Impact of Hair Coat Differences on Rectal Temperature, Skin Temperature, and Respiration Rate of Holstein X Senepol Crosses in Florida

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Summary

The effect of hair type on rectal temperature, skin temperature, respiration rate, and feed intake under confinement in ¾ Holstein: ¼ Senepol crossbred cattle was studied during the summer of 2000 at two locations in Florida. The hair type was classified subjectively as 1) "slick", very short, sleek and shiny and, 2) normal, similar to that of purebred Holstein cattle of the same age. The visual hair differences were quantified by collecting clipped hair samples. The hair samples were weighed, and slick animals averaged 11.47 mg/cm^2 as opposed to 17.82 mg/cm^2 for normal haired animals. Clipped hair weight was also lower ($P < 0.05$) in black as compared to white areas of the same spotted animals. The rectal temperatures of animals classified as slick was 0.34° C ($P < 0.05$) lower than that from normal-haired animals. The skin temperatures of slick animals was 0.49° C ($P < 0.05$) lower than that of normal haired animals while the respiration rate of slick animals was 12.4 ($P < 0.05$) breaths per minute less than that of animals with normal hair. The impact of hair type on feed intake was not significant, perhaps because the animals where not fed under a high level of heat stress. Greater differences in rectal temperatures might also be expected in cattle which were under greater heat stress due to lactation or grazing with a lack of shade.

Introduction

It is estimated that 75% of the cattle that are milked in the tropics of Latin America are dual-purpose animals (Vaccaro et al, 1994). Such cattle must be adapted to the local conditions because the majority of the producers in these areas do not have the economic resources to alleviate heat stress through fans, sprinklers, artificial shade, etc. as we do in the southern areas of the U.S. Dual-purpose cattle in the American tropics usually must produce on grazed forage, with natural shade from trees being their only protection from the climate. In the U.S. we have utilized a number of improvements in management and facilities all designed to reduce the impact of heat stress on dairy cattle. In spite of these advances, high embryonic mortality and low pregnancy rates during periods of high ambient temperatures continue to be a problem. During periods of heat stress, pregnancy rates as low as 15% can be observed due to poor heat detection and increased embryonic mortality (Hansen and Aréchiga, 1999).

The majority of the world's widely used breeds of cattle were developed in temperate zones and were selected for production in that environment, possibly resulting in animals that are more

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sensitive to the heat stress of tropical environments. Breeders in tropical regions, on the other hand, have been unsuccessful at improving breeds of livestock native to the tropics to adequate levels of milk production. Because of this, the development of dairy cattle of *Bos taurus* origin that are more resistant to heat stress would be very useful.

Senepol cattle are quite tolerant of the high temperatures and humidity of Florida, conditions under which Holstein cattle often suffer. Studies conducted in Florida (Hammond and Olson, 1994; Hammond et al., 1996, 1998), Puerto Rico and Venezuela (Lucena and Olson, 2000) have shown that breeds of cattle with short, sleek hair coats possess good heat tolerance, maintaining rectal temperatures up to 0.50° C lower than those of unadapted, temperate breeds. Olson et al. (2003) have also demonstrated that the short hair of the Senepol; designated as "slick", is controlled by a single dominant gene. A number of criollo or criollo-influenced breeds of Central and South America, including the Reyna of Nicaragua, the Criollo Limonero and the Carora of Venezuela, and the Chino Santandereano, the Blanco Orejinegro, and the Romosinuano of Colombia possess the type of hair coat produced by the *slick hair* gene.

In this study, the environment–animal interaction during thermal stress was quantified through environmental measurements (ambient temperature, black globe temperature, relative humidity) and the physiological measurements of cattle (rectal temperature, skin temperature, respiration rate) were evaluated. The physiological differences among animals with similar genetic composition but differentiated by the presence of a short, shiny, "slick" hair coat or a normal Holstein type hair coat were quantified. The objective of this study was the characterization of the differences in the effects of heat stress on the normal and slick-haired Holstein x Senepol crossbred animals.

