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Physiology of the Birds: The Significance of Environmental Control to Ensure Bird Performance in Harsh Climates

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Birds are homeothermic animals, that is, they have the capacity to regulate and keep their body temperature within a narrow range. The maintenance of thermal homeostasis is influenced by both the bird's physiological state and the environmental conditions to which it is exposed. Among the main mechanisms involved in this process are non-evaporative or sensible heat exchange (conduction, convection, and radiation), and latent evaporative dissipation, predominantly through breathing.

When environmental conditions are outside the bird's comfort zone, whether it is due to heat or cold, the peripheral and central sensory thermoreceptors are activated, sending signals to the hypothalamus. This, in turn, acts as an integration center, processing thermal data and triggering responses in the effector systems, to restore thermal balance and maintain the animal within the thermoneutral zone (Rocha et al., 2004).

The thermoregulatory system in birds operates through neural mechanisms and complex hormonal interactions acting in a coordinated manner for homeothermic maintenance. Regarding the endocrine aspect, the relevance is on the hypothalamic-pituitary-thyroid (HPT) axis and the hypothalamic-pituitary-adrenal (HPA) axis, critical for metabolic regulation and adaptive responses to heat stress. Studies show that thyroid hormones, thyroxine (T4) and triiodothyronine (T3), play a central role in the thermal response of chicks during their first weeks post-hatching, a phase characterized by functional immaturity of the thermoregulatory system and by the progressive maturation of the neuroendocrine mechanisms involved in homeothermic maintenance. Additionally, the thyrotropin-releasing hormone (TRH), produced in the hypothalamus, is capable of inducing thermoregulatory responses when administered via the intracerebroventricular route in recently hatched birds, highlighting the central role of the neuroendocrine system for thermal control.

The efficiency of these endocrine mechanisms is directly affected by environmental conditions to which birds are exposed. Factors such as an ambient temperature outside the thermoneutral zone, increased relative humidity, high solar radiation, and low air speed compromise heat dissipation processes and overload thermal control systems. Under these conditions, the limited thermoregulatory capacity may lead to homeostatic imbalances, causing heat stress and an overactive HPA axis.

In this context, thermoneutrality may be defined as the ambient temperature range in which the metabolic rate is minimal and homeothermy is maintained with low energy expenditure *(Figure 1)*.

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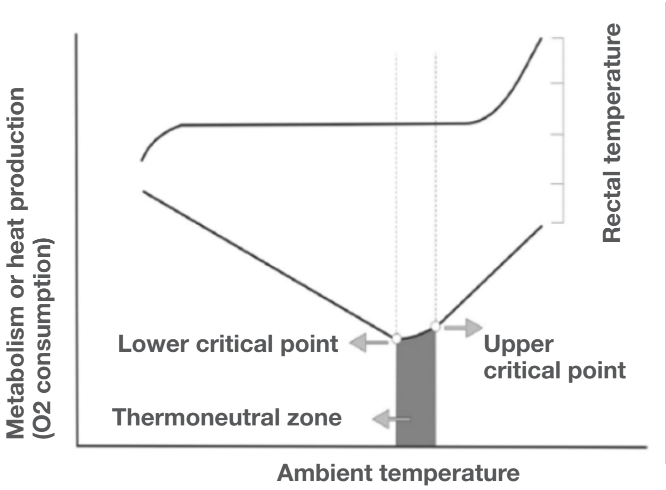


Figure 1. Schematic representation of the metabolic curve in broilers in relation to ambient temperature, creating a thermoneutral zone where metabolism is minimal and productivity is maximized. The lower critical temperature corresponds to the temperature below which metabolic heat production increases to maintain body temperature. The upper critical temperature represents the thermal limit where heat dissipation mechanisms become insufficient to maintain homeothermy, resulting in heat stress (Rocha et al., 2024).

Although these mechanisms allow for homeothermic maintenance, modern broilers show physiological limitations when facing intense thermal challenges. Rapid growth, associated with increased metabolic heat production and a reduced capacity for heat dissipation, makes these birds particularly sensitive to heat stress, with a direct impact on performance, health, and welfare.

Cold Stress

Exposing chicks, even briefly, to temperatures below the thermal comfort zone may trigger a series of physiological and metabolic alterations, with a direct impact on productive performance. During the first weeks of life, temperatures below 32 and 35 °C may result in reduced feed intake, greater use of body reserves for thermogenesis, impaired immune responses, and increased mortality (Vieira et al., 2016). Also, studies show that cold stress is associated with alterations in intestinal energy metabolism, negatively affecting the efficient use of the nutrients ingested.

