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Physiological performance and grazing behavior of Senepol, Brahman and Holstein heifers in Puerto Rico

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Summary

A three-year study from 1992-94 was conducted at the Isabela Agricultural Substation, University of Puerto Rico to evaluate the physiological responses and grazing behavior of three breeds of cattle: two *Bos taurus* breeds, the tropically adapted Senepol and the Holstein, adapted to temperate conditions, and the tropically adapted Brahman (*Bos indicus*). Fifteen to 17 yearling heifers per breed per year were used. Weight, rectal temperature and respiration rate of each heifer were recorded during July-November, 1992-94. Ambient temperature, relative humidity, and black globe temperature (shaded and in full sun) were also measured. Blood samples were collected to estimate hematocrit percentage and cortisol levels in the blood. During the third year of the study, grazing behavior was observed the day before and the day after the physiological responses were measured. Hourly observations occurred from 0800 to 1600; the number of heifers in the sun vs. the shade was expressed as percentage of the total number of heifers of each breed. Data analysis was done using PROC GLM (SAS) and year and breed were included as main effects in the model. Rectal temperature was significantly ($P < 0.01$) different among breeds. Senepol heifers had the lowest rectal temperature (39.1 ± 0.6 °C), followed by the Brahman heifers (39.4 ± 0.7 °C), with the Holstein heifers having the highest temperatures (39.9 ± 1.1 °C). Respiration rate measured as breaths/minute was lowest in Brahman heifers (39.47 ± 6.69), intermediate for the Senepol (53.79 ± 9.30), and highest for Holstein heifers (81.34 ± 19.65). Brahman heifers had the highest hematocrit percentage (35.38 ± 3.15 %), Holstein the lowest (27.68 ± 2.40 %), and Senepol were intermediate (31.51 ± 2.81 %); all differences were significant ($P < 0.05$). Brahman heifers spent more time grazing in the sun (75 %) than Senepol (61 %) and Holstein (59 %) during the hottest hours of the day when temperatures reached over 38 °C. Holsteins spent most of the time in the shade, and their grazing was done mainly during the morning and late afternoon hours. Average daily gain of Brahman heifers was the highest ($P < 0.05$), followed by Senepol and Holstein (0.58, 0.46 and 0.28 kg/d, respectively). Our results demonstrated that the breeds varied in their adaptation to the environmental conditions in Puerto Rico for all variables evaluated. These breed differences appear to be due to genetic differences in the breeds' adaptation to tropical environments. Results also indicate the capacity of the *Bos taurus* Senepol cattle to tolerate and perform well under the hot-humid climate conditions of northern Puerto Rico.

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Resumen

El estudio se realizó en la Subestación Agrícola de Isabela de la Universidad de Puerto Rico durante tres años, (1992-1994), con el objetivo de evaluar y comparar respuestas en la temperatura corporal, ritmo respiratorio y comportamiento a pastoreo de novillas de tres razas: Brahman (*Bos indicus*), Senepol (*Bos taurus* de origen tropical) y Holstein (*Bos taurus* de clima templado). Se utilizaron 15 a 17 animales por raza cada año. Temperatura rectal, ritmo respiratorio y el peso de cada animal se registraron durante los meses de julio a noviembre conjuntamente con temperatura ambiente, humedad relativa y temperatura bulbo negro (sol y sombra). Se obtuvieron muestras de sangre para determinar el porcentaje de hematocrito y niveles de cortisol sanguíneo. El comportamiento a pastoreo se observó de 8:00 am a 4:00 pm, los días anterior y siguiente a las mediciones de las variables fisiológicas. Los resultados se expresaron en porcentaje del total de cada raza. Los datos fueron analizados con el sistema PROC GLM del programa SAS utilizando año y raza como efectos principales. Las novillas Senepol presentaron temperatura rectal significativamente menor ($P < 0.001$) que las novillas Brahman y Holstein (39.1 ± 0.6 , 39.4 ± 0.7 y 39.9 ± 1.1 °C, respectivamente). Las Brahman exhibieron un ritmo respiratorio menor (39.47 ± 6.69 inspiraciones por minuto, $P < 0.001$) que las Holstein (81.34 ± 19.65 insp./min.) y Senepol (53.79 ± 9.30 insp./min.). El porcentaje de hematocrito fue más altos en las novillas Brahman (35.38 ± 3.15 %, $P < 0.05$), intermedio en las Senepol (31.51 ± 2.81 %) y más bajo en las Holstein (27.68 ± 2.40 %). Aquéllas también pasaron más tiempo pastoreando al sol (75%) respecto a las novillas Senepol (61 %) y Holstein (59 %), durante las horas más cálidas del día (temperatura ambiente > 38 °C). Las novillas Holstein permanecieron más tiempo bajo sombra y su pastoreo ocurrió principalmente durante las primeras horas de la mañana y a media tarde, lo que se reflejó en el aumento de peso diario de las novillas (Brahman 0.58, Senepol 0.46 y Holstein 0.28 kg/d; $P < 0.05$). Los resultados indican que existen diferencias entre razas en las variables fisiológicas estudiadas que pueden relacionarse a distintos componentes genéticos de adaptación al clima tropical. También se evidencia que la raza Senepol tolera y produce bien en las condiciones de clima húmedo y cálido que impera en el norte de Puerto Rico.

