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Effect of variable water intake as mediated by dietary potassium carbonate supplementation on rumen dynamics in lactating dairy cows

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ABSTRACT

Water is a critical nutrient for dairy cows, with intake varying with environment, production, and diet. However, little work has evaluated the effects of water intake on rumen parameters. Using dietary potassium carbonate (K_2CO_3) as a K supplement to increase water intake, the objective of this study was to evaluate the effect of K_2CO_3 supplementation on water intake and on rumen parameters of lactating dairy cows. Nine ruminally cannulated, late-lactation Holstein cows (207 ± 12 d in milk) were randomly assigned to 1 of 3 treatments in a replicated 3 × 3 Latin square design with 18-d periods. Dietary treatments (on a dry matter basis) were no added K_2CO_3 (baseline dietary K levels of 1.67% dietary K), 0.75% added dietary K, and 1.5% added dietary K. Cows were offered treatment diets for a 14-d adaption period followed by a 4-d collection period. Ruminal total, liquid, and dry matter digesta weights were determined by total rumen evacuations conducted 2 h after feeding on d 4 of the collection period. Rumen fluid samples were collected to determine pH, volatile fatty acids, and NH_3 concentrations, and Co-EDTA was used to determine fractional liquid passage rate. Milk samples were collected twice daily during the collection period. Milk, milk fat, and protein yields showed quadratic responses with greatest yields for the 0.75% added dietary K treatment. Dry matter intake showed a quadratic response with 21.8 kg/d for the 0.75% added dietary K treatment and 20.4 and 20.5 kg/d for control and the 1.5% added dietary K treatment, respectively. Water intake increased linearly with increasing K_2CO_3 supplementation (102.4, 118.4, and 129.3 L/d) as did ruminal fractional liquid passage rate in the earlier hours after feeding (0.118, 0.135, and 0.141 per hour). Total and wet weights of rumen contents declined linearly and dry weight tended to decline linearly as dietary K_2CO_3 increased, suggesting that the increasing water intake and fractional liquid passage rate with increasing K_2CO_3 increased the overall ruminal turnover rate. Ruminal ammonia concentrations declined linearly and pH increased linearly as K supplementation increased. As a molar percentage of total volatile fatty acids, acetate increased linearly as dietary K increased, though propionate declined. Increasing dietary K_2CO_3 and total K in the diets of lactating dairy cows increased water consumption and modified ruminal measures in ways suggesting that both liquid and total ruminal turnover were increased as both water and K intake increased.
Key words: dairy cow, potassium, water intake

INTRODUCTION

Water has long been established as the most essential nutrient for a lactating dairy cow, though it is often the one most overlooked. A typical lactating dairy cow will drink between 75 and 189 L of water daily, but that amount varies depending on several factors, including stage of lactation, environmental conditions, and diet intake and composition (Squires, 1988). Increased water intake has been associated with increased rumen turnover rates and decreased total ruminal VFA concentrations, with an altering of individual ruminal VFA concentrations (Rogers et al., 1979, 1982). West et al. (1987) concluded that increases in water consumption stimulate a greater turnover rate in the rumen. The changes in VFA concentrations were attributed to the fact that with an increase in rumen turnover rate, certain substrates are removed from the rumen before their fermentation occurs or is complete (West et al., 1987). However, little research has looked specifically at the effects of increased water intake on rumen digesta measures such as ruminal liquid passage rates or dry matter of rumen contents.

Few studies have evaluated the relationship between potassium (K) and water intake. Potassium is often considered to be the principal intracellular cation within body tissues and is the third most abundant mineral element found within the body (NRC, 2001). It is well established that K plays a variety of roles within

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the body, including participation in the maintenance of osmotic potential within the cells and maintenance of normal kidney function (NRC, 2001; Harrison et al., 2011). Potassium is also a major component in the concept of DCAD and is part of the DCAD equation [(Na + K) − (S + Cl)] (Tucker et al., 1991). Regarding the effect of K on water intake in dairy cattle, direct relationships between K intake and increased urinary excretion have been reported (Bannink et al., 1999; Nennich et al., 2006), from which one could infer that increased K intake results in greater water consumption. Recently, Appuhamy et al. (2014) reported that drinking water was positively related to dietary ash content independent of DMI, milk yield, and dietary DM content. However, intake of individual minerals was not evaluated in their study. Murphy (1992) developed an equation to predict water intake that included DMI, milk production, Na intake, and weekly minimum temperature, but K intake was not considered. Potassium carbonate (K_2CO_3) has been evaluated as a dietary supplement of K. It has been shown to affect the lactation performance and DMI of dairy cattle (Schneider et al., 1984; West et al. 1987; Harrison et al., 2011), but its influence on water intake has not been reported.

