HEAT TOLERANCE IN ½ SENEPOL- AND $^{5}/_{8}$ HOLSTEIN - $^{3}/_{8}$ BRAHMAN CROSSBRED CALVES.

Tolerancia al Calor en Becerros Mestizos ½ Senepol- y $^{5}/_{8}$ Holstein- $^{3}/_{8}$ Brahman.

Armando Quintero-Moreno [1], Derwin Calatayud [1], Julio Boscán [2], Nidia Rojas [1], Darwuin Arrieta [3] y Roberto Palomares [2]

[1] *Unidad de Producción Animal (UNIPA). E-mail: armando.quintero@uab.es*
[2] *Unidad de Reproducción Animal (UNIRA). Facultad de Ciencias Veterinarias, Universidad del Zulia. Apartado 15252. Maracaibo 4005-A, Venezuela.* [3] *Cátedra de Farmacología y Toxicología Veterinaria. Facultad de Ciencias Veterinarias, Universidad Central de Venezuela.*

ABSTRACT

Two trials were conducted to determine heat tolerance between crossbred ½ Senepol- (S-) and $^{5}/_{8}$ Holstein-$^{3}/_{8}$ Brahman (HB). Differences between crossbred in trial 1, and crossbred and ambient temperature (Ta: 25 and 34°C) in trial 2 were evaluated through rectal temperature (Tre), respiration rate (RR), heat tolerance index (HTC), coefficient of adaptability (CA), average daily gain (ADG), and plasma cortisol. Trial 1 used 324 observations in 18 S- calves and 12 HB calves, while trial 2 used 90 observations in 8 S- calves and 7 HB calves. The statistical analysis of the parameters evaluated was carried out by mixed model with repeated measurements, whilemeans the ADG was perform by T-test. In trial 1, S- and HB calves had similar heat tolerance (P>0.05). In trial 2, Tre and RR in HB were greater (P<0.05) than S- calves, and also HTC, CA and ADG were the best in S-. At 34°C of Ta, the HB calves had significantly (P<0.05) greater Tre, and lower HTC than S- calves (P<0.01). The results demonstrate the great heat tolerance of the crossbred Senepol.

Key words: Adaptation, heat tolerance, crossbred, tropics, calf.

RESUMEN

Se realizaron dos ensayos para determinar la tolerancia al calor entre becerros mestizos ½ Senepol (S-) y $^{5}/_{8}$ Holstein-$^{3}/_{8}$ Brahmán (HB). En el primer ensayo se evaluaron las diferencias entre los 2 grupos raciales, mientras que en el segundo ensayo, además de la diferencias raciales se evaluó el efecto de dos temperaturas ambientales (Ta: 25 y 34°C) sobre la temperatura rectal (Tre), tasa respiratoria (RR), índice de tolerancia al calor (HTC), coeficiente de adaptabilidad (CA), ganancia diaria de peso (ADG), y medición del cortisol plasmático. En el ensayo 1 se utilizaron 324 observaciones obtenidas de 18 becerros S- y 12 becerros HB, mientras en el ensayo 2 se utilizaron 90 observaciones en 8 becerros S- y 7 becerros HB. El análisis estadístico de las variables estudiadas se realizó mediante medidas repetidas, a excepción de la variable ADG que se determinó mediante la prueba de T-test. En el ensayo 1, los becerros S- y HB presentaron valores similares de tolerancia al calor. Sin embargo, en el ensayo 2, los becerros HB presentaron Tre y RR superior a los S- (P<0,05), lo cual derivó en mejores coeficientes de tolerancia al calor (HTC, CA) y ADG en los S- (P<0,05). A los 34°C de Ta, los becerros HB obtuvieron mayor Tre (P<0,05) y menor HTC que los becerros S- (P<0,01). Los resultados demuestran la mayor tolerancia al calor en los becerros mestizos Senepol.

Palabras clave: Adaptación, tolerancia al calor, mestizaje, trópico, becerro.

Recibido: 08 / 01 / 2007. Aceptado: 28 / 02 / 2007.

INTRODUCTION

In the majority of cattle farms in tropical areas of America, *Bos indicus* breeds are used as the fundamental base in crossbreeding strategies, both for beef and milk production; this is due to the fact that this species is not only tolerant of heat but also transmits this tolerance. On the other hand, the *Bos taurus* breeds from temperate climates cannot be used “in their pure state” because of their limited capacity to adapt to the high ambient temperatures found in the tropics, a fact widely supported by the registers of cattle farms that have very low milk production, slow growth rate, high death rate and poor immune resistance to infectious diseases and parasites.

