Voluntary solar radiation exposure and vaginal temperature in slick-haired purebred Senepol and Senepol x Red Angus crossbred heifers[1,2]

Héctor L. Sánchez-Rodríguez[3], Gladycia Muñiz-Colón[4], and Katherine Domenech-Pérez[5]

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ABSTRACT

Senepol is a slick-haired *Bos taurus* breed highly adapted to tropical countries, and their meat is usually low in intramuscular fat. Crossbreeding with breeds more suited to higher marbling scores (e.g., Angus; a wild type-haired breed) may help improve this meat quality trait. However, the question of adaptability to tropical weather in the resulting crossbreeds remains. This study compared the voluntary exposition to direct solar radiation or shade and the vaginal temperatures of slick-haired 50% Senepol - 50% Red Angus (n=5; 50:50), 75% Senepol - 25% Red Angus (n=5; 75:25), and 100% Senepol (n=5; 100:0) heifers in February 2023. Data were analyzed by the GLIMMIX procedure (SAS). The 50:50 heifers recorded lower solar radiation exposure than their 75:25 and 100:0 counterparts at 1100 ($P \leq 0.001$), 1115 ($P \leq 0.0003$), 1130 ($P < 0.0001$), 1145 ($P \leq 0.004$), and 1200 h ($P \leq 0.004$). Respective average values of 20,601.40±3,615.03; 32,627.40±4,437.84; and 32,260.40±4,424.65 lx were observed during this period. No differences in vaginal temperature were observed between heifer groups ($P = 0.8135$), with daily averages of 37.27±0.54, 37.23±0.53, and 37.23±0.54 °C for the 50:50, 75:25, and 100:0 heifers, respectively. Heifers with 50% Red Angus blood needed to spend more time under shade during the hottest hours of the day to maintain a body temperature similar to those heifers with greater Senepol influence.

Keywords: Senepol, Senepol x Red Angus crossbreeds, solar radiation exposure, vaginal temperature, slick-haired

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[3]Professor, Animal Science Department, College of Agricultural Sciences, University of Puerto Rico-Mayagüez Campus.

[4]Former Graduate Student, Department of Horticulture, College of Agricultural Sciences, University of Puerto Rico-Mayagüez Campus.

[5]Associate Professor, Animal Science Department, College of Agricultural Sciences, University of Puerto Rico-Mayagüez Campus.

RESUMEN

Exposición voluntaria a radiación solar y temperaturas vaginales en novillas de pelaje corto Senepol puras y cruzadas Senepol x Angus Rojo

El Senepol es una raza *Bos taurus* de pelo corto altamente adaptada a los países tropicales, donde producen carne usualmente baja en grasa intramuscular. El cruzamiento con razas con mayores índices de marmoleo (e.g., Angus; raza de mayor pelaje) podría ayudar a mejorar esta característica. Sin embargo, las cruzas resultantes podrían perder parte de la adaptabilidad al trópico del Senepol. El presente estudio comparó la exposición voluntaria a radiación solar directa o a sombra y las temperaturas vaginales de novillas de pelaje corto 50% Senepol - 50% Angus Rojo (n=5; 50:50), 75% Senepol - 25% Angus Rojo (n=5; 75:25) y 100% Senepol (n=5; 100:0) en el mes de febrero de 2023. Los datos se analizaron mediante el procedimiento GLIMMIX (SAS). Las novillas 50:50 registraron una menor exposición a la radiación solar directa que las 75:25 y las 100:0 a las 1100 ($P \leq 0.001$), 1115 ($P \leq 0.0003$), 1130 ($P < 0.0001$), 1145 ($P \leq 0.004$) y 1200 h ($P \leq 0.004$). Durante este periodo se observaron respectivos valores promedios de 20,601.40±3,615.03; 32,627.40±4,437.84 y 32,260.40±4,424.65 lx. No se observaron diferencias en temperatura vaginal entre los grupos de novillas ($P = 0.8135$), presentando valores promedios diarios de 37.27±0.54, 37.23±0.53 y 37.23±0.54 °C en las novillas 50:50, 75:25 y 100:0, respectivamente. Las novillas con 50% de sangre Angus Rojo tuvieron que pasar más tiempo bajo la sombra durante las horas más cálidas del día para poder mantener una temperatura corporal similar a aquellas novillas con una mayor influencia Senepol.

