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Short communication: The effects of morning compared with evening feed delivery in lactating dairy cows during the summer

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ABSTRACT

Delivering fresh feed in the evening is a management strategy sometimes used during periods of heat stress, but previous experiments have observed that night feeding increased feed intake during the 2 h after feeding and did not change intake during the overnight period. The objective of this study was to determine the effect of night feeding on daily rhythms of the dairy cow during the summer season. Twelve Holstein cows were used in a crossover design with 14-d periods. An automated system recorded the timing of feed intake over the last 7 d of each period. Treatments were ad libitum feeding with fresh feed delivery 1×/d at 0830 h or 2030 h. Milk yield and composition were not changed by treatment, but night feeding decreased the concentration of preformed fatty acids in milk fat. Night feeding decreased feed intake 1.7 kg/d, and decreased total-tract dry matter and neutral detergent fiber (NDF) digestibility by 0.7 and 0.8 percentage units, respectively. The amount of feed consumed in the first 2 h after feeding was 64% greater with night feeding, but intake did not differ between treatments during the night or early afternoon. A treatment by time of day interaction was observed for fecal NDF and indigestible NDF concentration and plasma glucose, insulin, and urea concentrations. Night feeding resulted in an increase in plasma insulin after feeding, which decreased plasma glucose. The daily rhythm of core body temperature was entrained by treatment, with the phase shifted and the amplitude decreased by night feeding indicating alteration of the central clock. In conclusion, feeding cows once per day in the evening during the summer caused a similar increase in feed intake and plasma insulin after feeding as previously observed during non-heat stress seasons. Night feeding also decreased intake and total-tract digestibility. The daily pattern of feed intake and other behaviors should be considered before initiation of night feeding.

Key words: circadian, daily pattern, feeding behavior, night feeding

Short Communication

Total mixed rations are commonly fed ad libitum, but fresh feed is often only delivered once per day. Delivery of fresh feed in the evening, or night-feeding, is sometimes employed during periods of heat stress to provide fresh feed during the cooler part of the day with the expectation that cows will be more active during this period (Aharoni et al., 2005). Limited work has investigated the efficacy of night feeding, but Calamari et al. (2013) recently reported that average core body temperature was decreased 0.34°C and respiratory rate was decreased 6.2 breaths/min by evening feeding compared with morning feeding.

Circadian rhythms are 24-h repeating cycles that affect most physiological processes in the body. The dairy cow has a natural daily pattern of feed intake with high intake after fresh feed delivery and during the afternoon and early evening and lower intake during the overnight period (e.g., Devries and von Keyserlingk, 2005; Rottman et al., 2015). This natural pattern appears to be a robust circadian rhythm that is maintained during evening feeding (Nikkhah et al., 2008; Niu et al., 2014). We recently compared feeding 1×/d at 0830 or 2030 h and 2×/d feeding at the same times and observed the daily pattern of feed intake and key plasma metabolites and metabolic hormones (Niu et al., 2014). However, the Latin square experiment was conducted during late winter in the absence of heat stress (February and March). The current experiment was conducted during late summer (August and September) at the Pennsylvania State University Dairy Production Research and Teaching Center to investigate the effect of night feeding on the daily pattern of feed intake during a warmer season (approved by the Penn State Institutional Animal Care and Use Committee). A temperature data logger recorded barn temperature over the day (HOBO Pendant Temp/Light, Onset Computer Corp., Bourne,

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MA). The highest daily temperature 25.7 ± 1.21°C (mean ± SD) around 1600 h and the lowest daily temperature was 19.3 ± 3.51°C (mean ± SD) around 0400 h. Twelve noncannulated multiparous Holstein cows (2.8 ± 0.27 parities; 254 ± 20.5 DIM; mean ± SD) were housed in a tiestall barn with rubber mats (Wingflex, Gummiwerk Kraigburg Elastik, Germany) and sawdust bedding and randomly assigned to treatment sequences in a crossover design with 14-d periods. The corn silage-based TMR contained 33.4% NDF, 18.4% starch, and 17.7% CP [Supplemental Table S1; https://doi.org/10.3168/jds.2017-13635; analyzed as described by Niu et al. (2014)]. Treatments were fed 1×/d at 0830 or 2030 h. A light-sensing data logger verified a consistent 18 h light and 6 h of dark schedule (dark ~2300 to 0500 h).

