J. Dairy Sci. 101:1–12
https://doi.org/10.3168/jds.2017-13254

Dynamics of methanogenesis, ruminal fermentation, and alfalfa degradation during adaptation to monensin supplementation in goats

Z. J. Li,* H. Ren,* S. M. Liu,† C. J. Cai,* J. T. Han,* F. Li,*‡ and J. H. Yao*[1]
*College of Animal Science and Technology, Northwest A&F University, Yangling, Shaanxi 712100, China
†UWA School of Agriculture and Environment, The University of Western Australia, Crawley, WA 6009, Australia
‡College of Pastoral Agricultural Science and Technology, Lanzhou University, Lanzhou 730020, China

ABSTRACT

This study aimed to examine the temporal (hourly within a day and daily over the long term) effects of monensin on CH_4 emissions, ruminal fermentation, and in situ alfalfa degradation in dairy goats during dietary monensin supplementation by controlling the confounding effects of feed intake and ambient temperature. Six ruminally cannulated dairy goats were used, and they were housed in environmental chambers and fed a restricted amount of ration throughout the experiment. The experiment included a baseline period of 20 d followed by a treatment period of 55 d with 32 mg of monensin/d. During the whole experiment, CH_4 production was measured every 5 d, whereas fermentation characteristics and in situ alfalfa degradation were analyzed every 10 d. The CH_4-depressing effect of monensin was time dependent on the duration of treatment, highly effective at d 5 but thereafter decreased gradually until d 55 even though CH_4-suppressing effect still remained significant. The decreasing effects of monensin on ruminal acetate proportion and acetate to propionate ratio also faded over days of treatment, and the acetate proportion returned up to the pre-supplementation level on d 50. Monensin supplementation elevated ruminal propionate proportion and decreased the effective ruminal degradability of alfalfa NDF, but both measurements tended to recover over time. The postprandial increase rate of hourly CH_4 emissions was reduced, whereas that of propionate proportion was enhanced by monensin supplementation. However, the postprandial responses to monensin in CH_4 emission rates, ruminal VFA profiles, and in situ degradation kinetics declined with both hours after feeding and days of treatment. Our results suggest that the CH_4-suppressing effect of monensin supplementation in goats was attributed to reductions in both ruminal feed degradation and acetate to propionate ratio, but those reductions faded with time, hours after feeding, and days of treatment.

Key words: goat, methane emission, monensin, ruminal fermentation and degradation

INTRODUCTION

Ruminant production is confronted with massive challenges in animal health and productivity. Ruminal acidosis is commonly observed in ruminants when they are fed grain-based diets to increase production (Russell and Rychlik, 2001). Negative energy balance and subclinical ketosis are inherent to ruminants during the transition period and early lactation (Drackley, 1999). Additionally, ruminal CH_4 emission contributes to global greenhouse gas emissions and represents an energy loss for the host animal (Johnson and Johnson, 1995; Hristov et al., 2013). As demonstrated by Shabat et al. (2016), inefficient cows produced less propionate but more CH_4 in the rumen than their efficient peers. Monensin, as an ionophore, has been used in ruminant production to alleviate the above problems and improve animal's energy efficiency (McGuffey et al., 2001; Duffield et al., 2008a, 2008b, 2012; Patra et al., 2017).

However, the persistence of monensin effects remains controversial, especially its CH_4-depressing effects (Sauer et al., 1998; Guan, 2006; Odongo et al., 2007; Appuhamy et al., 2013). For example, Guan (2006) reported that the CH_4-depressing effect of monensin was short lived in cattle, whereas it was long lived in the study of Odongo et al. (2007). The animal's feed intake may interfere with the evaluation of monensin effects as discrepancies in its CH_4-suppressing effects were found between measurements per day and per unit feed intake (Odongo et al., 2007). Additionally, it is well documented that ambient temperature can also influence CH_4 production (Salles et al., 2008; Bernier et al., 2012) by affecting animal's DMI and nutrient degradation (Kennedy and Milligan, 1978; von Keyserlingk and Mathison, 1993). However, the ambient temperature fluctuates in long-term studies, such as in

Received May 30, 2017.
Accepted October 23, 2017.
[1]Corresponding author: yaojunhu2004@sohu.com

the study of Guan (2006) where ambient temperature varied between −28.6 to 6.7°C over 16 wk.

