Paper No: 1

Paper Title: Food Chemistry

Module No: 27: Nutritional aspects and factors affecting composition of minerals in food

Minerals are the inorganic elements, other than carbon, hydrogen, oxygen and nitrogen, which remain behind in the ash when food is incinerated. They are usually divided into two groups – macrominerals and microminerals (or trace elements). The terms are historical in origin and originated at a time when the development of analytical equipment was still in its infancy and 'trace' was used to refer to components whose presence could be detected, but not quantified. Modern analytical equipment that allows determination of elements at levels in the nano- and even picogram range, can show the presence of most of the minerals in almost any food. Some are present in minute amounts, but others are at significant levels.

The minerals are classified as either essential or non-essential, depending on whether or not they are required for human nutrition and have metabolic roles in the body. Non-essential elements are also categorised as either toxic or non-toxic. Table 27.1 lists elements that occur in food and are important in human nutrition. In addition to the essential elements, some others, including arsenic, silicon and boron, have been shown to be required by certain animals and may also play beneficial roles in the human body.

Table 27.1. Mineral elements in food

Macrominerals (g/kg)	**Microminerals (mg/kg)**	**Toxic minerals (mg/kg)**
Calcium (<1–12)	Chromium (<0.02–0.95)	Cadmium (0.001–0.07)
Magnesium (1–4)	Cobalt (0.008–0.32)	Lead (0.01–0.25)
Phosphorus (1–6)	Copper (<0.2–3.3)	Mercury (<0.001–0.18)
Potassium (1–6)	Iodine (0.04–0.66)	
Sodium (1–19)	Iron (<0.2–92)	
Sulphur (<2–6)	Manganese (<0.10–14.0)	
	Molybdenum (0.004–1.29)	
	Selenium (<0.001–0.34)	
	Zinc (0.2–8.6)	

Ref: Reilly C (2002) *Metal Contamination of Food*, 3rd ed. Blackwell science: Oxford.

Chemical characteristics

Nearly all the minerals required by the body are elements of low atomic number, from sodium (11) to selenium (34); the exceptions are molybdenum (42) and iodine (53). In living matter, these elements are present in a number of different states: as inorganic compounds, as free ions in body fluids, or combined with organic compounds.

Approximately 99% of the body's calcium and 85% of its phosphorus are in the hard mineral component of bone. The two elements are combined together to form a compound similar to hydroxyapatite, Ca10(OH)2(PO4)6. Other inorganic elements, such as fluoride (F-), magnesium sodium and potassium are also incorporated into the bone mineral to form the partly amorphous and partly crystalline structure of bone.

In contrast to calcium in the skeleton, the element iron occurs almost entirely as part of co-ordination compounds based on the porphyrin nucleus involved in the transport of oxygen. Several of the other trace elements are also mainly present in biological tissues as organic compounds, such as selenium in the metalloenzyme glutathione peroxidase, and molybdenum in superoxide dismutase.

Impact on health, absorption and recommended intakes

Minerals function mainly in three ways in the body:

1. As structural components, e.g. calcium, phosphate and magnesium in bones and teeth.
2. In organic combinations as physiologically important compounds, e.g. phosphorus in nucelotides, zinc in enzymes such as carbonic anhydrase, iodine in thyroid hormone.
3. In solution in body fluids to maintain pH, help conduct nerve impulses, control muscle contraction, e.g. sodium and potassium in blood and intracellular fluids.

The macrominerals are mainly involved in functions 1 and 3, and the microminerals in function 2. A normal diet, composed of a mixture of both plant and animal foodstuffs, should supply all the minerals required by the body. When such a diet is not available, or in some other situations, it may be necessary to provide the missing elements in the form of supplements or by fortifying the diet with additional minerals. The minerals ingested in food are absorbed after digestion from the gut into the blood stream, which transports them to the sites where they function or are stored. Not all minerals are absorbed to the same extent. Some, including sodium and potassium, are readily absorbed as ions or as simple compounds. Others, such as calcium, magnesium and phosphorus may be combined as indigestible or insoluble compounds in food and are less easily taken up from the gut. A few others, especially some of the trace elements such as iron, are poorly absorbed.

Uptake of certain minerals from food can be affected by other components of the diet. Thus phytic acid and phytates in cereals can inhibit absorption of iron and zinc. The same effect can be caused by oxalate in certain vegetables. Iodine absorption can be limited by sulphur-containing compounds known as goitrogens, which occur in certain plants, such as some brassicae and cassava. Consumption of these vegetables can acerbate iodine deficiency and increase the likelihood of goitre.

If an essential element is at a low level in the diet, a nutritional deficiency may occur, with specific symptoms. Thus an inadequate intake of iron can cause anaemia when there is insufficient haemoglobin to meet the needs of the body for oxygen transport. A deficiency of iodine can lead to goitre when the body tries to compensate for a low production of the iodine-containing thyroid hormone by increasing the size of the thyroid gland. Inadequate zinc may result in growth failure in children. Usually these conditions are corrected when intake of the missing element is increased by improving the diet or by providing supplements.