The initial environment plays a crucial role in the modulation of the development of thermal control physiological mechanisms throughout the productive life of birds. Cold stress during the first weeks may affect the uniformity of the flock, mainly in relation to feed intake reduction during a critical period of intense growth and maturation of the digestive system (Rendall et al., 2000). What is more, during this initial phase, there is a rapid development of muscle and bone tissue, as well as of the immune system, processes highly dependent on an adequate availability of energy and nutrients.

Heat Stress

The capacity of birds to tolerate heat stress conditions usually varies throughout their development. In young birds, thermoregulation is limited due to the immaturity of the central nervous system and of the neuroendocrine axis, which makes them particularly sensitive to thermal variations.

As birds grow, thermoregulatory mechanisms progressively mature. However, the increase in body weight and metabolic rate causes a higher production of endogenous heat, reducing the birds' tolerance to environments with higher temperatures.

Thus, thermal conditions to which birds may be exposed are generally classified into zones: comfort zone, critical zone, upper critical zone, and lethal critical zone. However, these ranges are not absolute, as certain factors such as genetic heritage, age, sex, stocking density, physiological state, relative humidity, and wind speed directly affect birds' thermal tolerance (Chaiyabutr, 2004).

Under heat stress conditions, birds activate behavioral and physiological mechanisms to increase thermal dissipation, especially through non-evaporative means. Among these responses is the adoption of specific body postures, such as crouching while separating their wings from the body, exposing the highly vascularized ventral region, bristling feathers, and peripheral vasodilatation.

These adjustments increase blood flow to the body surface and to featherless areas, such as the feet, comb, and wattles, improving heat transfer to the environment.

The efficiency of these non-evaporative mechanisms for heat dissipation, such as peripheral vasodilatation and posture changes, is directly related to the cardiovascular system, which is responsible for redistributing blood to peripheral tissues, while relatively reducing the blood supply to internal organs, prioritizing thermal dissipation. While temperature rises and non-evaporative mechanisms become inefficient, an increase in respiratory rate is observed, characterized by panting, which intensifies air circulation through the respiratory system and promotes the loss of latent heat by evaporation. As a consequence of the higher respiratory rate, birds may develop disturbances in acid-base balance, characterized by respiratory alkalosis, which negatively affects productive performance, compromising feed consumption, feed efficiency, growth rates and survival.

When birds are exposed to higher temperatures, they reduce their feed intake as a strategy to minimize metabolic heat production. This intake reduction affects the availability of essential energetic and nutritional substrates, limiting the productive metabolism and, consequently, their performance. At the same time, heat stress promotes an increase in plasma levels of corticosterone, which alters the protein turnover, causing the breakdown of muscle protein. The intensification of muscle proteolysis not only increases endogenous heat production, but also contributes to the reduction of weight gain and productive efficiency.

Additionally, energy use is redirected towards the physiological mechanisms involved in homeothermic maintenance, considered the primary basal function of the organism, at the expense of the productive system. Behavioral and physiological responses, such as panting and stretching wings, increase the energy expenditure on maintenance. Consequently, there is a less efficient use of nutrients and energy from the diet, poorer feed conversion, generally expressed through higher values of that index in heat stress environments.

The combination of bird physiology and environmental management shows that homeothermic maintenance does not depend merely on internal regulation mechanisms, but mainly on external conditions provided in the house. When facing thermal challenges, the physiological and neuroendocrine systems are intensely activated to keep body balance, but at a high energy cost and a negative impact on performance. In this context, adequate environmental management —mainly ventilation, temperature, and relative humidity control— becomes essential to reduce the burden of heat stress, allowing birds to stay within their thermoneutral zone. Consequently, when the understanding of physiological processes is aligned with efficient ventilation practices and monitoring of birds' behavior, it is possible to optimize comfort, protect their health and maximize the productive efficiency of the flocks, especially in challenging climate conditions.

In order to minimize the aforementioned stressors and their impact on birds, the table below should be used as a reference, always comparing the variables body weight, relative humidity (%RH), and dry-bulb temperature.

