the later ages of the egg production cycle. This decrease is attributed to the low intake of calcium because of the low food consumption. The quality of the egg includes visible natural measurements as well as flavor and aroma. The effect of high temperature extends to the liquid components of the eggs, which quickly damage the internal contents of the egg yolk and reduces the quality and grade of the egg. Leaving the eggs for long periods under high temperature conditions lead to its total corruption, and these changes include the rapid erosion of the chemical layer, the number of open gaps, evaporation of large amounts of moisture content of the whiteness and with the persistence of high temperature, the yolk loses part of its moisture, the coagulation of the liquid components with rise. Fresh eggs production from layers is always of high quality, and there are many factors that affect the quality of eggs before produce it.

Changes in environmental conditions, especially the increase in temperature for the laying hens housing, resulting in lower quality of albumen and shell weak strength and small thickness and egg size, may be due to low consumption of food in the hot atmosphere. The importance of the role of management in the production of high egg quality in the case of high temperature, which is the selection of the strain that produces high egg quality, the balanced diet, diseases control, physiological disorders, and the organization of lighting, and food programs to control the beginning of the egg production. The eggs are damaged and reduced quality if not handled correctly. The most changes associated with changes in temperature is to increase the air sac size as the resulting of losing moisture, where the amount of evaporation for stored eggs depends on the environment temperature, humidity and ventilation as well as shell porosity. The signs of low egg quality turn into the water situation, and this shift depends on the heat stress, which is accompanied by natural reactions and

chemical result in the degradation of the construction of the albumen thick protein. As the water dissolves, the water leaks to the yolk through the yolk membrane with the toxic properties, causing the yolk to grow and weakening the vitelline membrane and becoming extensible and facilitates the permeability of the albumin to the yolk, which causes its appearance to be spotted. Fresh egg contains 0.5% CO_2, which is lost during the storage period, resulting in a change in the flavor of the eggs, increasing pH alkalinity from 7.6 to 9.5.

There are some recommendations that must be taken into account to maintain the high egg quality after the production such as, collecting eggs constantly 2–3 times a day, separate the eggs clean from the dirty and broken eggs, and mobilization eggs in clean containers, storing the fresh egg in 10–13 °C and humidity ratio about 70–85%. Also, washing eggs with water temperature higher than the temperature of eggs; because the opposite causes shrinkage of the contents of the egg, resulting in the discharge accompanied by the entry of contaminated water into the components of the egg through the internal gaps, causing the contamination of the egg internally bacteria. Finally, it is possible to dip eggs in paraffin oil to close the gaps and reduce evaporation during storage; because the process of washing eggs lead to the removal of the shell cuticle.

Egg Shell Quality

The eggshell formation one of the processes that interferes with many factors such as genetics, nutrition, health status, hormones and environmental factors surrounding the birds these factors must be in a similar case to obtain the high eggshell quality. The amount of calcium element in the shell about 2.2 g Calcium carbonate form (94%), organic matrix (about 4%), the chicken pours about 25 mg of calcium on the egg surface, which is formed every 15 min during the 20 h period needed to form the eggshell. Due to the spawning of laying hens production, it deposits 24 times more calcium in the eggshell than in its bones. The quality of the eggshell including the color, the number of porosity, the shell strength and its durability as well as its tolerance to stress and shock.

The birds during heat stress resort to increase the rate of breathing in the minute, which phenomenon of panting. In this way, the excess heat is eliminated through the surfaces of the mouth and respiratory passageways. In general, the bird begins panting when the temperature reaches 29 °C as a visible response to stress. The increase in the rate of panting, increase losing of CO_2 by the lungs, leading to a decrease in its molecular pressure and consequently lower bicarbonate ions in the blood, which leads to a decrease in hydrogen ions causing a rise in alkalinity of blood [7].

This egg shell forming is reflected process in the uterus, where carbon dioxide combines with water to give carbonic acid and then enters the carbonic anhydrase enzyme in the reaction and produces carbonic acid in the mucosal cell of the secretion of the shell (uterus). Then combines the bicarbonate with the calcium ion to form carbonate calcium. High temperature and imbalance of pH, where the concentration

of bicarbonate become low (the second slice necessary to form the egg shell) and do not find enough calcium ions to connect with it for the formation of calcium carbonate, which is the basic component of the shell as mentioned above. As a result of this, eggs are produced with weak shell sickness and the proportion of eggs without shell.