Materials and Methods

Data for this study were collected from 30 Senepol x Holstein crossbred heifers and bulls. The breed composition of the cattle included nine Senepol x Holstein F_1 and 21 ¾ Holstein: ¼ Senepol animals. The ¾ Holstein: ¼ Senepol were produced from two Senepol X Holstein F_1 cows via embryo transfer and were the progeny of two registered Holstein bulls. The data for the first experiment were collected from August 1999 to June 2000 at the Subtropical Agricultural Research Station (STARS; 28° 37' N latitude, 82° 22' W longitude) located near Brooksville, Florida. A second experiment was conducted at the Beef Research Unit (BRU; 82° 17' W latitude, 29° 45' N longitude) of the University of Florida, which is located 12 miles NE of Gainesville, Florida.

In the first experiment, rectal temperatures (RT) were measured monthly beginning in August of 1999 and ending in June of 2000 for a total of 11 measurement dates. Rectal temperature measurements were made with a microprocessor thermometer. Respiration rate (RR) data were collected at the same time. Breaths per minute (BPM) calculations were made from the measurements of movements of the flanks in a given period of time as recorded with a chronometer, and were standardized to one minute. The relative humidity (RH) of the air was calculated using a sling psychrometer. Black globe thermometers were placed in sunny and shaded areas to register the black globe temperature (BGT). This measurement is important because it not only accounts for environmental temperature, but is also affected by radiation and air movement. Ambient temperature (AT) was registered with a dry bulb thermometer in an area adjacent to that where the records were taken. A temperature-humidity index (THI) was used to characterize the heat load. The THI was calculated as follows: THI = .8AT + RH x [(AT – 14.3)

+ 46.3], where RH is expressed in decimal form.

At the STARS, the cattle grazed throughout the year on improved pastures, which were primarily bahiagrass (*Paspalum notatum*). Supplemental feeding was practiced during the winter period, and because of an extremely dry spring in 2000, supplementation lasted through May. At the BRU, the cattle used were a sample of the ¾ Holstein: ¼ Senepol described previously. They were sorted by sex into groups and placed in feedlot pens with individual feeders. The pens had a shaded portion over the feeders, however, this shaded area was not enough to have all the animals sheltered at the same time. The corrals where the animals were penned prior to measurement offered natural shade, and the chute where the measurements were taken was roofed. Each individual feeder was equipped with a Calan gate (American Calan, Inc., Northwood, NH.) Each Calan gate could be opened only by a single animal as determined by a transmitter suspended from its neck. This allowed the feed intake for each animal to be quantified. Individual feed intake was calculated from the difference between the weight of the feed offered and that of the feed refused. The diet was composed of approximately 25% cottonseed hulls, 24% soybean hulls, 20% alfalfa hay, 14% ground corn, 12% citrus pulp, 4% soybean meal, and minerals. The animals were initially offered about 2% of their body weight of this diet (on a dry matter basis) daily. They were gradually offered more feed when they consistently consumed all the feed offered.

The hair coat was evaluated visually and classified as either "slick", short and shiny, typical of that of the Senepol breed, or as normal, similar to that of Holsteins. Previous studies (Olson et al., 2003) had indicated that classification into additional categories based on apparent hair length/quantity was not necessary. Hair coat type was also estimated quantitatively from the weight of samples clipped from each animal. The hair was clipped from an area of 57 cm^2 on the right loin, 12 cm below the spine. The hair sample was taken with an electric clipper. Separate hair samples for each color were collected from the black and white areas of spotted cattle. The same location was used to measure skin temperature in the second experiment. An infrared thermometer was used to measure skin temperature. The measurements were taken from the shaved area to record the skin temperature without hair interference. The shaving of these areas was repeated at least once a week. Infrared thermometers have only rarely been used in animal research but are widely used for ear temperature measurement in human medicine (Stavem et al, 1997). Skin temperatures, as well, are rarely reported in animal literature (Goodwin, 1998); however, we think they may be useful for identification of differences between slick and normal-haired animals.

