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Exchanging physically effective neutral detergent fiber does not affect chewing activity and performance of late-lactation dairy cows fed corn and sugarcane silages

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ABSTRACT

The objective of this study was to determine whether replacing the physically effective neutral detergent fiber (peNDF) of corn silage with sugarcane silage peNDF would affect performance in dairy cows. Twenty-four late-lactation Holstein cows were assigned to eight 3 × 3 Latin squares with 21-d periods. The dietary treatments were (1) 25% peNDF of corn silage, (2) 25% peNDF of sugarcane silage, and (3) 12.5% peNDF of corn silage + 12.5% peNDF of sugarcane silage. The physical effectiveness factors (pef) were assumed to be 1 for corn silage and 1.2 for sugarcane silage, as measured previously by bioassay. Thus, peNDF was calculated as neutral detergent fiber (NDF) × pef. The concentrate ingredients were finely ground corn, soybean meal, pelleted citrus pulp, and mineral-vitamin premix. Dry matter intake (22.5 ± 0.63 kg/d), 3.5% fat-corrected milk yield (28.8 ± 1.13 kg/d), milk composition (fat, protein, lactose, urea, casein, free fatty acids, and somatic cell count), and blood metabolites (glucose, insulin, and nonesterified fatty acids) were unaffected by the treatments. The time spent eating, ruminating, or chewing was also similar among the diets, as was particle-sorting behavior. By contrast, chewing per kilogram of forage NDF intake was higher for the sugarcane silage (137 min/kg) than the corn silage diet (116 min/kg), indicating the greater physical effectiveness of sugarcane fiber. Based on chewing behavior (min/d), the estimated pef of sugarcane silage NDF were 1.28 in the corn silage plus sugarcane silage diet and 1.29 in the sugarcane silage diet. Formulating dairy rations of equal peNDF content allows similar performance if corn and sugarcane silages are exchanged.

Key words: chewing behavior, corn silage, physical effectiveness factor, sugarcane silage

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INTRODUCTION

Corn silage is one of the most important sources of forage fed to dairy cows worldwide (Neylon and Kung, 2003; Wilkinson and Toivonen, 2003). In many countries, corn silage produces more energy per hectare than any other crop. However, in tropical areas, fresh or ensiled sugarcane (*Saccharum officinarum* L.) is also characterized by a high DM yield (>30 t DM/ha) within one harvest and a suitable nutritive value at maturity (48-h DM digestibility >60%; Daniel et al., 2013a), enabling high animal stocking rates.

In dairy rations, exchanging NDF among usual forage sources (e.g., corn, sorghum, alfalfa, wheat) typically yields similar levels of performance (Mertens, 1995, 1996). However, the replacement of corn silage with sugarcane decreases DMI and milk yield (Costa et al., 2005), even when diets are formulated to contain identical concentrations of forage NDF (**FNDF**; Corrêa et al., 2003).

Although dietary forage adequacy is important to reduce the risk of ruminal acidosis, excessive amounts of FNDF may limit DMI and animal performance (Allen, 1997). Because not all sources of NDF are equal, the effective fiber concept was developed in an attempt to formulate rations based on a diet's ability to maintain optimal rumen function (Mertens, 1997). Physically effective NDF (**peNDF**) has been related to the physical and chemical characteristics of fiber (e.g., particle size, density, fragility, moisture, and digestibility) that influence chewing activity, rumen mat consistency, and rumen motility (Armentano and Pereira, 1997; Mertens, 1997). Mathematically, peNDF is the product of the physical effectiveness factor (**pef**) and the NDF content of a feed (i.e., peNDF = pef × NDF; Armentano and Pereira, 1997). Whereas NDF is determined by laboratory analysis (Van Soest et al., 1991), pef can be measured by both animal physiological responses (Armentano and Pereira, 1997; Mertens, 1997) and laboratory methods, such as the proportion of feed retained on a sieve with an aperture of 1.18 (Mertens, 1997; Kononoff et al., 2003) or 8 mm (Lammers et al., 1996).

In dairy diets containing usual forage sources (e.g., corn, alfalfa, temperate grasses, barley, or oat crops), peNDF estimated using sieves ($peNDF_{>1.18}$) is negatively correlated with DMI and positively correlated with rumen pH and chewing activity (Zebeli et al., 2006; 2012). However, $peNDF_{>1.18}$ is not entirely consistent with animal responses when different sources of NDF are considered, primarily because this method assumes, among others, that particle fragility and digestibility do not differ among sources of NDF (Mertens, 1997).

