The effect of a split feeding regimen and breed on body temperature of hair sheep ewes in the tropics

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ABSTRACT: Lactating St. Croix White and Dorper × St. Croix White ewes were used to evaluate the effect of breed and feeding a split ration on body temperature during the cool (March–April) and warm (July–August) seasons in the U.S. Virgin Islands. Within each season ewes were assigned to treatments (n = 8/treatment) based on breed, age, and number of lambs. Treatments consisted of individually feeding ewes daily 0.9 kg concentrate (16.4% CP and 68% TDN) in the morning (AM) or afternoon (PM), 0.45 kg in the morning and afternoon (AM-PM), or no feed (Control) for 56 d beginning on d 7 (lambing = d 0). Ewes were fitted with intravaginal temperature data loggers, set to record vaginal temperature (VT) at 5-min intervals, for 48 h in wk 2 (d 8–14), 5 (d 29–35), and 8 (d 50–56) postpartum. Repeated measures analysis of VT was conducted using a model including treatment, season, and breed as fixed effects. There was no effect of season so data were pooled across season. The interaction of breed with treatment or season was not significant so breed comparisons were made using data pooled across treatments and season. The mean temperature, relative humidity, and temperature–humidity index during the cool and warm seasons were 25.8°C, 85.9%, and 76.1 and 28.3°C, 86.7%, and 80.6, respectively. There was no effect of season or the breed × treatment × season interaction on VT (P > 0.10) so all data were pooled across season and breed for analysis of the treatment effect. During wk 2 there was no difference (P > 0.10) in VT among treatment groups. During wk 5 the AM-PM ewes had higher (P < 0.01) VT than AM, PM, or Control ewes. During wk 8 the AM-PM and PM ewes had higher VT (P < 0.01) than either the AM or Control ewes. To evaluate breed effect, data were pooled across treatments and seasons and analyzed using breed as the single main effect. Dorper × St. Croix White ewes had higher (P < 0.0001) VT than St. Croix White ewes. The results show that body temperature of ewes can be influenced by time of feeding and breed. The local breed of sheep, St. Croix White, had a lower body temperature than Dorper × St. Croix White sheep. Ewes that were fed in the afternoon for an extended time during the postpartum period developed elevated body temperatures, which could make them more susceptible to heat stress.

Key words: body temperature, ewes, feeding, hair sheep, tropics


INTRODUCTION

Methods used to alleviate heat stress in livestock have included changing management practices, providing shade and/or sprinklers, and using breeds that are adapted to the conditions. There has been little work done to evaluate methods of alleviating heat stress in small ruminants in the tropics. Feeding a split ration has been used in efforts to alleviate the impact of high heat and humidity, conditions that are common in the U.S. Virgin Islands (Gaughan et al., 1996; Brosh et al., 1998; Ominski et al., 2002; Davis et al., 2003). Other studies have been done to evaluate the impact of feeding frequency on rumen characteristics and nutrient absorption (Bunting et al., 1987; Soto-Navarro et al., 2000; Robles et al., 2007). Most of these studies have been conducted with either feedlot or dairy cattle, and very little has been done with small ruminants fed concentrate rations.

St. Croix White sheep are well adapted to the hot, humid climate found in the U.S. Virgin Islands but
other breeds of sheep such as the Dorper, which was initially selected for arid areas (Baker et al., 1999), may not be as suited to the humid tropics. There are benefits to using Dorper sheep in a crossbreeding program with St. Croix White sheep such as increased postweaning ADG of lambs and faster time to reach market weight (Dodson et al., 2005; Godfrey and Weis, 2005).

Using a split ration to mitigate the impact of high heat and humidity on livestock production, especially in small ruminants, in a tropical environment has not been studied extensively. In addition, there is little information on the impact of the climate in the U.S. Virgin Islands on body temperature of either St. Croix White or Dorper sheep. Therefore, an experiment was designed to evaluate the influence of breed and time of day of feeding a concentrate ration to lactating hair sheep ewes on body temperature.

**MATERIALS AND METHODS**

The sheep were managed in accordance with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999) and experimental procedures were approved by the University of the Virgin Islands Animal Care and Use Committee.

