Mineral Balances on Dairy Farms - Effect of Trace Minerals on the Environment

Alejandro R. Castillo, Ph.D.
Farm Advisor – Dairy Science
UC Cooperative Extension, Merced County, CA

INTRODUCTION

In the past 30 yr, one of the strategies to supply dietary minerals for dairy animals was to cover a high proportion (50 % or more) of dairy animal requirements with a mineral mix composition with minimal or, in some cases, no consideration of mineral content in the other dietary ingredients, i.e. forages, grains, and byproducts. In some cases, data from NRC and mineral chemical analysis (mainly macro minerals) of the different dietary ingredients were also used to adjust mineral contents in dairy diets. The bioavailability of minerals of common feeds is not well characterized, and is affected by: intake level, feed type, variations of the same feed, and interactions between mineral, soil fertilization, method of analysis, etc. (NRC, 2001, 2005). One of the objectives of overfeeding minerals was to avoid deficiencies for high genetic merit dairy cows. This feeding strategy did have an excellent response in terms of milk yield per cow, but it was negative from an environmental point of view when these nutrients were excreted and applied to the soil.

In California, Water Quality Regulations based on Waste Discharge Requirements (**WDR**) are affecting all dairy producers (CRWQCB, 2007). The WDR have 2 main objectives: (1) Waste Management Plan (**WMP**) and (2) Nutrient Management Plan (**NMP**). According to the WMP requirements for dairy farms, producers must be prepared with sufficient storage capacity to contain all the manure produced on their dairy to avoid illegal discharges on-site or off-site. They must also be prepared to apply manure according to a NMP based on the chemical composition of their manure and soil, as well as crop requirements. Today, dairy producers are dealing with nitrogen balances. But, more nutrients (minerals) might be included in the near future. The NRC (2005) identified 10 minerals with potential effects on crop yields or the environment (Cd, Cu, Fe, Hg, P, K, Na, Se, S, and Zn), where P is the main concern.

To help dairy producers comply with future environmental regulations and analyze possible solutions, it is necessary to evaluate where we are in terms of mineral content in dairy diets and analyze different ways to predict mineral excretion in lactating dairy cows, including possible environmental impacts.

The aim of this work is to present results from 2 surveys carried out in Merced County, CA on 90 dairy farms to obtain information on: mineral contents and balances in dairy diets, and also considering the possible relationships among trace mineral excretion on the environment, particularly on the nitrogen cycle (Castillo et al., 2000, 2007, 2009 a,b, 2010; Castillo, 2009).

EFFICIENCY OF NITROGEN UTILIZATION

When analyzing animal nutrition and environmental impact it is necessary to consider possible interrelationships between nutrients. The dietary nitrogen characterization should be considered as the first step. The dietary efficiency of nitrogen utilization and estimations of nitrogen excretion are important not only to improve lactation performance (milk yield/cow, animal health, and reproduction), but also, because of the possible interrelationships between nitrogen with other minerals in the manure and soil.

The nitrogen utilization efficiency as the proportion of nitrogen from the diet harvested in the milk in lactating dairy animals was estimated as about 0.28 (Castillo et al., 2000). In California, dietary efficiency of nitrogen utilization was estimated at 0.26 ± 0.03 (n=50 dairies), and ranged from 0.20 to 0.34 (Castillo et al., 2005). More recently, a second survey was carried out in Merced County, CA a mean efficiency of nitrogen utilization of 0.24 ± 0.04, range 0.15 to 0.33, was obtained on 40 dairies. In both surveys a high correlation between dietary efficiency of nitrogen utilization and feed conversion was observed. For optimal efficiency of nitrogen utilization (30%), a feed conversion of 1.6-1.7 lb milk/lb DMI is expected. These results combine 2 important objectives for dairy producers, reducing manure production and improving economical efficiency of the dairy systems, or producing more milk with the same amount of feed.

DIETARY MINERAL CONTENT AND BALANCE IN DAIRY DIETS

Some results of the surveys carried out in Merced County, CA on mineral contents in the dairy diets are:

- Minerals considered a concern because of their potential effect on crop yields and the environment (NRC, 2005) were 120 % over the requirements on more than 60 % of the dairies. Particularly, Cu, Se, and Zn were 120 % over the NRC requirements in 48, 78, and 66 % of the dairies, and 200 % over in 18, 5, and 18 % of the dairies, respectively.
- Two trace minerals (Fe and Mn) were 200 % over NRC requirements in all dairies evaluated in this study.
- The Maximum Tolerable Levels (NRC, 2005) for K, S, Fe, were exceeded on 5, 47 and 15 % of the dairies respectively.
- Concentration of Ca, P, Na, S, and Cu in milk was different for high (mean 36 kg [80 lb] milk/cow/d) compared to low (mean 27 kg [60 lb] milk/cow/d) yielding dairy cows.

Feeding minerals according to NRC requirements maximized Mineral Milk Gross Utilization Efficiency (**GUE** = milk/intake). Dietary mineral content (total mixed rations and water minerals) were highly correlated with percentages of minerals harvested in milk (GUE) and with the mineral balances (total intake – total milk output). These high linear correlations ($R^2 \geq 0.80$) among dietary mineral contents and mineral balances (total intake – total milk output), indicates that it could be possible to predict mineral excretion in lactating dairy cows through mathematical models based on mineral content in the dairy diets.

