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Response of early lactation Holstein cows to partial replacement of neutral detergent soluble fibre for starch in diets varying in forage particle size

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ABSTRACT

This study investigated the effects of partial replacement of neutral detergent soluble fibre (NDSF) for starch in diets varying in particle size (PS) of alfalfa hay on chewing activities, ruminal fermentation, nutrient digestibility and performance of early lactation dairy cows. Eight multiparous Holstein cows (66 ± 5 d in milk; 42.9 ± 3.1 kg milk/d) were used in a replicated 4 × 4 Latin square design with four 22 d periods with the last 8 d used for data collection. The experiment was a 2 × 2 factorial arrangement with 2 levels of NDSF (low = 84 g/kg or high = 118 g/kg diet dry matter) each combined with 2 PS (short = 20 mm or long = 40 mm) of alfalfa hay. Feeding short PS in combination with low level of NDSF increased intake of DM and OM ($P < 0.05$). Total chewing time was not affected, however, total eating time and eating times spent per kg of DM and NDF consumed decreased when forage particle size was reduced ($P < 0.05$). High NDSF diets increased total eating time and eating times spent per kg DM and NDF ingested and increased apparent digestibility of NDF ($P < 0.05$). However, feeding high NDSF diet increased the OM digestibility only in long PS diet ($P < 0.05$). Treatments did not affect ruminal pH; however, feeding short PS tended to increase total volatile fatty acid concentration, decreased molar proportion of acetate and increased that of propionate. Inclusion of NDSF decreased molar proportion of propionate and increased that of butyrate and decreased ruminal ammonia concentration ($P < 0.05$). Milk yield and composition and milk energy output were similar among treatments. Results show that partial replacement of NDSF for starch increases nutrient digestibility, most notably for NDF, and maintains milk yield and composition of early lactation cows fed diets varying in forage PS.

1. Introduction

A major challenge to the current feeding systems of high-producing dairy cows is how to reconcile feeding of energy-dense diets with adequate amounts of dietary physically effective neutral detergent fibre (peNDF) (Zebeli et al., 2012). Starch increases ruminal propionate, which, in turn, increases energy and glucose supply for milk synthesis (Knowlton et al., 1998). However, feeding excessive amounts of degradable starch may predispose cows to sub-acute ruminal acidosis (SARA) and consequently impair cow

Abbreviations: ADF, acid detergent fibre; AH, alfalfa hay; CP, crude protein, DM, dry matter; MS, maize silage; NDF, neutral detergent fibre; NDSF, neutral detergent soluble fibre; OM, organic matter; pef, physical effectiveness factor; peNDF, physically effective neutral detergent fibre; TESC, total ethanol (0.8 ml/ml) soluble carbohydrates; TMR, total mixed ration; VFA, volatile fatty acids

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productivity (Enemark, 2008). Hence, as the level of ruminally fermentable starch is increased, the requirement for peNDF, which is necessary to stimulate rumination and reduce the risk of SARA, is also increased (Zebeli et al., 2008a). This situation is challenging, particularly for early lactation cows, because increasing the peNDF may lower DM intake (Kononoff and Heinrichs. (2003a)) and hinder cow to attain maximum milk production. For high producing cows during early lactation, a rewarding feeding strategy is to decrease the amount of ruminally degradable starch in the diet, thereby reducing the requirement of peNDF, which, in turn, can increase the DM intake (Zebeli et al., 2012).

Despite the potential benefits of the above-mentioned strategy, most studies investigating dietary starch dilution through replacement with non-forage fibre sources (NFFS) (e.g. Broderick et al., 2008; Voelker and Allen, 2003a) have not addressed the physical characteristics of the forage portion or the total mixed ration (TMR). Furthermore, in these studies, the effects of partial replacement of grains with NFFS, rather than the effects of altered profiles of non-fibre carbohydrates (NFC) including neutral detergent soluble fibre (NDSF), have been discussed. Importantly, NDSF including pectins and β-glucans are readily degraded in the rumen, but they do not induce the pH-lowering effect of starch because they generally are not fermented to lactate and their fermentation ceases at low pH (Hall and Herejk, 2001). In this regard, we showed that in diets containing marginal peNDF levels, replacement of NDSF for starch resulted in a significant increase in nutrient digestibility with no change in milk production (Alamouti et al., 2009). The latter study was conducted in mid-lactation cows, and the grain portion of the diet consisted of ground barley and corn that was proportionally replaced with beet pulp. We hypothesized that partial replacing of beet pulp for a more rapidly degradable starch source, e.g. ground barley, in diets of early lactation cows approaching peak DM intake may better indicate the interaction between the non-fibrous carbohydrates and forage PS. The hypothesis is plausible because it has recently been shown that ruminal degradability of starch and level of DM intake can remarkably alter the minimum requirement for peNDF (Zebeli et al., 2008a). Hence, in diets consisting of a mixture of alfalfa hay (AH) and maize silage (MS) two levels of particle size (PS) of AH were combined with two levels of NDSF to investigate their interaction on milk yield and composition, nutrient digestibility and intake behavior in early lactation cows.