An excessive intake of a mineral may also have serious consequences for health. Too much sodium in the diet may be associated with high blood pressure and increased risk of a stroke. Acondition known as siderosis, in which an excess of iron is deposited in the body, can result when too much iron is absorbed. Selenosis, a sometimes fatal effect of an excessive intake of selenium is known to occur in parts of China where high levels of the element enter locally grown foods from selenium-rich soil. Less serious effects, such as nausea, can be caused by a high intake of zinc.

In addition to their nutritional and physiological role, minerals contribute to food flavour and texture. They activate or inhibit the enzyme catalyzed and other reactions. Even though minerals are present in low concentrations, they often affect the physical and chemical properties of food because of their interactions with other food components.

Macrominerals: Physiological Importance and Food Applications

As the name suggests, these minerals are required in relatively larger amounts in the diet, generally greater than 100 mg/day. It follows that they are also present in greater amounts in the body. Table 27.2 gives the food sources, physiological roles and food applications of macro-minerals.

Calcium magnesium and phosphorus play an important role in the stability of fluid milk products such as liquid milk, concentrated milk, lassi etc and control the texture of semisolid products like cheese, ice-cream, *chhana*, *paneer*, *khoa* etc. While calcium and magnesium, the two divalent cations impart hard texture to cheese, ice cream, *chhana*, *paneer* and *khoa*, the divalent anions like phosphate and citrate import soft texture characteristie to these products. Concentrations of minerals in the food may also effect its digestability.

Table 27.2. Food sources, physiological role and food applications of some macrominerals

Minerals	**Food sources**	**Physiological roles**	**Food applications**
Calcium	All the dairy product, green leafy vegetables and fish bones contain calcium	• Calcium has important structural or mechanical role • Component of blood, lymph and soft tissues • Blood clotting process • Muscle contraction and nerve impulse transmission, mediator of hormone action, enzymes and proteins regulation • Deficiency leads to osteoporosis in later life.	Forms gel with Some macromolecules as texture modifier and firms canned vegetables.
Phosphorous	Foods such as nuts, oil seeds, pulses and cereals	• Involved with the formation of bones and teeth • Constituent of various physiologically important molecules and nucleic acids, DNA and RNA, a variety of coenzymes – NAD+, NADP+, FMN, FAD. • Influences the acid-base balance of blood	As phosphates as acidulant in soft drinks for moisture retention in meats and aids in emulsification.
Magnesium	Whole grains, nuts, legumes and green leafy vegetables	• Forms part of the bone tissue and along with calcium and some other cations affects fluidity and permeability of the membrane	Colour modifier in foods removal of magnesium from chlorophyll changes colour from green to olive-green.
Sodium and potassium	All foods, fruits and vegetables are rich sources.	• Maintenance of osmotic pressure, cell volume and membrane potential.	Potassium as potassium acid tartarate as leavening agent Potassium chloride as salt substituent Sodium chloride may be used as a preservative and

			lowers the water activity in food. Some of the sodium salts used as leavening agents.
Sulphur	Sulphur is widely distributed in nature	• Sulphur is antimicrobial in nature and is widely used in wine making.	Sulphur dioxide and sulphites as browning inhibitors

Trace Elements: Physiological Importance and Food Applications

Microminerals occur in living tissues in minute amounts. In fact early workers who were unable to measure their precise concentrations with the methods then available, frequently referred to them as occurring in 'traces'. For this reason they came to be known as 'trace elements'. Other popular names used include 'minor elements' or 'oligo-elements' (from the Greek 'oligos' meaning scantly). The micro-minerals are required in amounts less than 100 mg/day.

The trace elements may be subdivided into 3 groups:

- **Essential trace elements** – These have been shown to be dietary essentials as these are vital to the enzymatic processes of the living cell. Iron, copper, iodine, zinc, manganese, cobalt, molybdenum, selenium and chromium belong to this category.
- **Possibly essential trace elements** – These exhibit some metabolic activity, revealed by both in vivo and in vitro studies and likely to be essential. Nickel, tin, vanadium, cadmium, silicon, barium and strontium belong to this category
- **Non-essential trace elements** – The essentiality of these elements have not been established. Aluminium, boron, lead, mercury, fluorine and arsenic are the examples of this category.

The food sources, physiological role and food applications of some microminerals are given in Table 27.3.