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Introduction

Increasing beef production efficiency in Puerto Rico is a constant challenge for all sectors of the industry. The *Bos taurus* breeds that are very productive in temperate regions are not adapted to hot and humid climate of the Caribbean tropics (Pearson de Vaccaro, 1973; Finch, 1986). *Bos indicus* breeds like Brahman and the composite Charbray predominate in Puerto Rico; however, in spite of their superior thermoregulatory abilities, *Bos indicus* breeds have reduced reproductive and feed

efficiencies, as well as lower meat tenderness as compared to *Bos taurus* breeds (Larsen et al., 1990).

As a means of improving beef production and meat quality in the tropics, crosses between *Bos taurus* and *Bos indicus* have been suggested (Olson, 1992). An alternative approach would be to evaluate tropically adapted *Bos taurus* breeds for possible substitution for the Brahman as a pure breed in beef production programs and for use in crossbreeding programs. Research indicates that the Senepol and Romosinuano breeds possess similar thermoregulatory capabilities as the Brahman and are superior to their European counterparts when evaluated under subtropical conditions (Olson, 1992; Spiers et al., 1994). The Senepol was developed in St. Croix, US. Virgin Islands (Padda, 1987) and was introduced to Puerto Rico in 1983 by the College of Agriculture, UPR (Cianzio, 1996). It is considered a *Bos taurus* breed, being developed from crosses of the *Bos taurus* N'Dama and Red Poll breeds.

In Puerto Rico, *Bos taurus* Holstein cows which are not adapted to the tropics are used by the dairy industry and cull cows and male calves are also used for meat production. Brahman, a *Bos indicus* breed adapted to the tropics, was, until recently, the main breed used for meat production in Puerto Rico. The relatively newly introduced, tropically adapted Senepol offers a possibility for increased beef production efficiency in Puerto Rico. Information, however, is lacking as to how the three breeds compare in their performance in the Puerto Rican environment. The objectives of this study were, therefore, to evaluate the physiological responses of each of these breeds to hot climatic conditions of Puerto Rico and to study their grazing behavior as it relates to changes in diurnal temperature.

Materials and Methods

The study was conducted at the Isabela Experiment Substation located on the north coast of Puerto Rico at 67°10'W latitude, 18°28'N longitude during the months of July to November over three years (1992-94). Climate in Puerto Rico is defined by an average annual rainfall of 158 cm and average annual temperature of 25°C.

Fifteen to 17 yearling heifers of each breed were used each year. The Holstein heifers were daughters of cows born and raised in Puerto Rico but inseminated with semen imported from the continental United States. Senepol and Brahman heifers were also born and raised in Puerto Rico having been conceived on the island using natural service bulls of each breed. Each year of the study, heifers were kept together in a 21 ha pasture divided into 3 ha paddocks that were utilized using rotational grazing. Guinea grass (*Panicum maximum* sp.) was the predominant pasture species in these paddocks.