It is recommended to develop a mineral content data base of the feeds utilized on each dairy, including the drinking water (with > 500mg TS/L), forages, the most commonly purchased concentrate feeds, and byproducts. In a few years, each dairy would have information to provide correct mineral balances and to control mineral supplements strictly according to the animal's requirements. This will improve production efficiency, reduce feed cost, reduce manure production, and help dairy producers comply with environmental regulations.

TRACE MINERAL EXCRETION AND MANURE GREEN HOUSE GASES (GHG) AIR EMISSIONS

The normal bioavailability of trace minerals in dairy diets is very low. A high proportion of dietary trace minerals will be excreted through the feces. The effect of these minerals in the manure on GHG air emissions is not very well studied, particularly on manure from dairy diets and under different management conditions and sources of minerals. Recent studies indicate that some trace minerals may play an important role in the nitrogen cycle.

Richardson et al. (2009) analyzed the mitigation of N_2O by enhancing the transformation of NO_3^- to N_2, and describes the enzymes required to sequentially reduce NO_3^- ion to N_2 in the nitrogen cycle. Each enzyme uses a redox active metal cofactor, such as molybdenum for NO_3^- reduction, iron or copper for NO_2^- reduction, iron for NO reduction, and copper for N_2O reduction.

The relationship between trace mineral nutrition of dairy animals and its possible effects on the nitrogen cycle and GHG air emissions in manure and soil open new possibilities for dairy cattle nutrition. When feeding cows, we are also *feeding* manure, which has an important impact on our environment and should be managed under controlled conditions. Dairy diets should be adjusted according to the animal's requirements to maximize animal performance, and probably in the future, some nutrients (minerals) should be reduced and /or added in the diets to be excreted in the manure, and improve the efficiency of some specific chemical reactions to mitigate environmental impacts. According to Richardson et al. (2009), better understandings of the factors that influence the nitrogen denitrifying process (trace minerals, bacteria, enzymes, soil quality, etc.) require more research.

FINAL CONSIDERATIONS

Feed management on dairy farms should be planned to maximize the dietary efficiency of nutrient utilization, where nitrogen should be considered as the first step. This will result in better feed conversion or more money per unit of feed intake, and less manure to comply with environmental regulations.

Dairy diets affect mineral content in the manure. Trace mineral excretion can be predicted through the mineral content in the diets. But, more research is needed to estimate the importance of some trace minerals in the manure and soil on the nitrogen cycle.

Chemical analyses of the different dietary ingredients are needed to control nitrogen utilization efficiency and mineral excretion. A data base with nutrient contents (including macro and trace minerals) of different forage crops and concentrate feeds on each dairy farm will be necessary to maximize animal performance; to totally control dairy diets, nutrient excretion, and manure chemical composition; and to comply with actual and future air and water quality regulations mitigating environmental problems.

LITERATURE CITED

California Regional Water Quality Control Board (CRWQCB). 2007. Waste Discharge Requirements General Order for Existing Milking Cow Dairies. Order No R5-2007-0035. May 2007. 125p

Castillo, A.R., E. Kebreab, D.E. Beever, and J. France. 2000. A review of efficiency of nitrogen utilization in dairy cows and its relationship with the environmental pollution. J. Anim. & Feed Sci. 9:1-32.

Castillo, A.R., J.E.P. Santos, and J.H. Kirk. 2005. Feed conversion and efficiency of NPK utilization in lactating dairy cows. J. Dairy Sci. 88 (Suppl. 1): Abstract 252.

Castillo, A.R., J.E.P. Santos, and T.J. Tabone. 2007. Estimation of mineral balances in dairy herds including minerals in the drinking water. Calif. Agric. 61(2):90-95.

Castillo, A.R. 2009. Whole-farm nutrient balances are an important tool for California dairy farms. Calif. Agric. 63(3):149-151.

Castillo, A.R., N. St-Pierre, and N. Silva del Rio. 2009a. Mineral balances in California dairy farms. J. Dairy Sci. 92 (Suppl. 1): Abstract 724.

Castillo, A.R., J. Silva del Rio, and N. St-Pierre. 2009b. Total mixed ration mineral contents in California dairy farms. J. Dairy Sci. 92 (Suppl. 1): Abstract W293.

Castillo, A.R. 2010. Effect of dairy diets on manure chemical composition. *In:* 2010 Conf. Proc. Am. Soc. Agron., California Chapter. Session V Dairy Issues. page 88-90.

National Research Council (NRC). 2001. Nutrient Requirements of Dairy Cattle. 7th Revised Edition. Natl. Acad. Press. Washington, D.C.

National Research Council (NRC). 2005. Mineral Tolerance of Animals: Second Revised Edition. Natl. Acad. Press. Washington, D.C.

Richardson, D., H. N. Felgate, A. Watmough, Thomson, and E. Baggs. 2009. Mitigating release of the potent greenhouse gas N_2O from the nitrogen cycle – could enzymic regulation hold the key? Trends in Biotech. 27:388-394.