Ewes were managed as one flock in an accelerated lambing system to produce a lamb crop every 8 mo. Multiparous, lactating St. Croix White (STX) and Dorper × St. Croix White (DRPX) ewes that lambed in July 2005 (warm season; 2.4 yr of age; 47.2 kg BW) or March 2006 (cool season; 2.9 yr of age; 43.5 kg BW) were maintained on guinea grass (*Panicum maximum*) pastures in a rotational grazing system throughout the data collection period each year. Ewes were rotated through a set of eight 0.8-ha paddocks so that forage availability was never limited. Ewes were assigned to treatments (*n* = 8/treatment) each year at lambing (d 0) based on breed, ewe age, and number of lambs born. Treatments consisted of individually feeding ewes daily 0.9 kg concentrate (16% CP and 68% TDN as fed; PMI Nutrition, Mulberry, FL) in the morning (AM) or afternoon (PM), 0.45 kg in the morning and afternoon (AM-PM), or no feed (Control) beginning on d 7 and continuing through d 63, when lambs were weaned. The concentrate ration was provided to the ewes at 70% of the recommended amount for lactating ewes in the tropics (Kawas and Huston, 1990). The sorting of the fed ewes was initiated in the morning between (0830 and 0930 h) or in late afternoon between (1530 and 1630 h) and took 5 to 10 min each time. The Control, AM, and PM ewes not receiving feed were sorted off into a pen with no feed for the duration of the AM or PM feeding each day. The AM, AM-PM, and PM ewes were fed individually using pen dividers with individual feed containers and orts were weighed after each feeding. Lambs were separated from all ewes, including the Control ewes, during the feeding periods. The ewes stayed in the feeding pens until feed was consumed by all ewes or for up to 30 min after sorting, whichever came first. Ewes adapted to the feeding schedule very quickly and were consuming the total ration of feed in the 30-min period within the first 3 d of feeding. After each feeding all ewes were returned to the same pasture.

Previous work in our lab has shown that rectal temperature and vaginal temperature (VT) are highly correlated [\( r = 0.95, P < 0.0001 \) (Willard et al., 2006); \( r = 0.96, P < 0.0001 \) (Godfrey et al., 2007)]. To monitor body temperature ewes were fitted with intravaginal temperature data loggers (Stowaway Tidbit data logger; Onset Computer Corp., Bourne, MA) set to record VT at 5-min intervals for 48 h in wk 2, 5, and 8 postpartum. The intravaginal data loggers were calibrated before use. Environmental conditions (temperature and relative humidity) during the study period within each season were monitored using Hobo data loggers (HOBO H8 Pro Series; Onset Computer Corp.). Temperature–humidity index (THI) was calculated using the formula THI = \((0.8 \times T) + \left[\left(\frac{RH}{100}\right) \times (T – 14.4)\right] + 46.4\), in which T = temperature (°C) and RH = relative humidity (NOAA, 1976).

**Data Analysis**

Repeated measures of ewe VT in wk 2, 5, and 8 were analyzed using the mixed model procedure of SAS (SAS Inst. Inc., Cary, NC). Terms included in the model were treatment, season, breed, and time within day and the appropriate interactions. There was no effect of season on VT so all data were pooled across season for final analysis of treatment effect within wk 2, 5, and 8. The interaction of breed with treatment, season, or week was not significant so comparisons between breeds were made using data pooled across treatments, season, and week. Mean separation was conducted using the pdiff option. All results are presented as least square means ± SEM.

**RESULTS**

The mean and ranges of temperature, relative humidity, and THI during the data collection periods in the warm and cool seasons are shown in Table 1. The average daily profiles for temperature, relative humidity, and THI in the cool and warm seasons are shown in Fig. 1. The morning feeding took place at a time of day when temperature and THI were increasing and humidity was decreasing. The afternoon feeding took place at a time of day when temperature and THI were decreasing and humidity was increasing.
Feed intake, as a percentage of feed offered, was lower ($P < 0.0001$) for AM and PM than AM-PM fed ewes (91.2, 93.1, and 99.4%, respectively). There was no difference ($P > 0.10$) in feed intake between STX and DRPX ewes (94.7 vs. 94.4%, respectively).

