The Effects of a Morning Fasting on the Evening Grazing Behavior and Performance of Strip-Grazed Beef Heifers

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ABSTRACT

This study assessed the impact of morning fasting periods on strip-grazed beef heifers with afternoon herbage allocation, evaluating evening eating, rumination, and idling time, bite rate, ADG, change in BCS, and estimating daily herbage DMI. Treatments were afternoon herbage allocation (1430 h) with or without morning fasting (9 h). A behavioral and a performance experiment were simultaneously conducted. In the behavioral experiment, 8 heifers strip-grazed Lolium multiflorum Lam. pastures in a crossover design. Behavior was recorded every 2 min from 0630 to 1830 h. During the evening (1430 to 1830 h), bite rate was measured in each grazing bout. In the performance experiment, 58 heifers were randomized across treatments and strip-grazed over 14 wk in a complete randomized design. Every 2 wk the heifers were weighed, BCS was evaluated, and DMI was estimated. Behavior and DMI were tested by ANOVA. Performance was analyzed as repeated measurements in time. Fasting tended ($p = 0.10$) to increase (20 min) the evening eating and reduce ($p = 0.09$) idling times (16 min), and rumination time was 0 min for both treatments. Bite rate increased ($p = 0.01$) for fasting compared with nonfasting (54 vs. 62 bites per min). Treatment did not affect ADG (0.66 kg/d; $p = 0.88$), change in BCS (0.0135; $p = 0.77$) and DMI (4.43 kg; $p = 0.19$). Morning fasting generates longer and more intense evening grazing bouts, increasing the DMI of higher nutritive herbage, making cattle perform equally in shorter grazing sessions.

Key words: cattle, grazing behavior, fasting and herbage allocation, performance, strip grazing

INTRODUCTION

Grazing management defines a basic link between primary and secondary productivity of pasture-based livestock production systems. Diurnal grazing time may be seen as a cluster of discrete grazing bouts (Gibb, 1998; Gibb et al., 1998). Therefore, on a daily scale, when to begin, which frequency of, and how to distribute grazing bouts is relevant because these decisions determine how cattle allocate eating time to meet their nutritional needs (Gregorini et al., 2006b). Regardless of the frequency, the longest and most intense grazing bouts occur at dusk (Hodgson, 1990), with cattle attempting to maximize their intake rate at the time herbage contains the highest nutritive value (Mayland et al., 2005; Gregorini et al., 2007a).

From dawn to dusk, herbage loses moisture and accumulates total non-structural carbohydrates, which dilutes NDF and CP concentration (Fisher et al., 1999; Delagarde et al., 2000), increasing IVDMD (Gregorini et al., 2006a) and palatability (Provenza et al., 1998). The pattern of grazing bouts is not inflexible and can be affected by management. Orr et al. (2001) and Gregorini et al. (2006a) modified the grazing pattern, improving the performance of dairy cows and beef heifers due to alterations in glucogenic and aminogenic nutrients supplied (Gregorini, 2007). They matched the pattern of grazing bouts to the diurnal herbage accre-
tion of total nonstructural carbohydrates through afternoon herbage allocations. Neither Orr et al. (2001), Gregorini et al. (2006a), nor Gregorini (2007) found differences in herbage intake, in contrast to its diurnal pattern.

Generally, the degree of hunger of animals affects grazing behavior variables that determine herbage intake (Illius and Gordon, 1999; Gregorini et al., 2007b). Greenwood and Demment (1988) and Gregorini et al. (2007b) showed that herbage intake rate is generally below the maximum possible because previous fasting and low levels of ruminal fill can substantially increase it. In addition, Iason et al. (1999) and Gregorini (2007) demonstrated that at high herbage availabilities, daily fasting periods counteract reductions in available diurnal grazing time. The objectives of this study were to match afternoon herbage allocation management with a morning fasting period and determine if stimulating a higher herbage intake during the evening would directly affect animal performance.