Data were collected on each heifer every 15 days during the 112 day-period of the study in the hottest months (July to November) for a total of 8 records per heifer/year. Data collection was always done from 1000 to 1400, and for this purpose heifers were penned in corrals at 0830. Heifers were weighed before being returned to the paddocks. Variables recorded were: 1) live weight; 2) respiratory rate, measured as the average count of two persons observing flank movements over a period of 15 seconds; and 3) rectal temperature recorded immediately after the conclusion of the respiratory rate counts for each heifer. Rectal temperature is the index most utilized to measure heat tolerance in livestock (Hammond et al., 1996). A precision rectal thermometer Vet III

(Advanced Animal Instruments, Inc., Willinston Park, N.Y.) was utilized. The sensor device was introduced approximately 12 cm into the rectum and temperature registered to a precision of 0.1°C.

Blood samples were collected from the coxigeal vein every 30 days to obtain hematocrit percentage and cortisol concentration of each heifer. Heparinized vacuum tubes with needles of 18x1 1/2 caliber were used to draw blood from the vein. Samples were kept refrigerated until processing in the lab the same afternoon of collection. Duplicated values of hematocrit were obtained after centrifugation of the capillary tubes at 2,000 rpm for 30 minutes. Percentages were estimated by reading the plasma column in a Spiracrit graph (Microhematocrit capillary tube reader, Oxford Labware) and the average was calculated. Cortisol concentration was determined at the University of Florida in Gainesville.

Several ambient variables were also recorded each time the physiological parameters of heifers were obtained. Temperatures in the sun and in an adjacent shaded location were recorded with regular and black globe thermometers; relative humidity using a thermometer with dry and wet bulbs was also obtained. A temperature-humidity index as defined by McDowell (1972) was later estimated from these data. Ambient variables were recorded twice during the day, at the beginning and the end of data collection. The average for each variable was calculated and assigned for the day.

Grazing behavior was recorded during the third year (1994) of the study. Observations were made the day before and after physiological measurements were measured for a total of 16 observation-days. Numbers of heifers, by breed, which were observed to be grazing, ruminating or resting in the sun, as opposed to being under the shade of trees were recorded every hour from 8:00 am to 4:00 pm. Ambient temperatures, dry and black bulbs, were also recorded at the beginning of the grazing observations.

Data were analyzed using the Statistical Analysis System (SAS); the model included year, breed and their interaction (year x breed) as fixed main effects. Dependent variables were respiratory rate, rectal temperature, hematocrit and live weight gain. Cortisol concentration was used as covariate for the physiological measurements along with initial live weight for weight gain. The interaction of year x breed was used as the error term for the main effects of year and breed, while heifer/year x breed was the error term used to test the interaction. Duncan's test was utilized to determine significant differences among treatment means. Regression and frequency distributions were also conducted to relate the physiological and ambient variables to the grazing behavior data.

Results and Discussion

Overall means for the three years indicated that black bulb temperature was 8.3°C higher than ambient temperature in the sun (38.5 vs. 30.2°C). Black bulb temperature integrates ambient temperature with solar radiation (Hammond et al., 1996) and is, in general, 6°C higher than the ambient temperature (McDowell, 1976). The average temperature-humidity index was 81.2. It has been indicated that high-producing dairy cows are affected by heat stress when this index surpasses 72 (Armstrong, 1994), although an index of 78 seems to be a critical limit for every kind of livestock (McDowell, 1972). Our data indicate that ambient conditions in Puerto Rico likely were severe enough for the breeds to show differences in heat tolerance responses.

Rectal temperature. Senepol heifers had lower rectal temperatures ($P < 0.001$) than Brahman, while Holstein had rectal temperatures that were 0.8°C greater than those of Senepol (Table 1). Similar results were reported in Florida (Hammond et al., 1996).

