

Precision Nutritional Strategies for Poultry During Thermal Stress

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Introduction

In the realm of modern animal agriculture, the environmental temperature remains one of the most significant external factors influencing productivity and welfare. Poultry, unlike mammals, possess unique physiological characteristics such as the phylogenetic absence of sweat glands and the insulation provided by feathers that make them particularly susceptible to high environmental temperatures. When ambient temperatures surpass the bird's thermoneutral zone, a complex cascade of physiological changes is triggered, collectively known as heat stress. While environmental modifications are the first line of defense, a growing body of scientific research highlights that precision nutritional management is equally critical to maintain homeostasis, safeguard immunity, and sustain production performance. This article delves into the academic and practical components of nutritional strategies to mitigate heat stress in poultry, tailored for students and professionals in animal science and poultry production.

The Physiology of Thermal Stress: The "Why" Behind the Symptoms

To effectively manage nutrition during heat stress, one must first understand the bird's internal battle. The thermoneutral zone for adult poultry generally ranges between 18°C and 25°C, though this varies by breed and humidity. When temperatures exceed this range, the bird can no longer rely solely on passive heat dissipation mechanisms like convection, radiation, and conduction. At this tipping point, the reliance shifts dramatically to active, evaporative cooling.

The Panting Paradox and Respiratory Alkalosis

The most visible sign of heat stress is panting, or thermal tachypnea. This rapid, shallow breathing increases airflow across the moist surfaces of the upper respiratory tract, facilitating evaporative cooling. While effective at

removing heat, this process has a critical physiological side effect: the excessive expulsion of Carbon Dioxide (CO₂).

According to the chemical equilibrium principle, a loss of CO₂ (a gas which forms carbonic acid, H₂CO₃, in the blood) leads to a decrease in hydrogen ion (H⁺) concentration. This imbalance results in an abnormal rise in blood pH, a condition known as respiratory alkalosis. To compensate, the bird's kidneys increase the excretion of bicarbonate ions (HCO₃⁻) and retain hydrogen ions, but this process also triggers the depletion of essential electrolytes, primarily Potassium (K⁺) and Sodium (Na⁺). For layer hens, this alkalosis is especially devastating because bicarbonate is a direct precursor to the calcium carbonate needed for eggshell formation. Consequently, when bicarbonate is prioritized for excretion to restore blood pH, eggshell quality drops precipitously.

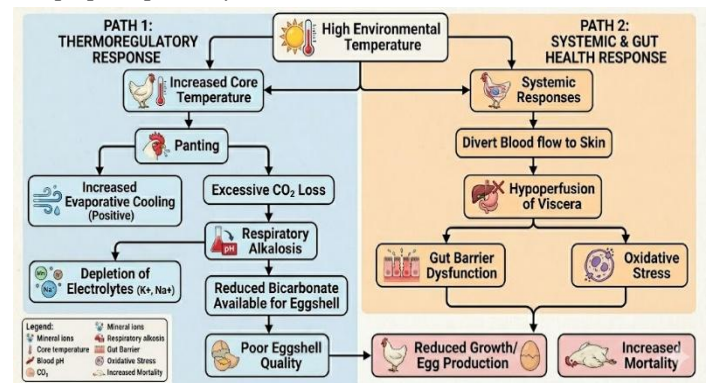


Fig. 1. Physiological Cascade of Heat Stress in Poultry The Gut Barrier and Oxidative Stress

Beyond acid-base balance, heat stress dramatically impacts the cardiovascular and digestive systems. As the bird diverts up to 50% of its total cardiac output to the skin to enhance sensible heat loss, visceral organs, including the intestinal tract, experience hypoperfusion (reduced blood flow). This restriction in oxygen and nutrient supply to the gut tissue can trigger intestinal inflammation, weaken the

tight junctions between the lining cells, and disrupt the microbiota. This "leaky gut" scenario allows pathogens and toxins into the bloodstream, triggering immune activation and shifting energy away from production towards maintenance and survival. Furthermore, the metabolic burden of dealing with high temperatures leads to an overproduction of Reactive Oxygen Species (ROS), resulting in oxidative stress, which damages cellular structures, including lipid membranes and DNA.

