



## Review

# The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation



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## ABSTRACT

**Background:** As minerals have diverse functionalities and potentials in the body's metabolism and homeostasis, deficiency of these bioactive constituents can result in an abundant incidence of common disorders and disease symptoms. Maintenance knowledge of the mineral content in terms of safe food fortification and processing techniques can significantly increase their absorption and bioavailability rate. **Scope and approach:** This overview mainly discusses current investigations about the identification of high-available sources and remarkable functions of mineral elements, quantification methods for the bioavailability assessment, and influence of different processing practices and usual fortification strategies on mineral content and quality of staple food products.

**Key findings and conclusions:** The most dominant minerals to fortify various food preparations are iron, calcium, zinc and iodine. Utilization of isotopic approaches can sensitively determine the bioavailability values of food minerals. Modern processing techniques (e.g., high pressure and sonication) compared with the conventional processes have lower negative impacts on the content of micro- and macro-minerals. Accumulation of mineral elements in the edible tissues of crops using agrobiotechnological techniques (e.g., gene overexpression and activation control) and their direct fortification into formulation of processed foods along with nanoencapsulation could enhance the concentration and bioaccessibility of these bioactive ingredients.

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## 1. Introduction

Micronutrients include vitamins and minerals because small amounts of these components are needed for the body. Minerals are extensively divided into major minerals (macro-minerals) and trace minerals (micro-minerals). Major minerals are including calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), chloride (Cl), phosphorus (P) and sulfur (S); while trace minerals are iodine (I), zinc (Zn), selenium (Se), iron (Fe), manganese (Mn), copper (Cu), cobalt (Co), molybdenum (Mo), fluoride (F), chromium (Cr) and boron (B). Various food sources of major and trace minerals and their functions in the body are explained in Table 1. For a good and balanced nutrition, different plant (vegetables and fruits) and animal sources can be consumed to receive a number of important minerals (Table 1). Although the needed amounts of minerals in the body are not a sign of their significance, less amount of trace

minerals for the body is needed compared with major ones. As a result, a balanced diet can commonly support all essential minerals for the body (Lukaski, 2004).

Minerals have key roles in our body to do necessary functions - from building strong bones to transmitting nerve impulses - for healthy and lengthy life. Existence of a series of minerals not only can make different hormones, but also can regulate a standard heartbeat. Some macro- and micro-elements are found in the structure of teeth (Ca, P and F) and bones (Ca, Mg, Mn, P, B and F), whereas most micro-elements (Cu, Fe, Mn, Mg, Se and Zn) play a vital role as a structural part in many enzymes (Table 1). Macro-elements (Ca, Mg, P, Na and K) compared with micro-ones (I) have a lot more considerable functions in nerve cells (transmission and signaling). Although microelements have key roles in the formation of erythrocyte cells (Co, I and Fe), regulation of the glucose levels (Cr), and their protection via activation of antioxidant enzymes (Mo), macro minerals such as, Ca and K have a high potential to control blood pressure (Table 1). Minerals also involved in immune (Ca, Mg, Cu, Se and Zn), and brain (Cr and Mn) systems (Table 1).

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**Table 1**  
Main sources and functions of essential minerals.

