Nitrogen Balance, Microbial Protein Production, and Milk Production in Dairy Cows Fed Fodder Beets and Potatoes, or Barley

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ABSTRACT

Fourteen multiparous midlactation dairy cows were used in a change-over experiment with 3 periods and 3 diets to evaluate the effects of fodder beets and potatoes on N metabolism, microbial protein production, and milk production. A basal ration of alfalfa/grass silage offered *ad libitum*, 1 kg of grass hay and 1 kg of heat-treated rapeseed cake was supplemented with 5 kg DM of either rolled barley/raw potatoes 80:20 (BAP), fodder beets/raw potatoes 80:20 (BEP) or rolled barley (BA). Urine and feces were collected quantitatively from 8 cows and ruminal samplings, and evacuations were performed on 4 cannulated cows. Intake and production did not differ between BAP and BA, but the BEP diet lowered intake of both silage and total ration by 0.9 kg DM. Daily yield of energy-corrected milk (ECM) was decreased by 1.7 and 2.3 kg compared with BAP and BA, respectively. Milk urea concentration was 1 mM lower with the BEP diet. The proportion of feed N recovered in milk was 20 to 21% for all diets. With the BEP diet, urinary N amount and proportion were reduced correspondingly to the lower total N intake. Fecal N amount remained unchanged, and hence nitrogen apparent digestibility decreased by 5 percentage units with the BEP diet. Microbial protein production, assessed by allantoin excretion, tended to be highest with the BAP diet. Acetate proportion of VFA was lowered by the BEP diet, while proportions of propionate and butyrate both tended to increase. Different fermentation patterns, probably related to differences in rumen microbiota, could explain why changes in energetic efficiency and milk composition reported in the literature did not occur in the actual experiment when roots replaced barley. Compared with barley, roots appeared to have a greater negative effect on silage intake in

conjunction with a prewilted silage with high intake potential allowed *ad libitum* and this decreased milk production by a magnitude corresponding to the lower intake of ME.

(Key words: fodder beet, potato, dairy cow, microbial protein)

Abbreviation key: AAT = amino acids absorbed in the digestive tract, BA = *ad libitum* silage diet supplemented with rolled barley (5 kg DM), BAP = *ad libitum* silage diet supplemented with rolled barley (4 kg DM) and raw potato (1 kg DM), BEP = *ad libitum* silage diet supplemented with fodder beet (4 kg DM) and raw potato (1 kg DM), ECM = energy-corrected milk, FIA = flow injection analysis, FW = fresh weight, PBV = protein balance in the rumen.

INTRODUCTION

Nonstructural carbohydrates are an essential part of diets for high yielding dairy cows. These provide energy at the animal level and supply rumen microbes with the energy needed for capture of degraded feed protein into microbial protein. The most important source of nonstructural carbohydrates in Western countries is grain, where corn and barley are the predominant grains of North America and Europe, respectively. Root crops have been used extensively in dairy rations but have been replaced by grains and maize silage because of labor costs. Increasing awareness of the need to improve nitrogen utilization in animal husbandry has placed focus on the importance of the balance between RDP and fermentable carbohydrates in the diet. The sucrose that on average constitutes 59% of fodder beet DM (Gruber, 1994) should promote use of degraded feed protein by microbial synthesis, according to feed evaluation systems that predict increased microbial efficiency with increasing carbohydrate fermentation rate (Russell et al., 1992). Experiments comparing pure sucrose with isolated starch have indicated sucrose to be superior in ammonia utilization and microbial syn-

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thesis *in vivo* (Chamberlain et al., 1993; Oh et al., 1999), while recent *in vitro* work (Hall and Herejk, 2001) showed an advantage for sucrose only at the first hours of incubation but higher microbial protein production from starch thereafter. Sannes et al. (2002) recorded a tendency for decreased ruminal ammonia concentration if sucrose partly replaced corn grain, but also a decreased microbial protein production. The starch source may be of importance, because ruminal fermentation rates vary over a wide range, with barley being more rapidly fermented in the rumen than corn grain but less energy dense (Yang et al., 1997). Because earlier experiments with root crops fed to dairy cows were aimed at increasing milk production from nonconcentrate feeds, the possibilities to improve nitrogen efficiency by exchanging grain starch for root sucrose deserves investigation. The ambiguous results reported for the effects of roots on total DMI (Krohn and Andersen, 1979; Dulphy et al., 1990; Birkenmaier et al., 1996) also justify evaluation under various conditions. The objective of the experiment reported here was to compare the effects on intake and production traits, nitrogen balance, and rumen characteristics when fodder beets replaced barley in a dairy cow ration with *ad libitum* access to a high-quality silage rich in RDP. The effects of exchanging 1 kg of DM barley for potatoes were also examined, based upon observations at our laboratory of increased microbial protein production *in vitro* if potatoes were included in rumen fluid donor cow diets.

MATERIALS AND METHODS

Animals and Feeding

The experimental design and all handling of the animals were approved by the Uppsala Local Ethics Committee. Fourteen multiparous, lactating Swedish Red and White dairy cows (BW 607 ± 13 kg, parity 2.8 ± 0.2 , DIM 115 ± 8 at start), from the Kungsängen Research Center's experimental herd where cows are selected for high or low milk-fat concentration but equivalent production of energy-corrected milk (ECM), were used for comparing the effects of fodder beets, potatoes, and barley on milk production and intake. Furthermore, quantitative collection of urine and feces was performed on 8 of the cows, of which 4 were ruminally cannulated and also subjected to rumen sampling. The experiment was arranged as a replicated Patterson and Lucas (1962) change-over design No. 2, with 4 blocks, 3 periods, and 3 treatments as shown in Table 1. The cows were blocked with respect to selection line, cannulation, and DIM. Each period lasted 28 d, of which the first 21 d were considered as the adaptation period and d 23 to 27 were used for sampling. The cows were housed in

individual tie stalls with rubber mats and sawdust bedding throughout the experiment and milked in their stalls at 0530 and 1600h.