Based on animal physiological responses (i.e., chewing behavior and rumen parameters), we recently demonstrated that the physical effectiveness of sugarcane forage NDF was 20% higher than that of corn silage (Goulart et al., 2009). A higher pef of sugarcane NDF is most likely because the low NDF digestibility (<35%), as measured in vivo (Corrêa et al., 2003) or 48-h in vitro (Daniel et al., 2013a), which results in a higher potential to regulate feed intake due to rumen filling (Goulart et al., 2009; Oliveira et al., 2011). Accordingly, the main objective of the present study was to determine if the source of peNDF affects the performance of lactating dairy cows. We hypothesized that balancing peNDF would equalize the feed intake, chewing activity, and milk yield of dairy cows fed diets based on corn silage, sugarcane silage, or both.

MATERIALS AND METHODS

All experimental procedures were approved by the Committee on Animal Use and Care at the College of Agriculture "Luiz de Queiroz," University of São Paulo.

Forage Sources

Corn and sugarcane crops were cultivated at the Department of Animal Science ("Luiz de Queiroz" Campus) during the 2009 and 2010 crop year. Whole-plant corn (30F90Bt DuPont Pioneer; Santa Cruz do Sul, Brazil) was harvested and chopped to a theoretical cut of 10 mm (Pecus 9004 Nogueira, São João da Boa Vista, Brazil) at 34% DM, packed in a bunker silo without any additive, and ensiled for 290 d. Sugarcane (RB85–5453 variety; Ridesa Brasil) was mechanically harvested at 14 mo of growth with a pull-type forage harvester (Colhiflex Mentamit, Cajurú, Brazil) to a theoretical cut of 10 mm. A hand refractometer (DZ Tokyo; Tokyo, Japan) was used to measure the concentration of soluble solids in the stalk juice, which averaged 21.6 ± 0.8°Brix. In sugarcane, more than 90% of the Brix content comprises soluble sugars; therefore, the sugarcane was mature at harvest (Preston, 1977).

During harvesting, a solution of sodium benzoate (375 g/L) was sprayed onto the chopped sugarcane (4 mL/kg) to obtain a final dosage of 1.5 g of sodium benzoate per kilogram as fed. The treated sugarcane was ensiled in a bunker silo for 65 d. Although most Brazilian farmers do not use additives when ensiling whole-plant corn (Bernardes and Rêgo, 2014), fermentative losses in sugarcane silages can only be prevented if additives are adopted (Schmidt et al., 2007). In addition, the length of storage of corn silage was longer than that for sugarcane silage because the corn crop was harvested in the summer (February), whereas the sugarcane crop matured and was harvested in the spring (October). After packing, silage densities were 659 ± 53 and 645 ± 39 kg/m^3 (as-fed basis), whereas feedout rates were 26 ± 6 and 29 ± 4 cm/d for corn and sugarcane silages, respectively.

Experimental Design and Data Collection

Twenty-four lactating Holstein cows (9 primiparous and 15 multiparous) were housed and individually fed in a tiestall barn with sand beds and a cooling system. Fresh water was provided ad libitum. At the beginning of the trial BW of cows was 640 ± 55 kg, milk yield was 30.7 ± 3.4 kg/d, and DIM was 292 ± 38 d (mean ± SD).

Cows were grouped based on parity and milk yield into eight 3×3 Latin squares with 21-d periods (14 d for adaptation and 7 d for sample collection) and randomly assigned to 3 dietary treatments: (1) 25% peNDF of corn silage (**CS**); (2) 25% peNDF of sugarcane silage (**SS**); and (3) 12.5% peNDF of corn silage + 12.5% peNDF of sugarcane silage (**CSSS**). The CSSS treatment was included to investigate possible interactions between peNDF sources. The pef values were assumed to be 1 for corn silage and 1.2 for sugarcane silage, as determined previously by bioassay (Goulart et al., 2009). To measure pef, chewing activity (min/kg of DM) was chose as animal response to alter according to fiber input in 3 diets: negative control (containing 10% NDF from corn silage), positive control (containing 20% NDF from corn silage), and test (containing 10% NDF from corn silage + 10% NDF from sugarcane). Fiber from concentrates (finely ground corn, protein supplement, and minerals) was considered ineffective (pef = 0). By concept, the pef of a given feed is relative to a standard feed, for instance, corn silage (pef = 1). The slope ratio in which chewing (min/kg of DM) was plotted against dietary input of NDF from corn silage and sugarcane was therefore used to define the sugarcane pef as 1.2 (Goulart et al., 2009). Additional details on the measurement of pef based on animal responses are provided in Armentano and Pereira (1997).

Ration ingredients were mixed for 15 min in a self-propelled mixer (Data Ranger American Calan, North-