Diurnal vaginal temperature cycles of Senepol and crossbred beef heifers with different hair coat types and colors under tropical conditions[1,2]

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ABSTRACT

This study evaluated the influence of hair coat type and color on vaginal temperature (VT) regulation of beef heifers. The VT was recorded in five slick-haired, red colored Senepol (SENEPOL); six slick-haired, light-colored crossbred (SLICK); and four wild-type long-haired, light colored crossbred (REGULAR) heifers, every five minutes for four days. Crossbred heifers were obtained from Charbray x Senepol x Charolais crosses. Air temperature and relative humidity were recorded in synchrony with VT for thermal humidity index (THI) calculation. Heifers were kept in a large paddock with access to natural shade. Data were analyzed by the GLIMMIX and CORR procedures (SAS). Hair type-color interacted with the time of day to affect VT; REGULAR heifers registered greater VT than SLICK and SENEPOL from 2200 to 2400 h (39.33±0.03, 38.84±0.01, and 38.74±0.02 °C, respectively). The highest positive correlations between THI and VT were obtained when using the THI value from seven hours earlier in SENEPOL (r=0.25) and SLICK (r=0.30), and from eight hours earlier in REGULAR (r=0.32) heifers. Regardless of color, the short-haired phenotype conferred superior thermoregulatory capacity. We suggest introducing genes for the slick phenotype of the Senepol into other Puerto Rican beef breeds as a means of reducing the negative impact of heat stress.

Key words: heat stress, slick hair, coat color, Senepol, vaginal temperature

RESUMEN

Ciclos diarios de temperatura vaginal en novillas tipo carne Senepol y cruzadas con diferentes tipos y colores de pelo bajo condiciones ambientales tropicales

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Este estudio evaluó la influencia del tipo y color del pelaje sobre la regulación de la temperatura vaginal (TV) en novillas de carne. Se registró la TV, cada cinco minutos durante cuatro días, de cinco novillas Senepol de pelo corto y rojizo (SENEPOL); seis novillas cruzadas de pelo corto y claro (PELONAS); y cuatro novillas cruzadas de pelo largo y claro (REGULARES). Las novillas cruzadas se obtuvieron del cruce Charbray x Senepol x Charolais. También se registró la temperatura y humedad relativa del aire en sincronía con la TV para calcular el índice de temperatura y humedad (ITH). Las novillas ocuparon un cercado grande con libre acceso a sombra. Los datos se analizaron mediante los procedimientos GLIMMIX y CORR (SAS). El tipo-color de pelo interactuó con la hora del día para afectar la TV; siendo las TV mayores en novillas REGULARES que en las PELONAS y SENEPOL entre las 2200 a 2400 h (39.33±0.03, 38.84±0.01, y 38.74±0.02 °C, respectivamente). Se obtuvieron las mayores correlaciones positivas entre el ITH y la TV al usar el valor de ITH observado siete horas previas en las novillas SENEPOL (r=0.25) y PELONAS (r=0.30) y de ocho horas previas en las novillas REGULARES (r=0.32). Independientemente del color, el pelo corto facilitó una superior capacidad termorreguladora. Se sugiere que la introducción de genes para el fenotipo pelo corto provenientes del Senepol en otras razas de ganado de carne puertorriqueño podría ayudar a reducir el efecto negativo del estrés por calor.

Palabras clave: estrés por calor, pelo corto, color de pelo, Senepol, temperatura vaginal

INTRODUCTION

The hot and humid environmental conditions of the tropics cause considerable heat stress in cattle (Kumar et al., 2011). Heat stress results when the animal's means to dissipate body heat are surpassed by its heat gain, resulting in a body temperature increase (West, 2003; Kumar et al., 2011). Such thermal effects limit dry matter intake (Rhoads et al., 2009; O'Brien et al., 2010), decrease rate of weight gain (Ray, 1989; Mitlohner et al., 2001), and impair reproductive function (Biggers et al., 1987; De Rensis and Scaramuzzi, 2003), thus adversely affecting performance in cattle. Selection for heat tolerant breeds in tropical regions is, therefore, imperative to achieve productive efficiency.

