Light sensors assess solar radiation vs. shade exposure of slick- and wild-type Puerto Rican Holstein cows[1,2]

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ABSTRACT

Anecdotal data suggest that slick-haired cows (SLICK) graze under solar radiation longer than their wild type-haired (WT) counterparts. However, to the authors' knowledge, empirical data regarding the suggestion is scarce. This study aimed to use light sensors (HOBO Pendant MX) to study solar radiation exposure. Sensors (attached to a collar) were validated in 20 Holstein cows rotated from shade (0837 to 0906h) to sunlight (0907 to 0932h) and then back to shade (0933 to 1005h). After validation, sensors were used to compare the differences in solar radiation exposure between 10 SLICK and 10 WT Holstein cows. Data were analyzed by the GLIMMIX and FREQ procedures (SAS). Light intensity was greater under solar radiation than during the first (*P*<0.01) and second (*P*<0.01) shade periods (51,026.00±682.25; 2,282.40±647.64 and 1,907.27±626.28 lx, respectively). No differences were observed between shade periods (*P*=0.62). The SLICK cows spent more time under solar radiation than the WT cows (52.67 vs. 47.33%, respectively; *P*<0.01). Hair coat type and period interacted (*P*<0.01), with greater light intensities in SLICK than in WT cows under solar radiation (24,702±106.65 vs. 20,518±98.43 lx, respectively); but no differences were observed under shade (1,856±7.03 and 1,793.2±6.53 lx, respectively). The SLICK cows showed greater exposure time to direct solar radiation than their WT counterparts.

Key words: solar radiation on cattle, slick-haired cows, light sensors

RESUMEN

Sensores de luz para evaluar la exposición solar vs. sombra en vacas Holstein pelonas y regulares en Puerto Rico

Datos anecdóticos sugieren que las vacas de pelaje corto (PELONAS) pastorean bajo el sol por más tiempo que las de pelaje normal (REGULARES). Sin embargo, según el conocimiento de los autores, datos empíricos sobre

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este tema son escasos. Por esto, el presente estudio fue dirigido a usar sensores de luz (HOBO Pendant MX) para el estudio de esta variable. Los sensores (unidos a un collar) fueron validados en 20 vacas Holstein rotadas de sombra (0837 a 0906h) a radiación solar (0907 a 0932h) y regresadas a sombra (0933 a 1005h). Luego de validados, los sensores fueron usados para comparar las diferencias en la exposición a la radiación solar entre 10 vacas PELONAS y 10 vacas REGULARES de la raza Holstein. Los datos fueron analizados mediante los procedimientos GLIMMIX y FREQ (SAS). La intensidad de la luz fue mayor bajo radiación solar que bajo el primer (P<0.01) y segundo (P<0.01) periodo de sombra (51,026.00±682.25; 2,282.40±647.64 y 1,907.27±626.28 lx, respectivamente). No se observaron diferencias entre los periodos de sombra (P=0.62). Las vacas PELONAS pasaron más tiempo bajo radiación solar que las REGULARES (52.67 vs. 47.33%, respectivamente; P<0.01). El tipo de pelaje y el periodo interactuaron (P<0.01), con mayores intensidades de luz observadas en las vacas PELONAS que en las REGULARES durante la exposición a radiación solar (24,702±106.65 vs. 20,518±98.43 lx, respectivamente), pero no se observaron diferencias bajo sombra (1,856±7.03 y 1,793.2±6.53 lx, respectivamente). Las vacas PELONAS pasaron más tiempo expuestas a la radiación solar que sus contemporáneas REGULARES.

Palabras clave: radiación solar en el ganado, vacas pelonas, sensores de luz

INTRODUCTION

Heat stress is known to limit feed intake in dairy cattle, consequently affecting their productive and reproductive performance (West, 2003). In tropical countries this problem is exacerbated due to constantly elevated air temperature and humidity values. Unlike breeds of temperate cattle that normally spend more time under shade during periods of high solar radiation (i.e., not grazing), tropically adapted cattle may be able to spend more time grazing under direct solar radiation. Such behavior may help decrease the negative effects of heat stress by an increased feed intake.

The slick-haired dairy cow from Puerto Rico is an example of tropically adapted cattle (Sánchez-Rodríguez, 2019a). In previous studies these cows have shown lower body temperature (Sánchez-Rodríguez, 2019b) and respiration rates (Castro et al., 2015; Sánchez-Rodríguez, 2019b), as well as larger sweat glands (Sánchez-Rodríguez, 2019b) and greater milk yields (Delgado et al., 2014; Sánchez-Rodríguez, 2019b) than their wild type-haired counterparts. These slick-haired cows are commonly observed grazing under the sun, while their wild type-haired counterparts rest in the mud, protected by the shade of trees close to the paddock fences.

