MINERALS

INTRODUCTION

- 90 elements in the earth’s crust.
- 25 are known to be essential to life, they are present in living cells, including in food.
- Food contains additional, non-essential elements.
- Some elements enter food as contaminants
- “Minerals” --- elements other than C, H, O and N.
- Major and trace minerals.

- There are two groups of minerals:
  - Major salt components: K, Na, Ca, Mg, Cl^-, sulfate, phosphate, and HCO_3.
  - Trace elements, usually <50 ppm:
    - Essential nutritive elements: Fe, Cu, I, Co, Mn, Zn, Cr, Ni, Si, F, Mo and Se.
    - Non-nutritive, non-toxic elements: Al, B, and Sn
    - Non-nutritive, toxic elements: Hg, Pb, As, Cd and Sb.
- The mineral material present as inorganic or organic salts or combined with organic materials, e.g., P with phosphoproteins and metals with enzymes.

Minerals

- Usually determined by ashing or incineration that destroy the organic compounds.
- The ash does not include the nitrogen contained in protein.
  - Organic anions disappear during incineration
  - Metals are changed to their oxides
  - Carbonates in ash may be the result of decomposition of organic material

Minerals

- P and S of proteins and P of lipids are also part of ash.
- Some of trace elements and some of salts may be lost by volatilization during the ashing. NaCl will be lost from the ash if the temperature is >600^{o}C.
- While comparing data on mineral composition of foods, attention must be paid to the methods of analysis used.

Minerals - Solubility

- Solubility in aqueous systems is critical --- the availability and reactivity of minerals.
- Minerals in their elemental forms are not biologically available (except for oxygen and nitrogen).
- The forms of elements present in food depend on the chemical properties of the element.

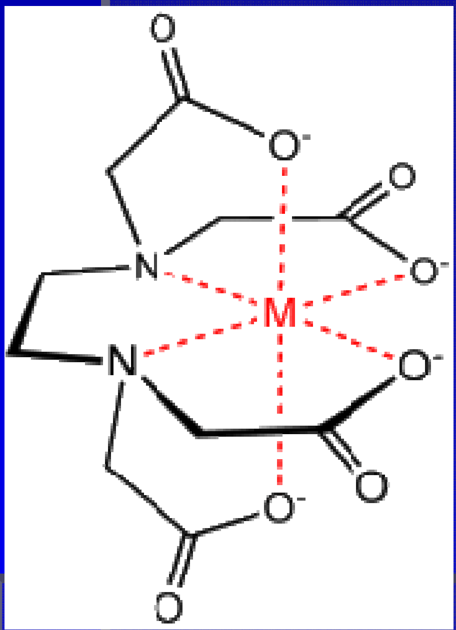
Minerals - Solubility

- Elements from groups IA and VIIA exist in foods as free ionic forms (Na^+, K^+, Cl^-, and F^-). Those ions are highly water soluble and have low affinities for most ligands.
  - Ligands → the electron-donating species of mineral complexes.
  - The principle electron donating atoms in ligands are oxygen, nitrogen, and sulfur → including proteins, carbohydrates, phospholipids and organic acids.
- Most other minerals exist as minerals complexes, chelates or oxygen-containing anions.

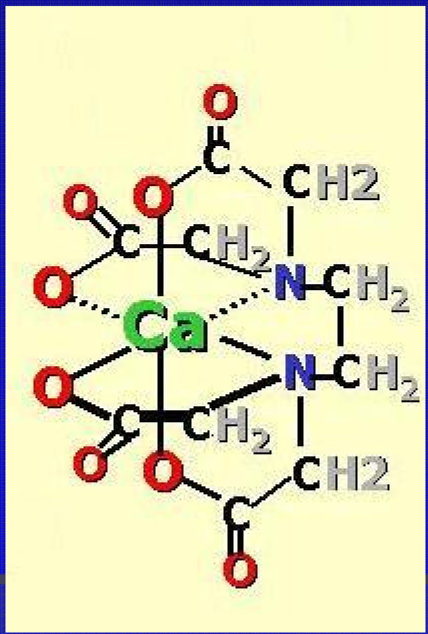
Chelating Agents

- A complex resulting from the combination of a metal ion and multidentate ligands (the ligands form two or more bonds with the metal, resulting in a ring structure that includes the metal ion).
- The chelating ligand must contain at least 2 functional groups capable of donating electrons.
- Chelates have greater thermodynamic stabilities.
- For example:
  - EDTA (ethylene diaminetetra acetic acid) with metal ion
  - Calcium with oxalate
  - Ferric ion with citrate

