

Respiratory functions and adaptation: an investigation on farm animals bred in tropical environment

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Abstract: To better understand the physiology responses in adapted breed to tropical environment this study evaluated the relationship between responses of adaptation and respiratory functions in ruminants raised in the tropics. Five trials were conducted for different species/breeds (five Nellore beef cattle, 10 Guzerat beef cattle, nine Anglo Nubian goats, 12 Jersey dairy cows, and 12 Morada Nova sheep). An indirect calorimetry system was used with a facial mask adjusted on the muzzle of the animal. Metabolic heat production (q_{met} , W kg⁻¹), respiratory rate (RR, breaths min⁻¹), ventilation (VE, L min⁻¹), tidal volume (VT, L breath⁻¹), CO₂ production (VCO₂, L h⁻¹ animal⁻¹), and O₂ consumption (VO₂, L h⁻¹ animal⁻¹) were measured simultaneously. Environmental data, including air temperature, relative humidity, and solar radiation were recorded from each site. Tidal volume values of 0.01, 0.008, 0.0075, 0.007, and 0.004 L breath⁻¹ kg⁻¹ were found for Morada Nova sheep, Anglo Nubian goats, and Jersey, Guzerat, and Nellore cattle, respectively, indicating that tidal volume per unit weight decreased with body weight wherever Morada Nova Sheep present a higher VO₂ consumption per unit of weight. Indeed, all the tropical breeding present a lower respiratory rate consequentially an indication of some adaptation.

Keywords: Nellore, respiratory rate, spirometry

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Introduction

Understanding the thermal exchanges in the respiratory system between the animal and its environment has been the focus of several studies (Maia et al 2005). Comprehend this dynamic in livestock within their natural environment, without controlling the weather changes throughout the day is of great importance in studies of thermoregulation and heat balance and described the adaptation to hot climate and strategies to alleviate heat stress in livestock production.

Studies about respiratory physiology have the principles to explain many biological processes, including ventilation, gas exchange and the dissipation of heat and mass, they see being discussed in research in veterinary medicine and the application of thermodynamic processes (Krog, 1916; Ferrannini, 1988; Diener, 1997).

Tropical breeds and adapted breeds are better able to regulate body temperature in response to heat stress than are animals from a variety breeds of European origin. Moreover, exposure to elevated temperature has less deleterious effects on cells from zebu cattle than on cells from European breeds. Superior ability for regulation of body temperature during heat stress is the result of lower metabolic rates as well as increased capacity for heat loss.

Therefore, this study aimed to study the relationships of respiratory physiological functions and adaptation responses in different ruminants' breeds.

Material and Methods

The study was conducted in four different regions São Paulo State University (UNESP), Campus of Jaboticabal, SP, Brazil (21° 8' S, 48° 11' W and 583 m altitude), Apta Ribeirao Preto, SP, Brazil (21°08' S, 48°11' W, 583 m altitude), UNESP, Campus of Ilha Solteira, SP, Brazil (20° 25' S, 51°20' W, 379 m altitude) and São Joao do Cariri, PB, Brazil (07° 23' S, 36° 31' W, 458 m altitude). Was used five adapted breeds for tropical environment, been five Nellore beef cattle, nine Anglo Nubian female goats, 12 Jersey dairy cattle, ten Guzerat beef cattle, 12 Morada Nova female sheep, with an average of body weight: 743.4, 61.67, 362.1, 420, 33.42 kg, respectively. The animals were observed in a latin square during 20 (Nellore), nine (Anglo Nubiana), 20 (Guzerat), 12 (Jersey and Morada Nova) consecutive days. At the end of the trial all the animals were evaluated in each one of all days and in all the periods. The environment variables were measured by Data Loggers (*model HOB0, Onset*), in regular ten-minute intervals, air temperature (T_{AR} , °C), black globe temperature (T_g , °C) and relative humidity (U_R , %).

