PHYSIOLOGY, ENDOCRINOLOGY, AND REPRODUCTION

Acid-Base Balance of the Domestic Turkey During Thermal Panting[1,2]

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ABSTRACT The objectives of this research were to evaluate the effects of thermal panting in domestic turkeys on arterial blood values for the acid-base variables, pH_a, bicarbonate concentration ($[HCO_3^-]_a$), partial pressure of carbon dioxide (P_aCO_2), and hemoglobin concentration [Hb]. In addition, body temperature and partial pressure of oxygen (P_aO_2) were measured to determine the effectiveness of panting in their control. Nine adult (23 wk) broad-breasted white turkey toms, all from the same hatch and reared contemporaneously in the same facility, were acclimated to room conditions of 19°C and 65% RH. After a 1-wk control period, a 3-wk heat-stress period (32°C, 65% RH) was induced, for a heat-stress group of 9 turkeys. Thermal panting began at this time and continued to its end. A 1-wk recovery period followed (19°C, 65% RH) during which panting ceased. An age-matched group of 8 turkeys was similarly acclimated (19°C, 65% RH) but was continued at this level to the end of the experiment. During the heat-stress period, the bicarbonate concentration increased, whereas pH_a and P_aCO_2 did not change significantly. Body temperature changes were not significant. Parabronchial ventilation was not compromised by panting, as noted by a significant increase in P_aO_2. Hemoglobin concentration decreases were significant. The only significant change that occurred for the age-matched group was an increase in [Hb]. Domestic turkeys, reared in confinement, have the ability to resist changes in blood pH and prevent the development of respiratory alkalosis while panting in response to thermal stress. Normal body temperature and oxygenation of the blood are also maintained.

Key words: turkey, thermal panting, acid-base balance

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INTRODUCTION

Thermal panting occurs in most birds during times of high ambient temperatures as a means of reducing body temperature by respiratory evaporative cooling (Marder and Arad, 1989). During heat stress in birds, respiratory frequency markedly increases while tidal volume decreases, the net effect being a 6- to 7-fold increase in minute ventilation (Ludders, 2004). In some birds, a large increase in minute ventilation results in a change in arterial blood gases and pH, and in others it does not (Frumkin et al., 1986; Marder and Arad, 1989). To combat disturbances of pH, there are 3 basic mechanisms: chemical buffering, respiratory adjustment of blood carbon dioxide concentration ($\mathbf{P_aCO_2}$), and excretion of hydrogen or bicarbonate ions by the kidneys (Houpt, 2004).

There is a tendency for hyperpnea and panting in mammals to increase alveolar ventilation as well as that of the dead space and subsequently decrease P_aCO_2, whereby respiratory alkalosis (increased pH, decreased bicarbonate) can develop (Houpt, 2004). Unlike mammals, birds have a unique group of peripheral receptors called intrapulmonary chemoreceptors (Burger et al., 1974). They are located in the parabronchi of the lung and are acutely sensitive to carbon dioxide of lung gas and insensitive to ambient hypoxia. They affect the rate and volume of breathing on a breath-to-breath basis by acting as the afferent limb of an inspiratory-inhibitory reflex. As PCO_2 in the lung gas decreases, the receptors become stimulated and increase their rate of discharge. As the rate of discharge increases, ventilation decreases. Because of the breath-to-breath control, P_aCO_2 remains constant.

Inasmuch as birds vary in their ability to resist changes in arterial blood gases and pH associated with large increases in minute ventilation, it has been suggested that there may be differences in carbon dioxide responsiveness of intrapulmonary chemoreceptors depending on the ecological niche occupied by a particular species (Ludders, 2004). The ecological niche of domestic turkeys relates to their production in confinement. Accordingly, it is not

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known if acid-base balance is maintained when panting occurs due to thermal stress.

The objectives of this research were to evaluate the effects of thermal panting in domestic turkeys on arterial blood values for the acid-base variables, pH_a, P_aCO_2, bicarbonate concentration ($[HCO_3^-]_a$), and hemoglobin concentration **[Hb]** to determine if respiratory alkalosis develops. In addition, body temperature and arterial partial pressure of oxygen (P_aO_2) were measured to determine the effectiveness of panting in their control.

MATERIALS AND METHODS

Seventeen adult (23 wk) broad-breasted white turkey toms, all from the same hatch and reared contemporaneously in the same facility, were randomly separated into an age-matched group (8 turkeys) and a heat-stress group (9 turkeys). These groups were placed into separate rooms for acclimation, where the temperature and RH were maintained at 19°C and 65%, respectively, for a 2-wk conditioning period. This period was required for acclimation as recommended by Marder and Arad (1989). Consistent with industry standards, each turkey was provided with a floor space of 1.535 m^2, a minimum feeder space of 3.8 cm, and a minimum watering space of 11.4 cm (Berg and Halvorson, 1985).

