The 8th Revised Edition of the Nutrient Requirements of Beef Cattle: Minerals, vitamins, and water

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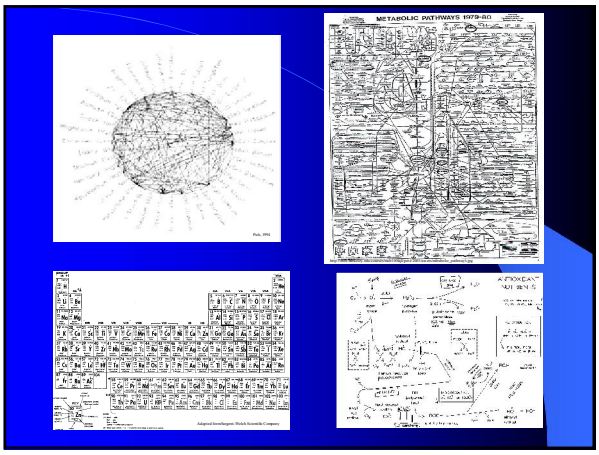
Outline

- Objective
- Approach
- Determining mineral requirements
- Updates/changes made:
  - Minerals section
  - Vitamins section
  - Water intake section

Objectives:

- Conduct a review of the published scientific literature on mineral and water requirements of beef cattle.
- Incorporate new information into the revised Nutrient Requirements of Beef Cattle publication.
- Incorporate information from previously published NRC's (Dairy, Small Ruminants, Mineral tolerances of livestock, etc.) where appropriate.


METABOLIC PATHWAYS 1979-80

Approach = Questions?

- Can we more accurately estimate mineral requirements (vitamins and water intake) for beef cattle based on literature published since the 1996 Nutrient Requirements of Beef Cattle publication?
- Ground rule – Is there any information that supports changing requirements?

Minerals

- Macrominerals
  - Calcium
  - Phosphorus
  - Magnesium
  - Potassium
  - Sodium
  - Chlorine
  - Sulfur
- Microminerals
  - Chromium
  - Cobalt
  - Copper
  - Iodine
  - Iron
  - Manganese
  - Molybdenum
  - Nickel
  - Selenium
  - Zinc

Determining Mineral Requirements

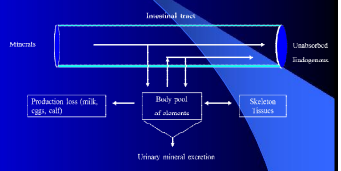
- Factorial estimates/modeling (best approach; ARC, 1965)
- Mineral balance and retention (duration, initial estimate, and final estimate)
- Dietary experimentation estimates (most common)

Determining Mineral Requirements

- Factorial estimates – determining gross mineral requirement
  - Sum of the components of net requirements for maintenance and production and divide the total by the coefficient of absorption
    - Net requirements:
      - Maintenance – apparent absorption and retention experiments. Then calculate endogenous losses to be able to calculate true absorption.

Determining Mineral Requirements

- Net requirements (Cont.)
- Endogenous losses
  - Feed element at different concentrations and measure mineral output. Regress fecal mineral excretion on mineral intake
  - Measure fecal mineral losses in animals fed a diet free of the element
  - Use radioisotopes: I.V.
  - Maintenance requirements increase in relationship to increased production due to increased feed intake.
  - Production – element in production products. i.e. milk, muscle, fetus.
- Gross requirement



Determining Mineral Requirements

- Dietary experimentation estimates (most common)
  - Basic approach – supplement a diet deficient or suspected of being deficient in a mineral with one or more concentrations of a specific mineral of interest.
  - Response variables are then measured (i.e. growth, reproduction, bone strength, etc.)

Determining Mineral Requirements

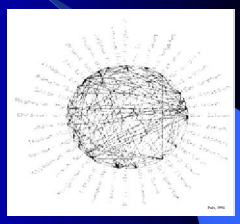
- Factorial estimates
  - Advantages
    - Requirements of a specific mineral can be estimated for a wide range of production levels and physiological stages. Works well for Ca and P measurements – high degree of accuracy.
  - Disadvantages
    - Difficult to accurately measure and studies are limited.
    - Maintenance requirements and absorption coefficients are potentially a major source of error.
    - Absorption coefficients can also be affected my dietary as well as physiological status of the animal.
    - Absorption coefficients for certain trace minerals are more accurately measured when dietary concentrations are at or below the animal's requirements. Elevated concentrations activate homeostatic control mechanisms that can reduce absorption.

