OPTIMAL NUTRITIONAL STRATEGIES AGAINST HEAT STRESS AT POULTRY IN THE CONTEXT OF CLIMATE CHANGES

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REVIEW

Abstract
Global warming and climate change has an increasing impact on the agricultural and livestock sector, especially for the poultry production. Heat stress is one of the most important factors which negatively influence the poultry productivity in the industrial systems causing a substantial economic losses. Modern poultry genetic lines are more susceptible to the negative impact of heat stress induced by the high temperatures in the stable. Therefore, heat stress affects the normal physiological response of the birds, decrease the feed intake which will affect the productive performances (growing rate and weight gain, egg production, feed conversion, quality of productions), impairs immune response and oxidative status of the body leading to increased mortality in the flock. Researches in the field present numerous nutrition and feeding practices to mitigate these effects, such as: dietary manipulation by adjusting feed energy density or protein level and amino acid balance; dietary enrichment via electrolytes balance, vitamins, minerals and additives such as betaine. Feeding strategies include the effeciency of double feeding, size of the compound feed particle and feeding traits, drinking water temperature and feeding restrictions during the day. However, in the practice only a few of these are used, therefore this review aims to highlight the impact of heat stress on poultry health and productions as well as the optimal feeding and nutrition strategies to mitigating the impact of heat stress.

Keywords: heat stress; poultry; amino acids; betaine; nutritional strategies
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INTRODUCTION

Climate changes represent a major concern for today's livestock farming systems around the world because are affected the natural food and water resources, as well as animal health and production. As a result, the capacity of the current livestock systems to sustain and satisfy the increasing requirements of food for humans is thus unstable (Godde et al, 2021). The livestock sector currently plays an important role in the supply of food for population and in the safety of foods. Animal products (meat, milk and eggs) contribute with 15 - 31% of global calories and proteins intake per capita, with regional variations (Herrero et al, 2013).

Studies regarding the impacts of climate change on the livestock often focus on the potential for mitigating the effects associated with high climate temperatures on livestock and on the describing of adaptation practices. Heat stress is primarily induced by exposure to high ambient temperatures and low relative humidity, which limit the ability of animals to lose body heat when are on the farm or during transport. Vulnerability to heat stress varies by species, breed, feeding phase, genetic potential, health status, developmental stage, skin thickness or feather distribution, and previous exposure to high temperature (Bernabucci et al, 2010; Saeed et al, 2018).

In most cases, the impact of heat stress is to reduce animal productivity and welfare, and under of prolonged exposure leads to the increase of mortalities. Lowered feed intake is one of the first and important consequences of heat stress. Heat stress is an adaptive response that occurs when the thermolysis rate (the homeotherm-specific process for lossing body temperature) is below that of thermogenesis (the homeotherm-specific process for body heat production) and the body's ability to lose heat is exceeded by the heat load acquired through the exposure to high ambient temperatures (Al-Saffar & Rose, 2002).

The importance of animal response to heat stress applies to all species but the birds are one of the most sensitive due to their limited biological possibilities for body heat loss. Climate change will influence poultry production indirectly by affecting long-term quantitative production but also the nutritional quality of feed; and directly as a result of heat stress that will affect the productive performances, the quality of production andt also its economical efficiency (Abdel-Moneim et al, 2021).

The aim of this review is to highlight the currently used feeding and nutritional strategies to reduce the negative impact of heat stress on poultry sector.

