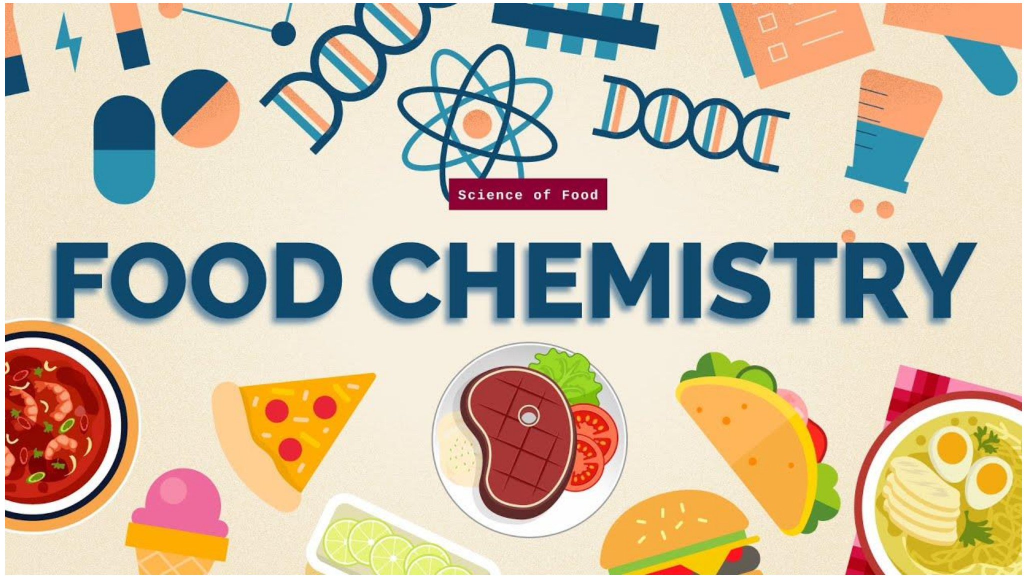
Food Chemistry 0711-2101



DEPARTMENT OF NUTRITION & FOOD ENGINEERING
DAFFODIL INTERNATIONAL UNIVERSITY

Today’s topic

Chemistry of Vitamins & Minerals

Lecture objectives

To learn about:

Chemical Composition → Structure → Stability & Degradation

of Vitamins & Minerals

Vitamins are minor but essential constituents of food. They are required for the **normal growth**, **maintenance** and **functioning** of the human body. Hence, their preservation during storage and processing of food is of far-reaching importance. Vitamin losses can occur through chemical reactions which lead to inactive products, or by extraction or leaching, as in the case of water-soluble vitamins during blanching and cooking.

The vitamin requirement of the body is usually adequately supplied by a balanced diet. A deficiency can result in **hypovitaminosis** and, if more severe, in **avitaminosis**. Both can occur not only as a consequence of insufficient supply of vitamins by food intake, but can be caused by disturbances in resorption, by stress and by disease.

An assessment of the extent of vitamin supply can be made by determining the vitamin content in blood plasma, or by measuring a biological activity which is dependent on the presence of a vitamin, as are many enzyme activities.

Vitamins are usually divided into **two** general classes:

1. Fat-soluble vitamins:

- Vitamin A (Retinol)
- Vitamin D (Calciferol)
- Vitamin E (α-Tocopherol) and
- Vitamin K_1 (Phylloquinone)

2. Water-soluble vitamins,

- Thiamin (B_1)
- Riboflavin (B_2),
- Nicotinamide (niacin or B_3)
- Pantothenic acid (B_5)
- Pyridoxine (B_6)
- Biotin (B_7)
- Folic acid (B_9)
- Cyanocobalamin (cobalamin or B_{12})
- Ascorbic acid (C)

Table 6.3. Recommended daily intake of vitamins

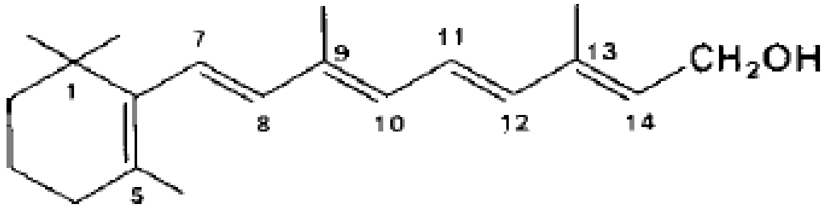
Age group (years)	A (mg Retinol[a])	D (μg)[b]	E (mg)[c]	K (μg)[d]	C (mg)	B_1 (mg)	B_2 (mg)	Niacin[e] (mg)	B_6 (μg)	Folic acid[f] (mg)	Pantothenic acid (mg)	Biotin (μg)	B_{12} (μg)
<1	0.5–0.6	10	3–4	4–10	50–55	0.2–0.4	0.3–0.4	2–5	0.1–0.3	60–80	2–3	5–10	0.4–0.8
1–4	0.6	5	6	15	60	0.6	0.7	7	0.4	200	4	10–15	1.0
4–10	0.7–0.8	5	8–10	20–30	70–80	0.8–1.0	0.9–1.1	10–12	0.5–0.7	300	4–5	15–20	1.5–1.8
10–15	0.9–1.1	5	10–14	40–50	90–100	1.0–1.3	1.2–1.6	13–18	1.0–1.4	400	5–6	20–35	2.0–3.0
15–25	0.9–1.1	5	15	60–70	100	1.0–1.3	1.2–1.5	13–17	1.2–1.6	400	6	30–60	3.0
25–51	0.8–1.0	5	14	60–70	100	1.0–1.2	1.2–1.4	13–16	1.2–1.5	400	6	30–60	3.0
52–65	0.8–1.0	5	13	80	100	1.0–1.1	1.2–1.3	13–15	1.2–1.5	400	6	30–60	3.0
>65	0.8–1.0	10	12	80	100	1.0	1.2	13	1.2–1.4	400	6	30–60	3.0
Pregnant women	1.1	5	13	60	100	1.2	1.5	15	1.9	600	6	30–60	3.5
Lactating women	1.5	5	17	60	150	1.4	1.6	17	1.9	600	6	30–60	4.0

