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Intake, milk production, ruminal, and feed efficiency responses to dietary cation-anion difference by lactating dairy cows

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ABSTRACT

Previous meta-analyses of the effects of dietary cation anion difference (DCAD; mEq/kg; Na + K − Cl − S) in lactating dairy cow diets used studies conducted after the development of the DCAD concept. Dietary buffers, such as $NaHCO_3$ and K_2CO_3, increase DCAD and have been used in lactating dairy cow diets for several decades. However, most published studies on buffer feeding were conducted before the development of the DCAD concept. Our objective was to determine the intake, milk production, ruminal, and feed efficiency responses to DCAD using previous studies with dietary buffer addition and more recent studies that focused on DCAD as dietary treatments. The database consisted of 43 articles that were published between 1965 and 2011. The studies included 196 dietary treatments and 89 treatment comparisons with a range in DCAD from −68 to 811 mEq/kg of diet DM, with the vast majority between 0 and 500 mEq/kg of diet DM. For studies that lacked analyses of one or more of the dietary strong ions (Na, K, Cl, or S), ion percentages were estimated from ingredient composition using the 2001 dairy National Research Council software. Two basic models were used to evaluate DCAD responses using the NLMIXED procedure in SAS 9.2 (SAS Institute Inc., Cary, NC): (1) a simple linear model, $Y = A + B \times (DCAD)$, where A = intercept and B = the increment (slope) in performance per unit DCAD (mEq/kg of diet DM); and (2) a nonlinear model, $Y = A + M[1 - e^{(K \times DCAD)}]$, where M = maximal increment in performance from DCAD and K = the rate constant. In both models, study was designated as the random effect. The DCAD effects best described by the linear model included milk fat percent, fat yield, ruminal pH, NDF digestibility, and feed efficiency [3.5% fat-corrected milk (FCM; kg)/dry matter intake (DMI; kg)] where a 100 mEq/kg increase in DCAD resulted in respective increases of 0.10%, 36 g/d, 0.032 pH units, 1.5% NDF digestibility, and 0.013 FCM/DMI units. The DMI, milk yield, and 3.5% FCM were best described by the nonlinear model where the maximal responses were 1.92, 1.11, and 4.82 kg/d, respectively. The expected increments in DMI, milk production, and 3.5% FCM by increasing DCAD from 0 to 500 mEq/kg were 1.7, 1.2, and 3.4 kg/cow per day, respectively. The results of this meta-analysis suggest that DCAD has significant effects on intake, milk production and composition, digestion, and feed efficiency in lactating dairy cows.
Key words: DCAD, feed efficiency, meta-analysis, dairy cows

INTRODUCTION

The original manipulation of DCAD in dairy cow diets was to combat milk fever in periparturient cows (Block, 1984; Delaquis and Block, 1995). More recent research has been focused on the productivity and intake responses to DCAD (Hu and Murphy, 2004; Roche et al., 2005; Harrison et al., 2012; Iwaniuk et al., 2015). Several studies suggested that increasing the DCAD concentration can increase milk yield, milk fat percentage, and optimize DMI in the lactating cow (Tucker et al., 1988b; Hu and Murphy, 2004; Wildman et al., 2007b,c; Apper-Bossard et al., 2010).

Studies with dietary buffers, such as $NaHCO_3$ and K_2CO_3, were reported in earlier literature (1960–1990). Buffers were shown to increase DMI, milk production, and feed efficiency, especially in low-forage, high-starch diets (Erdman, 1988). The addition of dietary buffers in the ration of lactating dairy cows undoubtedly altered the DCAD concentration; however, these data were published before the emergence of the DCAD concept and thus have not been included in previous meta-analyses of DCAD effects on dairy cow performance (Hu and Murphy, 2004). Further, many of these studies lacked complete chemical analysis of Na, K, Cl, and S to calculate DCAD using the most common DCAD equation (Na + K − Cl − S). Although the DCAD effects were not originally reported or discussed in the earlier buffer literature, the data reported has value in that it could be potentially used in a retrospective

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(meta) analysis to determine the effects of DCAD concentration and source of strong ion (Na vs. K) on dairy cow performance.

