The effect of frequency of pasture allocation on the milk production, pasture intake and behaviour of grazing cows in a subtropical environment

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Abstract
Two studies were conducted in a subtropical environment to examine the effects on milk production and nutrient intake of Holstein-Friesian cows of offering a daily pasture allowance as various numbers of allocations within a day.

In Study 1, 24 multiparous cows [half early lactation (mean ± s.e. of 57 ± 16.2 d post-partum), half mid–late lactation (204 ± 32.9 d post-partum)] were allocated to 2 groups based on genetic merit, milk production, liveweight (LW) and days post-partum. These groups were offered a daily herbage allowance (HA) of approximately 19 kg dry matter (DM) of kikuyu (Pennisetum clandestinum) cv. Common pasture (above 5 cm from ground level). One group (KB2) received 75% of their HA at 16.30 h and the remaining 25% at 07.30 h the following morning. The other group (KB4) were offered 41.6% of their HA at 16.30 h, 16.7% at 19.00 h, 16.7% at 24.00 h and 25% at 07.30 h. Cows were allowed to regraze allocations given within 24 h (i.e. 16.30 h–16.30 h).

In Study 2, 32 cows (8 primiparous, 24 multiparous) in early lactation (133 ± 23.3 d post-partum) were allocated to 4 groups based on lactation number and criteria used in Study 1. All cows were offered a daily HA of approximately 40 kg DM of biennial ryegrass (Lolium multiflorum) cv. Concord or prairie grass (Bromus willdenowii) cv. Matua pasture. One group (RB1) received 100% of their daily HA at 07.30 h and the remaining 25% at 07.30 h the following morning. The other group (RB4) were offered 66% at 07.30 h with the remainder at 17.00 h. One group (RB3) was offered 44% at 07.30 h, 22% at 12.00 h and 34% at 17.00 h, while the fourth group (RB4) was offered 22% at 07.30 h, 22% at 12.00 h, 22% at 14.00 h and 34% at 17.00 h. Cows were allowed to regraze allocations given within 24 h (07.30 h–07.30 h).

Frequency of pasture allocation had no effect (P>0.05) on pasture intake, yields of milk, fat or protein, milk concentrations of fat or protein, or LW change in either study. Milk lactose concentrations of cows in KB4 were (P<0.05) higher than those of cows in KB2. In Study 1, milk fat levels of cows in early lactation (3.04 vs 3.38% for KB2 and KB4, respectively), milk yields (18.1 ± 0.30 vs 17.1 ± 0.30 L/d) and milk lactose concentrations of cows in late lactation (5.10 ± 0.013 vs 5.13 ± 0.13%) were different but not significantly so. In Study 1, frequency of pasture allocation had no effect (P>0.05) on grazing behaviour, with an average time spent grazing of 424 min/d. Seventy percent of grazing occurred between 07.00 h and 19.00 h. In Study 2, cows in RB1 and RB2 spent more time grazing (P<0.05) between 07.30 h and 12.00 h than cows in RB3 and RB4. Between 12.00 h and 14.00 h, cows in RB4 spent more time grazing and less time idle (P<0.05) than the other treatment groups. These studies indicate that the diurnal frequency of allocating pasture has little effect on the milk production, pasture intake and grazing behaviour of dairy cows grazing pastures in the subtropics.

Introduction
Feedbases for lactating dairy cows in northern Australia are primarily based on perennial tropical grasses (Pennisetum clandestinum, Chloris gayana, Setaria spp.) and both annual and perennial temperate grasses (Lolium spp., Bromus willdenowii) (Cowan et al. 1998; Fulkerson et al. 2000). Various supplements such as conserved forages, grains, protein meals and byproducts are fed in these systems; however,
their cost is high in comparison with well utilised pasture (Cowan et al. 1998). For many producers in this region, increasing their herd’s intake and utilisation of pasture is an attractive approach to improving profitability.

Increasing the pasture intake of lactating cows while maintaining pasture utilisation is a challenge. Utilisation has been observed to decline markedly as herbage allowances (HA) are increased (e.g. Wales et al. 1998; Dalley et al. 1999). Although dry stock can be used to remove excess pasture residues, this system of grazing management has a cost in terms of labour. Moreover, continuous stocking of pastures for >24 h can be detrimental to the rate of pasture regrowth due to the depletion of plant water-soluble carbohydrate reserves (WSC) (Fulkerson et al. 1994).