EFFECTS OF HEAT STRESS ON POULTRY PRODUCTIONS

Heat stress at poultry begins when the thermal comfort threshold is exceeded, which affects the body's homeostasis. In fast-growing broiler chicks, the problem of heat excess occurs with the growth and development when takes place the maturation of the body's thermoregulatory system, development of plumage and increased metabolic heat production generated by the fast growth rate supported by the high nutrient intake. High susceptibility to heat stress also results from limited development of the cardiovascular and respiratory system (Yahav, 2000) and lack of sweat glands (Mitchell et al, 2005). Thus, broiler chicks temperature requirements decrease from 33.5˚C on day 1 to below 20˚C after 30 days of age. By the technological point of view, this period overlaps to the second part of the growing phase and to the entire finishing period. Under these conditions, during summer periods with the temperatures above 30˚C, the microclimate system of the stables is no longer able to maintain the optimal inside temperature for the chicks. Thus, at the level of the chick oragnism, a series of defence mechanisms are happen, which are associated with nutrients losses and disorders due to thermoregulation processes (through thermolysis) (Abioja & Abiona, 2021). Broilers have a relatively short thermal comfort zone, and as the ambient temperature in the stable exceeds the upper limit of the thermal tolerance range, the birds' ability to lose heat is diminished and dangerous hyperthermia occurs (Abioja & Abiona, 2021). An ambient temperature above the thermal comfort zone will produce a series of neuroendocrine processes that affect broiler welfare and productivity. Prior to this stage, body temperature is mainly regulated by heat losses to the environment through conduction, convection and radiation, also known as non-evaporative heat loss (Borges et al, 2003).

Once the body temperature increase above the tolerance limit, the birds will show a typical behavior of polypnea. Polypnea is an adaptive behaviour for the birds to lose body heat by evaporation along the respiratory tract and presenting an open beak with a intense breathing. The respiratory rate can increase from 25 to 150 breaths/min over a 20 minutes period. An healthy broiler chick throught the hyperventilation and polypnea can eliminate approximately 0.54 Kcal/g of water lost (Abioja & Abiona, 2021). Frequent breathing after a time period will produce a decrease in blood CO_2 concentration, which will lead to respiratory alkalosis due to the increase of blood pH above normal limits as a result of the altered CO_2 concentration (Franco-Jimenez et al, 2007). Respiratory alkalosis has been identified as a marker to assess the heat stress periods at poultry (Barrett et al, 2019; Franco-Jimenez et al, 2007). Excessive removal of CO_2 results in reducing the availability of blood bicarbonate used by laying hens for eggshell mineralization and induces a high availability of organic acids which decreasing the blood free calcium levels and negatively affect the eggshell (Marder & Arad, 1989).

In breeders, heat stress affects reproductive functions by disrupting hormonal regulation between the hypothalamus and ovary, i.e. by decreasing sperm volume, sperm concentration, motility and viability (Rozenboim et al, 2007; Elnagar et al, 2010; Joshi et al, 1980; McDaniel et al, 2004).

The negative effects of heat stress consit in the decrease of feed intake and an increased water consumption, intense heart rate and respiration, electrolytes imbalance, changes in haematological parameters and enzyme activities. All of these negatively affect the productive performances of poultry.

Impact of climate changes on the egg production and quality

In laying hens, the main selection criterion is laying performance, and heat stress primarily affects egg production and egg quality (Barrett et al, 2019). Temperature on laying hen farms averages in the range of 18 - 20˚C being difficult to maintain during hot summer periods. Decreased feed intake is the starting point for the most acute effects of heat stress, leading to decrease in body weight, feed conversion ration (FCR), egg production and egg quality (Deng et al, 2012; Mashaly et al, 2004). In addition, heat stress has been shown to reduce the digestibility of feed nutrients and decrease blood calcium and plasma protein levels (Mahmoud et al, 1996; Bonnet et al, 1997; Zhou et al, 1998).

In a study it is proven that a 12-days period of heat stress led to a 28.5 g/bird reduction in average daily feed intake and a 28.8% decrease of egg production (Deng et al, 2012). Star et al (2009) reported a reduction with 31.6% of feed conversion ratio and with 36.4% in egg production, as well as a decrease with 3.41% of egg weight in laying hens housed in heat stress conditions. Also, a research conducted by Ebeid et al (2012) shows that heat stress causes a reduction in egg weight by 3.24%, in shell thickness by 1.2% and in eggshell weight by 9.93%. Another study reports that heat stress is associated with a decrease in laying performance, in a reduction of eggshell thickness and with an increase in the percentage of broken eggs (Lin et al, 2004).

