Estimation of Intake in High Producing Holstein Cows Grazing Grass Pasture

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ABSTRACT

The objectives were to estimate intake of pasture and total DMI by high producing cows grazing grass pastures and to measure changes in nutrient composition of grass pasture during the grazing season. Sixteen multiparous Holstein cows averaging 31 kg of 4% FCM/d at the start of the trial grazed grass pastures at a stocking rate of 2.5 or 3.9 cows/ha from April until October 1990. Intake was estimated using Cr2O3 as an indigestible fecal marker. Pasture samples were analyzed for nutrient composition at six times during the grazing season corresponding to the times of intake estimation. Total daily DMI increased from 21.3 kg in early spring to 22.4 kg in late spring and then decreased as lactation progressed; however, DMI exceeded NRC recommendations during most of the grazing season. Daily pasture DMI varied with season, ranging from 11.6 to 15.6 kg and was lowest (11.6 kg) in the summer. Estimated NE_L intakes were lower than NRC recommendations in early spring. During the grazing season, pasture ranged from 39 to 48% NDF and from 22 to 30% CP with 15 to 20% ruminally degradable protein on a DM basis. Grazing cows consumed adequate DM from pasture except in early spring. Although nutrient composition of pasture varied with season, quality remained high.

(Key words: intake, pasture, orchardgrass, lactating cows)

Abbreviation key: IVDMD = in vitro DM digestibility, NIRS = near infrared reflectance spectroscopy, RDP = ruminally degradable protein, PDMI = pasture DMI, SP = soluble protein, TDMI = total DMI.

INTRODUCTION

Because of the potential economic advantages of intensive grazing over conventional stored feeding of forages (10, 24), many dairy producers in the northeastern United States have replaced stored forages with pasture during all or most of the grazing season. One of the challenges in using pasture as the primary or sole source of forage for lactating dairy cows is estimating pasture DMI (PDMI). Researchers outside of the United States (8, 18, 27) have estimated PDMI of lactating cows, but the forage species, environmental conditions, and animal production potential differ from those in the northeastern United States. Estimates of PDMI of high producing cows grazing naturalized grass pastures in the United States have not been published. Likewise, few published data exist that quantify nutrient changes in naturalized grass pasture throughout a grazing season. The objectives of this research were to estimate PDMI and total DMI (TDMI) of high producing Holstein cows grazing naturalized grass pastures in the northeastern United States and to measure changes in nutrient composition of that pasture during an entire grazing season.

MATERIALS AND METHODS

Pastures and Cows

Pastures were located at The Pennsylvania State University dairy production research center (University Park). A botanical survey for species presence, conducted using randomly sited transects, indicated that pastures contained approximately 38% orchardgrass (Dactylis glomerata L.), 34% Kentucky bluegrass (Poa pratensis), 18% smooth bromegrass (Bro-
PASTURE INTAKE OF HIGH PRODUCING COWS

TABLE 1. Schedule for application of NH₄NO₃.

<table>
<thead>
<tr>
<th>Date</th>
<th>(kg NH₄NO₃/ha)</th>
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<tbody>
<tr>
<td>April 6</td>
<td>247.6</td>
</tr>
<tr>
<td>May 30</td>
<td>194.1</td>
</tr>
<tr>
<td>July 6</td>
<td>164.7</td>
</tr>
<tr>
<td>August 6</td>
<td>115.3</td>
</tr>
<tr>
<td>August 30</td>
<td>98.8</td>
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mus inermis L.), and small amounts of assorted herbaceous weeds. Because of the greater individual mass of orchardgrass, its relative contribution to the total sward mass was higher than reflected in the 38% figure. Very little clover (Trifolium spp.) was observed. Pastures were divided into a replicated paddock system with 14 paddocks per stocking rate, and half of the paddocks were set aside for silage in the spring. Once silage was harvested and regrowth was sufficient, cows were allowed to graze these paddocks. Cows grazed each paddock for 2 d so that the intervals between grazing paddocks were 14 d in the spring and 28 d in the summer and fall. Intervals between grazing were the same for each stocking rate, and paddock size differed such that stocking rate was either 2.5 or 3.9 cows/ha. A temporary electric fence divided each paddock in half so that cows had access to only the front half of the paddock on the 1st d and to the entire paddock on the 2nd d. Pastures were fertilized with NH₄NO₃ five times during the grazing season and were clipped once in June (Table 1). Cows were allowed to graze during the day (0800 until 1500 h) for 1 wk before the start of the trial to adapt to the new diet and the grazing system. During this time, cows were fed a TMR indoors at night.

