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Efficacy of oral potassium chloride administration in treating lactating dairy cows with experimentally induced hypokalemia, hypochloremia, and alkalemia

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ABSTRACT

Hypokalemia occurs commonly in lactating dairy cows. The objectives of this study were to determine (1) whether a 24-h oral KCl dose of 0.4 g/kg of body weight (BW) was effective and safe in hypokalemic cattle; (2) whether potassium was best administered as 2 large doses or multiple smaller doses over a 24-h period; and (3) the effect of oral KCl administration on plasma Mg concentration and urine Mg excretion in fasted lactating dairy cattle. Plasma K and Cl concentrations were decreased, and blood pH increased, in 15 lactating Holstein-Friesian cows by administering 2 intramuscular (i.m.) 10-mg injections of isoflupredone acetate 24 h apart followed by 2 i.m. injections of furosemide (1 mg/kg of BW) 8 h apart and by decreasing feed intake. Cows were randomly assigned to 1 of 3 treatment groups with 5 cows/group: untreated control (group C); oral administration of KCl at 0.05 g/kg of BW 8 times at 3-h intervals (group K3); and oral administration of KCl at 0.2 g/kg of BW twice at 12-h intervals (group K12). A 24-h KCl dose rate of 0.4 g/kg of BW increased plasma and milk K concentration and plasma Cl concentration, and corrected the metabolic alkalosis and alkalemia, with no clinically significant difference between 2 large doses (group K12) or multiple small doses (group K3) of KCl over 24 h. Oral KCl administration decreased peripheral fat mobilization in cattle with experimentally induced hypokalemia, as measured by changes in plasma nonesterified fatty acid concentration, and slightly augmented the fasting-induced decrease in plasma Mg concentration. Our findings support recommendations for a 24-h oral KCl dose of 0.4 g/kg of BW for treating moderately hypokalemic cattle. Additional Mg may need to be administered to inappetant lactating dairy cattle being treated with oral KCl to minimize K-induced decreases in magnesium absorption.

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INTRODUCTION

Hypokalemia occurs commonly in lactating dairy cows with left displaced abomasum (**LDA**), right displaced abomasum, abomasal volvulus, abomasal impaction, clinical mastitis, retained placenta, and hepatic lipidosis (Smith et al., 2001; Wittek et al., 2005; Kalaitzakis et al., 2010; Constable et al., 2013). The high prevalence of hypokalemia in sick lactating dairy cows is most likely due to a combination of decreased DMI, alkalemia due to sequestration of chloride in the gastrointestinal tract in cattle with LDA, right displaced abomasum, abomasal volvulus, or decreased abomasal emptying rate, hyperinsulinemia secondary to hyperglycemia, the obligatory loss of potassium in milk (1.4 g of K/L of milk), sympathetic nervous system activation, aldosterone release in response to hypovolemia and the need for sodium retention, and decreased whole-body K stores due to the relatively low muscle mass in dairy cows (Grünberg et al., 2006; Constable et al., 2009, 2013). Whole-body depletion of K may be present in healthy dairy cattle immediately after calving, based on the results of K balance studies (Shalit et al., 1991), studies documenting decreased skeletal muscle K content at calving (Kowalczyk and Mayer, 1972), and decreased urine [K] immediately after calving (Hörügel and Fürll, 1998). Hypokalemia is most commonly defined as serum or plasma [K] <3.9 mEq/L in adult cattle (Radostits et al., 2007), although some studies have used a value <3.9 mEq/L for serum or plasma [K] to define hypokalemia (Constable et al., 1991, 2013).

Oral potassium administration is the method of choice for treating lactating dairy cattle with hypokalemia. Oral administration of KCl appears to provide the optimal salt formulation for treating cattle with hypokalemia in that K is needed in cattle with whole-body K depletion, and chloride is needed in cattle with alkalemia and pH-induced compartmental shift of K to

the intracellular space (Constable et al., 2013). Current treatment recommendations are to administer 30 to 60 g of feed-grade KCl orally twice at a 12-h interval to inappetant dairy cattle with mild to moderate hypokalemia, thereby providing a total 24-h dose of 60 to 120 g of KCl (Constable, 2003). The KCl is administered by use of a balling gun and gelatin boluses or by ororuminal intubation. The treatment recommendation for dairy cattle with severe hypokalemia (<2.5 mEq/L) is 120 g of KCl orally, followed by two 60-g KCl oral treatments at 8-h intervals, for a total 24-h treatment of approximately 240 g of KCl (Sattler et al., 1998; Constable, 2003); this dose is equivalent to a daily KCl dose of 0.4 g/kg of BW for a 600-kg dairy cow. Total daily oral doses of KCl exceeding 0.4 g/kg of BW are not currently recommended except in cattle with profound hypokalemia because they have the potential to result in diarrhea, excessive salivation, muscular tremors of the legs, labored breathing, convulsions, and death (Dennis and Harbaugh, 1948; Peek et al., 2000; NRC, 2001; Constable, 2003).