[a] 1 mgretinol = 1 mgretinol equivalent = 6 mg all-trans-β-carotene = 12 mg other provitamin A carotinoids = 1.15 mgall-trans-retinyl acctate = 1.83 mg all-trans-retinyl palmitate (IU = 0.34 μg retinol).
[b] Ergocalciferol (D_2) or cholecalciferol (D_3) (1 IU = 0.025 μg).
[c] Tocopherol equivalent (cf. 6.2.3.1).
[d] Phylloquinone (cf. 6.2.4).
[e] 1 mg niacin equivalent = 60 mgtryptophan.
[f] 1 μg folate equivalent = 1 μg food folate = 0.5 μg folic acid (PGA, cf. 6.3.7.1).

Retinol (Vitamin A)

Retinol (I) is of importance in protein metabolism of cells which develop from the ectoderm (such as skin or mucouscoated linings of the respiratory or digestive systems). Lack of retinol in some way negatively affects epithelial tissue (thickening of skin, hyperkeratosis) and also causes night blindness.

Furthermore, retinol, in the form of **11-cis-retinal (II)**, is the chromophore component of the visual cycle chromoproteins in three types of cone cells, blue, green and red (λmax 435, 540 and 565 nm, respectively) and of rods of the retina.



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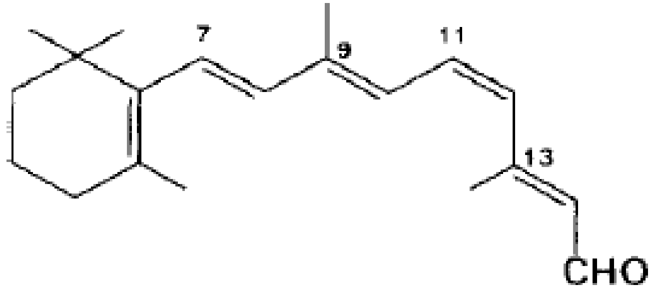

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Retinol (Vitamin A)

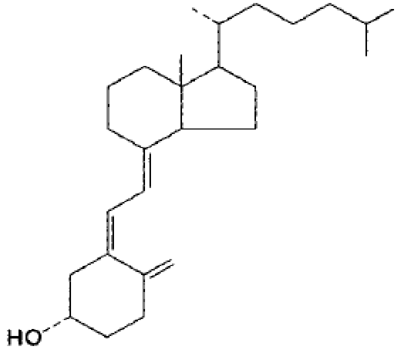
Vitamin A occurs only in animal tissue; above all in fish liver oil, in livers of mammals, in milk fat and in egg yolk. Plants are devoid of vitamin A but do contain carotenoids which yield vitamin A by cleavage of the centrally located double bond (provitamins A). Carotenoids are present in almost all vegetables but primarily in green, yellow and leafy vegetables and in fruit which is often used for yellow coloring. Animal carotenoids are always of plant origin, derived from feed.

Stability & Degradation

Food processing and storage can lead to 5–40% destruction of vitamin A and carotenoids. In the absence of oxygen and at higher temperatures, as experienced in cooking or food sterilization, the main reactions are isomerization and fragmentation. In the presence of oxygen, oxidative degradation leads to a series of products, some of which are volatile. This oxidation often parallels lipid oxidation (cooxidation process). The rate of oxidation is influenced by oxygen partial pressure, water activity, temperature, etc. Dehydrated foods are particularly sensitive to oxidative degradation.

Calciferol (Vitamin D)

Cholecalciferol (vitamin D_3, I) is formed from cholesterol in the skin through photolysis of 7-dehydrocholesterol (provitamin D_3) by ultraviolet light ("sunshine vitamin). Similarly, vitamin D_2 (ergocalciferol, II) is formed from ergosterol. Most natural foods have a low content of vitamin D_3. Fish liver oil is an exceptional source of vitamin D_2. The D-provitamins, ergosterol and 7-dehydrocholesterol, are widely distributed in the animal and plant kingdoms. However, the most important vitamin D source is fish oil, primarily liver oil. The vitamin D requirement of humans is best supplied by 7-dehydrocholesterol.