Bos indicus cattle possess anatomical and physiological adaptations that confer resistance to heat stress and that are not normally present in most *Bos taurus* breeds. One of these adaptations is the presence of a short-haired coat that allows increased heat dissipation to the external environment (Hansen, 2004). However, *Bos indicus* cattle produce tougher meat (Franke, 1980; Highfill et al., 2011), reach puberty later, and have longer gestation periods (Randel, 2005) than *Bos taurus*, which greatly limits the benefits of introducing the slick-haired phenotype in *Bos taurus* cattle by crossbreeding with *Bos indicus* breeds. Fortunately, there are some exceptions in terms of hair coat type in the *Bos taurus* breeds. Senepol is an early maturing *Bos taurus* breed with a red, short, and sleek hair coat, famous for its adaptation to the tropics (Cianzio, 2002).

Coat color may also be associated with the ability of cattle to withstand thermal stress. In some studies cattle with white or light-colored hair have maintained lower body temperatures than dark-haired animals when exposed to solar radiation (Finch, 1986; Mader et al., 2002; Davis et al., 2003). Such a difference could result from the reflection of radiation of the visible light spectrum from white-colored surfaces (Hunter, 1958); black colored surfaces absorb such radiant energy (Hanrahan and Krueger, 1993). Given that light is a form of energy, it can be neither created nor destroyed, but only transformed into other energy forms such as heat (Richardson et al., 2009); thus light reflection results in less heat absorbed from solar radiation exposure. This phenomenon is of special importance in countries close to the equator where solar radiation is a major challenge to regulating body temperature. The Charolais and Charbray breeds are *Bos taurus* and *Bos taurus* x *Bos indicus* composites, respectively, widely used for beef production in Puerto Rico. Both breeds have white to light cream-colored coats, but the Charolais breed, which originated in temperate France (Ciampolini et al., 2006), has a long and dense coat that may limit body heat dissipation under tropical conditions. However, little is known about the effect of these hair coat characteristics on thermoregulation under local conditions.

The major gene associated with the slick-haired phenotype in Senepol cattle is believed to be of simple dominant inheritance (Olson et al., 2003). Therefore, when Senepol cattle are crossed with regular-haired breeds, some of the offspring will have the slick hair phenotype while others will be normal haired. It has not been determined whether this slick phenotype confers a thermoregulatory advantage on these crossbred animals when dealing with hot and humid weather. The present study was designed to evaluate if hair coat type and color exert an influence on body temperature regulation in Puerto Rican beef cattle exposed to a hot and humid environment and to assess the magnitude of such effects.

MATERIALS AND METHODS

Fifteen non-pregnant beef heifers of the herd at Finca Montaña (Agricultural Experiment Station, University of Puerto Rico, Aguadilla, Puerto Rico) were used. The distribution and characteristics of the heifers are described in Table 1. Five purebred Senepol (SENEPOL; slick and dark red colored hair), six slick-haired crossbred (SLICK;

TABLE 1. –*Description of the groups of heifers used in this study.*

	Hair Type-Color Group		
	SENEPOL[1]	SLICK[2]	REGULAR[3]
N	5	6	4
Age, d[4]	689±21	714±10	713±8
Genotype	100% Senepol	50% Charbray, 37.5% Senepol, 12.5% Charolais	50% Charbray, 37.5% Senepol, 12.5% Charolais
Hair Coat Type	Slick	Slick	Wild type; long and dense
Hair Coat Color	Dark red	Light cream	Light cream

[1]SENEPOL = Purebred Senepol heifers with dark red and slick hair coats.
[2]SLICK = Crossbred beef heifers with cream colored and slick hair coats.
[3]REGULAR = Crossbred beef heifers with cream colored and regular hair coats.
[4]Age values are reported as mean ± standard deviation.

slick and cream colored hair), and four regular-haired crossbred (REGULAR; wild-type long and cream colored hair) heifers were evaluated. The study was conducted from January 28 to 31, 2014; during which time air temperature (AT) ranged from 20.79 to 31.43° C and relative humidity (RH) from 52.74 to 89.75%. Heifers were kept in a large paddock with ad libitum access to tropical grasses and water. Natural shade was available close to the fences of the paddock.

