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Ruminal protein metabolites and fibre fermentation differ among nonfibre carbohydrate and protein sources*

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ABSTRACT

Effects of nonfibre carbohydrate source (NFC) and protein degradability (RDP) *in vivo* on concentrations of NH_3, amino acids, and branch chain volatile fatty acids (BCVFA) in ruminal fluid, and on *in situ* disappearance of neutral detergent fibre (NDF) were evaluated. Treatment differences noted in BCVFA and amino acid concentrations suggest that ruminal protein digestion or use differs by NFC source. NFC source and the interaction of NFC × RDP affected *in situ* NDF disappearance; the effects did not appear to purely pH related. *In situ* NDF disappearance provided relative, not absolute, evaluation of NDF digestibility.

KEY WORDS: nonfibre carbohydrates, starch, sucrose, pectin, fibre, protein

INTRODUCTION

Nonfibre carbohydrates (NFC) encompass the dietary carbohydrates exclusive of the cellulose and hemicellulose found in neutral detergent fibre (NDF). They include mono- and oligosaccharides, starch, fructans and non-starch, non-NDF polysaccharides. The NFC can provide 5 to more than 40% of diet dry matter, depending upon forage composition and amount of supplementation with byproduct feeds or grains. In most current nutrient supply estimates for dairy cattle, all NFC are estimated to be equal in their potential yield of metabolizable nutrients to the animal (NRC, 2001), except as this is affected by rate of

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fermentation (CPM Dairy, 1998). Although there is evidence that various NFC differ in their effects on animal performance and ruminal measures beyond what is readily explained by fermentation rate (Heldt et al., 1999; Sannes et al., 2002), their effects on nutrient supply to the animal, and their interaction with protein sources have not been well explored. The objective of this study was to evaluate the effects of altering the dietary complement of NFC at two different dietary concentrations of ruminally degradable protein (RDP) on ruminal measures of microbial fermentation products and NDF disappearance.

MATERIAL AND METHODS

Six ruminally cannulated, multiparous lactating Holstein cows were randomly assigned to a series of dietary treatments in a partially balanced, incomplete Latin square design with three 21 day periods (14 days for acclimation and 7 days for sample collection). In the 3 × 2 factorial arrangement of treatments, the three NFC dietary treatments were starch (ST), soluble fibre plus sugar (SF), or sugar (SU), achieved by altering the proportions of ground maize, citrus pulp, liquid molasses, and sucrose included in the diets. Inclusion of 48% soyabean meal alone (+RDP) or a combination of expeller soyabean meal (SoyPLUS; West Central Soy, Ralston, IA) and 48% soyabean meal (-RDP) were used to modify dietary protein degradability. On a dry matter basis, all diets were formulated to contain similar basal concentrations of roughage (maize silage at 250 to 260 g kg^{-1}, sorghum silage at 120 g kg^{-1}, and cottonseed hulls at 40 g kg^{-1}), to be isonitrogenous, and to contain similar concentrations of total NFC and NDF (Table 1). Dry matter intake was measured daily.

Table 1. Chemical composition of study diets

Measured component	Diets[1]					
g kg^{-1} of dry matter	ST+RDP	ST-RDP	SF+RDP	SF-RDP	SU+RDP	SU-RDP
CP	171	156	166	159	173	163
NDF	387	381	411	405	372	391
Sugar	40	44	79	72	131	136
Starch	231	237	135	150	141	117
NDSF[2]	20	31	52	47	42	51
NDFCP	36	39	38	38	45	40

[1] dietary treatments: ST - starch, SF - sugar + soluble fibre, SU - sugar, +RDP - higher ruminal protein degradability, -RDP - lower ruminal protein degradability

[2] neutral detergent-soluble fibre

Extent of *in situ* ruminal NDF disappearance of dried sorghum silage was measured on days 16, 17, and 18 of each period by the dacron bag technique using polyester bags (10 × 20 cm) with an average pore size of 53±10 μm (Bar Diamond, Inc., Parma, ID, USA) and 5 g of air dry ground sorghum silage per bag (Nocek, 1988). Duplicate

bags inserted into nylon mesh bags were incubated in the rumen for 0, 6, 12, 18, 24, 30, and 48 h. The weights of NDF residue in each bag were determined using heat-stable, alpha-amylase and were corrected for ash content.