Determining Mineral Requirements

- Dietary experimentation estimates
  - Advantages
    - Supplementation experiments can arrive at an estimate of the requirement in the whole animal.
  - Disadvantages
    - Supplementation experiments rarely give precise estimates of requirements.
    - It is difficult and costly to estimate requirements using experiments for cattle of different ages and varying physiological states (growth, maintenance, reproduction, lactation, etc.).
    - Dependent on response variables measured

Factors that impact mineral requirements in cattle

- Chemical
  - Mineral – mineral interactions
    - Gastrointestinal tract
      - Rumen
      - Small intestine
        - Lumen
        - Cellular level
        - Toxicity prevention
- Metabolic/Physiological
  - Animal factors
    - Species and breed
    - Immune response
    - Gestational Status
  - Environmental factors
    - Stress (shipping, heat, physical, etc.)



Calcium

- Factorial approach
  - Maintenance requirement - calculated as 15.4 mg Ca/kg body weight (BW; Hansard et al., 1954, 1957)
  - Retained Ca in excess of maintenance requirements were calculated as 7.1 g Ca/100 g protein gain. (Ellenberger et al. 1950).
  - The Ca requirement for lactation in excess of maintenance needs was calculated as 1.23 g Ca/kg milk produced.
  - Fetal Ca content was assumed to be 13.7 g Ca/kg fetal weight. This requirement was distributed over the last 3 months of pregnancy.

Calcium

- New information
  - Series of serial slaughter experiments were conducted by Watson et al. (2014 a,b).
  - Investigating different levels of gain prior to feedlot entry and different growth technologies.
  - Expressed as grams of Ca/100g of protein gained were 13.41(6), 8.24 (3), and 14.44 for British crossbred steers in the first experiment, British crossbred steers in the second experiment, and Holstein steers in the third experiment, respectively.
  - Due to the variation in the data reported by Watson et al. (2014 a,b) further research is needed to warrant changing the current NRC recommendation of 7.1 g calcium/100 g protein.

Phosphorus

- Factorial approach
  - The maintenance requirement for P was considered to be 16 mg P/kg BW.
  - Retained P needs in excess of maintenance requirements were calculated as 3.9 g P/100 g protein gain (Ellenberger et al..1950). Phosphorus needs, during lactation, in excess of maintenance, were calculated as 0.95 g P/kg milk produced. Fetal P was assumed to be 7.6 g P/kg fetal weight, and this requirement was distributed over the last 3 months of pregnancy.
  - New information - Watson et al. (2014 a,b) 4.1, 4.3, 7.5 g/100g of protein gain for British crossbred steers in the first two experiment, and Holstein steers in the third experiment, respectively. The authors indicated that P retention values from all three experiments were relatively consistent with the NRC (2000) values.

Magnesium

- As a percentage of DM, recommended Mg requirements are as follows:
  - Growing and finishing cattle, 0.10%
  - Gestating cows, 0.12%
  - Lactating cows, 0.20%
  - Based on dose response experiments where blood Mg was maintained above 2.0 mg/dL
- Absolute requirements for Mg were estimated as follows:
  - Replenishment of endogenous loss, 3 mg Mg/kg live weight;
  - Growth, 0.45 g Mg/kg gain
  - Lactation, 0.12 g Mg/kg milk
  - Pregnancy, 0.12, 0.21, and 0.33 g Mg/day for early, mid, and late pregnancy, respectively (Grace, 1983).
- Add citations for information regarding nutritional management to help prevent grass tetany in beef cows: NRC (2001) and Kvasnicka and Krysl (2014).

