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Effects of alfalfa hay particle size in high-concentrate diets supplemented with unsaturated fat: Chewing behavior, total-tract digestibility, and milk production of dairy cows

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ABSTRACT

This study evaluated the effects of increasing the physically effective neutral detergent fiber (peNDF) intake of lactating dairy cows fed high-concentrate diets supplemented with unsaturated fat on intake, eating behavior, diet sorting, chewing activity, total-tract digestibility, and milk production and composition. Diets contained 24% alfalfa hay (AH), 16% corn silage, 58% concentrate, and 2% yellow grease [dry matter (DM) basis], and dietary peNDF content was increased by varying the particle size (PS) of the AH. Nine multiparous cows averaging 87.8 ± 14.8 d in milk and weighing 653 ± 53 kg were randomly assigned to a triplicate 3 × 3 Latin square. During each 21-d period, cows were offered 1 of 3 total mixed rations that varied in PS of AH: fine, medium, and long, with a geometric mean particle length of 3.00, 3.57 and 3.87 mm, respectively. Increasing PS quadratically affected DM intake (DMI; 24.7, 25.4, and 23.7 kg/d, for fine, medium, and long, respectively), but cumulative DMI at 2, 4, and 6 h after feeding was similar across treatments, averaging 23.4, 35.6 and 46.4% of total DMI for the 3 time points, respectively. Increased peNDF intake did not affect feed sorting, but increased daily eating time, and eating and total chewing time per kilogram of DMI. Daily rumination time exhibited a quadratic response, with highest rumination time for the medium diet. Dietary PS had no effects on digestibility in the total tract, but we observed, for fine, medium, and long diets, quadratic responses in milk production (41.5, 43.3, and 40.4 kg/d), 4% fat-corrected milk production, and milk protein yield. Milk fat content decreased linearly with increasing PS, but milk fat content and fat:protein ratio were low for all treatments, likely due to adding unsaturated fat to a diet containing a high level of nonfiber carbohydrates (42.2% of DM). The composition, degree of saturation, and total conjugated linoleic acid content of fatty acids in milk fat were not affected by the change in peNDF content of the diet. The study indicates that a moderate increase in the PS of AH in diets containing unsaturated fat elevates peNDF intake and increases chewing activity, DMI, milk yield and milk fat production. However, the effects of dietary PS were quadratic, with maximum DMI and milk production observed with diets supplying 24% dietary peNDF (measured as the proportion of the ration retained on sieves >1.18 mm multiplied by dietary neutral detergent fiber content; DM basis).
Key words: particle size, alfalfa hay, feed sorting, unsaturated fat

INTRODUCTION

Increasing the physically effective NDF (**peNDF**) content of the diet increases the chewing activity of dairy cows, which is beneficial for salivary secretion and rumen function (Mertens, 1997). The peNDF content of diets can be increased by incorporating a higher proportion of forage in the diet and by increasing the particle size (**PS**) of forages (Yang and Beauchemin, 2007). Increased forage proportion can lower energy intake; thus, in commercial dairy operations, the peNDF content of diets is often achieved by substituting a portion of the silage with coarsely chopped hay.

The effects of PS of alfalfa hay (**AH**) on chewing behavior and milk production of dairy cows has been studied previously (Teimouri Yansari et al., 2004; Zebeli et al., 2007; Nasrollahi et al., 2012). Increasing the PS of AH can increase DMI, eating and rumination time, ruminal pH, FCM production, and milk fat production, particularly when diets are low in peNDF, but the results are often inconsistent depending upon the conditions of the experiment. As direct measurements of ruminal pH are not always possible in intact dairy cows, the need exists to better understand the effects of forage PS on aspects of feeding behavior and other indicators of healthy rumen function.

It is not known whether increasing the PS of AH to increase peNDF of diets containing unsaturated fat

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would be beneficial. Cows fed diets supplemented with unsaturated fat, particularly diets that contain a high level of NFC, often experience low ruminal pH (Coomer et al., 1993). Fat supplementation of dairy cow diets can be a useful means of increasing the NE_L content of the diet, but high concentrations ($\geq$25 g/1,000 g of DM) of supplemental unsaturated fat can compromise feed intake, ruminal digestion, and milk composition and production (Harvatine and Allen, 2006a,b,c). Because unsaturated fats are precursors for *trans* FA, specifically *trans*-10 C18:1, and its immediate precursor in the rumen, *trans*-10,*cis*-12 conjugated linoleic acid (**CLA**), low milk fat production can occur when unsaturated fats are fed to cows with low ruminal pH (Bauman and Griinari, 2001).