Palabras clave: Senepol, cruzas Senepol x Angus Rojo, exposición a la radiación solar, temperatura vaginal, pelo corto

INTRODUCTION

Senepol is a slick-haired (Huson et al., 2014) *Bos taurus* cattle breed (Hammond et al., 1996) developed in Saint Croix, US Virgin Islands, highly adapted to the tropics (Wildeus et al., 1992). In fact, multiple researchers have noted that these animals tolerate elevated environmental temperatures (Hammond et al., 1996) and solar radiation (Sánchez et al., 2016) while eating forages with low nutritional quality (Hays, 1990) and maintaining acceptable growth and reproduction (Lugo-Ruiz, 2019) under tropical and subtropical conditions. However, the meat produced by Senepol cattle may present low marbling scores when the animals are only fed tropical grasses (Hernández-Márquez, 2020). Meat quality characteristics (including intramuscular fat) may be influenced by multiple factors, including nutrition (Guerrero et al., 2013), genetic selection (Vanek et al., 2008), and genotype (Guerrero et al., 2013). Unfortunately, under Puerto Rico's conditions, improving beef quality by nutritional changes may be cost prohibitive. Genetic selection, although effective, consumes a great amount of time and resources (Braga-Magalhaes et al., 2019). Thus, the evaluation of alternatives to improve meat quality in a relatively short time and

without considerably altering farm management practices deserves attention. Crossbreeding with breeds with desirable meat quality attributes has been suggested as an alternative to improve meat quality in tropical countries where cattle diets are based only on grass (Favero et al., 2019). However, such breeds [e.g., Angus, which is a wild type-haired breed (Mariasegaram et al., 2007)] have been developed in countries with temperate environmental conditions, which probably leads to reduced adaptability to tropical environmental conditions in the resulting crossbred offspring. A comparison of voluntary exposure to direct solar radiation or to shade and the vaginal temperatures between Senepol x Red Angus crossbreeds and purebred Senepol heifers could serve as an indicator of adaptation or tolerance to Puerto Rico's weather.

MATERIALS AND METHODS

Animals

We evaluated 15 virgin heifers from Finca Montaña's herd in Aguadilla (Puerto Rico), divided into three groups: (1) 50% Senepol - 50% Red Angus crossbreeds (n=5; 50:50); (2) 75% Senepol - 25% Red Angus crossbreeds (n=5; 75:25); and purebred Senepol (n=5; 100:0). Purebred Senepol heifers were originally artificially inseminated with one of three commercially available Red Angus bulls to produce a group of F1 heifers and bulls. The F1 heifers and bulls were naturally mated (avoiding inbreeding) to obtain the 50:50 heifers. A group of the F1 heifers were naturally mated to purebred Senepol bulls to obtain the 75:25 heifers. The purebred Senepol heifers were obtained from Finca Montaña's herd. The Red Angus breed was used because of its distinguishable meat quality attributes while the Senepol's characteristic red coat color was maintained in the resulting crossbreeds. Heifers' genotypes were balanced by body weight and age (Table 1). Before the study, all heifers were evaluated for the presence of the SLICK1

TABLE 1.—*Average body weight and age for the heifer groups evaluated.* Data are presented as means ± SEM. *All evaluated heifers were genomically slick-haired (heterozygous or homozygous) due to the SLICK1 allele mutation and were red-colored.*