Producers who practise rotational grazing in this region often offer daily pasture allowances as either a single allocation or as 2 allocations following a.m. and p.m. milkings. At high stocking rates, dairy cows offered herbage once or twice daily usually graze intensively for 2–3 h and then are reluctant to graze fouled areas (Holmes and Wilson 1984; Sporndly 1996) resulting in 10–45% of pasture being rejected (Leaver 1985). In light of this, it may be beneficial to offer pasture gradually throughout a day to reduce fouling.

High ambient temperatures experienced during summer in northern Australia can reduce daytime grazing and increase night grazing (Cowan 1975). In these circumstances, pasture intake per cow could be increased by strategically offering fresh pasture allocations during the night. Alternatively, WSC concentrations in temperate pastures (e.g. Lolium spp.) in northern Australia during spring gradually increase throughout daylight hours and are at their highest in late afternoon (Fulkerson et al. 1994). Given that the non-structural carbohydrate: protein ratio of temperate grasses is low (Fulkerson et al. 1998), an increase in WSC intake by providing fresh allocations of temperate pasture during late afternoon may improve this ratio.

Increasing the diurnal frequency of pasture allocation could have the added benefits of reducing satiety by lowering peak concentrations of rumen volatile fatty acids, rumen temperature, duodenal lactate flow and distention of the rumen-recticulum (Forbes 1984, 1987; Baile and Della-Fera 1988). Higher milk fat concentrations have also been observed in cows offered more meals within a day (Gibson 1984).

The two studies reported here were carried out to determine if increasing the diurnal frequency of allocation of a daily herbage allowance (HA) of pasture could improve the nutrient intake and milk production of lactating dairy cows grazing tropical grass pastures during summer and temperate pastures during spring in a subtropical environment.

Materials and methods

Two studies examining the feeding frequency of daily HAs of pastures were conducted at Wollongbar Agricultural Institute (28° 51′ S, 153° 25′ E; elevation 150 m) in north-eastern New South Wales, Australia. Study 1 commenced on January 20, 2000 and concluded on February 18, 2000 (17 d adjustment period, 13 d observation period) with cows grazing rainfed, kikuyu (Pennisetum clandestinum) cv. Common-dominant (>90%) pastures. Study 2 began on September 24, 2001 and concluded on October 19, 2001 (14 d adjustment period, 11 d observation period). Cows grazed irrigated biennial ryegrass (Lolium multiflorum) cv. Concord or prairie grass (Bromus willdenowii) cv. Matua-dominant pastures during this study.

Experimental animals and design

Study 1. Twenty-four multiparous Holstein-Friesian cows of average genetic merit [mean (±s.e.) Australian Breeding Value (ABV) for fat plus protein of 41 ± 31.9 kg] were allocated to 2 groups matched for parity, lactation length, milk production at that stage, liveweight (LW) and ABV. Half were in early lactation (57 ± 16.2 d post-partum) with the remainder in mid–late lactation (204 ± 32.9 d post-partum). The 2 groups grazed as separate herds and were offered approximately 19 kg dry matter (DM)/cow/d of kikuyu measured from 5 cm above ground level. One group (KB2) received 75% of their HA at 16.30 h, after p.m. milking with the remaining 25% offered at 07.30 h after a.m. milking. The other group (KB4) was given 41.6% of their HA at 16.30 h, 16.7% at 19.00 h and 16.7% at 24.00 h, with the remaining 25% given at 07.30 h, after morning milking. Strips of pasture were separated by electric fences. Allocations were offered at 19.00 h and 24.00 h by using spring gates and an automatic timed-release device.
Cows were allowed to regraze allocations given between 16.30 h and 16.30 h the following day.

