ABSTRACT

Inheritance of the SLICK1 allele of the prolactin receptor gene improves thermotolerance of lactating Holstein cows under humid heat stress conditions. The aim of this study was to investigate whether pre- and postweaning Holstein heifers carrying the SLICK1 allele would show physiological responses indicative of higher tolerance to heat stress in high- and low-humidity climates. A total of 101 heifer calves of two age groups heterozygous for the SLICK1 allele and 103 wild-type half-siblings were evaluated during July 2020 in 3 dairy farms in central California and 2 in south Florida. Dry bulb temperature and relative humidity data were recorded during evaluation and used to calculate the temperature-humidity index (THI). Physiological measurements were obtained between 1600 and 1900 h in California, and 1200 and 1400 h in Florida and included rectal temperature, respiration rate, skin temperature, and sweating rate. Data were analyzed via Generalized Linear Mixed Models including the main effects of genotype, state, group, sire, farm within state, and interactions, with THI included as a covariate. The correlations between THI and dependent variables were analyzed via linear regression. The average 24-h THI was higher in Florida compared with California (90 vs. 72, respectively); the main driver of the higher THI in Florida was the high relative humidity (average 85.6% in Florida vs. 36.7% in California). In Florida, the rectal temperature of slick calves was 0.4°C lower than non-slick calves (39.5 ± 0.1 vs 39.9 ± 0.1°C); no differences were detected between slick and non-slick calves in California. Regardless of genotype, heifer calves in Florida had higher respiration rate, higher rectal and skin temperatures, and lower sweating rate than in California. This study is the first to evaluate physiological responses of calves carrying the SLICK1 allele under heat stress conditions in different climates. Our findings demonstrate that the presence of this allele is associated with lower rectal temperatures in pre- and post-weaning Holstein females. According to the physiological parameters evaluated, calves raised in Florida appeared to be under more severe heat stress; in those conditions, the SLICK1 allele was advantageous to confer thermotolerance as evidenced by lower rectal temperature in slick animals. Key words: heat stress, SLICK1, Holstein, calf, slick

INTRODUCTION

The negative impact of heat stress on health, production, and reproduction of dairy cattle is well recognized. Adjusting estimates to 2021 US dollars, heat stress costs the US dairy industry approximately $1.3 billion each year owing to losses associated with reproductive failure, increased disease incidence, and decreased milk production (St-Pierre et al., 2003). Heat stress ensues when the combined heat load from external forces and basic metabolic functions exceeds the animal’s ability to dissipate heat. Milk yield and DMI are associated with increased heat production in lactating dairy cows (Igono et al., 1992). Lactating dairy cows are more susceptible to heat stress compared with dry cows and growing heifers because of a higher metabolic rate associated with milk production and a lower ratio of body surface area to body mass (West, 2003). Although young stock (i.e., calves and growing heifers) are generally considered to be less susceptible to heat stress than lactating cows (St-Pierre et al., 2003; Kovács et al., 2018), it is becoming clear that exposure to high environmental temperature, humidity, or both can have long-term consequences to the health and productive life of young animals (Wang et al., 2020; Laporta, 2021). The environmental conditions that preweaning Holstein calves are typically exposed
to in areas of high temperatures lead to physiological responses consistent with heat stress and affect their health and welfare (Kovács et al., 2018; Dado-Senn et al., 2020a,b).

Genetic selection for increased heat tolerance can provide a long-term solution to ameliorate the effects of heat stress in cattle. The introduction of the SLICK1 allele into the Holstein breed has resulted in cows that are more tolerant to heat stress. The SLICK1 allele is a SNP in the prolactin receptor (PRLR) gene, which results in a premature stop codon in the cytoplasmic tail of the receptor (Littlejohn et al., 2014). Other point mutations have been identified that result in shortening of the PRLR protein (Porto-Neto et al., 2018; Flóres Murillo et al., 2021), and the effects of these mutations in improving thermotolerance are also being investigated. In contrast to the inheritance of a missense mutation in the prolactin (PRL) gene, which causes a thick, long hair coat and lactation failure (Littlejohn et al., 2014), the SLICK1 mutation of the PRLR is associated with a short, fine hair coat phenotype and no detectable lactation defects (Dikmen et al., 2008, 2014). Indeed, animals with mutations in PRLR have been reported to have higher milk yield in the summer (Olson et al., 2003; Dikmen et al., 2014). These mutations act in a dominant fashion, and therefore, heterozygous animals typically present the slick phenotype.