Table 1. Rectal temperature and respiratory rates of Senepol, Brahman and Holstein heifers measured at Isabela, Puerto Rico, over three years. Means \pm standard deviations

Breeds of heifers	Number of heifers	Rectal temperature ¹ ($^{\circ}\text{C}$)	Respiratory rhythm ² (breaths/min.)
Senepol	49	$39.1^{\text{c}} \pm 0.6$	$53.8^{\text{b}} \pm 9.3$
Brahman	47	$39.4^{\text{b}} \pm 0.7$	$39.5^{\text{c}} \pm 6.7$
Holstein	49	$39.9^{\text{a}} \pm 1.1$	$81.3^{\text{a}} \pm 19.6$

^{1,2} Means in column with different letters are significantly different ($P < 0.001$)

No significant year effect was observed in our study of rectal temperature. The interaction of year x breed, however, was significant ($P < 0.05$), probably due to a smaller difference between Senepol and Brahman that was observed in 1992. Still, Senepol had consistently lower rectal temperatures than Brahman, while the Holsteins had the highest temperature every year of the study (Figure 1). Amakiri and Funsho (1978), comparing N'Dama and Holstein, reported that rectal temperature was a characteristic of each breed and was stable, with small variations among years and seasons within year.

Also of interest are the standard deviations of rectal temperature found in our study (Table 1). Senepols had lower standard deviations (0.6) than Holsteins, almost twice as high (1.1). Bianca (1965) and Finch (1986) indicated that genetic differences exist in rectal temperature within breeds. In fact, heritability coefficients for this variable have been estimated, ranging from 0.29 (Turner, 1982) to 0.64 (Garcia and Rodriguez, 1976). This greater variability in rectal temperature for the Holstein suggests that selection for lower rectal temperature might be successful as a means of improving heat tolerance in the Holstein breed and thus improving performance in hot climates.

Ambient temperature affects rectal temperature. Previous research indicated that *Bos indicus* and *Bos taurus* cattle showed differences in their abilities to maintain constant rectal temperature at ambient temperatures above 30°C (Spiers et al., 1994). The average ambient temperature (dry bulb) during the three years of our study was 30.2°C , higher than the critical point reported by Kibler and Brody (1950) for the Holstein breed ($21-27^{\circ}\text{C}$) but lower than that reported for the Brahman ($32-35^{\circ}\text{C}$). Therefore, breed response to heat tolerance in our study is in agreement with previous reports. When the ambient temperature (dry bulb) increased from 29 to 31°C , Senepol and Brahman heifers reacted similarly having an increment of 0.2°C in their rectal temperature. The rectal temperatures of Holstein, on the other hand, increased 3 times as much (0.6°C) (Table 2). According to Finch (1986), a valid index of tropical adaptation is the ability to