The adequate management of ventilation in houses is one of the most important tools to ensure bird comfort, productive performance, health, and welfare. The ventilation system — consisting of the house, equipment, and a controller— must be designed to deal with local environmental variation throughout the day and the different seasons. The main goal is to provide a stable environment, adjusting to both cold weather and intense heat and high humidity.

Principles showing how the optimum dry-bulb temperature for broilers may vary with RH. Dry-bulb temperatures at the ideal RH for body weights below 200 g (0.44 lb)+ are shown in green.

Body weight g (lb)	Dry-bulb temperature °C (°F)			
	40% RH	50% RH	60% RH	70% RH
44 (0.10)	36.0 (96.8)	33.2 (91.8)	**30.8 (87.4)**	**29.2 (84.6)**
100 (0.22)	33.7 (92.7)	31.2 (88.2)	**28.9 (84.0)**	**27.3 (81.1)**
180 (0.40)	32.5 (90.5)	29.9 (85.8)	**27.7 (81.9)**	**26.0 (78.8)**
290 (0.64)	31.3 (88.3)	28.6 (83.5)	26.7 (80.1)	25.0 (77.0)
425 (0.94)	30.2 (86.4)	27.8 (82.0)	25.7 (78.3)	24.0 (75.2)
590 (1.30)	29.0 (84.2)	26.8 (80.2)	24.8 (76.6)	23.0 (73.4)
790 (1.74)	27.7 (81.9)	25.5 (77.9)	23.6 (74.5)	21.9 (71.4)
1015 (2.24)	26.9 (80.4)	24.7 (76.5)	22.7 (72.9)	21.3 (70.3)
1260 (2.78)	25.7 (78.3)	23.5 (74.3)	21.7 (71.1)	20.2 (68.4)
>1530 (3.37)	24.8 (76.6)	22.7 (72.9)	20.7 (69.3)	19.3 (66.7)

(Table 2.5 from the Broiler Manual 2025 - Aviagen [page 30])

Ventilation has many goals: to keep thermal comfort, to provide fresh air, to remove excess humidity, to eliminate harmful gases (such as ammonia and carbon dioxide), to control temperature, to preserve litter quality and to distribute air uniformly. During cold periods, the priority is to remove humidity and keep air quality without excessively losing heat. During hot periods, the focus is on removing heat and cooling birds through the wind-chill effect and, if necessary, through evaporative cooling.

A fundamental concept is effective temperature —that is, the temperature perceived by birds - which is affected by relative humidity (RH).

- At low RH, birds feel cooler.
- With a high RH, birds feel warmer, as the capacity to dissipate heat through evaporation (panting) decreases.

Thus, the target temperature in the house must take into account not only the thermometer, but also humidity and, mainly, birds' behavior. Bird behavior is the most reliable indicator to assess if the environment is adequate:

Huddled birds indicate cold temperatures:

Environment is too cold:
Birds huddle together or under heat source, and may be noisy and distress-calling, showing that they are cold.

Action
Increase temperature.

Panting birds away from the heat source indicate excessive heat:

Environment is too hot:
Birds move away from the heat source, are quiet and pant; their heads and wings droop, showing that they are hot.

Action
Reduce temperature.

Well-distributed birds indicate comfort:

Environmental conditions are correct:
Birds are spread evenly; noise signifies contentment, showing that they are at the correct temperature.

Action
No action required

(Figures from page 3 - AviagenEssentialVentilationManagement-2019-PT)

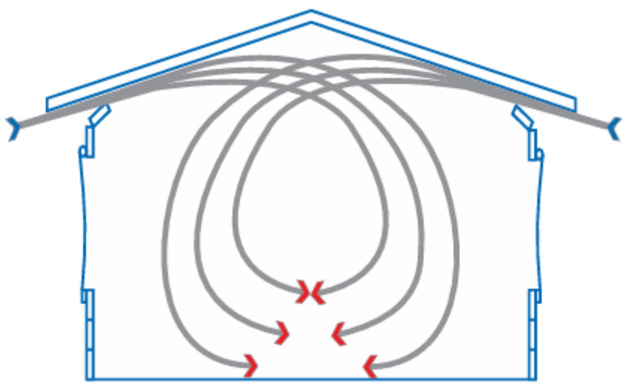
Most modern houses operate under negative pressure. That means extraction fans remove air from inside, reducing internal pressure in relation to the external environment. This forces air to enter in a controlled manner through air inlets. The greater the pressure difference, the higher the incoming air velocity. A well-sealed house is essential to maintain this negative pressure effectively and guarantee that the air enters through the correct places.