Genotype	Body weight, kg	Age, d
50:50	457.82±16.12	696.60±5.12
75:25	466.27±14.63	696.80±6.46
100:0	440.18±9.55	696.80±3.28
P-Value	0.4172	0.9995

allele mutation (which codifies for a slick-haired coat) by means of the TaqMan Real Time PCR at the Animal Molecular Biotechnology Laboratory (University of Puerto Rico at Mayagüez) following the procedure described by Sosa et al. (2021). All heifers evaluated were slick-haired (heterozygous or homozygous) and red-colored. Heifers were allocated at a grazing paddock with ad libitum access to *Cynodon nlemfuencis* for grazing and water. The experimental grazing paddock had a row of large *Ficus benjamina* and *Ficus elastica* trees at one of the fence lines which provided continuous shade during the day. Heifers voluntarily chose when to be under the shade or exposed to direct solar radiation.

Environmental conditions

Previously, Sánchez-Rodríguez and Domenech-Pérez (2021) validated the use of light intensity sensors (Pendant MX Temperature / Light Data Logger; Onset Computer Corporation, Bourne, MA)[6] as indicators of solar radiation exposure in cattle and the surrounding environment. In this study, light intensity (determined by the aforementioned sensors) and air temperature (TidbiT v2 Water Temperature Data Logger; Onset Computer Corporation, Bourne, MA) sensors were installed on top of the fence posts directly exposed to solar radiation all day (without shade; n=3) and under the shade of the Ficus trees (with shade; n=3) at approximately 1.5 meters high. Both environmental conditions, under direct solar radiation and under shade, were recorded every 15 seconds, from 10 February 2023 at 0600 h through 17 February 2023 at 0700 h. The data obtained (averaged every 15 minutes) are presented in Figures 1 and 2 as descriptive statistics of the existing environmental conditions during the study.

Exposition to solar radiation

The light intensities recorded by a Pendant MX Temperature / Light Data Logger (Onset Computer Corporation, Bourne, MA) attached on top of a nylon cow collar (Nasco, Fort Atkinson, WI) were used as an index of the heifers' voluntary solar radiation exposure as previously validated by Sánchez-Rodríguez and Domenech-Pérez (2021). While restricted in the working chute, each heifer received a collar with the data logger on top and a weight (a chain link weighing an average of 131.8 g) under the neck, to ensure the position of

[6]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

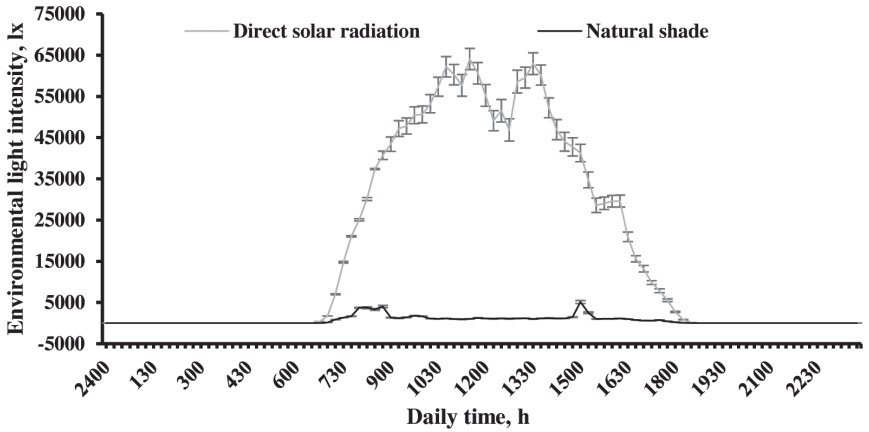

FIGURE 1. Descriptive statistics (means ± SEM) for environmental light intensities (as an indicator of solar radiation) recorded under direct solar radiation exposure (solid gray line) and under the natural shade of the trees at the paddock fence (solid black line).

the data logger (always on top of the heifer's neck). To avoid any unwanted effect of cattle restriction and management over the data obtained, data loggers were programed to record light intensities each 15 seconds beginning at 0600 h the day after heifers received their collars. Data were collected from 10 February 2023 at 0600 h through 17 February 2023 at 0700 h and averaged every 15 minutes for statistical analysis.