The proportions of carbon dioxide (CO_{2E}), oxygen (O_{2E}) and methane (CH_{4E}) in the exhaled air of the animals were measured using an indirect calorimetry system with a facial mask adjusted on the animal's muzzle (figure 1). In this system, during each breath, the inlet flow (inspired air) and the outlet flow (exhaled air) were carried through two valves. The exhaled air coming out from the facial mask was directed through a tracheal tube (MLA1015 Breathing Tube, ADInstruments, Australia), to the flow head (MLT1.000, ADInstruments, Australia). The flow head was connected to the gas mixing chamber (MLA246, ADInstruments, Australia), and this to the spirometer (ML141, ADInstruments, Australia). The gas mixing chamber was connected to the Field Metabolic System (FMS-1201-05, Sable System, USA) through a plastic tube (Bevaline Tubing, Sable System, USA). Inside the tube a sample of the exhaled air (150 mL min^{-1}) was continuously aspirated by the air pump of the Field Metabolic System and it was forced to the gas analyzers (H_2O , O_2 and CO_2) also in the FMS. Firstly, the sample went to the H_2O vapour analyzer and to the dryer (Magnesium perchlorate - $Mg(ClO_4)_2$); then, it was carried through the CO_2 and O_2 analyzers, and finally to the CH_4 analyzer (MA-10, Sable System, USA). With a connection between the FMS with the Spirometer, it was possible the digital reading of the proportions of CO_{2E} and O_{2E} , respectively. Also, were measured the respiratory rate (R_R , breath. min^{-1}), ventilation (V_E , $L \text{ s}^{-1}$) and Tidal Volume (V_T , $L \text{ breath}^{-1}$).

The volumes of VO_2 and VCO_2 ($L \text{ s}^{-1}$) were calculated according to McLean (1972), using a Haldane transformation for STPD conditions, which means that the gas volume is expressed under Standard conditions: Temperature ($273^\circ K$ or $0^\circ C$), Pressure (760 mm Hg), and Dry (no water vapour),

$$VO_2 = V_{E(STPD)} \left[O_{2A} \left(\frac{1 - O_{2A} - CO_{2A} - CH_{4A}}{1 - O_{2E} - CO_{2E} - CH_{4E}} \right) - O_{2E} \right]$$
$$VCO_2 = V_{E(STPD)} \left[CO_{2E} - CO_{2A} \left(\frac{1 - O_{2A} - CO_{2A} - CH_{4A}}{1 - O_{2E} - CO_{2E} - CH_{4E}} \right) \right]$$

where,

$$V_{E(STPD)} = V_m \frac{P_{atm} - P_{exp}}{T_{exh} + 273.15} \left(\frac{273.15}{101.325} \right)$$

The proportions of oxygen, carbon dioxide and methane in the atmosphere (O_{2A} , CO_{2A} and CH_{4A} , respectively) were analyzed by the FMS and the CH_4 analyzer. These measurements were done every time that the facial mask was taken of the animal's muzzle; however, the vapour pressure in the atmosphere was continuously recorded by an external H_2O vapour analyzer (P_V , kPa) (RH-300, Sable System, USA) connected to a pump (SS4, Sable System, USA) which aspired continuously an air sample of the atmospheric air (150 ml min^{-1}) close to the animals' mask inlet valve.

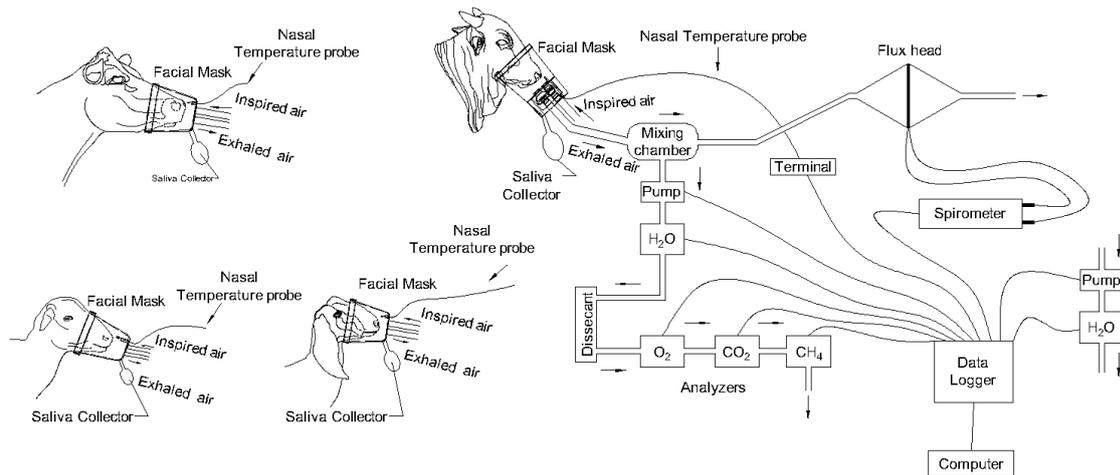


Figure 1. Physiological measurement system with mixing chamber, spirometer, gases analyzer and specific facial mask developed for beef cattle, goats, sheep, and dairy cattle.

Data were analyzed by the least-squares method (Harvey, 1960) using the Statistical Analysis System (SAS Institute, 1995).