MATERIALS AND METHODS

All animal procedures in the following experiments were conducted in accordance with the animal care and use guidelines recommended in the Consortium (1988).

Research Site

These studies were conducted during winter from June 7 to September 21, 2005, at the experimental farm “El Amanecer” of the National University of La Plata, (lat 35°15’00”S, long 57°37’30”W) as the continuation of the studies published by Gregorini et al. (2006a). Detailed description of the forage source improved and utilized [Flooding Pampa Range and annual ryegrass (Lolium perenne Lam.)] and average environmental conditions are presented in Gregorini et al. (2006a). During the experimental period the mean daily temperature, radiation, and precipitation were, respectively, 12.5°C, 1,864.8 Wat/m², and 52.1 mm for the 4 mo of winter (June to September).

Experimental Procedures

Behavioral and performance experiments were conducted simultaneously. The behavioral experiment analyzed eating, rumination, and idling time during the daylight (0630 to 1830 h), and bite rate (from 1430 to 1830 h) of beef heifers under strip-grazing. Strips of annual ryegrass-dominated (>88% on a DM basis) swards were allocated daily in the afternoon (animals were turned onto an ungrazed strip at 1430 h daily) with (FAST) or without (UNFAST) a previous 9-h fasting period from 0630 to 1430 h each day. Animals were kept 50 m from daily strips in a 625-m² resting corral in which forage, salt, and water were not available. The performance experiment evaluated ADG and change in BCS, as well as the estimated daily herbage DMI of beef heifers under the same treatments (UNFAST and FAST).

Performance Experiment

For this experiment, 58 Angus heifers (BW = 189.54 ± 0.26 kg and BCS = 5.49 ± 0.18) were utilized. Heifers were rotationally grazing native range (Flooding Pampa). Therefore, before starting the experiment, heifers were subjected to strip-grazing on the annual ryegrass-dominated swards for 10 d. The new daily strip was allocated at 1100 h because at that time of day herbage would have a medium value in nutritive value (P. Gregorini, unpublished data). After this diet standardization period, heifers were randomly assigned to treatments, either FAST or UNFAST in a complete randomized design (Gill, 1978). After the diet standardization period and treatment assignment, heifers had a preconditioning week to treatment management, and then started the measurement period of 14 wk. Heifers grazed according to treatments 2 sets of strips apart from each other (heifers could not see each other), using strip-grazing method throughout the experiment. Strips to be grazed were always in vegetative stage (between 3 and 4 green leaves per tiller). Herbage allowance was 6% (DM basis) of BW. The sizes of the daily strips were determined according to the herbage mass (kg/ha) and allowance. Herbage mass was determined weekly at noon by cutting 9 squares of 30 cm² with manual mowers to a stubble height of 3 cm. Then, clipped herbage was collected, weighed, and sampled for DM (oven-dried at 60°C for 48 h). In keeping with common practice in this area (Northeast Flooding Pampa) heifers were not provided with shelter, salt, or free drinking water (because of the high water concentration in the herbage, 21% DM).

Heifers were weighed and BCS (1 to 9 point scale) assigned every 2 wk. To minimize differences in ruminal fill, all weights were taken at 0530 h, before heifers in FAST started the daily fasting period (0630 h). Herbage DMI of each group of heifers (FAST and UNFAST) was estimated every 2 wk by the sward cutting method (herbage disappearance), pregrazing herbage mass minus postgrazing herbage mass refused (cutting 9 squares of 30 cm² with manual mowers at a stubble height of 3 cm). Samples for this estimation were taken between 1400 and 1430 h. Clipped herbage was weighed and sampled for DM determination (oven-dried at 60°C for 48 h).