Improve Egg Shell Quality

There are many trends and practices that minimize the harmful effects of exposure to long periods of heat stress, including environmental issues related to management factors and herd care, including the treatment of nutrition [8]. For example, the addition of ascorbic acid at the rate of 250 mg/kg of important treatments that reduce the impact of heat stress on birds and improve the properties of eggshell produced, this vitamin reduces the level of cortisone in blood plasma and helps stimulate the absorption of calcium and vitamin D of the intestine, then increase the calcium level in the plasma to the point where it supports the normal deposition of minerals in the bones [9].

Respiratory alkalosis can also be combated nutritionally by providing a source of anion via feed or water. Supplemental ammonium chloride in drinking water of chronically heat-stressed birds can return blood pH to normal [10]. During acute heat stress, the provision of ammonium chloride or carbonate water has been found to decrease blood pH. Many researchers pointed to the need to add sodium bicarbonate in the drinking water of the laying hens at a rate of 0.5–2% under the conditions of thermal stress, lead to increase the shell strength and improve its quality. The addition of bicarbonate leads to the adjustment of pH, which positively affects the quality of egg shell [11].

Some minerals, such as zinc, manganese and copper, are involved in the metabolism of the eggshell, by acting as catalysts for enzymes involved in the formation and stimulation of calcium carbonate deposition to form the egg shell. The addition of the zinc element of the important points to increase the level of the enzyme carbonic anhydrase, which enters as a component in the composition of the enzyme, with increases its activity in the liquid of egg gland.

3.2 Meat Production

The heat produced from broiler is very high, because it consumes high energy in food while keeping 40%. Thus, 60% of food energy is eliminated in the form of heat production. Under heat stress birds reduce feed consumption and thus produce degradation. The performance of birds varies according to the environmental conditions in the breeding area. In areas with high temperatures during the day and low at night, performance is better than those characterized by high temperature. On this basis, the raising of broilers in the open bays gives better results in the temperate

seasons (spring and autumn) compared to the other seasons in year, where growth rates are clearly lower during the summer.

The efficiency of the birds is also different depending on the composition of the temperature and humidity. We find a decrease in the weight of the birds raised in areas with high temperature and humidity, as in Egypt, compared to other high temperature and low humidity. Also, the continuity of high and constant temperature for long periods has a serious role in the deterioration of growth rates and low conversion efficiency of food, and increase the mortality rate when compared to fluctuating temperature (cycling). The latter allows the bird to recover and increase its consumption of feed during periods of moderate heat, and the occurrence of hot flashes during the early stages of broiler is less dangerous than in the advanced stages, especially before marketing.

3.2.1 Meat Quality

It is known that the bird's under cold weather conditions needs more energy to maintain its body temperature. In the case of high temperature, this energy decreases and increases in the ratio of solids, fats and energy in the carcass, while the percentage of protein decreases. Unsaturated fatty acids such as oleic, linoleic, linolenic, in the fat of the carcass are high in ambient temperature, which means high saturated fatty acids in the carcasses intended for marketing. This increase was found to be higher in females than in males during high temperature. High temperatures also caused a decrease in the aminoity of glycine and proline in carcass tissues, especially the muscles of the breast. Early finishing of broilers from the viewpoint of fatty acid composition because the polyunsaturated fatty acid to saturated fatty acid ratio declines significantly with age, regardless of temperature.

The symptoms of heat stress on the carcasses in the form of weakness of coloration and roughness of the skin, dry muscles, increase blood density and color density and then the value of carcasses. The heat stress has been found bad effect on the ratio of reflux and the amount of meat eaten and the proportion of breast muscles. Broilers may be exposed to a variety of stressors during transport from the production farms to the processing facilities, including thermal challenges of the transport microenvironment, acceleration, vibration, motion, impacts, fasting, withdrawal of water, social disruption, and noise. As part of this complex combination of factors, thermal stress, in particular heat stress, plays a major role. The adverse effects of these factors and their combinations range from mild discomfort to death. In fact, heat stress during transport has been associated with higher mortality rate, decreased meat quality, and reduced welfare status.

3.2.2 Pathological Phenomena Associated with Heat Stress

Ascites

Ascites is a symptom of metabolic disorder due to several factors affecting the environment, temperature, carbon dioxide/oxygen ratio, rapid growth rates, high energy content, and high basal metabolic rate. As a result, a combination of lymphatic liquids and blood plasma that leaks from the liver accumulates in the body cavity, often leading to death. The symptoms of ascites are associated with an abnormal increase in blood pressure between the heart and lungs, leading to the failure of the right ventricle and increase blood pressure in the veins, and the great acceleration in the production of fluids from the liver that seeps into the body cavity. The symptoms appear on the birds in the form of inactivity and laziness and difficulty breathing, Skin and congestion, decreased growth and fill the abdomen with liquids.

