The Effect of Carbohydrate Source on Nitrogen Capture in Dairy Cows on Pasture

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Introduction

Lush pasture has a high rate of crude protein (CP) degradation in the rumen (Van Vuuren et al., 1991), rapidly releasing nitrogen (N). One of the challenges of utilizing pasture is maximizing ruminal N capture. Van Vuuren et al. (1991) found N in ryegrass degrades at a rate of 9 to 14%/h, while pasture organic matter (OM), composed mostly of structural carbohydrates, degrades at a rate of 7%/h, creating an asynchronous relationship between protein and energy availability for rumen microbial protein synthesis. This inefficient N capture can result in high ruminal ammonia, blood urea nitrogen (BUN), and milk urea nitrogen (MUN) in cows grazing pasture. Blood urea N and MUN levels greater than 20 mg/dL have been associated with low pregnancy rates. There is also an energetic expenditure for urea synthesis. Using the Cornell Net Carbohydrate and Protein System model, Kolver and Muller (1998) predicted a 1.8 kg/d reduction in milk production due to urea synthesis for cows consuming pasture.

Beever et al. (1986) found N in ryegrass pasture degraded in the rumen at a rate of 13 to 14%/h with 6.4 to 11.7% instantly degradable and 89.3 to 92.9% potentially degradable. Theoretically, a carbohydrate source with a degradation rate of 13 to 14%/h would be the best choice to optimize N capture when cows are grazing grass pasture. The starch in corn, the most common starch source fed to dairy cattle, degrades at a rate of approximately 4.0 to 6.4%/h (Herrera-Saldana et al., 1990; Tamminga et al., 1990), which is considerably slower than the degradation rate of pasture protein.

Carbohydrate sources that degrade at faster rates than corn may result in higher rates of microbial ammonia capture and improved efficiency. The starch content of barley degrades at a much faster rate in the rumen (14.7-24.5%/h) (Herrera-Saldana et al., 1990; Tamminga et al., 1990) than starch from corn. Hall et al. (1998) reported that citrus pulp contains 34.5% neutral detergent soluble fiber, most of which is pectin that degrades at a rate of 13%/h, similar to the degradation rate of pasture N. In addition, the NDF component of citrus pulp is 20.5%, is highly digestible, and degrades at a rate of 15%/h (Hall et al., 1998). A partial replacement of corn with barley and molasses, a rapidly degraded carbohydrate, or citrus pulp and molasses should provide a more synchronized supply of carbohydrates and N for grazing dairy cows than a supplement with corn as the only grain source. The objective of this experiment was to evaluate the partial replacement of corn with barley and molasses or citrus pulp and molasses as supplements for grazing cows.

Materials and Methods

Fourteen Holstein cows from Clemson University’s LaMaster Dairy Center (Clemson, SC) were used in a 9-wk trial to study the effect of carbohydrate source on nitrogen capture in dairy cows grazing annual ryegrass pasture. Cows were allocated to 3 groups based on milk production and then randomly assigned to one of 3 dietary treatments within a 3 x 3 Latin
square design with three 21-d periods. Treatments were grain supplements based on: (1) dry ground corn (CORN), (2) rolled barley and molasses (BM), or (3) citrus pulp and molasses (CM). For BM and CM, diet composition was the same as CORN except a portion of the dry ground corn was replaced with rolled barley and molasses or citrus pulp and molasses. The control diet (CORN) was 61.4% corn. BM had 26.3% corn, 26.3% rolled barley, and 8.8% molasses. CM had 26.3% corn, 26.3% citrus pulp, and 8.8% molasses. Additionally, the grain supplements contained 10.1% cottonseed hulls, 11.8% whole cottonseed, 6.0% soybean hulls, 5.9% soybean meal, and 4.2% minerals and vitamins. Supplements were formulated to be isonitrogenous and isoenergetic.

Cows had ad libitum access to ryegrass pasture from 0830 to 1530 h and from 1730 to 0630 h. Cows were milked at 0700 and 1600 h and fed the supplement individually using Calan gates in equal parts immediately after milking. Cows were given approximately 1 hour to consume their supplement before returning to pasture. Supplement was fed at a rate of 1 kg grain per 4 kg milk based on pretrial milk production (Bargo et al., 2002a).

