Mineral and Vitamin Supplementation to Dairy Cows Under Different Situations

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Summary

The new NASEM (2021) is an excellent starting point when formulating diets for dairy cows; however, adjustments to mineral and vitamin recommendations are often needed. In most situations and for most minerals and vitamins, nutritionists should formulate diets that exceed the needs of the average cow in the pen. Based on expected variation, a safety factor of about 20% (i.e., NASEM x 1.2) is probably adequate in normal situations. Vitamin A supplementation may need to be increased when high starch diets or high straw diets are fed and reduced when cows are grazing good pasture. Vitamin D supplementation can be reduced when cows are exposed to direct, intense sunlight. Increased supply of magnesium, copper, and perhaps manganese and zinc is often warranted because of reduced absorption caused by potassium (for magnesium) and sulfur (for trace minerals) antagonism. Feeding hydroxy or organic trace minerals may not reduce the amount of mineral needed but may have positive effects on health and production when they replace sulfate trace minerals.

Introduction

Cows need to absorb adequate, but not excessive amounts of minerals and vitamins to maintain good health and obtain high milk yields. The amounts of minerals and vitamins a cow needs to consume depends on the requirement for absorbed mineral and vitamins, the absorbability of the nutrients, and environmental conditions. Absorbed requirements depend on body weight, dry matter intake (DMI), milk yield, stage of gestation, and rate of growth. Absorbed requirements are generally positively correlated with all those factors. Some of these baseline requirements are affected by environmental conditions such as heat stress but these effects are poorly quantified. The amount of mineral or vitamin needed in the diet is calculated as the absorbed requirement divided by the absorption coefficient (AC). Absorption depends on the source of mineral (i.e., the specific feedstuff), concentrations of other minerals and vitamins in the diet and water, and concentrations of some macronutrients such as fiber and starch. Baseline requirements and AC for minerals and vitamins are from NASEM (2021); this paper will discuss situational adjustments to those requirements and AC.

Vitamins

We have little quantitative data on vitamins requirements, and essentially no information on vitamin absorption by cows. In addition, nutritionists rarely, if ever obtain assayed concentrations of vitamins in feedstuff. Therefore, NASEM recommendations are based on supplemental vitamins without considering absorption. For most situations, those recommendations are adequate, but nutritionists should include a safety factor to account for

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normal biological variation in supply and requirements. Based on data from laboratory animals and humans, a safety factor of about 20% should be adequate. In other words, for most situations feeding 1.2X NASEM recommendations should be adequate.

Supplementation of vitamins A, D and E, should be modified in certain situations. NASEM vitamin recommendations assume typical supplies of basal vitamins. Diets that contain more fresh forage provide more B-carotene (vitamin A precursor) and more tocopherol (vitamin E) than typical should require less supplemental vitamins A and E. Conversely, diets that contain substantial amounts of bleached hay or straw provide less basal vitamins A and E. Supplemental vitamin A is destroyed in the rumen and destruction increases as dietary starch increases. NASEM assumes cows are fed diets with about 25% starch; therefore, additional supplementation is needed with higher starch diets. Lastly, cows with direct exposure to sunshine can synthesize substantial amounts of vitamin D and will require less supplementation.

Suggested adjustments to NASEM vitamins A, D, and E

- 30-40% of diet DM is pasture: -500 IU/d of vitamin E (this adjustment is included in NASEM software)
- 30 to 40% of diet DM is pasture: -50,000 IU/d of vitamin A
- Majority of forage is hay rather than silage: +5000 IU of vitamin A/d
- ~8 lbs of straw in prefresh diet: +15,000 IU of vitamin A/d
- Diet starch >25% of DM: +2000 IU of vitamin A/d per percentage unit of starch >25%
- Cows have 2 to 3 hours of exposure to direct intense sunlight: -20,000 IU of vitamin D/day (intense sunlight probably only occurs in late spring, summer, and early fall)

Choline (rumen-protected), biotin, niacin, and B-carotene are vitamins that can have positive effects on cow health and milk production, but NASEM did not establish recommendations. The committee considered those effects as responses rather than requirements. In other words, similar responses can occur without supplementing those vitamins. Rumen protected choline (~15 g/d of choline) usually increases milk yield in early lactation and can reduce ketosis and fatty liver. Biotin (20 mg/d) usually increases milk production and improves hoof health. Niacin, at high enough inclusion rates (12 g/d) has increased milk yields but responses are not as consistent as those from biotin and choline. B-carotene can improve immune function and reproductive efficiency.

