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REVIEW

Growth and reproduction hormones of ruminants subjected to heat stress

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Abstract The adaptation of the animals, either temperate or tropical climate, is mainly related to physiology and its adaptation to the environment. When subjected to different air temperature and air humidity from the usual, these animals found in heat stress difficulty reproduction and production. The endocrine system is one of those responsible for controlling the stress response, and rapid and appropriate growth is one of the elements of greatest economic importance toward meat production, and more producers want to improve, to accelerate the production rate and decreasing production costs. Thus, the aim of this review was to evaluate, through research papers found in the literature, the influence of heat stress on the hormones of growth and reproduction in ruminants. It was observed that even in studies that do not consider the productive performance of the animals, the influence of these parameters is significant in the ambience and the degree of adaptation of the same. However, more research should be conducted in order to evaluate the production of animals of different species under the conditions of different regions, as well as search for alternatives to achieve the best animal production levels, either by finding the best way of introducing exotic breeds, or the possibility of bringing more comfort to the animals in their various productive and reproductive stages.

Keywords: adaptability, bioclimatology, endocrine system

Introduction

It is assumed that the expansion of the industrial system in recent decades has helped significantly to the Earth's climate change. According to information from the IPCC (2007), the increase in carbon dioxide concentrations, resulting from the use of fossil fuels, and methane and nitrous oxide, related to the expansion of agricultural activities, in the atmosphere, is one of the reasons responsible for episodes of extreme climatic events, such as the increase of global temperature.

Thus, climate change may accentuate the thermal stress in response to differences in the balance of temperature between the animal and the environment, which is influenced by environmental factors such as radiation, temperature, relative humidity and wind speed, as well as thermoregulation mechanisms, such as conduction, radiation, convection and evaporation (Sirohi and Michaelowa 2007), modifying the thermal neutral zone, under changes in these factors and triggering discomfort to the animal.

There is no specific source to stress, being it appointed as the disruption of balance or pressure on the homeostatic mechanism, overcoming the capacity of adaptation. Livestock production in the tropics is marked essentially by heat stress. Given this, the most observed animal behavior changes consist in increased water consumption, decreased daytime grazing, increased night grazing, increased of the animal resting time, a way to restore its equilibrium thermoregulation, anestrus, suppression of period of reproduction, drop in the quantity and quality of semen, among other factors.

In animal production, the climatic element of greater importance is the temperature, because it exerts a great action on the two classes that have the most representative number of domestic animals, which are mammals and birds. Animals found in these classes are homoeothermic, or have the ability to control their body temperature within a narrow range upon big temperature changes (Medeiros and Vieira 1997). In order to reduce the effects of stress, the animals begin a series of responsive mechanisms to stressful stimuli, which are controlled by hormones and coordinated by the nervous system and the endocrine system which is responsible for regulating metabolic, reproductive and growth processes (Greenspan 2006).

The endocrine system coordinates and regulates the physiological processes by means of chemical messengers called hormones. These are defined as chemical substances produced by specific tissues and conducted by the vascular system to operate in any other tissue, however, they only work on target cells with specific receptors capable of responding to them (Cunningham 2008). Hormones are classified as to their chemical structure, protein (growth hormone, insulin), amines (dopamine, melatonin,

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epinephrine), peptides (oxytocin, vasopressin) and steroids (p. Eg., Cortisol, vitamin D, progesterone) (Reece 2006).

By the peculiarities of each species related to thermoregulation and the importance of the mechanisms established by each agency targeting production and survival while facing thermal discomfort situations, this study aimed on showing the effects of heat stress on growth hormones and reproduction in ruminants.

Influence of heat stress on the hormonal and reproduction physiology

A range of factors such as genetics, age, sex and physiological conditions relate to the nature of the biological response of an animal to a stressor. In general, the nervous system and the endocrine system coordinate the response to stress, and hormone response pattern varies with the type of stressor (Rodrigues et al 2010).

Under the stimulus of heat stress, the brain, in connection with the hypothalamus is responsive to the activation of the hypothalamic-pituitary-adrenal axis, secreting corticotropin releasing hormone (CRH) and antidiuretic hormone (ADH), with subsequent secretion of adrenocorticotropic hormone (ACTH) from the anterior pituitary. The latter is responsible for stimulating the adrenal cortex to release of glucocorticoids, which is responsible for regulating the intensity of the response to the stress, particularly cortisol, as well as causing the secretion of adrenaline and noradrenaline by the adrenal medulla and the sympathetic nerve terminals (Kolb 1987; Santos 2003; Santos 2005; Randall 2010). Therefore, in a stressed body, the pituitary gland secretes less growth hormone (GH), and less thyroid stimulating hormone (TSH), leading to a reduction of thyroid activity (incarnation, 1992).