In the tropical areas of Latin America, cattle farmers have made great efforts to find the "ideal crossbred" capable of producing moderate-to-high milk production, and at the same time, of being tolerant to harsh environments. For this purpose, researchers have dedicated many years to the breeding of dual purpose cattle (beef and dairy) with the emphasis on milk production. They have developed crossbreeding systems in which there is a predominance of Holstein, Brown Swiss and Jersey among others, and the Brahman breed. The Brahman is well known for its ability to adapt to tropical and subtropical areas of America as demonstrated by its capacity to transmit to its young the same ability to adapt to heat as well as its good reproductive rate. However, it is not a good milking producer and despite its heat tolerance and good grazing qualities, its growth rate is only moderate.

In recent years, isolated efforts have been made to find a crossbred animal capable of adapting to heat stress situations and at the same time providing efficient growth rates and high milk production so as to be able to compete in the international markets with breeds recognised for their great milking capacity. Recent studies have evaluated heat tolerance in beef cattle and have used breeds such as the Romosinuano, Tuli, and Senepol [12,13]. The Senepol is composed by the Red Poll and N'Dama from Africa and was developed on the Caribbean island of St. Croix, which has also been the object of many adaptation studies in the subtropical climate of Florida [11,12,13], the Virgin Islands [14] and Venezuela [3,21]. The Senepol shows great ability to control rectal temperature during the summer season, as demonstrated by studies carried out in the Caribbean and in the subtropical zones of Florida [11,12,13]: this has also been confirmed by its ability to graze at very high ambient temperatures when other breeds would be in the shade. This ability of the Senepol to control rectal temperature seems to be inherited as a dominant characteristic in the crossbreeding with those breeds not tolerant of the heat, which indicates the easy incorporation of the heat tolerance gene into tropical cattle farms.

An efficient method of determining if an animal is tolerant or not of heat stress is by measuring rectal temperature [8,11,12,13], the plasma cortisol [4,12,13,26] and calculating the heat stress tolerance value [2]. All of these have long been considered to be valid values in measuring the adaptation of animals to heat. High rectal temperature, high respiration rate and high plasma cortisol are indicators of heat stress when, of course, other pathological signs are absent. For this purpose, 2 trials were conducted with the main objective of determining the presence of physiological adaptation to heat stress, calculated by rectal temperature, respiration rate, heat tolerance rates, average body weight and plasma cortisol in crossbred yearling calves $^5/_8$ Holstein - $^3/_8$ Brahman and ½ Senepol- under very hot conditions in subtropical rainforests in western Venezuela.

MATERIALS AND METHODS

Two trials were carried out, one from December to July, and the second during the months of August and November of 1998. These trials were undertaken in one of the University of Zulia farms, located in the region of Machiques, Zulia State, Venezuela. This ecological area is characteristic of tropical rainforest with an annual rainfall of 1600 mm and two wet seasons (May-June and September-October). The annual temperature ranges from 22 to 35°C, with an annual average of 28°C.

Trial 1

For the first trial, 30 crossbred calves (12 $^5/_8$ Holstein – $^3/_8$ Brahman, and 18 ½ Senepol - $^5/_{16}$ Holstein- $^3/_{16}$ Brahman) were evaluated in the afternoon for 11 weeks consecutively (324 observations), and were incorporated into the study a few days after birth. The calves were fed from birth to 3 months with artificial suckling using cow's milk obtained from milking (2 litres in the morning and 2 litres in the afternoon), ½ Kg of concentrated feed and grazing restricted to 4 hours per day (10:00 am to 14:00 pm.). At 3 months of age, the calves were weaned off the milk and only grazed in *Brachiaria brizanta* throughout the day, although during the day they were also fed the supplementation on a daily basis of morning ration that did 500 g/d.

Measuring of environmental factors includes the ambient temperature (Ta), relative humidity (ϕ) and rainfall average during the period of data gathering on the farm and in the Ministry of the Environment Research Center (TABLE I), located less than 5 kilometres from where the trial was being conducted. The humidity temperature index (THI) was calculated [12,13,25]. The measurements taken from the calves are those of rectal temperature (Tre) using a mercury thermometer and, subsequently, the respiration rate (RR) using a stethoscope. Measuring of heat tolerance was carried out by using two tests, the first being the heat tolerance index (HTC), and adapted to this trial to degrees Celsius (°C) [2]. This rate is calculated by taking the difference between the Tre of a animal after a period of exposure in daylight hours when Ta is highest, and the Tre considered normal for cattle, using the following formula: HTC= 100-[20(Tre-37.4)], where 37.4 is the Tre normal for calves; 20 = constant to transform the degrees of deviation of the Tre from a normal to a unitary base and 100 = perfect efficiency in maintaining the Tre at °C. The second test used takes the coefficient of adaptability (CA), which uses the formula CA = Tre/38.3 + RR/23, where the numerical values referred to in the denominators correspond to normal values per minutes of Tre and RR. Calf body weight and the average daily gain (ADG) were calculated during this trial [2].

