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Effect of forage to concentrate ratio with sorghum silage as a source of forage on rumen fermentation, N balance, and purine derivative excretion in limit-fed dairy heifers

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ABSTRACT

Sorghum silage has been shown to be a good alternative to corn silage for dairy cows; however, studies regarding heifers are insufficiently explored. Therefore, the objective of this study was to evaluate effects of changing forage to concentrate ratio (FOR:CON) in diets based on sorghum silage on N digestibility, rumen fermentation, N balance, C excretion, and microbial N yield in limit-fed dairy heifers. A split-plot 4 × 4 Latin square design with 19-d periods (15 d of adaptation and 4 d of sampling) was conducted with 8 rumen cannulated dairy heifers (age 13.7 ± 0.6 mo and weight 364.8 ± 17.6 kg). Heifers were fed sorghum silage–based diets with 4 FOR:CON (85:15, 75:25, 65:35, and 55:45) balanced for similar metabolizable energy intake per unit of body weight and crude protein concentration. Diets were fed to allow 900 to 1,000 g/d body weight gain and were fed once daily. Total collection of feces and urine was completed on d 15 to 19 to determine N, C, urea N, allantoin, uric acid, and creatinine excretion. Rumen contents were sampled on d 19 at 0, 1.5, 3, 4.5, 6, 9, 13, 17, 21, and 23 h after feeding to measure pH, volatile fatty acid (VFA), ammonia-N, and free AA concentrations. The pH decreased linearly while ammonia-N and free AA levels increased linearly with decreasing FOR:CON of diets. Although mean total VFA did not differ among treatment diets, molar proportions of VFA did. Acetate proportion decreased while propionate and butyrate increased with decreasing FOR:CON. Intake of N and urea N excretion decreased with decreasing forage proportion in diets while total N excretion, apparent N digestibility, and N retention were not different. Intake of C and excretion in feces (g/d) decreased linearly with decreasing FOR:CON in diets. Creatinine, allantoin, and uric acid excretion were not affected by FOR:CON; however, microbial N yield tended to increase linearly with greater concentrate in diets. Heifers limit fed diets based on sorghum silage demonstrated the effect of available ammonia-N and readily fermentable carbohydrates with subsequent effects on nutrient utilization when different FOR:CON were applied. Based on the presented results, FOR:CON 65:35 had the most suitable balance of available ammonia-N and readily fermentable carbohydrates for the most optimal results.

Key words: dairy heifer, sorghum silage, forage to concentrate ratio, limit-fed, protein

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] and corn (*Zea mays* L.) are among the top-producing crops in the world, with corn being more prevalent in dairy rations. Corn silage is a key component of ruminant diets because of its high yield and energy content. Compared with cows fed conventional sorghum silage, cows fed with corn silage have greater DMI and greater milk production (Aydin et al., 1999). However, the decline in water resources and extreme weather conditions such as drought or high summer temperatures present considerable risk for corn silage production. When irrigation is not an option, producers are forced to grow crops that are more water efficient than corn. Sorghum is one such crop because of its greater ability to extract water from deeper soil layers compared with corn (Farré and Faci, 2006).

Extensive breeding efforts have been made in recent years to improve sorghum silage quality, including reducing lignification, which leads to greater fiber digestibility. Furthermore, Oliver et al. (2004) showed that the brown midrib trait in sorghum improved fiber digestibility to a level close to that of corn, and cows fed brown midrib sorghum forage hybrids had milk production similar to cows fed with corn silage.

With the development of new hybrids, sorghum silage is becoming increasingly applicable in dairy nutrition, and its utilization has been extensively studied in dairy

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cows (Grant et al., 1995; Aydin et al., 1999; Oliver et al., 2004; Miron et al., 2007). However, studies that report utilization of sorghum silage in heifer diets are not available. Heifers are typically fed a high-forage, low-energy ration to meet their energy and nutrient requirements.