Potassium, Sodium, Chloride

- Potassium
  - Feedlot cattle 0.6% K diet DM.
  - Potassium requirements of beef cows are not well defined. Clanton (1980) suggested that gestating beef cows require 0.5 to 0.7% K.
- Sodium and Chloride
  - Requirements for Na in non-lactating beef cattle do not exceed 0.06 to 0.08%, whereas lactating beef cows require approximately 0.10% Na (Morris, 1980).
- Cation:anion balance

Sulfur

- The recommended concentration in beef cattle diets is 0.15%.
  - Added information regarding:
    - Using available S for ruminal reduction when formulating diets (Sarturi et al., 2013 a,b).
    - Polioencephalomalacia – feed and water [S].
    - Sulfur, copper, molybdenum, and selenium interactions.
    - Maximum tolerable concentration range 0.30-0.50% (previously 0.40%).

Microminerals

- Chromium - has been shown to influence carbohydrate metabolism (Mertz, 1993), lipid metabolism (Abraham et al., 1991; Bernhard et al., 2012a), and protein absorption and metabolism (Okada et al., 1983; Kornegay et al., 1997).
- Recently, Cr supplementation has been reported to decrease the impact of heat stress in lactating Holstein dairy cows through anti-inflammatory mechanisms (Zhang et al., 2014).
- Several publications focusing on glucose kinetics (8), growth performance (6), and immunity (9) in beef cattle have been conducted.

Chromium (cont.)

- Spears et al. (2012)
  - 36 Angus and Angus x Simmental heifers
  - Treatments were 0, 0.47, 0.94, and 1.42 mg of supplemental Cr/kg of DM
  - Conducted GTT at d 44.
  - Reported Cr supplemented animals had a lower: area under the glucose response curve, serum [insulin] , molar ratio of insulin:glucose and suggested that the Cr requirement was 0.47 mg Cr/kg DM.
- Challenges – no dose response observed, deficiency signs in ruminants?
- Glucose clearance – influenced by Cr bioavailability, diet type, physiological status, glucose dose and time of feeding (dose 0.45 g of glucose/kg BW vs. 0.45 g of glucose/kg $BW^{0.75}$), laboratory analysis.
- Based on the review of the literature published since the NRC (2000), further research is warranted to substantiate setting a dietary Cr requirement.

Cobalt

- The NRC (2000) set the Co requirement of cattle at 0.10 mg/kg DM diet based on research by Smith (1987; B_{12} synthesis; dose response MMCoA mutase; 5-MH-transferase).
- Dose response studies (0.07 – 1.0 mg Co/kg DM forage and high concentrate-based diets) both *in vivo* and *in vitro* indicate that Co requirements for beef cattle should be increased form 0.10 to 0.15 mg Co/kg DM. (Schwarz et al., 2000; Stangl et al. 2000; Tiffany, 2003; Tiffany et al., 2006).
- Barley based diets - rapid fermentation.

Copper

- Requirements of Cu can vary from 4 to more than 15 mg/kg of dietary DM depending largely on the concentration of dietary molybdenum (Mo) and S.
- The recommended concentration of Cu in beef cattle diets is 10 mg Cu/kg diet. This amount should provide adequate Cu if the diet does not exceed 0.25% S and 2 mg Mo/kg DM.
- Less than 10 mg Cu/kg diet might meet requirements of feedlot cattle because Cu is more available in concentrate diets than in forage diets.

Copper (Cont.)

- Add discussion about Cu antagonists (S and Mo).
  - Suttle and McLauchlan (1976; log [Copper Absorbable] = -1.153 - 0.076 [S, g/kg] - 0.013 [S, g/kg x Mo, mg/kg])
- Reduced the maximum tolerable dietary Cu concentration from 100 to 40 mg Cu/kg DM.
- Long term copper supplementation (2 years) at close to 40 mg Cu/kg DM caused copper toxicity in adult cattle.

Iodine, Iron

- Iodine requirements of beef cattle are not well established; 0.5 mg I/kg diet should be adequate unless the diet contains goitrogenic substances that interfere with I metabolism.
- The Fe requirement is approximately 50 mg/kg diet in beef cattle. Studies with young calves fed milk diets have indicated that 40 to 50 mg Fe/kg is adequate to support growth and prevent anemia

Manganese

- The Mn requirement for growing and finishing cattle is approximately 20 mg of Mn/kg diet and gestating and lactating cows 40 mg of Mn/kg DM.
- Since the publication of the NRC (2000), research conducted by Legleiter et al. (2005) and Hansen et al. (2006b) would support the continued recommendation of 20 mg of Mn/kg DM for growing and finishing cattle.