A pure stand of alfalfa and a mixed grass field dominated by perennial ryegrass, both grown near Uppsala, Sweden (18° E, 60° N), were utilized for production of experimental silage and hay. Alfalfa silage was made from the first cut in bud-stage on June 15 and grass silage was made from the second cut in vegetative stage on August 20, whereas the experimental hay had been harvested from the same grass field in head-stage on July 4. Alfalfa and grass were prewilted and ensiled in big bales with 4 to 5 L tonne^{-1} fresh weight (FW) of an additive (Kofasil Ultra, Hansson and Möhring, Halmså, Sweden) containing hexamine and sodium nitrite. Alfalfa and grass silages were then mixed 60:40 on a DM basis prior to feeding. All 3 experimental diets were based upon *ad libitum* allowance of silage. In addition, 1 kg (as fed) of grass hay and 1 kg (as fed) of heat-treated rapeseed cake (EXPRO, Carlshamn Crushing, Karlshamn, Sweden) was included in all diets together with minerals according to Swedish standards (Spörndly, 1999). The basal diet was then supplemented with 5 kg DM of either rolled barley/chopped raw potatoes 80:20 (BAP), chopped fodder beets/chopped raw potatoes 80:20 (BEP) or rolled barley (BA). Fodder beets and potatoes were chopped with commercial, farm-scale equipment (Herborg A/S, Videbæk, Denmark) for the respective crop, giving cube-like pieces with approx. 5 cm side for fodder beets and approx. 3 cm side for potatoes. The chemical composition and nutritional value of the feeds is given in Table 2. Silage, rapeseed cake, fodder beets, and barley were fed individually with 4 equal meals at 0500, 0900, 1400, and 1800h, potatoes with 2 equal meals at 0900 and 1400h and hay once daily at 1000h. Two separate feed troughs were used, one small trough for potatoes and barley and one large trough for silage and fodder beets. This allowed separation and daily weighing oforts from the different feeds.

Sampling and Laboratory Analyses

The cows were weighed at 0900h on d 17 and 18, and a body condition scoring was also performed, using a 5-point scale (0 = emaciated to 5 = very fat). Milk yield was recorded d 23 and 24 by the Tru-Test technique (Tru-Test Ltd, Auckland, New Zealand). The milk was sampled and analyzed for fat, protein, and lactose by infrared spectroscopy (DairyLab2 A7S Foss Electric, Denmark), for SCC (Fossomatic 90, A/S Foss Electric, Hillerød, Denmark), and for urea by a flow injection analysis (FIA) method using pH difference (Ramsing

Table 1. The change-over design with 14 cows, 3 treatments, and 3 periods. Cows denoted with "Q" or "R" were used for quantitative excreta collection and ruminal sampling, respectively.

Selection line	High fat index							Low fat index						
Block	1				2			3				4		
Cow	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sampling	Q, R		Q		Q		Q, R		Q, R		Q, R		Q	
Period 1	BAP	BEP	BA	BEP	BAP ¹	BEP	BA	BAP	BEP	BA	BAP	BEP	BAP	BA
Period 2	BEP	BA	BAP	BA	BA ¹	BAP	BEP ²	BEP	BA	BAP	BEP	BAP	BA	BEP
Period 3	BA	BAP	BEP	BAP	BEP ¹	BA	BAP	BA	BAP	BEP	BA	BA	BEP	BAP

¹Quantitative urinary data were excluded from this cow because of leaking.

²All data were excluded from this cow in period 2 because of consumption problems.

et al., 1980). Furthermore, milk samples were analyzed for acetone by a FIA method (Marstorp et al., 1983).

Daily feed samples were obtained d 22 to 26 and stored at -30°C . The samples were pooled within feed type while still frozen. Kjeldahl N was analyzed promptly in the thawed silage to avoid ammonia losses. A fully automated procedure (Kjeltec 1030, Tecator, Höganäs, Sweden) was used. Samples were then dried overnight at 60°C , milled through a 1-mm screen on a Kamas hammer mill, and analyzed by standard procedures. Kjeldahl N was analyzed by the same procedure

as for the silage. Ash, DM, and ether extract were determined as described by Murphy et al. (2000). In addition, feeds were analyzed for the ash-free content of NDF (Chai and Udén, 1998), and ADF and lignin (Van Soest et al., 1991). A heat-stable α -amylase (Termamyl 300L, Novo Nordisk, Bagsvaerd, Denmark) was used in the NDF determination. Nonstructural carbohydrates (sugar, maltodextrines, and starch) were determined enzymatically according to Larsson and Bengtsson (1983). The fraction reported as sugar comprises sucrose, fructanes, monosaccharide glucose, and monosac-

Table 2. The chemical composition and nutritional value of the experimental feeds. If not stated different $n = 3$.

	Silage		Hay		Barley		Fodder beets		Raw potatoes		Rapeseed cake ¹	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
DM, %	33.8	1.10	90.8	0.81	88.1	0.27	16.3	0.19	18.0	0.74	93.1	0.07
	% of DM											
OM	90.7	0.36	93.9	0.14	97.5	0.07	91.5	0.22	94.7	0.13	93.0	0.08
CP	19.3	0.58	10.1	0.27	11.9	0.08	8.1	0.08	10.0	0.86	32.8	0.09
RDP ²	14.6	0.60	4.4	0.12	7.8	0.05	5.8	0.06	7.9	0.80	10.8	0.03
NDF	41.6	1.60	68.6	1.58	14.1	0.55	15.5	0.55	6.1	1.39	35.0	2.50
ADF ³	30.4	1.01	38.4	1.13	4.7	0.64	8.3	0.79	3.7	0.13	22.5	0.28
Lignin	7.9	0.61	7.9	0.50	1.4	0.18	2.0	0.59	1.2	0.03	6.6	0.24
Sugar	2.3	0.43	8.2	1.25	2.4	0.30	61.9	1.51	7.7	1.92	5.6	2.52
Maltodextrines	-0.4	0.09	-0.7	0.04	3.9	0.42	0.5	0.16	3.6	0.38	0.0	0.04
Starch	0.6	0.16	0.8	0.16	56.4	1.14	1.8	0.35	61.0	0.82	3.8	0.41
Ether extract	ND	—	ND	—	2.4	0.01	ND	—	ND	—	14.4	0.14
	NDF degradation rate (%/h) and potential digestibility (% of NDF)											
NDF degr. rate ²	5.4	0.55	3.1	—	14.9	—	9.5	0.90	10.4	0.47	8.2	—
NDFDIG ^{4,2}	68.2	2.26	69.4	—	77.1	—	88.2	0.37	94.0	0.63	68.9	—
	Nutritional value, kg DM ⁻¹											
MJ ME	10.1	0.08	9.1	0.04	13.8	0.06	12.6	0.03	13.1	0.07	14.9	0.02
AAT ⁵	73.2	1.04	85.2	0.76	103.6	0.46	93.5	0.10	92.4	0.75	185.5	0.19
PBV ⁶	65.0	7.18	-48.2	1.29	-55.2	0.60	-79.1	0.90	-61.1	9.71	54.3	0.77

¹Heat-treated (EXPRO, Carlshamn Crushing, Karlshamn, Sweden).

