Ventilation, a major but a paradoxal environmental parameter in broilers and turkeys development

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Abstract

Recent decades have seen significant progress in the genetic selection of fast-growing meat-type broiler chickens and turkeys. However, fast growth has coincided with inferior development of the visceral systems, contributing to difficulties in coping with heat stress. This situation, where growth rate (heat production) improves on a yearly basis demands an efficient means to economically improve the acquisition of thermotolerance by the fowls in hot climates. It is important to understand the physical aspects of poultry excess heat dissipation in relation with the improvement of thermotolerance. This paper focuses on air velocity as a principal parameter which dramatically affects sensible heat loss and its contribution to the ability of acclimated poultry to efficiently maintain a favorable energy balance under hot conditions. The reviewed studies in this paper demonstrate that: a. air velocity plays a major role in the broiler's energy balance under high ambient temperatures; b. the optimal air velocity for achieving maximal growth performance differs at different ambient temperature and has a turning point at ambient temperature below 30°C, where chilling affects the broiler; c. air velocity affects turkey's performance; d. genetic selection for growth performance has been to some extent at the expense of the broiler's ability to maintain favorable energy balance.

Introduction

Recent decades have seen significant progress in the genetic selection of fast-growing meat-type broiler chickens and turkeys. The improved growth rate of broilers was documented by Havenstein *et al.*, (1994, 2003a). However, fast growth has coincided with inferior development of the visceral systems as the cardiovascular and respiratory one (Havenstein *et al.*, 2003b), which contributes to the difficulties that broilers have in coping with heat stress.

Birds are homeotherms, i.e., they are able to maintain their body temperature (T_b) within a narrow range. An increase in T_b above the regulated range, as a result of exposure to heat stress and/or the metabolic heat production from rapid growth, may initiate an irreversible chain of thermoregulatory events that can be lethal.

Acclimation is one of the mechanisms enable hometoerms to confront successfully the environment. Acclimation has been defined as a physiological response that reduces strain or enhances endurance of strain caused by climatic factors applied experimentally (acclimation) or naturally (acclimatization) (IUPS Thermal Commission, 2001). During acclimation the thermoregulatory threshold response for heat production and/or heat dissipation is altered, and may reflect both production and dissipation (Yahav, 2000).

In birds, heat is dissipated through respiratory-evaporative mechanisms (Richards, 1968, 1970, 1976; Seymour, 1972; Marder and Arad, 1989), an evaporative cutaneous mechanism (Webster and King, 1987; Ophir et al., 2002) and sensible heat loss via radiation and convection. Evaporative heat loss via panting is associated with body water content and therefore dehydration will reduce heat loss via this pathway. An increase in sensible heat loss may, however, contribute to better thermotolerance acquisition at high T_as.

Sensible heat loss

The driving force for sensible heat loss by convection and radiation is the difference between the surface and ambient temperatures. The heat flux by convection, q_c, depends on the temperature difference between body and air, *ΔT*, the area of contact, *A*, and the heat transfer coefficient, *h*. Thus,

$$q_c = hA\Delta T\ .$$

The average heat transfer coefficient, *h*, depends on the geometry of the body, the physical properties of the air and the flow regime. The major difficulty in calculating q_c stems from the strong dependence of *h* on the flow regime.

The heat flux by radiation is estimated as:

$$q_r = \varepsilon_1 \sigma A_1 (T_1^4 - T_2^4)$$

where subscript *r* stands for radiation, indices 1 and 2 represent, respectively, the body surface and the environment, ε (=0.96) is the emmisivity of a biological tissue, σ is the Stefan-Boltzmann constant (= 5.669×10^{-8} W/m^{2}K^4), *A* is the surface area and *T* is the absolute temperature.

To calculate heat transfer from the fowl, each part of the surface is represented by a corresponding geometrical shape. For each part radiative and convective heat transfers are estimated using available and specially developed heat transfer relationships (Yahav et al., 2005).

The adoption of the thermal-imaging radiometry technology in poultry sciences (Yahav et al., 1998, 2004, 2005) has enabled accurate measurement of the body surface temperature, and determination of the contribution of sensible heat loss to body energy balance.

It has been assumed that sensible heat loss does not play an important role in the domestic fowl when T_a is above the upper limit of the thermoneutral zone (for review see Hillman et al., 1985). This was based on: a. the small temperature differences between the body surface (T_s) and T_a; and b. the reasoning that since in fully feathered birds only limited areas are unfeathered (ie. legs, head, wattle and comb). Therefore, convection at high ambient temperatures could be neglected (Tzschentke *et al.,* 1996). However, this paper demonstrated the importance of convection at high T_a's.