Chelating Agents



multidentate



Ca-EDTA

- Solubility of mineral chelates may be different from that of inorganic salts.
- Example:
  - $FeCl_2$ will presipitate soon when it is dissolved in water, but Fe^{2+} chelated with citrate is quite soluble.
  - Calcium chloride is quite soluble, but calcium chelated with oxalate is insoluble.

Interactions with Other Food Components

- Behavior of minerals is affected by the presence of other food constituents.

- Absorption of minerals is decreased by fibre:
  - Interactions of Fe, Zn and Ca with phytate, present in fibre.
  - Phytate can form insoluble complexes with Fe and Zn.
  - Phytate may interfere with the absorption of Ca by causing formation of fibre-bound calcium in intestines.

Interactions with Other Food Components

- Heme iron is firmly bound in the center of a porphyrin ring and does not dissociate form this ligand until after it is taken up by intestinal mucosal cells.
- Heme iron is found exclusively in meat, poultry and fish.
- The iron plant foods and about 40-60% of the iron in animal tissues in nonheme iron. It is bound primarily to proteins but also complexed with citrate, phytate, oxalate, polyphenolics or other ligands.
- The biovailability of heme iron is greater than that of nonheme iron.

Interactions with Other Food Components

- Iron bioavailability may be increased in the presence of meat.

  It has been suggested that amino acids or polypeptides that result from digestion are able to chelate non-heme iron. These complexes would facilitate the absorption of iron.

- In nitrite-cured meats some factors promote iron bioavailability, particularly heme iron and ascorbic acid or erythorbic acid.

Interactions with Other Food Components

- Enhancers of nonheme iron absorption include meat, poultry, fish, vit C, EDTA.
- Inhibitors of nonheme iron absorption include polyphenols (tannins in tea), phytates in legumes/cereals, some plants proteins, calcium, phosphate.

Minerals in Milk (Cow's Milk)

- Some of the mineral salts of milk are present at level exceeding their solubility, thus occur in the colloidal form.
- Colloidal particles in milk contain Ca, Mg, phosphate and citrate.
- The colloidal particles precipitate when milk is coagulated with rennin.

Mineral	Level (mg/100mL)
Sodium	50
Potassium	145
Calcium	120
Magnesium	13
Phosphorus (total)	95
Phosphorus (inorganic)	75
Chloride	100
Sulfate	10
Carbonate (CO_2)	20
Citrate	175

Minerals in Milk (Cow's Milk)

- Ca in milk is distributed between milk serum (about 30%) and the casein micelles (mainly present as colloidal calcium phosphate.
- Total Ca exerts a profound effect on the stability of the caseinate particles in milk.
- Ca can form soluble complexes with phosphate.
- Heating and evaporation can change the salt equilibrium and protein stability. When milk is heated, Ca and phosphate change from the soluble to the colloidal phase.

Minerals in Milk (Cow's Milk)

- Decreasing pH results in changing calcium and phosphate from the colloidal to the soluble form.
- At pH 5.2, all Ca and phosphate of milk becomes soluble.
- Addition of various phosphates, particularly polyphosphate can increase the caseinate stability of milk --- Ca chelated to polyphosphate.
- Ca and phosphate play an important functional role in cheese manufacture --- addition Ca before renneting shortens coagulation time.
- While the addition of Ca ions decrease the stability of milk.

