Minerals, function and deficiency symptoms

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Mineral classification

- Essential minerals are classified as ***macro***(Major) or ***micro*** (Trace)elements based on their abundance in body tissues and, therefore , dietary requirements.
- Trace elements are present in body tissues at concentrations<50mg/kg(50ppm).

Nutritionally important essential mineral elements and their approximate concentration in the animal

Major

Element	g/kg
Calcium	15.0
Phosphorus	10.0
Potassium	2.0
Sodium	1.6
Chlorine	1.1
Sulfur	1.5
Magnesium	0.4

Trace

Element	Mg/kg
Iron	20-80
Zinc	10-50
Copper	1-5
Molybdenum	1-4
Selenium	1-2
Iodine	0.3-0.6
Manganese	0.2-0.5
Cobalt	0.02-0.1

General minerals functions

- Enzyme activation (most essential mineral catalyze ≥ 1 cell reaction.
- Acid –base and water balance (Na^+,K^+,Cl^-)
- Skeletal structure (Ca,P in bones in keratin).
- Unique function e.g. Fe in heme;Co in vitamin B_{12} ;I in thyroid hormones

Factors affecting requirements

- Physiological state/level of production.
- Interaction with other minerals.
- Tissue storage
- Form fed

Deficiencies and Excesses

- Most minerals have an ***optimal range*** below which ***deficiency symptoms*** occur and above which ***toxicity symptoms*** occur.
- Deficiency or toxicity symptoms may take many months to develop, especially if the mineral in question is readily stored e.g. Cu.

Macro elements(>50mg/kg B.W.)

- Calcium
- Phosphorus
- Potassium
- Sodium
- Chlorine
- Sulfur
- Magnesium

Calcium: Biological function

- Skeleton and teeth structure (contain 99% body calcium),combined with phosphorus to form mineral hydroxyapatite.
- Note: bone calcium reserves can be restored and release to bloodstream during period of high calcium demand e.g. early lactation.
- Essential cofactor for many enzyme systems, including those needed for nervous transmission and muscle contraction.
- Required for blood coagulation .
- Normal plasma concentration 8-12mg/dl

Deficiency symptoms

- Rickets –misshapen bones, joint enlargement, lameness, in **growing** animals.
- Osteomalacia-brittle bones in **adult** animals.
- Milk fever(parturient paresis)-most common in dairy cows soon after calving; recumbency, muscular spasm followed by paralysis, unconsciousness and death if not treated

Dietary sources

- Milk; green leafy; crops; animal by products e.g. fishmeal meat, and bone ; mineral supplement e.g. ground limestone(Ca Co3), Dicalcium phosphate(Ca2Po4).Cereals are poor source of calcium.
- Calcium –phosphorus ratio: Because of interdependance of calcium and phosphorus utilization, an abnormal dietary ratio may be as harmful as a deficiency of either in the diet. Generally aim for ratio 1:1 to 2:1 especially important in horses .

Phosphorus : Biological function

- Skeleton –teeth.
- Vitally important in various aspect of energy metabolism e.g. ATP, sugar phosphates.
- Phosphoprotein, nucleic acid, phospholipids.

Deficiency symptoms

- Most widespread and economically important mineral deficiency, especially in tropical and subtropical grazing areas.
- Rickets or osteomalacia
- Pica(depraved appetite)-chewing of wood, bones, etc.
- Stiff joints, muscular weakness.
- Low fertility.
- Subnormal milk yield and growth.

Dietary source

- Milk; cereal grains; animal byproducts. Grass hays and straws are poor sources.
- Availability decreased when present in phytate salts e.g. in cereal grains

Potassium: Biological function

- Regulation of osmotic and acid – base balance (with sodium, chlorine, and bicarbonate ions).
- Major action of intracellular fluid, with special role in ionic basis of nerve and muscle excitability.
- Cofactor for several reactions in carbohydrate metabolism.

Deficiency symptoms

- Generally rare in forage –fed animals, dietary excess more common (rapidly excreted in urine).
- Reduced growth, paralysis occasionally seen in calves fed milk replacer low in potassium.

Dietary sources

- Very high in green forages and hays , lower in cereal grains.

Sodium: Biological functions

- Regulation of acid –base and osmotic balance of body fluids
- Major caution of extracellular fluid, with special roles in nervous transmission and active transport of sugars and amino acids.

Deficiency symptoms

- Decreased extracellular osmotic pressure, dehydration.
- Poor growth, inefficient utilization of digested protein and energy.

Dietary source

- Animal byproducts are good sources, most plants are poor sources .Supplemented when necessary as common salt.

Chlorine: Biological functions

- Acid – base and osmotic regulation (see notes on potassium, sodium).
- HCl and chlorine salts in gastric secretion.

Deficiency symptoms

- Metabolic alkalosis (increased bicarbonate compensation for decreased chloride).
- Growth retardation.

Sodium, rather chlorine, is probably the main limiting factor in salt – deficiency diets of cattle and sheep.

