HEAT STRESS IN BROILERS AND THE NEED OF CLIMATIZATION SYSTEMS

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\textbf{ABSTRACT}

Broilers have better production rates when housed in thermal comfort conditions, outside of this zone the poultry need to maintain homeothermy. The heat production and thermal exchanges are related to body weight and available surface for heat exchange. The genetic evolution of broilers ensured high production with improvement in the feed conversion and reducing the slaughter time. The faster weight gain difficult sensible heat exchange, increasing the needs for climatization systems, in days with high temperatures. Changes in heat waves frequency and days with extreme temperatures are challenging situations for ventilation and evaporative cooling systems in broiler facilities. This review discusses heat exchanges of broilers and the challenges in maintaining the thermal comfort zone in poultry facilities, in a reality of increase of heat stress conditions.

\textbf{Keywords:} welfare, heat production, body surface

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\textbf{RESUMO}

Frangos de corte apresentam melhores índices produtivos quando alojados em condições de conforto térmico, fora desta faixa necessitam manter a homeoterâmia. A produção de calor e as trocas térmicas estão relacionadas com o peso corporal da ave e a área de superfície disponível para as trocas térmicas. A evolução genética do frango de corte garantiu maior produção de carne com melhor conversão alimentar e menor tempo para o abate. A evolução do ganho de peso dificultou as trocas térmicas sensíveis aumentando a necessidade de sistemas de climatização, em dias com temperaturas elevadas. Estimativas para mudanças na frequência de ondas de calor e dias com temperaturas extremas são situações de desafio para os sistemas de ventilação e resfriamento evaporativo de aviários. Esta revisão discute as trocas térmicas de frangos de corte e os desafios em manter a zona de conforto térmico nas edificações em uma realidade de aumento de condições causadoras de estresse por calor.

\textbf{Palavras-chave:} bem estar, produção de calor, superfície corporal

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INTRODUCTION

Genetic selection allowed advances in poultry production with the growth rate of broilers from 1957 to 2005 increased 400%, with a simultaneous improvement of 50% in feed conversion (ZUIDHOF et al., 2014). On the other hand, the genetic improvement worsened the resistance of birds to heat stress. The Red Jungle Fowl (RJF) and Village Fowl (VF) were compared with the commercial broilers with the same weights (930 ± 15 g) and submitted to heat stress at 36 ± 1 °C for 3h. The RJF show lower heterophile: lymphocyte ratio, higher plasma corticosterone concentration, and higher heat shock protein 70 expression than VF and commercial broiler (SOLEIMANI et al., 2011; GU et al., 2012). Aggravating this condition, the actual heavier broilers are more susceptible to heat stress increasing the mortality and render more dependent of poultry facilities (VALE et al., 2010).

Poultry heat exchange to the environment depending on the temperature gradient, and may receive or lose thermal energy from environment, through sensible and latent heat exchanges. It represents that in hot environments is necessary to control productive losses due to environment influence and climate changes (NÓBREGA et al., 2011). At regions where high temperatures predominate during most of the year, the control of facility in the internal environment is fundamental to reach thermal comfort zones and improve productive indexes.

The models of climate projections indicate changes in global mean temperature and an increase in high temperatures in the coming years (KNUTTI & SEDLÁČEK, 2013). Global warming predictions increase the risk of exposure to heat stress, requiring more efficiency to maintain thermal comfort conditions inside the facilities (MENDONÇA, 2006).

This review discusses broilers thermal changes and the challenges to maintaining thermal comfort zone in a reality of increasing risk of heat stress conditions.

Thermal comfort zone and productive performance

The temperature range in which broilers have the best growth rate is defined as a thermal comfort zone. Out this condition, poultry need spend energy to maintain the homeothermy in detriment of productive performance, reduce protein deposition (OLIVEIRA et al., 2006). Conditions close the thermal comfort zone minimize the energy used for physiological adjustments to the thermoregulation and increasing the energy availability for protein synthesis and deposition (SAKOMURA et al., 2005; CARVALHO FILHO et al., 2006; OLIVEIRA et al., 2006). Temperature of 36 °C affects corticosterone levels and heterophile: lymphocyte ratio, acute stress indicators in poultry, increase the release of lactate dehydrogenase, an indicator of organ or tissue injury, and cause oxidative stress by oxygen free radicals in broilers (GU et al., 2012). In heat stress conditions the increase in plasma corticosterone changes the protein turnover, increasing the rate of degradation (catabolism) of the muscle protein, with a consequent increase in heat production due to nitrogen excretion of degraded proteins and worsening in the growth of broilers (QUINTEIRO FILHO et al., 2010). Temperature of 38 °C increase in the production of blood free radicals due to red cell oxidation (ALTAN...
et al., 2003), acute heat stress at 32 °C for six hours increases body temperature and induces metabolic alterations and oxidative stress (LIN et al., 2006).