The incidence of ascites has increased throughout the world over the past years. This increase coincides with continuous improvements in the genetic structure and nutritional efficiency of the herds, which caused the presence of strains with a rapid growth rate and food efficiency. Broiler led to a high rate of metabolism and increase in the size of the breast muscles, which did not develop with the internal organs as much as the heart and lungs and increased pressure to meet the needs of the body of chicken overload of blood feeding, unable to provide enough oxygen to maintain these high rates. The number of lighting hours can also be reduced to 18 h/day, which reduces the volume of cellular blood components and reduces the level of T3 hormone, which reduces the mortality rate resulting.

Pendulous Crop

Birds are under the conditions of thermal stress for long periods and in the presence of some genetic factors responsible for this phenomenon, begin to eat large amounts of feed over consuming when the moderate temperature and then drink large amounts of water with high temperature, which leads to fill the bulk of these quantities and cannot easily discharged. The muscles of the compass relax and lie in the shape of a bag filled with the front of the breast. This helps the weakness of elastin fibers forming the membrane of the compass of heat stress [12].

It should be noted that this phenomenon is more common in the strains of broiler chickens and turkeys especially heavy ones, and there are some administrative practices in the farm or food additives that help to the emergence of this phenomenon. Such as bird staging for long periods during the hot weather, containment of the feed on chemicals or disinfectants mycosis is caused by a secondary infection in the membranes and muscles, leading to weakness, and injury to the fungal contaminants or internal worms.

Breast Blisters and Crooked Sternum

This phenomenon occurs in heavy-weight birds which brooding in wire cages or on the floor. As age and weight increase, birds sit on the wired floor or mattress. During this period, this weight is placed on the bone sheath. There are blisters and breast ulcers, especially during high temperature, the birds search for the wet places inside the house. Also, the increase of humidity mattresses with poor specifications, high content of microbes and pathogens. This leads to the occurrence of breast defects and lower the carcass quality during the stages of slaughtering, then reduce economic return. The breeders can reduce the incidence of this phenomenon by work for a program to market heavy birds first to early ages, ensure the cleanliness and quality of the mattress and finally avoid the presence of dark areas in the house so as not to be left to birds.

4 Feeding Strategies to Deal with Heat Stress

4.1 Feed Restriction

Starving the birds during peak heat stress is an effective way to reduce body temperature and increase survival, as feed intake increases heat increment resulting from ingestion, digestion, absorption and metabolism of nutrients. Feed restriction, in the meantime, makes birds quiet and less energy-producers. Metabolic heat increment is a maximum after 3–6 h of feed intake. Therefore, it is necessary to feed the birds early in the morning and late in the afternoon so that the production of metabolic heat will not occur during higher temperature period of the day (09:00 to 16:00 h). By this way birds will be encouraged to eat during cooler periods of the day and help maintain their performance during hot weather.

4.2 Feed Pelleting

The amount of feed intake by chickens is reduced at hot weather [13] and as a result, the amount of feed components consumed decreases. This is one of the main reasons leading to lower productivity of birds and their performance with the high feed conversion ratio to non-economic degree. Therefore, there are many attempts to increase the quantity and/or the concentration of feed ingredients consumed, without increasing internal body heat, in order to improve birds' performance and productivity.

Pelleting process increases the physical density of feeds; the pelleted diet also improves the digestibility, decreasing the production of metabolic heat with respect

to the mash feed [14]. Over and above, birds prefer to eat more feed with larger particle size in hot weather.

4.3 Separated Feeding

A strategy of dividing the diet components at different times of the day could be applied during the hot climate. Birds under this regime are provided with their daily requirements of minerals, vitamins and other supplements in hot periods of the day, when on the other hand they are provided with their basic energy and protein requirements during cooler periods in the evening. This strategy is useful for birds to tolerate heat stress; considering that vitamins and minerals reduce the adverse impact of heat stress during the midday, while proteins and energy are important as major nutrients required to maintain good performance and productivity, providing those major nutrients at the evening reduces the excess heat overload resulted from nutrients digestion and metabolism during high temperature.

4.4 Self-selection

This method depends on giving the birds the opportunity to select from various feed ingredients that match their physiological requirements; this method is similar to what wild or even backyard birds naturally obtain their feed. Under heat stress conditions, the bird can adjust its consumption of different feed ingredients so that it consumes less protein and a slightly higher amount of energy (by consuming high caloric feed ingredients) compared to the complete mixture diet, in an attempt to regulate the heat load associated with metabolism during hot cyclic periods.