Results and Discussion

The average of T_{AR} was 29.9 ± 0.072 , 26.8 ± 0.082 , 28.9 ± 0.053 , 30.7 ± 0.052 , $31.8 \pm 0.043^\circ\text{C}$, the U_R was 61.1 ± 0.15 , 73.1 ± 0.21 , 36.8 ± 0.11 , 64.7 ± 0.24 , $49.5 \pm 0.16\%$ and T_{RM} was 31.1 ± 0.053 , 26.69 ± 0.037 , 29.2 ± 0.049 , 30.3 ± 0.053 , $31.8 \pm 0.037^\circ\text{C}$, for Nellore, Anglo Nubiana, Jersey, Guzerat and Morada Nova experiment, respectively. A small difference was observed between T_{AR} and T_{RM} because the research was done with animals protected of solar radiation. However, the variation between the sampling days was significant ($P < 0.05$). Solar radiation was highest in Ilha Solteira, SP, Brazil (655.03 W.m^{-2}), where the experiments on Guzerat beef cattle were conducted, and São João do Cariri, PB, Brazil (596.07 W.m^{-2}), where the Morada Nova sheep were tested). Metabolic rate expressed in W.m^{-2} , Jersey cattle had the highest metabolic rate, followed by Nellore and Guzerat cattle, Anglo Nubian goats, and Morada Nova sheep, with values of 230.4, 146.6, 90.8, 62.3, and 35.3 W.m^{-2} , respectively.

The average of body weight (B_W), V_E , V_T , R_R and V_{O_2} , V_{CO_2} , q_{MET} per kg of body weight was demonstrate in table 1.

There is no evidence that respiratory capacity for heat loss is superior for zebu cattle (Hansen, 2014), and the proportion of V_{O_2} consumption showed a lower metabolic rate. Table 1 showed that Morada Nova breed, raised and adapted to semi-arid region present a heat metabolism of 1.07 W kg^{-1} . A similar capacity to adjust to a low energy intake by reducing energy metabolism was found also in other desert herbivores, such as zebu cattle and llama, which are annually exposed for long periods to severe nutritional conditions in their natural habitats (Silanikove, 1987).

The relationship of V_E as function of body weight showed that Jersey and Guzerat had the higher values because they had a higher R_R , but when we see the V_T this relationship showed that animals with higher body weight had a higher V_T (Fig. 2). However, when the R_R was analyzed for kg of body weight the relationship was inverse, showed that small animals had a higher respiration for kg of body weight, with values of 0.02, 0.36, 0.1, 0.06, $0.6 \text{ breath min}^{-1} \text{ kg}^{-1}$. The equations in Fig. 3 indicated that increased of percentage of O_2 consumed for unit of body weight was no linear function, because small animal had a higher O_2 consumption.

Table 1: Mean values (\pm standard error) of body weight (B_W , kg), ventilation (V_E , $L \cdot s^{-1}$), respiratory rate (R_R , $\text{breath} \cdot \text{min}^{-2}$), tidal volume (V_T , $L \cdot \text{breath}^{-1}$), volume of O_2 consumed (VO_2 , $L \cdot h^{-1} \cdot \text{animal}^{-1}$), volume of CO_2 produced (VCO_2 , $L \cdot h^{-1} \cdot \text{animal}^{-1}$), and metabolic heat production (q_{met} , $W \cdot \text{kg}^{-1}$) in Nellore, Guzerat, and Jersey cattle, Anglo Nubian goats, and Morada Nova sheep.

Variable	Species – Breed									
	Beef cattle – Guzerat		Beef cattle – Nellore		Goats – Anglo Nubian		Dairy cattle – Jersey		Sheep – Morada Nova	
	N	Mean	N	Mean	N	Mean	N	Mean	n	Mean
B_W	10	420 \pm 15.3	5	743.4 \pm 15.8	9	61.7 \pm 3.4	12	362.1 \pm 9.3	12	33.4 \pm 0.9
V_E	1418	1.03 \pm 0.04	4109	1.09 \pm 0.02	3073	0.15 \pm 0.01	3796	1.39 \pm 0.05	6182	0.12 \pm 0.18
R_R	3743	24 \pm 0.05	5562	19 \pm 0.04	3683	22 \pm 0.13	5162	38 \pm 0.08	6987	20 \pm 0.04
V_T	1762	3.3 \pm 0.01	4084	3.5 \pm 0.01	3072	0.44 \pm 0.001	4805	2.78 \pm 0.01	6984	0.36 \pm 0.001
VO_2	1308	60.3 \pm 0.4	4136	140.6 \pm 0.46	2593	13.9 \pm 0.07	3054	128.2 \pm 0.47	5548	5.94 \pm 0.02
VCO_2	1308	81.9 \pm 0.5	4136	164 \pm 0.58	2593	16.2 \pm 0.07	3054	152.9 \pm 0.64	5548	5.73 \pm 0.02
q_{met}	1033	0.95 \pm 0.006	4136	1.17 \pm 0.004	2593	1.37 \pm 0.006	3054	2.21 \pm 0.11	5548	1.07 \pm 0.002