Minerals

NASEM mineral requirements are for total, not supplemental, mineral intake which means for some minerals no supplementation is needed. As discussed above, for most minerals, total dietary supply should be about 1.2 times NASEM requirements. Iodine (excess I in milk), phosphorus (normal recycling and high confidence in the equations), selenium (US FDA regulation) and sulfur (modest excess can cause significant problems) should be fed at NASEM recommendations without a safety factor. In addition to the standard safety factor, increased supplementation may be needed for some minerals in some situations. If the mineral is not discussed, NASEM recommendations with safety factor should be adequate.

Magnesium

Magnesium absorption is affected by numerous commonly occurring conditions which justify adjusting its safety factor.

- Dietary K has a strong negative effect on Mg absorption and the antagonism starts at very low K concentrations (Figure 1). The NASEM software includes an adjustment of the AC for Mg as dietary K changes but because of the prediction error associated with the equations, users may want to consider reducing the AC more than the model does.
- Long chain fatty acids can reduce Mg absorption. Diets with supplemental fat may need 10 to 20% more Mg.
- Availability of Mg from magnesium oxide is variable depending on particle size and manufacturing conditions. Some MgO may provide almost no absorbable Mg. We lack laboratory methods that accurately quantify these differences. Nutritionists should buy MgO from known, reputable sources. This uncertainty increases the risk of inadequate dietary Mg. The average AC for Mg from MgO is 0.23, you may want to reduce this by about 30% (i.e., AC of about 0.16)
- Feeding monensin at standard rates **increases** absorption of Mg by about 30% when MgO is the source of supplemental Mg (Tebbe et al., 2018). If you are feeding monensin, reducing the AC for MgO is probably not necessary (i.e., monensin is the safety factor)

Electrolytes and DCAD

Absorption of the electrolytes (sodium, potassium, chloride is high and consistent; therefore, uncertainty in supply does not justify increasing dietary concentrations above NASEM plus a 20% safety factor. However, cows often respond positively to feeding more than requirement. The NASEM committee considered these as responses rather than requirements (e.g., cows might produce more milk fat with increasing potassium, but increased potassium is not required to obtain additional milk fat). The response to additional electrolytes can be caused by the specific element or more often by a change in DCAD caused by changing concentrations of the electrolytes or sulfur. Feeding excess potassium or sodium increases water intake and urine output. This may be beneficial in hot conditions by increasing heat loss from the cow. If requirements for sodium, potassium, sulfur, and chloride are met, the diet will have a DCAD of about 175 mEq/kg. Increasing dietary DCAD by feeding additional potassium or sodium without increased chloride or sulfur can increase DM intake, milk yield, fat yield, fiber digestibility and dry matter digestibility. Maximum responses typically occur around 380 mEq/kg but the optimal concentration depends on cost of the supplements and the price of milk components and feed. Decreasing DCAD by feeding excess chloride or sulfur reduces risk of hypocalcemia after calving. Improved calcium metabolism usually requires DCAD less than about -100 mEq/kg.

