J. Dairy Sci. 96:460–469
http://dx.doi.org/10.3168/jds.2012-5724

Replacing alfalfa or red clover silage with birdsfoot trefoil silage in total mixed rations increases production of lactating dairy cows[1]

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ABSTRACT

The objective of this study was to compare milk production and nutrient utilization in dairy cattle fed silage made from alfalfa (AL) or red clover (RC) versus birdsfoot trefoil (BFT) selected for low, normal, and high levels of condensed tannins. Condensed tannin contents of the 3 BFT silages were 8, 12, and 16 g/kg of DM by butanol-HCl assay. Twenty-five multiparous Holstein cows (5 fitted with ruminal cannulas) were blocked by days in milk and randomly assigned within blocks to incomplete 5 × 5 Latin squares. Diets contained [dry matter (DM) basis] about 60% AL, 50% RC, or 60% of 1 of the 3 BFT; the balance of dietary DM was largely from high-moisture corn plus supplemental crude protein from soybean meal. Diets were balanced to approximately 17% crude protein and fed for four 3-wk periods; 2 wk were allowed for adaptation and production data were collected during the last week of each period. No differences existed in DM intake or milk composition due to silage source, except that milk protein content was lowest for RC. Yields of milk, energy-corrected milk, fat, protein, lactose, and solids-not-fat were greater for the 3 BFT diets than for diets containing AL or RC. Feeding BFT with the highest condensed tannin content increased yield of milk, protein, and solids-not-fat compared with BFT containing the lowest amount of condensed tannin. Moreover, milk-N/N-intake was higher, and milk urea nitrogen concentration and urinary urea-N excretion were lower for diets with normal levels of BFT than for AL or RC diets. Feeding RC resulted in the highest apparent digestibility of DM, organic matter, neutral detergent fiber, acid detergent fiber, and hemicellulose and lowest ruminal concentrations of ammonia and free amino acids. Ruminal branched-chain volatile fatty acid levels were lowest for RC diets and diets with high levels of BFT and highest for the AL diet. Overall, diets containing BFT silage supported greater production than diets containing silage from AL or RC. The results indicated that feeding BFT or other legume silages containing condensed tannins can enhance performance and N utilization in lactating dairy cows.

Key words: birdsfoot trefoil, condensed tannins, milk yield

INTRODUCTION

Condensed tannins (**CT**) are natural plant polyphenolic compounds that bind to proteins via hydrophobic interactions and hydrogen bonding (Mueller-Harvey, 2006). Plant CT can have beneficial or adverse effects on ruminant production, depending on their concentration and nature, animal species involved, physiological state of the animal, and composition of the ration (Waghorn, 2008; Patra and Saxena, 2011). Although birdsfoot trefoil (**BFT**; *Lotus corniculatus* L.) is not commonly grown on US farms, the feeding of conserved BFT or other forages containing moderate concentrations of CT could improve milk production and N efficiency of lactating dairy cattle. When fed as the sole component of the diet, freshly cut or grazed BFT improved milk production by 14 to 20% at similar DMI in cows (Woodward et al., 1999, 2000), and by 21% in ewes (Wang et al., 1996a), compared with BFT in which CT was inactivated by addition of polyethylene glycol. Improved performance with freshly cut or grazed BFT can be attributed to increased flow of plant protein to the abomasum and greater intestinal absorption of essential AA due to reduced ruminal degradation mediated by CT (Waghorn et al., 1987; Wang et al., 1996b). Condensed tannins may also limit proteolysis during conservation and ruminal fermentation of BFT hays and silages (Albrecht and Muck, 1991; Grabber and Coblentz, 2009; Grabber et al., 2011), but it is not known whether CT in BFT silage can enhance milk production and N efficiency of cows when fed as the forage component of a mixed ration.

Condensed tannins are not present in the foliage of alfalfa (**AL**) and ruminants make poor use of its high protein content because the NPN formed during ensil-

Received May 13, 2012.
Accepted September 24, 2012.

[1]Mention of any trademark or proprietary product in this paper does not constitute a guarantee or warranty of the product by the USDA or the Agricultural Research Service and does not imply its approval to the exclusion of other products that also may be suitable.

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ing and in the rumen that is not captured as microbial protein is largely excreted as urinary N and can be readily lost to the environment (Misselbrook et al., 2005). Red clover (**RC**) contains small amounts of floral CT (Sivakumaran et al., 2004), but NPN formation in RC silage is relatively low due to the action of *o*-quinones formed by polyphenol oxidase (**PPO**; Albrecht and Muck, 1991; Jones et al., 1995). Although yield of milk and protein were unchanged, replacing AL silage with RC silage has been reported to improve DM and N efficiency in lactating cows (Broderick et al., 2001).