Lactating Holsteins carrying the SLICK1 allele maintained vaginal temperature approximately 0.6°C lower compared with their nonslick half-siblings and unrelated counterparts in summer (Dikmen et al., 2008, 2014); moreover, slick cows had similar milk yield when calving in the summer and winter, whereas wild-type cows had lower milk yield when calving in the summer (Dikmen et al., 2014). The increased thermotolerance of slick Holsteins has been attributed, at least in part, to an increased sweating rate due to the shorter hair coat, leading to a superior ability to dissipate heat (Dikmen et al., 2008). Effects on sweating rate have not always been observed, however (Dikmen et al., 2014). The benefits of the SLICK1 mutation have also been demonstrated in beef calves under high temperature conditions, with slick calves maintaining an average rectal temperature 0.5°C lower than their wild-type counterparts (Olson et al., 2003).

Studies evaluating lactating dairy cows carrying slick mutations have been limited to a relatively small number of animals and to the high-temperature, high-humidity conditions found in subtropical Venezuela (Olson et al., 2003), Florida (Dikmen et al., 2008, 2014), and Puerto Rico (Ortiz-Colón et al., 2018). It remains to be determined whether presence of the SLICK1 allele in high temperature and low humidity would confer an advantage to withstand heat stress. Moreover, no studies to date have evaluated the response of SLICK1 carrier Holstein calves to heat stress. Therefore, the present study had 2 main objectives: (1) to investigate whether the presence of the SLICK1 allele would be advantageous to preweaning Holstein calves under heat stress, and (2) to evaluate if the potential effects of carrying the mutation would hold in both humid and dry heat conditions.

**MATERIALS AND METHODS**

**Animals and Treatments**

All experimental procedures involving animals were approved by the University of California Davis Institutional Animal Care and Use Committee (protocol no. 20919). The experiment was conducted in 5 commercial dairies: 3 in central California (Corcoran, 36.0980° N, 119.5604° W; Escalon, 37.7974° N, 120.9966° W; Hanford, 36.3275° N, 119.6457° W) and 2 located in south Florida (both in Okeechobee, 27.2439° N, 80.8298° W). Lactating Holstein cows were bred by AI with frozen-thawed semen from 2 registered Holstein sires heterozygous for the SLICK1 allele. Semen from sire A was X-sorted and semen from sire B was conventional. Inseminations were performed to yield 2 groups of calves: group 1 calves were born between November 2019 and March 2020, and group 2 calves between May and July 2020. Heifer calves were genotyped via Clarifide Plus test after the experiment (Zoetis) and classified as slick (carrying the SLICK1 allele) or nonslick (half-siblings not carrying the SLICK1 allele). Therefore, at the time of data collection, the research team did not have information about the genotypes. Female calves were included in the cross-sectional study performed in July 2020 to test the physiological responses to environmental conditions associated with heat stress. At the time of testing, the median age of group 1 calves (postweaning) in California was 195 d (range: 108–244 d), and the median age for group 2 calves (postweaning) was 23 d (range: 4 to 48 d). In Florida, the median age of group 1 calves (postweaning) was 242 d (range: 159 to 265 d), and the median age for group 2 calves (postweaning) was 29 d (range: 10 to 55 d). None of the calves in group 2 were weaned at the time of testing. Group 1 calves were kept in dry lots with shade structures and were brought to a feeding area containing headlocks (California) or kept in pasture pens and brought to a chute (Florida) for testing. Group 2 calves were kept in individual wood hutchess outside (2 locations) or individual pens inside a barn and in wood

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hutches outside (1 location) in California; in Florida, group 2 calves were kept in individual wire hutches with shade cloth.