Sixteen multiparous Holstein cows, averaging 31 kg of 4%FCM/d (SEM = 2.76), were blocked by parity, day of lactation, and milk production. Cows averaged 133 d of lactation at the start of the trial and were randomly assigned to a stocking rate of either 2.5 or 3.9 cows/ha with 8 cows per stocking rate. Cows grazed pastures from April 23 until October 15, 1990. Cows were milked twice daily at 0530 and 1530 h and were fed a concentrate mix at the approximate rate of 1 kg of concentrate DM/5 kg of milk with a maximum of 10 kg and a minimum of 4 kg of concentrate DM given twice daily in the barn after milking. Concentrate intakes were recorded daily and were adjusted according to the previous week’s milk production every 28 d. Ingredient and chemical composition of the concentrate mix are in Table 2. Cows grazed pasture at all times and were fed small amounts (about 2 kg of DM/d per cow) of grass silage (harvested from paddocks set aside in spring) in the barn during July. Cows used in this study were part of a larger experiment that evaluated the effects of stocking rate (11).

An additional year of experimentation was planned for 1991, but data were only collected for one grazing cycle in the spring. Drought conditions in 1991 necessitated feeding large

<table>
<thead>
<tr>
<th>Item</th>
<th>(% of DM)</th>
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<td>Item</td>
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amounts of silage during much of the grazing season, so intake estimates were discontinued after the spring cycle. Data from spring 1991 are included only for informational purposes. No statistical analyses were possible.

Experimental Measures and Sample Analyses

Milk production was recorded daily at each milking. Milk samples were taken once weekly at consecutive a.m. and p.m. milkings for analysis of fat and protein. Milk samples were analyzed for fat and protein by Pennsylvania DHIA (Foss 605B Milko-Scan; Foss Electric, Hillerød, Denmark). Cows were weighed at the beginning of the trial and at 4-wk intervals thereafter. Three independent observers scored cows for body condition based on a five-point scale (1 = thin to 5 = fat) (33) as cows were being weighed.

Intake was estimated at six times during the grazing season using Cr$_2$O$_3$ as an indigestible fecal marker. Cows were dosed twice daily at 0600 and 1600 h for 10 d with 5 g of Cr$_2$O$_3$ via gelatin capsule. Fecal grab samples were taken twice daily at dosing on d 7 to 11. Concentrate, pasture, and silage (if fed) samples were also taken during d 7 to 11. Pasture samples were plucked by hand from 10 different areas of the paddock to the approximate height to which cows grazed. The first dosing of marker began on the 1st d of the trial. Fecal, pasture, and silage samples were freeze-dried, ground through a 1-mm screen, and composited on an equal weight basis across sampling week prior to analyses. Fecal composites were analyzed for Cr by atomic absorption spectroscopy according to the procedure of Parker et al. (25). Pasture, silage, and concentrate samples were analyzed for DM, OM, and CP (2). Ruminally degradable protein (RDP) and soluble protein (SP) were determined according to methods of Krishnamoorthy et al. (21). The ADF and NDF contents were measured according to methods of Goering and Van Soest (12) and in vitro DM digestibility (IVDMD) according to methods of Tilly and Terry (28). Hemicellulose was determined by calculating the difference between NDF and ADF.