In this strategy, feeders containing feed ingredients (each separately) should be provided, including: (1) cereal grains such as corn, wheat, barley or other energy source either together or separately, (2) protein sources (26–48% protein content), (3) major minerals containing calcium and phosphorus, and (4) minor minerals and vitamins premix.

However, cautions should be taken with this feeding system in case of laying hens, which may prefer only grains feeders, which will lead to fat birds with low egg production rate. In general, containers of grains should represent only two-thirds of the total containers number, while the protein source and the premix containers represent one third of the total containers.

The results of the choice feeding strategy are variable, as it could be affected by some factors such as birds' age, the initial age from when the selection was offered, the particle size of the feed ingredients, the quality of energy and protein sources, as well as the difference between daily maximum and minimum temperatures.

5 Nutritional Applications for Heat Stress Mitigation

All poultry species are severely affected by heat stress conditions, preventing their access to the maximum biological performance, so it was necessary to search for modern solutions along with the traditional methods to challenge heat stress in order to protect birds and maintain their production. Nutritional solutions have now become more important to mitigate the detrimental effects of heat stress on birds, and this can be achieved by applying one or more nutritional procedures.

5.1 Using a High-Energy Diet

Birds mainly consume food to satisfy their energetic needs required for maintain life and perform various physiological functions. Fats contain 2.25 times the calories per unit of weight than protein or carbohydrates; generally they are used to increase the energy density of poultry diets. Indeed, fat gives less biological heat production compared to either protein or carbohydrates, because dietary fat metabolism has lower heat increment than protein or carbohydrates. Fat is characterized by decreasing the physiological duty inside the body leading to higher utilization of food energy to be used in different production functions, unlike the carbohydrate energy, which is characterized by the high amount of energy loses during digestion and metabolism.

Recently, researches revealed the benefits of supplementing poultry diets with vegetable oils to account for about 33% of the total dietary energy, replacing part of the traditional energy source (carbohydrate). Where it was noted that supplementing oils or fats by 3–5% of the diet increased the appetite and taste of feed, also it increased the utilization of various nutrients in the feed consumed, besides fat contains good amounts of soluble vitamins (A, D3, E, K) and the essential fatty acid (linoleic acid) needed for growth and egg production.

However, caution should be considered when formulating such these feeds since an appropriate antioxidant should be supplemented and not storing the feed for a long time in order to avoid fat rancidity.

5.2 Dietary Protein and Amino Acid

The requirements of protein and amino acids should be met at the recommended levels for growth and egg production, taking into consideration not to excessively increase the dietary protein level especially under heat stress conditions as the heat increment associated with protein catabolism is higher when compared to that of fats or carbohydrates.

Supplementation of essential amino acids is profitable for reducing the internal heat loss which leads to reduce the adverse effect of high temperature, in this regard

it was noted that increasing dietary lysine concentration is necessary to compensate partly for the reduced feed intake [15] and improve feed efficiency. There is a positive effect to increase the Arginine: Lysine ratio on feed conversion ratio and growth performance at high temperatures.

The imbalanced amino acids in the diet results in higher excretion of nitrogenous substances in faeces, which produces and accumulates ammonia in the house atmosphere causing harmful effects on the performance and welfare of birds. The accumulation of ammonia may increase the ambient temperature in poultry houses; therefore it makes difficult for birds to regulate their body temperature.

5.3 Vitamins

Supplementing vitamins to poultry diets is highly recommended during the hot weather, such as Vitamin A, E, C, etc., which play an important role in improving the performance and immunity of birds and significantly reduce mortality rates, especially when birds exposed to heat stress. It is suggested to increase the levels of vitamins during hot weather by 10–15% than the normal requirement because of the low feed intake and potential damage due to feed storage or exposure to oxidation factors, such as high temperature and/or humidity and trace elements presented in the diet, unsaturated fatty acids and oxidation of peroxides, which affects the stability of these vitamins.

5.3.1 Vitamin A

The supplementation of vitamin A in the diet reduces the detrimental effect of heat stress on egg production and has a positive effect on the immunity of laying hens. Higher dietary vitamin A intake is required by birds suffering from heat stress after Newcastle vaccination; in order to produce the maximal level of antibody [16]. Also, supplementing vitamin A to broiler diets improves body weight gain, feed efficiency and carcass traits.

5.3.2 Vitamin C

Ascorbic acid has an important role as an antioxidant in the biological system and under the heat stress conditions, it is important in maintaining the oxidation and reduction processes in birds body. Supplementing ascorbic acid to the diets improves egg production and egg shell quality of broiler breeders; additionally it has beneficial effects on the fertility and hatchability of broiler chicks as well as molting process of laying hens.