**Environmental Measurements**

The MX2301A HOBO temperature/relative humidity data logger (Onset) was used to record environmental data and set to record every 15 min with a sampling duration of 1 min. The data logger was attached to a pole inside the pen in the dry lots, a pole among the stalls inside the barn (1 location where some of the calves were inside a barn), or between hutches. In all locations, data loggers were installed approximately 140 cm above the ground, at least 15 min before the beginning of data collection. In California, the data loggers were kept in the pens for at least 24 h; at approximately midday, the instrument was rotated to the opposite side of the pole to keep it out of direct sunlight. In Florida, data loggers were turned off approximately 15 min after all data collection was completed. To complement the environmental data from Florida, we combined the data obtained via data logger during animal evaluation with data recorded by the Florida Automated Weather Network (https://fawn.ifas.ufl.edu/) to create 24-h temperature and humidity distribution during the days of the experiment. The environmental data were used to calculate the temperature-humidity index (THI) according to the following equation:

\[
\text{THI} = T_{\text{db}} - [0.55 - (0.55 \times \text{RH}/100)] \times (T_{\text{db}} - 58),
\]

where \(T_{\text{db}}\) is dry bulb temperature (°F) and RH is relative humidity expressed as a percentage according to Allen et al. (2015). The THI was then matched to the closest time point within a 15-min interval to the physiological measurement of each animal.

**Physiological Measurements**

Physiological measurements were obtained from slick and nonslick animals during the period of the day encompassing the highest THI (between 1630 and 1900 h in California and 1200 and 1400 h in Florida; Figure 1A). All measurements were taken in Florida before any rain events on that day.

Before the start of the experiment, the research team was trained on how to obtain each measurement. A rectal thermometer equipped with a 4-inch (10.2-cm) angled probe (AG-102 Animal Thermometer, AG-Medix, LLC) was used to measure rectal temperature by fully inserting and holding the probe against the rectal wall. Hair clippers (Oster Turbo 360 Clipper, Oster Professional Products) were used to remove the hair in an area of approximately 5 × 5 cm at a point caudal to the shoulder blade on the right side of the animal. Respiration rate was measured in breaths per minute (BPM) by counting flank movements for 1 min before obtaining the other physiological measurements. The skin temperature was measured using an infrared thermometer (IR270, FLIR Systems Inc.) with emissivity set to 0.98. To keep a consistent distance from the skin, a ruler was taped to the left side of the thermometer such that the opening for the thermometer was 25 cm away from the skin surface when the tip of the ruler was touching the animal. For the clipped skin measurement, the laser dot was pointed at the top of the square of clipped hair and the ruler was placed on the left side of the clipped square. For the unclipped measurement, the laser was placed at approximately the same level as the top of the clipped square but immediately to the side, to measure an area containing hair. Sweating rate was recorded using a SWL4 Vapometer (Delfin Technologies Ltd.) in both clipped and adjacent unclipped areas by holding the instrument against the skin for approximately 10 to 20 s until a sound signal indicated that the reading was complete.

**Measurement Schedule**

**California.** Postweaning heifers were in dry lot pens with shade and were restrained in headlocks during feeding. Animals were released as their measurements were completed. Preweaning calves had their measurements taken in their individual hutches or pens.

**Florida.** Postweaning heifers were brought from their pasture pens in the morning to a holding pen and were given a minimum of 2 h to settle before physiological measurements were taken. Animals had ad libitum access to water and partial shade in the holding pens. To obtain the physiological measurements, the animals were brought up to a chute. Preweaning calves were tested in their individual hutches.

**Statistical Analysis**

Analyses were performed via Generalized Linear Mixed Models using the GLIMMIX procedure of SAS version 9.4 (SAS Institute Inc.). Animal was the experimental unit and was considered random. Models included the main effects of genotype, state, group, sire, farm within state. The interactions were between genotype and state; genotype and group; state and group; and genotype, state, and group. The THI was included as a covariate. The variation in THI between...
states was analyzed via Generalized Linear Models using the GLM procedure of SAS.