However, (to the authors' knowledge) although logical, such statement is only based on anecdotal data, probably because of the complexity of direct behavioral studies about the time cattle voluntarily spend under direct solar radiation. Behavioral studies have been frequently performed by constant visual observations or video recording and analysis. These techniques, although highly reliable, are time consuming (Ledgerwood et al., 2010; Bonk et al., 2013; Nielsen, 2013) and labor consuming (Ito et al., 2009; Ledgerwood et al., 2010), which greatly limit their utility.

Thus, the objectives of these studies were to evaluate an automatic light sensor as a possible tool for the study of solar radiation vs. shade exposure in cattle and, once validated, to use these instruments to provide empirical data about the amount of time slick and wild type-haired Puerto Rican Holstein cows voluntarily spend under solar radiation.

MATERIALS AND METHODS

Animals

All experimental cows were obtained from the Agricultural Research Station dairy herd at Lajas, Puerto Rico. Descriptive statistics for the evaluated cows are provided in Table 1.

Validation Trial

Twenty lactating Puerto Rican Holstein cows were randomly selected, and each was fitted with a nylon collar containing a light sensor on top (HOBO Pendant MX Temperature / Light Data Logger, Onset Computer Corporation, Bourne, MA[5]; Figure 1). A chain link was attached to the bottom part of the collar (bottom of the neck) as a weight to assure that the sensor remained on top of the cow's neck. Sensors were programmed to record light intensity values every minute. Cows were rotated from artificial shade (0837 to 0906h) to direct sunlight (0907 to 0932h) and then back to artificial shade (0933 to 1005h).

Hair coat type comparison trial

A total of 20 Puerto Rican Holstein cows (10 slick and 10 wild type-haired; balanced by parity, days in milk and body weight; Table 1) were each fitted with a nylon collar attached to a light sensor (HOBO Pendant MX Temperature / Light Data Logger; Onset Computer Corporation, Bourne, MA) and a chain link as described earlier (Figure 1). Sensors were programmed to record light intensity values every second during two consecutive days. During the study the thermal humidity

[5]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.

TABLE 1.—*Descriptive statistics for the evaluated Holstein cows.*

	Validation Trial			
	n	Lactations	Days in milk	Body weight, kg
Randomly selected cows	20	2.8 ± 0.37	165.60 ± 27.75	549.73 ± 21.47

	Hair coat comparison trial				
	n	Lactations	Days in milk	Body weight, kg	Milk yield, kg/d
Slick	10	1.70 ± 0.26	95.80 ± 15.24	536.09 ± 19.71	25.65 ± 2.26
Wild type	10	1.70 ± 0.26	92.30 ± 15.29	492.90 ± 13.56	21.38 ± 1.76
P-Values		1.00	0.87	1.00	<0.01

Note. All evaluated animals were lactating Holstein cows from the Agricultural Experiment Station dairy herd at Lajas, Puerto Rico.

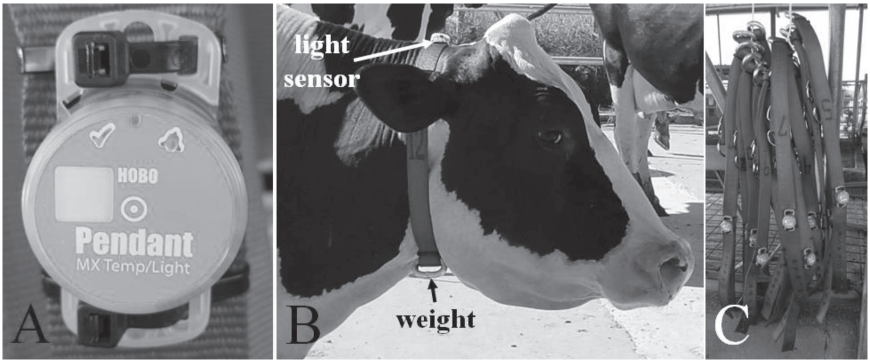

FIGURE 1. A close-up of the light sensor (A), a cow wearing a nylon collar with the attached sensor and weight (B), and the collars ready to be used (C).

index ranged between 66.98 and 85.21. Normal management practices of the dairy farm were maintained. Briefly, cows were milked at 0300 to 0600 and 1500 to 1800 h and allowed to graze from 0600 to 1400 h. The grazing paddocks had natural shade at the fences and artificial shade was provided in the milking and feeding barns. Daily milk production of each cow during the week prior to the study was also recorded.

