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REVIEW
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Adaptative thermal traits in farm animals

Características termoadaptativas em animais de produção

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Abstract Animal welfare is affected by weather conditions that influence on thermal comfort, therefore the aim of this literature review was to assess the influence of environmental factors on physiological variables of animals of zootechnical interest. Livestock production is limited by the animal stress as response to the environment where the individuals are reared. Animal adaptation is related to the individual physiological condition related to its survival zone, which is determined by thermoneutral zone (comfort), hypothermic zone (cold stress) and hyperthermia (heat stress). To assess the animal comfort some variables must be analysed, such as: respiratory rate (RR); sweat rate (SR); rectal temperature (RT); heart rate (HR); air temperature (AT); air humidity (AH); wet-bulb globe temperature index (WBGTI) and radiant thermal charge (RTC). The weather variables influence the animals' thermoregulation, affect their thermal comfort and decrease their welfare. The adaptation to the weather conditions of the region is one of the factors responsible for the productive capacity of the animal.

Keywords: homeothermy, physiological variables, weather factors

Resumo O bem-estar dos animais é afetado por fatores climáticos que proporcionam influências no conforto térmico, com isso o objetivo desta revisão de literatura foi avaliar a influência de fatores ambientais sobre variáveis fisiológicas de animais de interesse zootécnico. A produção animal é limitada pelo estresse do indivíduo como resposta ao ambiente onde o mesmo é criado. A adaptação do animal está ligada ao estado fisiológico do indivíduo em relação a sua zona de sobrevivência, que é definida pela zona de termoneutralidade (conforto), zona de hipotermia (estresse por frio) e zona de hipertermia (estresse por calor). Para avaliar o conforto dos animais, algumas variáveis devem ser analisadas, tais como: frequência respiratória (FR); taxa de sudação (TS); temperatura retal (TR); frequência cardíaca (FC); temperatura do ar (TA); umidade relativa do ar (UA); índice de temperatura de globo e umidade (ITGU); e carga térmica radiante (CTR). As variáveis climáticas influenciam a termorregulação dos animais, afetando o contorto térmico e reduzindo o bem-estar animal. A adaptação às condições climáticas da região é um dos fatores responsáveis pela capacidade produtiva do animal.

Palavras-chave: fatores climáticos, homeotermia, variáveis fisiológicas

Introduction

Animal welfare is affected by several weather factors that influence on thermal comfort, therefore animal adaptation is related to the individual physiological condition related to its survival zone, which is determined by the thermoneutral zone (comfort), hypothermic zone (stress by cold) and hyperthermia zone (stress by heat). Physiological variables are studied by seeking for assess physiological mechanisms related to weather variables particular from the environment where the animals are housed, thus it is noticed that the weather variables affect animals' homeothermy and reduces animal welfare. Animal adaptation to the weather conditions of the region is one of the factors responsible for the productive capacity of the animal.

Animals suffer the influence of the environment, which can affect production and makes important the study about the influences of environmental variables on thermoregulatory traits of animals of zootechnical interest. When the animal farming in temperate zones is compared to

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that in tropical zones is noticed that the animals which are reared in hot environments show lower productivity, what is resulted of several environmental factors that are above the ideal limit for an optimal performance of the herd (Eustáquio Filho et al 2011).

The thermoneutral zone is limited by the lower critical temperature, in which the animal activates its thermoregulatory mechanisms to cater to the need of producing heat to balance the heat loss for the cold environment, and by the upper critical temperature, which is the environmental temperature that is above the ideal range for each species and thereby provides the thermoregulation, which is a physiological response of the animal in order to dissipate the body heat to the environment (Sampaio et al 2004).

As the animal is subjected to an environment with temperatures above its ideal limit, its organism reacts to this factor by promoting an increase in its temperature to keep itself homoeothermic. In response to this condition thermoregulatory characteristics are activated in an attempt to balance the body temperature to the environmental variables existing in the place where animals are reared, aiming to achieve thermoneutral conditions which indicate animal welfare and consequently provide better productive and reproductive response (Luz et al 2014). The aim of this literature review was to assess the influence of environmental factors on physiological variables of animals of zootechnical interest.

Weather and animal adaptation

Brazilian Northeast is the easternmost part of the South American continent, located between the latitudes 3º e 18º S and the longitudes of 35º and 46º W. The northeastern semiarid zone is equivalent about 74.30% of the Northeastern area, with a dry tropical weather and humid or rainy annual season that lasts from four to six months and later a dry season from six to eight months. The region has an annual precipitation around 700mm and high temperature during whole year with thermal averages between 23-28°C (Cezar 2004). The weather where the Piaui and Maranhão states are located is an intermediate among the hot and dry weather that predominates in Northeast region and the hot and humid weather that is predominant in the North region of Brazil.

A genetic concept of adaptation takes into account the natural selection of certain species referring to its inheritable characteristics that will provide the survival. Genetically adapted animals have more possibility to survive, considering that the genetic improvement can incorporate desirable phenotypes for better adaptability and yield from the zootechnical viewpoint (Takashi; Biller; Takashi, 2009). A way to incorporate adaptation traits to weathers is crossing animals of the *Bos taurus* and *Bos indicus* species generating offspring with a higher degree of adaptability and better production, as the example of the Girolando breed.