Trial 2

For the second experiment, 15 calves were selected from the first trial: 7 crossbred Holstein and 8 crossbred Senepol, which were incorporated at an average age of 6 months and grazed in *Brachiaria humidicola* previously used by production cows having *ad libitum* access to water. The measurements of the Tre and RR were taken weekly in the afternoon on August 09, August 15, August 22, and very early in the

TABLE I

AMBIENT TEMPERATURE AND RELATIVE HUMIDITY, TRIAL 1 AND TRIAL 2/ TEMPERATURA AMBIENTAL Y HUMEDAD RELATIVA. EXPERIMENTO 1 Y 2

Month/ Date	Ambient temperature, Ta (°C)	Relative humidity, Φ, (%)	Temp-humidity index, THI (n) [a]
Trial 1			
December	26.8	57.5	75.0
January	28.0	50.0	75.7
February	27.6	51.0	75.3
March	28.2	46.5	75.4
April	29.0	50.5	77.0
May	28.1	55.5	76.5
June	28.2	57.0	76.9
July	28.0	54.0	76.2
Trial 2			
August, 09 [b]	34.7	55.5	85.5
August, 15 [b]	34.0	55.0	84.4
August, 22 [b]	33.7	47.5	82.6
November, 06 [c]	25.0	58.0	72.6
November, 13 [c]	24.8	61.0	72.6
November, 20 [c]	22.9	53.5	69.3

[a] Dry bulb temperature in °F – (0.55 – 0.55 x relative humidity index expressed as a decimal, dry bulb temperature-58) (West, 1994; Hammond et al., 1998). [b] Ambient temperature between 14:00 at 16:00 hours in the afternoon. [c] Ambient temperature between 4:00 at 7:00 hours in the morning.

morning on November 06, November 13, and November 20 by taking 3 consecutive measurements with an hour gap per day of evaluation. August is one of the months with the highest Ta in the area under study, with values of 34 to 36°C between 11:00 am and 16:00 p.m, while during the month of November between 4:00 and 7:00 am, the Ta ranges from 22 to 26°C; at the most critical times (afternoon), it is around 30°C. The experimental design used is similar to that established by other studies [12,13]. Measurement of the ambient conditions (Ta, Φ, annual rainfall, THI), body parameters (Tre, RR) and indexes (HTC, CA) was carried out using a methodology similar to that of the first experiment. In addition, blood samples were taken from the jugular vein during each hour of the evaluation and were immediately refrigerated and transported to the RIA laboratory where they were centrifuged to obtain the plasma, and then frozen at –20°C so as to determine plasma cortisol [8].

Statistical Analysis

Data were processed by the SAS statistic package [23]. Heat tolerance (Tre, RR, HTC, CA) was analyzed by using the mixed procedures, and a mixed data model was set with repeated measurements [3]. In the first trial, the model included the crossbred as fixed effect. In the second trial, crossbred, ambient temperature and their interaction were considered as fixed. In both experiments, before carrying out the Tre analysis, observations were subjected to a logarithmic transformation by taking the logarithm 10 from the difference between the Tre measurement and 37°C [13,16]. When significant differences were detected, the LSMEANS was used to carry out compare square averages. The TTEST was used to determine the ADG.

RESULTS AND DISCUSSION

No differences were found between the crossbred Holstein and crossbred Senepol calves younger than 6 months old (TABLE II); on the other hand, in animals aged between 6 and 9 months (TABLE III), differences were found (P<0.05) in all the parameters of heat tolerance evaluated. All these parameters evaluated (Tre, RR, HTC, CA and ADG values) were better in crossbred Senepol than those found in crossbred Holstein.