The second experiment was conducted during the summer of 2000, beginning July 14, and ending August 27th, 2000. The cattle had a one-week adaptation period before data were collected. Data collection occurred between 2:00 PM and 3:00 PM, Tuesday through Saturday. All environmental conditions were recorded in the same fashion as in the first experiment. The black globe temperatures from sunny areas were classified in four classes, Black Globe Temperature Class (BGTC) 1, less than 40.0° C; BGTC 2, between 40.0° C and 44.9° C; BGTC 3, between 45.0° C and 50.0° C; and BGTC 4, more than 50.0° C. Each class was formed to have similar numbers of observations. This time frame was chosen for the study as summer weather conditions were expected to provide the heat stress necessary to fulfill the objectives of the experiment.

All data were analyzed using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS). Sex effects were not significant ($P < 0.01$) in the initial analyses;

therefore, sex was not included in the final model. The RT data from the first experiment were analyzed with hair type as the only independent effect, and each month was evaluated as a separate dataset. The RT, ST, and BPM analyses of the second experiment were accomplished using a Repeated Measurements model (Littell et al, 1998) from the GLM procedure of SAS. Least squares means are reported for each variable. The final model of these data included the fixed effects of hair (H), BGTC, and the interaction between H and BGTC.

Results and Discussion
   Experiment 1: Weather conditions were recorded while the physiological information was being obtained and the highest ambient temperature during experiment 1 at STARS was 35.5° C in June of 2000. The same day THI reached 103 and the relative humidity was 44%. The lowest AT was 21° C at the end of February of the same year; the THI (73) that day was also the lowest measured during the study. The temperature-humidity index is used as an indicator of stress in humans and livestock.
   Environmental information, including THI, did not affect the physiological data measured during experiment 1 at the STARS. This fact was evident when we calculated the correlations between THI and RT. The correlations between THI and RT for normal and skick-haired animals were -0.10, $P > 0.76$; and -0.35, $P > 0.29$, respectively. These low correlations between weather and physiological data at the STARS may be due to the fact that the physiological data were measured only once per month, without consideration of previous days' conditions. Since climatic variations, such as heat wave peaks, might affect animals for several days (Valtorta, 1999), perhaps this is responsible for the low correlation between THI and RT in the STARS data. The pastures utilized at the STARS all included shade and this may have helped to avoid any excessive heat load. In addition, the chute where the measurements were taken was roofed and the corral where the cattle were penned prior to the measurement included shaded areas which should have helped to alleviate any extreme environmental stress.
   The rectal temperatures for slick-haired animals were lower during September (normal = 39.7, slick = 39.4° C; $P < 0.05$) and October (normal = 39.8, slick = 39.3° C; $P < 0.05$), while the difference was not significant from November (normal = 39.9; slick = 39.7° C; $P < 0.31$) through June in the year long experiment at the STARS. These results were not particularly surprising, as the advantage of shorter hair should manifest itself during hot weather. Frisch (1981) reported that under a lack of heat stress there was no advantage in productivity of animals with greater heat tolerance. The fact that normal-haired animals were able to maintain RT similar to those of slick-haired animals during cool weather suggests that their productivity should not be different in these conditions. The average daily gain over the entire year did not differ between slick, (1384 vs. 1345 g/day; $P < 0.10$), compared to normal-haired cattle. This is comparable to that observed by Olson et al. (2003) in slick and normal-haired Angus and Charolais crossbred cattle at the same location.

Experiment 2: Environmental conditions during the experiment at the BRU were somewhat harsh, considering that the average ambient temperature at the time of the measurements was 32.7º C and the average THI was 99.7. The highest AT was 36º C on August 9, 2000 and the highest THI of 107 occurred the same day. The BGT in unshaded areas was also the highest at 56.5º C on August 9. Under these conditions cattle with slick hair coats had lower (P < 0.05) rectal temperatures, 38.9 vs. 39.3º C (P < 0.05), skin temperatures, 37.5 vs. 38.0º C (P < 0.05), and respiration rates, 56.6 vs. 69.0 BPM (P < 0.05), than normal-haired cattle (Tables 1 and 2).