Dependent variables were rectal temperature, respiration rate, surface temperature, and sweating rate in clipped and unclipped skin. When THI had a significant effect, a regression analysis was performed between THI and the response variable using the REG procedure of SAS.

A second analysis was performed to evaluate the effects of clipping the hair on skin temperature and sweating rate. Animal was the experimental unit and was considered random. The model included the main effects of genotype, state, sire, farm within state, hair clipping (yes/no), and the interactions between genotype and state, genotype and hair clipping, and clipping and state.

The data are reported as least squares means ± standard error of the mean. Effects associated with $P$-values $\leq 0.05$ were considered significant. Tendencies were associated with $0.05 < P < 0.1$.

**RESULTS**

**Environmental Measurements**

The 24-h mean THI in California during the testing period was $72 \pm 0.2$ (range 61–82), whereas in Florida it was $90 \pm 0.2$ (range 83–100; $P < 0.0001$). Figure 1A depicts the 24-h variation of THI during testing days in both states; the boxes indicate the window of sample collection. The average temperature, relative humidity, and THI during the time of collection in California and Florida are depicted in Figure 1B, C. The THI was consistently higher in Florida compared with California, and in California, the animals experienced several hours of THI below 68 overnight.
In Florida, the THI remained above 80 for the entire study period.

**Physiological Responses to Heat Stress**

Table 1 depicts the number of animals per genotype and group that were evaluated in each state. The rectal temperature of slick animals was 39.3 ± 0.1°C, whereas for nonslick animals it was 39.5 ± 0.1°C (P = 0.01). This difference was only observed in Florida, where postweaning slick heifers had 0.31°C (P < 0.05) and preweaning calves had 0.55°C (P < 0.001) lower rectal temperature compared with their nonslick counterparts. In California, rectal temperature was not different between slick and nonslick animals (Figure 2A). Regardless of genotype, California animals had lower rectal temperature than Florida animals (39.2 ± 0.04°C vs. 39.7 ± 0.1°C; P < 0.001). Overall, postweaning heifers had higher rectal temperature than preweaning calves (39.7 ± 0.05°C vs. 39.1 ± 0.09°C; P < 0.0001). Again, this effect was due to differences observed in Florida, where postweaning heifers had higher rectal temperature than preweaning calves; in California, no difference was detected (Figure 2A).

Genotype did not affect respiration rate (Figure 2B). Overall, postweaning heifers had higher respiration rate compared with preweaning calves (78 ± 2 vs. 66 ± 4 BPM; P < 0.01). Postweaning heifers in Florida had the highest respiration rate, whereas no difference was found between age groups in California (Figure 2B).

The temperature in the clipped skin was not affected by genotype, state, or group (Figure 2C). We observed an interaction between group and state: preweaning calves had higher clipped skin temperature than postweaning heifers in California, whereas this relationship was the inverse in Florida (P < 0.01; Figure 2C). Skin temperature in unclipped areas was not affected by genotype, state, or group (Figure 2D).

Genotype had no effect on sweating rate regardless of presence of hair (Figure 2E,F). Overall, California heifers sweated more than Florida heifers in clipped (139.0 ± 6.0 vs. 63.6 ± 18.7 g/m²/h; P < 0.001) and unclipped skin (113.5 ± 5.9 vs. 70.3 ± 17.4 g/m²/h; P < 0.05). Postweaning heifers sweated more than preweaning calves in both clipped and unclipped skin (P < 0.01; Figure 2E,F).

Regardless of genotype, daughters of sire A had higher respiration rate (77 ± 3 vs. 68 ± 3 BPM; P < 0.01) and clipped skin temperature (35.1 ± 0.2 vs. 34.7 ± 0.2°C; P < 0.05) compared with daughters of sire B. Moreover, the sweating rate in clipped skin of daughters of sire A was lower than that of daughters of sire B (90.7 ± 9.1 and 115.7 ± 10.4 g/m²/h; P < 0.01). No interactions were found between genotype and sire.

