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Calf Note #244 – Mineral and Vitamin Requirements for Calves, Part 1

Introduction

The NASEM committee evaluated data published since the 2001 NRC publication as well as requirements published by others (e.g., 2016 Nutrient Requirements for Beef Cattle). They took a more quantitative approach and determined net mineral requirements for maintenance and productive functions such as growth, pregnancy, and lactation. Of course, for young calves, only maintenance and growth requirements were considered. The net requirements were then adjusted for absorption coefficients (**AC**) to determine the dietary requirements for each mineral.

Requirements for calves were divided into two sections for preweaned calves and for postweaned calves. Postweaned calves were assumed to have a functional rumen, and as such, different digestion and absorption coefficients. Further, there were fewer data available for preweaned calves, so the Committee occasionally relied on data from monogastric animals to determine requirements.

Table 1 contains equations for preweaned and postweaned calves. For postweaned calves, the sum of values for maintenance and gain is divided by the absorption coefficient to determine the daily requirement. This is the same approach taken by the NASEM Committee for adult cattle; however, the AC differ from those of adult cows to reflect differences in maturity of the animal. In the case of preweaned calves, there were insufficient data to calculate requirements using this factorial approach in most cases. Therefore, the Committee calculated "Adequate Intake" rather than requirements for minerals based on equations of Castro et al. (2019). The denominator in equations in Table 1 for preweaned calves are considered "retention coefficients" rather than absorption coefficients, so the values in the respective columns are not directly comparable.

Requirements in the 8th Edition of Nutrient Requirements for Dairy Cattle are calculated as grams or milligrams per day when sufficient information was available. Calculation of concentration of minerals and vitamins in the diets of weaned calves may be based on the assumption that calves prior to four months of age will receive diets containing 85-95% concentrate and 5 to 15% forage (usually grass hay). Prior to weaning, calves are fed both liquid and dry feeds; therefore, it is necessary to partition mineral intake between these two feed sources. The Committee calculated recommended mineral and vitamin concentrations using an iterative approach – by evaluating proportions of DM from calf milk replacer and calf starter and then determining the appropriate inclusion rates to achieve AI at various ages and target ADG. Table 2 contains NASEM recommended concentrations of minerals in calf milk replacers, starter and grower feeds using this iterative approach. Note that there are a few errors in the NASEM text and software (as of July, 2023). These errors are summarized in Appendix A.

I calculated recommended vitamin and mineral concentrations in milk replacers, calf starters, and growers using two modeling approaches, outlined in Appendix B. Briefly, I used GPS, a proprietary calf growth model, as a platform to model input variables needed to calculate mineral requirements (i.e., BW, ADG, DMI) in g/day or mg/d and then calculated requirements for each day of a 122-d growth period beginning on day 3 of age. Concentrations of each mineral in all feeds were then evaluated using an iterative approach to minimize the number of days that intake of mineral was below daily requirement. The second approach was a non-linear calculation (using Solver function of Excel) of mineral concentrations of each feed in four different diets (low, medium, high and very high milk feeding) to meet minimum mineral requirements (mg or g/day).

Values in Table 2 are results of the simulation under the heading "Adjusted". In many cases, recommended minimum concentrations are similar to recommendations of NASEM in Table 2. However, in other cases, differences are significant. The model used in GPS differs from the NASEM model; therefore, my calculation of minimum mineral concentrations differs in some cases from those of NASEM.

For example, NASEM recommended concentrations of P in starters and growers are 0.37 and 0.33%, respectively. I estimate the need for P to be higher in starters and growers. For example, at 64 d of age, I estimated that a calf previously fed up to 800 g of CMR/d will weigh 83 kg, consume 2.33 kg of DM/d and have an ADG of 0.89 g/d. Using the equation in Table 1 for postweaned calves, and assuming mature BW = 680 kg, we estimate the calf requires 12.8 g/d of Ca, or 0.55% of DM. Considering that calves are projected to eat approximately 6% of their DM from forage (assumed to contain about 0.2% of DM as P), then the required P in calf grower needs to be greater than the 0.33% recommended by NASEM.