Table 1. Measurements of rectal (RT) and skin temperatures (ST) in ¾ Holstein ¼ Senepol cattle in Florida, by hair type.

Hair Type	Days Measured	No.	RT, °C	ST, °C
Slick	24	8	38.99	37.49
Normal	24	8	39.32	38.03
Difference			-0.33*	-0.49*

* Means differ P < 0.05

Table 2. Measurements of respiration rates (BPM) in ¾ Holstein ¼ Senepol cattle in Florida, by hair type.

Hair Type	Days Measured	No.	BPM
Slick	24	7	56.61
Normal	24	8	69.02
Difference			-12.4*

* Means differ P < 0.05

Slick-haired animals maintained lower (P < 0.05) RT than normal-haired animals (38.9 vs.39.3º C) throughout experiment 1 (Table 1). The differences in RT between slick and normal-haired animals did not differ among BGTC. Both slick and normal-haired animals maintained similar RT across the BGTC and the advantage of the lower RT of slick over normal-haired animals was consistent. The advantage of slick-haired animals over normal-haired ones was 0.4º C, which may not seem to be substantial. However, body temperature in cattle can vary only from 38.5º C (normal) to 42.7º C (when death occurs) (Brody, 1948), a range of only of 4.2º C. Thus, the advantage of the slick-haired animals accounts for almost 10% of this possible variation. In addition, small variations in RT have been reported to be able to upset complex productive and reproductive processes (Brody, 1948). Differences between diurnal tympanic temperatures of acclimated and non-acclimated cattle have been reported to be between 0.1 and 0.4º C (Hahn et al., 1999). Therefore, the magnitude of the advantage in RT under high thermal

load of the slick-haired animals over their normal-haired half- and full-sib contemporaries is substantial and may be responsible for important variations in productivity under heat stress. It was quite apparent that RT did not respond to increasing BGTC. Rectal temperature may have failed to respond to temperature increases because it is slower to react to changes in thermal load (Curtis, 1981) or because, by increasing respiration rate, the animals in this study were able to dissipate the rise in body temperature associated with the increased BGT.

Skin temperature measured in experiment 2 at the BRU also revealed differences between slick and normal-haired animals. Skin temperature of slick animals was lower ($P < 0.05$) than that of normal-haired animals, 37.5 vs. 38.0º C, a difference of 0.5º C between the means of cattle of each hair type. The ST within each hair type varied more than 1º C from BGTC 1 to 4 ($P < 0.01$).   The values of ST of slick and normal-haired animals when BGTC was the lowest were, 36.9 and 37.4º C, respectively; while at the hottest BGTC were; 38.0 and 38.5º C, respectively. The ST was clearly influenced by changes of BGTC, which is logical since BGT as well as the skin of the animals is affected directly by solar radiation.

The skin is the part of the external layer of the animals in contact with the environmental stressors, and solar radiation is one of the most important external stressors. Skin temperature may have a substantial impact on several processes that affect energy flow between the environment and cattle. External temperature receptors are located in the external layers (shell) of the body, and this layer buffers thermal exchange with the surroundings. Robertshaw (1985) mentioned that the skin of various parts of the body varies in its ability to exchange heat. For example, the skin of the legs is more effective in heat exchange than the skin of the body itself. Future studies of ST measurements of different areas of the body may enhance our understanding of the relative utility of this measurement as compared to RT as an indicator of heat stress.