During wk 2 (d 8–14 postpartum) VT was not different ($P > 0.10$) between Control, AM, PM, or AM-PM ewes (Fig. 2, top panel; 39.51 ± 0.01 vs. 39.63 ± 0.01 vs. 39.68 ± 0.01 vs. 39.59 ± 0.01°C, respectively). During wk 5 (d 29–35 postpartum) AM-PM ewes had higher ($P < 0.0001$) VT than Control, AM, or PM ewes starting at 2000 h on d 1 (Fig. 2, middle panel; 39.81 ± 0.01 vs. 39.49 ± 0.01 vs. 39.52 ± 0.01 vs. 39.59 ± 0.01°C, respectively). By wk 8 (d 50–56 postpartum) the PM and AM-PM ewes had higher ($P < 0.0001$) VT than either the Control or AM ewes during the time from 1800 h on d 1 through 1000 h on d 2 and 1800 h on d 2 thru 0900 h on d 3 (Fig. 2, bottom panel; 39.69 ± 0.01 vs. 39.67 ± 0.01 vs. 39.40 ± 0.01 vs. 39.36 ± 0.01°C, respectively).

When VT was analyzed for the 3-h periods after each feeding (morning or afternoon) within each day and week, there was no difference ($P > 0.10$) among treatments at the morning feeding in wk 2 but at the afternoon feeding the PM ewes had higher VT ($P < 0.0001$) than AM, AM-PM, or Control ewes (d 8–14 postpartum; Fig. 3, top panel; 39.69 ± 0.02 vs. 39.53 ± 0.02 vs. 39.58 ± 0.01 vs. 39.48 ± 0.02°C, respectively). In wk 5 (d 29–35 postpartum) the AM-PM ewes had higher ($P < 0.0001$) VT than the Control, AM, or PM ewes at the morning (39.69 ± 0.01 vs. 39.53 ± 0.01 vs. 39.49 ± 0.01 vs. 39.60 ± 0.01°C, respectively) and afternoon (39.84 ± 0.01 vs. 39.57 ± 0.01 vs. 39.47 ± 0.01 vs. 39.61 ± 0.01°C, respectively) feedings (Fig. 3, middle panel). In wk 8 (d 50–56 postpartum) the PM and AM-PM ewes had higher ($P < 0.0001$) VT than either the Control or AM ewes at the morning (39.64 ± 0.01 vs. 39.64 ± 0.01 vs. 39.44 ± 0.01 vs. 39.41 ± 0.01°C, respectively) and afternoon (39.69 ± 0.01 vs. 39.73 ± 0.01 vs. 39.44 ± 0.01 vs. 39.44 ± 0.01°C, respectively) feedings (Fig. 3, bottom panel).

The average VT of DRPX ewes was higher ($P < 0.0001$) than that of STX ewes (39.79 ± 0.002 vs. 39.49 ± 0.002°C, respectively). The DRPX ewes had higher ($P < 0.0001$) VT at all times of the day compared to the STX ewes and both genotypes exhibited similar diurnal patterns of VT (Fig. 4).

**DISCUSSION**

Our hypothesis was that feeding ewes late in the day would allow the extra heat generated by the metabolic processes in the rumen to be dissipated better during the cooler night time than feeding early in the day when temperatures were rising. Ewes in the current study were fed in the morning at a time of increasing temperature and decreasing humidity or in the afternoon at a time when temperatures were decreasing and humidity was increasing. Brosh et al. (1998) reported that there was a greater increase in respiration rate and rectal temperature...
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from the morning to the afternoon in Hereford heifers that were fed in the morning (0830 h) compared to those fed in the afternoon (1630 h). The authors proposed that feeding heifers in the morning would lead to heat loading during the hot time of the day, which would limit heat dissipation compared to heifers fed late in the day when there were lower environmental temperatures. The results of the current study where ewes fed in the afternoon (PM) or fed a split ration (AM-PM) had higher body temperatures than the ewes fed in the morning (AM) or not at all (Control) are in contrast to those of Brosh et al. (1998). One possible reason for the discrepancy is a much narrower range in temperature and humidity compared to the present study, with the sheep in the present study being exposed to higher temperatures and humidity, which could impact their ability to dissipate heat. Lactating Holstein cows fed in the morning (0830 h) had higher VT between 1800 and 2000 h than those fed in the evening (2030 h) but lower VT between 0200 and 1000 h (Ominski et al., 2002). This is in partial agreement with the current study where AM ewes had lower VT than PM ewes at all times of the day during wk 8. The time of day of the afternoon feeding used by Ominski et al. (2002) is much later than in the current study, which may explain some of the difference along with the fact that the ewes were fed at 70% of their requirements and the dairy cows were fed a total mixed ration.