When analyzing the effect of hair clipping on skin temperature and sweating rate, we observed tendencies for the interaction of genotype by hair clipping on the sweating rate (P = 0.09) and skin temperature (P = 0.09) in preweaning calves in California. Slick calves showed little change in sweating rate (84.7 ± 10.8 vs. 99.2 ± 10.8 g/m²/h for unclipped and clipped skin, respectively) and skin temperature (34.59 ± 0.2 vs. 34.62 ± 0.2°C for unclipped and clipped skin, respectively), whereas nonslick calves had higher sweating rate (109.2 ± 14.3 vs. 143.7 ± 14.3 g/m²/h in unclipped and clipped skin, respectively) and higher skin temperature in clipped skin (34.67 ± 0.2 vs. 34.94 ± 0.2°C in unclipped and clipped skin, respectively). We did not observe differences in postweaning heifers in California or in either pre- or postweaning heifers in Florida.

**Effects of THI on Physiological Responses**

The THI at the time of measurement tended to affect rectal temperature (P = 0.06), and affected unclipped skin temperature (P = 0.03) and clipped skin sweating rate (P = 0.02). Therefore, we examined the effect of THI in each of these variables in slick and nonslick animals of both age groups combined. Slick animals kept a more stable rectal temperature as THI increased, whereas nonslick animals experienced an increase in temperature in response to increasing THI (Figure 3A). Response to THI for unclipped skin temperature and clipped skin sweating rate was similar for slick and nonslick animals (Figure 3B,C).
**DISCUSSION**

The present study had 2 main goals: (1) to evaluate whether the presence of the SLICK1 allele would be advantageous to Holstein preweaning calves and postweaning heifers under heat stress, and (2) to evaluate if the potential effects of carrying the mutation would hold in both humid and dry heat conditions. We found that in Florida, pre- and postweaning animals carrying the SLICK1 allele had lower body temperature compared with their wild-type half-siblings. No differences due to genotype in body temperature or the other parameters

![Figure 2](image-url)

*Figure 2.* Physiological responses to heat stress in preweaning and postweaning Holstein calves carrying the SLICK1 allele. Effects on (A) rectal temperature, (B) respiration rate (BPM = breaths/min), (C) skin temperature without hair (clipped), (D) skin temperature with hair (unclipped), (E) sweating rate without hair (clipped), and (F) sweating rate with hair (unclipped). SLK = animals carrying the SLICK1 allele; NON = half-sisters not carrying the allele; group 1 = Holstein heifers 108 to 265 d old; group 2 = Holstein calves 4 to 55 d old; Gen = genotype (SLICK1, wild-type). Where present, tendencies ($P < 0.1$) and significant differences ($P \leq 0.05$) are noted. Results are shown as LSM ± SEM.
The dominant SLICK1 allele was originally described in the Senepol breed in the Caribbean island of St. Croix. The resulting phenotype is a short and sleek hair coat, visually similar to many Bos indicus breeds (Olson et al., 2003). Later, the slick locus was mapped to bovine chromosome 20 (Mariasegaram et al., 2007; Carmickle et al.: HEAT STRESS RESPONSE OF SLICK HOLSTEIN COWS)

Figure 3. Effects of temperature-humidity index (THI) on (A) rectal temperature, (B) surface temperature in unclipped skin, and (C) sweating rate in clipped skin. SLK = animals carrying the SLICK1 allele; NON = half-siblings not carrying the allele. State (California and Florida) and age group (pre- or postweaning heifers) are combined within each genotype. Adj $R^2 = \text{adjusted } R^2$.

evaluated were detected in pre- or postweaning animals raised in California.