Air velocity dramatically affects body weight of broiler chickens exposed to different environments. Exposing broilers to 35°C and air velocity range from 0.8 to 3.0 m/sec exhibited a bell shaped response of body weight to air velocity, with maximum response at 2.0 m s^{-1} (Table 1). Broilers exposed to air velocity of 2.0 m s^{-1} exhibited significantly higher body weight and feed intake in comparison to broilers exposed to lower air velocity (0.8 and 1.5 m s^{-1}) (Yahav et al., 2004). It seems however, that at different high ambient temperatures, different air velocities will lead to maximal performance. Exposing broilers to 30°C and air velocities ranging from 0.8 to 2.5 m/sec at 3 to 5 weeks of age resulted in maximal body weight at 2.5 m/sec (Table 1). This coincided with significantly higher feed intake and the highest feed efficiency (Yahav et al., 2005). Whereas exposing broilers to 25°C resulted in maximal body weight at the lowest air velocity, 0.8 m/sec.

These results suggest a turning point in the performance response of broiler chickens to ventilation. This turning point is below 30°C, where increased air velocity probably caused chilling effect, which led to increased maintenance energy expenditure and reduced growth performance. It can further be speculated that at low ambient temperature even low air velocity may negatively affect the ability of the broilers to balance their energy losses.

In the experiment where broilers were subjected to 35^{o}C, heat loss by radiation and convection was calculated (For details see: Yahav et al., 2004). In this study, although heat loss by radiation did not differ among treatments, heat loss by convection increased significantly and linearly with increasing air velocity (Table 2). These results demonstrated for the first time that sensible heat loss can reach an average of 45% of the energy expended on maintenance, and therefore, plays a major role in the broiler's energy balance.

Table 1: The effect of air velocity on broiler chickens body weight while exposed to 35, 30 and 25°C at the age of 7, 5 and 6 weeks (wk), respectively, and to optimal relative humidity.

Variables	Air velocity (m s^{-1})			
	0.8	1.5	2.0	3.0
Body weight (g/ 7 wk; exposure to 35°C)	1878±54^{c}	2071±91^{b}	2308±39^{a}	2164±61^{ab}
	0.8	1.5	2.0	2.5
Body weight (g/ 5 wk; exposure to 30°C)	1749±24^{b}	1777±22^{ab}	1789±21^{ab}	1845±21^{a}
Body weight (g/ 6 wk; exposure to 25°C)	2507±29^{a}	2407±33^{b}	2489±31^{ab}	2417±28^{b}

In rows, values designated by different letters differ significantly ($P \leq 0.05$). n=4 replicates of 15 birds each.

The effort to control energy balance directs a large amount of energy towards maintenance in broilers exposed to the optimal air velocity (Figure 1). It was expected, however, that thermally unbalanced broilers, such as those exposed to low air velocities of 0.5 to 1.0 m/s, [demonstrating T_b of 43.9 °C; Yahav et al., 2004)] would expend even more energy in controlling their body temperature, especially when energy consumption was lower

Table 2: Heat loss (in watts) by radiation (Qr), convection (Qc), total heat loss (Qt) and Qt as a percentage of energy expended for maintenance (Qt %) in broiler chickens exposed to high ambient temperature (35°C) and 60% relative humidity. (According to Yahav et al., 2005).

Variables	**Air velocity (m/sec)**			
	0.8	**1.5**	**2.0**	**3.0**
Qr (watt)	1.05±0.09	1.11±0.22	1.33±0.13	1.32±0.11
Qc (watt)	2.32±0.16^{d}	3.26±0.41^{c}	4.37±0.30^{b}	5.52±0.29^{a}
Qt (watt)	3.37±0.43^{b}	4.37±0.46^{b}	5.69±0.43^{a}	6.83±0.42^{a}
Qt %	29.1±3.74^{b}	29.1±4.44^{b}	36.8±2.22^{ab}	44.7±4.75^{a}

In rows, values designated by different letters, differ significantly ($P \leq 0.05$; n = 8).

under these conditions (Yahav et al., 2001, 2004). However, the results obtained suggest an opposite response, namely a decline in the amount of energy directed for maintenance needs in chickens that exhibit difficulties controlling body temperature (Figure 1).

