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Nitrogen and phosphorus utilization and excretion by beef cows fed a low quality forage diet supplemented with dried distillers grains with solubles under thermal neutral and prolonged cold conditions

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ABSTRACT

A digestibility and balance study was conducted to evaluate N and P utilization by cows kept under thermal neutral and prolonged cold conditions and fed poor quality forage with and without protein delivered as dried distillers grains with solubles (DDGS). The study also examined forms of N and fractions of P excreted by cows when fed these diets. Twenty-four mature, non-pregnant and non-lactating beef cows (680 ± 57 kg BW) were fed a low-quality forage diet (deficient CP, 60 g CP/kg; 0 g/kg DDGS) and a low-quality forage diet supplemented with 100 g/kg DDGS (sufficient CP, 87 g CP/kg) or 200 g/kg DDGS (excess CP, 116 g CP/kg). The study was conducted from October through February, thus allowing assessment under thermal neutral and prolonged cold conditions. Fecal N excretion (g/d), fecal ammonium N, and urine ammonium N increased linearly ($P < 0.001$) with DDGS supplementation. Fecal ammonium N concentration was 25% greater ($P = 0.002$) in cows exposed to prolonged cold compared to thermal neutral conditions. The proportion of urine urea N (% of total N) increased from 29% to 54% and urine organic N decreased from 66% to 39% with DDGS supplementation. Nitrogen retention was influenced by diet and season ($P < 0.001$) increasing with increasing DDGS supplementation under thermal neutral conditions with minimum change under prolonged cold exposure conditions. Fecal P excretion (g/d), urine P concentration, and urine P excretion increased linearly ($P < 0.001$) with DDGS supplementation. Phosphorus retention decreased with increasing DDGS supplementation in both seasons but the decline was more drastic in cold-exposed cows. Feeding DDGS increases total N and P content of the resulting manure, as well as the forms of N and fractions of P that have the potential to increase field runoff when manure is field-applied. Cows exposed to prolonged cold utilize feed N and P differently from cows in thermal neutral conditions. The N and P requirements of cows exposed to prolonged cold in the northern agricultural regions of North America require further examination to meet animal metabolic requirements without increasing environmental risk.

Abbreviations: DM, dry matter; NE_m, net energy for maintenance; N, nitrogen; P, phosphorus; N:P, nitrogen to phosphorus ratio; N_{Org}, organic N; N_U, urea N; N_{NH4+}, ammonium N; H_2O-P, water-extractable P; $NaHCO_3$-P, sodium bicarbonate-extractable P; P_L, labile P; Res-P, residual P; DDGS, dried distillers grain with solubles; TMR, total mixed ration; MAFRI, Manitoba Agriculture, Food and Rural Initiatives.

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1. Introduction

The common practice by beef producers in the prairie region of Canada (Manitoba, Alberta and Saskatchewan) of keeping beef cows in dry lots during winter is being replaced by practices such as bale grazing and swath grazing, where cattle are kept on pasture for a significant period of time during winter (Jungnitsch et al., 2011; Kelln et al., 2011). Beef cows overwintered in such environments are exposed to extremely cold conditions. This is also the phase in the annual production cycle during which the breeding herd is fed poor quality forages. A 1999 survey (Small and McCaughey, 1999) showed that the predominant feed for overwintering cows in Manitoba was hay and straw. The availability of co-products such as dried distillers grains with solubles (DDGS), a source of protein, energy, and minerals, from Canada's expanding ethanol production industry (Nuez Ortín and Yu, 2009) offers an opportunity for beef producers to improve the quality of diets offered to overwintering cows.

Nutrients in cattle manure can increase soil fertility and increase crop and forage yields. However, application of manure at the wrong rate, time and/or place can lead to excess nutrient accumulation and potential nutrient losses to the environment. Manure deposition onto frozen soil or snow in winter can pose a significant risk in terms of N and P loss to the environment because there is no nutrient uptake by plants when dormant and snowmelt can transport nutrients over frozen soil to surface waterways (Salvano et al., 2009). Although N has traditionally been the nutrient of environmental focus, concern about P loading has increased dramatically in recent years due to its role in eutrophication of surface water bodies (Little et al., 2007).