Sawdust bedding was provided for each room. Bedding was replenished as needed throughout the course of the experiment but not changed. Diet consisted of a commercial formula for adult production turkeys and was made available free choice. Artificial lighting, controlled by a time clock, provided 12 h of reduced night lighting and 12 h of day lighting.

Heat-Stress Group

A control period began (d 1) after the 2-wk conditioning period. Room temperature and RH were maintained at 19°C and 65% RH, respectively, until d 6. On d 6, the room temperature was increased 2°C every hour until a temperature of 32°C was achieved. Relative humidity was continued at 65%. Room temperature and RH at these levels are sufficient to cause thermal panting in the domestic turkey (Anderson, 1991). Day seven was the first day of the heat-stress period, and the established temperature and humidity (32°C, 65% RH) were maintained until the end of the heat-stress period on d 21. All turkeys in this group continued thermal panting throughout the heat-stress period. On d 22, the room temperature was decreased by increments of 2°C every hour until the control period temperature of 19°C and 65% RH were achieved and maintained for a 1-wk recovery period. The recovery period ended on d 28.

Arterial and venous blood samples from each turkey in the heat-stress group were obtained on d 1, 7, 14, 21, and 28. Samples collected on d 1 were the baseline control samples. Samples collected on d 7, 14, and 21 were heat-stress period samples, and those collected on d 28 were recovery period samples.

Age-Matched Group

This group was established to account for physiologic changes that may be associated with increasing age. The turkeys selected for this group (8) were placed in a room similar to that provided for the heat-stress group. The room temperature of 19°C and 65% RH maintained for the 2-wk conditioning period was extended throughout the remaining 4 wk of the experiment. Arterial and venous blood samples were collected from each turkey on d 1 and 28 to determine if pH, blood gas values, and [Hb] changed across time. Body temperature was also determined at these times.

Blood Sampling Procedure

Fifteen minutes prior to blood sampling, the lights were dimmed (0.42 lx). Individual turkeys were then removed from the population and positioned for blood collection. They were placed in lateral recumbency, their feet bound with Velcro straps, and heads covered with a cotton drape. Because of the dim light, the turkeys remained calm and did not resist manipulation. Blood samples were collected into heparinized syringes from the ulnar artery and vein ("wing vein") with a 25 g 1.27 cm hypodermic needle. The arterial samples were placed on ice until blood gas analysis was performed. The venous samples remained at room temperature until [Hb] was determined.

Body Temperature Measurement

Body temperature was determined just prior to each blood sampling with a digital electronic thermometer while the turkey was in lateral recumbency. The probe of the thermometer was placed into the colon of each turkey until the temperature readout indicated that a stable measurement had been obtained.

Blood Sample Analysis

Venous samples were used for determining [Hb] by the cyanmethemoglobin method. Modification for avian blood required centrifugation and removal of red blood cell nuclei remaining in suspension after cell lysis so that a clear supernatant could be used for spectrophotometry.

Arterial samples were analyzed for pH and blood-gas values within 1 h of collection with a pH-blood-gas analyzer (model 1306, Instrumentation Laboratories Company, Lexington, MA). After thorough mixing, a 90-μL sample was placed into the analyzer after it had been adjusted for the body temperature and hemoglobin concentration of each turkey. The pH-blood-gas analyzer measures pH_a, P_aCO_2, and P_aO_2. The $[HCO_3^-]_a$ was calculated from the Henderson-Hasselbalch equation using pH_a and P_aCO_2 values.

Statistical Analysis

The data collected were statistically analyzed using the GLM procedure (GLM) of SAS software (SAS Institute,

Table 1. Means (±SD) for pH, blood gases, bicarbonate, hemoglobin, and body temperature for heat-stress group[1] and age control group[2]

	Control period		Heat-stress group			Recovery period	
Variable[3]	Day 1		Day 7	Day 14	Day 21	Day 28	
pH_a	7.333 ± 0.045	(7.352 ± 0.040)	7.385 ± 0.040[a]	7.376 ± 0.070	7.355 ± 0.060	7.340 ± 0.051	(7.344 ± 0.044)
P_aCO_2 (mm Hg)	46.63 ± 4.73	(47.53 ± 2.56)	43.59 ± 4.65	11.24 ± 6.42	46.98 ± 6.48	52.61 ± 5.62[a]	(47.05 ± 4.67)
$[HCO_3^-]_a$ (mEq/L)	23.76 ± 1.29	(25.61 ± 2.39)	25.27 ± 2.23[a]	24.92 ± 1.28[a]	25.28 ± 0.89[a]	27.60 ± 1.40[1]	(24.80 ± 1.50)
P_aO_2 (mmHg)	88.44 ± 7.13	(93.38 ± 5.63)	95.11 ± 4.57[a]	93.89 ± 7.67[a]	89.89 ± 5.44	78.00 ± 9.04[a]	(95.25 ± 7.13)
[Hb] (g/dL)	12.50 ± 1.10	(12.03 ± 0.77)	11.77 ± 0.95	10.83 ± 0.44[a]	11.24 ± 0.62[a]	11.96 ± 1.42	(13.13 ± 0.94[a])
Temperature (°C)	41.29 ± 0.43	(41.05 ± 0.36)	41.69 ± 0.28[a]	41.26 ± 0.38	41.42 ± 0.32	41.03 ± 0.30	(41.21 ± 0.30)