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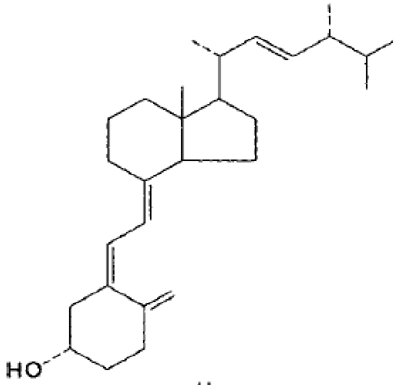

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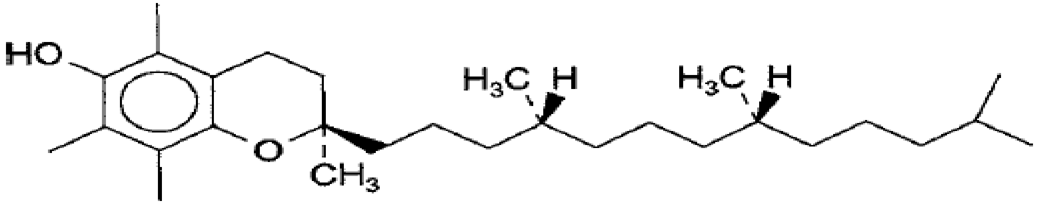
Stability & Degradation

Vitamin D is sensitive to oxygen and light. Its stability in food is not a problem, because adults usually obtain a sufficient supply of this vitamin.

α-Tocopherol (Vitamin E)

The various tocopherols differ in the number and position of the methyl groups on the ring. α-Tocopherol has the highest biological activity). Its activity is based mainly on its antioxidative properties, which retard or prevent lipid oxidation. Thus, it not only contributes to the stabilization of membrane structures, but also stabilizes other active agents (e. g., vitamin A, ubiquinone, hormones, and enzymes) against oxidation. Vitamin E deficiency is associated with chronic disordes (sterility in domestic and experimental animals). Its mechanism of actionis not fully elucidated. The main sources are vegetable oils, particularly germ oils of cereals.

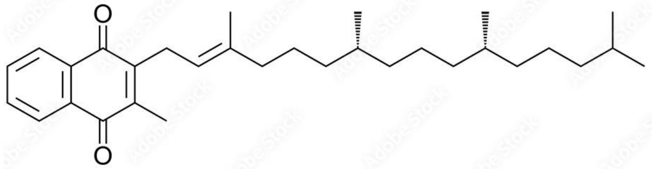


Stability & Degradation

Losses occur in vegetable oil processing into margarine and shortening. Losses are also encountered in intensive lipid autoxidation, particularly in dehydrated or deep fried foods

Phytomenadione (Vitamin K_1, Phylloquinone)

The K-group vitamins are naphthoquinone derivatives which differ in their side chains. Blood clotting factors (prothrombin, proconvertin, Christmas and Stuart factor) as well as proteins which perform other functions belong to the group of vitamin K-dependent proteins which bind Ca^{2+} ions at Gla. Deficiency of this vitamin causes reduce prothrombin activity, hypothrombinemia and hemorrhage. Vitamin K_1 occurs primarily in green leafy vegetables (spinach, cabbage, cauliflower), but liver (veal or pork) is also an excellent source



Phytomenadione
Vitamin K_1

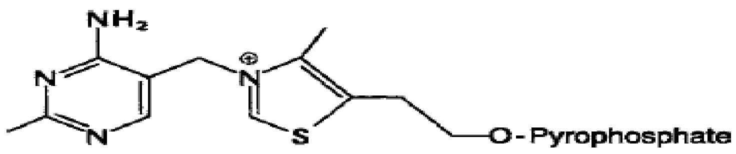
$C_{31}H_{46}O_2$

Stability & Degradation

Little is known about the reactions of vitamin K_1 in foods. The vitamin K compounds are destroyed by light and alkali. They are relatively stable to atmospheric oxygen and exposure to heat.

Thiamine (Vitamin B_1)

Thiamine, in the form of its pyrophosphate, such as pyruvate dehydrogenase, transketolase, phosphoketolase and α-ketoglutarate dehydrogenase, in reactions involving the transfer of an activated aldehyde unit. Vitamin B_1 deficiency is shown by a decrease in activity of the enzymes mentioned above. The disease known as **beri-beri**, which has neurological and cardiac symptoms, results from a severe dietary deficiency of thiamine. Vitamin B_1 is abundant in cereals, yeast, vegetables (such as potatoes), meat (pork, beef, fish), eggs, and animal organs (liver, kidney, brain, heart), as well as in human and cow's milk. However, refining processes like flour milling and rice polishing remove much of the vitamin found in the bran.

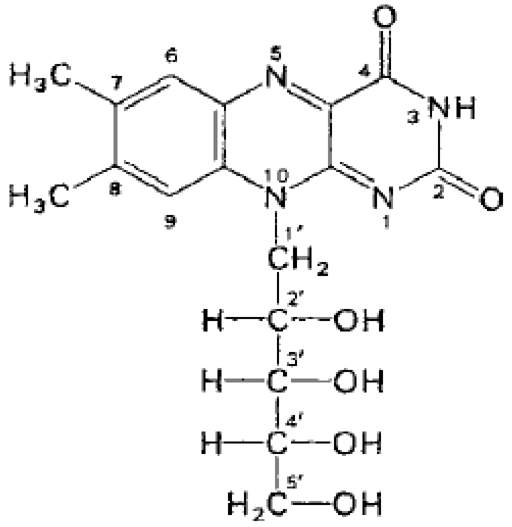


Stability & Degradation

Thiamine stability in aqueous solution is relatively low. Thermal degradation of thiamine, which also initially yields the thiazole and pyrimidine derivatives, is involved in the formation of meat-like aroma in cooked food Thiamine is inactivated by nitrites, probably through reaction with the amino group attached to the pyrimidine ring.