Mineral in Meat

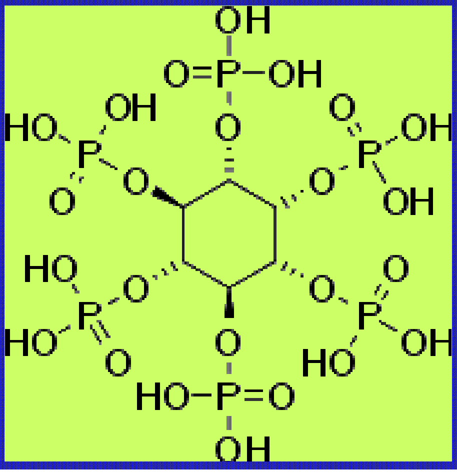
- Na, K and phosphorus are present in relatively high amounts.
- Meat also contains considerably more Mg than Ca.
- Other minerals are citrate and chloride.
- Non-soluble minerals are related with the proteins.
- The leaner meats usually have a higher mineral or ash content.

Mineral in Meat

- When liquid is lost from meat (drip loss), the major element lost is Na, and to a lesser extent Ca, K and phosphorus --- Na is mainly present in the extracellular fluid in association with chloride and bicarbonate.
- During cooking, Na may be lost but the other mineral are well retained.
- Processing does not usually reduce the mineral content of meat.
- Addition to neutral salts such as NaCl to meat increases WHC and swelling (mainly due to the chloride ion).

Mineral in Plant Products

- Plants generally have a higher content of K and Na.
- The major minerals in wheat include K, phosphorus, Ca, Mg and S.
- In soybeans, the ash content is relatively high (almost 5%). K and phosphorus are abundance in soybeans.
- About 70-80% of the phosphorus in soybeans is present in the form of phytic acid.



Mineral in Plant Products

- Fruits are generally not as rich in minerals as vegetables.
- The rate of senescence of fruits and vegetables is influenced by Ca content of the tissue.
- When fruits and vegetables are treated with Ca solutions, the quality and storage life of the products can be extended.

Mineral Fortification

- In the USA, it began in 1923, with salt iodization (to prevent development of goiter).
- Then, enrichment of white flour with Fe, vitamin B_1, B_2 and niacin made mandatory in 1943.
- At present, fortification of foods with Fe and I remains widespread. Ca, Zn and other trace minerals are sometimes added to breakfast cereals and other products.
- The largest number of added minerals is in infant formulae.

Iron fortification

- First recorded recommendation of Fe fortification – 4000 BC (Persia).
- Relatively high prevalence of Fe deficiency anemia
- Technological problems (some form of Fe catalyse oxidation of unsaturated FFAs and of vitamins A, E, and C; forms with high bioavailability are also most active catalytically)
- Stability problems
- $FeSO_4.7H_2O$ – the cheapest, most availability and most widely used.

Iron fortification

- Some studies indicated that off odor and off flavors occur in bakery products made from flour that heavily fortified with ferrous sulfate and stored for extended period of time.
- Recommendations:
  - The concentration ferrous sulfate fortified to flour is kept below 40 ppm and the flour is stored at moderate temperature and humidities not longer than 3 months.
  - Ferrous sulfate should not be used to fortify flour that maybe stored for extended period or flour used in mixes containing added fats, oils and other easily oxidized ingredients.

Iron fortification

- Since fortification using ferrous sulfate is likely to cause problems in foods, in the recent years, elemental ion powders have been the alternative source for fortification of flour. The different types of elemental iron powders include:
  - Reduced iron
  - Electrolytic iron
  - Carbonyl iron

Iron fortification

- Elemental iron powders are relatively stable and do not cause to serious problem with oxidation in food.
- However, iron powders are dark gray in color and do cause a slight darkening of white flour.
- Sodium iron EDTA is attractive as an iron fortificant due to its stability, but there has been reluctant to use iron EDTA in foods because of concern over the possible adverse effect of excessive levels of EDTA in the diet.