Also, differences were achieved (P<0.05) with regard to the Tre and HTC in crossbred Holstein calves between 25 and 34°C of Ta (TABLE IV). These results suggest that the crossbred Senepol calves showed the best tolerance to heat stress. Exposure to a step-wise time-related increase in Ta from 25 to 34°C resulted in a significant increase in 0.6°C of Tre in crossbred Holstein, meanwhile the crossbred Senepol calves maintained the same Tre. Also, the HTC was lowest in crossbred Holstein calves at 34°C of Ta. This parameter ranged from 88.5 to 87.1 in the crossbred Senepol calves and 86 to 74 in the crossbred Holstein calves. It is important to emphasize that all the calves at 25°C of Ta showed basal cortisol levels. These results could be explained by a correlation and potential effect between docile calf behaviour and the best heat endurance at

TABLE II

EFFECT OF CROSSBRED ON VARIABLES RELATED TO HEAT TOLERANCE IN CALVES, TRIAL 1 (MEAN ± STD ERROR)/ EFECTO DEL MESTIZAJE SOBRE LAS VARIABLES QUE EXPLICAN LA TOLERANCIA AL CALOR EN BECERROS, EXPERIMENTO 1 (MEDIA ± ERROR ESTÁNDAR)

Variables	Crossbred*	
	$^5/_8$ Holstein $^3/_8$ Brahman (n=12)	½ Senepol- (n=18)
Rectal temperature, °C	39.30 ± 0.037	39.29 ± 0.029
Log rectal temperature [a]	0.35 ± 0.007	0.35 ± 0.005
Respiration rate, breaths/ min.	43.19 ± 1.11	42.89 ± 0.94
Adaptability index [b]	2.88 ± 0.04	2.89 ± 0.04
Heat tolerance index [c]	81.93 ± 0.75	82.02 ± 0.58
Average daily gain, g/d.	396.9 ± 26.59	386.4 ± 36.5

*: P>0.05. [a] Logarithm 10 (rectal temperature – 37.0). (Turner, 1982; Hammond et al., 1998). [b] Rectal temperature/38.3 + respiration rate/23. [c] 100- 20 (rectal temperature-37.4).

TABLE III

EFFECT OF CROSSBRED ON VARIABLES RELATED TO HEAT TOLERANCE IN CALVES, TRIAL 2 (MEAN ± STD ERROR)/ EFECTO DEL MESTIZAJE SOBRE LAS VARIABLES QUE EXPLICAN LA TOLERANCIA AL CALOR EN BECERROS, EXPERIMENTO 2 (MEDIA ± ERROR ESTÁNDAR)

Variables	Crossbred	
	$^5/_8$ Holstein $^3/_8$ Brahman (n=7)	½ Senepol- (n=8)
Rectal temperature, °C	39.40 ± 0.07	39.00 ± 0.08
Log rectal temperature [c]	0.37 ± 0.01 [b]	0.29 ± 0.01 [a]
Respiration rate, breaths/ min.	38.18 ± 1.55 [b]	32.43 ± 1.66 [a]
Coefficient of Adaptability [d]	2.68 ± 0.06 [b]	2.42 ± 0.07 [a]
Heat tolerance index [e]	80.00 ± 1.50 [b]	87.85 ± 1.60 [a]
Average daily gain, g/d.	108.6 ± 22 [b]	192.5 ± 28 [a]

Different superscripts (a, b) in a row indicate significant differences (P<0.05). [c] Logarithm 10 (rectal temperature – 37.0). (Turner, 1982; Hammond et al., 1998). [d] Rectal temperature/38.3 + respiration rate/23. [e] 100- 20 (rectal temperature-37.4).

25°C, in comparison with the results obtained by the crossbred Holstein at 34°C of Ta. Four crossbred Holstein calves showed cortisol values between 11 and 24 ng/ml, and only one Senepol calf showed 30 ng/ml as mean value. It is important to emphasize that these calves and their dams have a gently, as on the farm where the trial was carried out, the entire herd is handled early.

In this study, the THI was between 75 and 85 in the majority of cases, these values were sometimes higher. Heat stress in *Bos taurus* animals associated with a THI superior to 72 limits efficient production and, if there is an increase to near 76, a reduction in the feed intake is evident; at extreme values such as 81, there is also a reduction in water intake [15,25]. If these findings are taken into account and are compared with this experimental conditions, it should be kept in mind that the agro-ecological zone where the experiment was carried out has a negative effect on the effective body heat regulation capacity of the animals; however, in the experiment conditions of tropical heat, there is a risk involved in reaching conclusions with respect to the threshold level of this rate, given that the majority of cattle farms are made up of crossbreeds, which present a greater degree of adaptation and, therefore, a higher THI threshold limit.