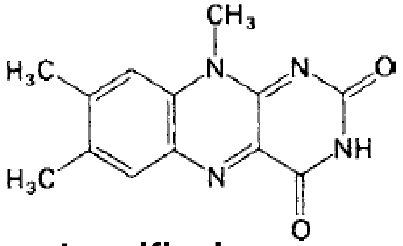
Riboflavin (Vitamin B_2)

Riboflavin is the prosthetic group of flavine enzymes, which are of great importance in general metabolism and particularly in metabolism of protein. Riboflavin deficiency will lead to accumulation of amino acids. A specific deficiency symptom is the decrease of glutathione reductase activity in red blood cells. The most important sources of riboflavin are milk and milk products, eggs, various vegetables, yeast, meat products, particularly variety meats such as heart, liver and kidney, and fish liver and roe.



Stability & Degradation

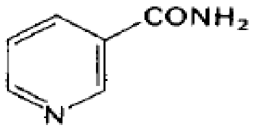
Riboflavin is relatively stable in normal food handling processes. Losses range from 10–15%. Exposure to light, especially in the visible spectrum from 420–560 nm, photolytically cleaves ribitol from the vitamin, converting it to lumiflavin:



Lumiflavin

Nicotinamide (Niacin, Vitamin B_3)

Nicotinic acid amide (**I**), in the form of nicotinamide adenine dinucleotide (NAD^+) or its phosphorylated form ($NADP^+$), is a coenzyme of dehydrogenases. Its excretion in urine is essentially in the form of N^1-methylnicotinamide (trigonelline amide, **II**), N^1-methyl-6-pyridone-3-carboxamide (**III**) and N^1-methyl-4-pyridone-3-carboxamide (**IV**).



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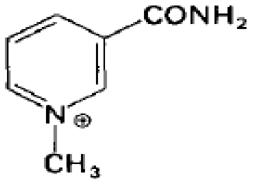

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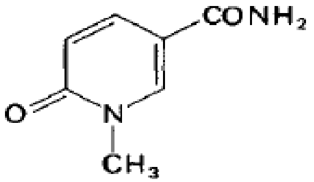

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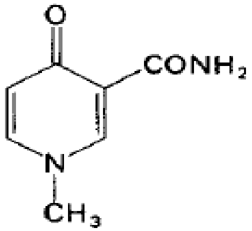


IV

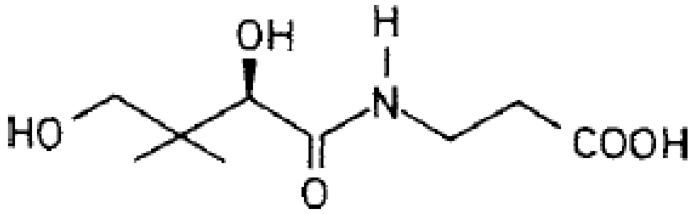
Initial vitamin deficiency reduces NAD+ and NADP+ in liver and muscles, while levels remain normal elsewhere. Pellagra, a classic deficiency disease, causes skin, digestion, and nervous system issues. Initial symptoms are nonspecific. The vitamin occurs in food as nicotinic acid, either as its amide or as a coenzyme. Animal organs, such as liver, and lean meat, cereals, yeast and mushrooms are abundant sources of niacin

Stability & Degradation

Nicotinic acid is quite stable. Moderate losses of up to 15% are observed in blanching of vegetables. The loss is 25–30% in the first days of ripening of meat.

Pantothenic Acid (Vitamin B_5)

Pantothenic acid is the building unit of coenzyme A (CoA), the main carrier of acetyl and other acyl groups in cell metabolism. Pantothenic acid occurs in free form in blood plasma, while in organs it is present as CoA. The highest concentrations are in liver, adrenal glands, heart and kidney. Animal proteins, avocado, broccoli &cabbage family, eggs, legumes and lentils, milk, mushrooms etc. contain vit. B_5

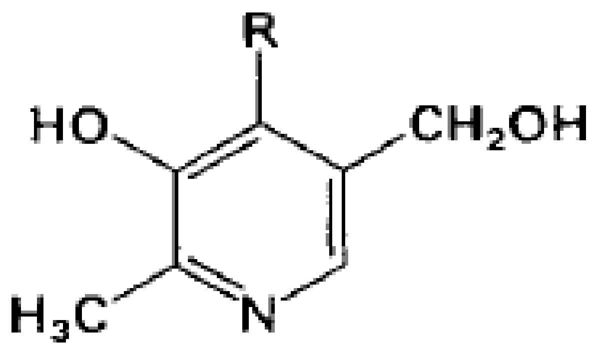


Stability & Degradation

Pantothenic acid is quite stable. Losses of 10% are experienced in processing of milk. Losses of 10–30%, mostly due to leaching, occur during cooking of vegetables.

Pyridoxine (Pyridoxal, Vitamin B_6)

Vitamin B_6 activity is exhibited by pyridoxine or pyridoxol (R = CH_2OH), pyridoxal (R = CHO) and pyridoxamine (R = CH_2NH_2). The intake of the vitamin occurs usually in the forms of pyridoxal or pyridoxamine. Pyridoxine deficiency in the diet causes disorders in protein metabolism, e. g., in hemoglobin synthesis. An indicator of sufficient supply is the activity of glutamate oxalacetate transaminase, an enzyme present in red blood cells. This activity is decreased in vitamin deficiency.

