Research in Veterinary Science 86 (2009) 529–532

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Duration of the effects of anionic salts on the acid–base status in cows fed different anionic salts only once daily

Carl-Christian Gelfert [a,*], Antje Löptien [b], Nicole Montag [b], Rudolf Staufenbiel [b]

[a] Clinical Department for Farm Animals and Herd Health Management, Clinic for Ruminants, 1210 VMU Vienna, Austria
[b] Clinic for Ruminants and Swine, FU Berlin, Germany

ARTICLE INFO

Article history:
Accepted 21 October 2008

Keywords:
Anionic salts
Calcium
Acid–base status
Feeding frequency
Dairy cattle
Blood analysis
Urine analysis

ABSTRACT

Seeing the fact that farm managers in Germany feed anionic salts to transition cows once daily, this study set out to evaluate whether the effects on the acid–base status (ABS) and calcium excretion in urine would persist throughout the entire day beyond this feeding practice. Eleven non-lactating, non-pregnant, Holstein–Friesian-cows with a rumen fistula were administered 2Eq of calcium chloride ($CaCl_2$/five cows) or calcium sulfate ($CaSO_4$/six cows) once daily for a period of 1 week. At day 7, blood and urine samples were taken every 4 h starting at 06:00 a.m. before feeding the anionic salts, and then ending at the same time the next day. Feeding anionic salts to the cows induced metabolic acidosis in both of the groups. The changes tended to be greater in $CaCl_2$-cows. After 12 h, the acidosis lessened and the initial values were reached after 24 h. The $CaCl_2$-cows, however, still showed signs of compensated metabolic acidosis. The results of the present study showed that feeding anionic salts once daily confined the risk of an interrupted effect of the anionic salts on the acid–base status as well as calcium metabolism after 12 h.

Feeding a diet to cows that contains anionic salts in the last weeks before parturition in turn activates calcium metabolism (Goff, 2000). Research that was started in the early 1960s (Ender et al., 1962) revealed that cows in their last weeks of pregnancy can be protected from clinical parturient paresis by feeding chloride salts or sulfate salts, which are now widely used in order to prevent severe hypocalcaemia and parturient paresis in dairy cows around parturition (Goff, 2000).

The monitoring of the use of anionic salts is necessary because cows might refuse consuming the diet due to the inherent bad taste of anionic salts (Oetzel and Barmore, 1993). Furthermore, the failures experienced when utilising this prophylactic method occur because of mistakes in feeding management. Feeding anionic salts is especially rather difficult in smaller and medium sized herds (<500 cows) as there is no special diet that exists for transition cows in the last 3 weeks before parturition. These cows are administered the same diet as the cows that are in early lactation, and the anionic salts must be additionally administered and mixed in by hand. Furthermore, a management decision by the farmer can stipulate feeding to occur once daily. In that case, the entire daily amount of the anionic salts is to be administered in the feed bunk, which will lead to the cows consuming most of the anionic salts within a rather short time (Goff, 2000). Confronted with this feeding technique through routine herd health management, the following study was initiated in order to evaluate whether the consumption of anionic salts once daily would result in a 24 h effect on the acid–base status and calcium excretion in urine. One chloride salt and one sulfate salt were chosen in order to have one strong and one weak anionic salt (Goff et al., 2004).

Recent studies have clearly shown that anionic salts induce a 24 h lasting effect on the acid–base status if the salts are given twice daily (Frömer, 2004; Löffler, 2004; Roche et al., 2007). To the authors' best knowledge, however, no data exists about the effects on anionic salts if they were given only once daily.

Eleven mature, non-lactating, non-pregnant, rumen-fistulated Holstein–Friesian-Crossbreed cows that were between five and 10 years old were housed individually in a tie-stall at the clinic for ruminants and swine at the Free University of Berlin, Germany as described previously (Gelfert et al., 2006, 2007). The cows were administered a diet of hay, concentrate, and lime two times daily at 07:00 a.m. and 02:00 p.m. (Table 1). Either 2Eq $CaCl_2$ (five cows) or 2Eq $CaSO_4$ (six cows) were administered once daily during the morning feeding for a period of 7 days via the rumen cannula. Dehydrated $CaCl_2$ was provided by Sigma–Aldrich Laborchemikalien, Seelze. $CaSO_4$ D10 is a naturally occurring salt with a grain size of 10 μm and is a by-product of the gypsum industry. The dietary cation–anion difference was 0mEq/kg DM after adding anionic salts.