Slick-haired animals had fewer breaths per minute (BPM) ($P < 0.05$) than normal-haired animals, 56.6 vs. 69.0 (Table 2). The differences were similar at each level of BGTC. Other authors have reported that lactating cows begin to suffer from heat stress at THI 72, but such threshold was not evident in our analyses. The respiration rate increased inconsistently in both normal and slick-haired animals as THI varied from 91 to 107. Perhaps the lack of a clear threshold value is due to the fact that the THI was substantially higher than 72 on all days of the experiment. Alternatively the diffrences may be caused by the use of non-lactating animals in our study. Both both normal and slick-haired animals levated ($P < 0.01$) their respiration rate as BGTC increased from 1 to 4; (normal: 64.0 to 77.1; slick: 53.4 to 64.9), but the rise of the BPM of normal-haired animals appeared to be more pronounced compared than that of the slick-haired cattle. An explanation of why the BPM of slick-haired animals did not rise from BGTC 1 to BGTC 2, (53.4 vs. 52.2; $P < 0.61$) (Figure 1) is not readily apparent. Open-mouth panting was
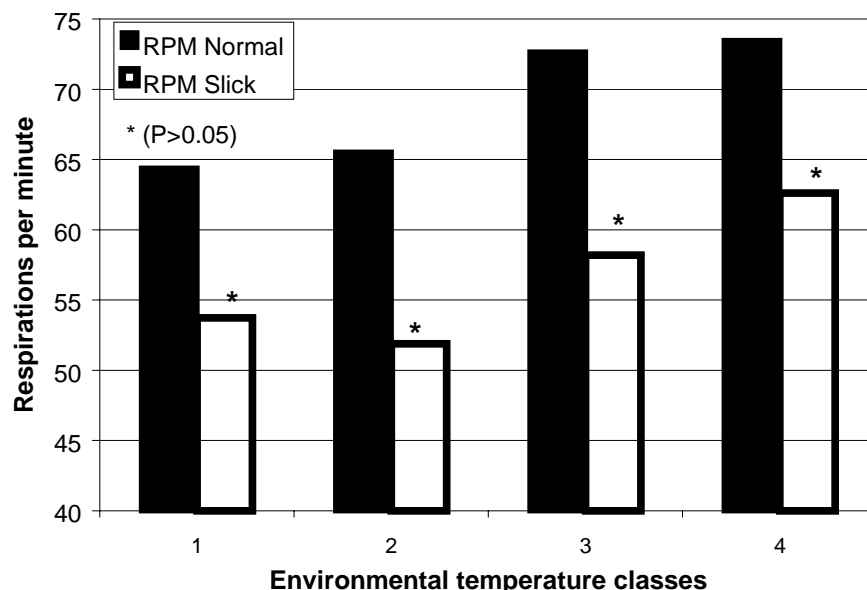
Figure 1. Respirations per minute (RPM) of slick (open bars) vs. normal-haired (solid bars) Holstein x Senepol animals by environmental temperature classes.

not observed at the time (2:30 PM) of the measurements, in spite of the fact that animals had high respiration rates and ambient temperatures were very high at the BRU on certain days.

Respiration rates of animals from each hair type were compared from days with the highest (107) and the lowest (91) THI. Normal-haired animals responded to this variation with their highest and the lowest respiration rates on such days (78, 60.5; $P < 0.10$), respectively. The respiration rates of slick-haired animals reacted similarly to these environmental variations (61 at 107 THI vs. 47 at 91 THI, $P < 0.05$). The results were very similar to those observed for respiration rates at various levels of BGTC. Respiration rate of slick-haired cattle varied from 52 at BGTC 2 to 64.9 at BGTC 4; respiration rate of normal-haired individuals increased in a similar fashion from 65.5 at BGTC 2 to 77.14 at BGTC 4 ($P < 0.01$). Figure 1 illustrates the relationship of respiration rate and BGT. The difference in respiration rate between slick and normal-haired animals was similar to the difference reported by Brown-Brandl et al (2001) between the respiration rate of shaded and non-shaded animals of equal adaptation during hot summer weather. It is also comparable to the differences observed between zebu crosses (adapted) and non–adapted *Bos taurus* cattle. Mc Dowell (1972) reported that adapted cattle that are less affected by higher heat loads and thus able to maintain lower respiration rates, are more efficient, and require less metabolic energy.