Data were analyzed as described by Niu et al. (2017). Briefly, data observed across the day were analyzed using the MIXED procedure of SAS with repeated measures (version 9.3, SAS Institute Inc., Cary, NC). The model included the random effects of sequence, period, and cow nested in sequence and the fixed effect of treatment, time, and the interaction of treatment and time. The effect of treatment was tested at each time point. Time course data were also fit to a cosine function with a 24-h period for circadian rhythm analysis using the linear form of the cosine function in Proc Mixed. The preplanned contrast tested the differences in amplitude and acrophase (reported as time at peak). Parameters averaged over the day were analyzed with a reduced model that did not include the effect of time using JMP (version 9.4, SAS Institute Inc.). Significance was declared at $P < 0.05$ and $P < 0.10$ for main effects and interactions, respectively, and tendencies at $P < 0.10$ and $P < 0.15$, respectively.

Cows were milked twice daily at 0500 and 1700 h and milk yield determined by an integrated milk meter (AfiMilk; SAE Afikim, Israel) and analyzed as the average of d 12 to 14 of each period. Milk yield averaged 31.2 kg/d and was not different between treatments (Table 1). Milk was also sampled at both milkings from d 12 to 14 of each period and analyzed for concentration of fat (filter B) and true protein by infrared spectroscopy (Dairy One Lab, State College, PA). Milk fat and protein concentration and yield was not different between treatments and both were above breed average (4.2% fat and 3.4% protein; Table 1). Milk fatty acid profile was determined by GC with a flame ionization detector at each milking on d 14 as described by Rico and Harvatine (2013) as modified by (Niu et al., 2014). Intermediates of the normal and alternate biohydrogenation pathway (*trans*-10 C18:1 and *trans*-11 C18:1, respectively) were not different between treatments. Niu et al. (2014) also did not observe a change in milk yield or composition or *trans* fatty acids (**FA**) in cows producing 50 kg/d of milk. However, in the current experiment, night feeding increased preformed (FA >16 C) 1.1 percentage points and decreased mixed source FA (16 C) 1.3 percentage points, whereas de novo synthesized FA (FA <16 C) were not changed. The decrease in preformed FA is opposite of classical diet-induced milk fat depression, which results in a larger decrease in de novo synthesized FA. As discussed below, plasma insulin was increased with night feeding and the decrease in preformed FA concentration is consistent with previous observations of decreased milk preformed FA during glucose and insulin infusion (reviewed by Harvatine et al., 2009).

Feed refusals were sampled before feeding from d 8 to 14 of each period. Daily DMI was decreased 1.7 kg/d in night-fed cows (Table 1). Night feeding did not change DMI during the winter in Niu et al. (2014) when feeding a lower NDF diet (29.7%) or during non-heat stress summer conditions (Manitoba, Canada; average 20.4°C and 68.1% humidity) in Nikkhah et al. (2008), who tested both high- and low-concentrate diets. In the current experiment, NDF digestibility was decreased by night feeding (discussed below) and in combination with the higher NDF level may have caused physical limitations of intake during some periods of the day.

Fecal samples were collected 6 times over the day and total-tract DM and NDF digestibility were determined using indigestible NDF (**iNDF**) as a flow marker as described by Niu et al. (2017). Total-tract DM digestibility of cows fed at night was decreased by 0.7 percentage points and NDF digestibility was decreased 0.8 percentage points. Digestibility has not been well studied during night feeding, but Niu et al. (2014) did report a numerical decrease in total-tract NDF digestibility. The decrease in digestibility may be due to the large amount of feed consumed after feeding in the night-fed group discussed below. This "slug-feeding" is expected to increase rumen acid load during the late evening and may inhibit fibrolytic bacteria. It is important to note that this rapid intake occurs after a moderate rate of feed intake during the afternoon, compared with morning-fed cows who have a much lower intake rate over the 8 h before feeding (overnight period). Thus, rumen starch concentration and amylolytic capacity are expected to be higher before feeding in night-fed cows, resulting in a larger effect of rapid feed intake on the rumen environment.

Fecal NDF and iNDF concentration are known to follow a daily pattern that is modified by feeding time (Niu et al., 2014, 2017). Fecal NDF concentration was 2.2 percentage units higher in morning-fed cows at 0700 and was 2.4 percentage units lower than evening fed cows at 1600 h (Figure 1). Fecal NDF and iNDF concentration fit a cosine with a 24-h period in