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Effect of dietary polymer-coated urea and sodium bentonite on digestibility, rumen fermentation, and microbial protein yield in sheep fed high levels of corn stalk

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ABSTRACT

Four ruminally cannulated thin-tailed Han × Dorper crossbreed wethers were used in a 4 × 4 Latin square design experiment to evaluate the effect of polymer-coated urea (PCU) (Optigen II, Alltech Inc., Nicholasville, KY) and sodium bentonite (SB) on intake, nutrient digestibility, nitrogen retention, rumen fermentation and microbial nitrogen in sheep fed high levels of corn stalk. Four isonitrogenous and isocaloric dietary treatments composed of 60% corn stalk and 40% concentrate (DM basis) were offered twice daily in two equal portions at 7:00 and 19:00 h ad libitum to ensure about 5% ort. The treatments were control (CON), PCU (soybean meal replaced by 1.8% Optigen), SB (CON diet with an additional 2% SB), and PCUSB (PCU diet with an additional 2% SB). Sheep on PCU treatment showed a greater OM digestibility ($P < 0.05$), and nitrogen digestibility ($P < 0.01$) compared to other treatments, but digestibility of other nutrients and dry matter intake (DMI) did not change. SB did not alter nutrient digestibility except for nitrogen. Different treatments did not affect nitrogen intake, or its urinary excretion. Nitrogen retention tended to be higher ($P = 0.09$) in sheep fed Optigen. Moreover, purine derivatives (PD) and microbial nitrogen were not influenced by different treatments. The pH and total VFA were also not influenced by the treatments. Propionate proportions increased ($P < 0.01$) in diets that included Optigen, but an addition of SB to Optigen did not alter the ratios. NH_3–N levels in PCU continuously increased, with the highest level achieved 3 h after feeding, which were sustained for up to 7 h. No differences were discerned in ruminal kinetics of corn stalk DM for different treatments. The PCU improved the effective degradability (ED) of corn stalk DM in 0.02 or 0.04 flow rates out of the rumen compared to both CON and PCUSB ($P < 0.05$), but SB improved ED in 0.06 flow rates out of the rumen compared to CON. Thus, using Optigen as a new source of non-protein nitrogen to replace soybean meal in sheep fed high levels of corn stalk improved the digestibility of OM, nitrogen, and ED. Addition of SB to Optigen had no beneficial effects on nutrient digestibility, nitrogen retention, microbial nitrogen, or rumen fermentation and ED.

1. Introduction

The major limitations of using cereal straws as feed for ruminants are low digestibility and poor nitrogen availability (Fazaeli, 2001). Fiber-digesting rumen bacteria require ammonia for protein synthesis (NRC, 2001), and digestion of high

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fiber forages increases when NH_3 and urea are added to fibrous hay (Ørskov, 1999). Urea is commonly added to ruminant diets as a source of non-protein nitrogen (NPN) due to the ability of ruminants to utilize the nitrogen, its high nitrogen density and low cost per unit nitrogen (Jooste, 2012). Urea is degraded rapidly in the rumen, but microbial growth and ruminal carbohydrate degradation is slower than ammonia nitrogen release (Satter and Roffler, 1975). This rapid ammonia release may result in inefficient nitrogen utilization in the rumen (Xin et al., 2010). Thus, it is important to produce a form of urea that would degrade more slowly in the rumen. OptigenII is a polymer-coated urea that allows the diffusion of urea through micro-pores and slows down the rate of nitrogen release in the rumen compared to conventional urea (ICF Consulting, 2004). Coated urea is potentially useful in a high-forage diet that has a low fermentation rate (Kononoff et al., 2006). Similarly, SB is an expanding lattice clay of the montmorillonite group of minerals (Bates and Jackson, 1980) that can increase bacterial protein supply to the small intestine and decrease ruminal NH_3 concentration (Ivan et al., 1992). Therefore, replacing soybean meal with Optigen in high-roughage diets may be beneficial when sheep diets are comprised of high levels of hay and limited protein concentrate. However, no specific studies have been conducted to evaluate the effect of Optigen and SB on digestibility and rumen fermentation in sheep fed a high fiber diet. We hypothesized that replacing soybean meal with Optigen could influence the rumen fermentation, increase the digestibility of corn stalk, and increase microbial protein synthesis in the rumen. We also hypothesized that adding SB to Optigen in sheep fed corn stalk could have more beneficial effects based on the addition of Optigen.