Ventilation management is divided into three main modes: minimum ventilation, transitional ventilation, and tunnel ventilation.

Minimum ventilation is commonly used during periods of cold weather and during brooding. The aim is to exchange the air to control humidity and gases, keeping internal heat. It works with cycle timers (on/off), generally in five-minute intervals.

Lateral air inlets should be evenly distributed and direct cold air towards the peak of the roof, where it mixes with accumulated hot air before coming down to bird level, as shown in the figure below:

MINIMUM VENTILATION



(Figures from page 5 - AviagenEssentialVentilationManagement-2019-PT)

- Most commonly used during brooding (chicks) and periods of cold weather, or whenever house temperature drops below the set-point.
- Time-driven process (timers).
- Evenly distributed air inlets.
- Air inlets operate on the basis of “negative pressure”.
- It brings in fresh air from outside.
- Cold incoming air is directed to the peak of the roof.
- Used to remove excess humidity to control RH.

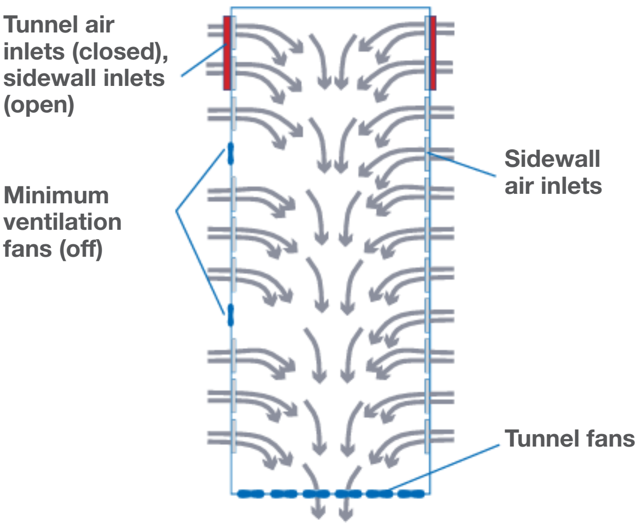
- Removes gases from the house.
- Requires well-distributed heat.
- Air movement at bird level is very low.

The recommended minimum opening of air inlets is 3 to 5 cm. The balance between inlet opening and negative pressure is essential to guarantee that the air travels a sufficient distance before reaching the birds. Tests with smoke or strips help verify if the flow is correct.

Minimum ventilation should be adjusted based on air quality and birds' behavior. Signals such as suffocation, high humidity, condensation, and wet litter indicate lack of sufficient ventilation. On the contrary, excessively dry litter, dust, and difficulty maintaining a steady temperature may indicate excessive ventilation.

Proper management requires daily inspections and gradual adjustments. Transitional ventilation is activated when the temperature inside the house exceeds the desired temperature and tunnel ventilation is not yet appropriate, whether it is due to external weather conditions or the birds' age (1 or 2 degrees above desired temperature). In this mode, exhaust fans operate continuously, increasing the volume of fresh air to remove heat. Inlets continue to operate with negative pressure and must direct air towards the roof. It is important to highlight that air must come in exclusively through the inlets, as described in the figure below:

TRANSITIONAL VENTILATION



(Figures from page 5 - AviagenEssentialVentilationManagement-2019-PT)

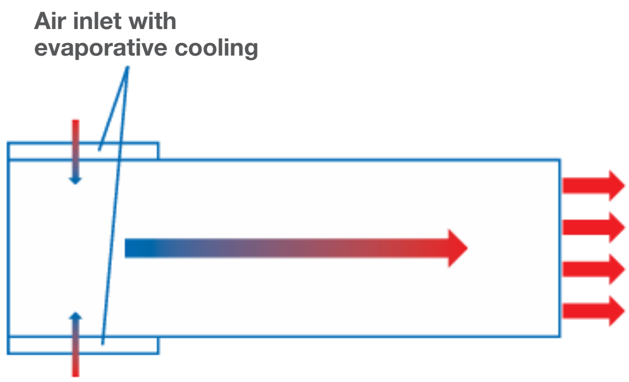
- Used when the temperature in the house rises above the set-point temperature and when it is too cold or birds are too young for tunnel ventilation.
- Temperature-driven process.
- Its primary function is to remove excess heat.
- It brings in a large volume of fresh air from outside.
- Air inlets operate on the basis of negative pressure.
- Air is directed up to the peak of the roof.