By feeding a split ration it was hoped to spread out and minimize the amount of extra heat generated by the metabolic processes in the rumen. Steers fed a split ration (33% in AM and 67% in PM) under hot conditions (24 to 39°C) had lower rectal temperatures than steers fed in the morning or afternoon (Gaughan et al., 1996). In contrast to these results the ewes fed a split ration in the current study had higher VT during wk 2 and
wk 8. The elevated body temperature of the PM and AM-PM fed ewes in the current study indicates that the ewes may not have been able to dissipate the heat load generated by feeding in the afternoon (as entire or split ration) even though this was at a time when environmental temperature and THI were both decreasing. Previous work in our laboratory has shown that dairy cattle are under some degree of heat stress, using a THI of 72 as an indicator when livestock are experiencing conditions of heat stress, throughout the entire year in the U.S. Virgin Islands (Godfrey and Hansen, 1996). Because the average THI during the cool and warm seasons were both above this level it is possible that the ewes were also under some amount of heat stress. But if this was the case, then the AM ewes would have also exhibited elevated VT, especially compared to the Control ewes. Perhaps any feeding in the afternoon adds to the heat load that the ewes are subjected to throughout the day and they cannot dissipate it as effectively as when they are fed only in the morning.

Because the AM-PM ewes had higher VT than other groups starting at wk 2 it may be possible that feeding a split ration under conditions of high heat and humidity leads to a longer period when excess heat generated by metabolic activity needs to be dissipated throughout the day, resulting in elevated body temperatures. The PM ewes did not have VT as high as AM-PM ewes at wk 5 but at wk 8 both groups were higher than the AM or Control ewes. Cattle have been shown to exhibit a diurnal pattern of heat production that is linked to time of feeding (Purwanto et al., 1990). Dairy cows under thermoneutral conditions (18°C and 78% relative humidity) had an increase in heat production and heart rate during the 3 h after the morning feeding followed by a decrease until the afternoon feeding when another rise in heat production occurred in the 3 h following the afternoon feeding and decreased until the early morning before feeding (Purwanto et al., 1990). Again, this is in contrast to the results of the current study, which may be due to the high ambient temperature and humidity and the time required for heat production caused by feeding concentrate to decrease. It appears that the PM and AM-PM ewes were not able to dissipate the heat produced by feeding in the afternoon, even a split ration, in an amount of time that would allow them to reach body temperatures of the Control or AM ewes at most times of the day.

In addition to the time of feeding, the level of feeding can also influence the metabolic heat load in livestock. Mader et al. (2002) found that in a hot climate (THI > 74) steers fed a restricted diet (75% of ad libitum intake) for either 21 or 42 d resulted in a decrease in tympanic temperature compared to steers offered feed ad libitum. The authors hypothesized that the temperature reduction was due to a decrease in metabolic heat load, a decrease in metabolic rate, or a combination. The concentrate ration provided to the ewes in the present study was approximately 70% of the recommended amount for lactating ewes in the tropics (Kawas and Huston, 1990). If the elevated VT of the ewes in the present study was due only to the amount of feed, it does not explain why the AM ewes did not show an increase in body temperature similar to the PM and AM-PM ewes. In the present study it seems that time of feeding had more of an impact on VT than amount of feed. Ewes that received feed, whether it was their entire ration or just half, in the afternoon had higher VT than ewes that received feed only in the AM or none at all.

The difference in VT between the STX and DRPX ewes adds to information reporting differences between the two breed types under tropical conditions. Other work in our lab (unpublished data) has also shown that DRPX ewes had higher VT than STX ewes measured over a 96-h period (39.26 ± 0.005 vs. 39.04 ± 0.005°C, respectively) but there was no difference (P > 0.10) in sweating rate between DRPX and STX ewes (19.9 ± 2.8 vs. 18.3 ± 1.6 g·m⁻²·h⁻¹, respectively). Perhaps if the DRPX ewes were able to increase their sweating rate they could have maintained their body temperature at a level similar to that of the STX ewes. The Dorper breed was initially selected for arid areas. Baker et al. (1999) indicated there is evidence for a breed × environment interaction for lamb growth, mature size, and ewe reproduction in drier less humid climates where Dorper sheep perform better and grow faster than Red Maasai. The high humidity observed in the current
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The results show that feeding lactating ewes twice a day or once in the afternoon resulted in higher body temperatures than in ewes that were fed once in the morning or not at all. Dorper × St. Croix White sheep are not as adapted to the hot, humid tropics as STX sheep are as evidenced by their higher body temperature. The increased labor involved in feeding a split ration to lactating ewes and the resulting increase in body temperature limits the feasibility of this being used as a management practice to alleviate heat stress in the tropics.

**LITERATURE CITED**


