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Mitigation of ammonia and nitrous oxide emissions from pasture treated with urine of sheep fed diets supplemented with sodium chloride

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ABSTRACT

This study was conducted to evaluate the effects of the inclusion of sodium chloride (NaCl) in the diet on growth performance and nitrogen (N) balance in sheep and subsequent ammonia (NH_3) and nitrous oxide (N_2O) emissions from pasture treated with urine of sheep. A total of 30 Ujimqin male sheep (a local breed, average body weight 15 ± 1.3 kg) were equally divided into three groups. The control group (C) was fed a standard NaCl diet (3 g NaCl/kg DM), and the treatments were a medium salt group (MS, 4.5 g NaCl/kg DM) and high salt group (HS, 6 g NaCl/kg DM). Urine samples collected from the control and HS groups were used for land application in a field experiment, which consisted of 5 treatments: soil group (S, soil without treatment), distilled water group 1 (W1, 326 mL), distilled water group 2 (W2, 458 mL), urine of sheep in control group (C, 326 mL, 102 kg N/ha), urine of sheep in HS group (HS, 458 mL, 92 kg N/ha). The supplementation of NaCl had no adverse effects on growth performance and N balance in sheep. The high NaCl diet increased total urine volume ($P < 0.05$) and average urine volume ($P < 0.05$) and reduced urinary pH ($P < 0.05$) and the N concentration in the urine ($P < 0.05$) compared with standard NaCl diet. Compared with the C treatment, the HS treatment resulted in a delay of the peak N_2O emission and decreased the average emission rates of NH_3 by 48% ($P < 0.05$) and N_2O by 26% ($P < 0.05$) from soil. In conclusion, high NaCl diet of grazing sheep (6 g/kg DM) seemed to be a feasible means of reducing emissions of NH_3 and N_2O from urine treated pasture by increasing urine volume and decreasing total N concentration in urine.

1. Introduction

Nitrous oxide (N_2O) is one of the important greenhouse gases, and has a global warming potential 298 times that of carbon dioxide (CO_2) (IPCC, 2007; Forster et al., 2007). By oxidizing into nitrogen oxides in the stratosphere, nitrous oxide also depletes ozone, a substance that protects the biosphere from harmful ultraviolet radiation (Crutzen, 1981). Although ammonia (NH_3) is not a greenhouse gas, it is an indirect source of N_2O (Zaman et al., 2009). Globally, the urine deposited by

Abbreviations: ADFom, acid detergent fiber expressed exclusive of residual ash; ADG, average daily gain; BW, body weight; IBW, initial BW; FBW, final BW; CO_2, carbon dioxide; CP, crude protein; DM, dry matter; DMI, dry matter intake; EE, ether extract; FCR, feed conversion ratio; GE, gross energy; N, nitrogen; aNDFom, neutral detergent fiber assayed with a heat stable amylase and expressed exclusive of residual ash; NH_3, ammonia; NH_4^+, ammonium ion; N_2O, nitrous oxide; NO_3^-, nitrate; NaCl, sodium chloride; OH^-, hydroxyl ions.

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Table 1
Ingredients and chemical composition of basal diet.

Item control diet	Basal diet
Ingredient (g/kg diet)	
Aneurolepidium chinense	300
Ground corn	425
Soybean meal	155
Wheat bran	100
Minerals and vitamins[a]	20
Chemical composition (analyzed)	
Dry matter (g/kg FM)	902.6
Crude protein (g/kg DM)	154.1
Ether extract (g/kg DM)	38.8
Neutral detergent fiber (g/kg DM)	322.5
Acid detergent fiber (g/kg DM)	209.7
Sodium (g/kg DM)	1.2
Gross energy (MJ/kg DM)	17.8

[a] Minerals and vitamins were purchased from commercial company (Continental Grain Corp., Beijing, China), and contained (per kg) 24,000 IU vitamin A, 2500 IU vitamin D_3, 4800 IU vitamin E, 32 g Ca, 11 g P, 5 g S, 65 mg Zn, 50 mg Mn, 120 mg Fe, 25 mg Cu, 0.9 mg Co, 0.8 mg Se.

