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Dietary starch source and protein degradability in diets containing sucrose: Effects on ruminal measures and proposed mechanism for degradable protein effects[1]

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ABSTRACT

A feeding study was conducted to evaluate ruminal effects of starch source (STA) and rumen-degradable dietary protein (RDP) in diets with added sucrose. The experimental design was an incomplete Latin square with three 21-d periods, 8 ruminally cannulated lactating cows, and a 2 × 2 factorial arrangement of treatments. Treatments were STA (dry ground corn or high-moisture corn) as more slowly and more rapidly fermenting starch sources, respectively, and relative amount of RDP (+RDP: added protein from soybean meal; −RDP: heat-treated expeller soybean product partially substituted for soybean meal). Diets were formulated to be isonitrogenous and similar in starch and neutral detergent fiber concentrations. Dry matter (DM) intake was 1 kg greater with +RDP compared with −RDP diets. For ruminal digesta measures made 2 h postfeeding, weight of digesta DM was unaffected by treatment; total kilograms of wet digesta and kilograms of liquid tended to be greater with +RDP than with −RDP, and no effect was observed of STA × RDP. Digesta DM percentage was greater with −RDP than with +RDP. At 2 h postfeeding, ruminal pool sizes (mol) of lactate and total AA were larger and those of total organic acids (OA) and ammonia tended to be larger with +RDP than with −RDP; no effects of STA or STA × RDP were detected. Rumen-degradable protein effects on lactate and OA pool sizes may be due to a protein-mediated increase in fermentation rate of carbohydrate. Organic acid concentrations at 2 h postfeeding did not show the same response pattern or significance as the pool size data; high-moisture corn tended to be greater than dry ground corn and no effect was observed for RDP or STA × RDP. Concentration and pool size for OA were more weakly correlated [coefficient of determination (R^2) = 0.66] than was the case for other ruminal analytes (R^2 >0.80). Organic acid pool size and kilograms of digesta liquid were strongly correlated (R^2 = 0.79), whereas concentration and kilograms of liquid were much less so (R^2 = 0.21). The correlation of OA moles with kilograms of liquid likely relates to the homeostatic mechanism of water flux across the rumen wall to reduce the osmotic gradient with blood as intraruminal moles of solute change. This action compresses the range of ruminal OA concentrations. With kilograms of ruminal liquid differing across individual measurements, the ruminal OA concentration data are not on the equivalent basis required to be reliably useful for assessing the effect of treatments. Further evaluation of protein effects on carbohydrate fermentation and of methods that allow accurate comparison of treatments for their effect on ruminal OA production are warranted.

Key words: fermentation, protein degradability, rumen, starch

INTRODUCTION

The concept of increasing animal productivity and efficiency by synchronizing the ruminal availability of carbohydrate and protein sources has long been proposed (Johnson 1976). However, the focus for synchrony has largely been on increasing efficiency of microbial N production (Kim et al., 1999) with little commentary regarding the effect of dietary protein on ruminal carbohydrate utilization. Increases in ruminally available protein have been shown to increase organic acid concentrations irrespective of the ruminal availability of carbohydrate (Herrera-Saldana and Huber, 1989; Aldrich, et al., 1993; Carruthers and Neil, 1997; Hall et al., 2010). The effect of protein degradability on these ruminal measures has also been shown to differ, depending on the supplemental carbohydrate source (dry ground corn, citrus pulp, or sucrose + molasses; Hall et al., 2010). Ruminally degradable protein has also been shown to affect ruminal pH, with greater amounts of RDP associated with lower ruminal pH values (Aldrich,

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et al., 1993; Hall et al., 2010). These effects of RDP would seem to contradict the general view that production of organic acids is driven primarily by ruminal availability of carbohydrate.

Protein-mediated changes in production of rumen VFA or pH would alter supply of nutrients to the cow and are not presently predicted in nutritional models. Insights into factors that generate such effects could allow design of dietary manipulations to increase energy derived from the diet and thus enhance animal performance and efficiency. The objective of this study was to evaluate effects of starch source, dietary protein degradability, and their interaction on ruminal variables. Cow behavior (rumination, eating, lying, standing, drinking, grooming, and sleeping), intake, and lactation performance were also measured, and the resulting data provided additional insights into factors that could affect ruminal function and the effect of treatments.