The importance of knowing whether a cow is adapted or not can be determined principally by measuring the Tre, as it is the most commonly used estimator in many investigative studies [1,2,6,8,11,12,13]. In the first experiment, the Tre was similar in both crossbreeds, while in the second experiment, the differences favoured the crossbred Senepol, which indicates that in ages over 6 months and elevated Ta, the crossbred Senepol demonstrates the best heat tolerance. In this trial, the rise in Tre reflects the setting in motion of heat regulation mechanisms to control heat stress and to dissipate heat at 34°C; and this marks a clear difference if it compare the similar Tre obtained for the crossbred Senepol at 25 and 34°C of Ta with the Ta obtained in crossbred Holstein. All of this confirms the ability of the Senepol breed to effectively regulate body heat when there is an increase in Ta, which indicates its potential for adaptation. An experiment conducted in Florida during the summer season found inferior values of Tre in the Senepol pure-breed and in the F_1 Senepol x Hereford in comparison with the Hereford and Brahman [11]. On comparing the Tre in pure-breed heifers Angus, Hereford, Brahman, Romosinuano, Senepol, and Senepol x Hereford, the lower Tre was obtained by the Senepol heifers, followed by the Senepol x Hereford, surpassing even the Brahman [12]. Studies conducted in environments with very high Ta found lower Tre values in Senepol x Angus heifers than in Senepol or in Tuli x Angus [13]. Other studies conducted on Holstein yearling calves subjected to hot Ta (36°C, Egyptian desert), indicate Tre values ranging from 39.9 to 40.1, which demonstrates significant heat stress [17].

TABLE IV

EFFECT OF CROSSBRED X AMBIENT TEMPERATURE INTERACTION ON VARIABLES RELATED TO HEAT TOLERANCE IN CALVES, TRIAL 2. (MEAN ± STD ERROR)/ EFECTO DE LA INTERACCIÓN MESTIZAJE X TEMPERATURA AMBIENTAL SOBRE LAS VARIABLES QUE EXPLICAN LA TOLERANCIA AL CALOR EN BECERROS, EXPERIMENTO 2 (MEDIA ± ERROR ESTÁNDAR)

Variables	Crossbred x Ambient temperature			
	$^5/_8$ Holstein $^3/_8$ Brahman (n=7)		½ Senepol- (n=8)	
	25°C	34°C	25°C	34°C
Rectal temperature, °C	39.1 ± 0.1	39.7 ± 0.1	38.9 ± 0.1	39.0 ± 0.1
Log rectal temperature [c]	0.31 ± 0.02 [a]	0.43 ± 0.02 [b]	0.29 ± 0.02 [a]	0.31 ± 0.02 [a]
Respiration rate, breaths/min.	33.9 ± 2.2 [a]	42.5 ± 2.2 [b]	31.1 ± 2.4 [a]	33.7 ± 2.4 [a]
Coefficient of Adaptability [d]	2.49 ± 0.09 [a]	2.88 ± 0.09 [b]	2.37 ± 0.10 [a]	2.48 ± 0.10 [a]
Heat tolerance index [e]	86.0 ± 2.13 [a]	74.0 ± 2.13 [b]	88.5 ± 2.27 [a]	87.1 ± 2.27 [a]

Different superscripts (a, b) in a row indicate significant differences (P<0.05). [c] Logarithm 10 (rectal temperature – 37.0). (Turner, 1982; Hammond et al., 1998). [d] Rectal temperature/38.3 + respiration rate/23. [e] 100- 20 (rectal temperature-37.4).

The mean RR in the first experiment was similar in both crossbreeds, while in the second experiment the differences favoured the crossbred Senepol (P<0.05), which indicates that there is no difference between the capacity of heat dissipation in those animals under 6 months old; however, the animal could be stressed, in such a way that the values found are moderately high in both groups if we compare them with the established norms of between 10 and 30 breaths/min, for this species [22]. From the age of 6 months, the crossbred Holstein presented higher RR than the crossbred Senepol, which indicates that this pathway is being used for heat dissipation, demonstrating heat stress. High RR values in the first experiment can be justified by the fact that the animals are very young, in which case high values could be normal. On the other hand, it could also be argued that these figures are due to heat stress which, although not life threatening for the animal, could have repercussions on its growth rate. When used to measure heat stress in very hot environments, the RR has the added value that its rise is very evident when high Ta challenges the animals' physiological mechanisms [2,12,13,17]. The RR is also a sign of heat stress when it causes panting [13]. It has been proposed that the use of RR as a means of measuring heat tolerance be abolished owing to the significant differences in individuals and breeds, which could lead to an erroneous interpretation. In spite of this, it is still used as the next best alternative to Tre. For example, the Brahman has a lower RR than other breeds due to its large oxygenation capacity which means that care should be taken when making comparisons between or judgements about physiological adaptability in crossbreeds which are predominantly of the *Bos indicus* breeds [6,12]. It is also important to take these factors into account when evaluating breeds with a similar adaptation potential, such as the Romosinuano, Tuli and the Senepol and when comparing non-adapted breeds. These differences could be more evident when evaluating crossbred animals composed of two or more breeds, as was the case in crossbred heifers $^{5}/_{8}$ Holstein x $^{3}/_{8}$ Brahman and in pure Holstein yearling calves with values superior to 100 r.p.m. [17,19].