Statistical Analysis

Validation Trial

Data were analyzed by Proc GLIMMIX in SAS, with the recorded light intensity values as the dependent variable of the model. The period (solar radiation or shade exposure) and the cows' identification numbers were considered the fixed and random effects of the model. Also, the numeric light intensity data were converted to behavioral categorical data through a visual analysis of the plotted numeric data, determining a maximum light intensity value of 4,624.62 lx during the shade period. This value was used as a cutoff to create the categories of solar radiation (> 4,624.62 lx) or shade exposure (≤ 4,624.62 lx) using the *if statement* in SAS. The sensitivity (probability that the created categories successfully represented their respective solar radiation or shade exposure periods) of these created categories was evaluated using Proc FREQ in SAS. Differences were detected at a $P \leq 0.05$.

Hair coat type comparison trial

In order to evaluate when the hair coat groups voluntarily chose exposure to direct solar radiation or to shade, the light intensity values recorded during the night (1801-0559 h) were excluded from the dataset (only the daylight period was analyzed). Using the cutoff light intensity value of 4,624.62 lx (determined in the validation trial), solar radiation or shade exposure categories were created with the *if statement* in SAS. Using Proc FREQ in SAS, the proportion of grazing time cows were exposed to direct solar radiation or to shade was evaluated. Data were also analyzed by Proc GLIMMIX in SAS. Light intensity was included as the dependent variable of the model, while the period (solar radiation or shade) and the hair coat type (slick or wild type-haired) were included as fixed effects of the model. The cows' identification numbers were included as a random effect. Daily milk production values (dependent variable; during the week previous to the study) were compared between hair coat groups by the GLIMMIX procedure of SAS. The period and hair coat type were included as fixed effects of the model, while the cow identification was also included as a random effect. Differences were detected at a $P \leq 0.05$.

RESULTS AND DISCUSSION

Validation Trial

No other studies evaluating light intensity directly on the animal in terms of solar radiation exposure or shade were found in the literature by the authors. However, Sullivan et al. (2011) evaluated the light intensities reaching the floor of shaded and unshaded cattle pens, finding that the first was 77% less than the second. Thus, the use of light intensity data loggers attached to the animal may allow for the automatic assessment of solar radiation and shade exposure in cattle. In the current study, the light intensity values recorded on top of cows' necks were greater during the solar radiation exposure period than during the first ($P<0.01$) and second ($P<0.01$) shade periods (51,026.00±682.25; 2,282.40±647.64 and 1,907.27±626.28 lx, respectively; Figure 2). However, no differences in light intensity were observed between shade exposure periods ($P=0.62$; Figure 2). Thus, the sensors used in the current trial were able to automatically differentiate cow exposure to direct solar radiation from artificial shade.

For such an instrument to be used as an indicator of cattle behavior, its numeric data should be easily converted into categorical data, and there must be a high degree of agreement between both the numerical and the categorical variables. Here, sensitivity values greater than 90% are classified as excellent (Janse et al., 2004; Paquet et al., 2008; Lake et al., 2012). In this study, the solar radiation and shade exposure categories that we created successfully identified their respective periods during 100 and 99.37% of the time (Table 2).

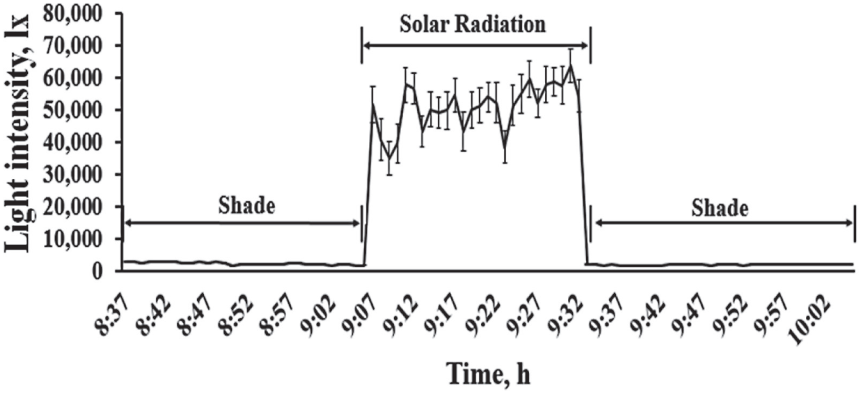

FIGURE 2. Light intensity values recorded during the shade or solar radiation exposure periods by light intensity data loggers for 20 Holsteins. Shade 1 vs. solar radiation (P<0.01); solar radiation vs. shade 2 (P<0.01). Cows were rotated from artificial shade (0837-0906h) to direct sunlight (0907-0932h) and then back to artificial shade (0933-1005h).

