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Effects of dietary effective fiber to rumen degradable starch ratios on the risk of sub-acute ruminal acidosis and rumen content fatty acids composition in dairy goat

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ABSTRACT

This study investigated the effects of dietary physical effective NDF (peNDF, g/kg of DM) to rumen degradable starch (RDS, g/kg of DM) ratios (PRR) on the risk of sub-acute ruminal acidosis (SARA), bacterial density, and rumen content fatty acid (FA) composition in dairy goats. Six ruminally cannulated dairy goats were assigned to 3 treatments in a repeated 3 × 3 Latin square design. Treatment diets consisted of three PRR levels: 1.81, 1.43, and 1.21, which were achieved by replacing dietary corn with wheat (0, 175, and 350 g/kg of DM). Diets with similar starch contents and identical forage to concentrate ratio (50:50) were used. The time and the area with a ruminal pH below 5.8 (from 2.97 to 7.17 h/d, and from 0.73 to 1.33 pH × h/d, respectively) or below 5.6 (from 1.20 to 3.05 h/d, and from 0.11 to 0.20 pH × h/d, respectively) linearly increased when the dietary PRR was reduced. With the reducing of dietary PRR, the molar ratio of acetate decreased, whereas that of propionate increased. However, the total VFA concentration showed a quadratic change in response to the dietary PRR. Reducing the dietary PRR caused a linear decrease in the rumen concentrations of *iso* C14:0, *iso* C15:0, *anteiso* C15:0, and *iso* C17:0. However, the C18:1 isomers concentration remained constant. The relative abundance of *Ruminococcus albus* and *Streptococcus bovis* was not affected by the dietary PRR, whereas that of *Ruminococcus flavefaciens* decreased with decreasing dietary PRR. These results suggested that the odd and branched FA content of the rumen might be used to determine the fluctuation of the ruminal pH and of the bacterial population. In addition, the recommended dietary PRR for dairy goats was 1.43.

1. Introduction

Sub-acute ruminal acidosis (SARA) is a common digestive disorder in dairy ruminants and affects rumen function and milk performance (Plaizier et al., 2008). The SARA is commonly caused by an undesirable rumen pH, which is due to the excessive non-structural carbohydrates intake and inadequate fiber intake of animals (Calsamiglia et al., 2012). Experimentally induced SARA was usually obtained by reducing dietary peNDF (Zhao et al., 2011) or by increasing dietary RDS (Gozho et al., 2007), respectively. However, diets containing excess fiber and low RDS may reduce the feed intake and lower the energy efficiency

Abbreviations: aNDF, neutral detergent fiber assayed with a heat stable amylase and expressed inclusive of residual ash; CP, crude protein; DM, dry matter; ERD, Effective ruminal degradability; OBCFA, odd and branched chain fatty acid; peNDF, physical effective neutral detergent fiber; PRR, physical effective to rumen degradable starch ratio; RDS, rumen degradable starch; SARA, subacute ruminal acidosis.

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(Yang and Beauchemin, 2006). Thus, it is necessary to provide an optimum dietary content of peNDF and RDS to ensure rumen health and high efficiency. Zebeli et al. (2008) found that the ratio of the dietary $peNDF_{1.18}$ (feed particle retained on 1.18 mm sieve) to RDS from grains is highly correlated with the ruminal pH ($R^2 = 0.41$) and a diet with a ratio of 1.45 could avoid the occurrence of SARA (pH > 6.2) in high-yielding dairy cows. The PRR was affected by both dietary peNDF and RDS. However, differences were reported in the fermentation pattern (acetate to propionate ratio), inflammatory response and microflora between high RDS based and low peNDF based SARA (Plaizier et al., 2008; Khafipour et al., 2009b). In high RDS based SARA, reducing the dietary PRR was usually achieved by replacing a portion of the total mixed ratio with grain (Khafipour et al., 2009a) or by increasing the dietary concentrate proportion (Sun et al., 2010; Metzler-Zebeli et al., 2013), which thereby improved the animal intake of RDS. In these procedures, both a low peNDF and a high RDS intake contribute to the low rumen pH. Therefore, the high RDS based SARA is required to avoid the confounding effects of the dissimilar peNDF intake between the treatments. In addition, data regarding the appropriate PRR for dairy goats is limited.