The Fundamental Feeding Paradox: Demand Versus Intake

The core challenge of nutritional management in heat stress is the immediate and dramatic reduction in voluntary feed intake. This reduction, which can exceed 30%

in severe cases, is a fundamental thermoregulatory mechanism; the bird instinctively decreases consumption to limit metabolic heat increment the heat generated during the digestion, absorption, and assimilation of nutrients.

However, while intake drops, the bird’s nutrient requirements do not follow suit. In fact, the maintenance energy needed to fuel the muscular activity of panting increases. This creates a severe nutritional deficit. If the formulation of the diet remains unchanged, the bird suffers a proportional reduction in all required amino acids, vitamins, and minerals. Effective nutritional strategy, therefore, is not about forcing the bird to eat more, but about making every bite denser, more digestible, and chemically balanced to support thermal tolerance.

Table 1: Comparative Effects of Heat Stress on Commercial Broilers vs. Layers

Production System	Primary Nutritional Consequences	Mitigation Focus through Nutrition
Broilers (Rapid Growth Focus)	Drastic drop in feed intake; proportional loss of amino acids (Lysine/Methionine); reduced muscle deposition (catabolic state). Elevated mortality due to metabolic demand.	Increasing energy density (fat); lowering heat increment (crude protein reduction + synthetic AA); electrolyte restoration (Na/K); antioxidant support.
Layers (Egg Output Focus)	Feed intake reduction leading to energy deficit for production. Severe drop in bicarbonate for eggshells due to respiratory alkalosis. Disruption in calcium/phosphorus mobilization.	Maintaining energy balance for egg production; specific calcium management (coarse limestone); bicarbonate replenishment (sodium bicarbonate); vitamin support (C, E).

Part 1: Macronutrient Management – Rebalancing Energy and Protein

The first nutritional adjustment focus must be on the two most critical components of the diet: Energy and Protein. Traditional formulations relying heavily on starch and crude protein are suboptimal during heat, as they contribute significantly to metabolic heat increment.

A Shift to Lipids for Energy Density

In thermoneutral conditions, carbohydrates (primarily from corn, wheat, or barley) are the dominant energy source. During heat stress, however, the metabolic heat generated from starch digestion becomes a burden. The optimal strategy is to replace a portion of these metabolic carbohydrates with dietary lipids (fats and oils, such as vegetable oil or blended fat).

Lipids provide two distinct advantages in thermal stress management. First, they possess the lowest heat increment among all macronutrients; the metabolic efficiency of converting dietary lipid to body lipid or energy is higher than for carbohydrates or protein, generating less thermal waste. Second, fats increase the overall energy density of the diet, helping to compensate for the reduction

in total feed intake. Furthermore, fats can slow the rate of passage in the gastrointestinal tract, allowing more time for other nutrients in the reduced volume of feed to be absorbed. A standard recommendation is that 3-5% of the total metabolizable energy should be derived from dietary fat in hot climates.

Protein: Quality Over Quantity – The Ideal Amino Acid Concept

Perhaps the most common error in hot weather management is the instinct to *increase* crude protein (CP) to compensate for reduced feed intake. Science shows that this is counterproductive. Excess crude protein requires a significant energy expenditure by the liver to catabolize and excrete the nitrogen as uric acid, generating substantial heat in the process. The optimal approach is to reduce the total dietary crude protein by several percentage points and meet the bird's amino acid requirements through the precise supplementation of crystalline, synthetic amino acids (L-Lysine, DL-Methionine, L-Threonine, and potentially L-Valine). This strategy, based on the Ideal Protein Concept, allows for a lower-CP diet that minimizes the excretion of excess nitrogen and the associated heat increment, while

ensuring that the essential amino acids necessary for tissue repair, egg production, and immunity are present in a perfectly balanced ratio.