Birds' comfort should drive adjustments. Heaters should not be on during this phase.

Tunnel ventilation is used in hot weather, especially with older birds. Air comes in through one side of the house and is removed through the other side, creating a high-speed airflow at bird level. This flow creates a wind-chill effect, reducing the effective temperature felt by birds. The decision on the number of exhaust fans in operation must be based exclusively on birds' comfort, not only on thermometer readings. Temperature differences greater than 3 °C from front to rear indicate issues such as air leakage or insufficient ventilation capacity.

Evaporative cooling complements tunnel ventilation when only increasing air speed is not enough. Evaporative pads reduce air temperature by transferring heat from the air to the water during evaporation.

TUNNEL VENTILATION



(Figures from page 5 - AviagenEssentialVentilationManagement-2019-PT)

- Used in hot weather, including hot, high-RH conditions.
- Generally used when birds are older (fully feathered).
- Its primary function is to remove excess heat.
- Used when transitional ventilation is no longer able to keep birds cool.
- It generates a high-velocity airflow at bird level.
- It creates a wind-chill effect that helps cool birds.
- It is important to maintain a high air-exchange rate.

Efficiency depends on external relative humidity. The drier the air, the greater its cooling potential, as shown in the chart below.

However, the process increases internal humidity, requiring careful monitoring to avoid excessive temperature oscillations. Ideally, the system should keep the temperature close to the set-point, avoiding sudden drops and frequent fluctuations.

External ambient	Relative humidity percentage						
temperature	20%	30%	40%	50%	60%	70%	80%
20 °C	12.0	13.0	14.5	15.5	16.5	17.5	18.5
25 °C	16.0	17.0	18.5	20.0	21.0	22.0	23.0
30 °C	19.5	21.0	22.5	24.0	25.0	26.5	28.0
35 °C	23.0	25.0	26.5	28.5	30.0	31.5	32.5
40 °C	26.5	29.0	31.0	32.5	34.5	36.0	-
45 °C	29.0	32.5	35.0	-	-	-	-

The table shows the approximate lowest temperature in the house, measured next to the cooling pad, given the external temperature and %RH. Values are based on a cooling efficiency of approximately 75%, which is typical for a 15-cm-thick cooling pad.

(Table from page 17 - AviagenEssentialVentilationManagement-2019-PT)

Conclusion

Birds' capacity to keep homeothermy depends on highly integrated physiological, behavioral, and neuroendocrine mechanisms. Events such as heat stress cause high maintenance costs, and nutrients and energy that should have been meant for growth are diverted to production and improvement of the immune system. Thus, an adequate environmental control is critical to ensure the full development of the birds, promoting improved performance and feed efficiency. Understanding the physiological mechanisms involved in thermoregulation supports the importance of integrated strategies in management, environmental conditions and nutrition as essential tools for sustainability and profitability of the poultry production systems.

All in all, efficient ventilation management requires integrating an adequate structural design, well-maintained equipment, precise control and, mainly, a constant monitoring of the birds' behavior. Success depends on more than just following set numbers: it also relies upon interpreting the environmental signs and accommodating gradually, prioritizing the flock's comfort and uniformity.

REFERENCES

CHAIYABUTR, N. Physiological reactions of poultry to heat stress and methods to reduce its effects on poultry production. Thai Journal of Veterinary Medicine 2004;34(2):1730.

RANDALL, D., BURGGREN, W., FRENCH, K. Fisiologia Animal. Mecanismos e Adaptações. 4th ed. Rio de Janeiro: Guanabara-Koogan. p. 729, 200

ROCHA, C.; PIRES, P.G.S.; MAIORKA, A. Aspectos fisiológicos e de manejo para manutenção da homeostase térmica. In: Produção de frangos de corte, 2024.

VIEIRA, A.M.C., VIEIRA, F.M.C., SILVA, J.O., BARBOSA FILHO, J.A.D. The influence of thermal conditions from an environmentally controlled preslaughter lairage on mortality of broiler chickens. Arq. Bras. Med. Vet. Zootecnia, v.68, 2016.

AVIAGEN: Princípios Básicos do Manejo de Ventilação, 2019.

AVIAGEN: Manual de Manejo - Frango de Corte, 2025.

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