Concentration of Selected Trace Minerals in Wheat and Milled Wheat Products

Mineral	Whole Wheat	White Flour	Wheat Germ	Millfeeds (bran)	Loss from wheat to flour
Iron	43	10.5	67	47-78	76
Zinc	35	8	101	54-130	78
Manganese	46	6.5	137	64-119	86
Copper	5	2	7	7-17	68
Selenium	0.6	0.5	1.1	0.5-0.8	16

Values are mg mineral/ kg product

Effects of Processing

- Mineral elements can't be destroyed by exposure to heat, light, oxidizing agents, extremes in pH.
- However, mineral elements can be removed from foods by leaching or physical separation.
- The most important factor causing mineral loss in food is milling of cereals.
- In cheeses, where the pH is low, substantial losses of Ca occur when the whey is drained.

Effects of Processing

- Since many minerals do have significant solubility in water, thus cooking in water would result in some losses of minerals.
- Generally, boiling in water causes greater loss of minerals from vegetables than steaming.
- Mineral losses during cooking of pasta are minimal for Fe but more than 50% for K --- due to K is present in foods as the free ion while Fe is bound to proteins and other high-molecular-weight ligands in food.

Minerals

- Concerns about the role of sodium in elevated arterial blood pressure (hypertension).
- In the USA the total daily intake of NaCl is 10-12 g (=4.5 g of Na) of which:
  - 3 g is occuring naturally in food
  - 3 g is added during food preparation and at the table
  - 4 to 6 g is added during commercial processing
- Daily requirement of NaCl is estimated at 0.5 g.
- NaCl has an important effect on the flavor and acceptability of a variety of food. It can be replaced with a mixture of NaCl and KCl.
- Ca plays an important role in regulating blood pressure.

Factors that May Influence Mineral Bioavailability from Foods:

- Chemical form of the mineral in food:
  - Highly insoluble forms are poorly absorbed.
  - Soluble chelate forms may be poorly absorbed if chelate has high stability.
  - Heme iron is absorbed more efficiently than non-heme iron.

Factors that May Influence Mineral Bioavailability from Foods:

- Food ligands
  - Ligands that form soluble chelate with metals may enhance absorption from some foods (e.g., EDTA enhances iron absorption).
  - High molecular weight ligands that are poorly digestible may reduce absorption (e.g., dietary fibre, some proteins).
  - Ligands that form insoluble chelates with minerals may reduce absorption (e.g., oxalate inhibits calcium absorption, phytic acid inhibits iron, zinc and calcium absorption).

Factors that May Influence Mineral Bioavailability from Foods:

- Redox activity of food components
  - Reductants (e.g., ascorbic acid) enhance absorption of iron but have little effect on other minerals.
  - Oxidants inhibit the absorption of iron.

Factors that May Influence Mineral Bioavailability from Foods:

- Mineral-mineral interactions
  - High concentrations of one mineral in the diet may inhibit the absorption of another (e.g., calcium inhibits iron absorption, iron inhibits zinc absorption, lead inhibits iron absorption).

Factors that May Influence Mineral Bioavailability from Foods:

- Physiological state of consumer
  - Homeostatic regulation of minerals in the body may operate at the site of absorption, resulting in enhanced absorption in deficiency and reduce absorption in adequacy. This is the case of iron, calcium and zinc.
  - Mal-absorption disorders may reduce absorption of minerals.
  - Iron and calcium absorption are reduced in achlorhydria (reduced gastric acid secretion).
  - Age (absorption efficiencies may decline in the elderly).

References

- Principles of Food Chemistry. John deMan (2003).
- Food Chemistry. Owen R. Fennema (1996).

Thank you….

Tugas (diskusi jurnal)

- Faktor apa sajakah yang membatasi fortifikasi suatu mineral pada produk pangan? Jelaskan alasannya!
- Jelaskan hubungan antara fortifikasi atau penambahan mineral dengan stabilitas produk pangan!
- Bagaimana interaksi mineral dengan komponen lain yang ada di produk pangan? Faktor apa saja yang berpengaruh?

Jurnal:

- Time – intensity characteristics of iron compounds (Food Quality and Preference-2006).
- Development, stability, and sensory testing of microcapsules containing iron, iodine and vitamin A for use in food fortification (Sensory and nutritive qualities of food-2006).
- Baby foods: formulations and interactions (Critical reviews in food science and nutrition-2006).