Organic Mineral Sources. The role of organic trace minerals has been studied in different classes of cattle, including dairy calves. Generally, replacement of inorganic sources of Cu, Zn, Se, Fe, and/or Mn has not resulted in consistent improvements in productive responses (growth, intake, efficiency), but many studies have documented improve health and resistance to disease when calves were supplemented with organic sources of Se (Salles et al., 2014; Gelsinger et al., 2016) and Cu, Zn, Mn, and/or Co (Jacometo et al., 2015; Pino et al., 2017; Price et al., 2017; Ogilvie et al., 2023).). Use of organic minerals may be more useful to improve calf performance when higher levels of milk are fed (Osorio et al., 2015). Similar responses to improved immune response have been shown in older beef heifers supplemented with zinc (Chirase and Greene, 2001; Kegley et al., 2001), though not all studies reported positive effects of organic trace minerals in beef calves (e.g., Ryan et al., 2015). Finally, Caramalac et al. (2017) reported improved palatability of diets containing hydroxychloride sources of Zn, Cu, and Mn versus sulfate/oxide forms of these minerals.

Abdollahi et al. (2019) reported that increasing Zn concentration of the diet from 35 to 50 mg/kg DM improved growth from 7 to 100 d and DMI from 31 to 100 d of age in Holstein calves. Further, incidence of disease (pneumonia and diarrhea) were reduced and indices of immune competence were improved when Zn was added to the diet. Supplemental Zn was added by either standard or high-surface ZnO. High surface ZnO was reported to increase postweaning intake and feed digestibility. Chinese researchers (Chang et al., 2020) reported that supplementing calves with 80 mg/d of Zn from ZnO (104 mg of ZnO per day) during d 1-3 reduced diarrhea during the first 3 d of life. Further, supplementation with 80 mg/d of Zn from Zn-methionine (457 mg of Zn-met/day) increased growth and reduced incidence of diarrhea for the first 14 d of life. Changes in fecal microflora were also observed due to Zn supplementation. Similarly, Ma et al. (2020) reported that 80 mg of supplemental Zn from Zn-met reduced incidence of diarrhea and improved growth during the second week of life. Zinc was added via milk replacer to a basal diet of milk (4.05 mg Zn/kg DM) and calf starter (176 mg/kg). Addition of 80 mg of Zn via ZnO had no effect on diarrhea or growth in this study, suggesting that organic Zn may be more effective than ZnO in promoting gut integrity and reduce risk of disease.

Pennsylvania researchers fed dry cows inorganic or organic minerals for 60 d prior to calving. Their calves were also assigned to receive organic or inorganic minerals in milk replacer, starter, and TMR, until 110 day in milk after calving. Heifers fed organic minerals tended to calve earlier than those supplemented with inorganic minerals ($P = 0.07$). Overall milk yield until 100 DIM was greater in organic mineral supplemented heifers ($P = 0.09$)

A general program of organic trace minerals (Co, Cr, Cu, Fe, Mn, Se, and Zn) was added to calf starter to approximately meet 2021 NASEM mineral recommendations (Mousavi-Haghshenas et al., 2022). Compared to calves supplemented with similar amounts of minerals from inorganic sources, calves fed organic minerals were healthier (fewer incidences of diarrhea) and greater starter intake and preweaning ADG, particularly in calves with lighter BW.

Several trials have reported improved calf health and resistance to disease when dry cows were supplemented with organic trace minerals (e.g., Jacometo et al., 2015; Pino et al., 2017; Price et al., 2017; Ogilvie et al., 2023). In the study by Ogilvie et al., cows were fed inorganic or organic minerals for 45 days prepartum at target concentrations of 0.25, 13.7, 40.0, 0.3, and 40.0 mg/kg for Co, Cu, Mn, Se, and Zn, respectively, for both treatments. Reductions in calf health problems were observed in calves born from primiparous, but not multiparous cows. Price et al. (2017) fed Angus × Brangus cows with sulfate or organic forms of Se, Co, Cu, Mn, and Zn (Se-yeast and proteinates). Calves born to cows supplemented with organic minerals had improved absorption of IgG and IgA and improved growth. Jacometo et al. (2019) suggested that maternal nutrition may alter neonatal innate immune response, potentially via changes in gene and mRNA expression.