During heat stress, the activation of the hypothalamic-pituitary-adrenal axis (HPA) inhibits the hormones of the hypothalamic-pituitary-gonadal axis (HPG). According to Leite (2002), in the hypothalamus, the secretion of the releasing corticotropin hormone inhibits the gonadotropin-releasing hormone (GnRH) and in the anterior pituitary there is the suppression of the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH). Note that the gonads (ovaries and testicles), due to heat stress, are not affected only by suppressing the HPG, but also suffer action directly in their tissues, with consequent hormonal imbalance and reduced sensitivity of cells to the action of FSH and LH (Santos 2003).

The follicles are damaged by the suppression of gonadal hormones, however continue to grow. There is a slow development of one or two follicles and there isn't the choice of a dominant follicle, where an ovulation of subfertile oocytes takes place (Hafez and Hafez 2004). Vianna (2002) points out a stress started on the eighth day of the estrous cycle decreased the volume and diameter of the dominant follicle. Santos (2003) highlights that there is a high incidence of twin pregnancies in the months of high temperature due to the fact occur decrease in the degree of dominance in the follicle, resulting from the presence of larger amounts of medium-sized follicles developing.

Still in the point of view of reproduction, testosterone is the hormone that regulates spermatogenesis, the expression of secondary sexual characteristics and sexual behavior (Todini et al 2007). Results related to this hormone are still quite disparate in the literature and should therefore be used with caution as an indication of heat stress. Coelho et al (2008) reported that goats subjected to heat stress showed no variation in the concentration of testosterone. However, Salles (2010) described an increase in testosterone levels over the period of the year with the occurrence of greater thermal discomfort.

The increase of plasma concentrations of cortisol, resulting from the activation of the hypothalamic-pituitary-adrenal axis, is the most remarkable response of the animal to stress conditions (Souza and Batista 2012). Cortisol secretion is responsible for stimulating physiological mechanisms allowing the animal to tolerate stress caused by a high temperature environment (Silanikove 2000). Ludri and Sarma (1985) report that plasma cortisol from an Indian goats race in lactation stage were higher in the month showed higher temperature, indicating that the stress influence in cortisol concentrations. Salles (2010) found that males of the Saanen race had higher cortisol levels in the period of the year that were pointed higher air temperatures. Moreover, a serious chronic stress can cause high cortisol levels, decreasing the animal's fitness due to immunosuppression and atrophy of defense tissues of the body, making it more susceptible to infectious diseases (Al-Busaidi et al 2008).

Among the relevant endocrine alterations caused by stress the decrease in the activity of the hypothalamic-pituitary-thyroid axis must be noted also, with decreased thyroid hormone concentrations, Tetraiodothyronine (T4) and triiodothyronine (T3) (Reece 2006). These hormones act by increasing basal metabolism, making available more glucose into cells for energy production purposes and stimulating protein synthesis and cardiac and neuronal functions in addition, act in the control of heat production in animals homeothermic, increasing the oxygen consumption of tissues with consequent increase of heat production (McNabb 1995).

According Habbeb et al (1992) T3 is the most associated hormone with thermogenesis in animal hormone. However, it is noteworthy that the T4 hormone has six to seven days useful lifespan, while the T3 has only 24 hours of useful lifespan, and therefore, the changes in the peripheral concentrations of T3 more easily noticed (Reece 2006). According to Nascimento (1994), there is the urge to

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differentiate the long effects and short duration of the heat stress on circulating levels of T3 and T4, as the adaptability to chronic stress generates endocrine changes that may be different from those observed the momentary stress.

Coelho et al (2008) studied goats of Saanen and Alpine breeds, observed that heat stress resulted in significant changes in plasma concentrations of T3 only in male Saanen. These data are similar to the results found in research with bovine animals, which also showed racial differences in resistance to heat stress (Pegorer et al 2007). Thus, it is convincing that thyroid hormones present important role in controlling the production of heat in warm-blooded animals and the suppression of the concentration of T3 in response to heat stress, can act as a mechanism for adaptation to reduce thermogenesis (Roberts et al 2010).

It is known that heat exposure can cause direct or indirect effects on animal organism, such as the reduction of food consumption. The consumption of food is regulated by the hypothalamus that with the heat influence reduces the stimulation of the medulla of the adrenal reducing the production of hormones responsive by the manifestation of hunger (Navas et al 2016). Le Bellego et al (2002) affirms that the decline in food consumption occurs due to the heat of the inhibitory action on the appetite center, due to the high respiratory rate and reduced motility of the gastrointestinal tract, with subsequent reduction of food pass rate in the digestive tube.

Thus, we emphasize the importance of knowledge of the effects caused by heat stress, either directly influencing the hormonal physiology and reproduction, as secondarily causing changes in physiological and behavioral responses of animals, reduced intake and feed efficiency, growth, reproduction and milk production, as well as hematological abnormalities.