2. Materials and methods

This experiment was conducted from July to October 2011 at the Experimental Station of the Chinese Academy of Agricultural Sciences (CAAS) in Nankou, Beijinig, China. All animal care, handling, and surgical techniques followed protocols approved by the Animal Ethics Committee of Chinese Academy of Agricultural Science. Humane animal care and handling procedures were followed throughout the study.

2.1. Animals, diets, housing, and experimental design

Four mature thin-tailed Han × Dorper crossbreed wethers with ruminal cannula (initial BW 48 ± 0.25 kg) were randomly assigned to 1 of 4 dietary treatments in a 4 × 4 Latin-square design balanced with 4 trial periods for carry-over effects. Wethers were housed in an enclosed, climate-controlled room in individual pens. Each period lasted 24 days (d) with 14 d of diet adaptation and 10 d of sampling (5 d for digestibility and 1 d of rest before rumen fluid sampling to prevent interference with the digestibility trial, 1 d for rumen fluid collection, and 3 d for the in situ trial). Four days prior to the digestibility trial, animals were placed in individual metabolism cages and allowed to adapt to their cages. Four isonitrogenous and isocaloric dietary treatments composed of 60% corn stalk (DM basis) and 40% concentrate (DM basis) were formulated (Table 1). The treatments were control (CON), PCU (soybean meal isonitrogenously replaced by Optigen), SB (CON diet with an additional 2% SB), and PCUSB (PCU diet with an additional 2% SB). The Optigen was prilled urea

Table 1
Ingredients and nutritive composition of experimental diets.

Item	Treatment[a]			
	CON	SB	PCU	PCUSB
Ingredient composition of diet, % of DM				
Corn stalk	60.6	60	60	60
Barley	9.8	13	14.4	12.4
Wheat bran	18.2	12.4	11.7	11.7
Corn grain	0	0	11.4	11.4
Soy bean meal	10.5	12	0	0
Polymer coated urea (Optigen)	0	0	1.8	1.8
Sodium bentonite	0	2	0	2
Mineral and vitamin premix[b]	0.2	0.2	0.2	0.2
Ca carbonate	0.6	0.4	0.5	0.5
Nutrient composition of diet				
DM	91.4 ± 0.4	91.7 ± 0.5	91.5 ± 0.3	91.7 ± 0.4
CP	12.6 ± 0.1	12.5 ± 0.2	12.8 ± 0.1	12.6 ± 0.2
ME (mJ/kg)[c]	7.0	6.9	6.9	6.8
NDF	49.8 ± 0.1	48.1 ± 0.1	47.5 ± 0.2	47.2 ± 0.1
ADF	25.9 ± 0.3	25.2 ± 0.2	24.4 ± 0.1	24.3 ± 0.3
ADL	5.5 ± 0.2	5.4 ± 0.1	5.4 ± 0.1	5.4 ± 0.2
Hemi cellulose	23.9	22.8	23.1	22.9
Cellulose	20.3	19.8	19.0	18.9
Ca	0.51 ± 0.02	0.43 ± 0.04	0.43 ± 0.03	0.43 ± 0.02
P	0.38 ± 0.03	0.34 ± 0.03	0.29 ± 0.04	0.28 ± 0.01

[a] CON: Control, SB: control+sodium bentonite, PCU: Polymer coated urea (Optigen); PCUSB: Polymer coated urea+sodium bentonite.
[b] Manufactured by Precision Animal Nutrition Research Centre, Beijing, China. The premix contained (per kg): 22.1 g Fe, 13.0 g Cu, 30.2 g Mn, 77.2 g Zn, 19.2 g Se, 53.5 g I, 9.10 g Co, 56.0 g vitamin A, 18.0 g vitamin D3 and 170 g vitamin E.
[c] Nutrient requirements of small ruminants 2007.