Intake was estimated using the equation DMI = fecal output/(1 - IVDMD). Fecal output (FO) was calculated by the equation FO = (grams of Cr dosed per day)/(grams of Cr per gram of fecal DM). The first run of the calculations utilized the IVDMD values from pasture alone. Pasture DMI was determined by difference between the estimated TDMI and the known grain and silage (if fed) DMI. Once DMI of all diet components were estimated, the diet IVDMD was calculated. The second run of the calculations used the diet IVDMD rather than the pasture IVDMD for a more accurate estimate. Only values from this second set of calculations are presented.

Statistical Analyses

The experimental design was a randomized block design. Within-block replication was accomplished using field replicates, and there was no replication within a block × replicate unit. The model used for all cow data was $Y = \text{block} + \text{replicate} + (\text{block} \times \text{replicate}) + \text{stocking rate} + (\text{block} \times \text{stocking rate}) + (\text{replicate} \times \text{stocking rate}) + (\text{block} \times \text{replicate} \times \text{stocking rate}) + \text{time} + (\text{time} \times \text{stocking rate}) + (\text{time} \times \text{block}) + \text{error}$. The block × replicate term was used as an error term to test the effect of block and replicate. Time refers to the period when intake measurements were made and samples were taken, the month when BW and body condition score were analyzed, or the week when milk data were analyzed. The model used to test forage data was $Y = \text{stocking rate} + \text{replicate} + \text{error}$. Data were analyzed using the general linear models procedure of SAS (26), and all means presented are least squares means.

RESULTS AND DISCUSSION

Pasture Composition

No differences in nutrient composition of pasture were found for either stocking rate or replicate, so the least squares means are the pooled means ($n = 4$) (Table 3). In the larger experiment (data not shown), Fales et al. (11) found significant differences in IVDMD and NDF content of pasture that were due to stocking rate. Although the method of sample collection was similar between the two trials, Fales et al. (11) collected more samples on different days, and sometimes in different pad-
TABLE 3. Nutrient composition of grass pasture for six sampling times throughout the grazing season.

<table>
<thead>
<tr>
<th>Item</th>
<th>Apr 30</th>
<th>May 28</th>
<th>Jul 2</th>
<th>Jul 30</th>
<th>Aug 27</th>
<th>Sep 24</th>
<th>SEM2</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM  (% of DM)</td>
<td>90.2</td>
<td>91.3</td>
<td>89.9</td>
<td>90.3</td>
<td>90.5</td>
<td>91.1</td>
<td>56</td>
</tr>
<tr>
<td>CP (%)</td>
<td>24.3</td>
<td>22.2</td>
<td>26.6</td>
<td>25.0</td>
<td>26.7</td>
<td>29.7</td>
<td>80</td>
</tr>
<tr>
<td>Soluble protein (%)</td>
<td>3.3</td>
<td>5.1</td>
<td>7.2</td>
<td>5.4</td>
<td>7.1</td>
<td>14.6</td>
<td>75</td>
</tr>
<tr>
<td>Degradable protein (%)</td>
<td>20.2</td>
<td>18.6</td>
<td>16.3</td>
<td>16.1</td>
<td>14.9</td>
<td>19.3</td>
<td>1.09</td>
</tr>
<tr>
<td>ADF (%)</td>
<td>24.6</td>
<td>25.6</td>
<td>26.6</td>
<td>26.3</td>
<td>26.7</td>
<td>23.6</td>
<td>48</td>
</tr>
<tr>
<td>NDF (%)</td>
<td>41.3</td>
<td>44.9</td>
<td>45.1</td>
<td>48.2</td>
<td>44.7</td>
<td>39.3</td>
<td>1.18</td>
</tr>
<tr>
<td>Hemicellulose (%)</td>
<td>16.7</td>
<td>19.3</td>
<td>18.5</td>
<td>21.9</td>
<td>18.0</td>
<td>15.7</td>
<td>70</td>
</tr>
<tr>
<td>In vitro DM digestibility</td>
<td>68.5</td>
<td>70.0</td>
<td>68.8</td>
<td>64.4</td>
<td>67.7</td>
<td>70.0</td>
<td>1.21</td>
</tr>
</tbody>
</table>

*Means differ because of date (P < .05).
1Dates shown are for the 1st d of the 5-d sampling period.
2n = 4.