Twenty-four hours previous to the experiment, heifers were restricted in a working chute and implanted with an intravaginal dispositive consisting of a waterproof thermometer (TidbiT v2 Water Temperature Data Logger; Onset Computer Corporation; Bourne, MA)[6] attached to a blank controlled internal drug release device (CIDR; Pfizer Ireland, Dublin, Ireland). Prior to implantation, the genital and surrounding area was washed with surgical soap (Stone, Stone Mfg & Supply, Kansas City, MO) and water, rinsed with a chlorhexidine solution (Nolvasan, Fort Dodge Animal Health, Fort Dodge, IA), and dried with a clean paper towel. The previous day, the CIDRs were washed with soap and water and autoclaved before being attached to the pre-programmed vaginal thermometers. The latter were programmed to measure and record vaginal temperature (VT) every five minutes throughout the study. Once mounted, the complete dispositive (CIDR + vaginal ther-

[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.

mometer) was washed in soap and water, rinsed with a chlorhexidine solution, dried, and lightly covered with a sterile obstetric lubricant (K-Y Jelly, Reckitt Benkshire Group, Slough, Berkshire, UK). The dispositives were inserted intravaginally by means of a CIDR applicator gun.

Three environmental data loggers (HOBO Pro v2 temp/RH Data Logger; Onset Computer Corporation; Bourne, MA) were programmed to record AT and RH values every five minutes in synchrony with the vaginal thermometers. Environmental data loggers were installed in a working facility close to the experimental paddock and protected by artificial shade, but no walls. The AT and RH data were used to calculate the thermal humidity index (THI) by the formula THI = (1.8 x AT + 32) – (0.55 – 0.55 x RH) x [(1.8 x AT + 32) - 58]; where, AT is in° C and RH is expressed as a decimal (Vitali et al., 2009).

All statistical analyses were performed using SAS (SAS Inst., Inc., Cary, NC). Environmental conditions and VT data were averaged by hour. The VT was analyzed as the dependent variable of the model by means of the GLIMMIX procedure of SAS. Time of day (hour) and hair type and color were included as fixed effects, while the heifer's identification number was considered a random effect. Environmental data (THI and AT) were also analyzed as dependent variables of the model by means of the GLIMMIX procedure of SAS. In this model, time of day (hour) was included as a fixed effect. When significant effects were detected, means were separated by the LSD test of SAS. The correlation procedure (Proc CORR in SAS) was used to generate Pearson correlation coefficients to relate THI and VT (data not averaged by hour) in the different hair type and color groups. To study the delayed effect that environmental conditions have on body temperature (lag time), the correlations were performed taking into consideration the THI recorded previous to the VT in one-hour intervals (from 1 to 24 h earlier). Also the correlation between THI and AT was determined. Unless otherwise stated, results are reported as means ± standard error. Significant differences were established at a P value ≤ 0.05.

RESULTS AND DISCUSSION

The daily THI and AT (not averaged by hour) ranged from 64.60 to 93.07 and from 20.79 to 31.43° C. Figure 1 presents the daily trends in THI and AT during the study. Maximum and minimum THI daily values (averaged by hour; $P<0.0001$) were observed at 1500 (81.58±0.80) and 0800 h (71.87±0.80), respectively. Also, the AT reached mean extreme values of 31.12±0.48 and 22.83±0.50° C at the same respective hours ($P<0.0001$). The THI and AT values were highly associated ($r=0.98$; $P<0.0001$); there-

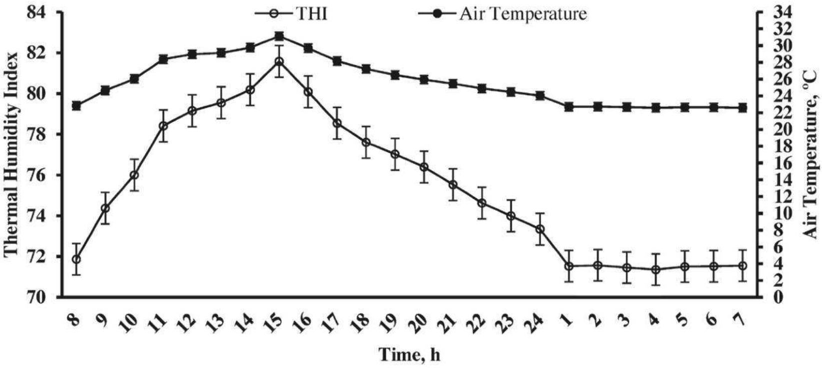

FIGURE 1. Daily thermal humidity index (THI) and air temperature trends during the study. Data are presented as means ± standard error.