We were interested in 3 questions related to the treatment of hypokalemia in lactating dairy cattle. The first was to verify whether a 24-h oral KCl dose of 0.4 g/kg of BW was effective and safe. The second was to determine whether KCl was best administered as 2 large doses or multiple smaller doses over a 24-h period. Two large doses over 24 h may be preferable because oral administration of KCl results in a dose-dependent increase in rumen [K] and, consequently, a dose-dependent increase in the number of moles of potassium absorbed per unit time (Scott, 1967). However, a large K dose may activate a gut or hepato-portal sensor that detects K intake and sends a signal to the kidney to increase K excretion in response to increased K ingestion (Greenlee et al., 2009), thereby resulting in less absorbed K being retained. The third issue was to determine the effect of KCl administration on plasma Mg concentration and urine Mg excretion. This was of interest because increasing dietary K intake decreases Mg absorption across the rumen epithelium (Leonhard-Marek et al., 2010) and apparent Mg digestibility (Weiss, 2004). Oral KCl administration therefore has the potential to decrease plasma Mg concentration. A randomized, controlled study in lactating dairy cows with experimentally induced hypokalemia and decreased feed intake was therefore undertaken to explore the 3 issues of interest related to oral KCl treatment. The experimental model was designed to provide a clinically relevant model of hypokalemia, hypochloremia, metabolic alkalosis, alkalemia, decreased feed intake, whole-body K depletion, and mild dehydration in sick lactating dairy cows.

MATERIALS AND METHODS

All methods were approved by the Purdue University Institutional Animal Care and Use Committee.

Animals, Housing, and Feeding

Eighteen pluriparous Holstein-Friesian cows were monitored after parturition and acclimated to a tiestall at the Purdue Dairy Research and Education Center (West Lafayette, IN). All cows were healthy based on the results of routine physical examination and were enrolled into the study at 7 to 14 DIM. Cows were fed a balanced TMR that met the requirements of early lactating cows as recommended by the National Research Council (NRC, 2001). The ration was fed once daily between 0800 and 1000 h and was based on corn silage, alfalfa haylage, and high-moisture corn (typical analysis: CP, 17.3%; ADF, 20.1%; NDF, 30.2%; Ca, 0.97%; P, 0.37%; Mg, 0.34%; K, 1.42% in DM with an energy density of 1.72 Mcal of NE_L/kg of DM). Amounts of TMR fed and refused on a wet weight basis were recorded daily during the study period. Water was available ad libitum throughout the study. Cows were milked twice daily after calving between 0730 and 0900 h and between 1600 and 1930 h in a double-sided herringbone milking parlor. Milk weights were recorded for every milking.

Physical examination and sampling when done on a daily basis occurred between 0800 and 1200 h and before administration of any treatments. Urine samples were obtained daily by perineal stimulation and free catch of a midstream voided sample, except on d 4 when urine samples were collected via a Foley catheter in the bladder. Respiratory rate was determined by visual inspection of thoracic excursions for 30 s. Heart rate was determined by thoracic auscultation for 30 s. Cardiac rhythm was monitored daily, except on d 2, using a base-apex lead system connected to an electrocardiograph (PageWriter Xli, Hewlett-Packard, Boise, ID), which recorded a standard 10-s rhythm strip at 25 mm/s and 1 cm = 1 mV. Cattle were kept in a standing position during recording. Rectal temperature was determined by placing an electronic thermometer into the rectum for at least 30 s. Rumen contraction rate was determined by auscultation of the left dorsal paralumbar fossa for 3 min. Cows were weighed using a calibrated digital large-animal scale immediately after the morning milking on d 1, 4, and 7.

Experimental Method

Cows were administered 2 i.m. 10-mg injections of isoflupredone acetate (9-fluoro-prednisolone acetate;