Recent research indicated that milk fat odd and branched chain FA (OBCFA) can be used as a biomarker for the detection of SARA (Fievez et al., 2012; Colman et al., 2013). The milk OBCFA originated from rumen bacteria FA, and the microflora differed between the SARA induction protocols (high grain or low peNDF, Khafipour et al., 2009b). The objective of this study was to assess the effect of reducing dietary PRR on the risk of SARA and rumen content FA composition in dairy goats by replacing corn with wheat without changing the dietary concentrate to forage ratio.

2. Materials and methods

All experimental procedures were approved by the Northwest A&F University Animal Care and Use Committee.

2.1. Animals, diets, and experimental design

Six ruminally cannulated Xinong Saanen dairy goats (BW, 55 ± 4 kg) were used in a replicated 3 × 3 Latin square design that was balanced for carryover effects. Each experimental period was 30 d, with 21 d were used for adaptation to diets, and the remaining 9 d were used for samples collection and measurements. Treatment diets consisted of three PRR levels: 1.81 (H-PRR), 1.43 (M-PRR), and 1.21 (L-PRR), which were achieved by replacing dietary corn with wheat (0, 175, and 350 g/kg of DM; Table 1). The starch, crude protein, and ether extract compositions were similar between the treatments. The experimental diets were composed of alfalfa hay (450 g/kg of DM), corn silage (50 g/kg of DM), and the respective concentrates (500 g/kg of DM).

The goats were raised in individual metabolism crates (0.75 m × 1.5 m) and fed twice daily with equal portions at 07:00 h and 19:00 h for *ad libitum* intake (allowing for 5–10% orts). The animals had free access to water throughout the study.

2.2. Sample collection

During the collection periods, the amount of feed offered and orts of each goat were recorded daily. Samples of diets and orts were collected daily, and representative samples were prepared and stored at −20 °C. The orts samples were pooled by animal per period. Ruminal fluid (approximately 50 ml) was collected from the ventral rumen sac with a frequency of three hours among sampling times (from 07:00 h on day 22 to 18:00 h on day 24). For the analysis FA of rumen content and for bacteria DNA extraction, approximately 100 g of rumen content was sampled twice before the morning and evening feedings on day 25. Samples of the rumen contents were mixed by stirring, and one portion (5 g) was immediate frozen at −80 °C for microbial DNA extraction. The remaining amounts of each sample were freeze-dried for 24 h and then stored at −40 °C for FA extraction.

2.3. Chemical analysis

The feed samples were dried at 55 °C for 72 h and ground through a 1 mm screen. The analytical DM content of the samples was determined by drying at 135 °C for 3 h. The aNDF and ADF contents were sequentially determined according to methods that were described previously by Van Soest et al. (1991), with heat stable α-amylase and sodium sulfite, which were used in the aNDF procedure (inclusive of residual ash). The crude protein content was determined by the Kjeldahl procedure (AOAC, 1990; method 976.05). The starch in the sample was determined by an enzymatic method (α-amylase and amyloglucosidase) using a commercial starch analysis kit (Megazyme, International Ireland Ltd., Bray, Co. Ireland). The particle size distribution of each diet was determined using a Penn State Particle Separator, which contained 3 sieves (19, 8, and 1.18 mm) and 1 pan (Kononoff et al., 2003). Physical effectiveness factors (peF) of diets were calculated as the sum of the DM proportion that was retained on 1.18 mm sieve (Kononoff et al., 2003). The $peNDF_{1.18}$ content of each diet was calculated by multiplying the NDF content of the diet by $peF_{1.18}$.

For VFA determination, after filtration 4 ml of rumen liquor was mixed with 1 ml metaphosphoric acid (250 g/l) and stored at −40 °C. Thawed samples of the rumen fluid were centrifuged for 15 min at 19,000 × *g* at 4 °C. Two milliliters of the supernatant were mixed with 200 μl crotonic acid (10 g/l) and then filtered through a 0.45 μm filter. The ruminal VFA was separated and quantified by gas chromatography (Agilent Technologies 7820 GC system) using a 30 m × 0.25 mm × 0.33 μm fused silica column (AE-FFAP; ATECH Technologies Co., Ltd. China). The injector and detector temperatures were set at 200 °C