We hypothesized that the addition of data from the dietary buffer literature could be used to enhance our understanding of dairy cow responses to altered DCAD concentrations. Therefore, the objective of our study was to combine earlier buffer feeding literature in lactating dairy cows with more recent studies on DCAD effects to build surface response equations that relate DCAD and dietary strong ion effects (Na and K) on DMI, milk production, milk composition, ruminal characteristics, digestibility, and feed efficiency (**FE**).

MATERIALS AND METHODS

Data Collection

Results from 63 published journal articles involving the use of buffers in the diets of lactating dairy cows were reviewed for inclusion. Journal articles were selected from 4 primary journals: *Journal of Dairy Science*, *Canadian Journal of Animal Science*, *Journal of Animal Science*, and the *Journal of Animal Production*. Each specific journal article was selected from the reference list of a review article that discussed the effects of dietary buffers (Erdman, 1988).

For a study to be included, treatment means for DMI, milk production, and milk fat concentration had to be reported or be able to be calculated such that FE could be calculated. Feed efficiency was defined as 3.5% FCM per unit of DMI. The most common reason for the rejection of a study was the lack of treatment DMI or lack of milk fat concentration required to calculate 3.5% FCM such that FE could be calculated. In many instances, dietary Na, K, Cl, or, most frequently, S were not reported. In this case, dietary ingredient information was used to estimate the missing strong ion. Thus, it was essential that specific ingredient information be included so missing strong ion could be estimated using the diet evaluation software in the 2001 Dairy NRC (NRC, 2001). Journal articles were also rejected from the data set if diet information was unclear. For example, some papers did not provide the list of ingredients in a vitamin-mineral premix; therefore, it was unknown if specific DCAD-altering ingredients, such as potassium carbonate or sodium bicarbonate, were present in the vitamin-mineral mix. Some experiments reported ingredients that were not included in the Dairy NRC software and composition information was not available from published feed labels. After removing papers with insufficient animal performance information, feed ingredient, or ingredient composition data, 43 papers involving 89 treatment mean comparisons were used to compile the data set. A summary of the literature studies used in this meta-analysis are shown in Table 1.

Data Assembly

Several measurements, when available, were collected from each journal article to compile the data set. Data were collected from 4 general categories: (1) diet composition, including dietary CP, ADF, NDF, Na, K, Cl, S, Ca, Mg, P, and reported DCAD, were either collected or calculated using the Dairy NRC Software; (2) intake and milk production, including daily milk production and fat concentration and DMI, were collected along with milk protein, lactose, and TS concentrations, when available; (3) digestibility of DM, ADF, NDF, and starch were also collected when reported; and (4) mean ruminal pH along with mean ruminal acetate, propionate, butyrate molar percentages, and total VFA (mEq/L) were entered when reported. The number of observations, mean, standard deviation, and the minimum and maximum values each variable are presented in Table 2.

Missing Data Points

One of the major problems associated with data set assembly was the lack of measured concentrations for the minerals Na, K, Cl, or S. If one of dietary strong ion values was missing, the DCAD concentration (Na + K – Cl – S) of that particular diet could not be calculated. Because these experiments were conducted before the emergence of the DCAD concept, several papers did not report one or more of the strong ion values. To overcome this obstacle, a preliminary study was conducted to determine whether the Dairy NRC ration evaluation software could be used to estimate missing dietary ion concentrations. Journal articles which measured the 4 dietary (Na, K, Cl, and S) ion concentrations were used as test articles. The experimental dietary ingredient information for each treatment was extracted from each article and entered into the Dairy NRC ration evaluation software that was used to estimate the mineral concentrations based on either the software estimates or when the reported value was measured for each feed ingredient. A strong correlation was observed between the estimated ion concentrations from by the NRC software and the measured ion concentrations reported in each paper, as illustrated in Figure 1. The respective coefficient of determination (R^2) and root mean predicted standard error (RMPSE) of the estimate for Na, K, Cl, and S were 0.88, 0.84, 0.81, and 0.47 and 0.06, 0.21, 0.17, and 0.06, respectively. Where DCAD concentrations were reported in a study, NRC software was used estimated concentration of each mineral and