²In sacco determinations performed on silage and potatoes for all periods and on fodder beets for periods 1 and 2. Determinations on other feeds performed on samples pooled by feed across all periods. RDP for these feeds calculated from actually determined CP and rumen degradability in pooled sample.

³Nonsequential.

⁴Potential digestibility of NDF determined by 96 h in sacco incubation.

⁵Amino acids absorbable in the digestive tract, grams.

⁶Protein balance in the rumen, grams.

charide fructose. Maltodextrine and starch values were corrected for monosaccharide glucose content after a separate determination of this fraction. Megajoules ME for the silage and hay was determined from the 96-h *in vitro* digestible OM (Lindgren, 1979). For the supplements, MJ ME was determined from the Weende analysis of feeds, using standard digestibility coefficients and energy values (Axelson, 1941). Crude fiber for the Weende analysis was determined according to Jenische and Larsson (1990). *In situ* determination of degradation rates for CP and NDF in the feeds was also performed by standard methods for feed evaluation in nonlactating cows on maintenance diets (Lindgren, 1991), with the incubation intervals 2, 4, 8, 16, 24, and 48 h. The rumen indigestible NDF fraction was determined in a separate 96-h *in situ* incubation.

Starting at 0600 on d 23, quantitative collection of urine was performed during 72 h by secure placement of a natural rubber/latex mold fitted tightly over the vulva and maintained in place by a custom-fitted harness extending from around the hind legs forward to the breast section. The permanent presence of personnel for the simultaneous quantitative fecal collection guaranteed total control of the urine collection system's functionality. Collection of urine was performed into 1.8 M H₂SO₄, with 500 mL added at collection vessel renewal each 12th hour in period 1. In periods 2 and 3, a second dose of 500 mL was added when urine amount in the vessel approached 5 L, making a total of 1000 mL/12 h. Each 12th hour, the urine volume was measured, and two 10-mL aliquots in test tubes and a subsample containing 5% of the total volume were frozen at -30°C. After thawing, one of the aliquot samples was analyzed for allantoin (Lindberg and Jansson, 1989) and the second for urea (Technicon, 1974a) and creatinine (Technicon, 1974b). At the end of the sampling period, subsamples were pooled within cow, thawed, and analyzed for Kjeldahl N with the same methodology as that used for feeds.

Feces were collected quantitatively during 96 h, starting at 0900 of d 23. Cows used for fecal collection received no bedding during collection. Collection was performed manually into plastic barrels with personnel continuously present. The collected feces were weighed daily, tap water equivalent to 10% of FW was added, and a subsample of 10% was frozen after thoroughly mixing. The subsamples were thawed and pooled within cow and period, and Kjeldahl N was then determined directly on the thawed sample as described for silage. About 600 g of each pooled sample were then weighed into Petri dishes and lyophilized. Feces were then milled and analyzed for DM, ash, NDF, ADF, and lignin as described for the feeds, except that sodium sulfite but no α -amylase was used in the NDF analysis. Feces

were also analyzed for the sum of starch, maltodextrines, and glucose by only performing the starch determination procedure of the enzymatic method used for the feeds, without deducting monosaccharide glucose.

From the 4 cannulated cows, a ruminal liquid sample was obtained each fifth hour during d 23 to 26. This yielded a total of 17 samples from each cow and period. Sampling was done by manually inserting a 50-mL centrifuge tube just below the ruminal mat. After removal from the rumen, pH was measured in the tube (Checkmate, Mettler-Toledo, Schwezenbach, Switzerland), and the sample was immediately frozen at -30°C. Volatile fatty acids were determined in the samples by gas chromatography as described by Murphy et al. (2000), and ammonia and total α -amino nitrogen were determined simultaneously on a Technicon AutoAnalyzer (Broderick and Kang, 1980). A total rumen evacuation was also performed at 0400, 1900, and 1300h on d 23, 24, and 25, respectively. Contents were weighed, a representative sample of about 2 kg was obtained, and rumen contents were then immediately returned to the cow. Emptying and returning of rumen contents was done manually, with the aid of a 500-mL plastic container to obtain the liquid phase at the bottom of the rumen. The evacuation process from opening of the fistula to when rumen contents were replaced after weighing took about 20 min. The rumen contents were dried to constant weight at 60°C, milled and analyzed for DM, ash, and NDF as described for the feeds. The total sugar, and the sum of starch, maltodextrines, and monosaccharide glucose were also determined by the methods described for feeds and fecal samples, respectively. In addition, total purine content was determined with yeast RNA as standard (Aharoni and Tagari, 1991).

Calculation and Statistical Analysis

Digestible carbohydrates, amino acids absorbed in the digestive tract (**AAT**), protein balance in the rumen (**PBV**), and rumen protein degradability were calculated according to Madsen (1985) and Spörndly (1999), based upon feed analysis and *in situ* determinations performed in the experiment. A protein outflow rate of 8%/h was assumed. *In situ* parameters for NDF degradation rate were estimated by the program Table Curve 2D (Jandel Scientific, Erkrath, Germany) at an outflow rate of 3%/h. The function for undegraded NDF was:

$$Y = a + b \times e^{(-cx)},$$

where Y is undegraded proportion, a is indigestible NDF, b is potentially digestible NDF, c is digestion rate in %/h, and x is incubation time in hours. Intake was

calculated by deducting the orts of each feed from the amount fed, assuming the same chemical composition in the orts as in the feeds. ECM was calculated according to Sjaunja et al. (1991) as:

$$\text{ECM} = \text{milk yield (kg)} \times \{[383 \times (\text{fat \%}) + 242 \times (\text{protein \%}) + 165 \times (\text{lactose \%}) + 20.7]/3140\}.$$

Data from urinary and ruminal samplings were pooled within cow and period before statistical analysis of main treatment effects.

Data from one cannulated cow in period 2 was excluded because of low consumption of the experimental diet. Furthermore, because of leaking, all data relying on quantitative urine collection were excluded from a second cow for the entire experiment. The data sets for final evaluation therefore consisted of 41 observations for production and intake data, 23 observations for fecal and nonquantitative urinary data, 20 observations for quantitative urinary data, and 11 observations for pooled ruminal data. All data sets were first tested for effects of selection line, block within selection line, period, diet, previous diet, 2-way interaction between selection line and diet and 2-way interaction between period and diet. Because effects of selection line, block, previous diets and all interactions were nonsignificant except for the selection line effects analyzed separately as described below and the 2 interactions stated in the Results section, evaluation of diet effects for all data sets was performed with procedure GLM of SAS (1996) according to:

$$y_{ijk} = \mu + P_i + D_j + C_k + e_{ijk}$$

where μ = overall mean, P_i = effect of i th period, D_j = effect of j th diet, C_k = effect of k th cow and e_{ijk} = random residual error. Means were separated by PDIFF test for the probability of comparisonwise error. For the 3 possible comparisons between diets, the experimentwise error probability, if calculated by the more conservative Tukey or Bonferroni methods, would be about 2.4 to 3 times higher (the comparisonwise error probability of 0.02 approximately equals the experimentwise error probability 0.05). Because data were unbalanced, results are reported as least square means with the largest standard error of difference.