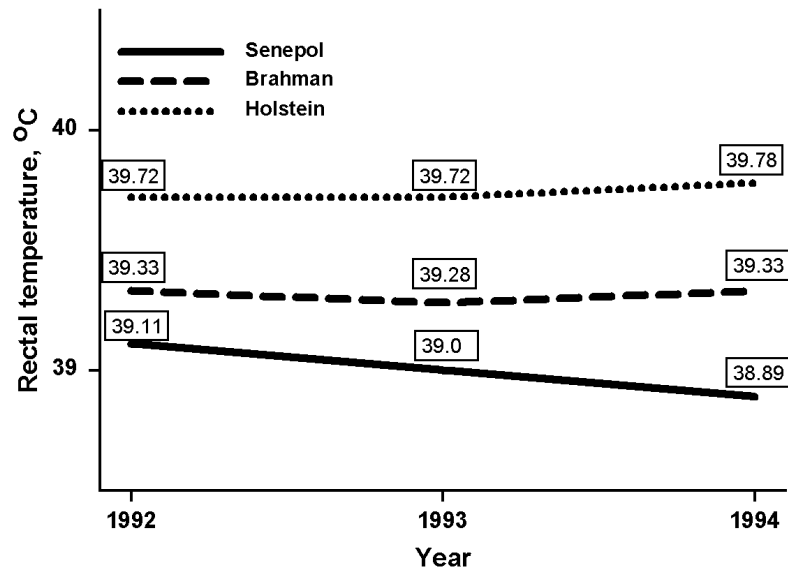


Figure 1. Mean of rectal temperature of heifers by breed and year

maintain constant rectal temperature under high ambient temperatures. Using this basis of evaluation, our study showed that the Senepol and Brahman breeds exhibit similar heat tolerance and adaptability to the hot tropical conditions in the region, while the Holstein breed is lacking in this aspect.

Table 2. Relationship between ambient and rectal temperatures in heifers of three breeds. Means of three years.

Ambient temperature (°C)	Number of observations ¹	Rectal temperature (°C)		
		Senepol	Brahman	Holstein
29	4	38.9	39.2	39.4
30	11	39.1	39.3	39.7
31	9	39.1	39.4	40.0

¹ Number of observations-days with the indicated ambient temperature

Respiratory rate. Important differences in respiration rate were observed among breeds (Table 1). Holstein heifers breathed at an average rate of 81.3 breaths/minute, significantly greater ($P < 0.001$) than that of the Brahman. Senepol were intermediate although still statistically different from the other two breeds. The high rectal

temperature of Holstein heifers could be responsible for their rapid respiration rate as a means of attempting to dissipate excess internal heat to the environment. Inside their comfort zone (10 – 24°C), approximately 75 % of the heat body losses occur by convection, radiation and conduction (McDowell, 1985).

Of greatest interest for the tropics are the physiological reactions of animals when ambient temperatures surpass critically high values. Cattle lose internal heat through evaporation using sweating and by increasing their respiration rate (Blight, 1984; McDowell, 1985). The mean ambient temperature in our study was 30.2 °C, surpassing the critical value for temperate cattle. This temperature stress appears to have been sufficient to explain the elevated respiration rate of the Holstein heifers as they attempted to eliminate excess body heat.

In contrast to rectal temperature, respiration rate has shown to be less stable among breeds across years (Amakiri and Funsho, 1978). In our study, year significantly affected respiration rate ($P < 0.05$), although the interaction with breed was not significant.

Observations presented in Tables 2 and 3 suggest that a critical ambient temperature occurs approximately at 30 °C for the three breeds, above which rectal temperature and respiratory rate increase, particularly in the non-tropically adapted Holstein heifers. Respiratory rate of Holsteins at 31 °C reached 94.5 breaths/minute, slightly more than 1.5 breaths/second. Senepol and Brahman had respiratory rates of less than 1 breath/sec. Since the Holstein heifers had reached rectal temperatures of 40 °C (Table 2), their rapid respiration rate is not surprising. It is also important to indicate that 41.5 °C was the black globe temperature equivalent to an ambient temperature of 31 °C, the temperature at which Holstein heifers began to show extreme stress responses.

Table 3. Relationship between ambient temperature and respiratory rate in heifers of three breeds. Means of three years.

Ambient temperature (°C)	Number of observations ¹	Respiratory rate (breaths/min.)		
		Senepol	Brahman	Holstein
29	7	49.6	36.5	70.4
30	9	51.6	38.2	73.7
31	8	56.5	42.6	94.5

¹ Number of observation-days with the indicated ambient temperature

Temperature-humidity index. The mean temperature-humidity index, as defined by McDowell (1972), was 81.2 over the three years of the study. This value was higher than the value of 72 which Armstrong (1994) indicated was the threshold value for heat stress in lactating Holstein cows and also above the value of 78 that McDowell (1972) suggested as a similar threshold for cattle in general. Kibler and Brody (1950) determined that 27°C was the critical ambient temperature for Holstein cows. Our research was designed to study the effects of naturally occurring hot climatic conditions on the physiological parameters of heifers. It would be speculation on our part to predict the reactions of Holsteins at ambient temperatures below 29°C, however, this temperature was the lowest average recorded during the three-year period. It is also likely that some