[a]Means within rows differ significantly from their respective control period value ($P \leq 0.05$).

[1]n = 9 for each mean; values shown for d 1, 7, 14, 21, and 28.

[2]n = 8 for each mean; values are in parentheses; shown for d 1 and 28.

[3]pH_a = arterial blood pH; P_aCO_2 = arterial blood partial pressure for carbon dioxide. $[HCO_3^-]_a$ = arterial blood bicarbonate concentration; P_aO_2 = arterial blood partial pressure for oxygen; [Hb] = hemoglobin concentration.

1999). To compare mean outcomes across time, turkeys were included in the ANOVA as a random blocking factor. Separate ANOVA were computed for the heat-stressed group and the age-matched group. The same probability level ($P \leq 0.05$) has been used throughout the manuscript.

RESULTS AND DISCUSSION

Means and their significance for each of the sampling periods when compared with the control period are presented in Table 1 for pH_a, P_aCO_2, $[HCO_3^-]_a$, P_aO_2, [Hb], and body temperature for the heat-stress and age-control groups. For the heat-stress group, during the heat-stress and recovery periods, significant changes were noted for pH_a, $[HCO_3^-]_a$, P_aO_2, [Hb], and body temperature at one or more of the sampling days. The significant change for pH_a only occurred on d 7, and no significant changes occurred thereafter. The only significant change in P_aCO_2 occurred during the recovery period.

The P_aCO_2, $[HCO_3^-]_a$, and [HB] are the variables measured that determine the pH of the extracellular fluid (**ECF**). The pH of the ECF is one of the most vigorously regulated variables of the body (Houpt, 2004), and as measured by pH_a, it was maintained after d 7. The only significant change in P_aCO_2 occurred during the recovery period. If the loss of CO_2 from the parabronchi exceeds its rate of production, respiratory alkalosis may develop. This is characterized by low P_aCO_2 and alkalemia, a pH value above normal (Houpt, 2004). Accordingly, respiratory alkalosis did not develop during the heat-stress period.

Increases in $[HCO_3^-]_a$ were significant for all sampling days. The bicarbonate buffer system is the principal buffer of the blood and of the ECF. Bicarbonate is reabsorbed or excreted by the kidneys and assists in maintenance of ECF pH by the following mechanism. Carbon dioxide, whether formed from cellular metabolism or its presence in the blood, is hydrated to form hydrogen ions and bicarbonate ions in the renal tubular epithelial cells. The hydrogen ions are secreted into the tubular fluid, whereas the bicarbonate is maintained by a simultaneous movement of tubular sodium ions into the cells in exchange for hydrogen ions and further movement of sodium into the blood with bicarbonate ions. A reduction in hydrogen ion formation would result in excretion of bicarbonate ions (Houpt, 2004). In this study, bicarbonate ions were reabsorbed, rather than excreted, to assist with maintenance of pH.

During the heat-stress period, increases for P_aO_2 and decreases for [Hb] were significant on d 7 and 14 for P_aO_2 and d 14 and 21 for [Hb]. Hemoglobin is the principal component of erythrocytes and functions not only as an important acid-base buffer for blood but also transports oxygen. The stimulus for erythrocyte production is erythropoietin secreted when there is a tissue need for oxygen (Reece and Swenson, 2004). The increased P_aO_2 values on d 7 and 14 indicate that oxygenation of the blood was maintained during thermal panting, and a decrease in [Hb] followed on d 14 and 21.

A significant increase in body temperature occurred on d 7. Body temperature was maintained on the other sampling days. At the end of the recovery period (d 28), significant changes for the heat-stress group occurred for P_aCO_2, $[HCO_3^-]_a$, and P_aO_2. Recovery to control period values was not complete.

Differences between the mean values of measurements obtained on d 1 and 28 for the age-matched groups are shown in Table 1. Only the increased value for [Hb] on d 28 was significant. This is consistent with another study where it was shown that packed cell volume increases with age in growing turkeys (Reece et al., 2000).

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