Where the initial testing had indicated selection line effects with $P < 0.10$ on urinary and ruminal data, evaluation of these effects was performed with procedure MIXED of SAS (Littell et al., 1996). Selection line, period, and diet were fixed class variables in this analysis, while cow within selection line was the random class variable. Results are reported as least square means

with standard error of difference obtained from PDIFF test.

Time $\times$ diet effects on ruminal data were analyzed as a split-plot design with procedure MIXED of SAS (1996). Cow, period, and diet were whole-plot sources of variation, whereas time and time $\times$ diet were subplot sources of variation. This model yields the same results as a repeated measurements analysis with the compound symmetry option. Satterthwaite's method for approximation of degrees of freedom (DF) was used to obtain correct estimates for probability of contrasts. For the variables displayed in Figure 1, DF were in the range 12 to 72 for comparisons between diets and 128 for comparisons within diets. Results are plotted as least square means, with the largest standard error of difference for each variable reported in the figure caption.

Linear regressions for microbial protein markers against production and intake data were performed with procedure GLM of SAS (1996), when initial testing revealed no significant quadratic relationships.

RESULTS

Except for the factors used in the final evaluation of diet effects, there was a period $\times$ diet interaction ($P = 0.03$) for kg of milk/d and an interaction of selection line $\times$ diet ($P = 0.02$) for lactose concentration. Daily allantoin excretion and ruminal butyrate proportion differed by selection line ($P = 0.04$ and $P = 0.02$, respectively).

Due to minor deviations in DM concentrations of the supplements from values obtained during the adaptation period, the actually fed amount in the sampling period was 0.9 kg DM of potatoes and 4.1 kg DM of fodder beets. There were orts from all feeds except rape-seed cake. Besides the planned silage refusals, there were 0.2 kg DM of orts from hay for all diets and 0.2, 0.4, and 0.1 kg DM of supplement orts for, respectively, BAP, BEP, and BA. Table 3 shows the consumed amount of each feed and nutrient and the chemical composition of the actually consumed diets, assuming the same chemical composition of the orts as for the feeds. Total DMI was 1 kg lower with the BEP diet than with the other diets, mainly because of a lower silage intake (Table 3). This also led to a lower nitrogen intake, a lower protein balance in the rumen (**PBV**), and a reduced supply of metabolizable energy (**ME**) and amino acids absorbable in the digestive tract (**AAT**). The lower milk yield with the BEP diet (Table 4) corresponded to the lower intake because balances of ME and AAT (data not shown) were not altered ($P > 0.57$), and were 114 to 117% of the requirements according to Swedish standards (Spörndly, 1999) for all diets.

Figure 1. Diurnal variation of ruminal fermentation characteristics for lactating cows allowed to alfalfa/grass silage ad libitum, 1 kg (as fed) hay and 1 kg (as fed) rapeseed cake supplemented with 5 kg DM of barley/raw potatoes 80:20 (▲), fodder beets/raw potatoes 80:20 (○), or barley (△). Values are least squares means. Largest SED = 0.16, 0.90, 0.86, and 0.53 for pH, acetate, propionate, and butyrate, respectively.

Changes in BCS and BW from first to last sampling period (data not shown) were nonsignificant (+0.2 points, $P = 0.60$ and +5 kg, $P = 0.10$, respectively). Fat and lactose concentrations were not altered by diet, while protein concentration was moderately higher ($P \leq 0.05$) with the BA diet than with the other diets. Milk urea concentration was 0.95 to 1.14 mM lower in the BEP diet than in the 2 other diets, but there was no difference in nitrogen efficiency. Acetone concentrations were below 0.1 mmol/L in all samples.

Daily feces excretion and urine were similar for the diets (Table 5), but fecal DM content was lower ($P < 0.05$) with the BEP diet. However, the difference was of small magnitude (14.8% DM for BEP vs. 15.4 and 15.6% for, respectively, BAP and BA). Digestibility of DM tended to be lower with the BEP diet, OM digestibility was not affected by diet, and fiber digestibility tended to be highest with the BEP diet. Digestibility of nonstructural carbohydrates was >99% for all diets. The partitioning of N excretion was different with the BEP diet, where lower N intake, constant fecal N excretion, and reduced urine N excretion caused an increase in the fecal N proportion. The lower urinary N excretion was due to a lower urinary urea concentration with the BEP diet. Creatinine excretion was also 8.5% lower with the BEP diet. Allantoin excretion tended to be highest with the BAP diet.

The BEP diet resulted in smaller ruminal amounts of both fresh weight and DM (Table 6). With the BEP

diet, sugar, and starch amounts in the rumen also tended to be lower, the purine pool was significantly lower, and ash concentration was higher. Neither pH nor total VFA concentration differed among diets, but the distribution among different VFA did. The BEP diet lowered acetate proportion and tended to increase proportions of both propionate and butyrate. Iso-acid proportion was also diminished by the BEP diet, while ammonia concentration only displayed a weak tendency towards reduction with the BEP diet. The total amino acid concentration was not affected by the diet.

The BEP diet tended to give a larger diurnal fluctuation than BAP in ruminal pH (Figure 1), but this was because of a high pH before morning feeding rather than because of any marked pH drop. VFA proportions also varied most with the BEP diet, with propionate proportion peaking at 1100, 1600, and 2000h, 2 h after each meal. Acetate proportion decreased correspondingly at the same occasions. The peaks in butyrate proportion for the BEP diet at 0900, 1400, and 1800h were due to decreased concentrations of acetate and propionate at these sampling times.

The effects of selection line with $P < 0.10$ are in Table 7. The high fat index cows had a fermentation pattern with higher butyrate proportion and lower propionate proportion than the low fat index cows, but a lower daily allantoin excretion.

Table 8 shows overall correlations between the 2 microbial markers used and different intake and produc-

Table 3. Intake in dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes, and barley.