The nutrient composition of the pasture (Table 3) showed high but somewhat variable CP throughout the grazing season. Pasture CP was highest in the fall (September 24) and lowest in late spring (May 28). The high CP in the fall reflected the cool wet conditions, and the low CP in late spring might have been the result of N fertilizer application after sampling in May. Even at the lowest CP content of 22% of DM, the pasture was as high or higher in CP than typical stored grass silage and grass hay (23). A high proportion of the CP (60 to 80%) in pasture was RDP. Other researchers (1, 30) have shown by both in vitro and in situ techniques that fresh forages have high amounts of RDP. Holden et al. (16) found that in vivo measurements of ruminal NH₃ N were higher for dry cows grazing grass pasture than for those fed grass hay or silage.

In the present study, the RDP in pasture was highest in the spring and the fall and lowest in the summer, but the SP increased throughout the grazing season. The high RDP content of pasture corresponded to the cooler portion of the growing season and also to the time when fiber content is lower. Because RDP is lower when fiber is higher, more of the N may be bound in NDFN and may not be as ruminally degradable.

The increase in SP throughout the grazing season was not expected and may be related to the accumulated effects of N fertilization. Also, the increase in SP may possibly be associated with sample handling procedures. Kohn and Allen (20) found that freezing decreased the amount of phosphate buffer SP by more than 40% for bromegrass; however, the length of time the samples were frozen before analysis did not affect the amount of SP. In the current study, all samples were lyophilized simultaneously, so samples from the spring were frozen longer than samples from the fall. The increase in SP as the grazing season progressed may be an artifact of the freezing time, but, more importantly, the SP content was probably affected by freezing and may not be truly representative of fresh forages. Further research is warranted on the handling of samples in relation to nutrient content. The composition of protein and fractions for the 1991 early spring pasture was 27.5% CP, 20.9% RDP, and 6.4% SP.

As expected, ADF and NDF increased (P < .05) during the warmer summer months and were lowest in the cooler spring and fall months (Table 3). The highest NDF value was 48.2% in late July, and the highest ADF value was 26.7% in late August. The low fiber content of the pasture seems to be uncharacteristic...
TABLE 4. Average nutrient intake from pasture, total DMI, and milk production and composition for 16 cows at six times during the grazing season.

<table>
<thead>
<tr>
<th>Item</th>
<th>Apr 30</th>
<th>May 28</th>
<th>Jul 2</th>
<th>Jul 30</th>
<th>Aug 27</th>
<th>Sep 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM, kg/d*</td>
<td>13.9</td>
<td>15.1</td>
<td>12.9</td>
<td>11.6</td>
<td>14.3</td>
<td>15.6</td>
</tr>
<tr>
<td>CP, kg/d*</td>
<td>3.3</td>
<td>3.3</td>
<td>3.4</td>
<td>2.9</td>
<td>3.8</td>
<td>4.6</td>
</tr>
<tr>
<td>Degradable protein, kg/d*</td>
<td>2.8</td>
<td>2.8</td>
<td>2.1</td>
<td>1.9</td>
<td>2.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Soluble protein, kg/d*</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Grain DMI, kg/d*</td>
<td>7.3</td>
<td>7.2</td>
<td>7.6</td>
<td>7.5</td>
<td>5.5</td>
<td>4.8</td>
</tr>
<tr>
<td>Total DMI, kg/d*</td>
<td>21.3</td>
<td>22.4</td>
<td>22.4</td>
<td>20.6</td>
<td>19.9</td>
<td>20.3</td>
</tr>
<tr>
<td>DMI, % of BW</td>
<td>3.7</td>
<td>3.8</td>
<td>3.8</td>
<td>3.4</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Milk production, kg/d*</td>
<td>36.0</td>
<td>30.1</td>
<td>26.9</td>
<td>22.7</td>
<td>19.6</td>
<td>17.4</td>
</tr>
<tr>
<td>4% FCM, kg/d*</td>
<td>29.7</td>
<td>26.2</td>
<td>22.2</td>
<td>18.9</td>
<td>16.8</td>
<td>14.9</td>
</tr>
<tr>
<td>Milk fat, %</td>
<td>2.8</td>
<td>3.1</td>
<td>2.8</td>
<td>2.9</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Milk protein, %</td>
<td>2.6</td>
<td>2.7</td>
<td>2.7</td>
<td>2.8</td>
<td>2.8</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*Means differ because of date (P < .05).
1Date is the 1st d of the 5-d sampling period.
2n = 16.
3Silage intake during July 2 averaged 1.2 kg of DM/d per cow and during July 30 averaged 2.0 kg of DM/d per cow.