measure of acclimation to high temperatures had already occurred in the Holstein heifers used in this study since they, along with their dams, were born, raised and maintained in Puerto Rico. Nevertheless, an ambient temperature of 30°C seems to be the critical temperature at which *Bos taurus* and *Bos indicus* begin to differ in their ability to maintain near normal rectal temperatures and respiratory rates, results that are similar to the findings reported by Spiers et al. (1994). A regression analysis to further determine the caloric stress of the Holstein in the tropics indicates that for every unit of increase in ambient temperature, the response of the Holsteins was three to four times greater than that observed in the Senepol and Brahman. Regression coefficients in Holstein heifers were 0.15°C for rectal temperature and 5.3 breaths/min. ($P < 0.05$) for respiratory rate per degree of increase in ambient temperature.

Hematocrit. Hematocrit percentages of Holstein heifers were the lowest ($P < 0.05$), while those of the Brahman heifers were the highest (Table 4). Senepol heifers were intermediate in hematocrit concentration, confirming the better tropical adaptation of this *Bos taurus* breed. Heat tolerance of breeds has been related to increased hematocrit percentage (Bianca, 1965), and Hammond and Olson (1994) provided a possible explanation. The authors indicated that superior heat tolerance may be a consequence of improved capability to transport oxygen to body tissues, and hence, lower respiration rates are sufficient. Another possible explanation is that the low hematocrit percentage of the Holstein could be due to hemodilution that may occur because of greater water consumption to control body temperature (Brody, cited by Schalm, 1964; McDowell, 1972). Roussel et al. (1969) reported that rectal temperature and respiration rate were negatively related to hemoglobin, oxyhemoglobin and hematocrit concentrations in blood.

Table 4. Hematocrit percentages per breed of heifers. Means and standard deviations.¹

Breed of heifers	Number of heifers	Hematocrit (%) ²
Senepol	32	31.51 ^b ± 2.81
Brahman	32	35.38 ^a ± 3.15
Holstein	32	27.68 ^c ± 2.40

¹ Data of two years (1993 and 1994)

² Means with different letters are significantly distinct ($P < 0.05$)

Weight gain. It is of fundamental importance for the cattle business in the tropics that breeds with better tolerance to high temperature also demonstrate improved productivity. To that end, weight gain of the heifers during the evaluation period was recorded (Table 5). Senepol heifers had similar weight gains to those of the Brahman in spite of starting the study substantially heavier. Both Senepol and Brahman heifers had weight gains ($P < 0.05$) that were superior to those of the Holstein. The Holstein heifers spent more time in the shade (Figure 2) which may have reduced their grazing time and, therefore, forage intake. This behavior, in combination with the extra energy required to eliminate body heat, may explain the low weight gains of Holsteins during the grazing period.

Table 5. Liveweight changes in heifers of three breeds. Means of three years.¹

Breed of heifers	Initial weight (kg)	Final weight ² (kg)	Weight increase ³ (kg)	Daily gain ⁴ (kg)
Senepol	261	308 ^a	47 ^a	0.46 ^a
Brahman	223	280 ^a	57 ^a	0.58 ^a
Holstein	230	258 ^b	28 ^b	0.28 ^b

¹ Data from 100 days of grazing. Means adjusted by initial weight differences.

^{2,3,4} Means with different letters are significantly distinct (P<0.05)