The poultry metabolic body heat can be estimated from body weight (Eq. 1), and more weight promotes more heat production (SALLVIK, 1999). As poultry are homeothermic, with higher heat production, more heat needed to be exchanged with the environment in order to maintain body temperature.

\[ \Phi_{\text{tot}} = m^{0.75} \]  

where:
- \( \Phi_{\text{tot}} \) - Heat production in Watts;
- \( m \) - Poultry weight in Kg.

**Heat exchanges**

Poultry body temperature is related with ambient temperature, the birds can receive or lose energy through changes in the behavioral and physiological process, which involves sensible and latent heat exchanges (BORGES et al., 2003; WELKER et al., 2008; NÄÄS et al., 2010).

The sensible heat changes depend on the temperature gradient between the body surface and the ambient temperature, occurring by conduction, convection and, radiation. With a greater body contact area, more efficient the heat changes to the environment. The surface area of broilers as a function of body mass can be estimated from a non-invasive empirical equation (Eq. 2; SILVA et al., 2009).

\[ Sa = 3.86 \pm 1.06 Bm^{0.74 \pm 0.01} \]  

where:
- \( Sa \) – Superficial area in cm²;
- \( Bm \) – Body mass in g.

The skin surface has a flat distribution while the weight and the body mass have a three-dimensional distribution. As poultry weight gain the produced heat increase, and the surface area for heat exchange is smaller in relation to body volume. From the study of ZUIDHOF et al. (2014) and the application of the equation of SALLVIK (1999; Eq. 1) and SILVA et al. (2009; Eq. 2), is possible to verify that, with genetic selection, broilers gained more weight per time unit, generating more heat and reducing the exchange surface area available to dissipate heat (Figure 1).

![Figure 1. Estimative of total body heat production in Watt per cm² of body surface in broilers lineages from 1957, 1978 and, 2005 at 56 days of age (ZUIDHOF et al., 2014; SALLVIK, 1999; and SILVA et al., 2009)](attachment)

The Watt ratio produced by body area varies less in the poorly improved birds (lineage of 1957, Figure 1) which depend less on the cooling conditions of
housing environment compared to 2005 broilers.

At 30 days of age, the broiler completes feathering, difficult heat changes due to greater insulation in feathered areas (CANGAR et al., 2008; NÄÄS et al., 2010), requiring expansion of latent heat exchanges in heat stress conditions.

At high temperatures, above 35 °C, the principal means of broilers dissipate heat is evaporation (SANTOS et al., 2009). The poultry efficiency to lose latent heat decreases with the increase in air relative humidity, independent of environment temperature, and the exchanges can be zero in environments with 90% air relative humidity and temperatures of 30 to 35 °C (GENÇ & PORTIER, 2005).

Temperature and Humidity Index (THI) is a comfort index that can express animal wellbeing relate to temperature and air relative humidity. The THI, proposed by Chepete et al. (2005), considers comfort changes with broilers age, in two periods. The first corresponds to an equation from three to four weeks of age (Eq. 3) and the second, an equation from five to six weeks (Eq. 4).

\[
\text{THI}_{3-4s} = 0.62T_{db} + 0.38T_{wb} \quad (3)
\]

\[
\text{THI}_{5-6s} = 0.71T_{db} + 0.29T_{wb} \quad (4)
\]

where:
- \(T_{db}\) - Dry bulb temperature (°C);
- \(T_{wb}\) - Wet bulb temperature (°C);

There is a reduction of 38 to 29% in the THI equation of wet bulb temperature participation in the broiler comfort between three to four and five to six weeks of age, respectively (CHEPETE et al. 2005). This represents more difficulty of latent exchange heat and, more participation of dry bulb temperature in broilers comfort.