The remainder of the intake, in addition to pasture, was from grain. In all other months only grain was fed.

of orchardgrass but may be partly the result of the contribution of other forage species, in some cases small amounts of legumes, mixed in with the grass.

Despite differences (P < .05) in both NDF and ADF because of sampling cycle, there was no difference in IVDMD because of sampling cycle. The hemicellulose content of pasture varied (P < .05), ranging between 15.7 and 21.9%. Hemicellulose is recognized to be the most digestible fiber fraction (5, 19). Although the fiber content did increase during the summer months, the increase was in the hemicellulose fraction, and the IVDMD of the forage did not change significantly, ranging between 64 and 70% on a DM basis. Pasture samples from spring 1991 averaged 41.6% NDF, 24.3% ADF, and 17.3% hemicellulose, on a DM basis, and had an IVDMD of 71.8%.

Using prediction equations (23) that related TDN to NE_L, and using IVDMD instead of TDN, the NE_L content of pasture ranged between 1.46 Mcal/kg of DM in late July to 1.60 Mcal/kg of DM in both late spring and fall. Data from these calculations are interpreted with caution because the equations used were validated using stored forages and may not be applicable to fresh forages. More data for composition of fresh forages are needed for accurate prediction of nutritional characteristics based on calculation, particularly for NE_L.

Intake Estimates

There were no differences from stocking rate in any of the cow measures; thus, least squares means are the pooled means (n = 16) in Table 4. Both TDMI and PDMI varied over time (P < .05), and TDMI declined with milk production during the grazing season. Average PDMI was highest in late spring and autumn and was lowest in summer (Table 4). Because pasture intake is related to availability (14), some of the variation in PDMI in the current trial may have been the result of variation in available herbage. During the spring, estimates of available pasture DM averaged 3600 kg of DM/ha for the low stocking rate and 2815 kg of DM/ha for the high stocking rate. During the summer, estimates of available pasture DM were 3164 and 2662 kg of DM/ha for the low and high stocking rates, respectively. During autumn, estimates of available pasture DM averaged 3818 and 3098 kg of DM/ha for the low and high stocking rates, respectively. Estimates of available pasture DM were made prior to grazing according to the methods of Fales et al. (11). Cows were fed small amounts,
approximately 2 kg of DM/d per cow, of grass silage in the barn during the summer when pasture availability was low. Increases in PDMI in autumn may be related to reduced grain intake (Table 4). It is not clear how the reduced concentrate intake may have influenced the PDMI. In 1991, TDMI averaged 22.2 kg/d per cow, and PDMI averaged 14.2 kg/d per cow for the first spring cycle when milk production averaged 32 kg/d per cow and concentrate was fed at a rate of 1 kg of concentrate DM/4 kg of milk.

Comparison of TDMI values from this study with the NRC (23) recommendations for DMI based on BW and milk production indicates that cows met or exceeded recommendations for DMI at all times except in early spring. Given a similar energy density, a decrease in DMI decreases energy intake. Because NRC recommendations are based on stored forages, comparison of energy intake in megacalories of NE₃L, as well as DMI, is useful. Figure 1 shows that, similar to DMI, NE₃L intake met or exceeded NRC requirements except in early spring when cows were deficient in NE₃L by nearly 3 Mcal/d. The average TDMI increased from 21.3 kg/d in late April to 22.4 kg/d in late May, increasing energy intake by 2.2 Mcal/d. It is not clear why DMI in early spring was less than optimal when cows were grazing high quality pasture and were at the highest milk production.