ruminant animals is a major agricultural N_2O and NH_3 source (Oenema et al., 2005). It has been estimated that 750–900 g/kg of the nitrogen (N) ingested by grazing cow is returned to the pasture in the form of animal excreta of which over 700 g/kg is urine with urine patches applying 700–1000 kg/N/ha (Haynes and Williams, 1993; Whitehead, 1995; Jarvis et al., 1995; Zaman et al., 2009). As urine patches have N levels which exceed plant demand, within or around the patch, the excess N is readily lost to the environment *via* physical, chemical and biological processes (Haynes and Williams, 1993). Urea is the dominant urine-N compound and is hydrolyzed quickly within 1–2 days and produces ammonium ion (NH_4^+), hydroxyl ions (OH^-) and CO_2 (Mulvaney and Bremner, 1981). The large production of NH_4^+ and OH^- provides ideal hotspots for NH_3 volatilization (Zaman et al., 2009). The N_2O is released during conversion of the NH_4^+ through the microbially controlled processes of nitrification and subsequent denitrification of nitrate (NO_3^-) (Firestone and Davidson, 1989; Inubushi et al., 1996; Bertram et al., 2009). At present, the rapid expansion of dairy farming and high stocking rates are aggravating N losses *via* gaseous emissions of NH_3 and N_2O. Therefore, developing mitigation options for ruminant NH_3 and N_2O emissions are critical to minimizing environmental degradation.

Various mitigation options have been suggested to reduce gaseous N losses from grazed pasture. These include applying nitrification inhibitors (*e.g.* dicyandiamide), decreasing urine inputs to pasture or the concentration of N in urine through reducing crude protein content in animal diet (Smith et al., 2008; Zaman and Blennerhassett, 2010). In a laboratory study, Groenigen et al. (2005) found that reducing the N concentration of synthetic urine tended to reduce N_2O emissions from incubated soil cores by 5–10%. However, no field measurements of NH_3 and N_2O emissions using real animal urine have been reported in the context of different dietary strategies. We hypothesized that sodium chloride (NaCl) supplementation in sheep diet could reduce urinary N concentrations by increasing total urine volume without increasing total N excretion and then reduced NH_3 and N_2O emissions from urine treated pasture. This study was conducted to investigate the effects of NaCl supplementation in sheep diet on mitigating NH_3 and N_2O emissions from urine treated pasture.

2. Materials and methods

2.1. Animal experiment

2.1.1. Animals and diets

All procedures were approved by the Administration Office of Laboratory Animals, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences.

A total of 30 Ujimqin male sheep (a local breed) with average age of 80 ± 5.5 d, initial body weight (IBW) of 15 ± 1.3 kg were equally divided into three experimental groups ($n = 10$) and fed a diet with 3 (control group, C), 4.5 (medium salt group, MS) or 6 (high salt group, HS) g NaCl/kg dry matter. The diets were formulated according to the recommended values from NRC (the target body weight, 20 kg; the target average daily gain, 100 g/kg; 2007) for all components except NaCl (Table 1). To prepare the experimental diet, appropriate amount of salt was mixed with concentrate and then mixed with *Aneurolepidium chinense*. The diet was fed as a total mixed ration.

The DM was determined by oven drying at 105 °C overnight (AOAC method. 930.15, 1995). Crude protein (CP) was measured by a Kjeldahl nitrogen analysis (AOAC method. 954.01, 1995). Ether extract (EE) was determined using a Soxhlet apparatus (AOAC method. 945.16, 1995). Salt (chlorine as sodium chloride) was determined by AOAC method. 937.09 (AOAC, 1995). Neutral detergent fiber (aNDFom) and acid detergent fiber (ADFom) contents were determined as explained by Van Soest et al. (1991) using heat stable amylase (A3306, Sigma) and sodium sulfite, and expressed without residual ash. Gross energy (GE) content was determined using the values for heat of combustion by an adiabatic bomb calorimeter (Parr Instrument Co., 1970).