	Diet least squares means				Diet effect ³	Probability for diet differences		
	BAP ¹	BEP ¹	BA ¹	SED ²		BAP-BEP ⁴	BAP-BA ⁴	BEP-BA ⁴
Consumed feeds, kg DM/d								
Silage	13.6	12.7	13.5	0.365	0.05	0.02	0.71	0.05
Hay	0.65	0.68	0.68	0.06	0.87	0.65	0.66	0.99
Rapeseed cake	0.91	0.90	0.90	0.01	0.47	0.35	0.25	0.85
Fodder beets	—	3.72	—	—	—	—	—	—
Raw potatoes	0.86	0.87	—	0.01	0.35	0.35	—	—
Barley	3.81	—	4.85	0.05	<0.001	—	<0.001	—
Total DM ⁵	20.0	19.1	20.1	0.346	0.01	0.01	0.88	0.008
Consumed nutrients								
OM, kg/d	18.35	17.25	18.43	0.315	0.002	0.002	0.80	0.001
CP, g/d	3539	3204	3556	67	<0.001	<0.001	0.80	<0.001
RDP, g/d	2488	2269	2487	51	<0.001	<0.001	0.99	<0.001
RDP of CP, %	70.2	70.7	69.7	0.16	<0.001	<0.001	0.01	<0.001
NDF, kg/d	7.02	6.72	7.06	0.148	0.07	0.06	0.79	0.03
ADF, kg/d	4.81	4.69	4.78	0.109	0.55	0.30	0.83	0.41
Starch, kg/d ⁶	2.93	0.70	2.99	0.05	<0.001	<0.001	0.27	<0.001
Sugar, kg/d	0.58	2.77	0.54	0.07	<0.001	<0.001	0.52	<0.001
MJ ME	221	206	223	3.59	<0.001	<0.001	0.65	<0.001
AAT, g/d ⁷	1695	1584	1711	26.2	<0.001	<0.001	0.53	<0.001
PBV, g/d ⁸	647	495	640	29.8	<0.001	<0.001	0.83	<0.001
Composition of consumed diet, %								
DM	39.07	28.40	42.51	0.34	<0.001	<0.001	<0.001	<0.001
Composition of consumed DM, %								
OM	91.70	90.55	91.88	0.04	<0.001	<0.001	<0.001	<0.001
CP	17.66	16.82	17.67	0.09	<0.001	<0.001	0.90	<0.001
RDP	12.40	11.91	12.33	0.08	<0.001	<0.001	0.42	<0.001
NDF	35.06	35.23	35.19	0.25	0.76	0.49	0.58	0.88
ADF	23.99	24.58	23.83	0.22	0.007	0.01	0.46	0.003
Starch ⁶	14.73	3.82	15.02	0.36	<0.001	<0.001	0.42	<0.001
Sugar	2.92	14.46	2.69	0.32	<0.001	<0.001	0.47	<0.001

¹BAP = rolled barley/raw potatoes 80:20, BEP = fodder beets/raw potatoes 80:20 and BA = rolled barley.

²Largest standard error of difference is given because of unbalanced data. n for BAP and for BA = 14, n for BEP = 13.

³Probability for F-test of diet effect.

⁴Comparisonwise error probability for difference between diets obtained by PDIFF test.

⁵Includes 150 g mineral supplement (Kvarnby VM1, Kvarnby, Sweden).

⁶Maltodextrines included here.

⁷Amino acids absorbable in the digestive tract.

⁸Protein balance in the rumen.

tion traits. The daily allantoin excretion generally correlated more to these variables when compared with the rumen purine pool. The correlation between allantoin excretion and intake of different feed fractions was highest for NDF, while no significant correlation to intake of nonstructural carbohydrates existed. Scaling for live weight increased all coefficient of determination (R^2) values for allantoin from 0.11 to 0.18 units and gave for NDF $R^2 = 0.78$.

DISCUSSION

The effects on milk yield in this experiment seem to be the result mainly of a reduced silage intake when fodder beets replaced barley. The decrease in silage intake was about 0.24 kg DM of silage for each kilogram

DM of barley that was exchanged for fodder beets. Earlier studies have reported similar substitution rates for grain and fodder beets (Krohn and Andersen, 1979; Dulphy et al., 1990) and a marked decrease (Birkenmaier et al., 1996) in silage intake if fodder beets replaced grain. These differences may be attributed to different types of silage. Low DM (21 to 27%) silage was fed in the former experiments and high DM (33 to 52%) silage in the latter. The silage in the current experiment had an average DM content of 34% and concentrations of fermentation products (data not shown) indicating high intake potential (Huhtanen et al., 2002). The general intake level of silage was therefore high, which would make it more sensitive to substitution effects from other feeds, in agreement with the findings in the meta-analysis of Huhtanen et al. (2002).

Table 4. Milk yield and milk composition in dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes, and barley.

	Diet least squares means			SED ²	Diet effect ³	Probability for diet differences		
	BAP ¹	BEP ¹	BA ¹			BAP-BEP ⁴	BAP-BA ⁴	BEP-BA ⁴
Milk, kg/d	23.2	21.8	23.4	0.413	0.002	0.003	0.63	0.001
ECM, kg/d	24.7	23.0	25.3	0.516	0.001	0.004	0.20	<0.001
Fat, %	4.63	4.58	4.72	0.114	0.46	0.66	0.42	0.23
Protein, %	3.16	3.15	3.21	0.023	0.04	0.64	0.05	0.02
Lactose, %	4.79	4.77	4.78	0.023	0.75	0.48	0.56	0.89
Fat, kg/d	1.07	0.99	1.11	0.031	0.005	0.02	0.21	0.001
Protein, kg/d	0.73	0.68	0.75	0.015	0.001	0.01	0.22	<0.001
Lactose, kg/d	1.11	1.04	1.12	0.021	0.002	0.003	0.75	0.002
SCC/ml ⁵	46,362	42,702	56,204	—	0.31	0.65	0.28	0.14
Urea, mM	5.83	4.88	6.02	0.141	<0.001	<0.001	0.17	<0.001
N eff., % ⁶	20.3	20.9	20.7	0.50	0.48	0.24	0.45	0.65

¹BAP = rolled barley/raw potatoes 80:20, BEP = fodder beets/raw potatoes 80:20, and BA = rolled barley.

²Largest standard error of difference is given because of unbalanced data. n for BAP and for BA = 14, n for BEP = 13.

³Probability for F-test of diet effect.

⁴Comparisonwise error probability for difference between diets obtained by PDIFF test.

⁵Somatic cell count. Data were subjected to Log₁₀ transformation before statistical analysis but backtransformed values are presented.

⁶Milk N of N intake.