Traditional ad libitum high-forage, low-energy diets of growing heifers can be replaced with limit feeding when controlled intake for targeted ADG is achieved. Controlled DMI, with the purpose of targeting a set rate of ADG, increases nutrient efficiency (Lascano and Heinrichs, 2011) and reduces manure production (Hoffman et al., 2007; Moody et al., 2007). Additionally, limit feeding enables introduction of high-concentrate diets without negative effects on heifer growth and first-lactation milk production in comparison with high-forage diets (Hoffman et al., 2007; Zanton and Heinrichs, 2007). Traditional corn silage as a source of forage could be replaced with sorghum silage, which has already been shown to be a good alternative to corn silage without detrimental effects on steer performance or ruminal fermentation (Abdelhadi and Santini, 2006). In addition, the often-reported lower DM digestibility of sorghum compared with corn silage might be beneficial in reducing readily available carbohydrates in high-concentrate diets. The extent that sorghum silage could be used in limit feeding dairy heifers is insufficiently explored. Therefore, the objective of this research was to evaluate forage to concentrate ratio (**FOR:CON**) in diets with sorghum silage as the sole forage source in terms of N digestibility, rumen fermentation, N balance, C excretion, and microbial N yield in limit-fed dairy heifers. The hypothesis was that a decreased FOR:CON when sorghum silage is the sole forage source will decrease ruminal pH and N excretion compared with an increased FOR:CON in diets for dairy heifers.

MATERIALS AND METHODS

Sorghum Silage

Brown midrib-6 brachytic dwarf sorghum (AF7102, Altaseed, Amarillo, TX) was grown in fall of 2015 at the Pennsylvania State University. This variety can typically be harvested between 85 and 92 d of growth with high yield and forage quality because brachytic dwarf genes provide strong stalks with good standability. Sorghum was harvested at middough stage with a field chopper (Forage Harvester 8600, John Deere, Moline, IL) with knives adjusted to a 2-cm theoretical length of cut after 2-d wilting because of the high moisture content. Table 1 shows the chemical composition of experimental sorghum silage.

Animals and Feeding

All procedures involving the use of animals were approved by the Pennsylvania State University Institutional Animal Care and Use Committee (IACUC no. 46266). Eight Holstein heifers were surgically prepared with a rumen cannula (10-cm i.d.; Kehl, São Carlos, SP, Brazil) under local anesthesia before the beginning of the experiment. Heifers were allowed a 40-d recovery and pretrial adaptation period for facilities and diets before the start of the experiment. During all periods, heifers were housed in individual tie-stalls with rubber mattress bedding in a mechanically ventilated barn. Heifers had free access to water at all times and were released for exercise 3 to 4 h/d in a paved pen on non-sampling days.

Heifers (13.7 ± 0.6 mo of age and 364.8 ± 17.6 kg of BW at the beginning of experiment) were randomly assigned to a split-plot 4 × 4 Latin square experimental design. Treatments (Table 2) were 4 TMR containing (DM basis) 85, 75, 65, or 55% sorghum silage as the sole forage plus 15, 25, 35, or 45% of a concentrate mix based on corn grain, canola meal, and slow-release urea (Optigen; Alltech Inc., Nicholasville, KY). Each experimental period was 19 d in length and consisted of 15 d of adaptation and 4 d of sampling. Heifers were weighed on 2 consecutive days at 7-d intervals (d 1, 2, 8, and 9 or d 2, 3, 9, and 10 depending on period), and BW was determined by the average of 2 measurements taken at 0800 and 1130 h on the same day. The amount of TMR offered during the experiment was adjusted on a weekly basis, based on BW, to allow an ADG of 900 to 1,000 g/d. Treatment ration refusals were never present in this system of feeding. Eating patterns were checked at least every 30 min during the day and 2 h during the night; when feeder boxes were empty, time elapsed from feeding time (i.e., eating time) was recorded.

Rations were fed once daily at noon, and the predicted DMI was calculated based on energy intake; diets were formulated to provide 0.22 Mcal of ME/kg of $BW^{0.75}$

Table 1. Chemical composition (% of DM unless otherwise noted) of experimental sorghum silage

Item	Value
DM, %	26.30
CP	8.06
Soluble CP, % of CP	35.85
RDP, % of CP	67.70
NDF	62.95
ADF	38.10
Starch	1.08
Sugar	5.00
Crude fat	2.99

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