Summary and Recommendations. Updated equations to calculate mineral requirements for preweaned and postweaned calves are in Table 1. These equations can be used in models to calculate requirements or adequate intakes on a milligram or gram per day basis. Required concentrations can be calculated by dividing intakes by DM intake for a given day. Recommendations for minimum concentrations in starters, growers, and milk replacers are in Table 2. Differences between NASEM and Adjusted recommendations reflect differences in predictions of growth and intake using the respective models. We recommend using Adjusted recommendations in Table 2 for formulation matrices.

Organic trace minerals (e.g., Cu, Mn, Zn, Co) have been shown in a majority of published studies (notwithstanding publication bias) to positively affect calf health, and in some cases, growth and intake. Future milk production is likely to be improved with long-term supplementation of organic minerals. Supplementation in CMR and calf starter formulas with organic trace minerals replacing inorganic sources is recommended on published research. Most of the research conducted with inorganic vs. organic sources in CMR and starter feeds has been complete replacement of inorganic sources with organic sources. Therefore, partial replacement of inorganic forms is generally not supported by the published data.

APPENDIX A. Errors in 2021 NASEM Mineral Requirements

1. Errors in Text
   a. **Equation 7-2.** There should be no minus sign for Mature BW. The correct equation is: ((9.83*MBW^0.22)*BW^-0.22)*ADG.
   b. **Equation 7-6.** Requirements are expressed in g/d, not kg/d.
   c. **Equation 7-40.** Growth = 0.7 * ADG, not 2.0.
   d. **Table 10-12**. Absorption coefficient differs from Eq. 10-27.

2. Errors in Software
   a. **Magnesium.** Absorption coefficient for Mg is set at 100% instead of 26% as stated in the text.
   b. **Sodium.** Absorption coefficient is incorrect. When basal + growth requirements are summed, they do not equal total absorbable requirement.

APPENDIX B – Modeling mineral nutrient requirements

Two methods were used to estimate minimum mineral requirements for young calves.

1. The first was a non-linear modeling approach utilizing. We simulated intake and growth using GPS at 7, 35, 56, 63, 70, 77, 84, 98, 105, and 112 days. Holstein calves were fed 700, 800, 900, or 1,000 g/d of CMR solids (24% protein and 18% fat) to weaning at 56 d of age. Calf starter (18% CP, 35% starch) was offered for ad libitum consumption from 3 to 89 d of age and grower (16% CP and 25% starch) was offered from 90 to 122 d of age. Minimum mineral requirements were calculated using equations in Table 1. Each feed (CMR, starter, and grower) was assigned a starting concentration of a nutrient and the difference between intake and minimum requirement was calculated. The GLG minimization strategy of Excel was used to calculate the concentrations of each feed that minimized the difference between intake and requirement. Differences were not allowed to be below zero. Non-zero constraints were included for mineral concentrations in each feed. Excel limits non-linear minimization datasets to 200 data points and 100 constraints; therefore only a subset of the GPS data were used.

2. The second approach also used GPS and modeling a typical feeding program with CMR (24/18), calf starter (20% CP, 18% NDF) offered ad libitum from d 3 to d 60, grower (16% CP, 25% NDF) to a maximum of 3 kg from d 61 to 122, and grass hay offered. Vitamin and mineral requirements were calculated for each day of the simulation (122 days) and the difference between intake and requirement was calculated. Amounts in milk replacer, starter, and grower were adjusted to ensure zero days of insufficient nutrient intake yet minimizing excess mineral intake.