The negative effect of heat stress on egg production is higher with the longer time exposure. Thus it was shown that as the exposure time of laying hens to heat stress increased from 8-14 days to 30-42 days and to 43-56 days respectively, the egg production decreased accordingly by 13.2%, 26.4% and 57% (Farnell et al, 2001). In another study it was shown that a exposure over a period of 5 weeks caused a decrease in egg production by 28.8% in the same time with a reduction in feed intake by 34.7% and body weight by 19.3% (Mashaly et al, 2004). Barrett et al (2019) demonstrate that average daily gain, FCR, eggshell weight and albumen Haugh unit were significantly affected when laying hens were housed at 35°C for 6.5 hours from the 24 to 28 weeks of age.

Impact of climate change on meat production and quality

Selection and genetic progress over the last decade has been aimed to obtain fast growing line of broilers, which considerably has decreased the natural resistance of organism to the environmental factors. The major problem for broilers during heat stress is associated with the lowering of feed intake (Awad et al, 2019). Broiler chickens subjected to a chronic heat stress showed a lower feed intake by 16.4%, lower body weight by 32.6 % and FCR by 25.6% at 42 days of age (Sohail et al, 2012).

It has been shown that exposure of broiler chickens to heat stress negatively affects fat deposition and meat quality (Lu et al, 2007). Subsequent research has shown that heat stress is associated with decreased chemical composition and meat quality in broilers (Dai et al, 2012; Imik et al, 2012) showing a decrease of breast portion at the same time with the increase of thigh portion, as a percentage of live weight (Zhang et al, 2012).

Research conducted on broilers Cobb 500 and Ross 308 demonstrates a reduction of feed intake with 8-9%, of weight gain with by 17% and a worst FCR by 9-10% when chickens were exposed to 34°C for 6 hours daily from 22 to 35 days of age (Awad et al, 2019). The mechanism underlying these findings could be related with the stimulation of appetite-related hormones such as cholecystokinin (CCK), which is secreted in anorexia (He et al, 2018). Given that weight gain is directly correlated with feed intake, and the small intestine is the main site of nutrients digestion and absorption, if during heat stress the feed intake decrease (due to lowering appetite) then further decreases in total intestinal mass and length may occur, as well as changes in mucosal villous morphology (Garriga et al, 2006; Liu et al, 2016). Heat stress has been found to affect the regulation of genes responsible for nutrients transport, which also affects daily gain in broilers (Garriga et al, 2006; Habashy et al, 2017). Water consumption was increased by 5-10% when birds were exposed to high temperatures (32°C) from 17 to 42 days of age (Deeb & Cahaner, 2002).

NUTRITIONAL AND FEEDING STRATEGIES IN POULTRY TO MITIGATE THE EFFECTS OF HEAT STRESS

Nutritional strategies

Energy density of feed

Heat sources for broilers come from metabolism, movement activity and from stable environment. Metabolic heat production in broiler is high due to intensive feeding and nutrients intake compared to other bird species. The high growing rate is supported by the feed intake, which leads to heat production in the body (Abioja & Abiona, 2021). As the ambient temperature in the stable exceeds the upper limit of the thermal tolerance range, the ability of broilers to lose heat is decreased, which makes the excessive heat production to accumulate in the body.

It is well known that fats generate the lowest metabolic heat when is used in the feed as an energy source, so high-fat diets can reduce the total heat production in broilers. Increasing the metabolisable energy content of feed by adding fat is an increasingly common practice in the summer period. Adding more fat to recipes will increase the energy density of the feed which will increase the intake of energy, thus compensating the energy losses of the broilers in heat stress periods (Lin et al, 2006; Lara & Rostagno, 2013). Fat generates less body-heat than proteins or carbohydrates, and some researches shows that a higher fat content in the diet (up to 5-6%) decrease the negative effects of heat stress in broilers (Daghir, 2009). Also, the use of higher percentages of fat in feed will contribute to a slower intestinal passage rate of digestive content, thus increasing the time for digestion and absorption of nutrients. Therefore, diet supplementation with fats will indirectly helps to increase the energy value of other feed ingredients (Daghir, 2009). Another advantage of adding fats with reference to vegetable fats (oils) is the presence of linoleic acid, which is important for poultry production (Szymczyk et al, 2001). However, the oxidative stability and the rancidity process of fats in feed must be taken into account.