The N forms and P fractions that are excreted by cattle and their potential to impact environmental sustainability are important. Ammonium N and urea N are generally considered the two forms of N in livestock manure that are most readily available to plants and most susceptible to environmental loss (Powell et al., 2008). Ammonium N can be lost as NH_3 through volatilization (Powell et al., 2008) or as nitrate in water movement or as nitrous oxide (Arriaga et al., 2010). Phosphorus in manure can exist in either inorganic or organic forms, and unlike N, both organic and inorganic P forms can be considered plant-available and labile in water (Meyer et al., 2006). The role of dietary N on forms of N in urine and feces for dairy (Broderick, 2003; Powell et al., 2006; Arriaga et al., 2010) and feedlot (Hao et al., 2009) cattle is well characterized. The same is true for fractions of P excreted by dairy and feedlot cattle (Ebeling et al., 2002; Hao et al., 2009; Geisert et al., 2010).

Despite increasingly restrictive environmental regulations, little attention thus far has been paid to N and P utilization and excretion by cows in overwintering environments. This study was conducted to evaluate N and P utilization by overwintering cows fed poor quality forage with and without protein supplementation in the form of DDGS under thermal neutral and prolonged cold conditions. Secondly, forms of N and fractions of P excreted in feces and urine of cows managed under these conditions were assessed.

2. Materials and methods

This study was conducted in the metabolism unit at the University of Manitoba's Glenlea Research Station (49.8° N, 100° W). The Metabolism Unit has eight raised metabolism stalls equipped with GrowSafe feed bunks (GrowSafe Model 4000E feed monitoring system, GrowSafe Systems Ltd., Airdrie, Alberta), watering bowls and padded floor mats. Manure grates at the end of each stall allow insertion of collection trays for ease of fecal collection. Ambient temperature in the unit was monitored using HOBO temperature loggers (HOBO U12 Stainless Temperature Data Logger, Onset Computer Corporation, Pocasset, MA).

Twenty-four mature, non-pregnant and non-lactating beef cows (680 ± 57 kg BW) were assigned to one of three diets as follows: a low-quality forage diet (deficient CP, 60 g CP/kg; 0 g/kg DDGS), a low-quality forage diet supplemented with 100 g/kg DDGS (sufficient CP, 87 g CP/kg), and a low-quality forage diet supplemented with 200 g/kg DDGS (excess CP, 116 g CP/kg). The diets were designated as deficient, adequate or excess based on protein requirements of 62–88 g CP/kg DM for mature, non-lactating beef cows (680 kg body weight) at 8 and 12 months post-partum (NRC, 1996). The low-quality forage diet was a mixture of chopped grass hay (63 g CP/kg) and oat straw (52 g CP/kg; Table 1). A 50:50 mixture of wheat and corn DDGS containing 378 g CP/kg, DM basis, was used as the protein supplement. The diets were fed as a total mixed ration. Cane molasses (102 g CP/kg, DM basis) was added to minimize DDGS separation from forages.

The study was conducted under thermal neutral conditions in the fall and prolonged cold conditions in winter. Thermal neutral conditions generally range between −15 °C and 28 °C for a mature beef cow (FASS, 2010). Prolonged cold conditions were defined by temperatures below the lower critical temperature (−15 °C) for non-pregnant and non-lactating cows (Young, 1983). Prior to entering the metabolism unit, the cows were exposed to thermal neutral conditions from October 23 to November 22, 2008 and to prolonged cold from January 26 to February 21, 2009, when they were kept in a dry lot. Information regarding the dry lot facility and management are reported in Bernier et al. (2012). Cows were assigned to the same diet for the thermal neutral and cold periods. To ensure cows were in similar physiological condition following the thermal neutral period, the cows were placed into three groups and fed to lose, maintain or gain weight. The diet used for this purpose was a total mixed ration (TMR) containing 760 g/kg corn silage, 220 g/kg oat straw and 9 g/kg DDGS, and limestone. The diet was restricted to 80% of *ad libitum* intake to achieve maximum weight loss. For moderate weight loss, the diet was fed at 90% of *ad libitum* intake and to maintain weight, the diet was fed *ad libitum*. Weight change was monitored every few days and, once the cows reached their pre-test weights, they were fed to maintain body weight.