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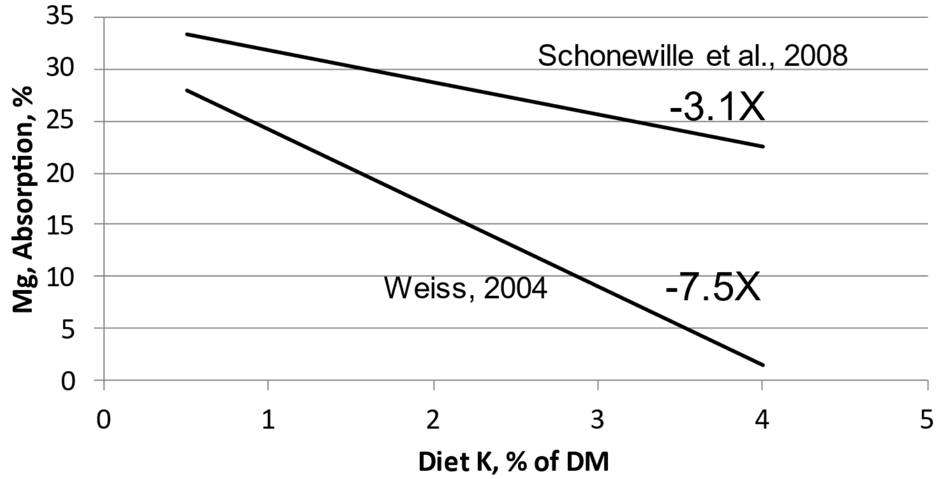

Figure 1. Relationship between dietary potassium concentration and magnesium absorption by dairy cows from two different studies. Slopes are shown in the figure. Data from (Schonewille et al., 2008) was derived mainly from dry cows consuming an average of 0.45% Mg and data from (Weiss, 2004) was derived mainly from lactating cows fed diets that averaged 0.25% Mg. The main reason potassium has a less negative effect on Mg absorption in the Schonewille et al study was because feeding extra Mg reduces the antagonism.

Trace minerals

Absorption of many trace minerals can be reduced by many 'real world' conditions. Excess dietary sulfur (including sulfur in drinking water) reduces the absorption of copper, manganese, and zinc although the effects have not been quantified with great accuracy. For copper, and perhaps the other metals, absorption can be reduced with as little as 0.3% sulfur in the diet. Based on limited data, absorption of copper in diets with about 0.2 to 0.25% sulfur averages 5% but with 0.3% sulfur it may drop to 4.2% and with 0.4% S it may be only 3.5%. Molybdenum interacts with sulfur to further reduce copper absorption. For example, with 4 mg/kg Mo, copper absorption may decrease those AC by another 25% (NASEM, 2021). Although data are lacking with dairy cows, apparent absorption of Mn was reduced about 65% when growing steers were fed diets with 0.7% S compared with feeding a 0.24% S diet (Pogge et al., 2014). A similar reduction in apparent zinc absorption was found. This suggests that antagonism of Mn and Zn by S may follow a similar pattern as that for Cu.

Source of trace mineral can affect absorption but because measuring true absorption of trace minerals is exceedingly difficult almost no direct absorption data are available. Based on relative availability assays, high quality organic copper and hydroxy copper chloride are more available than copper sulfate especially in the presence of antagonists. Selenium from selenized yeast is probably about 50% more absorbable than selenium from selenite but because of the way selenium methionine is used in the body, 'bioactivity' is probably only about 20% higher (Weiss, 2003). Some forms of organic zinc are more absorbable in a cell culture model than is zinc from zinc sulfate (Sauer et al., 2017) but whether this occurs in cows is not known. Apparent absorption of Mn by dairy cows did not differ between manganese sulfate and organic manganese (Weiss and Socha, 2005). Although data showing organic or hydroxy trace minerals are actually more absorbable than sulfate trace minerals is very limited, clinical responses such as milk production, digestibility, immune function, and health are often positive when specialty trace minerals replace some of the sulfate minerals (sampling of papers: (Rabiee et al., 2010, Osorio et al., 2016, Faulkner and Weiss, 2017).

Some data suggests that at least some of the responses observed when specialty trace minerals are fed is not caused by improved absorption but rather by effects on the ruminal and intestinal microbiome ((Faulkner et al., 2017). If this is the case, then AC would not change when using specialty trace minerals, rather various positive responses would be expected when specialty trace minerals replaced sulfate minerals at similar dietary concentrations (i.e., NASEM x 1.2). Experiments quantifying actual, not relative, absorption are needed to confirm this.

Chromium is a required nutrient but similar to biotin and choline, the NASEM committee did not establish a requirement. This was because a clinical chromium deficiency has never been reported (indicating basal chromium supply may be adequate). Although no deficiencies have been reported, supplementing chromium (at about 0.5 mg/kg diet) often increases milk production in early lactation.

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