Molybdenum and Nickel

- Molybdenum (Mo) functions as a component of the enzymes xanthine oxidase, sulfite oxidase, and aldehyde oxidase (Mills and Davis, 1987). Requirements for Mo, however, are not established. There is no evidence that Mo deficiency occurs in cattle under practical conditions, but Mo might enhance microbial activity in the rumen in some instances.
- Nickel (Ni) deficiency has been produced experimentally in a number of animals (Nielson, 1987); however, the function of Ni in mammalian metabolism is unknown. Nickel is an essential component of urease in ureolytic bacteria (Spears, 1984).

Selenium

- Based on the available research data the Se requirement of beef cattle can be met by 0.1 mg Se/kg of dietary DM.
- The maximum tolerable concentration of Se was set at 2 mg/kg diet DM by NRC (1980).
- This is most likely an underestimate of Se tolerance in ruminants under practical dietary conditions (Underwood and Suttle 1999; McDowell, 2003; NRC, 2005).
- No signs of Se toxicosis were noted in controlled feedlot experiments where beef cattle were fed (for greater than 100 days) feedlot diets containing high seleniferous feedstuffs (wheat, hay, or alfalfa/grass hay) where the total mixed diets exceeded 2.0 mg Se/kg of DM (Hintze et al., 2002; Lawler et al., 2004). Similar results have been reported in ruminants fed dietary supplements fortified with Se (Taylor, 2005, Cristaldi et al., 2005; Davis et al., 2006,b; Juniper et al., 2008).
- Maximum tolerable concentration was set at: 5 mg Se/kg DM.
- Selenium can legally be supplemented in beef cattle diets to provide 3 mg/animal daily or 0.3 mg/kg in the complete diet as stated in the Code of Federal Regulations (21CFR § 573.920 [2013]).

Zinc

- The recommended requirement of Zn in beef cattle diets is 30 mg of Zn/kg of diet
- No data were available to support changing the Zn requirement for beef cattle.

Data Comparison

Macrominerals and Trace Element Requirements for Beef Cattle. 2015. Costa e Silva L. F., S. de Campos Valadares Filho, T. E. Engle, P. P. Rota, M. I., Marcondes F. A. S. Silva, E. C. Martins, and A. T. Tokunaga. *PLoS ONE* 10: e0144464.

- Utilized 87 Nellore animals to estimate net mineral requirements of maintenance and growth (Factorial Approach → gross requirements)
- Bulls, heifer, and steers – fed at maintenance and for a specified gain.
- Digestibility experiments
- Tissue harvest – serial slaughter - (net requirements for maintenance and true retention coefficient; net requirements for growth.

ARC: Agricultural Research Council. The nutrient Requirements for Ruminant Livestock; AFRC – Agriculture and Food Research Council (Report 6); NRC – National Research Council Nutrient Requirements for Beef/Dairy Cattle; CSIRO – Commonwealth Scientific and Industrial Research Organization; BR Corte – Nutrient requirements for Zebu beef cattle. Valadares Filho et al., (2010).

Calcium and Phosphorus Comparisons

Net Requirements for Maintenance		
	mg/kg body weight	
Item	Ca	P
ARC (1965/1980)	16.0	12.0
NRC	15.4	16.0
Valadares Filho et al. (2010)	---	17.6
Costa e Silva	20.0	16.1

Costa e Silva et al. (2015) Comparisons

Dietary Requirements

	g/kg dry matter intake			
Item	Mg	K	Na	S
NRC	1.0	6.0	0.80	1.5
CSIRO (2007)	1.3	---	0.80	---
Costa e Silva et al. (2015)	0.79	2.4	0.96	1.47

Costa e Silva et al. (2015) Comparisons

Dietary Requirements

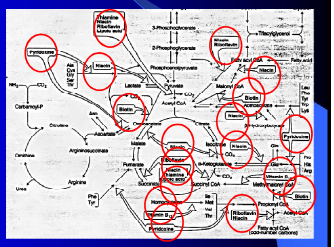
	mg/kg dry matter intake					
Item	Cu	Fe	Mn	Se	Zn	Co
NRC	10.0	50	20	0.10	30	0.15
CSIRO (2007)	---	---	---	0.05	11.6	---
Costa e Silva et al. (2015)	9.53	218	9.5	0.57	61	2.78