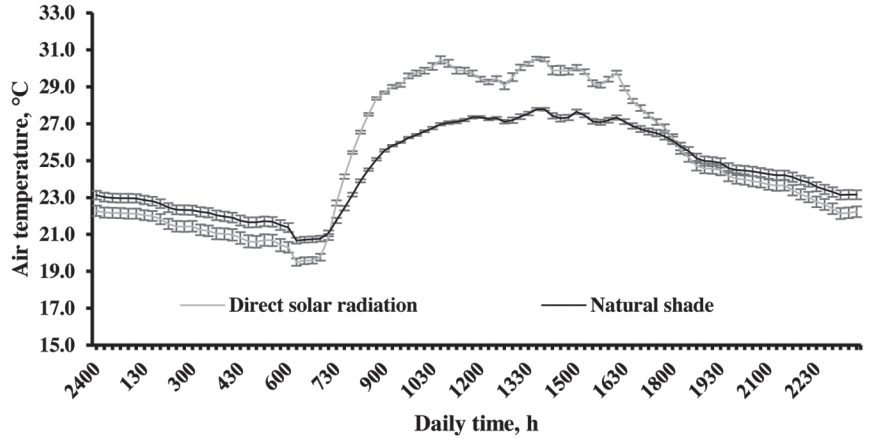

FIGURE 2. Descriptive statistics (means ± SEM) for air temperatures recorded under direct solar radiation exposure (solid gray line) and under the natural shade of the trees at the paddock fence (solid black line).

Vaginal temperature

Concurrently with the nylon collars, all heifers received a blank intravaginal controlled internal drug release device (CIDR) without progesterone (Pfizer Ireland, Dublin, Ireland) tied to a TidbiT v2 Water Temperature Data Logger (Onset Computer Corporation, Bourne, MA) as previously described by Sánchez et al. (2016). Before the insertion, the vulva was washed with soap and water, rinsed with a chlorhexidine solution (Durvet Inc., Blue Springs, MO), and dried with a clean paper towel. The clean CIDR + data logger devices were rinsed with a chlorhexidine solution, dried with a clean paper towel, and covered with obstetrical lubricant (OB Lube; AgriLabs, St. Joseph, MO). Devices were inserted intravaginally by means of a CIDR applicator gun. The data loggers were programed to record vaginal temperature every 15 seconds beginning the day posterior to the insertion of the CIDR + data logger device. Vaginal temperature data were also recorded from 10 February 2023 at 0600 h through 17 February 2023 at 0700 h and averaged every 15 minutes for statistical analysis.

Statistical analysis

Light intensity (voluntary solar radiation exposure) and vaginal temperature data were averaged every 15 minutes for statistical analysis using the GLIMMIX Procedure of SAS. Both the light intensity and vaginal temperature were included as dependent variables of their respective models. The daily time and heifer genotype were included as fixed effects, while the heifer identification number was included as the random effect of the model. Data are presented as means ± standard errors of the means (SEM). Significant differences were detected at a P-Value ≤ 0.05.

RESULTS AND DISCUSSION

Figure 3 shows the light intensity values recorded by the neck sensors on the collars as indicators of solar radiation exposure within each heifer group. Daily time and genotype interacted to affect the light intensities recorded (P=0.0047). At 0815 (P≤0.02) and 0830 h (P≤0.05) the 75:25 heifers showed greater average light intensities than their 50:50 and 100:0 counterparts by 2,848.5 and 8,164 lx, respectively. At 1100 (P≤0.001), 1115 (P≤0.0003), 1130 (P<0.0001), 1145 (P≤0.004), and 1200 h (P≤0.004) the 50:50 heifers recorded lower average light intensities than the 75:25 and 100:0 heifers. The 50:50 heifers' recorded light intensities were 11,010.5; 12,738.0; 14,848.0; 10,474.5; and 10,141.5 lx lower than the average between the 75:25 and 100:0 heifers at 1100, 1115, 1130, 1145, and 1200 h, respectively. At 1415 (P<0.0001) and 1430