Environmental effect on body growth (before/after birth)

The definition of body growth is the increase in size and functional development of tissues and organs that occur from fecundation to maturity, directed to processes of synthesis and cellular metabolism, in which happens interaction of genetic factors, hormonal, metabolic and the environment (Geraseev et al 2006).

According to Grant and Helferich (1991), the prenatal growth is fast, happening at an exponential rate in all animal species. In the beginning of gestation, the fetal growth is small and controlled by the genetic patterns of specie, however, in the third final of gestation, is high and strongly influenced by mother’s nutrition. According to Araújo (2008), the postnatal growth, is noteworthy that maternal influence on growth proves to be superior during the first two months of lactation.

The most vulnerable period in animal life happens before and immediately after birth, a period denominated as perinatal. The period of perinatal mortality of small ruminants is occurring between 60 days of gestation and 28 days after birth (Nobrega Jr. et al 2005).

Many factors influence on neonatal mortality, including nutritional causes, such as failure colostrum intake, infectious and parasitic diseases, environmental factors, and even the presence of predators. However, factors targeted to pregnant female can influence the birth and viability of newborns, such as the thermal stress during pregnancy.

The rapid and adequate growth is one of the most important economic elements related to the production of meat, and what more producers want to improve, aiming that animals which has higher weight gains require fewer days to reach the ideal slaughter weight, being most cost effective and economically viable, speeding up the production rate and decreasing production costs (Vieira 2004).

The body growth is influenced by many factors, including those related to the genotype, environment, sex, weight, type of birth, health, as well as the quantity and quality of food offered (Araújo 2008). With regard to the numerous effects that influence the growth of animal, the season of birth has special importance (Biffani et al 1999). Among the causes that can be highlighted as the interference of the influence of the year of birth on the weight variation of the animals, there are the changes in the management and in the form of food given to the animals, the use of different breeders from one year to the another, modifying the genetics of the herd, and variations in climatic factors such as rainfall, temperature and humidity that generate numerous effects on the animals and on the quality and availability of pastures (Araújo 2008).

Oliveira and Lôbo (1992) studied the environmental factors associated with weight at 18 months in Guzerá cattle, and reported that there was a significant influence of sex, season and year of birth. Phillips (2004) found that the goats which were born in rain season had higher weight at birth and grew to weaning faster compared to those goats born in dry season, fact explained, possibly due to compensatory growth phase in which all animals were in good conditions of pasture and supplementation. Shaat (2004), observing reproduction characteristics and growth of crossbred goats, described that, the year of birth generated significant influence on the weight at birth, at 56, at 84 and 112 days of age.

Based on this, it is highlighted that the effect of environmental conditions can be either directly, reaching the functions of the animal body, or indirectly, that causes fluctuations in the quantity and quality of food or increasing the prevalence of diseases, will cause influence significantly in productivity of animals.

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Effect of environment on the reproduction of ruminants

The ruminants like all mammals are homoeothermic animals, which, under extreme conditions of ambient temperature, exhibit the ability to regulate their body temperature by mechanisms of physiological, behavioral and metabolic, by thermolysis or thermogenesis (Bridi 2010). Because of these mechanisms, they can reach the zone of thermal comfort, the state in which the animal reaches the thermal neutral and there is a minimum energy consumption to maintain equilibrium by temperature, achieving the best potential of productive and reproductive (Silva 2000).

However, when the zone of thermal comfort isn't reached, the interaction 'animal x environment´ hits the condition of heat stress, limiting the productive and reproductive animal development, resulting in economic losses (Cruz et al 2011). In heat stress there is an activation of the thermoregulatory center in the central nervous system, with the activation of compensatory mechanisms by thermolysis (peripheral vasodilation, increased respiratory rate, decreased food intake, increased water intake), inducing the animal to lose heat through sensitively (conduction, convection and radiation). In latently way, the efficiency of heat dissipation, depends on the function of the sweat glands (Smith et al 2001).

With the activation of the hypothalamic-pituitary-adrenal axis, occurs the release of corticotropin (CRH) by the hypothalamus, which regulates the release of adrenocorticotropic hormone (ACTH) by the hypophysis. The ACTH regulates the release of glucocorticoids, including cortisol and catecholamines, adrenalin and noradrenalin by the adrenal, promoting interference in the hypothalamic-pituitary-gonadal center (Ferro et al 2010).

The temperature of the scrotal skin raises according to changes in environmental temperature, this fact was observed by Barros et al (2009) in study designed with cattles, in which with an increase in the environmental temperature a gain of surface scrotal temperature was observed, being the regulation of internal temperature of the scrotum a great importance in the reproductive efficiency of males.