The Vitamins

- Fat-soluble:
  - A, D, E, and K
- Water Soluble:
  - Biotin
  - Choline
  - B_{12}
  - Folic Acid
  - Niacin
- Water Soluble: Cont.
  - Pantothenic Acid
  - Pyridoxine
  - Thiamin
  - Riboflavin
  - Vitamin C

Vitamins for Beef Cattle: Background

- Vitamins are required metabolically by beef cattle to sustain normal body function and life processes.
- In addition, they are required in adequate amounts to enable animals to efficiently utilize other nutrients.
- Many metabolic processes are initiated and controlled by specific vitamins throughout life.



Vitamins for Beef Cattle: Background

- Minimum dietary requirements are amounts needed in the diet to prevent the appearance of a deficiency disease or a metabolic syndrome associated with specific vitamin deficiencies and to provide for normal life and production processes.
- It is with this classical view of vitamin requirements in mind that dietary requirements for vitamins have been traditionally established.

Vitamin A Requirements

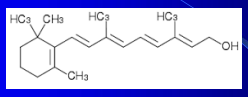
- Vitamin A requirements for livestock are reported in either International Units (IU) or Retinol Equivalents (RE).

TABLE 8-1 Definitions and Relationships of International Units (IU) and Retinol Equivalents (RE) as Related to Vitamin A[a]

1 IU	0.3 µg of all-trans retinol
1 IU	0.344 µg of retinyl acetate
1 IU	0.55 µg of retinyl palmitate
1 RE	1 µg of all-trans retinol, 2 µg of synthetic supplemented all-trans ß-carotene, 6 µg of dietary all-trans ß-carotene, or 12 µg of other dietary provitamin A carotenoids[b]

[a]SOURCE: NRC 1989a, 2001, 2007b; IOM, 2000
[b]SOURCE: NRC,1989a, 2007b, IOM, 2000

Vitamin A Requirements



- Beef cattle requirements for vitamin A were previously reported (NRC, 1984, 1996) at 2,200 IU/kg dry feed for beef feedlot cattle; 2,800 IU/kg dry feed for pregnant beef heifers and cows; and 3,900 IU/kg dry feed for lactating cows and breeding bulls.
- These requirements are approximately 47, 60, and 84 IU/kg BW for feedlot cattle, dry pregnant heifers and cows, and lactating cows and bulls, respectively.

Vitamin A Requirements

- Existing data indicate that requirements set by the previous NRC committees are reasonable, even though in practice many nutritionists include an additional margin of safety
- Insufficient evidence exists to elevate the vitamin A requirements for beef cattle above those recommended in the previous

No Change

Vitamin D

- The vitamin D requirement of beef cattle was previously reported to be 275 IU/kg dry diet (NRC, 1996).
- An IU of Vitamin D is defined as 0.025 µg of D3 or its equivalent.
- These previously recommended levels equate to approximately 5.7 IU/kg BW. These values are similar to NRC (2007) recommendations of 5.6 IU/kg BW for maintenance and early pregnancy in ewes

Vitamin D

- It was reported that mean vitamin D levels included in finishing cattle diets was 329 IU/kg DMI (Vasconcelos and Galyean, 2007).
- However, in their extensive survey of consulting feedlot nutritionist the mode value for vitamin D dietary inclusion was 0 in feedlot diets.

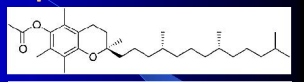
Vitamin D

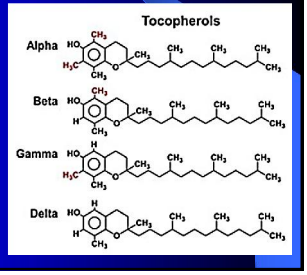
- For dairy cattle, the NRC (2001) set a requirement of 30 IU/kg BW, which, admittedly, provided a wide margin of safety.
- It is important to note that little recent data exist regarding vitamin D requirements for beef cattle.