Study 2. Thirty-two Holstein-Friesian cows (8 primiparous, 24 multiparous) were allocated to 4 groups using the same criteria as in Study 1. Cows in Study 2 had a mean ABV for kg fat plus protein of 38 ± 27.9 kg and were 72–156 d post-partum (mean ± s.e. of 133 ± 23.3 d). The 4 groups grazed annual ryegrass and prairie grass pastures as separate herds and were offered a daily HA (above ground level) of approximately 40 kg/cow DM. One group (RB1) received 100% of their daily HA after a.m. milking (07.30 h). A second group (RB2) was offered 66% of their daily HA at 07.30 h with the remainder at 17.00 h after p.m. milking. A third group (RB3) was offered 44% of their daily HA at 07.30 h, 22% at 12.00 h and 34% at 17.00 h, while a fourth group (RB4) was offered 22% of their daily HA at 07.30 h, 22% at 12.00 h, 22% at 14.00 h and 34% at 17.00 h.

Feed management

In Study 1, eight 1.0 (± 0.04) ha paddocks were grazed at an interval of 3–4 new leaves per tiller. Three paddocks were grazed once with the remaining paddocks grazed at a mean rotation of 10 ± 1.7 d. Paddocks were grazed in pairs with treatment groups alternating between paddocks. The size of daily pasture strips (0.28 ± 0.001 ha) was altered based on pasture availability. Swards were fertilised (100 kg/ha) with urea (46% N) once per month in December 1999, January 2000 and February 2000.

A grain-based concentrate was individually fed twice-a-day (2.7 kg DM/cow/milking) at a.m. and p.m. milking. No refusals of concentrate were noted. The mean nutrient concentration in pasture fed to cows in each treatment and the nutrient levels in concentrate are shown in Table 1.

In Study 2, 6 paddocks of annual ryegrass and 5 paddocks of prairie grass with mean areas of 1.2 (± 0.18) ha and 1.0 (± 0.14) ha, respectively, were grazed at an interval of 2.5–3 new leaves per tiller. Each paddock was divided in half and grazed over two days with cows refused access to the previous day’s grazing. Nine paddocks were grazed once, with 2 paddocks (annual ryegrass) grazed at a mean interval of 20 ± 0.7 d. Annual ryegrass swards were grazed on Days 1–2, 5–6, 15–20 and 23–25 with prairie grass swards grazed on Days 3–4, 7–14 and 21–22. All paddocks had received 500 kg/ha of mixed fertiliser [15.1% N, 4.4% phosphorus (P), 11.5% potassium (K), 13.6% sulphur (S)] during May 2001 and were fertilised with 100 kg/ha of urea every month from June 2001 until the end of the study. Irrigation was provided based on root depth and evapotranspiration. Cows grazed strips in the same paddocks during the same 24 h with treatment groups separated by electric fences. Strips were randomly allocated. A grain-based concentrate was fed as in Study 1. No refusals of concentrate were noted. The mean nutrient concentrations in pasture and concentrate in Study 2 are shown in Table 1.

Milk yield and liveweight

Study 1. Milk yield was measured by recording volumes at all milkings throughout the observation period with the exceptions of Days 1, 10 and 13. On Days 3, 9 and 12, samples were collected from consecutive milkings and analysed for fat, protein and lactose (Milkoscan 133B, N Foss Electric, Denmark). Liveweight was recorded on the first, second and last days of the observation period. Liveweight change (LWC) was calculated as the difference between the mean of LWs recorded on Days 1 and 2 and LWs recorded on Day 13.

Study 2. Daily milk yield and composition were measured as in Study 1 on Days 1, 3, 8 and 10 of the observation period. LWs were recorded on Days 1, 2, 10 and 11. LWC was calculated as the difference between the mean of LWs measured on Days 1 and 2 and the mean of LWs measured on Days 10 and 11.

Pasture measurements and nutrient analyses of pasture and concentrate

During each study, pre- and post-grazing pasture mass were measured over the experimental period using an Ellinbank rising plate meter (RPM; Earle and McGowan 1979) using the calibration curves of Reeves et al. (1996), Fulkerson and Slack (1993) and Fulkerson et al. (2000) for kikuyu, ryegrass and prairie grass, respectively. Intake was calculated as the difference between pre- and post-grazing pasture mass.
During the observation period of Study 1, pasture samples were plucked from treatment swards to simulated grazing height (5 cm) prior to grazing and pooled from Day 1–6 and Day 7–13 of the observation period. During Study 2, plucked pasture samples were collected daily pre-grazing and pooled on a per paddock basis. Four cages were also placed in each paddock during Study 2 and pasture samples were plucked daily from within these cages at 07.00 h and 16.30 h. These samples were pooled into a.m. and p.m. samples for each paddock over the observation period. In Study 1, concentrate samples were collected on Days 2, 4, 6, 9 and 11 of the observation period. Samples were pooled between Days 2 and 6, and between Days 9 and 11. In Study 2, concentrate was sampled on Days 1, 3, 5, 8, 10 and 11 of the observation period. These samples were then pooled for Days 1–5 and Days 8–11.

