Plenary session 2:
NUTRITION INTERVENTION FOR CLIMATE CHANGES

FEEDING AND NUTRITIONAL STRATEGIES FOR COMMERCIAL POULTRY DEALING WITH CLIMATE CHANGE

Rajesh Jha and Birendra Mishra

Department of Human Nutrition, Food, and Animal Sciences, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, HI, USA

rjha@hawaii.edu

EFFECTS OF CLIMATE CHANGES ON POULTRY HEALTH AND PRODUCTION

The earth’s average temperature has risen 1.1 to 1.6°C over the past century and is projected to rise another 0.5 to 8.6°C over the next hundred years (Lensen et al., 2019). Climate change is a global issue affecting livestock production, including poultry. Climate change directly affects poultry production through heat stress and indirectly by promoting an environment for diseases. Among the livestock species, poultry is more prone to heat stress because of higher body temperature, the presence of feathers, and the absence of sweat glands. Heat stress is one of the major environmental stressors in the poultry industry, resulting in a substantial economic loss by altering the poultry’s health and production. Due to a higher metabolic rate, they produce more body heat and cellular free radicals and are prone to heat stress. Heat stress significantly decreases feed intake and body weight and increases the feed conversion ratio (FCR) in broilers (Wasti et al., 2021). Heat stress negatively affects feed intake, body weight, and egg production in laying hens (Wasti et al., 2020). Hens under heat stress had higher cortisol levels, reduced estradiol and progesterone levels, and induced ovarian follicular atresia, reducing ovulatory follicles and egg production (Li et al., 2020). Hens under heat stress also displayed panting to reduce body temperature resulting in respiratory alkalosis. The elevated blood pH causes poor bioavailability of calcium for eggshell biomineralization, resulting in poor eggshell quality. Heat stress negatively affects gut health, including altering the morphometric of the gastrointestinal tract, cecal volatile fatty acid production, and expression of heat shock, antioxidant, immune, and tight junction-related genes (Wasti et al., 2021). Exposure to a high temperature negatively impacts the poultry’s intestinal microbial ecology, specifically by decreasing the species’ abundance (Rostagno, 2020; Wasti et al., 2021), affecting poultry performance.

STRATEGIES TO MITIGATE THE ADVERSE EFFECTS OF HEAT STRESS

Climate change due to global warming is a threat to the poultry industry. Because of heat stress, the poultry industry faces increased production costs, severely altering the meat and egg quality. Many studies have revealed that high environmental temperature causes oxidative stress by producing excessive reactive oxygen species (ROS) and decreasing cellular antioxidants (Mishra and Jha, 2019). Previous studies in poultry have shown that heat stress is associated with cellular oxidative stress. The oxidative stress in poultry is associated with severe health disorders, poor growth performances, and economic losses. As oxidative stress is downstream of heat stress on poultry health and production, several feeding and nutritional strategies have been implemented to mitigate heat stress-induced oxidative stress in poultry.

Feeding strategies for mitigating heat stress

Feeding strategies like restricted feeding, wet or dual feeding, and adding fat to diets have been widely studied and found to reduce the deleterious effects of heat stress (Wasti et al., 2020). Restricted feeding during the hotter period of the day reduces the metabolic rate of birds. Feed restriction reduces rectal temperature, minimizes mortality, and decreases abdominal fat in heat-stressed broilers and layers. As this approach results in a reduced growth rate and delayed marketing age of the birds, it is not widely practiced in the poultry industry. Feed restriction results in overcrowding and rush at a re-feeding time, resulting in additional mortality. Thus, the dual feeding regime ensures that birds can feed throughout the day. The thermic effects of proteins are higher than carbohydrates and produce higher metabolic heat. Therefore, the protein-rich diet is provided during the cooler period, and the energy-rich diet during the warmer period to reduce body temperature and mortality in the heat-stressed broilers. Due to heat stress, birds lose water through respiration, and water intake is markedly increased to restore thermoregulatory balance (Wasti et al., 2020). Wet feed also reduces viscosity in the gut resulting in the faster passage of the feed. Wet feeding promotes digestion, improves the absorption of nutrients from the gut, and accelerates the action of the digestive enzyme on the feed. In broilers, wet feeding enhanced the feed intake, body weight, and weight of the gastrointestinal tract (GIT). In laying hens, wet feeding increases dry matter intake, egg weight, and egg production (Li et al., 2020). Although this approach is beneficial in managing heat stress, it is less common among poultry producers due to the risk of fungal growth in the wet feed. Higher energy diets (fats) produce lower heat increment during metabolism than protein and carbohydrates. Fat supplementation in the poultry diet increases nutrient utilization in the GIT and also helps to increase the energy value of the other feed constituents and increase feed intake in heat-stressed broilers and layers. Essential oil supplementation in the diet relieved the negative effects of chronic heat stress on broiler and layer’s performance.