No Change

Vitamin E Requirements

- The vitamin E requirement for beef cattle was estimated to be between 15 and 60 IU/kg dry diet (or 0.31 to 1.25 IU/kg BW)
- For vitamin E, an IU is defined as 1 mg of all racemic α-tocopherol acetate





Vitamin E Requirements

- Inadequate data currently exist to set vitamin E requirements for most classes of beef cattle. Consequently, previous recommendations for beef cattle still seem reasonable (15 to 60 IU/kg DMI).
- One exception to this would be calves that have undergone stress associated with marketing and transportation.

Change

Vitamin E Requirements

- Recent work (*Stress Chapter*) indicates that stressed receiving calves should be provided from 400 to 500 IU/calf daily during the receiving period for a 250-kg calf.
- This level of supplemental vitamin E would equate to approximately 1.6 to 2.0 IU/kg BW.

Summary of New Recommendations Regarding Vitamin E

- It is likely that for non-stressed mature beef cattle, vitamin E requirements are low, and that vitamin E needs are likely most often met through normal dietary ingredients.

Summary of New Recommendations Regarding Vitamin E

- For growing cattle, evidence exists for dietary recommendations of vitamin E. For newly received stressed calves, the committee recommends 400 to 500 IU/d or 1.6 to 2.0 IU/kg BW during the receiving period.

Summary of New Recommendations Regarding Vitamin E

- The data are limited for other classes of beef cattle and additional research during periods of stress would provide insight into vitamin E requirements for beef cattle.

Water Chapter Summary

- Hicks et al. (1988) equation - DMI, temperature, precipitation, and dietary salt.
- Arias and Mader (2011) – mean ambient temperature, minimum temperature, and temperature-humidity index were the primary factors that influenced daily water intake.
- Sexson et al., (2012) - body weight, humidity, sea level pressure, DMI, temperature the previous day, daily temperature, change in temperature from the previous day, average wind speed, and the temperature- humidity index were positively related to daily water intake.

Water Quality

- Chemical –
  - pH
  - Total dissolved solids (amount of dissolved salts; salinity)
  - Hardness (calcium and magnesium contribute)
  - Total dissolved oxygen
- Organoleptic (odor and taste)
- Excess elements (iron, sodium, sulfates, etc.)
- Toxic compounds (nitrate NO_3, arsenic, cyanide, lead, mercury, hydrocarbons, etc.).
- Bacteria

Guidelines for Total Soluble Salts (TSS) in Water for Cattle
Source: NRC (1974, 2001).

TSS (mg/L)	Comments
<1,000	Safe and should pose no health problems.
1,000–2,999	Generally safe but may cause a mild temporary diarrhea in animals not accustomed to the water.
3,000–4,999	Water may be refused when first offered to animals or cause temporary diarrhea. Animal performance may be less than optimum because water intake is not maximized.
5,000–6,999	Avoid these waters for pregnant or lactating animals. May be offered with reasonable safety to animals where maximum performance is not required.
7,000	These waters should not be fed to cattle. Health problems and/or poor production will result.

Nitrate in Water
Source: NRC (1974, 2001).

Nitrate (NO_3) (mg/L)	Nitrate Nitrogen (NO_3-N) (mg/L)	Guidelines
0 - 44	0 - 10	Safe for consumption by ruminants
45 - 132	10 - 20	Generally safe in balanced diets with low nitrate feeds
133 - 220	20 - 40	Could be harmful if consumed over long periods
221 - 660	40 - 100	Cattle at risk; and possible death
661	100	Unsafe - possible death; should not be used as a source of water

Generally Considered Safe Concentrations of Some Potentially Toxic Nutrients and Contaminants in Water for Cattle

Item	Upper-limit guideline (mg/L)
Aluminum	0.5
Arsenic	0.05
Boron	5.0
Cadmium	0.005
Chromium	0.1
Cobalt	1.0
Copper	1.0
Fluorine	2.0
Lead	0.015
Manganese	0.05
Mercury	0.01
Nickel	0.25
Selenium	0.05
Vanadium	0.1
Zinc	5.0

NRC 2001. Montana State University. Reed Brandt, Dave Hutchison

Thank You!