During each of the three 21-d periods, d 1 to 17 were used to adjust the cows to the dietary treatments, and d 18 to 21 were used for sample collection. Supplement and pasture samples were analyzed for dry matter (DM), ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, in vitro DM digestibility (IVDMD), crude protein (CP), soluble protein, minerals, starch, and fatty acids. Blood samples were collected on day 21 at 4-hour intervals starting at 0800 and analyzed for blood urea nitrogen (BUN). Chromic oxide was used as an indigestible fecal marker to determine pasture intake (Holden et al., 1995). Daily milk production was recorded and milk samples were collected and analyzed for milk fat, protein, MUN, somatic cell count (SCC) and fatty acids. Data were analyzed by least-squares ANOVA using the mixed procedure of SAS (2003).

**Results and Discussion**

Supplement intake was not different across treatments, but pasture intake tended ($P < 0.10$) to be lower for cows on BM (13.7 kg/d) than for cows on CORN (15.9 kg/d) or CM (16.1 kg/d) (Table 1). This resulted in a trend ($P < 0.10$) for a difference in total dry matter intake (DMI) among treatments with cows on BM (22.8 kg/d) tending to be lower than for cows on CORN or CM (25.0 or 25.2 kg/d). Intakes of CP and NDF were not different among treatments. Intake of ADF was lower ($P < 0.05$) for cows on BM than for cows on CM, because total intake tended to be lower for cows on BM, and because CM contained the highest ADF level. Body weights and body weight change did not differ among treatments (Table 1).

Fiber-based concentrates may have advantages over feeding starch-based concentrates to grazing cows by increasing DMI. When early lactation cows grazed ryegrass pasture, pasture and total DMI were increased 0.7 (Meijs, 1986) and 0.8 kg/d (Sayers et al., 2003) when fiber-based concentrates replaced starch-based concentrates. Bargo et al. (2003) suggested that replacing starch-based concentrates with fiber-based concentrates would increase rumen pH, enhance pasture digestion, and result in higher DMI. Pasture and total DMI were similar with both types of concentrates for late-lactation cows grazing orchardgrass (Delahoy et al, 2003). Although there are a low number of studies, Bargo et al. (2003) reported that, overall, fiber-based concentrates slightly increased DMI 0.13 kg/d but there was a large variation among studies and ranged from -0.7 to 1.4 kg/d.

Treatments had no effect on yield of milk, 3.5% FCM, or ECM, or on milk fat percentage or yield (Table 1). Milk protein percentage was higher ($P > 0.05$) for cows on
CORN compared to cows on CM (2.81 vs. 2.70%). Delahoy et al. (2003) also reported higher milk protein content in milk from grazing cows supplemented with ground corn compared to supplementation of non-forage fiber sources (beet pulp, soybean hulls, and wheat middlings), (3.23 vs. 3.19%). Khalili and Sairanen (2000) found no differences in milk protein percentage for grazing cows with no supplement or supplemented with barley or a mixture of concentrate sources that included non-forage fiber (wheat bran and molasses sugar beet pulp), 3.42 vs. 3.49%. However, protein yield was lower for cows on pasture only compared to cows fed barley, which was lower than that for cows fed non-forage fiber (0.61 vs. 0.67 and 0.73 kg/d) because of lower milk yield.

Meijs (1986) also reported increased milk production when fiber-based concentrates of beet pulp and soybean hulls replaced corn and cassava. Two other grazing studies, however, reported similar milk yields (Sayers, 2003; Delahoy et al., 2003) and others reported reduced milk yield (Valk et al., 1990). Bargo et al. (2003) reported that milk production was slightly reduced across published studies (-0.46 kg/d) when fiber-based concentrates replaced starch-based concentrates for grazing dairy cattle, but milk response ranged from -2.6 to 1.3 kg/d.

Sayers (2003) reported higher milk fat percentage with fiber-based concentrates compared to starch-based concentrates. Most studies, however did not report changes in milk fat percentage (Meijs, 1986; Valk et al., 1990; and Delahoy et al., 2003). In addition, Bargo et al. (2003) summarized that replacing starch-based concentrates with fiber-based concentrates reduced milk protein -.06 percentage units (range: -0.21 to 0.05 percentage units). In this study, partial replacement of corn with citrus pulp and molasses did not affect milk fat percentage or yield but did result in lower milk protein percentage (2.81% versus 2.70%); neither were different from BM (2.77%).

