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The effect of buffering dairy cow diets with limestone, calcareous marine algae, or sodium bicarbonate on ruminal pH profiles, production responses, and rumen fermentation

C. W. Cruywagen,*[1] S. Taylor,† M. M. Beya,*[2] and T. Calitz*[3]
*Department of Animal Sciences, Stellenbosch University, Stellenbosch, 7600, South Africa
†Celtic Sea Minerals, Cork, Ireland

ABSTRACT

Six ruminally cannulated Holstein cows were used to evaluate the effect of 2 dietary buffers on rumen pH, milk production, milk composition, and rumen fermentation parameters. A high concentrate total mixed ration [35.2% forage dry matter (DM)], formulated to be potentially acidotic, was used to construct 3 dietary treatments in which calcareous marine algae (calcified remains of the sea weed *Lithothamnium calcareum*) was compared with limestone (control) and sodium bicarbonate plus limestone. One basal diet was formulated and the treatment diets contained either 0.4% of dietary DM as Acid Buf, a calcified marine algae product (AB treatment), or 0.8% of dietary DM as sodium bicarbonate and 0.37% as limestone (BC treatment), or 0.35% of dietary DM as limestone [control (CON) treatment]. Cows were randomly allocated to treatments according to a double 3 × 3 Latin square design, with 3 treatments and 3 periods. The total experimental period was 66 d during which each cow received each treatment for a period of 15 d before the data collection period of 7 d. Rumen fluid was collected to determine volatile fatty acids, lactic acid, and ammonia concentrations. Rumen pH was monitored every 10 min for 2 consecutive days using a portable data logging system fitted with in-dwelling electrodes. Milk samples were analyzed for solid and mineral contents. The effect of treatment on acidity was clearly visible, especially from the period from midday to midnight when rumen pH dropped below 5.5 for a longer period of time (13 h) in the CON treatment than in the BC (8.7 h) and AB (4 h) treatments. Daily milk, 4% fat-corrected milk, and energy-corrected milk yields differed among treatments, with AB being the highest, followed by BC and CON. Both buffers increased milk fat content. Treatment had no effect on milk protein content, but protein yield was increased in the AB treatment. Total rumen volatile fatty acids and acetate concentrations were higher and propionate was lower in the AB treatment than in CON. The molar proportion of acetate was higher in AB than in CON, but that of propionate was lower in both buffer treatments than in CON. The acetate:propionate ratio was increased in the AB and BC treatments compared with CON. Lactic acid concentration was higher in the CON treatment than in the buffer treatments. Treatment had no effect on rumen ammonia concentrations. Results indicated that buffer inclusion in high concentrate diets for lactating dairy cows had a positive effect on milk production and milk composition. Calcareous marine algae, at a level of 90 g/cow per day, had a greater effect on rumen pH, milk production and milk composition, and efficiency of feed conversion into milk than sodium bicarbonate at a level of 180 g/cow per day.

Key words: Acid Buf, buffer, rumen metabolism, milk production

INTRODUCTION

To meet the energy demands for lactation and reproduction, animals of improved genetic merit are commonly fed highly digestible diets containing large amounts of readily fermentable carbohydrates (Plaizier et al., 2008). Providing such diets with limited amounts of effective fiber may result in changes in rumen VFA profiles that may increase rumen acidity (Krause and Oetzel, 2006), thus increasing the risk of SARA (Plaizier et al., 2008). Excess rumen acidity may also result in inconsistent DMI, poor feed and fiber utilization and diarrhea, (Allen, 1997; Nocek, 1997), milk fat depression, laminitis (Nocek, 1997), and death (Plaizier et al., 2008).

Although most of the VFA produced in the rumen are absorbed via the rumen wall, more than 30% are neutralized by salivary sodium bicarbonate and phosphate buffers, the flow of which is stimulated by chewing and consequently by the level of dietary effective NDF

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[1]Corresponding author: cwc@sun.ac.za
[2]Current address: OSI Group, Brisbane, Queensland, Australia.
[3]Current address: Tanqua Feeds, Riviersonderend, South Africa.

(Allen, 1997; Beauchemin, 2007). Sodium carbonates have been used as dietary buffers to complement this endogenous supply for high yielding animals on concentrate rich diets since the 1960s (Russell and Chow, 1993). Dietary buffers reduce rumen acidity (Erdman, 1988) and provide a more favorable environment for microbial activity (Harrison et al., 1989). They have been successful in alleviating the symptoms of SARA, and especially milk fat depression (Enemark, 2008).