The HTC and CA values showed for the crossbred Senepol were better than those found for the crossbred Holstein. The HTC obtained by the crossbred Senepol calves at 25 and 34°C are good and indicate that they are potentially heat tolerant. On the other hand, the crossbred Holstein endures Ta well at 25°C, but has great problems of endurance tolerance at 34°C. In humid and tropical area of Nigeria, were evaluated various breeds of cattle exposed at 21.4°C of Ta and elevated, and the White Fulani breed showed better adaptation to heat stress (CA: 2.10) than N'Dama (2.19), German Brown / N'Dama (2.50) German Brown (2.72) and Friesian (2.79) [2]. They point out that this coefficient presents great limitations because it uses the RR for carrying out the formula and, as a result, the CA could be affected by the proven difference that breeds and crossbreeds present [2,6]. In the same Nigerian trial, it was found that when a beast is exposed to Ta ranging from 20 to 22°C, the Tre (38.56 –38.65°C) and the RR (15 – 31 r.p.m.) were inferior to those obtained in the Ta ranging from 31 to 35°C (39.1°C and 23 to 50 r.p.m), although no differences were found in the animals with regard to the HTC [2]. Another study found dramatic increases in the Tre and RR in the afternoon (14:00) in ¾ Holstein and ¼ Zebu heifers when compared with $^{5}/_{8}$ Holstein and $^{3}/_{8}$ Zebú, which demonstrates the activation of these pathways because of the need to compensate the elimination of heat in this particular cross [19]. Variations in the Tre and RR of approximately 0.4°C and 15 r.p.m. respectively were found in heifers of different breeds and/or crosses exposed to Ta of 32.8°C and 18.3°C, although the cortisol plasma remained constant [12]. On comparing the summer and autumn periods, very similar results were found for the Tre, while there were marked differences in the RR [13].

In the analysis of ADG, no significant differences were found in the first 6 months of life. This indicates that all the calves have a similar growth rate and heat tolerance, at least at a very young age. However, from 6 to 9 months old the ADG was superior in the crossbred Senepol (P<0.05). Another study found similar results between the same crossbreeds within the first 3 months of life, while at other studies found that the body weights of crossbred Senepol at 7 months old were superior to those of the crossbred Holstein and the mixes composed of Holstein, Brown Swiss, Brahman and local breeds, and this in spite of having a lower weight at birth [3,21]. The ADG obtained in the first experiment is quite acceptable given that the conditions of reduced feed supplement and the consumption of grass having low to moderate nutritional value. The ADG obtained is in accordance with other experiments conducted in the tropics, but is low if compared with those obtained in other latitudes [20]. In the second experiment, the ADG obtained is very deficient due to the consumption of grass having low nutritional value, together with the lack of feed supplementation. The low ADG obtained by the ruminants in harsh tropical environments is due, among other things, to the fact that the high Ta causes a reduction in feed intake. Heat stress stimulates the peripheral thermal receptors located in the skin, which in turn transmit the nerve impulses to the appetite centre located in the hypothalamus, with the purpose of decreasing the feed intake, in order to minimise internal heat load [10]. As a result, a smaller amount of extract is available to synthesise hormone and to perform other important metabolic functions. A suppression of release factors in the hypothalamus is therefore produced, causing a decrease in pituitary hormonal secretion and subsequently lower excretion of the thyroid hormones, which has a dramatic effect on growing [17]. Another important hypothesis states that the increase in the glucocorticoids or the decrease in insulin could reduce the capacity to synthesise proteins in climates with high Ta [1, 9, 17].