Despite the overall importance of water to dairy cattle and the potential effects on rumen dynamics, little research has been done to evaluate the effect of water intake on rumen digesta measures. Although increasing dietary K supplementation would seem likely to increase water intake, it has not been well characterized in lactating dairy cows. The primary objective of this study was to evaluate the effect of changing water intake on ruminal digesta measures in lactating dairy cows. Supplemental dietary K as K_2CO_3 was used as the approach to increasing water intake, which also allowed evaluation of the effect of K_2CO_3 on water intake.

MATERIALS AND METHODS

Design and Treatments

Five multiparous (210 ± 10 DIM) and 4 primiparous (205 ± 6 DIM) ruminally cannulated, Holstein cows were randomly assigned to a treatment sequence in a replicated 3 × 3 Latin square design with 18-d periods. All experimental procedures were approved by the Purdue Animal Care and Use Committee (#11–112). The 3 periods consisted of a 14-d adaptation period, followed by a 4-d period used for data and sample collection. Treatments included a control diet (**LK**), which included a baseline diet with 1.67% dietary K (DM basis); a diet (**MK**) with supplementation of 0.75% K (2.35% dietary K on a DM basis); and a diet (**HK**) with 1.5% supplemented dietary K (3.08% dietary K on a DM basis). Potassium carbonate (DCAD Plus, Arm and Hammer Animal Nutrition, Princeton, NJ) was used for K supplementation and was substituted for soyhulls (Table 1). All diets were formulated to meet or exceed NRC (2001) requirements by up to 10%. All cows were fed their respective treatment diets throughout each 18-d period.

Table 1. Ingredients of experimental diets[1] for cows fed increasing levels of potassium carbonate

Diet ingredient, % of DM	LK	MK	HK
Corn silage	38.2	38.2	38.2
Alfalfa haylage	14.9	14.9	14.9
Orchardgrass hay	2.8	2.8	2.8
High-moisture corn	16.4	16.4	16.4
Soybean meal	10.8	10.8	10.8
DCAD Plus[2]	0.0	1.6	3.2
Soyhull pellet	3.9	2.3	0.7
Megalac[2]	1.1	1.1	1.1
Supplement[3]	10.4	10.4	10.4
Protein AA blend	5.4	5.4	5.4

[1]LK = baseline diet with 1.67% dietary K; MK = baseline diet with added 0.75% dietary K; HK = baseline diet with added 1.5% dietary K.

[2]Arm and Hammer Animal Nutrition (Princeton, NJ).

[3]Supplement consisted of 38.3% fine-ground corn, 29% dried molasses, 7.3% Ca carbonate, 6.3% Na bicarbonate, 3.8% CaPhosMono, 3.8% NaCl salt, 2.5% Diamond V XP Yeast (Diamond V, Cedar Rapids, IA), 2.3% magnesium oxide, 1.8% urea, 1.8% Ca sulfate, 1.8% Omnigen AF (Prince Agri Products, Quincy, IL), 1.1% GSC TMV, 0.3% niacin (99%), 0.2% vitamin E (20,000), and 0.07% Rumensin 90 (Elanco Animal Health, Greenfield, IN).

Data and Sample Collection

Cows were housed in individual tie stalls in the metabolism unit at the Purdue University Dairy Teaching and Research Center. Stalls consisted of rubber mattresses that were bedded with sawdust and cleaned twice daily. Cows had access to feed ad libitum; orts and feed offered were weighed and recorded for each cow daily and daily DMI calculated. Feed was offered to cows at approximately 0700 h daily using a Calan Data Ranger (American Calan Inc., Northwood, NH). Cows were fed at 110% of expected intake. Water meters (3/4-inch Multi-Jet Water Meter, Master Meter, Fort Worth, TX) were installed on each individual water cup in each tie-stall, and individual cow water intake was recorded each day during the collection period. Ort samples collected daily during the collection period were composited between cows on the same dietary treatments. Individual feed ingredients were collected on d 1 and 4 of the collection period and were composited within period. Drinking-water samples were collected on the first day of every treatment period. Samples were frozen at −20°C until water-quality analysis was conducted.