Table 27.3. Food sources, physiological role and food applications of some microminerals

Minerals	Food Sources	Physiological role	Food application
Iron	Green leafy vegetables, cereals, legumes, meat etc. are good sources. Also food cooked in iron utensils also provides iron.	• Oxygen transport by haemoglobin • To ensure availability, of oxygen in muscle cells oxygen is stored combined with iron containing muscle protein, myoglobin • Constituent of enzymes peroxidase and catalase which catalyze oxidation-reduction reactions	Catalyze lipid peroxidation in foods. Colour modifier in Foods Cofactor to many enzymes like cytochromes, hypoxygenase etc.
Iodine	Available in iodized salt, sea food, plants and animals grown in areas where soil iodine is not depleted.	• An integral part of thyroid hormone • Insufficient quantities of iodine in the diet results in the disease goitre. • Thyroid deficiency during	Potassium iodate improves baking quality of wheat flour. Therefore, it is used as a dough improver.

		the prenatal period results in serious detriment in both mental and physical development in the growing child.	
Selenium	Sea foods, organ meats, cereals	• Present in amino acids as constituents of proteins, • Selenocysteine occurs at the active site of several enzymes and functions as enzymes cofactor	
Copper	Organ meats, sea foods, nuts and seeds.	• A part of a number of proteins including many important enzymes. Some of these are: copper-binding proteins, metallothionein, albumin, blood clotting factor V, amine oxidases, ferroxidases, cytochrome C oxidase, superoxide dismutase, tyrosinase, C18, Δ9 desaturase.	As a catalyst; Colour modifier; Enzyme cofactor; Texture stabilizer
Cobalt and Manganese	• Green leafy vegetables, especially spinach are the richest source • Dairy products and cereals are the poorest.	• Cobalt is a constituent of vitamin B12, functions as a coenzyme • Manganese as Mn2+ activates a number of plant and animal enzymes including oxidoreductases, lyases, ligases, hydrolases, kinases, transferases and various decarboxylases.	Manganese as enzyme cofactor e.g. pyruvate carboxylase, superoxide dismutase.

TOXIC METALS: SOURCES AND SYMPTOMS

The mineral elements causing toxicity are generally the heavy metals like, arsenic, cadmium, lead, mercury, chromium and beryllium. These heavy metals can be present in foods, drinking water and the exhaust of automobiles and industries. The sources and the symptoms of the exposure to toxic metals are compiled in Table 27.4.

Table 27.4. Sources and the symptoms of the exposure to toxic metals

Toxic metal	Sources	Symptoms
Aluminum	Cookware, cans, tap water, baking powders, antacids, processed cheese, some medications and physical exposure etc.	Alzheimer's disease, anaemia and other blood disorders, colic, fatigue, dental caries, kidney and liver dysfunctions, neuromuscular disorders, Parkinson's disease, etc.
Arsenic	Pesticides, beer, tap water, paints, pigments, cosmetics, fungicides, insecticides, contaminated food, etc.	Abdominal pain, anorexia, dermatitis, diarrhoea, oedema, goitre, headache, herpes, impaired healing, jaundice, kidney and liver damage, muscle spasms, vasodilation, vertigo, weakness, etc.

Beryllium	Polluted air (burning fossil fuels), plastics, electronics, steel alloys, etc.	Arthritis, depression, fatigue, osteoporosis and symptoms of slow metabolism, etc.
Cadmium	Cigarettes, processed and refined foods, fish, tap water, auto exhaust, galvanized pipes, air pollution from incineration and physical exposure, etc.	Hypertension, arthritis, diabetes, anaemia, arteriosclerosis, cancer, cardiovascular disease, reduced fertility, hypoglycemia, headaches, osteoporosis, kidney disease, etc.
Copper	Copper water pipes, tap water, pesticides, swimming pools, intra-uterine devices, dental amalgams, occupational exposure, etc.	Allergies, hair loss, anaemia, anxiety, arthritis, autism, cancer, depression, elevated cholesterol, cystic fibrosis, diabetes, dyslexia, inflammation, kidney and liver dysfunctions, tooth decay, etc.
Lead	Tap water, cigarette smoke, hair dyes, paints, pesticide and in batteries, industries, etc.	Abdominal pain, anaemia, arthritis, arteriosclerosis, blindness, cancer, depression, diabetes, epilepsy, fatigue, gout, infertility, inflammation, kidney dysfunction, etc.
Mercury	Dental amalgams, fish, medications, air pollution, adhesives, fabric softeners, waxes, etc.	Depression, dermatitis, fatigue, headaches, hearing loss, hyperactivity, memory loss, mood swings, nervousness, pain in limbs, thyroid, muscle weakness, etc.
Nickel	Hydrogenated oils (margarine, commercial peanut butter and shortening), shellfish, air pollution, etc.	Cancer (oral and intestinal), depression, heart attack, hemorrhages, kidney dysfunction, low blood pressure, paralysis, nausea, skin problems and vomiting

The metals from equipment or from packing materials, especially tin cans can cause contamination of food products. Tin gets into most of the canned food in the absence of oxygen. Examples of such foods are spinach, green beans, tomatoes, vegetable soups and some fruits juices like grape fruits juice. Foods rich in sulphur containing amino acids like pork, fish and peas undergo **sulphide staining** in tin cans. These stains are due to the formation of tin sulphide on heating. The nickel found in milk comes almost exclusively from stainless steel in the processing equipments. Similarly, on storing acidic foods, e.g. fruits juices in galvanized containers, enough zinc may get dissolved to cause poisoning.

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