Behavioral Experiment

Eight additional heifers (Angus, BW = 192 ± 1.67 kg) were inserted (as focal animals) and managed within the performance experiment (4 per treatment), using a simple crossover experimental design (Jones and Kendrick, 1989) with 2 periods and 2 treatments. Heifers were randomly assigned to treatments (UNFAST or FAST). Each period consisted of 10 d of adaptation to diet, treatment management, and presence of individual observers, and 1 d of behavioral measurements. Eating, rumination, and
idling behavior were visually determined every 2 min (Hirata et al., 2002) from 0630 to 1830 h by 2 trained observers who were randomly assigned to each treatment and period. From these data, eating, rumination, and idling time were calculated, multiplying each behavior frequency by a 2-min interval. To determine and graphically visualize grazing bout distribution, breaks in eating activity of more than 5 min in duration were considered as delimiting a grazing bout, whereas breaks less than 5 min were intra-grazing bout intervals (Rook and Huckle, 1997). For the purpose of this study, eating activity was considered when the heifer was directly engaged with acquisition into the mouth, mastication, and subsequent swallowing of herbage, as well as searching within the feeding station level. To measure bite rate (bites per minute), one trained observer was randomly assigned to each heifer every period. Bite rate was determined in every bout of the evening period (from 1430 to 1830 h), during periods of at least 1 min of uninterrupted eating activity.

Pastures and Herbage Quality

Annual ryegrass growth from the Flooding Pampa range was managed and N fertilized as in Gregorini et al. (2006a), creating swards with 88% of annual ryegrass, as determined by the dry-weigh-rank method (Gillen and Smith, 1986). Sward surface height was measured (pregrazing) weekly, using a sward stick as described by Barthram (1986). Herbage mass was also determined weekly as explained above. To measure variation of chemical composition of herbage available to heifers, 8 samples (150 g of fresh material) were taken every 4 wk 3 times daily (0700, 1300, and 1700 h), corresponding with the main gazing bouts. Samples were taken following the methodology of Gregorini et al. (2006a) by walking next to 8 randomly chosen heifers per treatment for 2 min, taking hand-plucked samples (mimicking as near as possible the harvesting movements of heifers) where and when heifers grazed ungrazed spots. Samples were pooled based on equal DM weight by time of day, oven-dried at 60°C for 48 h, ground to pass a 2-mm screen (Wiley Mill, Model S; Thomas Scientific, Swedesboro, NJ), and analyzed for NDF and ADF according Van Soest et al. (1991). Nonstructural carbohydrates were determined with the anthrone method (Yemm and Willis, 1954), CP (6.25 N) using Micro Kjeldahl (Bremner and Mulvaney, 1982), and IVDMD by Tilley and Terry (1963).

Statistical Analysis

The ADG and changes in BCS were analyzed using a statistical model including the effect of time (week of weighing) as a repeated measurement using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC). The error term used in this analysis to test treatment effect was heifer within treatment x time. The pooled residual error was used to test the effects of time and the interactions with time. Interactions between time and treatment were tested comparing least squares means analysis. Herbage mass, sward surface height, evening and daily eating, rumination, idling time, bite rate, as well as herbage DMI were analyzed by ANOVA using GLM of SAS (SAS Inst. Inc.). In the case of diurnal variation of chemical composition of herbage available for heifers, time of day was considered as treatment. Least squares means were separated using the option PDIFF in SAS (SAS Inst. Inc.). A significance level of P < 0.05 was considered significant.

RESULTS AND DISCUSSION

Pasture and Herbage Quality

Mean herbage mass and sward surface height did not differ between treatments (P > 0.05), with means of 2,349 ± 412 kg DM/ha and 23.97 ± 0.72 cm, respectively. These sward features, plus the herbage allowance applied (6% DM basis of BW) implied that in the present experiment heifers grazed without ingestive constraints (Combellas and Hodgson, 1979).