fore, both variables gave similar information about the environmental conditions during the present study. Other investigators have evaluated the critical environmental conditions under which a cow's mechanisms for heat dissipation become insufficient and physiological responses to heat stress are observed. Zimbelman et al. (2009) reported that the critical THI values for heat stress in dairy cattle are between 68 and 72. Relative to this standard, the heifers in this study were exposed to THI conditions exceeding the critical values of 68 and 72 during 96 and 64% of the day, respectively. As for the AT, the threshold for heat stress has been reported to be between 20.6 and 25.6° C in beef cattle (Lefcourt and Adams, 1996) and between 25 and 26° C in dairy cattle (Berman et al., 1985). The AT exceeded the proposed critical values of 20.6, 25.6, 25, and 26° C during 96, 23, 27, and 22% of the day, respectively. Therefore, in accordance with the literature, even when the present study was performed during the coolest season of the year (January) these animals were exposed to stressful environmental conditions.

Figure 2 shows the daily VT trends observed in the different hair type and color groups. Hair type and time of the day interacted to affect VT ($P<0.0001$). From 2200 to 2400 h REGULAR heifers presented higher VT values than their SLICK and SENEPOL counterparts (39.33±0.03, 38.84±0.01, and 38.74±0.02° C, respectively; $P<0.0001$). During the remaining daily time period (0100 to 2100 h) all three hair type-color groups presented similar VT values (38.75±0.01, 38.62±0.01, and 38.51±0.01° C for REGULAR, SLICK and SENEPOL heifers, respectively; $P>0.05$). The REGULAR heifers' VT peaked at 2200 to 2400 h when diurnal environmental conditions were approaching their coolest point. A dense and long-haired coat has been reported to act as a physical barrier that limits heat

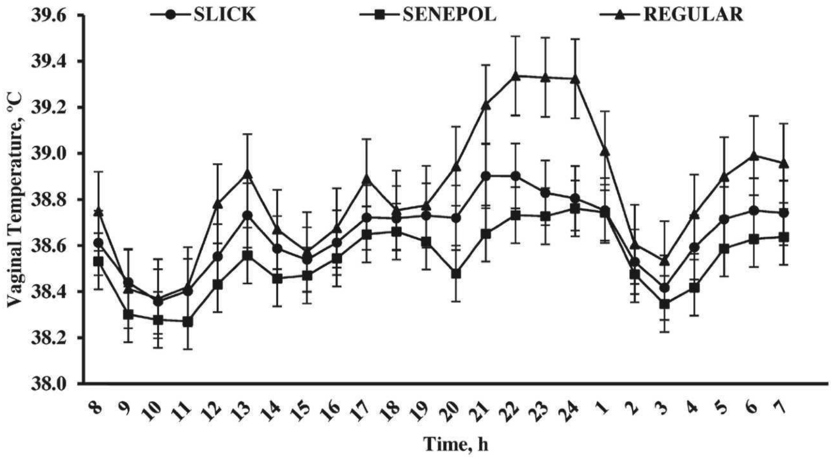

FIGURE 2. Daily vaginal temperature trends in beef heifers with different hair coat types and colors. REGULAR heifers were cream colored with long and dense hair coats; SLICK heifers were cream colored with slick hair coats; and SENEPOL heifers were dark red colored with slick hair coats. Data are presented as means ± standard error.

dissipation from the animal's skin to the air, resulting in body heat storage with a subsequent prolonged increase in body temperature (Finch, 1986). Therefore, the VT differences observed may be attributed to lower heat dissipation efficiency in the REGULAR heifers.