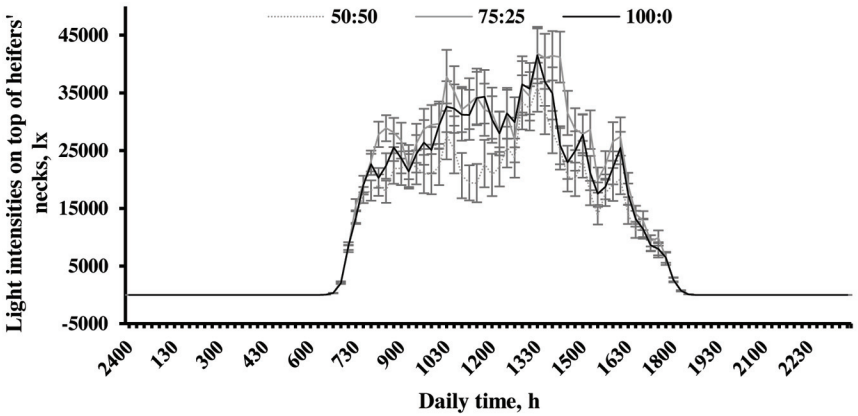

FIGURE 3. Light intensity values (as an indicator of solar radiation exposure; LSMeans ± SEM) recorded on top of heifers' necks; the 50:50 group (dashed gray line), 75:25 (solid gray line), and 100:0 (solid black line) heifers. Daily time x genotype (P=0.0047), daily time (P<0.0001), and genotype (P=0.1091). Ratios represent Senepol : Red Angus blood percentages in the evaluated heifer genotypes.

h (P≤0.009) the 75:25 heifers showed greater average light intensities than their 50:50 and 100:0 counterparts by 15,581.5 and 9,786.0 lx, respectively. At 1445 h (P=0.0080) the 75:25 heifers recorded greater average light intensities than the 50:50 group by 8,700.0 lx. No other differences were observed in the light intensity values recorded by the data loggers on the heifers' collars. In addition, during most of the daytime with solar radiation (Figure 1), all heifers recorded light intensity values (Figure 3) intermediate to those recorded by the environmental sensors under the shade and directly exposed to the sun. This finding suggests that solar radiation exposure occurs intermittently in all heifer groups.

Figure 4 presents the daily vaginal temperature values observed in the evaluated heifer genotypes. No daily time x genotype interaction (P=1.0000) or genotype (P=0.8135) simple effect was observed affecting vaginal temperatures. However, a time (P<0.0001) simple effect affected this variable. As expected, vaginal temperatures showed their minimum and maximum daily values during the morning and afternoon, respectively. Average daily ranges of 36.68 to 37.59 °C (1030 to 1715 h), 36.56 to 37.58 °C (1030 to 1715 h), and 36.67 to 37.48 °C (1030 to 1745 h) were observed in the 50:50, 75:25, and 100:0 heifers, respectively. However, an unexpected increase in this variable, resulting in an additional daily vaginal temperature maximum peak, was observed between 0600 and 0830 h. Between these time points vaginal temperatures averaged 38.35, 38.31, and 38.37 °C in