In this study, cows consuming BM tended (P < 0.10) to have a greater efficiency of energy-corrected milk yield than cows consuming CORN (1.40 vs. 1.29 kg milk/kg DMI), while there were no differences between CORN and CM (1.30 kg milk/kg DMI) or BM and CM (P > 0.11). There were no differences among treatments for efficiency of milk or fat-corrected milk yield. Selected milk fatty acids are shown in Table 1. Milk from cows on CORN and CM was higher (P < 0.05) in trans-11 C18:1 than for cows on BM. Trans-11 C18:1 is an intermediate in the biohydrogenation of C18:2 and C18:3 (Bauman and Griinari, 2003). It can also be converted to cis-9, trans-11 C18:2, commonly known as CLA, by the action of stearoyl-CoA desaturase in the mammary gland. C18:3 was higher (P < 0.05) in milk from cows on CM compared to milk from cows on CORN and BM. There were no differences among treatments for C4:0, C6:0, C8:0, C14:0, C14:1, C15:0, C16:0, C16:1, C18:0, C18:1, C18:2, cis-9, trans-11 CLA, trans-10, cis-12 CLA, or other fatty acids. Kelly et al. (1998) reported cows consuming mostly ryegrass pasture produced milk with 1.09 g/100g fatty acid CLA while cows fed a TMR in confinement produced 0.49 g/100g fatty acid CLA. CLA content in this experiment averaged 0.62 g/100g fatty acids and was slightly lower than levels reported by White et al. (2001) for Holstein cows grazing crabgrass and supplemented with a concentrate (0.72 g/100g fatty acids). Bargo et al. (2006) found that supplementation with a corn-based feed lowered milk CLA concentration as compared to no supplementation (1.18 vs. 1.36 g/100g fatty acid), but the values reported were higher than those found in this study. Bargo et al. (2006) also found a tendency (P = 0.07) for cows supplemented with cracked corn to produce higher levels of CLA than those consuming steam-flaked corn (2.73 vs. 2.26 g/100g fatty acid) but found no differences when cows consumed ground corn or a non-forage fiber supplement (average: 2.85 g/100g fatty acids).

BUN and MUN can be used as indicators of rumen N capture as these values are positively associated with rumen ammonia concentrations (DePeters and Ferguson, 1992).
Data for BUN is shown in Figure 1. Average BUN did not differ among treatments (average: 10.60 mg/dL). As expected, there was an overall effect of time on BUN ($P < 0.05$). BUN was lower for cows on CM than for cows on CORN at 0400 h.

Blood urea N values for this study were lower than expected for cows on pasture supplemented with a carbohydrate source. Bargo et al. (2002b) reported BUN values of cows grazing high quality pasture while being supplemented with a corn-based concentrate to be 17.2 mg/dL, while Kolver et al. (1998) reported BUN averaged 22.05 mg/dL for supplemented cows on pasture. Delahoy et al. (2003) found average BUN values of 13.1 mg/dL for cows supplemented with corn.

MUN was higher ($P < 0.05$) for cows on BM compared to cows on CORN and CM (Table 1). Similar to BUN values, MUN values are also lower in this study than expected. Other research reported MUN value of supplemented cows on pasture to average 19 mg/dL (range 14.8 to 37.6 mg/dL), (Bargo et al., 2002b; Delahoy et al., 2003; Khalili and Sairanen, 2000) with MUN values for cows on pasture only reported as high as 40 mg/dL (Khalili and Sairanen, 2000).

While there were differences in MUN among treatments, no significant differences were found for BUN values. However, numeric differences among treatments for BUN follow a similar pattern as those seen for MUN values, with cows consuming CM having the lowest BUN and MUN values (10.19 and 9.85 mg/dL), followed by CORN (10.62 and 10.05 mg/dL) and BM (10.99 and 11.43 mg/dL). The reason for the conflicting findings is unknown; however, the small differences in N capture were not reflected in changes in milk production.

One of the strategies to improved efficiency of grazing cows is to match the rate of degradation of the pasture N with the rate of carbohydrate degradation from the supplement. Kolver et al. (1998) reported peak ruminal ammonia concentrations were reduced 33% when grazing cows were fed concentrate synchronously with pasture rather than 4 h after pasture was fed.