Sodium bicarbonate has been the most popular dietary buffer (Chalupa et al., 1996). It has been shown to effectively neutralize rumen acidity and stabilize rumen pH (Thomas et al., 1984; Solorzano et al., 1989) and to improve the efficiency of fiber digestion, microbial protein synthesis (Rogers et al., 1982), and OM utilization (Mackie and White, 1990). It could furthermore increase milk fat content and feed intake (Enemark, 2008). However, as a soluble buffer, sodium bicarbonate is short lived in the rumen (Van Soest, 1994) and cannot effectively buffer ongoing production of acids in the rumen.

Acid Buf (also known as Calmin; Celtic Sea Minerals, Cork, Ireland) is the skeletal (calcified) remains of the seaweed *Lithothamnion calcareum*, harvested off the Irish and Icelandic coasts. Calcareous marine algae consists mainly of calcium carbonate that occurs in 3 different calcium structures, viz. calcite (65%), aragonite (23%), and vaterite (12%). Aragonite and vaterite are polymorphs of calcite (Railsback, 2006). Calcium (300 g/kg) is the major mineral of calcareous marine algae, and other minerals include Mg (55 g/kg), K (7 g/kg), Fe (800 mg/kg), P (500 mg/kg), Mn (50 mg/kg), I (30 mg/kg), Cu (10 mg/kg), Zn (10 mg/kg), B (10 mg/kg), Mo (0.2 mg/kg), Se (1.8 mg/kg), and Co (0.1 mg/kg), according to Celtic Sea Minerals (2014). The honeycomb structure of calcareous marine algae results in a slow release of minerals in an acid environment. When Acid Buf was included at 0.3% in a TMR for lactating Holstein cows, Cruywagen et al. (2004) found that it had a positive influence in the rumen and that milk yield, milk fat, 4% FCM, and milk protein content improved. Other than this, information regarding the effect of calcareous marine algae on rumen metabolism and milk production in dairy cows is limited. The objectives of the current study were to compare the effects of limestone, calcareous marine algae, and sodium bicarbonate on production and rumen metabolism parameters in dairy cows fed potentially acidotic diets.

MATERIALS AND METHODS

Animals and Housing

Six multiparous, ruminally cannulated Holstein cows, 129 ± 9.2 (SE) DIM and weighing 732 ± 10.3 (SE) kg, were used in the trial. The cows were kept at the Welgevallen Experimental Farm of the Stellenbosch University, Western Cape Province, South Africa. Cows were housed individually in 6 × 4 m pens in a well-ventilated, semi-open barn with a cement floor. Each cow had access to a sand-bedded sleeping crate, a feeding trough, and fresh water via a ball-valve-controlled water bowl. The trial protocol was approved by the Stellenbosch University's Animal Ethics Committee (reference: 2005B03001).

Experimental Design and Treatments

Cows were randomly assigned to treatments according to a double 3 × 3 Latin square design with 3 treatments and 3 periods. All cows received all 3 treatments during the course of the trial. The trial duration was 66 d. Each period (22 d) consisted of a 15-d adaptation period, followed by a 7-d data collection period.

All 3 treatments had the same basal diet, which was formulated to be potentially acidotic (Table 1). The differences between treatments were attributed to the inclusion of different buffers. The buffers used in this trial included limestone, calcareous marine algae (in the form of Acid Buf, also known as Calmin), and sodium bicarbonate. Experimental diets were in the form of TMR and were mixed by Nova Feeds (Malmesbury, Western Cape Province, South Africa). Diet formulation was done with CPM Dairy, version 3 (Cornell University, Ithaca, NY; University of Pennsylvania School of Veterinary Medicine, Kennett Square, PA; The William H. Miner Agricultural Research Institute, Chazy, NY; and The University of Maryland, College Park, MD), using the chemical composition of the ingredients as determined via NIR by Nova Feeds. After mixing each TMR, samples were taken and analyzed immediately for NDF and CP via NIR at the Nova Feeds laboratory, to confirm mixing efficiency. The treatment diets contained either 3.5 g of limestone/kg of DM (**CON**), replaced by 4 g of Acid Buf/kg of DM (**AB**), or by 3.7 g of limestone/kg plus 8 g of sodium bicarbonate/kg of DM (**BC**). Treatments were formulated assuming a DMI of 23 kg/d; thus, the marine algae product was included at a level to ensure a daily intake of 90 g/cow, whereas the sodium bicarbonate was included at a level to ensure a daily intake of 180 g/cow. Cows were fed twice daily at 0700 h (40% of the daily allowance) and at 1600 h (60% of the daily allowance) at a level of approximately 5% in excess of appetite.

Data Collection and Chemical Analyses

Feed intake was recorded daily during each 7-d data collection period by recording the amount of feed sup-