Nutritional strategies in mitigating heat stress

Supplementation of Electrolytes and Osmolytes

Panting in heat-stressed birds alters the blood plasma’s acid-base balance, ultimately leading to respiratory alkalosis. In heat-stressed birds, sodium and potassium supplementation is favored to increase the blood pH and HCO₃⁻. Supplementation of NaHCO₃ improved eggshell quality in layers, and growth performances in broilers. Besides including these salts in the diet, supplementation of 0.2% NH₄Cl or 0.15% KCl, 0.6% KCl, 0.2% NaHCO₃, and carbonated water in drinking water also improved the performance of the heat-stressed broilers. Osmolytes such as Betaine and Taurine are widely used in the poultry diet to alleviate the heat stress effects. Betaine plays a vital role in regulating the cellular osmotic environment, preventing dehydration by increasing the water-holding capacity of the cell. During heat stress, betaine supplementation improved poultry’s feed intake, carcass trait, and egg production parameters. In laying hens, supplementing betaine and vitamin C improved laying performance during chronic heat stress. In roosters, betaine supplementation improved sperm concentration and livability, seminal plasma total antioxidant capacity, fertility, and welfare under heat stress. Taurine plays a role in antioxidant action, bile acid conjugation, maintenance of calcium homeostasis, osmoregulation, and membrane stabilization. Supplementation of taurine in the drinking water demonstrated significant improvement in the final body weight of chronic heat-stressed broilers. Supplementation of taurine in broilers under heat stress improved jejunal morphology, decreased serum ghrelin concentrations, increased somatostatin, and peptide concentrations YY in the duodenum, and increased the expression of appetite-related genes. In addition, taurine supplementation in the laying hen enhanced oviducal health.

Supplementation of Vitamins and Minerals

Vitamins are essential to the poultry diet due to their health benefits, including growth performance, enhancing immunity, and alleviating oxidative stress. During heat stress, birds cannot synthesize enough vitamins. Therefore, supplementation of specific vitamins (vitamin E, A, and C) as an antioxidant in poultry diet is beneficial in mitigating heat stress effects on broilers’ and layers’ health and performances. Vitamin A is the most effective antioxidant at low oxygen tensions, and it is largely used for its health benefits and improved growth performance. Supplementation of 3% of vitamin A reduces the detrimental effects of heat stress in both broilers and layers (Wasti et al., 2020). Vitamin C is also beneficial in improving the antioxidant capacities of the body during heat stress. During heat stress, the body enters the crisis mode and the production of free radicals increases due to the stress. Vitamin C acts as an antioxidant and is essential to the body for removing these free radicals. Supplementation of 3% of vitamin C improved the performance of heat-stressed broilers and layers. Other vitamins, such as vitamin E, plays a vital role in the health and production of birds. Vitamin E helps to improve the immune system and is a potent antioxidant. Supplementing 2% vitamin E improved the performance of heat-stressed broilers and layers.

Supplementation of Carbohydrates and Lipids

Carbohydrates and lipids are essential parts of the poultry diet due to their various health benefits. Carbohydrates are the primary energy source for birds, and lipids provide essential fatty acids and other health benefits. Supplementation of carbohydrates and lipids in the diet improved the performance of heat-stressed broilers and layers. Addition of 10% of carbohydrates in the diet improved the growth performance of heat-stressed broilers and layers. Supplementation of 2% of lipids in the diet improved the performance of heat-stressed broilers and layers. Lipid supplementation improved the egg production and quality of heat-stressed layers.

Supplementation of Electrolytes and Osmolytes

Electrolytes and osmolytes play a vital role in the health and production of birds during heat stress. Sodium, potassium, and magnesium are essential electrolytes, and they help to maintain the pH balance of the body. Sodium supplementation improved the growth performance of heat-stressed broilers and layers. Potassium supplementation improved the performance of heat-stressed broilers and layers. Magnesium supplementation improved the performance of heat-stressed broilers and layers. Osmolytes such as Betaine and Taurine are widely used in the poultry diet to alleviate the heat stress effects. Betaine plays a vital role in regulating the cellular osmotic environment, preventing dehydration by increasing the water-holding capacity of the cell. During heat stress, betaine supplementation improved poultry’s feed intake, carcass trait, and egg production parameters. In laying hens, supplementing betaine and vitamin C improved laying performance during chronic heat stress. In roosters, betaine supplementation improved sperm concentration and livability, seminal plasma total antioxidant capacity, fertility, and welfare under heat stress. Taurine plays a role in antioxidant action, bile acid conjugation, maintenance of calcium homeostasis, osmoregulation, and membrane stabilization. Supplementation of taurine in the drinking water demonstrated significant improvement in the final body weight of chronic heat-stressed broilers. Supplementation of taurine in broilers under heat stress improved jejunal morphology, decreased serum ghrelin concentrations, increased somatostatin, and peptide concentrations YY in the duodenum, and increased the expression of appetite-related genes. In addition, taurine supplementation in the laying hen enhanced oviducal health.