The results obtained in plasma cortisol were very variables. The first indication that the organization of the stress response was chronically modified by experience was based on the "early handling" paradigm [18]. A study established that the pituitary-adrenocortical response to stress was lower in adult rats who were handled during their first 20 days of life than in non-handle control and the range of effects included basal glucocorticoids levels and cellular changes within specific regions of the central nervous system, including the hippocampus and frontal cortex [5,18]. Other hypothesis that could explain our results explain that when an animal is subjected to heat stress for the first time, there is a rise in the level of glucocorticoids, which continue by falling to very low levels if this effect remains constant for a long time; in other words, if the effect becomes chronic [1]. Taking all of these affirmations into account, the same conclusions could be reached with this experiment, as the plasma cortisol values found were basal compared with normal blood levels. At present, plasma cortisol is being used as measure of heat stress, although, so far, the results obtained have been contradictory, owing to the fact that cortisol can interact with other environmental factors; for this reason, it must be considered as complimentary, but not decisive evidence. In Brahman yearling calves of a few days old it was demonstrated that high levels of this hormone are present when it is exposed to low Ta (4°C), while at 31°C the values are normal, although the yearling calves ½ Simmental -¼ Brahman - ¼ Hereford showed normal values when exposed to both warm and cold environments [8]. In an experiment which evaluated the levels of plasma cortisol in heifers of the breeds Angus, Hereford, Brahman, Senepol, Senepol – Hereford and its reciprocal, it was demonstrated that the Senepol had inferior levels of plasma cortisol to the Brahman, although these differences between the two breeds could be due to differences in temperament [11,12]. The Senepol has a very docile temperament and is of a calm disposition, while the Brahman is the opposite [14, 24]. The plasma cortisol among Brahman and Hereford bulls from different areas were very similar, possibly demonstrating a common adaptation mechanism which involves the regulation of body temperature in both breeds [4]. Furthermore, greater levels of plasma cortisol have been found in Brahman than for Angus and Brahman x Angus [7]. Young Angus x Hereford bulls had lower levels of plasma cortisol than Brahman x Angus or Brahman x Hereford; meanwhile, other studies have failed to demonstrate that plasma cortisol levels subjected to heat stress are higher in Brahman bulls and cows [4,26].

CONCLUSION

The yearling crossbreed Holstein and crossbred Senepol calves showed similar heat tolerance up to the age of 6 months old; however, between 6 and 9 months old, the crossbred Senepol showed better heat tolerance, because the rectal temperature and heat tolerance index remains constant at 25 and 34°C of ambient temperature. In contrast, the crossbreed Holstein was affected when the ambient temperature was 34°C; this result favours the crossbreed Senepol having the best growth rate. The constant expression of heat tolerance indicates the ability to maintain a constant rectal temperature in ambient conditions with high temperatures. In tropical areas with high ambient temperatures, the Senepol breed could be used as a alternative to the Brahman breed in crossbreeding strategies. In addition, given its docile temperament, it could contribute to improvements this aspect in our herds, as it is evident that it transmits its capacity of adaptation to hot environments.

ACKNOWLEDGEMENTS

The authors wish to acknowledge to Hacienda San Pedro of the Faculty of Veterinary Science, University of Zulia for providing animals and facilities to conduct this investigation; and International Agency of Energy Atomic (IAEA, FAO, Viena).

BIBLIOGRAPHIC REFERENCES

[1] ÁLVAREZ, M.B; JOHNSON, H.D. Environmental heat exposure on cattle plasma catecholamine and glucocorticoids. **J Dairy Sci.** 56: 189-194. 1973.

[2] AMAKIRI, S.F.; FUNSHO, O.N. Studies of rectal temperature, respiratory rate and heat tolerance in cattle in the humid tropics. **Anim Prod.** 28: 329-335. 1979.

[3] ARANGUREN, J. A.; ROMÁN, R.; ISEA, W.; VILLASMIL, Y. Preweaning evaluation of crossbred calves using repeated measurements. **Rev Científ FCV-LUZ**. X (3): 240-250. 2000.

[4] BERARDINELLI, J.G.; GODFREY, R.; ADAIR, D.D.; LUNSTRA, D.J.; BYERLEY, H.; CÁRDENAS, H.; RANDEL, R.D. Cortisol and Prolactin concentrations during three different seasons in relocated Brahman and Hereford bulls. **Theriogenol.** 37: 641-654. 1992.

[5] BHATNAGAR, S.; MEANEY, M.J. Hypothalamic-pituitary-adrenal function in chronic intermittently cold-stressed neonatally handled and non handled rats. **J Neuroendocrinol**. 7: 97-108. 1995.

[6] BIANCA, W. Rectal temperature and respiratory rate as indicators of heat tolerance in cattle. **J Agric Sci.** 60: 113-120. 1963.

[7] BLECHA, F.; BOYLES, S.L.; RILEY, J.G. Shipping suppresses lymphocyte blastogenic responses in Angus and Brahman x Angus feeder calves. **J Anim Sci**. 59: 576-583. 1984.

[8] GODFREY, R.W.; SMITH, S.D.; GUTHRIE, M.J.; STANKO, R.L.; NEUENDORFF, D.A., RANDEL, R.D. Physiological responses of new-born *Bos Indicus* and *Bos Indicus* x *Bos taurus* calves after exposure to cold. **J Anim Sci**. 62: 258-263. 1991.