Dietary sources

- Similar to sodium

✓ Note: Because most plants are low in sodium and chlorine ,it is usual to supplement diet of herbivores with common salt.

✓ Over supplementation of salt can be harmful, causing excessive thirst, muscular weakness and edema.

Sulfur: Biological functions

- Integral component of sulfur amino acids, cysteine and methionine, which have many important biological roles e.g. synthesis of bioactive (insulin, glutathione) and structural proteins(Keratin-wool contain-4% sulfur).
- Chondroitin sulfate is a constituent of cartilage.

Deficiency symptoms

- Usually associated with protein deficiency.
- Reduced feed intake and cellular possible where urea is used as replacement for protein nitrogen, resulting in reduced body and wool growth.

Dietary sources

- Most dietary proteins are generally adequate in sulfur amino acids. Inorganic sulfates can be fed as supplements with urea to balance N:S ratio(10-12:1 is desirable).

Magnesium: Biological functions

- Closely associated with calcium and phosphorus ; about 70% of total magnesium is in skeleton, remainder in soft tissues and fluids. Commonest enzyme activation e.g. pyruvate dehydrogenase (pyruvate $\longrightarrow$ acetyle CoA)

Deficiency symptoms

- Young animal e.g. milk fed calves-low plasma magnesium, depleted bone magnesium, tetany, death if untreated.
- Hypomagnesemic tetany(grass tetany) in cattle , especially dairy cows in early lactation –low plasma magnesium(normal range 1.7- 4.0 mg\dl), often associated with low plasma calcium, nervous irritability, twitching, staggering gait, recumbency, convulsions, death if untreated.

Dietary sources

- Wheat bran, most vegetable protein concentrates are good sources; legumes are better than grasses; variable in forage crops. Most frequently supplemented as magnesium oxide.

TRACE ELEMENTS: Iron

- Biological functions

1- >90% 0f body iron is associated with proteins, >50% as hemoglobin; Vitally important for oxygen transport in blood.

2- heme is also a component of oxidized enzymes e.g. cytochrome c, peroxidase.

3- Absorbed iron is transported in blood plasma in the protein transferrin, and stored in spleen, liver , kidney and bone marrow in the protein ferritin.

Deficiency symptoms

- Anemia, especially in young milk –fed animals without access to soil or pasture, most common in pigs. Characterized by poor appetite and growth, labored and spasmodic breathing(thumps).

Dietary sources:

- Green leafy plant and seed coats are good; animal byproducts(meatmeal, fishmeal).
- Dietary requirement is normally low because of efficient conservation of iron from hemoglobin breakdown; normal diet,<10% ingested iron is absorbed but this increases with increasing requirement e.g. pregnancy , egg production.

Copper: Biological functions

- Essential for normal absorption, transport and mobilization of iron, and for hemoglobin synthesis.
- Integral component of many enzymes (e.g. cytochrome oxidase) and non-enzyme protein.
- Stored in most body tissues, especially liver.

Dietary sources

- Widely distributed in animal feeds but may be low in pastures grown on copper –deficient soils . A availability in ruminants affected by interaction with molybdenum and sulfur via formation of insoluble copper salts in rumen (see Molybdenum notes).
- Copper toxicity :Continuous overfeeding causes tissue accumulation of copper, especially in liver, eventually to toxic levels . Sheep are more susceptible than cattle or pigs.

Cobalt: Biological function

- Essential component of Vit.B12, precursor of coenzymes for several important metabolic reaction which is synthesized by rumen bacteria.
- Probable activator of some enzyme reactions.

Deficiency symptoms

- Wasting disease in ruminants, characterized by emaciation, anemia, and listlessness; alleviated by dietary supplementation with cobalt, or by parental administration of vit.B12.

Dietary source: Trace amount present in most feeds, pasture may be deficient on cobalt deficient soils. Can be supplemented in salt licks, as a cobalt bullet placed in the reticulum, or by fertilizing deficient pasture with cobalt sulfate.

Cobalt toxicity

- Very unlikely under normal conditions-wide margin between minimum requirement and toxic levels ;poorly retained by tissues.

Iodine: Biological function

- Essential for synthesis of the thyroid hormones, thyroxin and triiodothyronine.
- Thyroid hormone are required for normal skeletal, nervous and sexual development, and for synthesis of enzymes involved in oxidative reactions e.g. cytochrome enzymes.

Deficiency symptoms

- Goiter (enlarged thyroid gland causes swollen neck)
- Reproductive failure
- May be induced by goitrogens in some plants e.g. most brassicas(kale,cabbage,rape), soybean, linseed, peas, peanuts; these act by inhibiting thyroid hormone synthesis.

Dietary source

- Trace in most feed; especially high in marine plants(seaweeds) and fishmeal; deficient in plant grown on iodine –deficient soils.Can be supplemented as iodized salt(sodium or potassium iodide).

Iodine Toxicity: Minimum toxic dietary level varies widely between species . Toxicity associated with decreased weight gain, egg production, feed intake .