Pasture samples were dried in a forced-draught oven for 72 h at 60°C, and with grain samples, were milled through a 1 mm screen in preparation for analysis for in vitro DM digestibility (IVDMD) (Minson and McLeod 1972); metabolisable energy (ME) where ME (MJ/kg DM) = 0.17 × IVDMD — 2.0 (SCA 1990); organic matter (6 h at 550°C); N (Leco 2000 Nitrogen Analyser based on AOAC 1970) with crude protein (CP) calculated as N × 6.25; neutral detergent fibre (NDF) (except for concentrate in Study 2) and acid detergent fibre (Study 1 only) using the Fibertec system which is based on the methodology of van Soest et al. (1991) and Robertson and van Soest (1981); calcium (Ca), P, magnesium (Mg), K, sodium (Na), iron, zinc, copper and manganese using wet ashing and atomic emission spectroscopy based on USEPA (1997). Plucked samples were measured for water-soluble carbohydrates (WSC) as per Fulkerson et al. (1999).

### Pasture Intake

As a check against data obtained from pre- and post-grazing pasture mass, mean pasture intake of individual cows during the observation period of both studies was estimated using reverse

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kikuyu</td>
<td>Concentrate</td>
</tr>
<tr>
<td>IVDMD (%)</td>
<td>66.5</td>
<td>85.6</td>
</tr>
<tr>
<td>Metabolisable energy (MJ/kg)</td>
<td>9.3</td>
<td>12.6</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>91.3</td>
<td>92.7</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>21.8</td>
<td>9.0</td>
</tr>
<tr>
<td>Neutral detergent fibre (%)</td>
<td>55.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Acid detergent fibre (%)</td>
<td>26.3</td>
<td>4.8</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>0.29</td>
<td>1.15</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>0.38</td>
<td>0.55</td>
</tr>
<tr>
<td>Magnesium (%)</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>Potassium (%)</td>
<td>2.38</td>
<td>0.29</td>
</tr>
<tr>
<td>Sodium (%)</td>
<td>0.05</td>
<td>1.52</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>376</td>
<td>277</td>
</tr>
<tr>
<td>Zinc (ppm)</td>
<td>50</td>
<td>373</td>
</tr>
<tr>
<td>Copper (ppm)</td>
<td>9</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Manganese (ppm)</td>
<td>58</td>
<td>27</td>
</tr>
</tbody>
</table>

### Ingredients (% as fed)

- Maize: 47.4
- Barley: 44.2
- Salt: 2.4
- Limestone: 2.0
- DiCalcium phosphate: 1.9
- Sodium bicarbonate: 1.0
- Magnesium oxide: 0.1
- Zinc oxide: 0.1
- Vegetable oil: 2.0
- Salt: 0.9
- Limestone: 2.2
- Sodium bicarbonate: 1.5
- Magnesium oxide: 0.5
- Zinc oxide: 1.0

1 Dry matter basis. 2 In vitro dry matter digestibility.

Table 1. Nutrient concentrations in pasture and concentrates.
Pasture intake = (MER – MEI)/ME content of pastures where:

MER (MJ/d) = the sum of ME requirements for milk production, maintenance and LWC calculated according to NRC (2001); and

MEI (MJ/d) = the daily ME intake from concentrate.

Pasture ME in Study 2 was calculated pro rata based on the proportion of time cows grazed each pasture type (82% ryegrass; 18% prairie grass) and the average ME content of each pasture herbage (Table 1).

Grazing observations

Study 1. Grazing time was measured using vibrcoders based on the methodology of Stobbs (1970). At 07.30 h on Day 9 of the observation period, 3 cows from each treatment (paired within blocks) were fitted with vibrcoders which were removed at 15.00 h on Day 11 of the observation period. Grazing time between 07.30 h and 15.00 h on Day 9 of the observation period was ignored. The total grazing time in the remaining 48 h was then divided by 2 to produce an average grazing time for 24 h. The vibrcoders were then refitted to another 3 cows from each treatment at 15.00 h on Day 11 and removed at 15.00 h on Day 13. Average time spent grazing was calculated for the following periods: 15.00 h–19.00 h, 19.00 h–24.00 h, 24.00 h–07.00 h and 07.00 h–15.00 h.

