Minerals and trace elements in food and diet

Mineral elements in food

**Definition**: chemical elements contained in the ash of the foodstuff (matter remaining after total oxidation of organic compounds)

**Ash content** – used as an approx. indicator of the total content of mineral elements

**Origin** of mineral elements in food:
- naturally occurring food components
- contaminants
- additives
**Classes of mineral elements**

**According to content**
- major elements (content > 100 mg/kg) (Na), K, Mg, Ca, Cl, P, (S)
- trace elements

**According to significance**
- essential elements major + Fe, Zn, Cu, Mn, (Ni, Co), Cr, Si, (Mo, B), Se, I, F
- toxic elements Pb, Cd, Hg, As
- non-essential elements

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**Total amount of some elements in an adult human body**

<table>
<thead>
<tr>
<th></th>
<th>Ca</th>
<th>Fe</th>
<th>Ni</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000-1500 g</td>
<td>3-5 g</td>
<td>10 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>420-840 g</td>
<td>Zn 1.5-3 g</td>
<td>Cr 5 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>140-180 g</td>
<td>F 0.8-2.5 g</td>
<td>V &lt;1-20 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>140 g</td>
<td>Si 1.4 g</td>
<td>I 10-30 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>70-110 g</td>
<td>Cu 100-180 mg</td>
<td>Se 10-20 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>70-100 g</td>
<td>Mn 10-20 mg</td>
<td>Co 1-1.5 mg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td>24-40 g</td>
<td>Mo 5-10 mg</td>
<td>Cd 5-30 mg</td>
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</tbody>
</table>
### Compounds of metals

examples of amino-acids chelates:

- **Zn(Gly)₂**

- **M(Cys)₂**

- **M(His)₂**
Examples of metal-peptide complexes:

Metal-binding peptides of plant origin
*phytochelatines* (peptides derived from *glutathione*)

Metal-binding polypeptides in animal tissues
*metallothioneins* (MT)

occurrence: liver, kidney, intestinal wall, pancreas, brain
structure: peptide chain containing 60-63 AA, 20 Cys

\[ M_r: 6000-8000 \]

a molecule of MT can bind up to 7 atoms of Cd, Zn, Cu…

Schematic AA sequence of mammalian MT: ⃝ is Cys, ⃝ is other AA than Cys
Other compounds of metals:

- complexes with organic acids (citric, tartaric, phytic etc)
- insoluble salts of organic acids (calcium oxalate, ferric phytate)
- complexes of polysaccharides (pectin)
- metalloporphyrins (chlorophyls, hem)

- organometallics
  (MeHg\(^+\), Me\(_2\)Hg, Et\(_4\)Pb, Bu\(_4\)Sn, Bu\(_3\)SnX)

Compounds of metalloids and non-metals

- arsenic compounds
  - methylarsonic acid
  - dimethylarsinic acid
  - arsenobetaine
  - arsenocholine

- selenium containing amino-acids
  - selenocysteine
  - selenomethionine

- phosphorus compounds
  - phytic acid (phytate)
Sodium and potassium

Biochemical roles
• maintaining of osmotic pressure
• activation of enzymes: α-amylase (Na)
• effect on muscle activity

Metabolism
• rate of absorption approx. 90 %
• excretion in urine and sweat (Na)

Contents in foodstuffs
• Na: from tens mg/kg to units %
• K: from thousands mg/kg to units %

Recommended dietary intakes
• Na: 0.5 to 2.4 g/day (2.4 g Na is equivalent to 6 g NaCl)
• K: 2 g/day

Magnesium and calcium

Biochemical roles
• enzymes activation (Mg – phosphatases, kinases)
• effect on muscle activity (Ca – activation of myosin)
• regulatory functions
• blood coagulation (Ca – fibrinogen → fibrin transformation)
• building up bones

Absorption
• Mg absorption 40-50 % (decreased by phytic acid)
• Ca absorption 2-70 % (decreased by phytic acid, oxalic acid, increased by proteins)
Magnesium and calcium

Occurrence in food
• Mg: hundreds mg/kg to thousands mg/kg (higher content in food of plant origin)
• Ca: hundreds mg/kg to thousands mg/kg (higher content in milk and dairy products)

Recommended dietary intakes
• Mg 300-350 mg/day (adults), 70-200 mg/day (children), 450 mg/day (pregnant women and nursing mothers)
• Ca 800 mg/day (adults), 400-500 mg/day (children), 1200 mg/day (teenagers, pregnant women and nursing mothers)