Furthermore broiler chicks tend to consume more amount of the diet supplemented with ascorbic acid in the hot weather. Ascorbic acid supplementation improves

carcass quality, increases the carcass weight associated with higher crude protein retained in the carcass and reduces the carcass content of fat.

5.3.3 Vitamin E

Vitamin E acts as a natural antioxidant that protects the fat from oxidation rancidity and peroxides formation, especially at high temperatures. It also preserves some fat soluble substances such as vitamins A and D_3, carotene from damage.

Supplementing vitamin E to heat stressed laying hen diets enhanced egg production; this beneficial effect is accompanied with an increase in feed intake and the solids of albumen and yolk. The supplementation of vitamin E at high levels in the diet not only increases egg production but also improves the immunity of bird sat hot weather.

5.4 Electrolytic Balance

Birds get rid of the excess body heat through the respiratory system by panting. With the increase of panting, the body loses large quantities of carbon dioxide, leading to imbalance in the acid/base balance of the bird's body causing an imbalance in the electrolyte balance with severe high blood alkalosis that increases blood viscosity and blood pressure which may lead to an explosion in the arteries of the brain, liver or kidneys.

Supplementing electrolytes such as sodium or potassium bicarbonate ($NaHCO_3$, $KHCO_3$) and ammonium, sodium or potassium chloride (NH_4Cl, NaCl, KCl) in the diet or in drinking water by 0.5–1.0% stimulates water consumption and increases bird tolerance to heat stress [17], where electrolytes contribute to adjust the imbalance resulted from increasing blood pH (blood alkalosis), which contributes to produce stronger eggshell for laying hens and have a positive impact on broiler performance.

6 Managerial Application for Heat Stress Mitigation

Management of stress is the key to profitable poultry production during the hot summer months where temperature reaches 40 °C or more, moreover some sea dominating regions may have a relative humidity of 80%. Many production systems suffer from low efficiency and the losses are sometimes costly, such as low growth and survival rate. Decision-making on the type of strategy should be applied to manage stress requires an understanding of the physiological effects of heat stress. The profitability of any strategy during the summer months could be increased when using proper managerial applications.

6.1 Drinking Cold Water

The internal environment of the bird is water medium in which food components are exchanged. In addition to its other important functions of heat regulation, lubrication, softening and hydration verify that water as a food component must be considered. The positive relationship between water intake and body temperature indicates that water used plays an important role as a heat discharger and thus makes energy available for growth rather than body cooling.

Water consumption is very important for poultry in a heat stress environment. Birds must drink more water to prevent dehydration, since the primary method of reducing body temperature is by evaporation of water from the lungs. Securing cold drinking water will help to reduce body temperature and thus increase the survival rate.

Under normal conditions water intake is usually 1.5–2 times feed intake, however during hot weather water consumption increases by 3–6 times than the normal consumption, with an increase by 5% per every temperature degree above 22 °C.

6.2 Ventilation

Both of heat production and heat loss of birds are affected by the efficiency of ventilation system, as the thermal loss through heat emission by evaporation depends on the ability of air to carry water vapor from the hot exhalation air resulting from panting. Therefore, it is important to consider the ventilation system to remove the hot air out of poultry house and replace it with dry, fresh and cool air.

Good ventilation reduces the relative humidity at the house environment and reduces harmful gases (ammonia—carbon monoxide—carbon dioxide); it also provides birds with sufficient oxygen supply required for the biological activities. Ventilation should be at a rate of 5–6 m^3 air/h/kg live weight and the air should be changed at a rate of 20–50 times per hour, so that the excess heat inside the house could be eliminated.

6.3 Stocking Density

Increasing the number of birds in poultry house than the recommended number reduces the ability of birds to get rid of heat during hot weather. Therefore, it is necessary to decrease the density of birds in order to reduce; first its requirements of ventilation, oxygen, cooling … etc., second to reduce the complications of excreta, moisture, carbon dioxide, ammonia (resulting from the fermentation of litter material with organic matter) and urea resulting from birds urine. As the less density per square

meter of floor the more air available to birds and the lower relative humidity, which means better environment and condition to achieve higher profitability.

The number of birds per square meter of floor should not be increased than 7–8 birds in case of deep litter system, taking into account the strain size.

7 Conclusions

At hot weather, the use of light is important to regulate feeding behavior so that birds eat better during the cold hours of the night than during the hot times of the day. The intermittent lighting system improves feed efficiency and productivity, in addition to the above, has a positive effect in reducing body heat production during both lighting and dark periods.

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