Most studies that have considered the effect of forage PS and fat supplementation of the diet have used tallow as the fat source (Grant and Weidner, 1992; Jenkins et al., 1998; Onetti et al., 2003). Thus, it remains unclear how performance and behavior of dairy cows would be influenced by moderate increases in AH PS in diets supplemented with unsaturated fat. As increasing the PS of AH in diets supplemented with unsaturated fat increases peNDF intake, we hypothesized that an increase in chewing activity and a reduction in milk fat depression would occur. Therefore, the objective of our experiment was to evaluate the effects of increasing AH PS on eating behavior, sorting activity, chewing activity, total-tract digestibility, and milk production of lactating dairy cows fed high-concentrate diets supplemented with unsaturated fat. Yellow grease derived from used cooking oil was the source of unsaturated fat.

MATERIALS AND METHODS

Cows, Forages, and Diets

Nine multiparous lactating Holstein dairy cows (653 $\pm$ 53 kg of BW; mean $\pm$ SD) averaging 87.8 $\pm$ 14.8 DIM and producing 45 $\pm$ 4 kg/d of milk were used in the study. Cows were blocked by DIM and randomly assigned to a replicated 3 $\times$ 3 Latin square experimental design with 3 dietary treatments: fine, medium, and long PS achieved by incorporating AH of varying PS. Experimental periods were 21 d in duration, with 14 d for diet adaptation followed by 7 d for data collection. The experiment was conducted at the dairy facilities of the Lavark Research Station (Isfahan University of Technology, Isfahan, Iran). Animals were cared for according to the guidelines of the Iranian Council of Animal Care (1995) and the experiment was approved by the Institutional Animal Care Committee for Animals Used in Research.

Regrowth (second-cut) alfalfa from a single field was harvested at 50% flowering on a day without precipitation. The material was wilted and baled (small rectangular bales; average weight of 15 kg). Subsequently, the bales were chopped with a forage field harvester (Golchin Trasher Hay Co., Isfahan, Iran) using theoretical chop length settings of 30 and 15 mm to obtain the long and medium PS treatments, respectively. To obtain the fine PS treatment, medium-chopped AH was rechopped using a threshing machine (designed to separate cereal grains from straw) with a theoretical chop length setting of 10 mm (Golchin Trasher Hay Co.).

Corn silage was harvested using a pull-type chopper (model 965, Claas, Omaha, NE) set to produce particles with an average theoretical chop length of 25 to 30 mm. Corn, barley, and soybean meal were finely ground through a 4-mm screen using a hammer mill (model 5543 GEN, Isfahan Dasht, Isfahan, Iran). All diets were formulated using the Cornell Net Carbohydrate and Protein System, version 5.0 (Fox et al., 2000) to meet the requirements of a 650-kg multiparous cow producing 45 kg/d of milk (Table 1). Cows were housed in individual pens (4 $\times$ 4 m) in an open-sided barn, each equipped with a manger (1 m $\times$ 0.5 m $\times$ 0.4 m; length $\times$ width $\times$ height). Cows were allowed 30 min of exercise 3 times daily. Diets were offered as TMR once daily at 0900 h. Cows were fed for ad libitum intake allowing for 10% refusals, and cows had free access to water.

DMI, Total-Tract Digestibility, and Milk Production

On the last 5 consecutive days of each period, DMI was determined for each cow as the difference between TMR offered and orts weighed daily, with samples collected daily and pooled by period (and by cow for the orts) for the determination of DM and nutrient content. Additionally, samples of feces were collected directly from the rectum once daily on the last 5 consecutive days of each period and pooled (by cow and period). Fecal samples were stored at -10°C, pooled by period and cow, and processed for chemical analysis. Apparent total-tract digestibility was determined using acid-insoluble ash as an internal marker (Van Keulen and Young, 1977).

Cows were milked 3 times daily at 8-h intervals (0200, 1000, 1800 h) in a milking parlor, with cows provided with 30 min of exercise time following each milking. At each milking on the last 5 consecutive days of each period, milk yield was recorded and sampled into vials containing potassium dichromate as a preservative. Milk samples were analyzed for fat, true protein, and lactose content (134 BN Foss Electric, Hillerød, Denmark).