Minimum daily VT values ($P<0.0001$) were observed at 0900-1100 h (38.28±0.12° C), 1000-1100 h (38.38±0.14° C), and 0900-1100 h (38.40±0.17° C) in the SENEPOL, SLICK and REGULAR heifers, respectively ($P<0.0001$; Figure 2). At the time when mean daily VT began to increase (1100 h), mean daily THI was 78.41±0.78 and AT was 28.36±0.48° C. The same three respective groups of heifers presented maximum daily VT values ($P<0.0001$; Figure 2) at 2200-0100 h (38.74±0.12° C), 2100 h (38.90±0.14° C), and 2200-2400 h (39.33±0.17° C). After these peaks, mean daily VT began to decrease when mean daily THI and AT reached values from 73.34±0.78 to 75.53±0.78 and from 24.04±0.48 to 25.46±0.48° C. Therefore, these heifers, especially the SENEPOL withstood more severe environmental conditions without a thermal response than those previously proposed as threshold conditions [68 to 72 THI units (Zimbelman et al., 2009) or 20.6 to 26° C of AT (Berman et al., 1985; Lefcourt and Adams, 1996)]. Senepol is a heat tolerant (Hammond et al., 1996) beef breed developed in the Caribbean tropics and introduced to Puerto Rico more than 30 years ago (Cianzio, 2002). Bligh and Johnson (1973) stated that heat tolerance may be acquired by acclimatization or adaptation. They defined the term "acclimatization" as the phenotypic changes that occur in an animal in response to a change in climatic conditions; whereas "adaptation" refers to genetically fixed characteristics that provide the animal with a superior capacity to survive in a particular stressful environment and may result from genetic selection. Since Senepol is a breed that was originally selected for heat tolerance and subjected to further selection across several generations under the thermally stressful environmental conditions of Puerto Rico, it seems likely that some degree of further "adaptation" has been achieved.

Secondary unexpected minimum VT levels ($P<0.0001$) were observed at around 1500 and 0300 h in all three experimental groups. Similarly, unexpected maximum VT peaks ($P<0.0001$) were also observed at around 1300 and 0600-0700 h. The heifers were maintained in a large paddock with natural shade available close to the fences. Therefore, even though physical activity data were not recorded, it is possible that after daily VT values began to increase, heifers went to rest in the shade to avoid further body temperature increases. Once body temperature had recovered, heifers may have moved out of the shade to graze again resulting in a subsequent increase in VT. This assumption may help explain the VT peak observed at 1300 h. Early morning before sunrise is the coolest part of the day, which might logically allow heifers to efficiently dissipate body heat resulting in a decrease in their core body temperature. However, the opposite was observed; VT peaked between 0600 and 0700 h. Because physical activity (Sánchez-Rodríguez et al., 2013) and ruminal fermentation (Wahrmund et al., 2012) produce additional body heat, cattle exposed to heat stress tend to avoid or minimize behaviors that require muscular effort and to decrease feed intake in order to decrease metabolic heat production. When thermal homeostasis is reestablished, cattle may increase such behaviors and activities without compromising their physiology. Therefore, the 0600-0700 h maximum VT peak may be the result of a greater rate of behaviors that require physical activity, such as estrus expression and grazing, and/or the effect of a greater ruminal fermentation rate. However, such observations were not made in the present research and future studies should be directed toward evaluating these hypotheses.

Some research supports the hypothesis that white or light colored hair coats are associated with lower body temperature in cattle (Finch, 1986; Mader et al., 2002; Davis et al., 2003). White is the result of the complete reflection of the colors of the visible light spectrum (Hunter, 1958), thus light colored cattle should absorb less heat from solar radiation in the visible spectrum than dark colored cattle. Senepol cattle have a slick hair coat, but it is of a dark red color, which might reasonably be expected to absorb more heat from solar radiation. However, the results of this study fail to show such an effect; the dark red SENEPOL heifers presented VT values similar to those of the cream-colored SLICK heifers (Figure 2). In fact, while not different (P=0.5137), mean daily VT was numerically lower in SENEPOL than in SLICK heifers (38.54±0.01 and 38.65±0.01° C, respectively). Moreover, the REGULAR cream-colored heifers presented greater VT values than their SENEPOL and SLICK counterparts during part of the day. Apparently, the dark-colored coat of Senepol cattle does not have a significant effect on their efficient dissipation of body heat and maintenance of thermal homeostasis under tropical environmental conditions, as opposed to some previous findings (Finch, 1986). This observation should be expected because the Senepol breed originated in the tropics and the slick hair of these animals may allow for considerable heat dissipation to the external environment (Flori et al., 2012). In fact, King et al. (1988) reported that if regular-haired Holstein cows were cooled during the first 130 days of lactation, no differences were observed in milk yield between predominantly black and predominantly white cows. Thus, it appears that if the capacity of heat dissipation exceeds the heat gain from solar radiation, no differences associated with coat color will be observed. Also, the crossbred heifers of the present study had considerable Charolais influence (Table 1). The Charolais beef breed originated in France, a temperate region of the world (Ciampolini et al., 2006). Thus, it might be reasonably expected that these animals possess additional adaptations (other than long and dense coats) to conserve body heat under cold weather. Therefore, even if their light hair coat color may favor less environmental heat absorption, other Charolais related adaptations might limit body heat dissipation. One possible adaptation might be a limited number and small size of sweat glands. Cattle adapted to hot environmental conditions such as Senepol (Fernandes, 2008) and *Bos indicus* (Hansen, 2004) breeds are known to have sweat glands of greater density and size than other breeds thus favoring heat dissipation through evaporation. Future studies should be directed toward evaluating such possible adaptations.