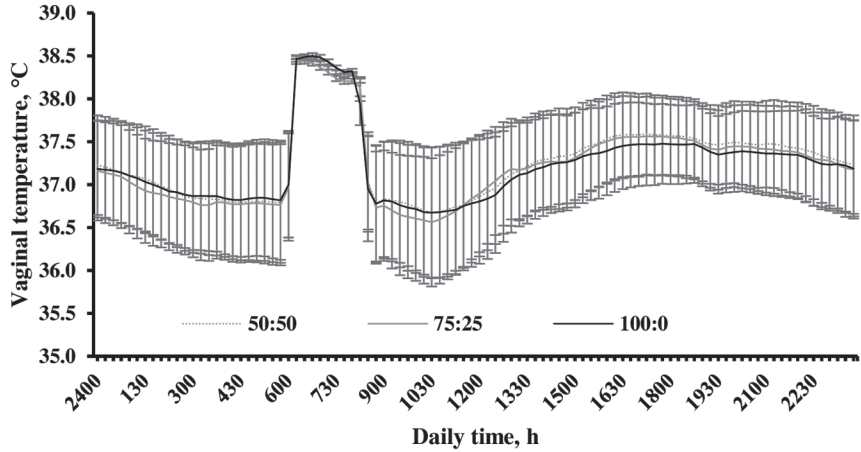

FIGURE 4. Vaginal temperature values (LSMeans ± SEM) recorded of the 50:50 (dashed gray line), 75:25 (solid gray line), and 100:0 (solid black line) heifers during the day. Daily time x genotype (P=1.0000), daily time (P<0.0001), and genotype (P=0.8135). Ratios represent Senepol : Red Angus blood percentages in the evaluated heifer genotypes.

the 50:50, 75:25, and 100:0 heifers, respectively. As observed in Figure 4, the standard error bars were reduced considerably during this period, suggesting that all heifers evaluated were at their maximum body temperature for the existing environmental conditions. Even though it was not part of our study, such a peak could be the result of increased activity allowed by the cool environmental conditions at this timepoint. Sánchez et al. (2016), who observed a similar pattern around midnight and early morning in purebred Senepol and crossbred (Charbray x Senepol x Charolais) heifers during the month of January, suggested the possibility of increased estrus related behaviors or ruminal fermentation as possible reasons for these events. Because the environmental conditions at this time do not represent a source of heat stress, the heifers can express such behaviors freely, without an unhealthy increase in body temperature. Moreover, even when this study didn't intend to evaluate environmental conditions, it is worth noting the apparent inversion in air temperature (Figure 2) observed between day and night. At night the air temperatures recorded by the shaded data loggers appear to be higher than in those representing the unshaded area. This may suggest the agglomeration of heifers under the trees (close by the shaded data loggers) at night with a subsequent concentration of released body heat, creating a warmer microenvironment. Further studies should be directed to evaluate these hypotheses.

Even though seeking shade during periods of high solar radiation is commonly observed in cattle (Tucker at al., 2008), some genotypes may be better adapted to withstand such environmental conditions. For instance, Sánchez-Rodríguez and Domenech-Pérez (2021) observed that slick-haired Puerto Rican Holstein cows spend a greater daily portion directly exposed to solar radiation than their wild type-haired counterparts. It is worth noting that, even when no differences in vaginal temperature were detected between the experimental groups in our study, during the 1100 to 1200 h period [the time of considerably higher solar radiation (Figure 1) and air temperature (Figure 2)], the 50:50 heifers showed lower light intensities than the other groups, reflecting a greater avoidance of direct solar radiation. In fact, Harris et al. (1960) noted that shade can effectively counteract the negative effects that solar radiation exerts on cattle physiology. Even though the 75:25 heifers showed greater exposition to direct solar radiation at some daily time points, environmental solar radiation was not at its highest during these points. Because the trial was performed during the coolest month of the year, avoiding solar radiation was enough to regulate the 50:50 heifers' body temperature. However, based on visual observations in tropical countries, daily grazing behavior is limited when cattle seek the shade during the day. Also, because all evaluated heifers were slick-haired, differences in thermoregulatory capacity recorded in this study may be accounted for by non-evaluated traits, such as sweat glands size and capacity. Thus, future studies ought to evaluate these heifers for productive performance and traits of tropical adaptation.

CONCLUSIONS

Even though all heifers evaluated were slick-haired, during the hotter period of the day (in the coolest month of the year in Puerto Rico), the heifers having 75 and 100% Senepol blood showed greater voluntary exposure to solar radiation than those with 50% Red Angus blood. Such differences in solar radiation exposure were not translated into vaginal temperature differences, suggesting a greater adaptability as the percentage of Senepol blood increases. Future studies ought to evaluate the grazing activity, productive performance, and adaptive traits of these heifers.

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