n= number of observations

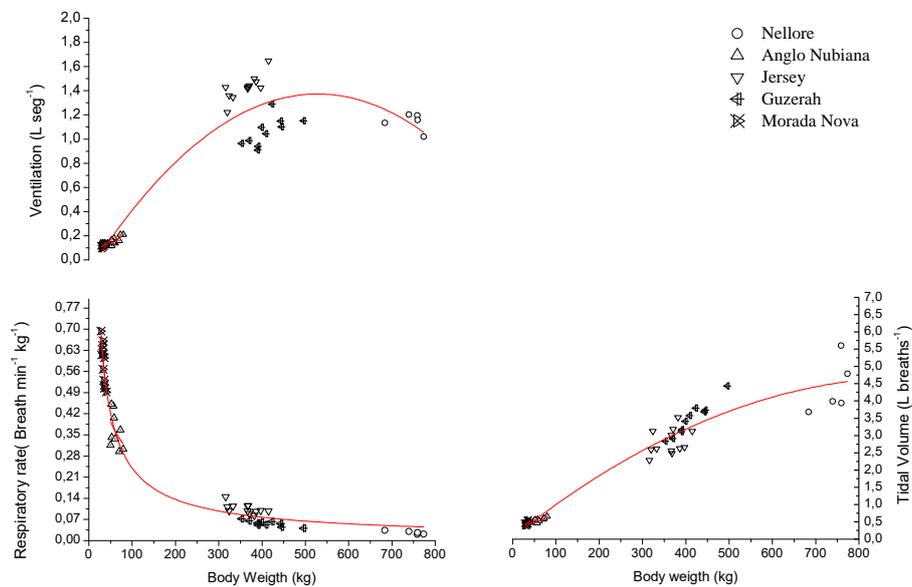


Figure 2. Variation of ventilation ($L \cdot s^{-1}$), Tidal Volume ($L \cdot \text{breath}^{-1}$); and Respiratory rate per unit weight ($\text{Breath} \cdot \text{min}^{-1} \cdot \text{kg}^{-1}$) as a function of body weight (kg) in Nellore, Anglo Nubian goats, Jersey, Guzerat and Morada Nova sheep.

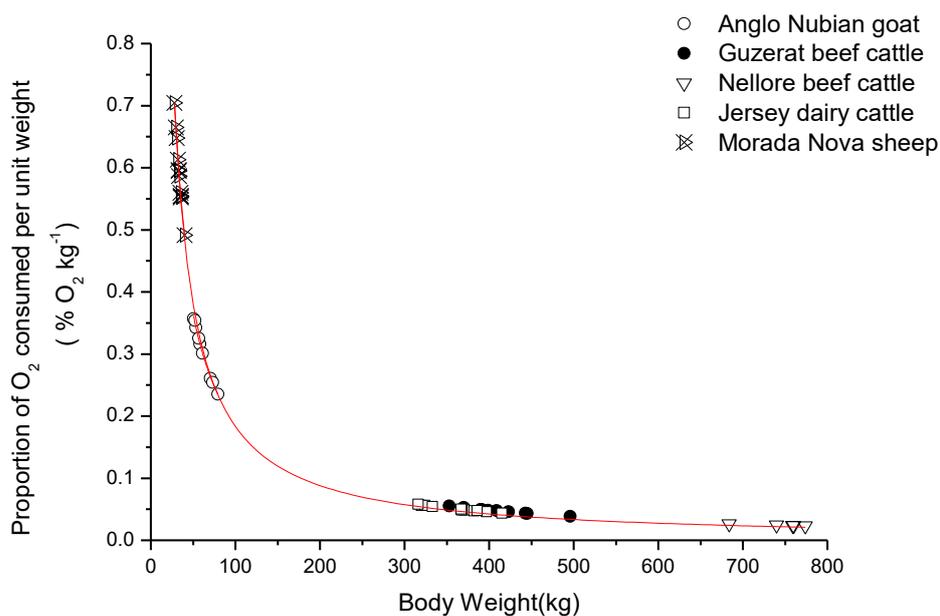


Figure 3. Relationship between proportion of O₂ consumed per unit weight and body weight in Nellore, Jersey, and Guzerat cattle, Anglo Nubian goats, and Morada Nova sheep.

Conclusions

Respiratory functions and their relation with body weight show a great parameter to describe the adaptation of animals raised in tropical environment.

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