Study 2. The percentage of cows grazing, ruminating and idle was recorded at 15 minute intervals (based on Gary et al. 1970) while cows were in paddocks between 07.30 h and 18.30 h on Days 3, 9 and 11 of the observation period. Average values for each activity were calculated for the following periods: 07.30 h–12.00 h, 12.00 h–14.00 h, 14.00 h–16.00 h and 17.00 h–18.30 h.

Climatic conditions

During Study 1, daily minimum and maximum air temperatures, rainfall, relative humidity (RH) at 15.00 h and cumulative wind speed per day (expressed as m/s; cup counter anemometer) were recorded approximately 8 km east of the experimental site. Daily temperature-humidity indices (THI) based on maximum (THI\textsubscript{max}) ambient temperatures and RH were calculated where: THI = (1.8 × ambient temperature + 32) – (0.55 – 0.55 × RH/100) × (1.8 × ambient temperature – 26). During Study 2, sunshine hours per day were measured at the same site.

Statistical analyses

In both studies, pasture variables [height, mass, allowance and intake (RPM)] were tested by analysis of variance. Days were treated as replicates. Milk production, milk composition, pasture intake (RS), LWC and grazing behaviour were tested by analysis of variance using cows as replicates with milk yield and composition (one observation from consecutive milkings) measured in the week prior to the start of the experiment used as respective covariates. The model contained effects due to treatment and block. Day was also included as a factor in the analysis of grazing behaviour from Study 1. Milk production data were also analysed separately for cows in early and mid–late lactation in Study 1. In Study 2, grazing behaviour was tested by analysis of variance with days and treatments as factors. All analyses were done using Minitab (Ryan et al. 1985).

Results

Daily pasture growth rates were 51 ± 18.8 kg/ha DM and 20 ± 20.5 kg/ha DM (ryegrass only) during Studies 1 and 2, respectively. There were no differences (P>0.05) in HAs, pre-grazing mass, post-grazing mass, or pasture intake (RPM or RS) between treatment groups in either Study 1 (Table 2) or Study 2 (Table 3). Pasture nutrient concentration was similar in both treatments in Study 1 (Table 1). Intakes of metabolisable protein, NDF, Ca, P, K, Mg and Na were adequate in each study given respective live-weights and milk production (SCA 1990; Fox et al. 1992). Estimated NDF intakes (%LW) were 1.43, 1.36, 1.28, 1.23, 1.20 and 1.23 for KB2, KB4, RB1, RB2, RB3 and RB4, respectively. The mean ME concentrations in kikuyu, ryegrass, prairie grass and concentrate (Study 1) and concentrate (Study 2) were 9.3, 10.5, 9.4, 12.6 and 12.8 MJ/kg DM, respectively, with the corresponding CP levels being 21.8, 25.5, 22.4, 9.0
Pasture allocation for dairy cows

and 9.0% DM. Mean WSC concentration (% DM) of pasture at 16.30 h (12.4 ± 0.69%) was higher (P>0.05) than at 07.00 h (9.1 ± 0.69%).

Frequency of pasture allocation had no effect on milk yield, concentrations of fat or protein, yields of fat or protein or LWC in Study 1 (Table 4). Milk lactose concentrations of cows in KB4 were higher (P = 0.004) than those of cows in KB2 during the observation period. KB2 cows in early lactation had lower (P = 0.024) milk concentrations of lactose than KB4 cows in early lactation (4.99 ± 0.013 vs 5.07 ± 0.013%; P = 0.125). Yields of FCM, fat and protein, concentrations of fat and protein, and LWC were not affected by treatment with overall means of 18.2 ± 0.34 L/d, 687 ± 14.6 g/d, 571 ± 11.6 g/d, 3.81 ± 0.076%, 3.17 ± 0.097% and 0.63 kg/cow/d, respectively.

In Study 2, frequency of pasture allocation had no effect on milk yield, concentrations of fat, protein or lactose, yields of fat or protein or LWC (Table 5).