Phosphorus

Biochemical roles
• energy storage (ATP)
• activation of substrates in enzyme-catalysed reactions
• activation of enzymes
• regulatory functions (cAMP, enzyme co-factors)
• building up biological structures (bones, bio-membranes)

Absorption
• absorption rate 50-70 % (low absorption of P bound in phytic acid)
• effect of Ca – optimum Ca/P ratio: from 1:1 to 2:3
Phosphorus

Occurrence in food
• chemical compounds: phytic acid (high content in cereals, legumes, nuts), other organic phosphates, inorganic phosphates, phosphoric acid
• content: hundreds mg/kg (vegetable, fruit) to thousands mg/kg (dairy products, egg yolk, cereals, legumes)

Recommended dietary intakes
• adults: 1200 mg/day
• children: 300-800 mg/day

Iron

Biochemical roles
• oxygen transport (hemoglobin)
• oxygen storing in muscle tissue (myoglobin)
• constituent of enzymes (catalase, peroxidase, cytochroms etc)

Absorption
• absorption rate 5-15 % (30-60 % in the state of deficiency)
• better availability of hem containing iron compounds
• non-hem iron forms:
  • reduced bio-availability in the presence of phytic acid, plant phenolic compounds (tannins from tea) and some types of dietary fibre
  • ascorbic acid, organic acids, amino-acids (His, Lys, Cys) and sugars increase iron bio-availability
• effect of iron valency: Fe^{2+} > Fe^{3+}
Iron

Occurrence in food

- total Fe content: units to hundreds mg/kg
- high Fe content: kidney, liver, egg yolk, tea leaves, legumes
- low Fe content: fish, poultry, vegetables (except spinach), fruit
- very low Fe content: milk, dairy products
- Fe-enriched food: infant formulas (addition of ferrous fumarate)

Recommended dietary intakes

- 10 mg (men), 12 mg (boys)
- 15 mg (girls and women), 30 mg (pregnant women)
- 6-10 mg (children)

Zinc and copper

Biochemical roles

- catalytic activities: metalloenzymes
- Cu affects metabolism of Fe

Absorption

- absorption rate: Zn approx. 30 %, Cu 25-70 %
- proteins and amino-acids increase Zn bio-availability
- phytic acid decreases Zn bio-availability
- ascorbic acid decreases Cu bio-availability

Occurrence in food

- Zn content: units to tens mg/kg
- Zn-rich food: cheese, liver, legumes, cereals
- Cu content: units mg/kg or lower
- Cu-rich food: liver, legumes, mushrooms
Zinc and copper

Recommended dietary intakes

<table>
<thead>
<tr>
<th>Group</th>
<th>Zn (mg/day)</th>
<th>Cu (mg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>15</td>
<td>1.5-3</td>
</tr>
<tr>
<td>Women</td>
<td>12</td>
<td>1.5-3</td>
</tr>
<tr>
<td>pregnant</td>
<td>15</td>
<td>1.5-3</td>
</tr>
<tr>
<td>nursing</td>
<td>16-19</td>
<td>1.5-3</td>
</tr>
<tr>
<td>Children</td>
<td>5-10</td>
<td>0.4-2</td>
</tr>
</tbody>
</table>

Iodine

Biochemical roles
constituent of thyroid gland hormones (thyroxine, triiodothyronine)

Metabolism
• absorption rate 100 %
• 60 µg/day is fixed in thyroid gland, excess is excreted in urine

Occurrence in food
• sea fish: hundreds µg/kg to units mg/kg
• milk, dairy products tens to hundreds µg/kg
• other food: units to tens µg/kg

Recommended dietary intakes
• 150 µg/day (adults)
• 175 µg/day (pregnant women), 200 µg/day (nursing women)
• 40-50 µg/day (babies), 70 µg/day (toddlers), 90-120 (children)
Selenium

Biochemical roles
- constituent of glutathioneperoxidase
- participation in metabolism of iodine

Metabolism
- absorption rate 50-100 %
- urinary excretion

Occurrence in food
- strongly depends on Se content in soil, water etc.
- higher Se content (tens µg/kg to units mg/kg): sea fish, liver, kidney, wholemeal cereals

Recommended dietary intakes
- 70 µg/day (men)
- 55 µg/day (women), 65-75 µg/day (pregnant and nursing women)
- 20-30 µg/day (toddlers and children),
- 40-45 µg/day (teenagers)