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Timing of feeding orchestrates circadian post-feeding intake rhythms in once-daily fed dairy cows

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Abstract

The objective was to establish effects of feed presentation time and dietary forage to concentrate ratio on circadian postprandial rhythms of feed intake in lactating cows. Four multiparous and four primiparous Holstein cows were fed in a 4 × 4 Latin square design (with a 2 × 2 factorial arrangement of treatments) a higher (HC, forage to concentrate ratio = 38.5:61.5) or a lower (LC, forage to concentrate ratio = 50.6:49.4) concentrate total mixed ration (TMR) at either 21:00 h or 09:00 h. A metabolic acquisition system was used to monitor continuous feed intake electronically. Feeding at 21:00 h vs. 09:00 h increased feed intake within 3 h post-feeding, from 26 to 37% of total daily intake; with daily dry matter intake remaining unchanged. Results establish that evening instead of morning feeding increased eating rate shortly post-feeding, and thus, is a key regulator of postprandial circadian intake rhythms in lactating dairy cows.

Key words: Intake rhythm, Feeding time, Chronophysiology, Dairy cow

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Introduction

Fresh feed delivery determines circadian patterns of eating activity in lactating cows (DeVries et al., 2003; Phillips and Rind, 2001). Effects of feeding timing on circadian and postprandial rhythms of feed intake need to be quantified to enable accurate analysis of feeding behavior and feed intake prediction. Presenting the protein supplement at 00:30 h vs. 08:30 h significantly increased protein meal dry matter intake (DMI) and to some extent increased total DMI (Robinson et al., 1997). The midnight protein supplement presentation stabilized rumen fermentation. Under cold weather, feed presentation at 20:00 h instead of 09:00 h improved growth rate in beef steers without affecting DMI (Small et al., 2004). DMI responses to feeding time have thus far been studied mostly in terms of animal thermodynamics. It remains unknown if and how feeding timing regulates feed intake and its postprandial rhythms under thermoneutral conditions. The objective of this study was to determine effects of feeding timing, dietary forage to concentrate, and their interaction on intake postprandial and circadian rhythms and daily DMI in lactating dairy cows.

Materials and Methods

Cow management and experimental design

Four multiparous (BW = 652 ± 14 kg, BCS = 2.87 ± 0.14, days in milk = 83 ± 22) and four primiparous (BW = 667 ± 110 kg, BCS = 3.19 ± 0.66, 81 ± 23 days in milk; mean ± SD) lactating Holstein cows were housed in tie stalls under thermoneutral conditions. The maximum air temperature of the metabolism unit did not exceed 25°C at any time during the experiment. Cows were offered either a higher concentrate diet (HC) with a forage to concentrate ratio (F:C) of 38.5:61.5 or a lower concentrate diet (LC) with a F:C of 49:51 at either 09:00 h or 21:00 h. The experimental design was a replicated 4 × 4 Latin square with a 2 × 2 factorial arrangement of feeding timing and dietary forage to concentrate ratio. Each experimental period lasted for 21 d with 14 d of adaptation. Cows were fed *ad libitum* permitting 5-10% orts, with unlimited access to fresh water. Circadian and postprandial rhythms of feed intake were monitored continuously using a data acquisition system within the metabolism unit (Grow-Safe Sys, Model

4000, Airdrie, AB). Total mixed rations were prepared every morning using a Data Ranger Mixer (American Calan, Northwood, NH) with a Weigh Tronix head (Model 1000, American Calan, Northwood, NH). Except for sampling weeks, cows were allowed for 2 h daily exercise (07:00-09:00 h). Milking was performed twice daily in the stalls at 04:00 and 16:00 h. Lights were on from 03:45 until 22:45 h.

Statistical Analyses

The amount of feed ingested within eight 3-h intervals (24-h phase) were expressed as percent of total daily TMR intake for individual cows. The amounts ingested within each 3-h interval were compared between evening-fed and morning-fed cows with Mixed Model Procedures of SAS program (SAS Institute, 2003). The effects of feeding timing, diet, parity, and their interaction were fixed, and effects of period and cow within parity were random. Tukey's multiple range test was used to compare the differences between least square means. Significant levels of fixed effects were declared at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

Results and Discussion

Feeding timing altered ($P<0.05$) circadian and postprandial rhythms of feed intake (Figure 1). The proportion of daily TMR intake consumed within 3-h post-feeding was 37% for 21:00 h-fed cows and only 26% for 09:00 h-fed cows ($P<0.05$). In cumulative terms, the amounts consumed between 0:00-6:00 h and 0:00-9:00 h post-feeding were similar between the two groups (Figure 1). Parity and diet did not interact with feeding timing on circadian rhythms of feed intake ($P>0.10$). Despite altering the post-feeding rhythms of intake, evening feeding did not affect daily DMI (20 kg/d).