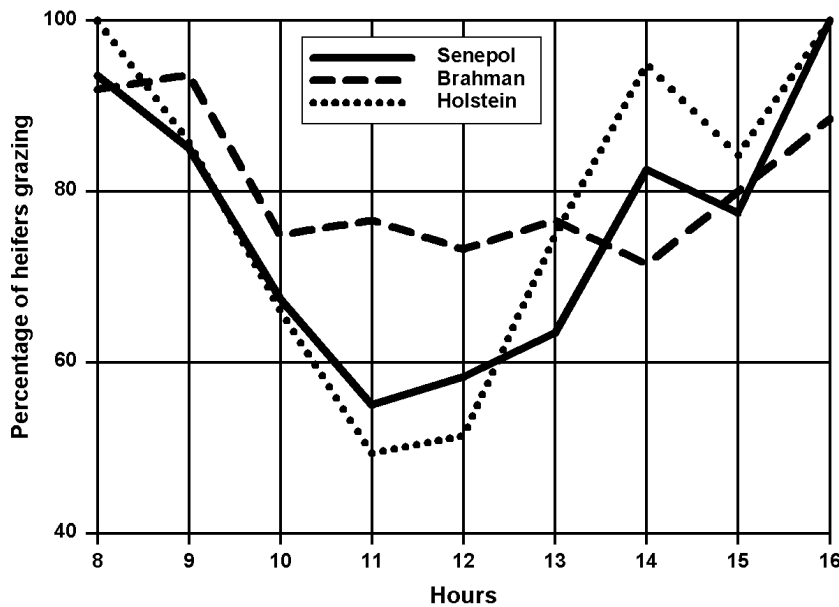


Figure 2. Pattern of hourly grazing of heifers by breed

Grazing behavior. The hourly observations of heifers grazing from 0800 to 1600 for two days every two weeks in 1994 indicated that Brahman heifers spent more time grazing than either Senepol and Holstein, particularly from 0900 to 1300 (Figure 2). During this period, 75 % of the Brahman heifers were observed to be grazing as compared to 61 % of the Senepol and 59 % of the Holstein heifers. The Holstein remained under natural shade (Figure 3) during the hottest hours of the day, grazing only early in the morning and after the mid-afternoon. At around mid-day, 80 % of the Holstein were found in the shade compared to 90 % of Brahman and Senepol that were either resting or grazing in the sun.

Body caloric increment due to digestive metabolism, the high temperatures at mid-day (Table 6), and the difficulty by the Holstein in eliminating excess body heat may explain their grazing behavior. When rectal temperature increases, the first defensive response of an animal is to remain under shade and to stop eating (Bligh, 1984; Robertshaw, 1984). The Holstein heifers reacted, therefore, as expected for a breed that is not adapted to the tropics. These observations agree with reports by Hammond and Olson (1994) in Florida.