Hair coat type comparison trial

In our study, slick-haired cows spent a greater proportion of daily grazing time exposed to solar radiation than the wild type-haired cows (52.67 vs. 47.33%, respectively; P<0.01). There was an interaction (P<0.01; Figure 3) between hair coat type and period, with greater light intensity values recorded for the slick relative to the wild type-haired cows during solar radiation exposure (24,702±106.65 vs. 20,518±98.43 lx, respectively), but no differences between hair coat groups during shade exposure (1,856±7.03 and 1,793.2±6.53 lx, respectively). As an attempt to deal with heat stress, cattle may spend longer periods under shade in order to decrease heat gain (Gaughan et al., 2002; Sullivan et al., 2011). Yasue et al. (2000) reported air temperatures 2° C lower (P<0.01) under natural shade (provided by trees) than under direct solar radiation in grazing paddocks in Japan.

TABLE 2.—*Sensitivity (%) for the solar radiation and shade exposure categories created.*

	Created Behavioral Classifications	
Real Events	Solar Radiation	Shade
Solar Radiation	100	0
Shade	0.63	99.37

Note. A cutoff value of 4,624.62 lx was visually determined from the plotted light intensity numeric values obtained during the validation trial; light intensities > 4,624.62 lx were classified as “solar radiation exposure”, while light intensity values ≤ 4,624.62 lx were considered “shade exposure”.

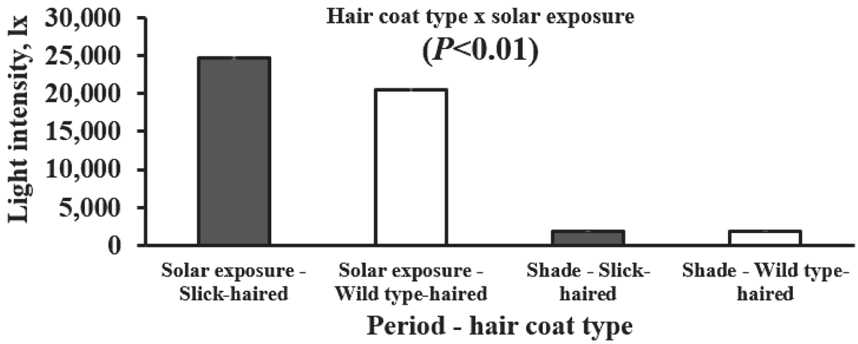

FIGURE 3. Light intensity values recorded in the slick (n=10) and wild type-haired (n=10) Holsteins during solar radiation and shade exposure periods from 0600 to 1800h (daylight hours). Hair coat type x period (P<0.01).

In beef cattle it has been reported that when air temperature is high during the daylight hours, resting time for heifers increases (Reppert, 1960) and grazing time decreases (Ehrenreich and Bjugstad, 1966). However, tropically adapted breeds are able to better regulate their body temperature under heat stress, including *Bos indicus* (Andersson, 2009) and slick-haired *Bos taurus* cattle (Mariasegaram et al., 2007). Thus, these breeds may be able to spend a greater proportion of the daylight time exposed to solar radiation compared to temperate-originated breeds. Bennett et al. (1985) observed during the day longer grazing time and shorter time periods under shade in purebred and crossbred Brahman steers than in Shorthorn steers. However, such differences disappeared during the night. Hammond and Olson (1994) observed longer grazing periods for Senepol cows relative to Hereford cows during the summer in Florida, USA. Sprinkle et al. (2000) also reported less time spent in shade by lactating and non-lactating Brahman x Angus cows, as well as lactating Tuli x Angus cows, when compared to purebred Angus cows. The opposite was reported for grazing time (Sprinkle et al., 2000).

Slick-haired cows produced more milk than their wild type-haired counterparts, averaging 25.65±2.26 and 21.38±1.76 kg/d, respectively (P<0.01; Table 1). In previous studies with slick-haired Puerto Rican cows, we have reported similar differences in milk production (Delgado et al., 2014; Contreras-Correa et al., 2016). Moreover, using different slick-haired dairy cattle Olson et al. (2003) have also reported similar milk yield differences. Even though grazing was not evaluated in this study, a longer time spent grazing by tropically adapted breeds may account for a greater daily feed intake, helping explain an increase in milk yield.

CONCLUSIONS

The evaluated sensors were able to differentiate cow exposure to direct solar radiation from shade. Moreover, the numeric light intensity values recorded by the evaluated sensors were easily and efficiently converted to behavioral data. Thus, these sensors may allow the automatic assessment of this variable in heat stress-related studies. The present study provided empirical data suggesting that the slick-haired Puerto Rican Holstein cows spend more time directly exposed to solar radiation during the day than their wild type-haired counterparts.

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