Mertens (22) showed that intake is related to the NDF content of the diet and that DMI was depressed when forage NDF in the diet fell to .7% of BW or below. Although the NDF content in early spring pasture was somewhat low (41.3% of DM), it was not below the critical level at which DMI may be depressed. Additionally, the NDF content of the pasture remained relatively low throughout the grazing season; however, DMI was only below NRC recommendations in the early spring.

Conrad et al. (7) concluded that DMI was governed by the capacity of the digestive tract (gut fill) and by the cow's energy requirements. In general, diets of low digestibility are subject to physical control, and diets of high digestibility are subject to physiological control. Conrad et al. (7) found the transition point between physical and physiological control to be 66.7% digestible DM for a 454-kg cow producing 16.8 kg of milk/d. Waldo (32) suggested that this transition point was not fixed but could occur at a higher level of digestibility for higher producing cows. Using this line of reasoning and considering the low NDF content of the pasture, the energy demand of the cow could be the major factor influencing DMI. However, it is unclear why both TDMI and PDMI are low in early spring, when milk production and energy demands are greatest and when pasture quality is high. Bywater (4) suggested that intake models should be dynamic rather than static and that multiple factors influence PDMI and TDMI simultaneously.

In the current study, multiple regression analysis of individual cow data using BW, milk production, milk composition, and pasture ADF and NDF contents as predictors of TDMI produced equations with R² greater than .6 for only 8 of the 16 cows. Inclusion of factors such as herbage availability, cow selection and preference, and differences in grazing management into an intake prediction model for grazing dairy cattle may enable more accurate predictions than traditional approaches.

The high water content of the fresh pasture may also limit DMI, and, consequently, DM values for pasture may help to improve prediction equations. Chase (6) reported that DMI declined about .02 kg/100 kg of BW for each percentage unit increase in moisture content of silage-based diets. However, changes in silage quality may have influenced these results because the moisture content of the silage is directly related to its fermentation properties. Dulphy and Demarquilly (9) found that fresh forage in cow diets resulted in higher DMI than either silage or hay. In contrast, Holden et al. (16) found similar DMI for grass pasture, hay, and silage with dry cows. Comparison between studies is difficult because DMI of lactating cows in the current study differs from that of dry cows. The moisture content of forages seems to have variable effects on intake, and it is unclear whether or not the moisture content of early spring grass pasture significantly influenced DMI in the current trial.

The low TDMI occurred only in early spring, and the TDMI increased 5% from early to late spring, remaining equal to or above NRC recommendations for the rest of the grazing season. The increase in TDMI on May 28
compared with that on April 30 was the result of a 9% increase in PDMI. This increase in TDMI from early to late spring was not caused by increases in DMI resulting from peak lactation because these cows averaged 133 DIM at the start of the trial. Only 3 of the 16 cows were less than 100 DIM. As TDMI increased 5% from early to late spring, milk production declined 16%, partially because of the lower than optimal DMI and NE\textsubscript{L} intake in early spring. The rapid decline in milk production in early spring in the present study was similar to the decline in milk production for the other cows that were part of the larger study (11) as well as those on a previous trial with similar pastures (15).

The adaptation period at the beginning of this study may not have been long enough to allow for changes in digestive tract function to be complete before the first samples were collected. A reasonable explanation for the lower DMI in early spring may be related to the retention time of digesta in the rumen. Holden et al. (16) showed a tendency for increased turnover of rumen fluid in cows grazing grass pasture compared with the fluid turnover in cows fed grass silage or hay. Additionally, Bergazhi and Polan (3) observed high fractional passage rates of both rumen fluid and DM from grazing cows. With a faster fractional passage rate and lower retention time, DMI could be increased without a change in gut fill. However, the change in fractional passage rate would not be expected to occur immediately, but rather over a period of time as the cow adapted to the fresh forage diet. Verite et al. (31) measured changes in digestion over a grazing season with fresh ryegrass (\textit{Lolium perenne} L.), and the time at which cows had the highest intake (11.5 kg of OM/d) was also the time when fractional passage rate of rumen fluid was the highest (14.6% /h).