As occurs variation at the environmental variables, mainly temperature and humidity, the usage of physiological mechanisms of thermoregulation is promoted. As consequence of these weather variations is that productive performance of any domestic species depends straight on the interaction of environmental factors with the individual genetic patrimony, thereby the study about the adaptation ability of the species and breeds reared at the environment and in the types of farming systems in which the animals will be reared is essential, as well as showing farming ways and husbandry practices which allow the livestock production without affecting animal welfare and sustainability to the farmers (Souza, 2007).

Livestock production is limited by the animal stress as response to the environment where the individuals are reared. A low production of the animals is resulted of multiple effects of an environment with high temperatures. Considering that thermal stress has been recognized like an important reason for the decrease in animal production in the tropics, what gives basis for evaluation studies about tolerance and adaptation ability of zootechnical production species (Silva et al 2006).

Temperature is an index that is linked to a series of other variables which causes several physiological factors in animals. High air temperatures associated to high air relative humidity affect milk production, reproduction, susceptibility to several diseases, increase mortality and cause noticeable economic losses to livestock production (Pereira, 2005).

Mechanisms of heat exchange

In a hot and dry environment is noticed that the main via of thermolysis in animals is the evaporation, both the coetaneous and the respiratory, because they are the first mechanisms performed by the individual to dissipate heat. When animals are subjected to physical exercises a thermal stress can be caused due to the activation of mechanisms responsible for regulating the heat loss and maintaining the thermal balance in an animal (Fonseca et al 2014).

As the cold air reaches a hot body, the air layer around the body surface is warmed up and rises away from the body carrying the heat, and thus cooling the body by convection process. Conversely, if the air temperature is higher than the temperature of the skin, the air movement will promote heat routing to the animal until the air temperature to be equal to the temperature of the skin when the heat transfer is finished. In conduction, heat exchange (transfer) occurs through communication that takes place between two bodies in direct contact, so the temperature

moves from hot to colder to achieve equilibrium (Silanikove 2000).

Since evaporative losses by respiratory and skin surface consist of heat exchange by changing the liquid state of water to gas (Pereira 2005). The thermoregulatory mechanisms are physiological responses of the animal to the environment to it offered. Excessive heat stress causes changes in homeostasis and potential change of temperature regulation mechanisms (respiratory rate, rectal temperature, and hormone levels), which are quantified in large economic losses in animal production (Al-Tamimi 2007). Under long periods of exposure to heat, the animals develop mechanisms to produce less heat towards the thermal equilibrium (Marai et al 2007).

Homeothermy in livestock production

Animal adaptation is related to its physiological status in relation to its survival zone, which is determined by thermoneutral zone (comfort), hyperthermia (heat stress) and hypothermic zone (cold stress), therefore weather elements will influence the thermal comfort zone of animals and consequently on their welfare, behavior, intake, production and reproduction. Azevêdo et al (2008) describe that as much as the animals are able to maintain the homeothermy, better adapted them will be to the climatic variations of a certain production environment.

Homeothermy is maintained when the heat that is produced in the metabolism plus the heat that is absorbed from the environment are equal to the dissipated heat flow from the animal to the environment. Hyperthermia occurs when the heat produced is received and exceeds the heat flow to the environment, which occurs through processes which depend on the room temperature (conduction, convection and radiation) and humidity (evaporation via transpiration and breathing). Increased respiratory rate in response to changes in environmental variables has as main objective maintaining homeothermy (Eloy 2007).

The environment and the animal keep relations that make them a system, in which one react each other. In tropical weather, the animal thermal environment must be considered as determining on comfort to the thermal environment, that is the temperature range in which the homeothermic animal does not need using its thermoregulatory system, whether to thermolysis or thermogenesis. Homeothermy is maintained when the heat that is produced in the body is similar to the amount of heat released to the environment (Luz et al 2013).

Thermoneutrality it is limited from the moment in which the animal starts to use the physiological responses to dissipate heat stress imposed upon it by the environment. When the level of internal heat of the animal is equated with the environment through heat exchange mechanisms it is stated that the animal is in homeothermy. Within the thermoneutral zone is observed that homeothermy is kept by the production processes and heat loss, such as conduction, radiation, convection and evaporation (Azevedo et al 2005).

An environment with high weather variables for a certain species causes various physiological responses which depend on the physiological adaptation ability of animals. Under certain environmental conditions animals can keep all their vital functions (maintenance, reproduction and production) efficiently. Depending on the degree of tolerance to the adversities existing in the environment in which they are reared, the priorities are set by the animals' organism. The tolerance of animals to high temperatures is defined by their higher or lower ability to dissipate excessive body heat, thereby keeping their average body temperature within the limits of homeothermy (Medeiros et al 2007).

Physiological variables of thermal equilibrium

Under heat conditions animals reduce the feed intake to decrease heat production caused by digestion, hence they consume more water in attempt to reduce the excessive heat. As a way of heat dissipation, the animal makes use of peripheral vasodilation, increased sweat production rate, increase in respiratory rate, reduction in basal and energetic metabolisms, increase in temperature of the skin and heart rate and consequently a reduction in feed intake (Rodrigues et al 2010).