2. Materials and methods

2.1. Cows, diets, and experimental design

Eight multiparous lactating Holstein cows averaging 66 ± 5 d in milk and producing 42.9 ± 3.1 kg milk/d were used. Cows were housed in individual 1.9 × 6 m open-side pens with free access to water and were fed at 09:00 and 14:30 h for ad libitum intake to allow for 5 to 10 % refusals. Cows were assigned in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of dietary treatments to one of the four diets: Short-High = short AH and high NDSF inclusion; Short-Low = short AH and low NDSF inclusion; Long-High = long AH and high NDSF inclusion; Long-Low = long AH and low NDSF inclusion. Diets were formulated by combining two factors: two amounts of NDSF (79 and 84 g/kg for low- and 118 g/kg DM for high NDSF diets) and two theoretical PS of AH (20 and 40 mm for short and long PS, respectively). Ingredients and chemical composition of experimental diets are in Table 1.

To partially replace the starch originating from ground barley, and provide the low and high amounts of NDSF for the diets, shredded beet pulp was used as a source of NDSF. The duration of the study periods were 22 d with the last 8 d used for sampling and data collection. Diets were formulated using the CPM Dairy program (version 3.0.7, University of Pennsylvania, Kennett Square, PA, USA) to meet the requirements of a cow weighing 650 kg and producing 43 kg/d of milk with 35 g/kg fat and 32 g/kg crude protein (CP).

Prior to the start of the experiment, the AH was chopped. The alfalfa was selected from a batch harvested from a single field. Half of the load was chopped using a conventional hay chopper (Agri-Equip, Nasr Co., Isfahan, Iran) with a 40 mm screen providing the long PS hay. The short variant of hay was obtained with a 20 mm screen installed on the same chopper. At least six representative samples were collected from each hay type at the beginning of each period, and used for PS distribution or composited for determination of chemical composition. The diets also contained MS that was obtained from a bunker silo filled with maize forage from two fields and chopped to approximately 30 to 50 mm theoretical chop length. When preparing the TMR for the experiment, the MS was removed from the bunker using a silage cutter (Model Gonella F.lli, Gonella Marco & C SNC, Torino, Italy), decreasing the variation in PS for MS in TMR. During the adaptation period, silage DM was determined weekly to adjust DM intake of cows.

2.2. Sampling and chemical analysis

Feeds and orts were weighed daily from day 15 to 22 to determine the feed intake of the cows by difference. Samples of TMR and MS were collected twice weekly and orts were collected daily. On day 17 of each period, the TMR of each cow was sampled at 0, 3, 8, and 24 h after feeding to determine sorting consumption of the feed in relation to time post-feeding. Feeds were composited by period while orts composited by cow in each period and were stored at −18 °C. One set of samples of MS and TMR were also stored for PS determination. After thawing, samples were analyzed for moisture by oven drying at 55 °C for 48 h, and ground to pass a 1 mm screen. Samples of TMR were analyzed in duplicate according to AOAC (AOAC (2000)) for N (955.04), ether extract (920.39), and ash (942.05) and for aNDF, ADF based on Van Soest et al., (1991). The sulfuric acid lignin content was only determined (973.18) for AH samples. The fractionation method of Hall et al. (1999) was followed to determine ND soluble carbohydrates of TMR with the modification that ethanol insoluble residue and neutral detergent residue were not corrected for ash content. After extraction in 0.8 ml/ml ethanol solution, the concentration of total ethanol soluble