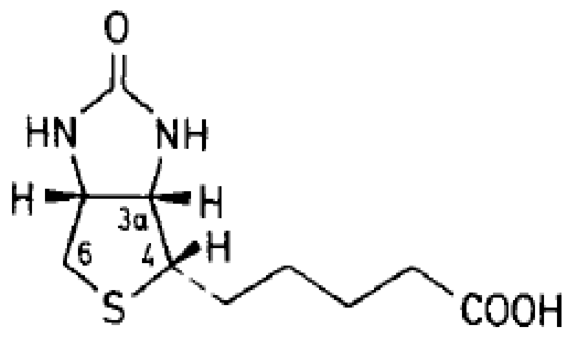


Stability & Degradation

The most stable form of the vitamin is pyridoxal, and this form is used for vitamin fortification of food. Vitamin B_6 loss is 45% in cooking of meat and 20–30% in cooking of vegetables. During milk sterilization, a reaction with cysteine transforms the vitamin into an inactive thiazolidine derivative.

Biotin (Vitamin B_7)

Biotin is the prosthetic group of carboxylating enzymes and therefore plays an important role in fatty acid biosynthesis and in gluconeogenesis. Biotin deficiency rarely occurs. Consumption of large amounts of raw egg white might inactivate biotin by its specific binding to avidin. Biotin is not free in food, but is bound to proteins.

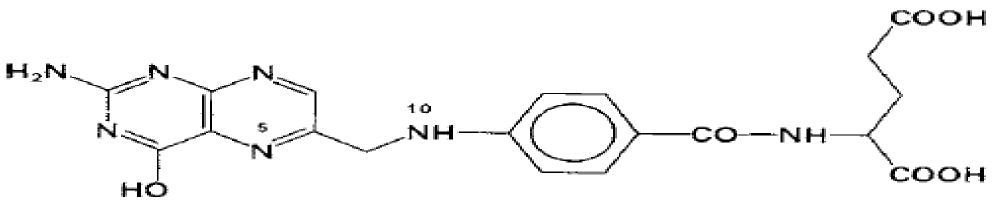


Stability & Degradation

Biotin is quite stable. Losses during processing and storage of food are 10–15%.

Folic Acid (Vitamin B_9)

The tetrahydrofolate derivative (II) of folic acid (I, pteroylmonoglutamic acid, PGA) is the cofactor of enzymes which transfer single carbon units in various oxidative states, e. g., formyl or hydroxymethyl residues. Folic acid deficiency, from diet insufficiency or absorption issues, is detected by decreased levels in red blood cells and plasma, correlating with altered blood cell patterns, impacting neural tube development and causing various diseases. Folate is naturally present in a wide variety of foods, including vegetables (especially dark green leafy vegetables), fruits and fruit juices, nuts, beans, peas, seafood, eggs, dairy products, meat, poultry, and grains



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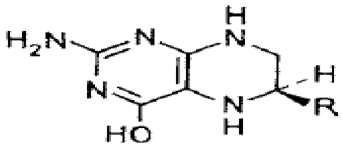

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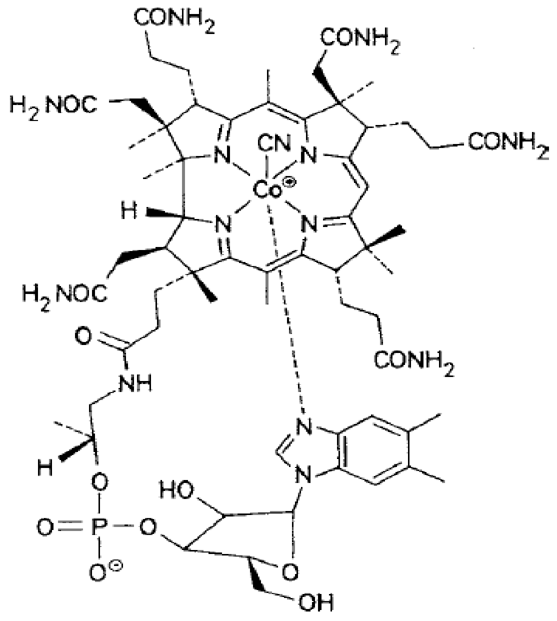
Stability & Degradation

Folic acid is quite stable. There is no destruction during blanching of vegetables, while cooking of meat gives only small losses. Losses in milk are apparently due to an oxidative process and parallel those of ascorbic acid. Ascorbate added to food preserves folic acid.