Herbage IVDMD digestibility increased 4.2% (P < 0.05) during daylight hours (Table 1). Neutral detergent fiber decreased by 20.54% and nonstructural carbohydrates increased by 33.5% from dawn to dusk (P < 0.05), whereas CP concentration did not show variation during the day (Table 1). Metabolizable energy increased 0.1 Mcal/kg DM from 0700 to 1700 h (3.608 × IVDMD). These results support the argument that the major change in diurnal nutritive value is attributable to an increase in photosyntheses, which leads to a passive dilution of NDF concentration (Delagarde et al., 2000). Considering the diurnal accretion of nonstructural carbohydrates and its potential to complete rumen fermentation (Van Vuuren, 1993), losses of N would be reduced, and a higher supply of aminogenic and glucogenic nutrients would be expected to increase during the dusk grazing bout.

Performance and Herbage Intake

In the present work, a period of fasting during the morning did not affect ADG (UNFAST, 0.7 vs. FAST, 0.62 kg/d; P = 0.88, SE = 0.11), the change in BCS (UNFAST, 0.012 vs. FAST, 0.014 points/d; P = 0.24, SE = 0.77), and the estimated daily herbage DMI (UNFAST, 4.69 vs. FAST, 4.17 kg/d; P = 0.36, SE = 0.19). The performance results match the fall and winter ADG and BCS reported by Gregorini et al. (2006a) for beef heifers grazing annual ryegrass pastures under UNFAST. The lack of difference in the estimated daily herbage DMI of the present experiment support the results found in sheep by Jason et al. (1999), who found that fasting periods counteracted reductions in available diurnal grazing time. In the current study, heifers in FAST had a reduction of 8 h in the available grazing time. This counteracting effect was also observed by Gregorini (2007), who found no differences in daily herbage DMI of heifers grazed with UNFAST or FAST plus a fasting
Fasting, grazing behavior, and performance

Table 1. Diurnal (daylight h) variation in chemical composition (% of DM) of herbage potentially consumed by strip-grazed beef heifers on an annual ryegrass pasture

<table>
<thead>
<tr>
<th>Variable</th>
<th>IVDMD</th>
<th>NDF</th>
<th>CP</th>
<th>TNC²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0700 h</td>
<td>75.5a</td>
<td>54.8a</td>
<td>16.7</td>
<td>12.0a</td>
</tr>
<tr>
<td>1300 h</td>
<td>76.5b</td>
<td>48.1b</td>
<td>15.6</td>
<td>14.7b</td>
</tr>
<tr>
<td>1700 h</td>
<td>78.7b</td>
<td>45.3b</td>
<td>16.4</td>
<td>16.0c</td>
</tr>
<tr>
<td>SE</td>
<td>1.93</td>
<td>5.05</td>
<td>3.78</td>
<td>1.09</td>
</tr>
</tbody>
</table>

* Means within a column with different superscripts differ (P < 0.05).

1 Values are the mean of 4 pooled dates.

2 TNC = total nonstructural carbohydrates.

period of 20 h (grazing sessions of 4 h daily).

Grazing in FAST was concentrated in the afternoon and evening (1430 to 1830 h), when herbage had the highest nutritive value (Table 1). Based on herbage chemical composition, IVDMD, and the lack of difference in the estimated daily herbage DMI, the intake of nutrients and energy for FAST heifers was theoretically higher. The question arises as to why FAST did not increase performance. An answer may be the following: the population of ruminal microflora in FAST heifers was not enough to receive a higher intake rate of herbage and, consequently, nutrients to digest. After a night ruminating, the ruminal microflora is the least at morning (M. J. Gibb, Institute of Grassland and Environmental Research, North Wyke, Devon, UK, personal communication). In addition, during the morning FAST heifers only ruminated and digested, clearing even more fill from the rumen. Prior fasting increased bite mass of grazing cattle on grass pastures (Chacon and Stobbs, 1977; Patterson et al., 1998, Gregorini, 2007). Laca et al. (1994) found a linear relationship between ingestive chewing by bite and bite mass, which indicates that the degree of herbage fragmentation during ingestion decreases with increasing bite mass. Ingestive chewing prepares forages for digestion by destroying protective layers (i.e., cutin, cell wall), exposing the cellular contents to digestive enzymes (Pond et al., 1984; Boudon and Peyraud, 2001). A mean of 65% of the plant water content would be released in the ingestive chewing (Hogan et al., 1987), presumably releasing around 50% of the soluble carbohydrates and 30% of the intracellular N (Mangan et al., 1976; Boudon and Peyraud, 2001). This hypothetical reduction in ingestive chewing efficiency may have enhanced the problem of a small microbial population coping with a high herbage intake rate. Consequently, changes in FAST ruminal fermentation patterns may not have been large enough to significantly alter the pattern of nutrient supply, in spite of the differential quality of herbage potentially consumed. Energy intake may have been greater in FAST heifers; nevertheless, it was probably not synchronized and efficiently utilized. This phenomenon may be explained by the results found by Gregorini (2007), who found no greater nutrient supplied (total VFA and duodenal microbial protein flow) for beef heifers when comparing FAST (in this case 20 h fasting) with UNFAST.

