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Case Study: Reducing dietary protein decreased the ammonia emitting potential of manure from commercial dairy farms

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ABSTRACT

Animal manure is the largest source of ammonia (NH_3) and is the third-largest source (after soil management and enteric fermentation) of greenhouse gas emissions from animal agriculture. The objective of this study was to decrease manure NH_3 emissions through reducing dietary CP concentration in field conditions on commercial dairy farms. Eleven free- and tie-stall Pennsylvania dairies with gutter-scrape, gravity-flow, or flush manure-management systems participated in the project. Fecal and urine samples were collected from randomly selected cows, and barn-floor and laboratory manure ammonia and greenhouse gas emissions from manure were measured during 8 sampling periods (2 in each: fall 2009, spring 2010, fall 2010, and spring 2011). Crude protein concentration of the high-producing-cow rations was decreased from an average across all farms of 16.5% during the background period (fall 2009–spring 2010; HCP period) to 15.4% during the experimental period (fall 2010–spring 2011; LCP period). Laboratory ammonia emission of reconstituted manure was on average 23% lower for LCP versus HCP manures (291 vs. 378 mg/m^2 per hour; $P < 0.001$). Barn-floor NH_3 emissions were lower for flush versus gutter-scrape and gravity-flow manure-management systems (167 vs. 352 and 426 mg/m^2 per hour, respectively; $P = 0.02$). Milk yield (32.2 vs. 32.5 kg/d) and milk composition were not different between the LCP and HCP periods ($P > 0.12$). Milk urea N concentration tended to be lower ($P = 0.06$) and milk N efficiency was higher ($P = 0.02$) during the LCP versus HCP periods. This on-farm study demonstrated that the NH_3-emitting potential of manure can be reduced by moderately decreasing dietary CP content without affecting milk yield and composition in dairy cows.

Key words: ammonia emission, greenhouse gas, dairy farm, dietary protein

INTRODUCTION

The role of ruminant animals in ammonia (NH_3) and greenhouse gas (**GHG**) emissions has been extensively discussed in the scientific literature and by international organizations (IPCC, 2006; Hristov et al., 2011a, 2013; Miller et al., 2013). Despite the uncertainty of livestock contribution to a specific air pollutant, there is a consensus that efforts should be made to reduce these emissions. Manipulation of animal diets is among the most effective and economically feasible NH_3-mitigation practices, and a clear link between dietary protein concentration or intake and NH_3 emissions from stored manure or following land application has been established (Külling et al., 2001; Hristov et al., 2011a; Lee et al., 2014). There is little evidence, however, that the relationship between dietary CP and manure NH_3 emissions established in controlled experiments is applicable to commercial dairy farms. Whole-farm NH_3 emissions reported by various groups (Ngwabie et al., 2009; Leytem et al., 2011; Lim et al., 2012) cannot separate the effect of diet from the effects of environment, building design, or manure system. Thus, there is a need to demonstrate to dairy producers that a decrease in dietary CP concentration can have a measureable effect on manure NH_3 emissions in field conditions.

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The objective of this on-farm study was to investigate the effect of reducing dietary CP concentration on barn-floor NH_3 emissions on commercial dairy farms in Pennsylvania. Our hypothesis was that, based on data from controlled animal experiments, a reduction in CP of the lactating-cow diet will produce, despite inherent variability associated with on-farm data, a measurable effect on NH_3 emission from the bran floor. Because of the strong and unpredictable effect of environmental factors on manure emissions, we also investigated the effect of dietary CP on the NH_3 (and GHG) emitting potential (**EP**) of manure in controlled conditions. Reductions in ration CP may result in decreased DMI and milk or milk protein yields (Lee et al., 2012a,c), and therefore, this study also monitored milk-yield and milk-composition effects of the dietary interventions implemented on the cooperator farms.

MATERIALS AND METHODS

Cooperator Farms and Diets

Procedures involving animals in this study were reviewed and approved by The Pennsylvania State University Animal Care and Use Committee. Cooperator farms for this study were located in central, southwest, and south-central Pennsylvania. Eleven of the initially selected 12 farms completed the study. One farm was removed from the study because of inconsistent TMR composition. Selection of the farms was based on geographic location (representative of the main dairy regions of the state), manure system, and interest in participating in the study. Ten dairies were Holstein herds, and one had a mixed Holstein–Jersey herd. The facilities were free-stall (5 dairies) or tie-stall (6 dairies) barns. Two dairies had a flush manure system (cleaning was on average twice daily; both dairies were free-stall), 4 dairies had a gutter-scrape system (once-a-day to continuous cleaning; all dairies were tie-stall), 3 dairies had a scrape system (once- or twice-a-day cleaning; all dairies were tie-stall), and 2 dairies had a gravity-flow manure system (manure accumulates under the barn floor and is removed from the facility usually twice a year; both dairies were tie-stall). The dairies used various types of bedding, from wood shavings and sand to peanut hulls and no bedding (water mattresses).

Four farms fed more than one diet, usually 2, based on milk production (high and low producers), and 7 farms fed a single TMR to the lactating cows. The study consisted of 2 phases: background or high-CP phase (**HCP**), during which the lactating cows in the participating dairies were fed their current diets, and experimental or low-CP (**LCP**) phase, during which dietary CP of the high-producing group of cows was reduced by approximately 1%-unit. The decrease in dietary CP from the HCP to the LCP phase was implemented by the consulting nutritionist in collaboration with the study team.

Data Collection, Sampling, and Analyses

The study consisted of 8 sampling and data-collections periods (Table 1): 4 during the HCP phase (2 in fall of 2009 and 2 in spring of 2010) and 4 during the LCP phase (2 in fall of 2010 and 2 in spring of 2011). During these sampling periods, data for TMR, feces, urine, and milk samples and gaseous emissions; ambient and manure temperatures and air humidity; milk production; and feed intake were collected. In collaboration with the farm owner and the consulting nutritionist, CP concentration of the lactating-cow diets was decreased by about 1%-unit (DM basis) from the HCP period to the LCP period of the study. In farms where multiple lactating-cow diets were fed, the CP reduction was implemented only to the high-producing cow ration. Consequently, for the farms feeding multiple diets, TMR, fecal- and urine-composition, and gaseous-emission data presented in this report are for the high-producing cow groups. Milk-production and milk-composition data are for all lactating cows.

Samples of TMR were collected twice during each sampling period

Table 1. Sampling events during the study[1]

Farm	HCP	LCP
A	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
B	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
C	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
D	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
E	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
F	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
G	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
H	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
I	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
J	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011
K	2 sampling events in fall of 2009 and 2 in spring of 2010	2 sampling events in fall of 2010 and 2 in spring of 2011

[1]HCP and LCP represent high- and low-dietary CP periods of the study.