The evaporation through the respiratory system or through the body surface is an essential mechanism of thermal regulation for animals, mainly at the hottest hours of the day. Silva and Starling (2003) describe that so far as that respiratory rate (RR) is elevated for a long time it may causes reduction in blood pressure of CO^2, also causes a noticeable increase in heat of the tissues, caused by the accelerated work of the respiratory muscles. Parameters such as respiratory rate and rectal temperature are variables widely used by researchers to show the adaptability of animals, being a way to assess the physiological animal welfare (Azevêdo et al 2008).

Rectal temperature (RT) is the indicator of difference between thermal energy developed inside the animal plus the energy received by the body and the thermal energy dissipated to the environment. Eustáquio et al (2008) comment that the level of body temperature is kept within narrow limits by a series of thermal regulation mechanisms in homoeothermic animals. Between the animal and the environment, it is ascertained a constant transfer of temperature divided into sensitive and non-sensitive heat. The resistance of an animal to high temperatures is defined by its higher or lower ability to dissipate the excess of body heat, thereby keeping its average body temperature within the limits of homeothermy (Medeiros et al 2007).

Sweating rate (SR) is a physiological mechanism that is used to dissipate the superficial temperature by the sweat glands in the morning and afternoon shifts, in the dry and rainy seasons. The highest average values occur in the morning and afternoon in the dry season, which favours the dissipation of heat by evaporation, because the maximum capacity of sweating is achieved under high temperatures and low humidity when there is an increase in the volume of blood to the epidermis, which provides greater stimulus for production of sweat glands (Ligeiro et al 2006).

As the animals are subjected to heat above its optimal range, it can increase heart rate (HR) as a means of dissipating heat. Heart rate is a physiological variable. Stress in a short time promotes activation of the Autonomic Nervous System (ANS), and in a long period of time is activated in the hypothalamus-pituitary-adrenal axis (HPA) the stimulation of the sympathetic portion of ANSand causes, among other changes, increased respiratory and heart rates and blood pressure (Veloni et al 2013).

Environmental variables that influence the thermal adaptation of animals in livestock production

Some environmental variables which influence thermoregulation of animals are air humidity (AH), air temperature (AT), wet bulb globe temperature index (WBGTI) and radiant thermal charge (RTC). Lately, attention has been dispensed to the thermal environment in which animals of zootechnical interest are produced, since the environment affects directly the performance of the farming and causes influence according to the species, age and rearing purposes (Lima et al 2011).

Swine species, for instance, undergoes influences of weather factors at various stages of life, what promotes the use of thermal comfort traits. The initial stage is not much affected by high air temperature, but the growth and termination phases are particularly sensitive to high air temperature, once animal breeding, reproduction intensity and low thermolytic capacity affect the reactions to thermal stress and therefore can affect animal production (Fagundes et al 2008). Pigs show thermal comfort at temperature of 22 ºC (Manno et al 2005).

Temperature greatly affects the poultry production, so that ideal air temperature for egg production is between 21 and 26ºC, under conditions of 26 and 29 ºC there is a reduction in size and quality of the eggshell, between 35 and 38ºC production is roughly reduced, causing in poultry the need to stay prostrated to try exchange heat with the surface of the perch (Takahashi et al 2009), highlighting that these situations are also affected when the environment has humidity condition out the average of 70% (Lara and Baião 2005).

Luz et al (2013) studied environmental variables and thermolysis mechanisms in sheep and observed that as the air humidity decreased up to reach average of 41.31% during the day, the use of thermal regulation mechanisms of animal was increased for them to keep themselves within the thermoneutrality. Air humidity shows the presence of micro droplets of water dispersed at the environment and therefore a low humidity changes evaporative processes (breathing and sweating) of animals.

The variable WBGTI was developed by Buffington et al (1981) which indicates the degree of thermal comfort of animals and the ideal value of 72 is adopted, because it combines the radiation effects, wind speed, air humidity and dry bulb temperature in a single value (Sampaio et al 2004). Tinôco et al (2007) reported that animals have better physiological welfare based on the value of 72 for the variable WBGTI.

Radiant heat load is an equation that indicates the heat exchanges by radiation what occur between animals and the production environment, thereby it is extremely important to assess the influence of radiation mainly in hot weathers regions to characterize if the environment is propitious or intolerable for animals. Sousa Júnior et al (2008) evaluated that high levels of radiation, which are presented by higher RTC, provided increases in rectal temperature and respiratory rate.

Final considerations

The wheater variables influence thermoregulation of animals, affecting their thermal comfort and reducing animal welfare. The use of physiological mechanisms of thermoregulation is a response of the organism that needs to dissipate the heat that comes from the effect of climate variables for achieving homeothermy zone.

The adaptation to the weather conditions of the region is one of the factors responsible for the productive capacity of the animal. Thus, it is necessary the adequacy of the zootechnical housings in order to reduce the interference of climatic factors on animal's adaptation to the microclimate found inside the production environment to reduce energy consumption for thermoregulation.

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