Since slick-haired animals were able to maintain lower RT while at the same time breathing more slowly across BGT levels, they appear to have a more efficient mechanism for maintaining homeostasis. Furthermore, it is of interest that the respiration rate of slick-haired animals at the highest BGTC (64.9) is very similar to that of the normal-haired animals at the lowest BGTC (64.0) (Figure 1). Nienaber et al (1999) reported that respiration rate has certain maximum levels, and after that open-mouth panting begins. Our data suggest that animals with slick hair will be able to withstand substantially higher levels of thermal stress before they begin open-

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mouth panting.

Slick and normal-haired animals were identified visually and the differences in hair weight per skin area were quantified. Slick-haired had less (P < 0.05), 11.47 vs. 17.82 mg/cm^2, hair weight per skin area than normal-haired animals (Table 2). Slick-haired animals also appeared to have a shinier and glossier coat compared with their normal-haired sibling and half-siblings from experiment 2 at the BRU.

The weight of hair clipped from both black and white areas of the spotted animals was measured as it appeared visually that the white areas possessed longer hair. Clipped weights from black and white hair from the same animal were compared; the hair weight per skin area of black hair was lower (P < 0.05), 11.02 vs. 18.28, than that of white hair (Table 3). This difference between black and white hairs was very similar to the one reported above between hair weight densities of slick and normal-haired animals. The black and white spots also had different skin colors at their base, as the white spots had pink skin and the black spots had mostly black skin underneath, as do purebred Holsteins. Some of the questions that this difference raises are: "How does the gene controlling spotting influence hair length?" and "Does the increased quantity of white hair on a white spotted, slick animal impact its heat tolerance?"

One of the objectives of the experiment was to determine if there were difference between the feed intake of slick and normal animals while under heat stress. Feed intake has critical effects on productivity. The difference in intake at the BRU approached significance (P < 0.07), with the slick animals tending to consume more (slick = 27.0, normal = 26.7 g of feed/g live wt/day). Our results might have been more dramatic if the cattle had been fed *ad libitum*

Table 3. Least square means of hair weight per area influenced by hair type and color.

Trait	N	Hair	LS means	SEM	P
Hair type	5	Slick	11.47	0.0162	P < 0.05
	8	Normal	17.82	0.0149	
Hair color	13	Black	11.02	0.0150	P < 0.05
		White	18.28	0.0150	

* From 16 animals in experiment 2, 3 were not measured because the absence of white and/or black hair spots.

throughout experiment 2. Variation in feed intake caused by heat stress normally occurs when homeostasis is disrupted (Hahn, 1999). At higher levels of temperature stress, the difference in feed intake between slick-haired, more heat tolerant animals and their normal-haired contemporaries might have been greater. Comparison of the feed intake of normal and slick-haired adult cows during lactation would likely be useful. Cows that are lactating may produce twice as much heat as non-lactating cows of the same size (Worstell and Brody, 1953).

Future investigation to clarify the importance of different hair coat characteristics could facilitate the understanding of the mechanisms of heat dissipation present in slick-haired animals.

Also, since ticks are a serious constraint to cattle production in most tropical and subtropical areas of the world, the effect of the slick hair trait on susceptibility to ticks, should be investigated. There are reports from both South America and Australia that suggest that slick-haired cattle are more tick resistant. Investigation of hair and sweat gland density of slick-haired animals could also aid in recognizing a broader spectrum of characteristics conferred to cattle by slick hair. The hair weight difference found between black and white hairs in cattle with Holstein type spotting requires more study to evaluate its potential influence on heat stress issues. Our data indicate that heat stress resistance could be readily improved through the incorporation of the slick hair gene into non-adapted breeds. The opportunity for improved productivity through use of the slick hair gene is greatest in cattle under the most severe heat load from the prevailing weather and production environment, such as in dual-purpose cattle and high producing milking cattle from tropical and subtropical regions.

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