Dietary protein level and amino acid balance

In the heat stress periods it is recommended to use compound feeds for poultry with a lower crude protein but well balanced in essential amino acids such as lysine, methionine, threonine, tryptophan and arginine (Saeed et al, 2018). The level of nutrients in the diet must be ensured according to the nutritional recommendations provided by the hybrid technology.

The amino acid profile of the ideal protein for broilers is changes during the growing period in accordance with their performances. Amino acid conversion and nitrogen excretion are lowest when diets are formulated according to the ideal protein concept. The excess of amino acids which cannot be used in protein synthesis due to a limiting factor (such as an amino acid deficiency, low energy level) are metabolised in the body. Compared to other nutrients, the oxidation of amino acids produces the greatest amount of metabolic heat which contributes to the total heat production. Consequently, heat increase is higher when amino acids are in excess in the diet and is not a proper amino acid balance. Research shows that essential amino acids such as lysine (Corzo et al, 2003), arginine (Mendes et al, 1997), methionine or the addition of 2-hydroxy-4-methylthiobutanoic acid to diets can be beneficial to the chickens during periods with high temperatures (Chen et al, 2003). Saeed et al (2018) recommend that ratio between digestible lysine and to be increased by 5%-10% during heat stress.

Electrolyte balance of feed

Cold water is the first and easiest to use for the reducing of negative effects of heat stress and it also brings electrolytes (Na, Cl, K and $NaHCO_3$) necessary to maintain acid-base equilibrium (Koelkebeck et al, 1993). During periods of heat stress in the broiler organism take places a disturbances of the acid-base balance, as a result the lost electrolytes can be recovered by using vitamin and mineral complexes in the water which also must contain sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl) and in addition bicarbonate (HCO_3) and sulphate (SO_4) (Ahmad & Sarwar 2006). Addition of potassium chloride in the amount of 0.2 - 0.5% and supplementation with sodium (0.20 - 0.25%) and chloride (0.30%) helps to maintain osmotic and acid-base equilibrium in broilers older than 29 days (Mushlag et al, 2007; Khattak et al, 2012). The addition of electrolytes to drinking water not only maintains the osmotic balance of the birds but also stimulates water consumption.

Vitamins

During the periods of heat stress, the vitamin requirements of broiler chickens are higher and therefore must be provided in feed or drinking water as a supplement (Lin et al, 2006). Vitamins and minerals are widely researched as adjuvants in mitigating the negative effects of heat stress (Vakili & Rashidi, 2011). For example, supplementation of laying hens diet with vitamin A, C and E has improved the egg production, hatchability, fertility and reduce the eggshell problems (Sahin et al, 2006). Also in broiler parents stock the supplementation with vitamin C and E improved eggshell quality, feed intake and the body weight in the periods with heat stress (Chung et al, 2005). Although vitamin C is synthesized in the body, dietary supplementation is useful due to insufficient availability of plasma ascorbic acid caused by the reduced capacity of the organism to synthesize under heat stress. For example, the adding of vitamin C in the feed or water of broilers helps in thermoregulation and reduce corticosterone levels during heat stress (Attia et al, 2009; Khattak et al, 2012). The action of vitamin C during heat stress is to fortify the immune system, support feed intake and as a result the weight gain, and reduce oxidative stress in broiler chickens (Attia et al, 2016; Orayaga et al, 2016).

A good antioxidant is vitamin E which provides cell protection, scavenges free radicals as a result of oxidative stress and defends against lipid peroxidation (Khan et al, 2011; Attia et al, 2016). It also protect lymphocytes and plasma cells against oxidative action and increase the immune system resistance (Khan et al, 2011; Khan et al, 2019; Attia et al, 2016).