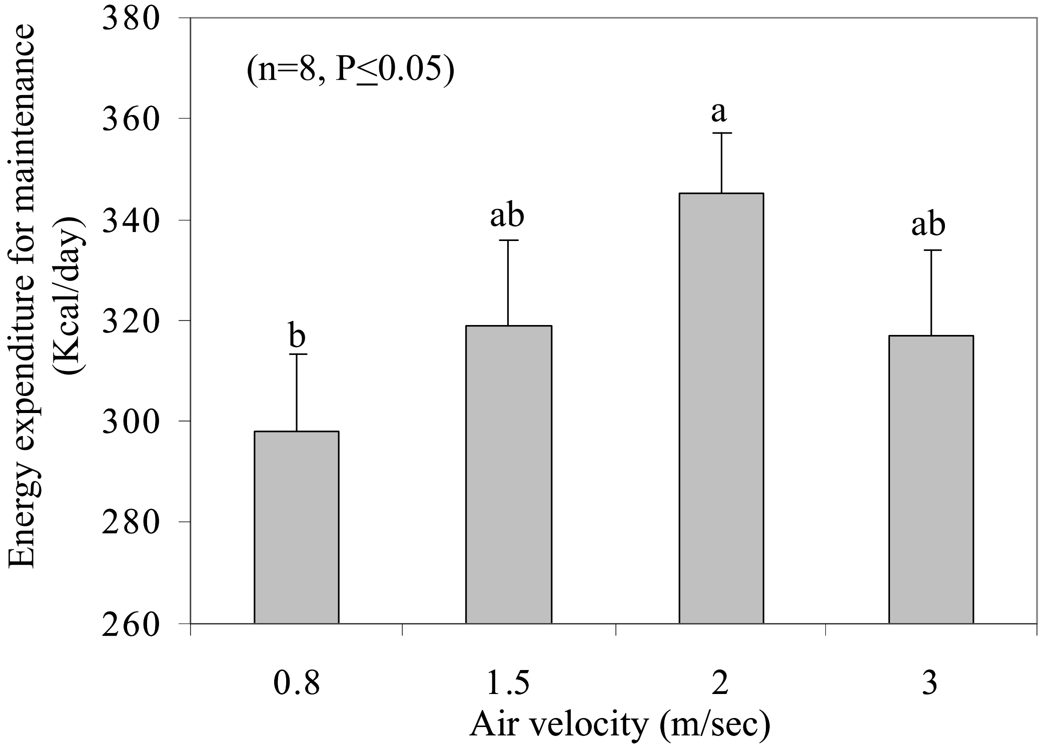

Figure 1: The effect of air velocity on energy expended for maintenance in broiler chickens exposed to 35°C and 60% RH. Columns with different letters differ significantly ($P \leq 0.05$). (According to Yahav et al., 2004, 2005).

One of the open questions raised during the research was: do turkeys, at similar ages as broilers (i.e up to 6 weeks), would respond in a similar manner to different air velocities. Male turkeys at the age of 3 weeks were exposed gradually (during one week) to the following environmental conditions: ambient temperature of 35°C; 50% RH; and air velocity of 0.8, 1.5, 2.0 and 3.0 m/sec. Thereafter, turkeys were raised under those conditions up to 6 weeks of age.

Table 3 summarized the effect of the environmental conditions on turkeys. Air velocity affect performance of turkeys aged 3 to 6 weeks. 2.0 m/second was demonstrated as the optimal one to reach the highest body weight. This was coincided with similar trend in feed intake and with significantly lower T_b. These results were found to be similar to that obtained for broiler chickens.

It can be concluded that air velocity plays a major role in broilers and turkeys. The optimal air velocity for achieving maximal growth performance differs with ambient temperature and possibly the poultry's age, and has a turning point (in chickens) at ambient temperature below 30°C, where chilling affects the broiler.

Table 3: The effect of different air velocities on performance parameters of male turkeys exposed to constant 35°C, and 50% rh from 3 to 6 weeks of age.

Variables	**Air velocity (m/sec)**			
	0.8	**1.5**	**2.0**	**3.0**
Body weight (g/ 42 days)	2556 ± 35^{b}	2666 ± 38^{a}	2692 ± 36^{a}	2612 ± 40^{ab}
Feed intake (g/ 21-42 days)	2856 ± 41^{b}	2948 ± 61^{ab}	3043 ± 81^{a}	2873 ± 27^{ab}
Feed efficiency (g/g)	0.621 ± 0.008	0.635 ± 0.002	0.625 ± 0.005	0.633 ± 0.006

In rows, values designated by different letters, differ significantly ($P\leq0.05$). n = 4 replicates of 15 birds, each.

The main conclusion is: Under each and every environmental condition a specific ventilation fine tuning must be elaborated. It will be based on the age of the chicken, the density of the flock and the ambient conditions: T_a, RH, ammonia, dust ect.

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