Fresh feed delivery is a major determinant of circadian rhythms in feed intake of tie-stall-housed (Haley et al., 2000) and loose-housed (DeVries et al., 2003) lactating cows. The stimulatory effect of feed presentation on eating activity can persist even with four times daily feeding (DeVries et al., 2005). Cows fed once daily at 05:30 h spent less time eating than cows fed twice daily at 05:30 and 15:15 h (DeVries et al., 2005). The longer eating time of cows fed twice daily was mostly due to increased eating time between 20:00 to 06:00 h. However, when Phillips and Rind (2001) presented fresh TMR either once daily at 06:00 h or four times daily at

06:00, 10:00, 14:00, and 19:00 h to early-lactation cows in free stalls, the total time spent eating did not differ. Nonetheless, cows fed four times daily tended to spend more time eating in evening (16:00-20:00 h) than in morning (04:00-12:00 h). The current data and the results of DeVries et al. (2005) and Phillips and Rind (2001) suggest that dairy cows eat when they are presented fresh feed and that the amount ingested after feed presentation depends on time of the day. None of the above studies quantified the proportional contribution of the more frequent feed delivery and/or evening feed delivery *per se* to greater eating time. DeVries et al. (2005) did not monitor daily DMI. If cows anticipate the feed presentation, they would exhibit a more pronounced peak in time spent eating upon fresh feed delivery (Nikkhah, 2011a,b). Thus, the possibility exists that cows may have more effectively anticipated the 21:00 h- vs. 09:00 h-feed delivery in the present study.

Plasma insulin levels were higher and plasma glucose were lower at 2 h post-feeding in 21:00-fed cows than in 09:00 h-fed cows (Furedi et al., 2006). Higher insulin could mean a destabilized glucagon action, thus reducing gluconeogenesis (Brockman, 1990). The intraperitoneal injection of glucagon antibodies to suppress glucagon effects stimulates feeding (Langhans et al., 1982). The intravenous glucagon has been shown to reduce feed intake in sheep (Deetz and Wangsness, 1981). Probably the higher blood insulin and lower blood glucose at 2 h post-feeding in evening-fed cows may have delayed the glucagon-driven satiety. This may have contributed to the increased eating rate within 3 h of the evening vs. morning feed presentation. The data provide novel information and insight into the nutritional chronophysiology of ruminant ecology.

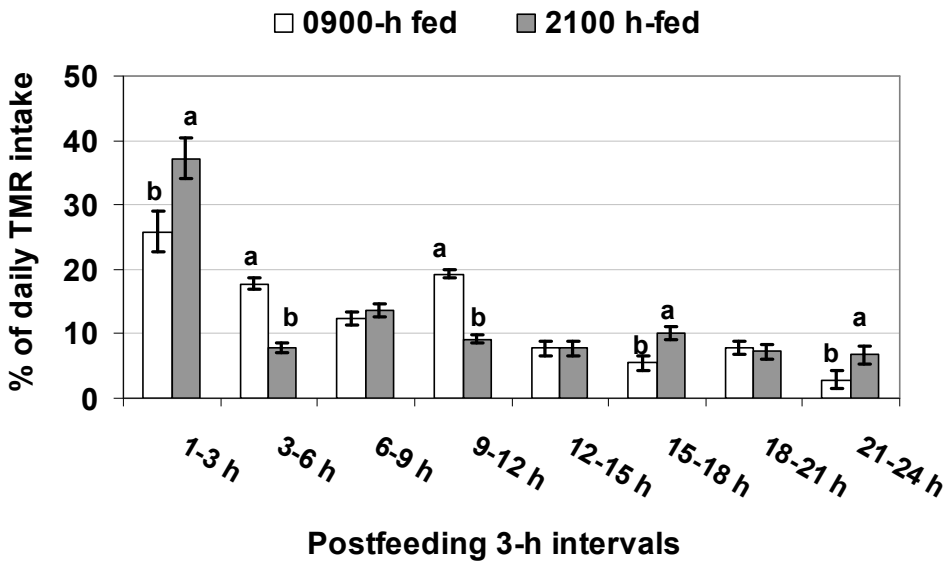

Figure 1. Post-feeding patterns of feed intake in cows fed either at 09:00 h (□) or at 21:00 h (■). Within each 3-h, different superscripts indicate $P < 0.05$.

Conclusion

Presenting higher and lower concentrate total mixed rations at 21:00 h vs. 09:00 h consistently increased eating rate and feed intake within 3-h post-feeding in both primiparous and multiparous lactating dairy cows, with daily dry matter intake remaining unchanged. Results provide novel evidence that altered feeding timing in once-daily fed lactating cows altered circadian and post-feeding intake rhythms. Timing of feeding is a key regulator of feed intake in high-producing dairy cows.

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