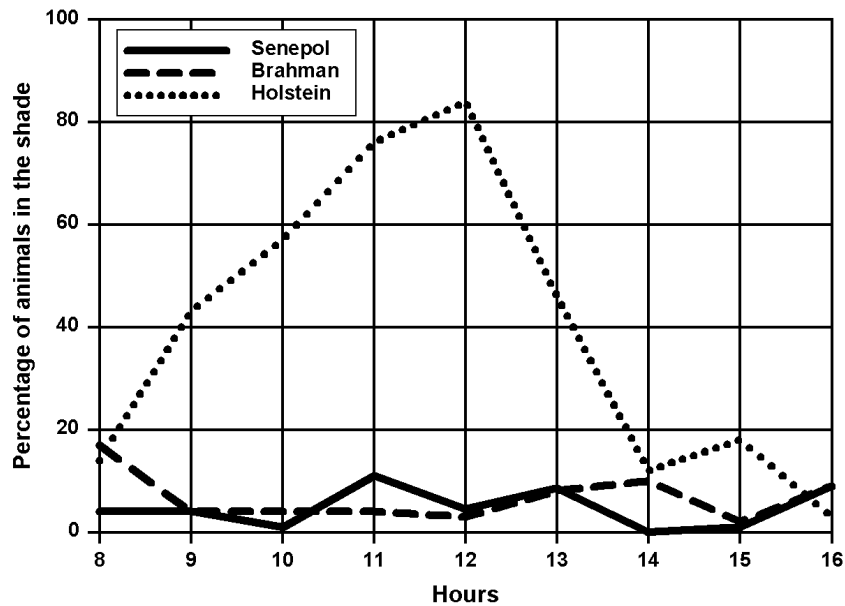


Figure 3. Hourly percentages of heifers under shade by breed

Grazing behavior was similar for all three breeds when black globe temperatures were between 32 and 37 °C (Figure 4). Black globe measurements incorporate the effect of solar radiation upon objects (McDowell, 1985). In our study black globe temperatures above 37 °C resulted in steady decreases in the percentage of heifers observed to be grazing. These decreases occurred in all three breeds, however, the decline was more noticeable in the Holstein heifers. Upon reaching a black globe temperature of 40 °C (33 °C dry bulb), 20 % of the Holstein remained grazing versus 49 % of the Senepol and 55 % of the Brahman. The rectal temperatures of the Holstein heifers averaged 40 °C at the time.

Table 6. Ambient temperatures during the day. Means by hour-periods.

Periods (hours)	Ambient Temperature ¹ (°C)	
	Dry bulb	Black bulb
8:00 - 10:00 am	30.2	33.7
11:00 – 1:00 pm	32.1	36.1
2:00 – 4:00 pm	30.7	33.9

¹ Data from 16-day-observations

Overall results from our study confirm that Senepol, a *Bos taurus* tropically adapted breed, has a similar heat tolerance and growth rate under tropical grazing conditions as the *Bos indicus* Brahman. The similarities of these findings with those reported by Hammond et al. (1996) in Florida, strengthen the possibilities of using the Senepol as an alternative breed to *Bos indicus* in order to improve beef production in the tropics.

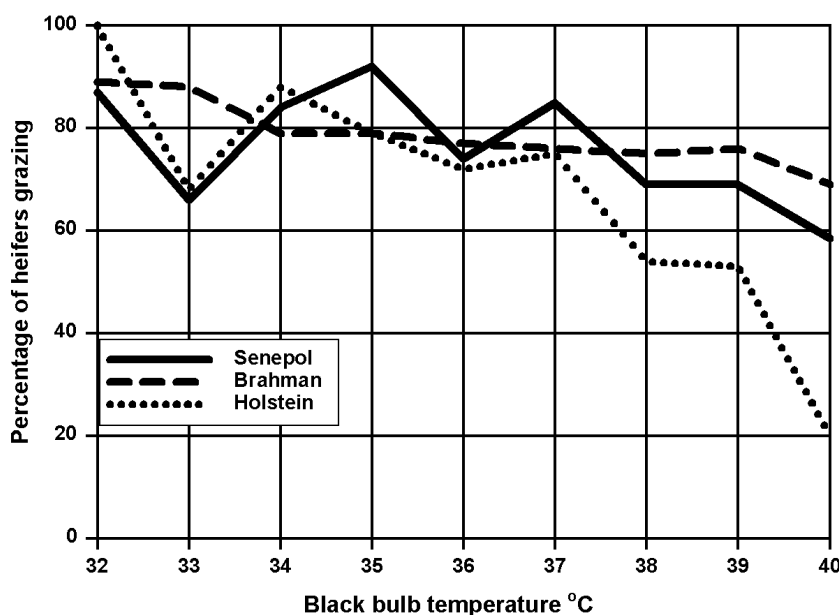


Figure 4. Effect of black bulb temperature and breed on percentage of grazing heifers

Conclusions and Implications

The results from our study indicate the capacity of the Senepol, a *Bos taurus* breed of tropical origin, to tolerate and perform well under the hot-humid climate conditions of northern Puerto Rico. Their rectal temperature was consistent and significantly ($P <$

0.001) lower (39.0 °C) than those of either the Brahman (39.4 °C) or the Holstein (39.9 °C). The respiratory rate and hematocrit levels of the Senepol heifers were intermediate (53.8 breaths/min., and 27.68 %) between the values of the Brahman and the Holstein and they had a grazing behavior similar to that of the Brahman.

On the basis of this study and previous research, the Senepol breed appears as an interesting alternative for use as either a purebred or in crossbreeding programs to improve beef production in the tropics. Research in progress will further evaluate the Senepol breed in these areas of utilization.

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