Cyanocobalamin (Vitamin B_{12})

Cyanocobalamin was isolated in 1948 from *Lactobacillus lactis*. Due to its stability and availability, it is the form in which the vitamin is used most often. In fact, cyanocobalamin is formed as an artifact in the processing of biological materials. Cobalamins occur naturally as adenosylcobalamin and methylcobalamin. Deficiency of vitamin B_{12} is usually caused by impaired absorption due to inadequate formation of "intrinsic factor" and results in pernicious anemia. Vitamin B_{12} is present in foods of animal origin, including fish, meat, poultry, eggs, and dairy products

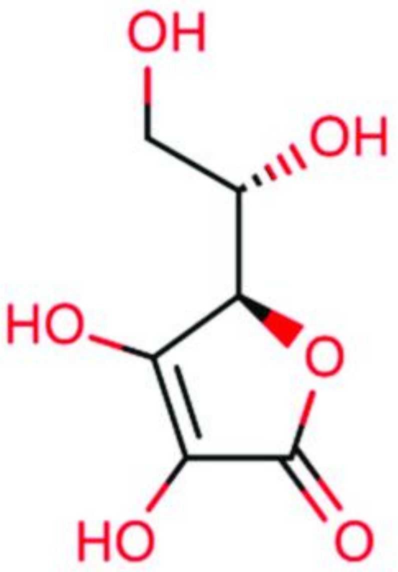


Stability & Degradation

The stability of vitamin B_{12} is very dependent on a number of conditions. It is fairly stable at pH 4–6, even at high temperatures. In alkaline media or in the presence of reducing agents, such as ascorbic acid or SO_2, the vitamin is destroyed to a greater extent.

L-Ascorbic Acid (Vitamin C)

Vitamin C is fully absorbed and distributed throughout the body, with the highest concentration in adrenal and pituitary glands. Scurvy results from a dietary deficiency of ascorbic acid, with a small portion of vitamin C pool excreted in urine, primarily as oxalic acid only at very high intakes. Insufficient vitamin supply is indicated by low plasma levels (0.65 mg/100ml); vitamin C is abundant in various plant sources but can be lost during storage, and most commercially available ascorbic acid is synthesized, with genetically modified microorganisms being cost-effective.



L-ascorbic acid

Stability & Degradation

Ascorbic acid is readily oxidized to dehydroascorbic acid, which exhibits weaker biological activity, with complete loss of activity when converted to 2,3-diketogulonic acid.

Minerals

Minerals are the constituents which remain as ash after the combustion of plant and animal tissues. Minerals are divided into:

• **The main elements** (Na, K, Ca, Mg, Cl, P) are essential for human beings in amounts >50 mg/day. Sulfur also belongs to this group.

• **Trace elements** (Fe, I, F, Zn, Se, Cu, Mn, Cr, Mo, Co, Ni) are essential in concentrations of <50 mg/day; their biochemical actions have been elucidated.

• **Ultra-trace eleme**nts (Al, As, Ba, Bi, B, Br, Cd, Cs, Ge, Hg, Li, Pb, Rb, Sb, Si, Sm, Sn, Sr, Tl, Ti, W) are elements whose essentiality has been tested in animal experiments over several generations and deficiency symptoms have been found under these extreme conditions.

Main elements in the human body

Element	Content g/kg
Calcium	10–20
Phosphorus	6–12
Potassium	2–2.5
Sodium	1–1.5
Chlorine	1–1.2
Magnesium	0.4–0.5

Nutritional and Toxicological Aspects of Minerals

Mineral	Function	Deficiency Effects	Adverse Effects from Excessive Intake	Food Sources
Calcium	Bone and tooth mineralization, blood clotting, hormone secretion, nerve transmission	Increased risk for osteoporosis, hypertension, and some cancers.	Excessive intakes rare; may cause kidney stones and milk alkali syndrome.	Milk, yogurt, cheese, fortified juices, tofu, kale, broccoli, fish bones.
Phosphorus	Bone mineralization; DNA and RNA synthesis; phospholipid synthesis, energy metabolism, cell signaling	Deficiency rare due to ubiquitous distribution in foods; low intakes may impair bone mineralization.	Impaired bone formation, kidney stones, decreased Ca and Fe absorption, iron and zinc deficiency due to high phytate intakes.	Present in virtually all foods. High-protein foods (meats, dairy, etc.), cereal products, and cola beverages (as H_3PO_4) are especially rich sources
Magnesium	Cofactor for numerous enzymes	Deficiency is rare except in certain clinical situations; patients recovering from cardiac surgery are often hypomagnesemic	Rarely occurs except from overconsumption of Mg supplements; causes intestinal distress, diarrhea, cramping, and nausea	Green leafy vegetables, milk, whole grains
Sodium	Predominant cation in extracellular fluid; controls extracellular fluid volume and blood pressure; required for transport of many nutrients into and out of cells	Deficiency is rare except in endurance sports. Deficiency may cause muscle cramping.	Chronically high intakes may lead to hypertension in salt-sensitive persons	Most foods are naturally low in Na. Processed and prepared foods contain varying levels of added Na

Nutritional and Toxicological Aspects of Minerals

Mineral	Function	Deficiency Effects	Adverse Effects from Excessive Intake	Food Sources
Iron	Oxygen transport (hemoglobin and myoglobin), respiration and energy metabolism (cytochromes and iron–sulfur proteins), destruction of hydrogen peroxide (hydrogen peroxidase and catalase), and DNA synthesis (ribonucleotide reductase)	Deficiency is widespread. Effects include fatigue, anemia, impaired work capacity, impaired cognitive function, impaired immune response, and poor pregnancy outcomes.	Iron overload leading to increased risk for some cancers and heart disease.	Red meat, cereal products, beans, fortified foods, green leafy vegetables.
Zinc	Cofactor in metalloenzymes, regulation of gene expression	Growth retardation, impaired wound healing, delayed sexual maturation, impaired immune response, and diarrhea	Inhibition of Cu and Fe absorption, impaired immune response	Red meat, shellfish, wheat germ, fortified foods.
Iodine	Required for synthesis of thyroid hormones	Goiter, mental retardation, decreased fertility, miscarriage, cretinism, and hypothyroidism.	Rare in iodine replete persons, hyperthyroidism in iodine deficient persons.	Iodized salt, seaweed, seafood, dairy products (if I is added to feed or iodine containing sanitizers are used).
Selenium	Antioxidant (as component in peroxidases)	Myocarditis, osteoarthritis, and increased risk for some cancers.	Hair and nail loss, skin lesions, nausea, increased risk for some cancers.	Cereals grown on high-Se soils, meat from animals supplemented with Se