Minerals

The organic salts of the minerals possess antioxidant properties that helps to reduce the creation of free radicals in the birds' organism, thus providing protection against oxidative stress. During heat stress it has been shown an increase requirements of P and Ca due to the lowered feed intake (Lin et al, 2006). Several studies show positive effects of minerals such as selenium, chromium, zinc on the growth performance and weight gain of broiler chicks, as well as reduction the level of heat shock protein and lipid peroxidation (Rao et al, 2016). Zinc has an important role in free radical suppression as it functions as a co-factor (Cu/Zn-SOD) and inhibits NADPH-dependent lipid peroxidation. It also contributes to improve antioxidant status and increase serum vitamin C and E concentration (Sahin et al, 2006). The usage of vitamins and minerals combination (vitamin E and Zn) in the diet have a synergistic effect in reducing the effect of heat stress in poultry, correlating with the improvement of weights, feed conversion and carcass quality (Sahin et al, 2006).

Feed additives

Betaine (trimethylglycine) is an intermediate metabolite in choline catabolism, which acts as a donor of methyl groups and has a lipotropic effect, protecting the liver. Betaine plays an important role in the optimal maintenance of biological processes involved in osmotic regulation (Honarbakhsh et al, 2007; Lever & Slow, 2010) and cellular water, ionic balance, methionine utilization and fat distribution (Attia et al, 2005; Hassan et al, 2005) respectively in the immunity (Graham, 2002). Also, the action of betaine is related to methionine and choline substitution (Graham, 2002; Attia et al, 2009). In one review, Saeed et al (2017) show in birds that betaine acts as an osmolyte to maintain cellular water and ionic balance in the body, preventing dehydration. The action of betaine is also linked to the promotion of a favourable gut microbiota against osmotic variations, helping to protect internal organs and increase fatty acid catabolism. The use of betaine in the diet of broiler chickens under heat stress has been shown to have a positive impact (Table 1) by improving growth performance, nutrient digestibility, immune system and physiological processes, hormone levels and mortality (Wang et al, 2004; Farooqi et al, 2005; Khattak et al, 2012; Saeed et al, 2017a). According to Table 1, the use of betaine in broilers during the periods with heat stress resulted in reduced intra-abdominal fat and increased breast portion in carcass, due to its important role in lipids metabolism by increasing fatty acids catabolism and thus reducing fat deposition. On the other hand, betaine is metabolized in glycine and therefore could improve the fat digestibility (Augustin & Danforth, 1999). An effect is also clearly attributed to its well-known role as a methyl group donor for lecithin synthesis which facilitates the fat transport in organism (Saeed et al, 2017a). In addition, betaine may improve the availability of choline thus providing more choline for the synthesis of very low density lipoproteins, which prevent fat storage in the liver by stimulating the burning processes (Yao & Vance 1989). According to McDevitt et al (2000) the increased of breast percentage may be due to the increased availability of methionine and cystine from feed to protein synthesis.

Betaine's role as a suitable donor of methyl groups favor a good intestinal electrolyte balance in birds and also protects the mucosal epithelium, therefore a higher nutrient absorption can be achieved which will improve the weight gain and use of feed by 3 to 15% (Hassan et al, 2005; Sayed & Downing 2011). Eklund et al (2005) show in a review that feed conversion of laying hens has improved by up to 9% when betaine was used in feed in a dose of 0.01-0.08%.

Heat stress lead to negative changes of endogenous bacterial microbiota of the gut, so the probiotics supplementation will support the diversity of useful microbiota, restoring the normal balance (Attia et al, 2006). Thus, the use of a probiotic containing *lactobacillus* culture lead to an improved feed intake of broiler chickens exposed to 36 ± 1°C for 3 hours daily, from 21 to 42 days of age (Zulkifli et al, 2000). In another study, the use of probiotics at broilers resulted in a better weight and FCR even the presence of heat stress (Al-Daraji, 2013). In laying hens, diets supplementation with probiotics reduced the negative effects of heat stress on the egg production and intestinal health (Deng et al, 2012; Kurtoglu et al, 2004; Mahdavi et al, 2005). These results suggest that positive effects of probiotics in birds are to improve feed intake because heat stress mainly affect it.