Time spent grazing (Table 6) and number of grazing bouts per day were unaffected (P>0.05) by frequency of allocation in Study 1. Total daily grazing time was unaffected by day of sampling; however, a significant effect of day was noted for 15.00 h–19.00 h observations.

In Study 2, cows in RB1 and RB2 spent more time grazing (P<0.05) between 07.30 h and 12.00 h than cows in RB3 and RB4 (Table 7). Cows in RB4 spent more time grazing and less time idle (P<0.05) between 12.00 h and 14.00 h than the other treatment groups. Cows in RB2 spent less time grazing (P<0.05) between 14.00 h and 16.00 h than cows in RB1 and RB3.

In Study 1, mean values for maximum and minimum air temperatures, relative humidity andTHI\(_{\text{max}}\) were 26 ± 3.4 °C, 19 ± 1.6 °C, 87 ± 6.5% and 90 ± 3.5%, respectively.

### Table 2. Mean kikuyu pasture height, predicted total and available (above 5 cm pasture) pasture mass, pasture allowances and intakes (rising plate meter) (Study 1).

<table>
<thead>
<tr>
<th>Pasture allocations/day</th>
<th>s.e.</th>
<th>P¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (KB2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (KB4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Adjustment period

<table>
<thead>
<tr>
<th>Pregrazing</th>
<th></th>
</tr>
</thead>
</table>
| Pasteure height (cm) | 9.9
| Available pasture mass (kg/ha DM) | 987
| Allowance² (kg DM/cow/d) | 19.1
| Post-grazing |  |
| Pasteure height (cm) | 7.1
| Available pasture mass (kg/ha DM) | 419
| Intake (kg DM/cow/d) | 8.7

#### Observation period

<table>
<thead>
<tr>
<th>Pregrazing</th>
<th></th>
</tr>
</thead>
</table>
| Pasteure height (cm) | 10.8
| Available pasture mass (kg/ha DM) | 965
| Allowance (kg DM/cow/d) | 19.5
| Post-grazing |  |
| Pasteure height (cm) | 8.1
| Available pasture mass (kg/ha DM) | 419
| Intake (kg DM/cow/d) | 10.6

¹ Probability of treatment effect.
² Allowance above 5 cm pasture height.
and 71 ± 4.0, respectively. Maximum THI was >75 on 10% of the days during the experimental period. There were 24 days when rainfall was recorded, with a mean daily rainfall of 18 ± 39.5 mm. In Study 2, there were 8.9 ± 3.06 h of sunshine per day.

Discussion

Although short-term grazing experiments are open to criticism, the current studies reported here had various characteristics which improved their scientific value. Adjustment periods in each study were >13 d, whereas typical adjustment periods for short-term studies range from 7 to 10 d. The use of blocking and covariates in the current studies also added to the expression of statistical significance.

Table 3. Mean pasture height, predicted total and available (above 5 cm pasture height) pasture mass (PM), daily pasture allowances and daily pasture intake (rising plate meter and reverse standards) (Study 2).

<table>
<thead>
<tr>
<th>Pasture allocations/day</th>
<th>s.e.</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1(RB1)</td>
<td>2(RB2)</td>
</tr>
</tbody>
</table>

Adjustment period

Pre-grazing
- Pasture height (cm)
  - Ryegrass: 12.1, 11.5, 12.3, 11.6
  - Prairie grass: 11.9, 11.4, 13.1, 12.4
- Average: 12.0, 11.4, 12.7, 12.0
- Pasture mass (kg/ha DM)
  - Ryegrass: 2363, 2196, 2388, 2206
  - Prairie grass: 1926, 1856, 2096, 1997
- Average: 2113, 2001, 2221, 2087

Post-grazing
- Pasture height (cm)
  - Ryegrass: 7.5, 7.3, 6.7, 7.3
  - Prairie grass: 7.4, 7.5, 8.1, 7.9
- Average: 7.4, 7.4, 7.8, 7.7
- Pasture mass (kg/ha DM)
  - Ryegrass: 1291, 1262, 1103, 1257
  - Prairie grass: 966, 981, 1055, 1035
- Average: 1091, 1089, 1071, 1120
- Intake (kg/cow DM)
  - 11.1, 10.3, 12.4, 11.4