Table 1. Equations to calculate recommended mineral requirements for young calves (NASEM, 2021).

Mineral	Preweaned[1]	Postweaned
Ca, g/d	(0.0127*EBW + (14.4*EBW^-0.139*EBG)) / 0.73	((0.9*DMI) + (((9.83*MBW^0.22)*BW^-0.22)*ADG)) / 0.6
P, g/d	(0.0118*EBW + (5.85*EBW^-0.027*EBG)) / 0.65	(((1.2+((4.635*MBW^0.22)*(BW^-0.22)))*0.9)+(0.8*DMI + 0.0006*BW)) / 0.75
Mg, g/d	(0.0035*EBW + (0.60*EBW^-0.036*EBG)) / 0.30	((0.3*DMI + 0.0007*BW) + (0.45*ADG)) / 0.26
K, g/d	(0.0203*EBW + (1.14*EBW^-0.048*EBG)) / 0.13	((2.5*DMI + 0.07*BW) + (2.5*ADG)) / 1
Na, g/d	(0.00637*EBW + (1.508*EBW^-0.045*EBG)) / 0.24	((1.45*DMI) + (1.4*ADG)) / 1
Cl, g/d	Na requirement*0.8	((1.11*DMI) + (1.0*ADG)) / 0.92
S, g/d		DMI*2†
Cu, mg/d	(0.0145*BW + 2.5*ADG) / 0.5	((0.0145*BW) + (2.0*ADG)) / 0.1
Fe, mg/d	(34*ADG) / 0.25	(34*ADG) / 0.1
Mn, mg/d	(0.0026*BW + 0.7*ADG) / 0.01	((0.0026*BW) + (0.7*ADG)) / 0.005
Zn, mg/d	(2* DMI + 24*ADG) / 0.25	((5*DMI) + (24*ADG)) / 0.25
Co, mg/d	NA‡	0.2*DMI†
I, mg/d	0.8*DMI	0.216*BW^0.528†
Se, mg/d	0.3*DMI	0.3*DMI†

[1]Total daily requirement for preweaned calves. BW = body weight (kg); ADG = average daily gain (kg/d); EBW = empty BW (BW * 0.94); EBG (kg/d) = empty BW gain (ADG * 0.91); DMI = DM intake (kg/d); MBW = mature BW (kg).

[2]Net requirement for maintenance in postweaned calves.

[3]Net requirement for growth in postweaned calves.

[4]Calculate the daily requirement as (maintenance + growth) / AC.

†Total dietary requirement; no AC is used.

‡No cobalt requirement is included, due assumed limited rumen microbial synthesis of vitamin B_{12}.

Table 2. NASEM and Adjusted recommended concentrations of minerals in milk replacer and starter to provide adequate intake for calves from 35 to 125 kg. Values are on a DM basis. Adjusted calculations based on non-linear minimization of mineral intake above requitements and modeling of daily mineral intake vs. requirement (g/d or mg/d).

	NASEM			Adjusted		
Mineral	CMR	Starter	Grower	CMR	Starter	Grower
Ca, %	0.80	0.75	0.65	0.85	0.75	0.65
P, %	0.60	0.37	0.33	0.60	0.60	0.60
Mg, %	0.15	0.15	0.16	0.18	0.18	0.18
K, %	1.10	0.60	0.60	1.35	0.75	0.75
Na, %	0.40	0.22	0.20	0.50	0.25	0.25
Cl, %	0.32	0.17	0.15	0.40	0.20	0.20
S, %				0.20	0.20	0.20
Co, mg/kg	NA	0.2	0.2	NA	0.20	0.20
Cu, mg/kg	5	12	12	5	12	12
I, mg/kg	0.8	0.8	0.5	0.8	0.8	0.5
Fe, mg/kg	85	60	55	90	110	110
Mn, mg/kg	60	40	60	70	60	70
Se, mg/kg	0.3	0.3	0.3	0.3	0.3	0.3
Zn, mg/kg	65	55	50	75	50	50

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