Manganese: Biological function

- Present in body in extremely small amount; important activator of several tricarboxylic acid TCA cycle Enzyme.

Deficiency symptoms:

- Retarded growth, skeletal abnormalities, neonatal ataxia and reproductive failure occasionally observed in pigs, poultry and housed ruminants.
- Involved ,but not exclusively, in development of parosis(slipped tendon malformation of leg bones) in young chicks

Dietary sources

- Widely distributed in animal feeds; adequate level in most forages and grains but low in corn and most animal byproducts.
- Manganese toxicity: Wide margin of safety between normal feed levels and toxic dose

Zinc : Biological function

- Integral component of several important enzymes e.g. carbonic anhydrase, pancreatic carboxypeptidases, glutamic dehydrogenase, pyridine nucleotide dehydrogenases.
- Cofactor for many other enzymes.

Deficiency symptoms

- Subnormal growth, depressed appetite, poor feed conversion.
- Parakeratosis (skin inflammation followed by eruptions which develop into scabs) in young pigs and calves.
- Deficiency may be aggravated by high dietary calcium levels and alleviated by decreasing dietary calcium and \or calcium :phosphorus ratio.
- Dietary sources: Yeast, cereal bran and germ are rich sources. Availability may be decreased by phytate in some cereal grains.

Molybdenum : Biological functions

- Integral component and probable cofactor of several oxidase enzymes e.g.Xanthine oxidase (involved in purine metaboloism).
- May be required by celluloytic Bacteria .

Deficiency symptoms: Reduced growth and uric acid production in chicks (uric acid,not urea, is principal end –product of nitrogen catabolism in birds).

- Reduced growth in lambs, related to poor ruminal cellulose digestion.

Molybdenum toxicity

- Manifested via reduced copper availability, usually associated with high sulfur intake. Characterized by diarrhea and weight loss, especially in young calves and lactating cows; also observed in sheep.

Selenium: Biological role

- Component of the enzyme glutathione peroxidase, which catalyzes removal of hydrogen peroxide and protect cells from autooxidative damage . Shares this role with Vit. E.

Deficiency symptoms

- Poor weight gain in calves and lambs, and impaired wool growth in lambs.
- Skeletal and cardiac myopathies (muscle degeneration, white muscle disease)in lambs and calves.
- Reduced hatchability and egg production in hens.
- Exudative diathesis(hemorrhage disease) in chicks.
- Liver necrosis in pigs.

Selenium Toxicity

- Alkali disease or blind staggers can occur in ruminants and horses grazing certain pasture species grown on seleniferous soils e.g. many local areas in western –central USA. Charcterized by dullness, joint stiffness, hair loss, hoof deformities. Relatively narrow margin between nutritional requirement and toxic level

Flourine

- Trace are required for normal growth and optimal tooth development, but toxicity is greater potential problem, especially where drinking water or herbage may be contaminated with natural(rock phosphate dust)or human (industrial pollution) sources of flurine . Toxicity (fluorosis) is charecterized by mottling and excessive wear of teeth, leading to inappetence and weight loss, and skeletal abnormalities.

Other Trace Elements

- Chromium, silicon, vanadium, nickel, tin, arsenic and possibly lead are now regarded as essential elements because in rodents and in some cases, chicks fed highly purified diets, growth was retarded when each of these individual elements was deleted, and restored when the elements was replaced.
- Their importance in larger farm animal species is not yet apparent. Adequate levels are probably provided not only by all common feeds but by the general environment. Some are extremely toxic e.g. arsenic, lead.

Vitamins

- Definition: Vitamins are organic compound that animals require in very small amount for normal body functions.
- Classification: Vitamins are classify on the basis of their relative solubility in lipid or water.

Vitamins	Chemical name
Fat –soluble vitamins	
Vit.A	Retinol
Vit.D2	Ergocalciferol
Vit.D3	Cholecalciferol
Vit. E	Tocopherol
Vit.K	Phylloquinone
Water soluble vitamins	
B complex	
Vit.B1	Thiamin
Vit.B2	Riboflavin
Vit.B3	Nicotinamide(niacin)
Vit.B6	Pyridoxine
Vit.B12	Cyanocobalamin
Vit.C	Ascorbic acid
	Pantothenic acid
	Biotin
	Folacin and Choline

Feature and General functions

- Chemically and biologically diverse, and therefore hard to classify systematically.
- Not used as metabolic fuels(like glucose, fatty acids) or structural nutrients (like amino acids, Ca,P).
- Generally act as catalysts(facilitators) of the metabolism of other nutrients.

- All vitamins are metabolically essential but not all are necessarily required in the diet, depending on the diet species, and vitamin concerned e.g. most mammals can synthesize B vitamins but ruminants (and other herbivores?) can obtain an adequate supply from bacterial synthesis in rumen (and hind gut?).
- Some compounds functions as vitamins only after undergoing a chemical change. These are called provitamins e.g. β-carotene yield vit.A.