Nutritional and Toxicological Aspects of Minerals

Mineral	Function	Deficiency Effects	Adverse Effects from Excessive Intake	Food Sources
Lead	None, not an essential nutrient	None	Learning and behavioral problems in children, anemia, kidney damage.	Contamination of foods from Pb-soldered cans, exhaust from cars burning leaded gasoline, some ceramic glazes
Mercury	None, not an essential nutrient	None	Numbness, vision and hearing loss, kidney damage.	Fish (especially long-lived carnivorous fish).
Cadmium	Unknown	Depressed growth in rats	Kidney damage, bone disease, cancer.	Grains and vegetables grown on Cd-contaminated soils.

Dietary Reference Intakes of Nutritionally Essential Minerals (Ca, P, and Mg)[a]

	Calcium (mg/day)	Phosphorus (mg/day)	Magnesium (mg/day)
Life Stage	RDA/AI/UL	RDA/AI/UL	RDA/AI/UL
Infants			
0–6 months	210/ND[b]	**100**/ND	30/ND
7–12 months	270/ND	**275**/ND	75/ND
Children			
1–3 years	500/2500	**460**/3000	**80**/65
4–8 years	800/2500	**500**/3000	**130**/110
Males			
9–13 years	1300/2500	**1250**/4000	**240**/350
14–18 years	1300/2500	**1250**/4000	**410**/350
19–30 years	1000/2500	**700**/4000	**400**/350
31–50 years	1000/2500	**700**/4000	**420**/350
50–70 years	1200/2500	**700**/4000	**400**/350
>70 years	1200/2500	**700**/3000	**400**/350
Females			
9–13 years	1300/2500	**1250**/4000	**240**/350
14–18 years	1300/2500	**1250**/4000	**360**/350
19–30 years	1000/2500	**700**/4000	**310**/350
31–50 years	1000/2500	**700**/4000	**320**/350
50–70 years	1200/2500	**700**/4000	**320**/350
>70 years	1200/2500	**700**/3000	**320**/350
Pregnancy			
≤18 years	1300/2500	**1250**/3500	**400**/350
19–30 years	1000/2500	**700**/3500	**350**/350
31–50 years	1000/2500	**700**/3500	**350**/350
Lactation			
≤18 years	1300/2500	**1250**/4000	**360**/350
19–30 years	1000/2500	**700**/4000	**310**/350
31–50 years	1000/2500	**700**/4000	**320**/350

Dietary Reference Intakes of Nutritionally Essential Trace Minerals (Fe, Zn, Se, I, and F)[a]

	Iron (mg/day)	Zinc (mg/day)	Selenium (μg/day)	Iodine (μg/day)	Fluoride (mg/day)
Life Stage	RDA or AI/UL	RDA or AI/UL	RDA or AI/UL	RDA or AI/UL	RDA or AI/UL
Infants					
0–6 months	0.27/40	2/4	15/45	110/ND[b]	0.01/0.7
7–12 months	**11**/40	**3**/5	20/60	130/ND	0.5/0.9
Children					
1–3 years	**7**/40	**3**/7	**20**/90	**90**/200	0.7/1.3
4–8 years	**10**/40	**5**/12	**30**/150	**90**/300	1/2.2
Males					
9–13 years	**8**/40	**8**/23	**40**/280	**120**/600	2/10
14–18 years	**11**/45	**11**/34	**55**/400	**150**/900	3/10
19–30 years	**8**/45	**11**/40	**55**/400	**150**/1100	4/10
31–50 years	**8**/45	**11**/40	**55**/400	**150**/1100	4/10
50–70 years	**8**/45	**11**/40	**55**/400	**150**/1100	4/10
>70 years	**8**/45	**11**/40	**55**/400	**150**/1100	4/10
Females					
9–13 years	**8**/40	**8**/23	**40**/280	**120**/600	2/10
14–18 years	**15**/45	**9**/34	**55**/400	**150**/900	3/10
19–30 years	**18**/45	**8**/40	**55**/400	**150**/1100	3/10
31–50 years	**18**/45	**8**/40	**55**/400	**150**/1100	3/10
50–70 years	**8**/45	**8**/40	**55**/400	**150**/1100	3/10
>70 years	**8**/45	**8**/40	**55**/400	**150**/1100	3/10
Pregnancy					
≤18 years	**27**/45	**12**/34	**60**/400	**220**/900	3/10
19–30 years	**27**/45	**11**/40	**60**/400	**220**/1100	3/10
31–50 years	**27**/45	**11**/40	**60**/400	**220**/1100	3/10
Lactation					
≤18 years	**10**/45	**13**/34	**70**/400	**290**/900	3/10
19–30 years	**9**/45	**12**/40	**70**/400	**290**/1100	3/10
31–50 years	**9**/45	**12**/40	**70**/400	**290**/1100	3/10