Table 5. Daily excretion in dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes, and barley.

	Diet least squares means			SED ²	Diet effect ³	Probability for diet differences		
	BAP ¹	BEP ¹	BA ¹			BAP-BEP ⁴	BAP-BA ⁴	BEP-BA ⁴
Voided								
Urine, L/d	26.5	26.6	24.8	1.42	0.34	0.96	0.21	0.23
Feces, kg/d	39.9	40.3	39.4	1.49	0.84	0.79	0.75	0.57
Fecal DM, kg/d	6.13	5.90	6.06	0.13	0.25	0.11	0.60	0.25
Apparent total tract digestibilities, %								
DM	69.3	68.5	69.4	0.34	0.06	0.06	0.62	0.02
OM	70.7	70.4	70.8	0.33	0.38	0.36	0.62	0.18
NDF	56.8	58.5	57.2	0.62	0.04	0.02	0.48	0.06
ADF	53.3	54.4	52.8	0.63	0.08	0.12	0.41	0.03
NSC ⁵	99.4	99.8	99.2	0.17	0.01	0.02	0.30	0.004
Partitioning of nitrogen excretion, % of N intake								
Milk N	20.0	21.0	20.4	0.50	0.17	0.07	0.40	0.25
Urinary N	43.7	38.0	43.1	1.62	0.01	0.006	0.67	0.01
Fecal N	30.3	35.0	29.6	0.56	<0.001	<0.001	0.21	<0.001
Balance	6.3	7.1	7.2	1.57	0.80	0.61	0.56	0.97
Urinary nitrogen fractions								
Total N, g/d	244	187	237	9.4	<0.001	<0.001	0.43	0.001
Urea N, g/d	196	142	195	10.1	0.001	0.001	0.98	0.001
Allantoin N, g/d	16.2	14.5	14.9	0.79	0.10	0.05	0.09	0.60
Creatinine N, g/d	5.28	4.83	5.28	0.14	0.01	0.008	1.0	0.009

¹BAP = rolled barley/raw potatoes 80:20, BEP = fodder beets/raw potatoes 80:20, and BA = rolled barley.

²Largest standard error of difference is given because of unbalanced data. For means of urinary N, balance, and urinary nitrogen fractions is n for BAP, and for BA = 7, n for BEP = 6. For other means is n for BAP and BA = 8, n for BEP = 7.

³Probability for F-test of diet effect.

⁴Comparisonwise error probability for difference between diets obtained by PDIFF test.

⁵Nonstructural carbohydrates (starch, maltodextrines, and sugar).

Table 6. Rumen characteristics of dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes, and barley.

	Diet least squares means					Probability for diet differences		
	BAP ¹	BEP ¹	BA ¹	SED ²	Diet effect ³	BAP-BEP ⁴	BAP-BA ⁴	BEP-BA ⁴
Rumen contents								
Fresh weight, kg	88.6	82.5	85.9	0.92	0.02	0.01	0.04	0.03
DM, kg	12.76	10.65	12.42	0.45	0.04	0.02	0.42	0.03
NDF, kg	7.26	6.10	7.13	0.33	0.08	0.04	0.64	0.05
Sugar, g	163	139	175	13.5	0.16	0.17	0.36	0.08
Starch, g	410	252	383	42	0.07	0.03	0.47	0.05
RNA eq. ⁵ , g	148	123	145	4.2	0.02	0.01	0.40	0.01
Ash, % of DM	8.89	9.96	8.81	0.23	0.03	0.02	0.70	0.01
Concentration in ruminal liquid								
pH	6.01	6.10	6.05	0.11	0.74	0.49	0.66	0.71
Total VFA, mM	148.1	140.0	144.5	5.0	0.38	0.20	0.43	0.43
Ac ⁶ , molar %	64.1	62.2	63.9	0.43	0.04	0.02	0.70	0.03
Pr ⁶ , molar %	18.2	20.1	18.8	0.50	0.07	0.03	0.26	0.08
Bu ⁶ , molar %	13.8	14.5	13.4	0.30	0.07	0.09	0.18	0.03
Iso ⁶ , molar %	2.02	1.45	2.03	0.05	0.003	0.001	0.90	0.001
Va ⁶ , molar %	1.87	1.77	1.88	0.02	0.03	0.02	0.79	0.01
Ac/Pr	3.52	3.09	3.42	0.10	0.05	0.02	0.29	0.04
(Ac+Bu)/Pr	4.28	3.81	4.13	0.12	0.07	0.03	0.24	0.08
NH ₃ -N, mg/dl	21.4	17.6	21.3	1.60	0.18	0.10	0.96	0.11
α -amino-N, mg/dl	3.8	4.5	5.3	1.11	0.36	0.56	0.19	0.53

¹BAP = rolled barley/raw potatoes 80:20, BEP = fodder beets/raw potatoes 80:20, and BA = rolled barley.

²Largest standard error of difference is given because of unbalanced data. n for BAP and for BA = 4, n for BEP = 3.

³Probability for F-test of diet effect.

⁴Comparisonwise error probability for difference between diets obtained by PDIFF test.

⁵Total purines determined as yeast RNA equivalents.

⁶Ac = acetate, Pr = propionate, Bu = butyrate, Iso = isobutyrate + isovalerate, Va = valerate.

In the experiments of Dulphy et al. (1990), only fodder beets with a low DM (12%) had a detrimental effect on silage intake, while beets containing 21% DM were similar to grain in that respect. This raises the question whether water per se has a detrimental effect on intake or if this is caused by other factors associated with a low DM content. The experiments of Lahr et al. (1983), where DM contents ranging from 40 to 78% were obtained by adding water to a TMR of alfalfa hay, corn

silage, and concentrates, suggested a linear intake reduction for reduced DM content. However, silage of differing DM content also have different properties because of the varying fermentation procedures and roots of different DM differ in chemical composition (Gruber, 1994). For instance, a low DM content will mean that more soil will be associated with a given amount of root DM. Thus, it cannot be concluded that the reduction in silage intake was simply an effect of the higher dietary

Table 7. Urinary and ruminal characteristics where *P* for effect of selection line was < 0.10 in dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes and barley.

	Least squares means		SED	<i>P</i>
	HFI ¹	LFI ²		
Allantoin N, g/d	13.1	16.8	1.29	0.04
RNA eq. ³ , g/kg ruminal DM	11.2	12.0	0.21	0.06
Pr, molar % ⁴	18.3	19.4	0.31	0.07
Bu, molar % ⁴	14.5	13.2	0.19	0.02
(Ac+Bu)/Pr ⁴	4.2	3.9	0.07	0.06

¹HFI = cows from selection line with high milk-fat concentration, 3 cows (8 observations) for allantoin N, 2 cows (5 observations) for ruminal data.