Because TDMI was above NRC recommendations (23) for a majority of the grazing season, high TDMI could partially be the result of rapid digesta passage. Early spring was the exception to this high TDMI, possibly because increasing digesta passage may be an adaptive process. Less than optimal TDMI may partially explain the rapid drop in milk production at the beginning of the grazing season. The NE\textsubscript{L} values of the pasture, silage, and grain can be calculated by an equation from Tyrrell and Moe (29) where IVDMD (Table 3) replaces TDN. For cows in the current study, maintenance energy requirements adjusted for grazing activity (23) reflect a 17.5% increase in NE\textsubscript{L} for maintenance, 10% for good pasture and 7.5% for walking .7 km/d. Comparison of the adjusted NE\textsubscript{L} requirements and the calculated NE\textsubscript{L} intakes showed that cows were deficient in energy by almost 3 Mcal/d per cow in early spring, but met or exceeded the adjusted requirements for the rest of the grazing season (Figure 1). Milk production per unit of TDMI (kilogram per kilogram) of 1.69 in April and 1.34 in May partly reflects a change in forage to concentrate ratio with increasing PDMI in May. Milk production per unit of PDMI was 2.59 in April and 1.99 in May. Clearly, the energetic efficiency of feed utilization or the mobilization of body reserves, or both, are altered from April to May. Despite a lack of gut fill limitation and a demand for additional energy, high producing cows did not consume sufficient DM to meet energy needs during early spring grazing.

The CP intake from pasture was highest in the fall, which was reflective of higher pasture intakes and higher CP in the pasture (Table 4). High RDP from pasture in the spring and fall is the result of higher pasture intakes rather than a change in forage composition because RDP did not change with time. However, a
larger portion of the CP intake was from RDP in the spring compared with that in the summer and fall. If high RDP from pasture resulted in excess N in the rumen and the excess N was converted to urea, then this energy expenditure could also increase maintenance energy requirements for grazing cows. Research (13, 17) indicates that availability of carbohydrate and protein in the rumen must be synchronized and in the correct proportions for optimal utilization. In the current trial, feeding of concentrate separate from pasture and the high RDP of pasture may have increased the likelihood of uncoupled fermentation in the rumen.

**BW and Body Condition Score**

The average BW and body condition score for each month of the grazing season are in Figure 2. Although average BW increased as the grazing season progressed, appreciable increases in BW did not occur until July. Cows gained an average of 47 kg of BW from the beginning to the end of the grazing season. Body condition score tended to decrease from April to May when TDMI was low and cows were not consuming adequate energy, and average body condition score did not exceed 2.5 until September. Cows finished the grazing season in less than optimal condition despite higher actual DMI than NRC recommendations and higher estimated NEL intakes than NRC requirements (23) for most of the grazing season.

**CONCLUSIONS**

When properly managed, grass pasture can be high in quality throughout the grazing season. Higher fiber and lower protein can be expected in the summer months when environmental temperatures are warmer, and lower fiber and higher protein contents can be expected during the cooler months. Much of the protein in pasture is degradable, especially in the spring.

A complete change from a diet with stored forage to one with pasture may require extensive adaptation to prevent lower than desirable DMI in early spring. High producing cows may not consume enough pasture DM in early spring to prevent rapid decreases in milk production when 65% of the diet is pasture DM and 35% is concentrate. With pasture as the sole forage source, DMI was higher than NRC recommendations for most of the grazing season, but low body condition at the end of the grazing season suggested that increases in maintenance energy for activity that were due to grazing may have been underestimated.

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