Functional Roles of Minerals and Mineral Salts/Complexes in Foods

Mineral	Food Sources	Function
Aluminum	Low and variable in foods; food additives (leavening acids, coloring agents) are a major source. Endogenous Al in plant food and contamination from Al cooking vessels also contribute.	*Leavening acid*: As sodium aluminum sulfate ($Na_2SO_4 \cdot Al_2(SO_4)_3$). *Colorant*: Al lakes of food dyes. *Emulsifying agent*: $Na_3Al(PO_4)_2$ in processed cheese.
Bromine	Brominated flour.	*Dough improver*: $KBrO_3$ improves baking quality of wheat flour. It has largely been replaced by ascorbic acid in the United States.
Calcium	Dairy products, green leafy vegetables, tofu, fish bones, Ca-fortified foods.	*Texture modifier*: Forms gels with negatively charged macromolecules such as alginates, low methoxy pectins, soy proteins, and caseins. Increases viscosity of alginate solutions. Firms canned vegetables when added to canning brine.
Copper	Organ meats, seafood, nuts, seeds.	*Catalyst*: Lipid peroxidation, ascorbic acid oxidation, nonenzymatic oxidative browning. *Color modifier*: May cause black discoloration in canned, cured meats. *Enzyme cofactor*: Polyphenol oxidase *Texture stabilizer*: Stabilizes egg white foams.
Iodine	Iodized salt, seafood, plants and animals grown in areas where soil iodine is not depleted.	*Dough improver*: KIO_3 improves baking quality of wheat flour.
Iron	Cereals, legumes, meat, contamination from iron utensils and soil, enriched or fortified foods.	*Catalyst*: Fe^{2+} and Fe^{3+} catalyze lipid peroxidation in foods. *Color modifier*: Color of fresh meat depends on the valence of Fe in myoglobin and hemoglobin: Fe^{2+} is red. Fe^{3+} is brown. Forms green, blue, or black complexes with polyphenolic compounds. Reacts with S^{2-} to form black FeS in canned foods. *Enzyme cofactor*: Lipoxygenase, cytochromes, ribonucleotide reductase, etc.

Magnesium	Whole grains, nuts, legumes, green leafy vegetables.	*Color modifier*: Removal of Mg from chlorophyll changes color from green to olive brown.
Manganese	Whole grains, fruits, vegetables.	*Enzyme cofactor*: Pyruvate carboxylase, superoxide dismutase.
Nickel	Plant foods.	*Catalyst*: Hydrogenation of vegetable oils and reducing sugars—finely divided, elemental Ni is the most widely used catalyst for this process.
Phosphates	Ubiquitous, animal products tend to be good sources; widely used food additive.	*Acidulent*: H_3PO_4 in soft drinks. *Leavening acid*: $Ca(HPO_4)_2$ is a fast-acting leavening acid. *Moisture retention in meats*: Sodium tripolyphosphate improves moisture retention in cured meats. *Emulsification aid*: Phosphates are used to aid emulsification in comminuted meats and in process cheeses.
Potassium	Fruits, vegetables, meats.	*Salt substitute*: KCl may be used as a salt substitute; may cause bitter flavor. *Leavening acid*: Potassium acid tartrate.
Selenium	Seafood, organ meats, cereals (levels vary depending on soil levels).	*Enzyme cofactor*: Glutathione peroxidase.

(*Continued*)

Functional Roles of Minerals and Mineral Salts/Complexes in Foods

Mineral	Food Sources	Function
Sodium	NaCl, MSG, other food additives, milk; low in most raw foods.	*Flavor modifier*: NaCl elicits the classic salty taste in foods and enhances other flavors. *Preservative*: NaCl may be used to lower water activity in foods to prevent or control microbial growth. *Leavening agents*: Many leaving agents are sodium salts, e.g., sodium bicarbonate, sodium aluminum sulfate, and sodium acid pyrophosphate.
Sulfur	Widely distributed as component of sulfur-containing amino acids, food additives (sulfites, SO_2).	*Browning inhibitor*: Sulfur dioxide and sulfites inhibit both enzymatic and nonenzymatic browning; widely used in dried fruits. *Antimicrobial*: Prevents and controls microbial growth; widely used in wine making.
Zinc	Meats, cereals, fortified foods.	ZnO is used in the lining of cans for proteinaceous foods to lessen formation of black FeS during heating.

Minerals in Food Processing

there are metal ions, derived from food itself or acquired during food processing and storage, which interfere with the quality and visual appearance of food. They can cause discoloration of fruit and vegetable products and many metal-catalyzed reactions are responsible for losses of some essential nutrients, for example, ascorbic acid oxidation. Also, they are responsible for taste defects or off-flavors, for example, as a consequence of fat oxidation. Therefore, the removal of many interfering metal ions by chelating agents) or by other means is of importance in food processing.

Mineral losses in food processing

Raw material	Product	Loss (%)						
		Cr	Mn	Fe	Co	Cu	Zn	Se
Spinach	Canned		87		71		40	
Beans	Canned						60	
Tomatoes	Canned						83	
Carrots	Canned				70			
Beetroot	Canned				67			
Green beans	Canned				89			
Wheat	Flour		89	76	68	68	78	16
Rice	Polished rice	75	26			45	75	


ANY
QUESTIONS?

THANK YOU!