MATERIALS AND METHODS

Cows, Diets, and Facilities

The experiment was conducted at the US Dairy Forage Research Center (Prairie Du Sac, WI) from May through July 2008. Eight ruminally cannulated Holstein cows (DIM: 158 ± 58; parity: 1.9 ± 1.0; milk production: 45.4 ± 3.4 kg; BW: 630 ± 46 kg; cannulas: 10 cm i.d.; Bar Diamond Inc., Parma, ID) were used. Cows were housed and fed individually in a tie-stall barn, with diets offered in ad libitum amounts once daily at approximately 0700 h. Cows were milked twice daily in a parlor at 0430 and 1530 h. Ambient temperature and humidity recorded hourly for 48 h on d 17, 18, and 19 (Big Digit Hygro-Thermometer 445703; Extech Instruments Corp., Waltham, MA) averaged 18.8°C and 76% relative humidity from 0100 to 1200 h and 22.6°C and 65% relative humidity from 1200 through 2400 h. Animals were maintained under protocols approved by the University of Wisconsin Institutional Animal Care and Use Committee (Madison).

The design of the study was an incomplete Latin square (Steel and Torrie, 1960) with a 2 × 2 factorial arrangement of treatments and 3 periods. Cows were randomly assigned to a series of 3 of the 4 dietary treatments, arranged such that in the entire study each treatment followed every other treatment including itself (Table 1). The periods were 21 d in length, with 14 d for acclimation and 7 d for sample collection.

The dietary treatments were designed to provide different starch source and protein degradabilities. Starch source treatments used dry ground corn (**DG**) and ensiled high-moisture corn (**HM**) to provide more slowly or more rapidly fermenting starch sources, respectively. The 2 treatments differing in dietary concentrations of RDP were achieved by supplementing with 48% soybean meal (**+RDP**) or partially substituting heat-treated expeller soybean product (SoyPLUS; West Central Cooperative, Ralston, IA) for 48% soybean meal (**−RDP**). All diets were formulated to contain similar basal concentrations of forage (alfalfa silage, grass silage, and corn silage) and sucrose, to be isonitrogenous, and to contain similar concentrations of starch and NDF (Table 2). Sucrose was included to maintain greater concentrations of readily fermentable NFC and avoid the potential for reduction in ruminal pH sometimes associated with feeding higher concentrations of starch (Heldt et al., 1999). The concentrations of ethanol-soluble carbohydrates in these diets are within the range found in diets containing unensiled forages and feedstuffs, such as molasses or citrus pulp, that contain elevated concentrations of sugars. Characterizations of starch sources and forages are shown in Table 3. Diets were formulated to meet NRC (2001) requirements for vitamins and minerals and contained monensin.

Milk weights were recorded for all milkings during collection periods and samples collected from all milkings on d 18 through 21 of each period. Milk samples were analyzed by AgSource Milk Analysis Laboratory (Menomonie, WI) for composition by infrared analysis using a Foss FT6000 instrument (method 972.16; AOAC, 1990), and for SCC using a Foss 400 instrument (method 978.26; AOAC, 1990; Foss Electric A/S, Hillerød, Denmark). Production of 3.5% fat- and protein-corrected milk (**FPCM**) was calculated by the following equation (derived from Tyrrell and Reid, 1965):

$$\text{3.5\% FPCM (kg/d)} = [12.82 \times \text{fat (kg/d)}] + [7.13 \times \text{protein (kg/d)}] + [0.323 \times \text{milk (kg/d)}].$$

Feed efficiency was calculated as 3.5% FPCM divided by DMI. Efficiency of dietary N utilization was calcu-

Table 1. Series of dietary treatments as applied to individual cows[1]

Cow	Period 1	Period 2	Period 3
1	A	C	B
2	B	D	C
3	C	A	A
4	D	B	A
5	A	B	B
6	B	C	C
7	C	D	D
8	D	A	D

[1]Diet A: DG+RDP; diet B: DG−RDP; diet C: HM+RDP; diet D: HM−RDP, where DG = dry ground corn, HM = high-moisture corn, +RDP = more RDP, and −RDP = less RDP.