²LFI = cows from selection line with low milk-fat concentration, 4 cows (12 observations) for allantoin N, 2 cows (6 observations) for ruminal data.

³Total purines determined as yeast RNA equivalents.

⁴Ac = acetate, Pr = propionate, Bu = butyrate.

Table 8. Coefficients of determination and probabilities for linear regressions of microbial markers against production and intake variables in dairy cows fed alfalfa/grass silage supplemented with fodder beets, potatoes, and barley.

	Allantoin N excretion		Rumen purine pool	
	R-square	P ¹	R-square	P ¹
Allantoin N excr.	—	—	0.10	0.34
Production				
Milk, kg	0.42	0.002	0.00	0.89
ECM, kg	0.43	0.002	0.03	0.63
Milk protein, %	0.04	0.39	0.41	0.03
Milk protein, kg	0.50	<0.001	0.00	0.81
Milk fat, kg	0.34	0.007	0.08	0.40
Intake				
DM, kg	0.55	<0.001	0.32	0.07
OM, kg	0.57	<0.001	0.34	0.06
NDF, kg	0.64	<0.001	0.31	0.07
NSC ² , kg	0.08	0.24	0.14	0.26
Dig CHO ³ , kg	0.61	<0.001	0.32	0.07

¹Probability for linear regression.

²Nonstructural carbohydrates (starch, maltodextrines, and sugar).

³Totally digestible carbohydrates available for microbial synthesis according to Madsen et al. (1985).

water intake with the BEP diet (Table 3), although this diet tended ($P = 0.07$) towards a lower rumen DM concentration.

Respiration experiments on dairy cows with fodder beets (Müller et al., 1994) or corresponding amounts of sucrose (Kirchgessner et al., 1994) both revealed a utilization of ME from the sucrose fraction that was 18% lower than for other feed fractions. However, because the balance of ME (although not measured, only calculated from proximate analysis of feeds) was the same for all diets in the current experiment, it does not seem that this occurred here. It is to be expected that different fermentation patterns occur with sucrose depending on total ration composition, and on the actual rumen microbiota, similar to the differences noted for Swedish cows vs. North American cows regarding fibrolytic flora and VFA distribution (Van Gylswyk and Murphy, 1993). The utilization of ME most likely would vary according to the fermentation pattern. The VFA proportions of the present experiment do not suggest a shift towards a fermentation pattern unfavorable to ME utilization for milk production when fodder beets replace barley.

The only statistically significant difference in milk composition was a small increase in protein concentration for the BA diet. In experiments in which fodder beets have been offered with a basal ration, milk concentrations of both fat and protein have increased (Roberts, 1987; Fisher et al., 1994). Müller et al. (1994) also noted the same changes in milk composition when fodder beets replaced grains, while a similar experiment (Birkenmaier et al., 1996) resulted in a nonsignificant increase for milk fat concentration and small

and inconsistent changes in milk protein concentration. The absence of large differences in milk composition for the present experiment is probably due to relatively small differences in proportions of fermentation products and also in the predicted supply of AAT.

The generally low N efficiency in the experiment was caused by ad libitum access to a protein-rich silage for cows in midlactation, which led to a large positive protein balance in the rumen (PBV). It seems that no protein-sparing effect could be detected for fodder beets in the experiment, only a difference in excretion routes. The different amounts of N excreted in urine corresponded almost exactly to the different N intakes. The constant amount of fecal N in spite of lower N intake with the BEP diet was probably not caused by a lower small intestine digestibility of RUP, considering the limited possible influence of the small amount of RUP in fodder beets (CP – RDP from Table 2). It was more likely due to a relatively larger fecal excretion of microbial N with the BEP diet, also supported by the lower milk urea concentration and lower allantoin excretion with BEP compared to BAP, which suggests microbial utilization of N without subsequent digestion of microbial N compounds. The excreted fecal N could only originate from rumen microbes if the BEP diet resulted in a microbiota with lower post-ruminal digestibility. A constant small intestine digestibility of rumen microbial N is currently assumed in Swedish feeding recommendations (Spörndly, 1999), based upon the experiment of Hvelplund (1985). Hvelplund (1985) found no significant diet effect ($P > 0.20$), although small intestine digestibilities differed numerically for total N in microbes harvested from cows on different diets. How-

ever, microbial fecal N produced by hindgut fermentation may provide an alternative explanation for the relatively larger fecal N excretion with the BEP diet. Sucrose is rapidly degraded in the rumen (Weisbjerg et al., 1998) and only small sugar amounts were detected in rumen samples. Hindgut fermentation with the BEP diet was then probably based upon structural carbohydrates that escaped rumen fermentation. Large amounts of readily available carbohydrates in the diet generally reduce ruminal fermentation of structural carbohydrates from grass silage (Huhtanen and Khalili, 1992). Because the total tract digestibility of NDF was increased rather than reduced with the BEP diet, it is likely that more of the fiber fraction was fermented in the hindgut. In spite of the low *in vitro* ruminal fermentation rate of raw potato starch (Cone et al., 1989), there was no sign of hindgut fermentation or lower total tract digestibility of potato starch in the actual experiment. Neither fecal N nor fecal starch excretion was larger with the BAP diet than with the BA diet. The tendency for higher allantoin excretion with the BAP diet actually suggests an improvement of microbial growth in the rumen. Even if the fermentation rate is slow, it seems that raw potato starch generally is degraded within the rumen and might be of value for maintenance of the rumen microbial system. Südekum and Brandt (1990) and Beyer et al. (1993) recorded ruminal starch digestibilities of 86 to 94% and total tract starch digestibilities of 98% for raw potato diets supplying 2.5 to 3.5 kg starch/d to steers and lactating cows, respectively. In addition, Beyer et al. (1993) showed that total tract N digestibility was only lowered from 60.6 to 58.4% if raw potatoes replaced barley as the starch source. Increasing the amount of potato starch fed moderately increases fecal starch and N excretion (our unpublished observations).

The lower rumen microbial protein production from BEP vs. BAP, combined with a tendency for lower ruminal ammonia concentration from BEP was most likely caused by the lower N intake with BEP, because the ratio between consumed N and allantoin excretion was the same for these diets ($P = 0.94$). However, Sannes et al. (2002) also reported lower microbial protein production together with a tendency for lower ruminal ammonia concentration, when sucrose with 3.2% of dietary DM replaced a comparative amount of grain starch in diets for mid lactation cows with almost isonitrogenous intakes. It is possible that decreased ruminal ammonia concentration when sucrose replaces starch in some cases is caused rather by decreased proteolysis than by increased utilization for microbial growth, according to the suggestion that there may exist a correlation between the expression of extracellular amylases and proteases (Griswold et al., 1999). A high starch content

would then induce expression of proteases for lysis of the protein matrix where starch granules are embedded and raise the ammonia level.