Table 1

Effects of using betaine in broiler diets during heat stress periods (adapted from Saeed et al 2017)

Betaine level in feed	Effects on productive performance	Reference
0.05 - 0.15 %	higher daily gain, lower fat percentage in carcass, higher breast portion	Virtanen & Rosi (1995)
0.15 %	increase the digestibility of proteins, fats, lysine and carotenoids from the compound feed	Remus et al (1995)
0.1 %	improved body weight	Farooqi et al (2005)
1 g/kg	higher daily gain and lower level of heterophile/lymphocyte ratio	Gudev et al (2011)
1472 mg/kg	improved body weight	Hassan et al (2005)
0.14 %	improved body weight	Rafeeq et al (2011)
0.05 - 0.10 %	increase daily gain	El-Husseiny et al (2007)
800 mg/kg	increase the portion of breast	Rao et al (2011)

Adding a combinations of prebiotics and probiotics in feed to produce a synergistic effect (synbiotics) is suggested to be beneficial for mitigating the negative effects of heat stress and improving performance of broiler chickens (Mohammed et al, 2018). In this regard, Sohail et al (2012) report a positive effect after the use in feed of mannan-oligosaccharides and a mix of prebiotics and probiotics on the growth performance, gut health and immunity in broilers kept in heat stress.

Acetylsalicylic acid has been used to improve the productive performances of broiler chickens, laying hens and quail in heat stress (Naseem et al, 2005; Roussan et al, 2008). Also the use of sodium zeolite has been shown to help against heat stress in poultry (Saeed et al 2019). Ahmad & Sarwar (2006) show that the use of sodium bicarbonate in poultry feed helps the organism in heat stress periods due to the role as pH buffering agent, being a source of CO_2.

Rosemary extract helps broiler chickens in heat stress probably by favoring the expression of HSP70 and CRYAB genes (Tang et al, 2018). Researches show a several medicinal herbs such as boldo (*Peumus boldus*) and *Morinda citrifolia* leaves as having antioxidant and preventive effects on the negative effects of heat stress in broilers (Flees et al, 2017; Toplu et al, 2014). The resveratrol is a bioactive compound, and its use in poultry diets helps to mitigate the negative effects of heat stress by supporting the intestinal barrier and reducing the negative effects associated with oxidative stress (Liu et al, 2016; Zhang et al, 2017). Liu et al (2013) report the beneficial effects of resveratrol (200, 400, or 600 mg/kg of feed) on the immune system, oxidative stress, and productive performance chickens exposed to heat stress.

Feed supplementation with additives such as phytobiotics or anthocyanin-like polyphenols during periods of heat stress in chickens can help due to their biochemical role as antioxidants, anti-inflammatories, immunizers or neuroprotectants (Hu et al, 2019; Saeed et al, 2017b).

Also, the use of plant derivatives such as phytochemicals in broilers feed is having popularity due to their potential antioxidant activities. For example, lycopene is a anti-stress antioxidant that enhances cell multiplication and the immune system but also has effects on gene transcription (Palozza et al, 2012). Another compound used is gamma-glutamylethylamide (L-thianine) from green tea leaves due to the antioxidant properties (Saeed et al, 2018).

Nutritional strategies

Feeding restrictions

Intermittent feeding of broilers is a practice increasingly used worldwide during periods with high temperatures and consists in depriving of feed during the darkness hours applied during the day. The main purpose of organizing feeding times is based on the concept that the peak of metabolic heat production to not overlap with the highest temperature degrees (Farghly et al, 2019). Practicing the feed deprivation will decrease the internal metabolic heat production of organism and this will help birds to reduce their body heat and will be more easily to resist at heat stress. Intense feeding is carried out during the cold hours of the day, i.e. in the morning, evening and all the night (Farghly et al, 2018). An advantage of the fasting periods also results from the inactivity of the birds, so that through the lack of muscle contractions no additional heat will be produced in the body.