The dominant SLICK1 allele was originally described in the Senepol breed in the Caribbean island of St. Croix. The resulting phenotype is a short and sleek hair coat, visually similar to many Bos indicus breeds (Olson et al., 2003). Later, the slick locus was mapped to bovine chromosome 20 (Mariasegaram et al., 2007;
Flori et al., 2012), and finally the mutation was found to be due to a loss of a cytosine in exon 10 of the prolactin receptor gene (PRLR) that causes a premature stop codon and the loss of 120 amino acids in the C-terminus of the resulting protein (Littlejohn et al., 2014). Additional mutations in the PRLR (named SLICK2–6) have been found in Limonero, Carora, and other breeds of cattle that also yield the slick phenotype (Porto-Neto et al., 2018; Flórez Murillo et al., 2021). The mutation explored in this study is the one described by Littlejohn et al. (2014), which has been notated as SLICK1 (Porto-Neto et al., 2018). Studies of lactating Holsteins and Holstein crosses have demonstrated that, compared with wild-type cattle, cows carrying the SLICK1 mutation are able to maintain milk yield and lower body temperature under tropical and subtropical heat stress conditions (Olson et al., 2003; Dikmen et al., 2008, 2014). Recently, Landaeta-Hernandez et al. (2021) examined the physiological responses of slick Criollo Limonero (likely carrying one of the other SLICK alleles) 1-yr-old heifers to heat stress in subtropical conditions and found that slick heifers maintained lower body temperature and respiration rate compared with nonslick heifers. To our knowledge, the present study is the first to evaluate the mutation in young Holsteins (less than 1 yr old), including preweaning calves; our data show that the presence of the SLICK1 allele confers distinguishable short hair and is associated with lower body temperature in subtropical heat.

The average THI experienced by the animals during data collection in California was 72 (range 61–80), whereas in Florida it was 90 (range 83–100), exceeding heat stress thresholds on a daily basis in both states (Dado-Senn et al., 2020a). Our data indicate that both preweaning calves and postweaning heifers experienced hyperthermia in both states, confirming that these animals were experiencing some degree of heat stress. To our knowledge, all previous studies looking at physiological responses to heat stress of animals carrying the SLICK1 allele have been conducted in subtropical or tropical climates. These climates are characterized by high temperatures and high humidity during the day that persist overnight. Conversely, California has a Mediterranean climate, characterized by high temperatures and low humidity during the day, often with a decrease in temperature accompanied by an increase in humidity overnight. A close evaluation of the drivers and the distribution of THI in each location confirmed that California had higher air temperature and lower relative humidity compared with Florida. Another important difference between the two states was that in Florida, the animals experienced several more hours of more severe heat stress each day, and no relief at night. Dado-Senn et al. (2020a) showed that exposure to chronic heat stress (i.e., no or short period of relief during the night) decreased the threshold at which preweaning Holstein calves begin changing their physiological parameters in response to heat stress. Perhaps the heat stress conditions in Florida were sufficiently severe to trigger the physiological responses observed, allowing the differences between the slick and wild-type animals to affect thermoregulation.

Cattle dissipate excess heat load via evaporative heat loss by increasing sweating and respiration rates, and the efficiency of these processes is largely dependent on the humidity of the air (dos Santos et al., 2021). The high humidity climate found in Florida compromises evaporative heat loss (Berman, 2006), whereas in California's low humidity climate, the water vapor easily leaves the hair coat, contributing to cooling (Gebremedhin and Wu, 2001). The faster the process of evaporative heat loss or water vapor moving from skin to air, the faster the animal can reduce its heat load (Gebremedhin et al., 2008). Accordingly, we observed lower rectal temperature, respiration rate, skin temperature, and higher sweating rate in animals raised in California. Although rectal temperature was at or above the threshold for hyperthermia in both states, postweaning heifers tested in Florida had significantly higher rectal temperature and respiratory rate compared with preweaning calves and to both age groups in California. Conversely, sweating rate was highest in the postweaning heifers raised in California, likely resulting in the lower skin temperature compared with Florida. Clearly, the animals raised in California were better able to dissipate heat via sweating.