The dietary NDF concentrations were the same for all diets and ruminal digesta NDF concentrations were also similar. The different amounts of NDF and also of DM in the rumen, were not associated with different ruminal turnover times ($P = 0.68$) and appeared simply to reflect the different intakes for the different diets. Barley NDF fraction had a higher fermentation rate than fodder beet NDF, but a lower predicted extent of ruminal digestibility (Table 2). If NDF passage rates were the same for barley and fodder beets, this should have resulted in removal of the rumen NDF pool at equal rates for all diets by the sum of fermentation and passage and would be in agreement with the similar ruminal NDF concentrations on all diets. The obvious difference in particle size between the rolled barley and the coarsely chopped fodder beets as they were ingested suggests a slower passage rate for fodder beet NDF, but the velocity of particle size reduction in the rumen would have a significant impact. No measurements of ruminal particle size were carried out as part of the experiment, although fodder beets in the digesta that was observed during rumen evacuations appeared to have undergone a rapid particle size reduction. It is still possible that particle size limited NDF passage rate of fodder beets, considering that Rinne et al. (2002) showed passage rates of less than 0.1%/h for grass silage particles >2.5 mm. The suppression of silage intake by BEP also suggests a lower passage rate for fodder beets than for rolled barley.

Sucrose often results in a higher ruminal butyrate proportion than does starch (Strobel and Russell, 1986; Chamberlain et al., 1993; Friggens et al., 1998). *In vitro* tests (our unpublished observations) showed inconsistent effects of the substrate per se but a strong effect of donor cow diet, where ruminal fluid from fodder beet-adapted cows created *in vitro* butyrate proportions of the magnitude found in the present experiment, while butyrate proportion was remarkably lower if donor cows were fed other diets. The butyrate proportions differed little among different diets in the experiment reported here. It is therefore possible that the diet-adaptation effect observed *in vitro* was a difference among different butyrate producing microbial species with respect to tolerance for *in vitro* conditions.

Substituting fodder beets for barley did not increase the ruminal sugar content. Even at the evacuation 1900, 1 h after the 1800h meal, the ruminal sugar amounts were ~320 g for all diets, despite the large difference in sugar intake (0.58, 2.77, and 0.54 kg/d for diets BAP, BEP and BA, respectively). Weisbjerg et al. (1998) reported a hydrolysis rate of 1200 to 1400%/h

for infused sucrose and a fermentation rate of 400 to 600%/h for the released monosaccharides. The absence of a higher ruminal sugar content with the BEP diet suggests a very rapid hydrolysis also of sucrose from coarsely chopped fodder beets in contrast to information available in literature (Zausch and Boldt, 1985). However, even if the sugar is no longer detectable in the rumen, a part of it will probably remain in the rumen microbial pool as storage carbohydrates, recovered as starch in the analysis. The ruminal starch content for BEP, which was 36% of ingested starch compared to 13 to 14% of ingested starch for the other diets, suggests that it partly originated from sugars. Taken the observed ruminal purine pool and purine concentrations in bacteria isolates from cows on similar diets (our unpublished observations), rumen bacteria pool would be about 2000 g of DM. The variation in carbohydrate content of bacterial DM, ranging from 15 to 49% when pure cultures stored excess glucose as glycogen polysaccharides or catabolized this stored glycogen (Wallace, 1980), corresponds then to a possible fluctuation of about 1000 g in microbial carbohydrate pool. Although it is unlikely that the variation in vivo should be of the same magnitude as under more extreme in vitro conditions, the higher proportion of intake starch recovered in the rumen with the BEP diet could clearly be explained by this.

The effects of selection line on VFA proportions, with a more lipogenic fermentation pattern for the high fat index cows, are logical and in agreement with previous studies in the same experimental herd (Murphy et al., 2000). In contrast to the experiment of Murphy et al. (2000), the butyrate proportion and not only the ratio between lipogenic and glucogenic VFA increased in the experiment reported here. The higher allantoin excretion from the low fat index cows was accompanied by a tendency for higher ruminal RNA concentration, while the RNA pool was the same ($P = 0.92$) for both selection lines. The higher microbial protein production, suggested by the higher allantoin excretion, may be related to a better supply of ATP for microbial growth from the larger propionate fermentation in the low fat index cows (De Vries et al., 1973). However, no effect of selection line on yield of milk or milk protein, which might be expected from increased microbial protein production, could be detected in this experiment.

The fact that no correlation was found between non-structural carbohydrate intake and allantoin excretion may be related partly to the narrow range of nonstructural carbohydrate intake. A correlation to the other intake measurements existed, with the highest R^2 for NDF intake, slightly higher than for intake of totally digestible carbohydrates, which are used for calculating microbial protein supply in the current Scandinavian

protein evaluation system (Madsen, 1985). This suggests a relatively large contribution to microbial flow from particle-associated bacteria, in agreement with findings from bacteria fractionating experiments (Legay-Carmier et al., 1989). It is likely that different ruminal outflow rates in individual cows explain why there was no correlation between rumen purine pool and urine allantoin excretion. Because no markers for passage rate were used in the experiment, it is not possible to calculate ruminal purine outflow with any certainty. However, an estimation of outflow from ruminal and fecal amounts of OM, adapting the principles that Robinson and Kennelly (1989) used for NDF flow calculations, gives an R^2 of 0.71 for allantoin excretion against calculated ruminal purine outflow.

CONCLUSIONS

Ad libitum intake by dairy cows of alfalfa/grass silage with high intake potential is lowered if barley grain is replaced by fodder beets. Milk production is reduced in proportion to the reduced intake of metabolizable energy. Changes in milk composition and metabolizable energy utilization from such an exchange could depend on whether or not the fermentation pattern is extensively altered. However, the present results give no indications of such alterations in Swedish conditions. Ruminal acetate proportion was moderately reduced by fodder beets, while proportions of both propionate and butyrate tended to increase. Overall recovery of feed N in milk was not improved if fodder beets replaced barley, but the lower DM and N intake reduced urinary N excretion while fecal N excretion remained unchanged. Microbial protein production was not improved by fodder beets, but inclusion of 1 kg of raw potato DM/d tended to increase microbial protein production compared to barley as the sole starch source.

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