Part 2: Water – The Most Critical (and Overlooked) Nutrient

Water is the essential medium for thermoregulation. During heat stress, water intake doubles or even triples, while feed intake drops. Water facilitates heat loss primarily through evaporation in the respiratory tract. Therefore, maintaining a reliable supply of cool, high-quality water is the singular most effective mitigation strategy.

The physical temperature of the water is paramount. Cool water acts as a thermal heat sink within the body, absorbing core heat via conduction before it is excreted. Research consistently demonstrates that providing cool water (e.g., around 10-15°C) stimulates water consumption and can decrease core body temperature. In contrast, warm water is unpalatable to poultry; they may restrict intake even when facing severe dehydration. Practical management requires frequent flushing of water lines, especially nipple systems, ensuring shade for water tanks, and possibly adding ice in extreme scenarios, as water lines exposed to a 35°C shed can quickly become warm and discourage drinking.

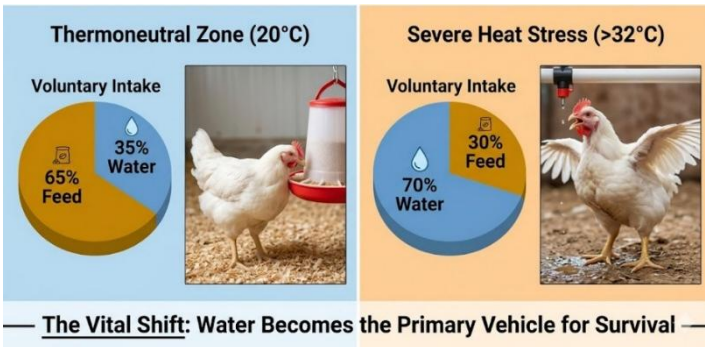


Fig. 2. Dynamic Shift in Feed/Water Intake Ratio in Poultry under heat stress

Part 3: The Nutritional Supplements – Additives to Maintain Homeostasis

Beyond basic macronutrients, a range of micro-additives can be strategically included in the feed or drinking water to provide physiological support, fight oxidative stress, and restore acid-base equilibrium.

Restoration of Electrolyte Balance and Blood pH

Given the electrolyte depletion and pH disruption caused by respiratory alkalosis, the supplementation of electrolytes is a scientific standard.

1. **Potassium (K):** Due to the high excretion of K⁺ during thermal stress, potassium supplementation is critical. The most common source is Potassium Chloride (KCl), typically added to drinking water at

rates of 0.5% to 1.0%. It helps stimulate water intake and replace the potassium lost during kidney compensation for alkalosis.

2. **Sodium Bicarbonate (NaHCO₃):** Often referred to as baking soda, this is arguably the single most important additive for layer hens. Dietary supplementation of NaHCO₃ (replacing some Sodium Chloride, NaCl) provides both Sodium and the bicarbonate ion. This directly replenishes the bird's depleted bicarbonate reserve, alleviating respiratory alkalosis and supporting the continuous formation of calcium carbonate for robust eggshells.
3. **Ammonium Chloride (NH₄Cl):** This salt is an acidifying agent. While NaHCO₃ addresses the alkalosis by providing bicarbonate, NH₄Cl addresses it from the opposite end by decreasing blood pH. It must be used with caution and precise monitoring of the Dietary Electrolyte Balance (DEB).

The target Dietary Electrolyte Balance (DEB) calculated as mEq Na + mEq K - mEq Cl becomes more critical during heat. While a normal range is 150-200 mEq/kg, research suggests optimized DEB levels around 250 mEq/kg are beneficial in tropical climates to buffer against the systemic alkalosis.

Vitamin and Mineral Antioxidant Support

The massive production of free radicals during oxidative stress in a heat-stressed bird overwhelms its natural antioxidant defenses. Strategic antioxidant supplementation can mitigate this damage.