* Corresponding author. Tel.: +43 1 250 77 5215; fax: +43 1 250 77 5290.
E-mail address: c_c_gelfert@yahoo.de (C.-C. Gelfert).

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doi:10.1016/j.rvsc.2008.10.009

Table 1
Composition of the basal diet.

Basal diet	Amount	Concentrate	Amount
Hay (kg)	8		
Concentrates (kg)	2		
Lime (kg)	0.3		
Dietary analysis[a]			
Dry matter (DM)	8.53	DM (%)	88.1
NEL (MJ/kg DM)	4.78	NEL (MJ/kg DM)	6.27
		Crude protein (%/DM)	19.0
		Crude fat (%/DM)	3.0
		Crude fibre (%/DM)	8.6
		Crude ash (%/DM)	6.3
Na (g/kg DM)	0.33	Na (g/kg DM)	3.8
K (g/kg DM)	15.15	K (g/kg DM)	10.9
Cl (g/kg DM)	3.51	Cl (g/kg DM)	5.0
S (g/kg DM)	1.29	S (g/kg DM)	1.2
Ca (g/kg DM)	9.63	Ca (g/kg DM)	7.5
Mg (g/kg DM)	1.81	Mg (g/kg DM)	3.3
P (g/kg DM)	2.45	P (g/kg DM)	6.2
DCAD[b] (meq/kg DM)	234		
DCAD (meq/kg DM) AS included	0		

[a] Blgg Deutschland GmbH, Parchim, Germany.
[b] Dietary cation–anion difference.

This animal experiment was undertaken in accordance with German animal welfare legislation, the Regional Authorities for Employment Protection, Health Protection, and Technical Security of Berlin.

On day 7, blood and urine samples were collected every 4 h starting at 06:00 a.m. before the morning feeding, and then ending at the same time the next day. The last day was selected to ensure that all the cows responded sufficiently to the anionic salts (Husband et al., 2002). Blood and urine samples were also taken at day zero before the first feeding of anionic salts to ensure that the cows were not suffering from any acidosis. Blood from the jugular vein was collected anaerobically into a heparinised 2 ml syringe. Each syringe was capped and placed on ice until its respective analysis. For serum analysis, the blood was transferred into tubes containing kaolin. The blood was allowed to clot and was then centrifuged within 2 h (10 min, 4000 g), in which the serum was transferred into vials and stored at −20 °C until the measurement of the macro minerals. A midstream urine sample was taken by provoking urination by way of the manual stimulation of the vulva. The urine was collected in plastic 100 ml vessels. After measuring the pH, the urine was stored at −20 °C until further analysis.

The base excess (BE), bicarbonate [HCO_3^-], and pH of the whole heparinised blood samples were determined immediately after their sampling (ABL5, Radiometer, Copenhagen, Denmark). The urinary pH was analysed by using a pH-metre (InoLab ph Level 1, WTW, Weilheim, Germany). The net-acid–base-excretion (NABE) was measured via the titration method as described by Kutas (1965) and modified by Lachmann (1981). Under physiological conditions, the NABE is positive with values between 107 and 193 mmol/l (Rossow et al., 1989). An increased reabsorption of [HCO_3^-] because of increased H^+-secretion in the case of acidosis (Bender et al., 2003) is indicative of decreased NABE.

