Effects of Source of Protein and Carbohydrate on Ruminal Fermentation and Passage of Nutrients to the Small Intestine of Lactating Cows[1]

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ABSTRACT

Four early lactation multiparous Holstein cows were used in a 4 × 4 Latin square to investigate the effects of source of protein (fish meal or soybean meal) and carbohydrate (corn or barley) on ruminal fermentation, flow of nutrients to the small intestine, and animal performance. The treatments, arranged in a 2 × 2 (protein × carbohydrate) factorial were: 1) corn plus soybean meal; 2) corn plus fish meal; 3) barley plus soybean meal; and 4) barley plus fish meal. Dry matter and starch intakes were greater when corn was fed than when barley was fed. Barley-based diets were more extensively degraded in the rumen than corn-based diets and therefore provided more energy for microbial growth. However, passage of amino acids and starch to the duodenum was greater for corn-based diets than barley-based diets, because of the greater intake and lower ruminal degradability of the corn-based diets. Microbial protein constituted a larger portion of the total N and had a greater influence on the pattern and quantity of amino acids that passed to the duodenum than did protein from fish meal or soybean meal, which escaped ruminal degradation. Feeding corn-based diets increased production of milk and milk protein compared with feeding barley-based diets.

INTRODUCTION

The requirement for nutrients to support high milk production during early lactation is tremendous. Cows in early lactation often suffer from a shortage of energy and protein because maximal DM intake does not occur until after peak milk production. Therefore, dairy cows usually mobilize energy, protein, and minerals from body stores to support milk production. To achieve high peak milk production, the quantity of nutrients supplied to cows must be maximized.

Two approaches for increasing the availability of nutrients for milk production are: 1) increase the quantity and improve the ratio of ruminal fermentation end products and 2) supplement nutrients to the diet that will escape ruminal fermentation and pass to the small intestine for absorption (4). Energy and amino acids are the two nutritional factors most likely to limit milk production. Unfortunately, the relationship between N and energy requirements is complex and not well understood. Furthermore, establishing an optimal ratio of N to energy for ruminants is complicated, because there are two requirements to be met: one for the ruminal microbes and another for the host animal.

The source of protein and energy has a significant effect on the utilization of N and energy in the rumen, the production of VFA, and the flow of nutrients to the small intestine.

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This study was conducted to examine the effects of feeding protein supplements that differ in ruminal degradability and concentrate sources that vary in rate and extent of ruminal digestion on ruminal fermentation, nutrient passage to the small intestine, apparent total tract nutrient digestibility, milk production, and milk composition.

MATERIALS AND METHODS

Management of Cows and Experimental Design

Four multiparous Holstein cows weighing an average of 583 kg and surgically fitted with ruminal and duodenal cannula approximately 6 wk prior to parturition were used. At the onset of the experiment, cows averaged 51 d postpartum and ranged from 48 to 58 d postpartum. The ruminal cannulas were made of soft plastic and were 10.2 cm in diameter, while the duodenal cannulas were of the type described by Komarek (14). The duodenal cannulas were placed proximal to the bile and pancreatic ducts approximately 10 cm distal to the pyloris. Cows were housed in conventional stanchions in a well-ventilated barn maintained at 10°C and milked daily at 0500 and 1700 h.

The experimental design was a 4 × 4 Latin square with a 2 × 2 factorial arrangement of treatments. The four treatments were: 1) ground shelled corn plus fish meal (FM, Zapata Haynie Corporation, Reedville, VA); 2) ground shelled corn plus soybean meal (SBM); 3) steam rolled barley plus FM; and 4) steam-rolled barley plus SBM. Ingredients and chemical composition of the experimental diets are shown in Table 1. The diets were fed twice daily at 0600 and 1800 h in ad libitum quantities as a total mixed ration.

Experimental periods were 16 d. The first 3 d of each period were used to gradually change the cows from one experimental diet to another. On the 1st d of each period, cows were fed the diet from the previous period and the diet fed during the current experimental period in a ratio of 3:1, on the 2nd d a ratio 1:1, and on the 3rd d, a ratio of 1:3. By the 4th d, cows were fed only the diet for the current experimental period. The following 10 d of each period were used for adjustment to the new diet and the last 3 were used for sample collection.

Dry Matter Intake, Milk Production, and Milk Composition

Feed intakes were recorded daily. Samples of the total mixed ration and feed refusals were collected daily during the last 5 d of each period and pooled. The composited samples were dried at 55°C in a forced air oven for determination of DM content and then ground in a Wiley mill (1-mm screen). Samples of feed and feed refusals were analyzed for ash, CP, ADF, NDF, and starch (1, 9, 13).

Milk weights were recorded daily at each milking. Samples from both the a.m. and p.m. milkings were obtained on the last 7 d of each period, preserved with potassium dichromate, and stored at 4°C. Daily a.m. and p.m. samples were composited according to milk production and analyzed for SNF (10), protein, and fat content (infrared analysis, Dairy Lab Services, Inc., Dubuque, IA). The mean of the milk and milk component yields for the last 7 d of each period were used to compare the effects of treatments.

Ruminal Fermentation and Flow of Nutrients to the Duodenum

Ruminal fluid was collected every 3 h during the last 3 d of each period from multiple sites in the rumen using a suction pump. The sampling time was adjusted ahead 1 h daily so that by the end of the 3rd d, 24 samples had been collected, one for each hour of the day. Ruminal fluid pH was immediately determined, and samples were acidified to pH 2.0 with 50% H_2SO_4 and frozen at −20°C until analyzed. Before analysis, the samples were thawed at room temperature and centrifuged (27,000 × *g*, 10 min, 4°C). The supernatant was analyzed for VFA (8) and NH_3 (3) concentrations.

Digesta flow and nutrient digestibilities were determined using the external marker, chromic oxide. Chromic oxide (10 g), wrapped in Whatman #1 filter paper, was placed in the rumen via the ruminal cannula twice daily at 0800 and 2000 h on d 7 through 16 of each period. Chromium concentration in duodenal digesta and feces was determined by the method of Williams et al. (36), using an atomic absorption spectrophotometer (Perkin-Elmer Model 2380, Norwalk, CT).

Duodenal digesta was collected at the same time as the ruminal fluid. Each digesta sample