Supplementation of Essential Oils

Essential oils are widely used in the poultry diet to alleviate the heat stress effects. Essential oils help to improve the immune system, and they also have antioxidant properties. Supplementation of essential oils in the diet improved the performance of heat-stressed broilers and layers. Essential oils such as Thyme, Clove, and Rosemary improved the growth performance of heat-stressed broilers and layers. Essential oils also helped to increase the energy value of the other feed constituents and increase feed intake in heat-stressed broilers and layers. Essential oil supplementation in the diet relieved the negative effects of chronic heat stress on broiler and layer’s performance.
which is found to reduce singlet oxygen, neutralize thyl radicals, and combine with and stabilize peroxyl radicals. Vitamin E is a fat-soluble vitamin with antioxidant activity and helps scavenge free radicals produced inside the cell. Vitamin E regulates inflammatory signaling, and the production of prostaglandins, cytokines, and leukotrienes and improves the phagocytic activity of macrophages in broiler chickens. Vitamin C protects against oxidative stress by scavenging ROS and protecting cells from oxidative damage. Vitamin C also improves immunity by enhancing the differentiation and proliferation of T and B cells. One of the major consequences of heat stress is an increase in mineral excretion and a lowering of these key nutrient levels in the circulating bloodstream and liver. Supplementation of Zinc, Chromium, and Selenium in poultry diet is highly beneficial in maintaining the redox system, birds’ performance, and product quality.

**Supplementation of Phytochemicals**

Phytochemical feed additives have been reported to alleviate the negative consequences of heat stress. Phytochemicals, such as Lycopene, Resveratrol, Epigallocatechin gallate (EGCG), Curcumin, dried plum (DP), and microalgae, have been studied in poultry under heat stress (Wasti et al., 2020; Mullenix et al., 2021). Supplementation of lycopene in heat-stressed broilers improved the cumulative feed intake, body weight, and FCR. Lycopene improved the level of antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) in broilers. In laying hens, dietary lycopene supplementation improved oxidative status, enhanced egg vitamin levels, and improved the egg’s oxidative stability and yolk color. Supplementation of resveratrol improved the average daily gain, decreased the rectal temperature, and lowered the level of corticosterone, adrenocorticotropin hormone, cholesterol, and MDA in yellow-feather broilers under heat stress. Resveratrol also improved gut health parameters such as microbial profile, villus-crypt structure, and expression of the tight junction and adherence junction-related genes in the heat-stressed broilers. In laying hens, resveratrol supplementation improved egg production, reduced the total serum cholesterol and triglycerides, reduced egg cholesterol content, improved antioxidant activity, and improved egg sensory scores. The EGCG is the polyphenol in green tea extract with high antioxidant and anti-inflammatory properties. EGCG supplementation increased body weight, feed intake, serum total protein level, glucose, and alkaline phosphatase activity in heat-stressed birds. Also, dietary inclusion of EGCG improved body weight and antioxidant enzymes (GSH-Px, SOD, and catalase) in the liver and serum of heat-stressed broiler birds. Curcumin is the primary polyphenol extracted from turmeric and possesses antioxidant and anti-inflammatory properties. Curcumin supplementation improves the growth performance of heat-stressed broiler chickens. Curcumin’s fortification reduced the mitochondrial MDA level; reduced the ROS production by increasing the activity of Mn-SOD, GSH-Px, Glutathione S-transferase and increased gene expression of thioredoxin-2 and peroxiredoxin-3 during heat stress in broilers. In laying hens, dietary curcumin supplementation improved the laying performance, egg quality, antioxidant enzyme activity, and immune function during heat stress. Dried plum contains a higher amount of antioxidants (fat-soluble carotenoids, alpha-tocopherol, etc.), polyphenolic compounds (chlorogenic acids, proanthocyanidins, etc.), sorbitol, and fibers. DP is a good source of several vitamins (vitamins A, C, K1, B1, B2, and niacin) and minerals (Ca, Mg, Se, and Zn). Besides its antioxidant role, DP has several beneficial effects on gut health, calcium metabolism, and immune function. The dietary supplementation of DP significantly improved the body weight, average daily gain, average feed intake, FCR, ileum histomorphology, cecal VFA production, and expression of heat shock, antioxidant, immune, and tight junction-related genes in the heat-stressed birds (Mullenix et al., 2021, unpublished data from our lab). Gut microbial metagenomics showed a higher alpha diversity in the heat-stressed birds supplemented with microalgae (unpublished data from our lab).

**CONCLUSION AND FUTURE DIRECTION**

Because of climate change, the detrimental consequences of heat stress on poultry health and production will likely continue. Commercial poultry breeds cannot withstand heat stress, resulting in substantial economic losses to the industry, which triggers food security issues. Therefore, there is a critical need to develop heat-tolerant breeds and feeding and nutritional strategies to minimize the adverse effects of heat stress on poultry production.

**REFERENCES**


Microalgae (*Spirulina platensis*) is rich in antioxidants and have several health benefits. The dietary supplementation of microalgae significantly improved the body weight, average daily gain, average feed intake, FCR, ileum histomorphology, cecal VFA production, and expression of heat shock, antioxidant, immune, and tight junction-related genes in the heat-stressed birds (Wasti et al., 2021, unpublished data from our lab). Gut microbial metagenomics showed a higher alpha diversity in the heat-stressed birds supplemented with microalgae (unpublished data from our lab).