Grazing Behavior

Analysis of the behavioral experiment (Table 2) showed that in the evening, eating time tended (P = 0.10) to increase (20 min), and idling time was reduced (16 min, P = 0.09) when heifers were in the FAST, whereas rumination time was the same at 0 min. Under FAST, bite rate increased (UNFAST, 54 vs. FAST, 62 bites/min; P = 0.01). Regarding daily behavioral times, the morning fasting reduced the daily eating time (P = 0.01) by 81 min, which is also reflected in the tendency (P = 0.06) to spend more time idling (51 min) during the morning. Daily rumination time was not affected (P > 0.05). The frequency and distribution (mean of all heifers) of behavioral activities is shown in Figure 1. These results, along with the herbage intake estimates in the performance experiment, demonstrate as in other works (Dougherty et al., 1989; Chilibroste et al., 2004; Gregorini et al., 2007b) the effects of hunger on ingestive behavior and its pattern. However, it seems that these effects are of short duration, comprising the first grazing bouts after fasting. Otherwise, FAST heifers would have continued grazing during the night, performing higher herbage DMI. This premise is supported by the results of Gregorini (2007), who found that 20-h fasted beef heifers stopped grazing before the 4-h grazing sessions ended. In the present experiment, when heifers were fasted, they tended (P = 0.1) to eat longer (20 min). The lack of effect probably means that the level of fasting was not enough to significantly modify the eating time in the evening. However, this does not mean that fasting had no effect on eating time at all. Fasting may have affected the frequency and distribution of grazing bouts over the evening grazing session, which may be observed in Figure 1. This distribution matches the one found by Greenwood and Demment (1988), who observed that steers fasted for 36 h grazed longer than nonfasted cattle in the initial grazing bouts. Patterson et al. (1998) found that the duration of the fasting effect depends on its level, explaining the lack of difference in evening eating time between treatments. According to Jung and Koong (1985), the strongest stimulus controlling the
response to fasting would be ruminal fill. It may well be that perception of rumen conditions (negative “physiological” feedback signals) dominates the short-term functional response, probably during a complete grazing session (Gregorini et al., 2007b), which may also explain the short duration of fasting effects. This concept is supported not only by the results of Patterson et al. (1998) but also Gregorini et al. (2007b). The latter found that level of ruminal fill was negatively and linearly related to grazing time and positively to searching time.

Within this same experiment Wade et al. (2006) conducted a behavioral trial focused on the effect of morning fasting on feeding station behavior. Heifers showed a significant effect of treatment, taking 2.8 bites more per feeding station (FAST, 11.5 vs. UNFAST, 8.7; \( P = 0.02 \)). Similar results were reported by Gregorini et al. (2007b). As ruminal fill increased, the number of bites taken per feeding station decreased. This indicates that hunger effects may also induce differences at lower levels of foraging decisions. Therefore, in the present experiment, treatments made heifers distribute not only their grazing time differently, but also the spatial distribution of their bites. This fact suggests that the reaction of the animal to the perception of the same resource was definitely affected by fasting.