Observation period

Pre-grazing
- Pasture height (cm)
  - Ryegrass: 10.0, 9.1, 9.3, 9.6
  - Prairie grass: 11.9, 11.4, 13.1, 12.4
- Average: 10.7, 9.8, 10.1, 10.1
- Pasture mass (kg/ha DM)
  - Ryegrass: 1958, 1767, 1814, 1881
  - Prairie grass: 1926, 1856, 2096, 1997
- Average: 1991, 1829, 1877, 1894
- Allowance (kg/cow DM)
  - 38, 31, 34, 35

Post-grazing
- Pasture height (cm)
  - Ryegrass: 6.5, 6.3, 6.5, 7.6
  - Prairie grass: 7.5, 7.5, 7.7, 7.0
- Average: 6.7, 6.5, 6.8, 7.6
- Pasture mass (kg/ha DM)
  - Ryegrass: 1196, 1141, 1194, 1407
  - Prairie grass: 954, 966, 994, 896
- Average: 1152, 1109, 1158, 1314
- Intake (kg/cow DM)
  - Rising plate meter: 11.5, 10.2, 10.3, 10.0
  - Reverse standards: 10.7, 10.3, 10.2, 10.5

1 Probability of treatment effect.
2 Weighted average based on the proportion of each pasture species grazed.

Table 4. Mean daily milk production and liveweight change (LWC) (Study 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pasture allocations/day</th>
<th>s.e.</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 (KB2)</td>
<td>4 (KB4)</td>
<td></td>
</tr>
</tbody>
</table>

Yield
- Milk (L): 21.1, 20.7
- 4% FCM (L): 19.1, 19.1
- Fat (g): 712, 723
- Protein (g): 625, 589
- Composition (%)
  - Fat: 3.57, 3.43

0.54, 0.571
0.70, 0.983
21.2, 0.973
15.4, 0.147
0.079, 0.219
Probability of treatment effect.

Pasture growth rates recorded during these studies were typical of these pasture types under these management conditions (W.J. Fulkerson, personal communication). Mean stocking rates in each study reflect these pasture growth rates and hence pasture availability.

Despite fresh allocations of pasture being provided during the night, grazing times recorded in Study 1 indicate that the majority of grazing (approximately 70%) still occurred during daylight hours (07.00 h–19.00 h). Weather conditions recorded during the period when grazing observations were taken were milder in comparison with the rest of the study with a mean maximum air temperature of 25°C and a mean THI max of 69. These compare with mean maximum temperature and THI max of 26°C and 71, respectively, for the experimental period. It is possible that grazing behaviour during Days 14–18 of the experimental period may have been atypical of cow behaviour during the entire experimental period. The high THI max (e.g. THI >75) recorded earlier in the experimental period would suggest that time spent grazing during the day may have been adversely affected by climatic conditions causing cows to graze more at night (Stobbs 1970; Cowan 1975; Flamenbaum et al. 1986). The significant effect of day of measurement on grazing time between 15.00 h and 19.00 h would appear to be an artefact caused by cows entering paddocks an average 17 min later on Days 13 and 14 compared with Days 11 and 12.

### Table 6. Total grazing time and diurnal grazing periods (Study 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pasture allocations/day</th>
<th>s.e.</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (RB1)</td>
<td>2 (RB2)</td>
<td>3 (RB3)</td>
</tr>
<tr>
<td><strong>Total grazing time (min/d)</strong></td>
<td>430</td>
<td>418</td>
<td>22.3</td>
</tr>
<tr>
<td><strong>Grazing bouts (no/day)</strong></td>
<td>4.8</td>
<td>4.8</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Grazing periods (min)</strong></td>
<td>15.00 h–19.00 h</td>
<td>159</td>
<td>141</td>
</tr>
<tr>
<td></td>
<td>19.00 h–24.00 h</td>
<td>86</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>24.00 h–07.00 h</td>
<td>35</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>07.00 h–15.00 h</td>
<td>150</td>
<td>142</td>
</tr>
</tbody>
</table>