Our hypothesis was that replacing dietary AL silage with BFT silage would improve N efficiency in lactating cows and result in similar N efficiency as feeding RC silage. Therefore, the objective of this study was to assess milk production and nutrient efficiency of dairy cattle fed mixed rations containing BFT silages with varying levels of CT. Responses to CT-containing BFT silages were compared with responses when feeding silages made from CT-free AL and PPO-containing RC.

MATERIALS AND METHODS

Experimental Procedure

Twenty-five multiparous Holstein cows (5 fitted with ruminal cannulas) were selected with mean (SD) parity 2.6 (0.9), 640 (54) kg of BW, 161 (51) DIM, and producing 47 (8) kg of milk/d at the start of the trial. Cows were housed in tiestalls bedded with straw and had free access to water throughout the trial. The Animal Care and Use Committee for the College of Agriculture and Life Sciences of the University of Wisconsin-Madison approved all animal procedures. Cows were blocked by DIM into 5 groups of 5 cows and randomly assigned within blocks to 5 treatment sequences in replicated, incomplete 5 × 5 Latin squares. Dietary treatments were fed during four 3-wk periods (total 12 wk). Each experimental period had 2 wk for adaptation and 1 wk for collection of production data and samples.

Following a seed increase in 2001, populations of NC-83 BFT with low CT (**LBFT**), normal (**NBFT**), and high (**HBFT**) concentrations of CT (Miller and Ehlke, 1997) were planted on April 17, 2002, at an average seeding rate of 10.3 kg/ha. The RC variety Marathon and the alfalfa varieties Forecast 1001 and Rebound 4.2 were planted around April 11 and April 24, 2002, at average seeding rates of 14.6 and 16.8 kg/ha, respectively. All forages were planted on silt loam soils in adjacent fields of the US Dairy Forage Research Center farm (Prairie du Sac, WI) using a no-till planter with row spacings of 19 cm. Following first-cutting (BFT) and second-cutting (AL) harvests in July, AL and BFT forages were cut with a mower-conditioner on August 19, 2002. Mowed forage was wilted to about 35% DM and chopped with a New Holland FX 58 forage harvester (CNH Global NV, New Holland, PA) to a 2-cm theoretical length of cut on August 20, 2002, and immediately ensiled into bag silos (Ag-Bag model G6000; Ag-Bag Systems Inc., St. Nazianz, WI). Second-cutting RC forage was also mowed, field-wilted, chopped, and ensiled into bag silos using the same equipment. Before ensiling, subsamples of chopped BFT were quick frozen in liquid nitrogen and subsequently freeze dried and ground through a 1-mm screen of a cyclone mill (Udy Corp., Fort Collins, CO) for the analysis of total CT by a butanol-HCl method (Grabber, 2008).

Diets were fed as TMR and contained about 60% of DM from AL or 1 of the 3 BFT silages plus 40% of DM from corn silage, high-moisture corn, solvent soybean meal, and minerals and vitamins. The RC diet contained about 50% RC silage DM plus additional high-moisture corn and soybean meal to adjust for higher NDF and lower CP content of that forage. Corn silage fed in this trial was a brown midrib variety (F657; Cargill Hybrid Seeds, Minneapolis, MN) harvested at about 50% milk-line. The corn was chopped to a theoretical length of 1.9 cm, with field processing of grain by rolling (roller clearance of 1 to 3 mm), and then ensiled in a large bunker silo without additives. Diets were formulated to 17% CP and 28% NDF. Cows were fed experimental diets once daily at 1000 h and orts were collected at 0900 h. The feeding rate was adjusted daily to yield orts equivalent to about 5 to 10% of intake.

Daily samples of about 0.5 kg of the 5 legume silages, corn silage, high-moisture shelled corn, each TMR, and mixed orts from each diet were collected and stored at −20°C to obtain weekly composites that were used to determine the composition of the diets actually consumed during the trial. Soybean meal was sampled once each week. Weekly legume silage composites were divided into 2 subsamples. One was stored at −20°C for later extract preparation and a second was dried at 55°C (48 h) and retained for chemical analysis. After drying, ingredients and TMR were ground through a 1-mm screen (Wiley mill; Arthur H. Thomas Co., Philadelphia, PA). Proportions of each ration ingredient on an as-fed basis were adjusted weekly based on DM content determined by drying weekly composites at 60°C (48 h). Intake of DM was computed based on the 60°C DM values for TMR and orts. Dried weekly TMR composites, and silage composites from each period, were analyzed for DM at 105°C, for ash and OM (AOAC, 1980), and for total N using a combustion assay (Leco FP-2000 N analyzer; Leco Instruments Inc., St. Joseph, MI). Samples were analyzed sequentially for NDF and ADF including heat-stable α-amylase and Na_2SO_3 added during NDF extraction (Van Soest et