Table 2 presents the relationships between VT and THI observed during the present study in real and lag time. Even when environmental conditions are well known to influence body temperature in cattle (West, 2003), in this study, the real time THI had a limited negative impact on VT in all hair type-color groups (P<0.0001). However, with each one hour in lag time the influence of THI on VT increased linearly until the greatest positive influence was observed at a 7 h lag time in SENEPOL and SLICK heifers, and 8 h lag time in REGULAR heifers (P<0.0001). Thereafter, from 8 to 17 lag time hours the impact of THI on VT decreased linearly in all three groups until reaching negative values (P<0.0001). However, from 8 to 12 lag time hours the THI influence on VT was greater in REGULAR heifers than in their SENEPOL and SLICK counterparts. Also, from 17 to 24 lag time hours the THI exerted a greater negative impact on VT in REGULAR than in the SENEPOL and SLICK heifers. Bovines are homeotherms, a term applied to animals that require maintaining their body temperature within a narrow range for a proper physiology (Boone and Bucklin, 2009). Metabolic heat and environmental heat are the main thermal sources in these animals (West, 2003). Under hot and humid environmental conditions cattle employ several heat dissipation mechanisms in an attempt to maintain a suitable body temperature, including evaporation, conduction, radiation, and convection (West, 2003). These mechanisms will allow the animal to avoid significant body temperature increases until their capacity is exceeded by the severity of environmental conditions, thus resulting in a delayed body temperature increase response. Therefore, when evaluating environmental effects on the animal's thermal status, such a lag period should be considered. Also, regular hair coats trap water vapor close to the skin decreasing the efficiency of heat dissipation through sweat evaporation (Finch, 1986), which exacerbates the environmental thermal effects.

In the present data, THI values only explained up to about 30 percent of the daily variation in VT (Table 2). Similarly, previous results consistently showed correlations between VT and THI in Puerto Rican beef cattle in the range of 0.20 to 0.30 (Acevedo et al., 2014; Castro et al., 2014). Other researchers have reported similar correlation coefficients when evaluating the relationship between THI and the tympanic (r=0.26; Gaughan et al., 2008) or vaginal (r=0.30; Nabenishi et al., 2011) temperatures in beef and dairy cattle, respectively. Therefore, a considerable portion of the thermoregulatory differences observed must be the result of other environmental factors. Solar radiation has important thermoregulatory effects (Harris et al., 1960; Collier et al., 2006; Mader et al., 2006). In Texas, Harris et al. (1960) found correlations between solar radiation and body temperature in dairy cattle in the range of 0.54 to 0.83. In Florida, Collier et al. (2006) reported that the use of shade could reduce the heat load of dairy cattle by 30 to 50%. The environmental data loggers used in the present experiment only had the capacity to record AT and RH (used for the THI calculations). In fact, these data loggers are white-colored and were protected from direct solar exposure to limit heat gain from solar radiation. Also, the THI measurements do not account for the effect of solar radiation exposure (Collier et al., 2006). Therefore, solar radiation may well be one of other variables responsible for a considerable portion of the observed thermoregulatory effects. Future studies, including the evaluation of such effects, could contribute to knowledge about the thermal status of Puerto Rican cattle.