Because the starch in barley degrades significantly faster than the starch in corn (24.5 vs. 4%/h), a partial replacement of corn with a barley and molasses mix should result in starch degradation that more closely matches the N degradation of pasture. Garcia et al. (2000) reported that ruminal ammonia concentration was significantly reduced when heifers fed fresh forage were supplemented with barley compared to corn (19.4 vs. 26.9 mg/dL). Khalili and Sairanen (2000) found that barley supplementation did not reduce rumen ammonia levels in cows grazing pasture that was 20.9% CP compared to corn supplementation, however, it was reduced by feeding a combination of barley, oats and beet pulp (28.7, 32.1 and 21.8 mg/dL for corn, barley, and barley/oats/beet pulp mix, respectively.) There were no differences in MUN between the concentrate mixture and barley (37.6 and 36.3 mg/dL), but both were significantly lower than corn (40.0 mg/dL). The grain mixture also increased yield of milk protein over corn or barley (0.73, 0.67, and 0.61 kg/d, respectively for mix, barley and corn) as well as milk yield (21.0, 19.7, and 18.4 kg/d, respectively for mix, barley and corn).

Because the neutral detergent soluble fiber in citrus pulp is thought to degrade at similar rates as ryegrass pasture N, 13%/h (Hall et al., 1998), a partial replacement of corn for citrus pulp and molasses should offer an advantage. Miron et al. (2002) reported that partial replacement of corn by citrus pulp in TMR fed to high-producing dairy cows resulted in improved feed efficiency because the digestibility of neutral detergent soluble carbohydrates was higher for the diet with citrus pulp versus the diet with corn. Fermentation of pectin is different from starch in that, although it is extensive, it produces little or no lactate and results
in a higher acetate to propionate ratio than starch (Hall et al., 1998). Although other sources of non-forage fiber, including beet pulp, soybean hulls, and wheat middlings have been evaluated for grazing cattle (Delahoy et al., 2003), there is a lack of grazing studies that have evaluated citrus pulp as a supplement for grazing cows.

Few studies that considered replacement of starch-based concentrates with forage-based concentrates reported ruminal ammonia, BUN, or MUN. Delahoy et al. (2003) included non-forage fiber sources (beet pulp, soybean hulls, and wheat middlings) in addition to ground corn in a supplement for late-lactation grazing dairy cows and reported that the cows fed ground corn had lower MUN than cows fed the non-forage fiber concentrate (14.9 vs. 15.4 mg/dL). Plasma urea N, however, was not different between treatments.

In this study, partially replacing corn with barley and molasses did not improve the capture of ruminal N and in fact, resulted in higher MUN. Blood urea N, however, was not different across treatments. Cows on BM, however, did result in improved efficiency of EMC because pasture intake was lower but milk yield was not different. Partially replacing corn with CM did not improve milk yield or overall capture of pasture N, but BUN was reduced during one collection period compared to CORN. Milk protein content was lower for cows on CM than for cows on CORN but milk protein yield was not different. One of the reasons that treatments effects were minimized may have been due to low CP content of the ryegrass pasture utilized in this experiment which averaged 16.5%.

Bargo et al. (2002b) found BUN and MUN levels for cows consuming TMR with 16.9% CP content to average 13.8 and 10.6 mg/dl, respectively, while BUN and MUN levels for cows consuming pasture averaging 26.3% CP and a corn supplement were found to be 17.2 and 14.9 mg/dl, respectively. BUN and MUN levels for cows on this trial were similar to cows on TMR than cows on pasture. If BM or CM improved nitrogen capture, the CP content of the pasture may not have been high enough to allow for detection of differences. Another explanation could be that the degradation of the corn in starch was more rapid than expected. Oba and Allen (2003) reported a degradation rate of 14%/h for the starch in corn, which is considerably higher than the 4%/h previously reported by Tamminga et al. (1990).

**Conclusion**

Partial replacement of corn with BM or CM did not offer advantages to cows grazing ryegrass pasture as measured by milk yield. Cows fed BM had higher MUN. However, cows on CM did have lower BUN during one collection period and may have shown more advantage if the pasture CP content was higher. For this reason, partial replacement of corn with citrus pulp for grazing cows should be further studied using pasture with higher CP content. In addition, if the price of barley or citrus pulp is favorable compared to corn, their inclusion in rations should be considered since milk yield did not decline and in fact, efficiency of ECM yield was improved with barley. Milk protein yield declined for cows fed C, so graziers that are paid for milk protein should limit the amount of citrus pulp that replaces corn.