The whole calcium and creatinine concentrations were determined in the samples of blood serum and urine. For the analysis of whole calcium, the samples were diluted to 1:40 and analysed by means of atomic absorption spectrophotometry (AAS PU 9200, Philips, Eindhoven, Netherlands). The creatinine was measured in the serum and urine by using the Jaffé reaction (Hitachi 704 Automatic analyser, Roche, Basel, Switzerland). The urine samples were diluted 1:10 before analysis. The fractional clearance of calcium (FC_{Ca}) was determined according to the following formula:

$$FC_{ca} = U_{ca}/S_{ca} \times S_{Crea}/U_{Crea} \times 100$$

(Lunn and McGuirk, 1990) where U_{Ca} is the urinary calcium concentration, S_{ca} is the serum calcium concentration, S_{crea} is the serum creatinine concentration, and U_{crea} is the urinary creatinine concentration.

Before the statistical analysis, the values of all parameters were tested for a normal distribution ($P > 0.05$) according the Kolmogorow-Smirnow test and all parameters fulfilled this condition. In a first step the values measured at day seven before the feeding were compared to those at day zero before starting the experiment by using a simple ANOVA for both anionic salts-groups separately. Then, the changes in the parameters during the following 24 h were statistically evaluated (SPSS 14.0) by using a repeated measure ANOVA (Litell et al., 1998). Because some parameters differed between the anionic salts before feeding the anionic salts (6 h), the repeated analysis was first calculated by using this time point as a covariate. No significant influence was observed. Therefore, the ANOVA was rerun by using all seven time points. Anionic salts served as the intersubject factor.

The model was

$$Y_{ij} = \mu + hour_i + AS_j + hour_i \times AS_{ij} + \sum_{ij}$$

where μ = mean intercept, $hour_i$ = the effect due to the $hour_i$, AS_j = the effect due to anionic $salt_j$, $hour_i \times AS_j$ = interaction between the hour and anionic salts, and $\sum$ = error associated with each Y_{ij}. The level of significance was fixed at $P = 0.05$.

At day zero before feeding any anionic salts, cows did not show any signs of acidosis in blood or urine (Table 3). The ruminal pH and the activity of the rumen microflora were in normal ranges.

At day seven at 06:00 a.m. before feeding, $CaCl_2$-cows were in a state of compensated acidosis (Pernthaner et al., 1996), and the values differed significantly from day zero ($P < 0.05$). In the $CaSO_4$-cows, no acidosis was observed before the feeding at day seven (Table 3) and no significant differences to day zero were detectable ($P > 0.05$). After feeding and administering anionic salts, the changes of all the parameters indicated strong metabolic acidosis (Table 2). The blood pH, BE, and [HCO_3^-] showed decreased values during the whole observation period in the $CaCl_2$-cows (Table 3). In the $CaSO_4$-cows, the parameters of ABS in blood reacted similar than in the $CaCl_2$-cows, however, the acidosis was weaker and all of the parameters associated with ABS in the blood returned to the values that were similar to those reported at the beginning of the 24 h period, in turn reflecting a return towards alkalosis (Table 3).

The urinary pH reacted similarly to the blood pH, showing decreased values in the $CaCl_2$-group for 24 h. In the $CaSO_4$- group urinary pH was low for 18 h and in normal ranges after 24 h. The NABE differed significantly between the $CaCl_2$-group and the $CaSO_4$- group ($P = 0.037$). In the latter, the course of NABE followed that of the urinary pH, whereas the NABE always remained on a significantly lower level with much smaller changes in the $CaCl_2$-cows. All of the other parameters also tended to be more affected by $CaCl_2$. After 24 h, a compensated acidosis was observed in the $CaCl_2$-cows, for the blood pH reached the physiological ranges, and all of the other parameters were still outside the physiological ranges (Table 3). In the $CaSO_4$-cows, all of the parameters of acid–base status were within the normal ranges after 24 h.

The urinary calcium and FC_{Ca} were higher in the $CaCl_2$-cows ($P < 0.05$) before feeding in the morning (Table 3). During the day, the urinary calcium remained on a stable, elevated level until the next morning in the $CaCl_2$-cows. In the $CaSO_4$-cows, the urinary calcium concentrations were also increased, however, excretion was less after 24 h. The concentrations were always lower than the levels in the $CaCl_2$-cows ($P = 0.061$). FC_{Ca} were higher