TABLE 2.—*Correlations between vaginal temperature and the thermal humidity index in real and lag time in the different hair type-color groups.*[1]

	Vaginal Temperature		
THI Lag Time, h	SENEPOL[2]	SLICK[3]	REGULAR[4]
0 (Real Time)	-0.12 <0.0001	-0.16 <0.0001	-0.14 <0.0001
1	-0.02 0.1422	-0.08 0.0007	-0.06 0.0015
2	0.07 <0.0001	0.05 0.0069	0.03 0.2246
3	0.16 <0.0001	0.16 <0.0001	0.13 <0.0001
4	0.21 <0.0001	0.21 <0.0001	0.24 <0.0001
5	0.22 <0.0001	0.22 <0.0001	0.21 <0.0001
6	0.23 <0.0001	0.24 <0.0001	0.26 <0.0001
7	0.25 <0.0001	0.30 <0.0001	0.28 <0.0001
8	0.24 <0.0001	0.27 <0.0001	0.32 <0.0001
9	0.20 <0.0001	0.23 <0.0001	0.29 <0.0001
10	0.15 <0.0001	0.17 <0.0001	0.26 <0.0001
11	0.10 <0.0001	0.12 <0.0001	0.22 <0.0001
12	0.08 <0.0001	0.07 0.0007	0.15 <0.0001
13	0.02 0.1997	-0.02 0.3521	0.05 0.0347
14	-0.05 0.0084	-0.10 <0.0001	-0.06 0.0134
15	-0.12 <0.0001	-0.18 <0.0001	-0.17 <0.0001
16	-0.20 <0.0001	-0.25 <0.0001	-0.28 <0.0001
17	-0.27 <0.0001	-0.29 <0.0001	-0.33 <0.0001
18	-0.28 <0.0001	-0.27 <0.0001	-0.33 <0.0001

[1]Values are Pearson correlation coefficients over their respective P-Values.
[2]SENEPOL = Purebred Senepol heifers with dark red and slick hair coat.
[3]SLICK = Crossbred beef heifers with cream colored and slick hair coats.
[4]REGULAR = Crossbred beef heifers with cream colored and regular hair coats.

TABLE 2.—(Continued) *Correlations between vaginal temperature and the thermal humidity index in real and lag time in the different hair type-color groups.*[1]

	Vaginal Temperature		
THI Lag Time, h	SENEPOL[2]	SLICK[3]	REGULAR[4]
19	-0.25 <0.0001	-0.22 <0.0001	-0.29 <0.0001
20	-0.22 <0.0001	-0.20 <0.0001	-0.29 <0.0001
21	-0.21 <0.0001	-0.20 <0.0001	-0.29 <0.0001
22	-0.20 <0.0001	-0.21 <0.0001	-0.30 <0.0001
23	-0.17 <0.0001	-0.19 <0.0001	-0.28 <0.0001
24	-0.13 <0.0001	-0.14 <0.0001	-0.23 <0.0001

[1]Values are Pearson correlation coefficients over their respective P-Values.
[2]SENEPOL = Purebred Senepol heifers with dark red and slick hair coat.
[3]SLICK = Crossbred beef heifers with cream colored and slick hair coats.
[4]REGULAR = Crossbred beef heifers with cream colored and regular hair coats.

CONCLUSION

In beef cattle, the slick hair phenotype was shown to confer superior thermoregulatory capacity under hot and humid environmental conditions regardless of hair coat color. Interestingly, in the present study the THI had only a limited influence on the VT, and its effect was lagged in time for a longer period in crossbred heifers with long and dense hair coats than in the slick-haired heifers. Incorporation of genes determining the slick-haired phenotype obtained from the Senepol breed into other *Bos taurus* breeds used for beef production in Puerto Rico could be an efficient way to reduce the negative impact of heat stress on animal performance. Future studies should determine the influence that solar radiation exerts on the daily thermoregulatory capacity of beef cattle raised under hot and humid environmental conditions. Also, physical activity and ruminal fermentation during the coolest hours of the day should be evaluated in order to achieve a better understanding of the vaginal temperature trends observed during this period.

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