[9] HABEEB, A.A. The role of insulin in improving productivity of heat stressed farm animals with different techniques, University. Egypt. Ph.D. Thesis. 120 pp. 1987.

[10] HABEEB, A.A.; MARAI, I.F.; KAMAL, T.H. Heat stress. In: Phillips, C., Piggins, D. (Eds.). **Farm animals and the environments**. 1st Ed, CAB International. U.K. 27-47 pp. 1992.

[11] HAMMOND, A.C.; CHASE JR.; C.C.; BOWERS, E.J.; OLSON, T.A.; RANDEL, R.D. Heat tolerance in Tuli, Senepol and Brahman-Sired F2 Angus Heifers in Florida. **J Anim Sci.** 76: 1568-1577. 1998.

[12] HAMMOND, A.C.; OLSON, T.A. Rectal temperature and grazing time in selected beef cattle breeds under tropical summer condition in subtropical Florida. **Trop Agric**. 71: 128-134. 1994.

[13] HAMMOND, A.C.; OLSON, T.A.; CHASE JR.; C.C.; BOWERS, E.J.; RANDEL, R.D.; MURPHY, C.N.; VOGT, D.W.; TEWOLDE, A. Heat tolerance in two tropically adapted *Bos taurus* breeds, Senepol and Romosinuano, compared with Brahman, Angus, and Hereford cattle in Florida. **J Anim Sci.** 74: 295-303. 1996.

[14] HUPP, H.D. History and development of Senepol cattle. Agriculture Experiment Station, College of the Virgin Island (San Croix). Report 11. 12 pp. 1978.

[15] JOHNSON, H.D. Bioclimate effects on growth, reproduction and milk production. In: Johnson, H.D (Ed.). **Bioclimatology and adaptation of Livestock**. Amsterdam/Netherlands. 35 pp. 1987.

[16] KEENE, O.N. The log transformation. **Statistic in Med**. 14: 811-819. 1995.

[17] MARAI, I.; HABEEB, A.A.; DAADER, A.H.; YOUSEF, H.M. Effects of diet supplementation and body cooling on Friesian calves reared in high ambient temperatures in the eastern desert of Egypt. **Trop Anim Health and Prod.** 4: 201-208. 1997.

[18] MASON, W.A. Early developmental influences of experience on behaviour temperament and stress. In: Moberg G. P. and Mench J. A. (Eds.). **The Biology of Animal Stress**. CABI Publishing, London, U.K. 269 pp. 2000.

[19] MORAIS, M. Heat tolerance in Holstein-Zebu cattle. Effect of environmental temperature and relative humidity on rectal temperature, respiratory frequency and sweat rate in crossbred heifers. **Rev Cub de Cien Vet**. 16: 193-200. 1985.

[20] QUINTERO-MORENO, A.; ROJAS, N.; ARANGUREN, J.; SOTO, G.; DURAN, D. Effects of supplementation and calving season on preweaning growth of female crossbred calves. **Rev Científ FCV-LUZ.** VII (2): 75-82. 1997.

[21] QUINTERO-MORENO, A.; ARANGUREN, J.; BUSTILLO, L.; GONZÁLEZ, D.; CALATAYUD, D.; RIVERO, A.; BOSCÁN, J.; PALOMARES, R. Use of probiotics in Senepol and Holstein crossbred calves. **Revi Científ FCV-LUZ**. III (Suppl. 1): 53-55. 1998.

[22] RADOSTITIS, O. M.; GAY, C.C.; BLOOD, D.C.; HINCHCLIFF, K.W. Estados Patológicos Generales. In: Saunders, Philadelphia, USA. **Veterinary Medicine**. 9th Ed. 15-16 pp. 2000.

[23] STATISTICAL ANALYSIS SYSTEM INSTITUTE (SAS). *SAS/STAC Software*: 6,11. Carry, NC. USA. 1996.

[24] TURNER, H.G. Genetic and biological aspects of Zebu adaptability. **J Anim Sci.** 50: 1201-1205. 1980.

[25] WEST, J.W. Interaction of energy and bovine somatotropin with heat stress. **J Dairy Sci**. 77: 2091-2102. 1994.

[26] ZAVY, M.T.; JUNIEWICS, P.E.; PHILLIPS, W.A.; VONTUNGLEN, D.L. Effect of initial restraint, weaning, and transport stress on baseline and ACTH-stimulated cortisol responses in beef calves of different genotypes. **Am J Vet Res**. 53: 551-557. 1992.