Ruminal fluid samples (~500 mL) were collected *via* ruminal cannulae on day 20 of each period, starting prior to feeding and continuing hourly for the next 12 h. pH was measured immediately. Ruminal fluid samples were analysed for organic acids, ruminal ammonia, and amino acids (expressed as leucine equivalents).

Dry matter intake and NDF disappearance at each hour were analysed with the MIXED procedure of SAS (1996) with cow as a random variable. All other ruminal measures, including pH (analysed as the hydrogen ion concentration), were analysed as repeated measures. The orthogonal contrasts ST vs SU+SF, and SU vs SF were performed. Significance was declared at $P \leq 0.05$.

This experiment was carried out under protocols approved by the University of Florida Institutional Animal Care and Use Committee. Due to multiple health disorders not related to the study, one of the cannulated cows was removed from the study and was not sampled in the third period.

RESULTS AND DISCUSSION

Not unexpectedly, ruminal NH_3 was greater on the +RDP diets but this effect was only noted as an RDP by time interaction in hours 1 through 3 (Table 2); there was no effect of NFC treatment. In the same time frame, ruminal free amino acids differed by NFC, with ST less than SU + SF; the interactions of NFC or RDP by

Table 2. Least squares means of ruminal measures for all diets[1]

Measure[2]	ST+RDP	ST-RDP	SF+RDP	SF-RDP	SU+RDP	SU-RDP
DMI, kg	26.2	20.9	21.0	23.0	21.9	23.8
NH_3, mM	12.3	10.8	12.1	9.6	11.8	10.1
AA, mM	1.64	1.46	1.86	1.73	1.94	1.76
BCVFA, mM	3.79	3.48	3.31	2.87	2.45	2.26
NH_3/BCVFA						
at h 2	3.41	3.08	3.33	2.71	5.77	3.73
at h 3	2.92	2.69	2.92	2.49	4.48	3.29
pH	5.99	5.98	6.11	6.03	5.83	6.07
24 h IS	0.19	0.26	0.21	0.20	0.16	0.21
30 h IS	0.26	0.32	0.32	0.26	0.22	0.27
48 h IS	0.39	0.42	0.43	0.40	0.39	0.39

[1] values represent NH_3 for sampling hours 1 through 3; and AA, BCVFA, and pH sampling hours 0 through 12. Dietary treatments: ST - starch, SF - sugar + soluble fibre, SU - sugar, +RDP - higher ruminal protein degradability, -RDP - lower ruminal protein degradability

[2] DMI - dry matter intake, AA - amino acids (leucine equivalents), BCVFA - branched chain volatile fatty acids, IS - *in situ* NDF disappearance as a proportion of original NDF

time was significant for all hours. The BCVFA differed by NFC source with ST greater than SU+SF, and SF tending to be greater than SU (P=0.07). The BCVFA tended to differ by RDP by time (P=0.10). The ratio of NH_3 to BCVFA differed among NFC treatments, though both are protein breakdown products. Evaluation of these ratios at two and three h after feeding showed a tendency for effects of both NFC and RDP (P<0.10). The ratio for SU was greater than that of SF. Sannes et al. (2002) reported decreased ruminal BCVFA in dairy cattle with substitution of sucrose for maize meal.

Ruminal pH showed a highly significant NFC by time interaction, but no other effect of dietary treatment. The ruminal pH of cows consuming the SU+RDP diet was lower over time than that noted on other diets. This is consistent with the report that cows consuming a diet containing rapidly fermenting carbohydrates and relatively more ruminally degradable protein had lower ruminal pH than animals consuming a diet with less ruminally degradable protein (Aldrich et al., 1993).

In situ disappearance of NDF differed for NFC and NFC × RDP in h 6, 18, 24, and 30, and tended to differ for NFC × RDP at 48 h (P=0.05). Differences did not appear to be due solely to ruminal pH.

The interaction of NFC and RDP tended to affect intake (P=0.08).

CONCLUSIONS

Differences in ruminal amino acid and BCVFA concentrations, and in the ratio of ammonia to BCVFA suggest that ruminal protein digestion or use differs by NFC source. The differences in *in situ* disappearance of NDF indicate that fibre digestion can be affected by dietary NFC source and the interaction of NFC and protein source. Accordingly, *in situ* results are not likely to be uniform across diets and may be best suited for relative, not absolute, evaluation of NDF digestibility.

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