**References**


Table 1. Least Squares Means for Nutrient Intakes, Milk Production and Components, and Body Weights\(^1\).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CORN</th>
<th>BM</th>
<th>CM</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture intake, kg/d</td>
<td>15.9(^y)</td>
<td>13.7(^z)</td>
<td>16.1(^y)</td>
<td>2.00</td>
</tr>
<tr>
<td>Supplement intake, kg/d</td>
<td>9.2</td>
<td>9.1</td>
<td>9.2</td>
<td>1.08</td>
</tr>
<tr>
<td>Total DMI, kg/d</td>
<td>25.0(^y)</td>
<td>22.8(^z)</td>
<td>25.2(^y)</td>
<td>2.29</td>
</tr>
<tr>
<td>Total CP intake, kg/d</td>
<td>3.7</td>
<td>3.5</td>
<td>3.7</td>
<td>0.16</td>
</tr>
<tr>
<td>Total NDF intake, kg/d</td>
<td>9.4</td>
<td>9.1</td>
<td>9.9</td>
<td>0.41</td>
</tr>
<tr>
<td>Total ADF intake, kg/d</td>
<td>5.0(^ab)</td>
<td>4.8(^a)</td>
<td>5.4(^b)</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Milk Yield (kg/d) | 30.6 | 29.9 | 30.0 | 3.44 |
Efficiency (kg milk/kg DMI) | 1.25 | 1.33 | 1.24 | 0.05 |
FCM\(^2\) (kg/d) | 28.9 | 28.6 | 28.5 | 2.42 |
FCM Efficiency (kg milk/kg DMI) | 1.18 | 1.27 | 1.19 | 0.04 |
ECM\(^3\) (kg/d) | 31.3 | 31.0 | 30.9 | 1.74 |
ECM Efficiency (kg milk/kg DMI) | 1.29\(^y\) | 1.40\(^z\) | 1.30\(^yz\) | 0.04 |
Fat (%) | 3.20 | 3.27 | 3.26 | 0.15 |
Fat Yield (kg/d) | 0.95 | 0.91 | 0.96 | 0.10 |
\(trans\) C18:1, g/100 g fatty acid | 2.74\(^a\) | 2.39\(^b\) | 2.86\(^a\) | 0.16 |
\(cis-9, trans-11\) CLA, g/100 g fatty acid | 0.63 | 0.63 | 0.61 | 0.03 |
C18:3, g/100 g fatty acid | 0.56\(^a\) | 0.60\(^a\) | 0.65\(^b\) | 0.02 |
Protein (%) | 2.81\(^a\) | 2.77\(^ab\) | 2.70\(^b\) | 0.08 |
Protein Yield (kg/d) | 0.83 | 0.78 | 0.80 | 0.08 |
MUN (mg/dL) | 10.05\(^a\) | 11.43\(^b\) | 9.85\(^a\) | 0.42 |
BUN (mg/dL) | 10.62 | 10.99 | 10.19 | 0.53 |
Body weights, kg | 606.4 | 605.5 | 606.9 | 14.9 |
Body weight change, kg | -3.2 | -2.02 | -3.5 | 2.90 |

\(^{a,b}\) Least square means in the same row with different superscripts differ \((P < 0.05)\).

\(^{y,z}\) Least square means in the same row with different superscripts differ \((P < 0.10)\).

\(^1\) BM = barley treatment, CM = citrus pulp treatment, CLA = conjugated linoleic acid.

\(^2\) 3.5% fat-corrected milk (FCM) = (0.4255 * kg milk) + [16.425 (% fat/100) * kg milk].

\(^3\) Energy-corrected milk (ECM) = (0.3246 * kg milk) + (12.86 * kg fat) + (7.04 * kg protein)
Figure 1. Diurnal changes in BUN for dairy cows grazing ryegrass and supplemented with corn (♦), barley and molasses (■), or citrus pulp and molasses (▲). Data points with different superscripts differ ($P < 0.05$).