The scrotal temperature control is performed via external cremaster muscle and Dartos fascia, which allows the scrotum to deviate from the cavity under elevated temperature conditions (Hafez and Hafez 2004). Another mechanism that assists in regulating this temperature is caused by pampiniform plexus located in the epididymis and sweat glands of the scrotum, which enable the maintenance of testicular temperature from 2° to 6° C below body temperature, which is ideal condition for spermatogenesis and steroidogenesis (Colas and Guerin, 1980).

Females do not have these anatomical conformations and when subjected to high temperature condition respond physiologically with impaired reproductive function. The heat stress directly affects the reproductive performance of animals through the hypothalamic-pituitary-gonadal axis by inhibiting gonadotropin-releasing hormone (GnRH) in the hypothalamus. In the anterior hypophysis interferes with the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH) and in the gonads changes the stimulating effect of gonadotropin secretion of sex steroids (River and Rivest 1991). Consequently, the reproductive efficiency is affected (Nunes et al 1997), since spermatogenesis is controlled by the neuroendocrine system and is influenced by the mechanism of the scrotum testicular thermoregulation.

In males, when subjected to heat stress, the impacts on reproduction occur instantaneously in the reduction of volume ejaculated, the sperm motility, number of sperm with defects and reduces libido (Porcionatto et al 2009).

According to Hafez and Hafez (2004) during the period in which the environmental temperature is elevated there is an increase in body temperature and this can lead to testicular degeneration and reduce the percentage of normal and fertile sperm in the ejaculate. Silva (2000) also reports a direct influence of environmental temperature on pH of semen when the animals were subjected to a maximum temperature of 33°C, and in case of staying for a long period in this stress condition, the animal may exhibit degeneration testicular irreversible.

In females the activation of the hypothalamic-pituitary-adrenal (HHA) results in decreased of excretion of the gonadotropins (LH and FSH), in the production of estrogen, which consequently leads to various reproductive disorders such as failure to detect estrus (silent estrus), failures in oocyte development, in fertilization and insemination. Shehab et al (2010) describe that during heat stress diameter of the dominant follicle is smaller, which leads to impairment of oocyte development capacity and quality of granulose cells, contributing to negative results on reproduction, particularly in milky cows of high production kept under conditions of heat stress.

The Embryo mortality is because of excretion of CRH which acts on GnRH inhibiting the release of LH and causing consequently fails in the oocyte release, changes in the endometrial cells and loss in pregnancy. Corassin (2004) reported that cows covered in rain period had five times more chances of conception than the cows that were covered in summer.

There are few reports in relation issues of climate effects on specific functional abnormalities of the reproductive organs in female goats (Ozawa et al 2005), however it is thought that the mechanisms are similar to those in cows. Silva et al (2010) evaluated the effects of reproductive conditions (pluriparous and nulliparous) under climate divergent (dry or rainy season) observing that the number and quality of embryos collected from super ovulated Boer goats, recovered from nulliparous donors,

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occurred more in rain season compared to the dry season, which was not observed in pluriparous donor. It is believed that this is because of the adaptability of climate, which is not a limiting factor for their reproductive potential.

Goats adapted to arid and semi-arid regions have a bipartite of the scrotum as a feature of adaptation to climate deviating from these region (Salviano and Souza 2010), and under adverse temperature conditions show changes in spermatogenesis. Silva et al (2005) studying goats observed lower sperm concentration during the hottest period of the year. Salles (2010) reported that in the dry period in which the environment temperature is higher, there is decrease in sperm quality, with changes in percentage of mobile spermatozoids and an increase of sperm pathologies. During this period there was an increase in testosterone levels.

Maia et al (2011) studding male Dorper sheep in state of Rio Grande do Norte (Brazil) reported that there is a variation in semen quality between the rainy and dry season, but this change did not affect the quality of semen, a fact explained by the race in study is adapted to the climate of region. According to data by Moreira et al (2001) when the male sheep underwent condition heat stress there was a raise in the seminal pH, sperm death, reduction in sperm concentration, azoospermy and decrease in scrotal circumference, demonstrating that breeds that are not adapted when subjected to elevated temperatures, have their reproductive efficiency compromised.

Final Considerations

Given these assumptions, it is concluded that heat stress results in changes in the physiology of animals, causing increased susceptibility to the emergence of diseases, with a decrease in reproductive and productive part, and deficit in the economic sector and commitment to animal wellbeing, which already is intensely affected due to their attempts to thermoregulation, triggering a high physical wear and providing all the consequences that have already been reported here previously.

So, the effects caused by climate conditions are important, given the range of body systems which are affected by stress hormones. One way to reduce these effects is to ensure the animals a wellness by giving them larger shading areas, proper management, facilities, equipment, proper nutrition, especially during periods of drought, breeding schemes, making the phase of higher nutritional requirement animal coincide with periods of increased fodder production, among other points that suppress the harmful effects of heat stress, induce thermal comfort and promote conditions for the animals express the most of their productive potential.

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