1. **Vitamin C (Ascorbic Acid):** Birds naturally synthesize Vitamin C in the kidneys. However, under the metabolic strain of heat stress, this synthesis cannot keep pace with the antioxidant demand. Dietary or water supplementation of Vitamin C (e.g., 200–500 mg/kg of feed or liter of water) enhances immunocompetence, reduces adrenal corticosterone output, acts as a primary antioxidant to protect tissues, and supports better carcass quality in broilers and shell quality in layers.
2. **Vitamin E:** This is the body's primary lipid-soluble antioxidant, protecting cellular membranes from ROS-induced lipid peroxidation. Vitamin E supplementation (e.g., 100–200 IU/kg) works synergistically with selenium to maintain cellular integrity and immune function during stress.
3. **Trace Minerals:** Zinc, Selenium, and Chromium are essential components of critical antioxidant enzymes (like Superoxide Dismutase and Glutathione Peroxidase). Chromium, in particular, has been

shown to reduce blood cortisol levels, improving metabolic resilience during environmental challenges. Utilizing organic (chelated) forms of these minerals ensures higher bioavailability, making them more effective at lower doses.

Specialized Osmo-Regulators and Immune Modulators

Betaine is a specialized additive that acts as an efficient organic osmolyte. It helps body cells retain water against osmotic pressure gradients without expending metabolic energy. This "cell-stabilizing" property is invaluable during heat stress, protecting the intestinal epithelium, muscles, and other tissues from dehydration caused by the alkalosis-driven electrolyte shift. Furthermore, probiotics and prebiotics play a key role in supporting the gut microbiota, which is severely disrupted when blood flow to the viscera is reduced, helping to prevent the invasion of opportunistic pathogens like *Salmonella* and *E. coli*.

Part 4: Practical Feeding Management – Timing and Form

Nutritional strategy is not only about *what* the diet contains, but also *when* and *how* it is presented to the bird.

Synchronizing Metabolism with Environmental Temperatures

Since the heat increment of feeding peaks several hours after a meal, it is highly disadvantageous for a bird to have a full gut during the hottest hours of the day. A crucial feeding strategy is to avoid feeding during peak heat (e.g., from 9:00 am to 5:00 pm in many tropical regions). Instead, feed should be withdrawn during this time and maximal feeding encouraged in the early morning and, even more effectively, in the late evening, night, or under a midnight lighting program. Allowing the peak of metabolic heat production to coincide with cooler environmental temperatures (often overnight) reduces the total thermal burden and drastically lowers mortality rates. For layer hens, overnight feeding also aligns perfectly with the time of maximal calcium carbonate deposition in the eggshell, which occurs primarily during the dark phase.

Physical Form of Feed: Mash vs. Pellets

The physical structure of the feed also impacts metabolic heat production. While pelleting is a standard industry practice to improve feed handling and convert mash into a denser form, it can have drawbacks during heat stress. The manufacturing process of steam pelleting can slightly alter starch structure and increase its digestibility, which potentially raises the metabolic heat increment compared to mash. Conversely, poultry may show a behavioral preference for the larger particle size of crumbles or pellets during heat, and the reduced energy spent on feeding behavior (since a pellet contains a complete meal) can be an advantage. The consensus is generally that, if adequate intake can be maintained with pellets without exacerbating mortality, they are preferred; however, in cases of extreme heat mortality, some producers switch to a high-density wet mash or coarse crumbles, which may reduce feeding activity and associated heat.

Conclusion

Beat the heat in poultry production is not a static challenge; it is a complex intersection of physics, physiology, and chemistry. While cooling systems and environmental control must always be the priority, the strategic application of precision nutritional management provides the essential biochemical framework for survival and performance in a warming climate. By moving away from treating heat stress as a production deficit and instead approaching it as a physiological state that requires specific biochemical inputs cool, palatable water, optimized lipid-to-carbohydrate ratios, precise amino acid balance, electrolyte restoration, and antioxidant support poultry scientists can empower the bird’s internal systems to maintain homeostasis. Nutrition, when integrated with robust management practices, transforms from a cost-variable into a dynamic tool for safeguarding animal welfare and food security in an increasingly volatile global landscape.