Furthermore, to our knowledge, the effects of monensin on postprandial variations of CH_4 emissions, ruminal VFA profiles, and in situ degradation kinetics over days of treatment have never been studied, limiting our understanding of the temporal responses of the ruminal ecosystem to monensin. The objective of the present study was to investigate how monensin affects CH_4 production, ruminal fermentation, and in situ degradation of alfalfa hay during a long-term (55 d) treatment in dairy goats by controlling the confounding factors of feed intake and ambient temperature. The postprandial temporal effects of monensin on the above measurements were also examined hourly following feeding monensin.

MATERIALS AND METHODS

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

Animals, Diets, and Experimental Design

Six nonlactating Xinong Saanen dairy goats, approximately 4 yr of age, with similar BW (54 ± 2.4 kg), body condition (health), and feed intake behavior (good appetite) were used in this study. The goats were fitted with permanent ruminal cannulas and had never been exposed to monensin before the experiment. A TMR (Table 1) was formulated to meet the nutrient requirements for maintenance (NY/T 816–2004; Ministry of Agriculture of China, 2004). The goats were fed the same amount of TMR equivalent to 330 g of alfalfa hay, 281 g of corn silage, and 408 g of concentrate twice daily in 2 equal meals at 0800 and 1800 h. The goats had free access to drinking water. The amounts of feeds refused, if any, were recorded daily.

The goats were first allowed to adapt to the environmental chambers and the TMR diet for 2 mo. Then, feeding experiment lasted for 75 d, including a baseline period (without monensin) for 20 d and a treatment period of 55 d (d 1–55), during which 16 mg of monensin (20% monensin in the Rumensin premix, Elanco Animal Health, Greenfield, IN) was top dressed onto a small amount of corn silage that was offered to each goat before each feeding.

Five indoor environmental chambers (7.4 m × 4.2 m × 2.7 m) were used in this study, with 2 chambers serving as adaptation chambers to allow the goats to adapt to the chamber environments and 3 chambers as gas measurement chambers. The goats were randomly divided equally into 2 groups, and the 3 goats of each group were housed in 1 of the 2 adaptation chambers. The 3 goats were separated by placing each in a metabolic cage (1.5 m × 1.0 m × 1.5 m). The adaptation chambers were kept open to the indoor atmosphere to ensure adequate air exchange. The feeding experiment started in a staggered manner for the 2 groups of goats with a 3-d interval so that gas emissions from each group of the 3 goats could be measured individually using the 3 gas measurement chambers. The temperature inside the chambers was maintained between 6 and 14°C, and the goats were subjected to a diurnal cycle of 14 h of light and 10 h of darkness throughout the experiment. The goats were housed in the adaptation chambers and were moved to the gas measurement chambers only when their gas emissions were measured.

Measuring Methane Emissions and DMI

During both the baseline and the monensin treatment periods, CH_4 and CO_2 emissions from each goat were measured every 5 d using the approach of Goopy et al. (2011) with minor modifications. By this approach, gas emission from each goat was measured by determining the gas accumulation inside each airtight chamber with a fixed volume over a period of time. The system-alarm concentration of CO_2 was set at 2,000 ppm, much lower than the threshold level of 10,000 ppm for animals (Weissman et al., 1984; Hellwing et al., 2012). The internal volume of each chamber was 83.9 m^3, which is about 137 times larger than that (0.613 m^3) used by Goopy et al. (2011), allowing for an extended duration of gas measurement in the closed chambers.

Table 1. Ingredients and chemical composition of the experimental diet

Item	% (DM)
Ingredient	
Corn silage	26.8
Alfalfa hay	33.3
Crushed corn	28.0
Soybean meal	10.8
Vitamin-mineral premix[1]	0.1
$CaHPO_4$	0.3
$CaCO_3$	0.3
Salt	0.4
Chemical composition	
DM	49.3
OM	93.8
CP	14.7
NDF	33.9
ADF	23.9

[1]Vitamin-mineral premix (per kg): 600 mg of Mn, 950 mg of Zn, 430 mg of Fe, 650 mg of Cu, 30 mg of Se, 45 mg of I, 20 mg of Co, 450 mg of nicotinic acid, 800 mg of vitamin E, 45,000 IU of vitamin D, and 120,000 IU of vitamin A.