The finding that sweating rate was not different between genotypes is inconsistent with previous reports that lactating slick Holsteins in Florida had higher sweating rate than nonslick counterparts (Dikmen et al., 2008, 2014); however, the results of previous reports are also inconsistent. In the first report, Dikmen et al. (2008) found that the sweating rate of slick cows was greater when the hair was present; however, removal of the hair abolished the difference, leading the authors to conclude that the difference observed was due to the shorter hair of the slick animals resulting in less humid air trapped within the hair. In a second report, Dikmen et al. (2014) did not find large differences in sweating rate between slick cows and their nonslick relatives. Landaeta-Hernandez et al. (2011), examining Criollo Limonero cows, found that animals carrying the slick mutation (likely the SLICK2 or SLICK3 allele) had larger sweat glands compared with wild-type herd mates, although the number of sweat glands was not different between the groups. Littlejohn et al. (2014),
however, did not find a difference in the number of sweat glands or hair follicles of cows carrying the SLICK1 allele. We did not evaluate the characteristics of the skin of our animals, and therefore, we cannot make inferences about whether a physical difference was present in sweat gland maturity and function compared with lactating cows, or if the lack of differences could be caused by a lower ability of young calves to regulate sweat in response to heat.

Analysis of the effect of hair clipping on sweating rate and skin temperature revealed no difference in sweating rate or skin temperature of preweaning slick calves in California before or after hair clipping, whereas nonslick calves had higher sweating rate and skin temperature when the hair was removed. Although this finding confirms the report by Dikmen et al. (2008) in lactating Holsteins that the hair of slick animals does not affect these parameters, it contradicts that report in the present finding that overall, slick calves sweated less than non-slick calves. Evaluation of our animals as they become lactating cows would be important to confirm or refute previous reports and shed more light into the relationship between the SLICK1 allele and evaporative heat loss by sweating.

One potential explanation for the lower body temperature found in Florida in the absence of differences in sweating rate could be that the slick animals had a lower metabolic rate, as suggested by Dikmen et al. (2008). However, analysis of milk yield demonstrated that slick cows produced the same or greater amount of milk (observed during summer; Dikmen et al., 2014), therefore refuting the hypothesis of a lower metabolic rate. Increased heat loss via conduction and convection could be caused by a lower ability of young calves to regulate sweat in response to acute heat stress. Journal of Dairy Science 91:3395–3402. https://doi.org/10.3168/jds.2019-15881.

Young cattle have generally been regarded as more resistant than lactating cows to heat stress. Recent data, however, show that preweaning calves can begin showing signs of heat stress at a THI of 65 to 69 (Dado-Senn et al., 2020a), that is, substantially lower than the previously estimated value of 77 (St. Pierre et al., 2003) and similar to the value of 68 established for lactating cows (Zimbelman et al., 2009). In a recent study, Young et al. (2020) showed that the temperature of preweaning Holstein calves surpassed the 39°C mark at a THI of 70. As more research is performed to evaluate how young cattle respond to excessive heat, it is becoming evident that heat stress can have long-term negative consequences to future health and performance (Laporta, 2021). Therefore, it is critical that we continue to focus on the development of sustainable strategies to improve the adaptation of Bos taurus cattle to heat stress.

CONCLUSIONS

This study demonstrated that the presence of the SLICK1 allele results in lower body temperature in young Holstein cattle exposed to the subtropical heat conditions found in Florida, whereas no differences were observed in the Mediterranean heat conditions found in California. The presence of the SLICK1 allele seems particularly important when high THI is driven by high humidity, and the effects of the mutation on the physiological responses to heat stress can be detected in Holstein calves as early as the preweaning stage of life.

ACKNOWLEDGMENTS

The authors thank Da Silva Dairy, Vanderham West Dairy, Wrened Ranch, Gracewood Dairy, and Larson Dairies 5 and 8 for participating in this experiment. Our gratitude is also extended to Jenna Larson for assistance with data collection in Florida. Funding was provided by the Holstein Association USA Research Grant Program and the L.E. “Red” Larson Endowment. The authors have not stated any conflicts of interest.

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