Decreased normal feed intake leads to reduced daily intake of nutrients required for weight gain and normal physiological processes. Evenf if some gain is lost, chicks can resist more easily at heat due to decreased of internal heat production, which will also positively influence flock mortality (Liu et al, 2013; Nawab et al, 2018).

Double feeding

The proteins produce a high heat metabolism, therefore was tested the use of two types of diets in less than 20 hours: during the day for 7 hours when temperatures are very high in broiler stables was used a low-protein but high energy diet; and during the night (17 hours) a high-protein and lower energy diet was used. The diets provided the appropriate nutritive requirements for feeding phase, starting with the broilers age of 20 days and up to 41 days. The results showed that mortality in the flock was lower and the broilers' body temperature during the heat-stressed day was also lower compared to the control group (De Basilio et al, 2001).

Particle size and feed form

The aim of pelleting the compound feed for broilers is to aggregate fine particles containing important nutrients into a compact pellet to ensure a high productive performances (Abdel-Moneim et al, 2021). Feeding with a quality pellets, free of dust and with adequate physical qualities, will contribute to the reduction of heat production required for feed consumption by the birds in heat stress. Syafwan et al (2011) found that feeding chickens with a feed with coarse particles (coarse diet) led to the development of gastrointestinal tract especially the gizzard. Also the coarse particles increased water retention in the brids body, being available for cooling.

The use of wet feed has been shown to better hydrate birds during the heat stress and also provide higher feed intake (Awojobi et al, 2009; Dei & Bumbie, 2011). In this regard, Syafwan et al (2011) report that wet feeding of broilers facilitates increased water intake, which can compensate the evaporative losses during polypnea episodes, thus helps to the thermolysis processes. Also, wet feeding improved feed intake and reduced the impact of heat stress in broilers reared in the warm tropics (Dei & Bumbie, 2011). However, related to this topic the available researches show a contradictory results, as further research is needed to elucidate this issue.

Drinking water temperature:

During heat stress birds drink more water needed to reduce body temperature (Lara & Rostagno, 2013). If birds fail to drink the required water there is will be an imbalance between the water intake and evaporated by cooling, which will affect serum ion concentration and blood osmolarity. This leads to the disruption of the cell functions, of the osmolarity of intra- and extracellular fluids and of pH of body fluids, which affect negatively the poultry productions (Abdel-Moneim et al, 2021). Under normal conditions, the water : feed ratio is 1.8 : 1. This ratio changes when temperatures increase, e.g. at 30-35°C, broilers over 30 days of age will have a water : feed intake ratio of 4.9 : 1 (Bruno et al, 2011; Saeed et al, 2019). Thus it is very important for water to be ad libitum, clean, cool (at 10°C) and fresh.

CONCLUSIONS

This negative effects of heat stress in poultry are associated with the decrease of feed and water intake, acceleration of heart rate and breathing, electrolyte imbalances, changes in hematological parameters, enzyme activities and in the bacterial populations at intestinal level; all negatively affecting the productive performances.

The main nutritional and feeding strategies to reduce heat stress consist in reducing the heat metabolism production; compensating the nutrient deficit resulting from the feed intake decreasing; mitigation the induced metabolic changes. The use of enzymes mixture in accordance with the compound feed structure leads to the improvement of nutrients digestibility. The use of betaine in poultry feed is proved to help in heat stress through its role as a donor of methyl groups which favor a good intestinal electrolyte balance and also protects the mucosal epithelium. Mitigation of heat stress can also be achieved by improving the oxidative body defense or by a good electrolyte balance.

Compensating the reduced nutrients intake also requires the implementation of high-performance technologies in manufacturing the compound feeds (hydrothermal treatments), as well as the maintaing of high pellet quality.

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