In large poultry flocks, mortality is an important indicator of heat impact. The mean THI higher than 23 °C increases mortality in broilers with more than 28 days housed in facilities without climatization system (VALE et al., 2008). In facilities with minimum climatization system (ventilation and nebulization), need more severe environment condition, with THI above 30.6 °C. A minimum climatization system allows a better comfort of broilers and, in this system, the external maximum temperatures should less than 34.4 °C of THI to avoid high mortality in broilers between 30 and 40 days of age (VALE et al. 2010). The values of mentioned studies are important because refer values measured in meteorological stations between one to 45 km near the broilers farms indicating the possibility to monitor flock by meteorological forecasting.

Temperature reduction potential

Poultry production facilities were physically adapted, especially in hot places. Characteristics such geographic location, roof type, outside roof color, tree shading, and others, influence the thermal insulation, given more independency of external conditions (ALVES et al., 2004; LIMA et al., 2009; SARMENTO et al., 2005).

In poultry houses with adequate thermal insulation, air renewal is more required on days with outside temperature above broiler comfort, necessary to maintain air quality, control temperature and, increase convection heat loss (CURI et al., 2014). The entrance of hot air into poultry facility, above broilers comfort temperature, requires evaporative cooling systems combined with positive or negative mechanical ventilation systems.

Positive ventilation and cooling systems in poultry facilities aggregate axial ventilators and nebulizers (WELKER et al., 2008). In negative pressure ventilation systems air enters at one extreme with evaporative panels and exits at the opposite side through exhaust fans. Negative pressure systems are more efficient in
The temperature reduction potential (TRP) of an evaporative system is measured by efficiency in approaching dry bulb temperature \((T_{db})\) to wet bulb temperature \((T_{wb})\). \(T_{wb}\) is lower or equal to \(T_{db}\), due to the transfer of heat, which occurs by the change of water's physical state, requiring 600 calories to convert 1 g of water to water vapor at 0 °C or, 540 calories at 100 °C per g of evaporated water.

The difference between \(T_{wb}\) and \(T_{db}\) is defined as wet bulb depression (WBD), equivalent to the total potential (100%) that an evaporative cooling system can reduce the temperature. The TRP calculation of evaporative panels allows estimating the efficiencies of adiabatic evaporative cooling systems in percentage by equation 5 (DAG˘TEKIN et al., 2009)

\[
TRP = \frac{(T_{db}e - T_{db}l)}{(T_{db}e - T_{wb}e)} \times 100 \quad (5)
\]

where:
- \(T_{db}e\) - dry bulb temperature entering the panel;
- \(T_{db}l\) - dry bulb temperature leaving the panel;
- \(T_{wb}e\) - wet bulb temperature that enters the panel.

This equation makes possible estimate the vulnerability of a cooling system in face of climatological normals and weather forecasts. Are few knowledge about cooling systems behavior in commercial broiler facilities in extreme heat conditions.

The vulnerability of older broilers to heat stress is high in most tropical and intertropical areas in most of the year, aggravated by estimates for changes in the frequency of heat waves (IPCC, 2007; COUMOU et al., 2013), which will require more evaporative cooling systems.

Heat waves are uncomfortable and excessively hot periods, at least two days with maximum temperature above 32 °C, and may last several days or weeks (INMET, 2017). For broilers, successive days with THI greater than 23 °C already trigger high mortality (VALE et al., 2008), however, a single day with facility inside temperature higher than 32 °C is sufficient to cause high mortality (VALE et al., 2010).

Among the 16 hottest years since 1880, 15 of these have occurred since 2001, being the hottest in 2015. Projections for the 21st century increase occurrence of heat waves (NOAA / NASA, 2016). The temporal persistence of high temperatures in warmer regions raise up the frequency of extreme temperatures, reflecting on high mortality risk (SALGADO & NÁÅS, 2010).

Climate changes, in most part, can occur during the winter and transition seasons tending to warmer nights, raising the minimum temperatures, with a high risk of heat waves (MARENGO & VALVERDE, 2007). Poultry better adapts to daily high maximum temperatures when the temperature in the night falls at 25 °C or lower. With warmer nights recovery are slower and the next extreme temperature day may a great risk (BALNAVE, 1998).

The dynamics of the typologies and thermal inertia of broilers facility options should be studied and allow a better understanding of thermal insulation, with evaporative cooling systems.

**FINAL CONSIDERATIONS**

The evolution in poultry production guaranteed higher weight gains, however, difficult sensible heat changes requiring better environmental conditions in poultry facilities.

The principal means to control the temperature in poultry houses are ventilation and evaporative cooling systems, with limitations dependent on air relative humidity.
It will be necessary more efficient climatization systems due to the increase in heat waves incidence.

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