In general, bite rate increases through the day, being the highest during the evening (Gibb et al., 1998). Several studies (Patterson et al., 1998; Iason et al., 1999; Realini et al., 1999) have already shown how bite rate is affected either by sward state or the internal state of the animal. However, only 3 published studies (Orr et al., 2001; Gregorini et al., 2006a, 2007a) show how this natural diurnal pattern of bite rate is enhanced by matching diurnal plant and animal states. Orr et al. (2001) and Gregorini et al. (2006a) found an increase \( (P < 0.05) \) in the bite rate at dusk when dairy cows and beef heifers, respectively, were turned out to the a new daily strip during the afternoon. The current study went further, and through a morning fasting increased \( (P < 0.05) \) the already increased bite rate of afternoon-allocated herbage by 8 bites/min (Table 2). Diurnal pattern of bite rate appears to respond to external and internal stimuli (Gregorini et al., 2006b). The present experiment combined both of them, increasing the stimuli that motivate feeding behavior, which resulted in higher bite rate. Theoretically, FAST heifers consumed the same amount of herbage in one-third of the time compared with UNFAST. Bite rate by itself may have not been the only compensation mecha-

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**Table 2. Times of eating, rumination, and idling during daylight and evening grazing events, and evening bite rate of beef heifers under strip-grazing management exposed to afternoon herbage allocation with (FAST) or without (UNFAST) 9-h morning fasting**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment</th>
<th>SE</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime (0630 to 1830 h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET (min)</td>
<td>FAST</td>
<td>201</td>
<td>21.16</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>RT (min)</td>
<td>FAST</td>
<td>68.7</td>
<td>8.95</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>54.2</td>
<td></td>
</tr>
<tr>
<td>IT (min)</td>
<td>FAST</td>
<td>347</td>
<td>19.34</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>296</td>
<td></td>
</tr>
<tr>
<td>Evening (1430 to 1830 h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ET (min)</td>
<td>FAST</td>
<td>201</td>
<td>8.54</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>181</td>
<td></td>
</tr>
<tr>
<td>RT (min)</td>
<td>FAST</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IT (min)</td>
<td>FAST</td>
<td>42</td>
<td>6.11</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>BR (bites/min)</td>
<td>FAST</td>
<td>62</td>
<td>1.71</td>
</tr>
<tr>
<td></td>
<td>UNFAST</td>
<td>54</td>
<td></td>
</tr>
</tbody>
</table>

\( ET = \) grazing time; \( RT = \) rumination time; \( IT = \) idling time; \( BR = \) bite rate.

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**Figure 1. Frequency and distribution of grazing bouts and rumination and idling events of beef heifers under strip-grazing management exposed to afternoon herbage allocation with (FAST) or without (UNFAST) 9-h morning fasting.**
nism; therefore, other changes such as bite mass may have been present. This is supported by the results of Greenwood and Demment (1988), Patterson et al. (1998), Gregorini (2007), and Gregorini et al. (2007b).

**IMPLICATIONS**

The challenge facing forage and cattle producers is to increase the efficiency of nutrients harvested by cattle, as well as to improve pasture production. Afternoon herbage allocations make the evening grazing bout longer and more intensive, when the herbage has the highest nutritive value. Short fasting periods prior to afternoon herbages enhance this behavioral change, generating even longer and more intense grazing bouts during the evening. This leads to the same nutrient intake and performance in shorter grazing sessions. Cattle trampling reduces pasture production, mainly because of physical plant injury, soil compaction, and a reduction in fertilizer and water penetration in the soil. Plants on compacted soils develop more roots at shallower depths and become susceptible to dry weather. Consequently, fasting prior to afternoon daily strip allocation enables producers to reduce residence time on pasture, future herbage production of such pasture would improve.

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**LITERATURE CITED**