### Table 7. Percentage of cows involved in various activities during varying time periods in Study 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>s.e.</th>
<th>P1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (RB1)</td>
<td>2 (RB2)</td>
</tr>
<tr>
<td>Grazing 07.30 h–12.00 h</td>
<td>65</td>
<td>57</td>
</tr>
<tr>
<td>12.00 h–14.00 h</td>
<td>42</td>
<td>35</td>
</tr>
<tr>
<td>14.00 h–16.00 h</td>
<td>58</td>
<td>42</td>
</tr>
<tr>
<td>17.00 h–18.30 h</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Ruminating 07.30 h–12.00 h</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>12.00 h–14.00 h</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>14.00 h–16.00 h</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>17.00 h–18.30 h</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Idle 07.30 h–12.00 h</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>12.00 h–14.00 h</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>14.00 h–16.00 h</td>
<td>24</td>
<td>33</td>
</tr>
</tbody>
</table>

Parameter Pasture allocations/day s.e. P1

1 Probability of treatment effect.

2 4% fat corrected milk.
Estimated pasture intake was not affected in either study which is consistent with the observations of Dalley et al. (2001). Pasture allowances in both studies provided opportunities for increased pasture intake as mean post-grazing residue height was above 6.5 cm in each study (Leaver 1985). The estimated NDF intakes of cows in Study 1 (1.36–1.43% LW) were similar to the observations of Reeves (1997) for cows offered either kikuyu pasture or harvested kikuyu herbage. The high NDF intakes recorded in Study 1 plus the high cellulose and lignin concentration of kikuyu (Granzin 2000) indicate that rumen fill may have been the primary factor limiting intake and that cows were unable to consume additional pasture when offered fresh allocations. High rumen foam production from kikuyu herbage (Pienaar et al. 1993) may have also added to rumen fill.

The increase in pasture WSC concentration in Study 2 between early morning and late afternoon (33 g/kg DM) was smaller than increases observed by previous authors in this environment. Fulkerson et al. (1994) recorded an increase in WSC concentration of biennial rye-grass varieties of approximately 50 g/kg DM between early morning and late afternoon in a glasshouse study. Energetically, an increase in WSC concentration of 33 g/kg DM as observed in the current study would be equal to an increase in ME concentration of approximately 0.5 MJ/kg DM. Given the small magnitude of this increase, and that grazing behaviour was not increased after 14.00 h by offering fresh pasture allocations in late afternoon, no practical improvement in milk yield could be expected.

The lack of an effect on milk yield with an increase in the diurnal frequency of pasture allocation is in agreement with the observations of Dalley et al. (2001) and Gibson (1984) who concluded that meal frequency had no effect on milk yield across a range of diets. The non-significant increase in milk fat concentration of early lactation cows in KB4 agrees with reports of previous authors where the number of meals offered daily has been increased (Gibson 1984; Sutton et al. 1986). Increased milk fat concentrations with increased diurnal meal frequency has usually been limited to high concentrate diets (e.g., >600 g/kg DM) and/or when milk fat concentrations were below 3.8% (Gibson 1984) with up to 75% of the variation in milk fat concentration being related to the ratio of rumen molar proportions of (acetate + butyrate): propionate (AB:P) (Sutton et al. 1986). While milk fat concentrations of early lactation cows in Study 1 were below 3.8%, the dietary proportion of concentrate was approximately 330 g/kg DM. The contribution of higher rumen proportions of AB:P to the change in milk fat concentrations of early lactation cows in this study is open to debate as rumen VFAs were not measured. However, this result does indicate that grazing behaviour may have been changed at some stage during Study 1, resulting in more meals being consumed per day.

The increase in lactose concentration of cows in KB4 is an indication of an improved energy intake (Holmes and Wilson 1984). McLachlan et al. (1994) also recorded a similar increase in milk lactose concentrations of early lactation cows grazing tropical pastures when energy intake was increased by feeding supplements. Since pasture intake was not affected in the current study, it is hypothesised that the efficiency of energy digestion and/or metabolism may have been improved by increasing the diurnal frequency of pasture allocation.

With the exception of non-significant benefits to milk fat concentrations of cows in early lactation in Study 1, these current studies indicate that increasing the diurnal frequency of allocating pasture in subtropical regions either during summer nights when cows graze kikuyu or during spring days when cows graze temperate pastures has little effect on grazing behaviour or nutrient intake and offers little potential benefit to producers in terms of milk production. Since any attempts to increase frequency of allocating pasture would involve additional expenditure, this practice can not be recommended.

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Pasture allocation for dairy cows

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