Minerals	Main sources	Main functions
<i>Macro-minerals</i>		
Calcium (Ca)	<i>Vegetable:</i> Greens (broccoli, mustard greens), legumes <i>Animal:</i> Milk and dairy products, fortified tofu and fortified soy milk, canned fish with bones (salmon, sardines)	Important for healthy bones and teeth; Helps to relax and contract the muscles; Important in nerve functioning, health of immune system, blood clotting and blood pressure regulation
Chloride (Cl)	<i>Vegetable/Fruit:</i> Seaweed, rye, tomatoes, lettuce, celery, olives; <i>Animal:</i> Meats, small amounts in milk; <i>Other:</i> Table salt, soy sauce; large amounts in processed foods, breads	Required to have a good balance in body fluids, An essential part of digestive (stomach) juices
Magnesium (Mg)	<i>Vegetable:</i> Nuts and seeds, legumes, artichokes, leafy and green vegetables; <i>Animal:</i> Milk and dairy products, seafood; <i>Other:</i> Chocolate, "hard" drinking water	Found in bones; Needed for the formation of protein, muscle contraction, immune system health and nerve transmission; Assists to avoid constipation
Phosphorus (P)	<i>Vegetable:</i> Seeds (pumpkin & squash), nuts (Brazil nut), legumes (beans & lentils); <i>Animal:</i> Meat (lean sirloin, lean beef), fish (salmon), shellfish (scallops), poultry, eggs, milk, low fat dairy (non-fat yogurt), cheese (Romano); <i>Other:</i> Processed foods (soda pop), soya foods (tofu)	Found in every cell; Needed for the body to make proteins providing the cell growth, maintenance, and reparation; ATP and energy production; Important for healthy bones and teeth; Part of the system that maintains acid-base balance; Works with the B vitamins to help kidney performance, muscle constrictions, regular heartbeat and nerve signaling
Potassium (K)	<i>Vegetable/Fruit:</i> Fresh and dried fruits and vegetables, whole grains, legumes; <i>Animal:</i> Meats, fish (salmon), milk, yogurt (plain, skim/non-fat); <i>Other:</i> Baked potato and acorn squash	Needed for proper fluid balance, nerve transmission, muscle contraction, suitable maintenance of blood pressure and waste elimination
Sodium (Na)	<i>Vegetable:</i> Pickles (cucumber), canned vegetables (sweet peppers); <i>Animal:</i> Cured meat & fish (bacon, cooked), small amounts in milk, cheese (Roquefort); <i>Other:</i> Table salt, breads, large amounts in processed foods; such as, soy sauce, instant soups (beef noodle), roasted and salted nuts & seeds (pumpkin seeds), snacks (pretzels), fast foods (egg & ham biscuit)	Needed for appropriate maintenance of electrolyte balance and fluid balance, heart function and specified metabolic activities, muscle contraction and nerve transition
Sulfur (S)	<i>Vegetable:</i> Cruciferous (broccoli, cauliflower, cabbage, kale, Brussels sprouts, turnips, Bok Choy, kohlrabi), and allium (garlic, onions, leeks, chives) vegetables, legumes, nuts; <i>Animal:</i> Meats, poultry, fish, eggs, milk; <i>General:</i> Occurs in foods as part of protein	Found in protein molecules; Helps resist bacteria and protects against toxic substances; Necessary for proper development of connective tissue; Helps skin to maintain structural integrity.
<i>Micro-minerals</i>		
Boron (B)	<i>Vegetable/Fruit:</i> Broccoli, carrots, onions, potatoes, Bananas, red grapes, peaches, pears, apples, avocados, olives, dried fruit (prunes, raisins), nuts (especially almonds, peanuts, hazelnuts), peanut butter, legumes (lentils, beans), wheat and oat bran; <i>Other:</i> Fruit juices, honey, bee pollen	Handles other minerals (e.g., Mg and P), Improving the estrogen concentrations in post-menopausal women and healthy men (estrogen is useful in keeping healthy bones and mental performance), Removes yeasts producing vaginal infections in common form of boric acid; Embryonic development; Important in maintaining cellular and organ membrane functions
Chromium (Cr)	<i>Vegetable/Fruit:</i> Whole grains, wheat germ, nuts, green peppers, apples, bananas, spinach, black pepper, molasses; <i>Animal:</i> Beef, liver, eggs chicken, oysters, cheese, butter; <i>Other:</i> Brewer's yeast, unrefined foods	Important in the metabolism of fats and carbohydrates; Important for brain function and other body processes; Stimulates fatty acid and cholesterol synthesis; Works closely with insulin to regulate blood sugar (glucose) levels
Cobalt (Co)	<i>Vegetable:</i> Cereals (oats), green leafy vegetables (broccoli, cabbage, lettuce, turnip and spinach), nuts, mushrooms (especially shiitake), figs; <i>Animal:</i> Meat, liver, kidneys, milk, oysters, mussels, fish, shellfish	As a part of the vitamin B12 is used in <i>pernicious anemia</i> by improving blood because it promotes the formation of red blood cells (erythrocytes); Help to solve the cases of fatigue, and digestive and neuromuscular issues
<i>Micro-minerals</i>		
Copper (Cu)	<i>Vegetable/Fruit:</i> Legumes (cooked beans and chickpeas), nuts (cashew nuts), seeds (sesame), whole grains, raw kale, mushrooms (shiitake, cooked), dried fruit (prunes), avocados; <i>Animal:</i> Organ meats, seafood (oysters, cooked); goat cheese (soft); <i>Other:</i> Drinking water, fermented soy foods (tempeh)	A structural part in many enzymes; Desirable for Fe and protein metabolism; Essential to the proper functioning of organs and metabolic processes; Stimulates the immune system to fight infections; Repairs injured tissues; Promotes healing; Helps to neutralize free-radicals causing intense cell damage
Fluoride (F)	<i>Vegetable:</i> Most teas; <i>Animal:</i> Seafood (fish, shellfish), mechanically deboned meat/chicken, <i>Other:</i> Drinking water (either fluoridated or naturally containing fluoride), processed cereals, beverages (beer, wine, Juice), & other foods (canned fish and shellfish)	Involved in bones and teeth development; Helps to prevent tooth decay; Help to reduce cavities in children by more than half by adding fluoride to tap water (called fluoridation); Help maintain bone structure and slows-down bone density loss
Iodine (I)	<i>Vegetable/Fruit:</i> Foods grown in iodine-rich soil, bananas, cranberries, dried prunes, organic strawberries, organic navy beans, organic potatoes; <i>Animal:</i> Seafood (cod fish, shrimp, lobster), dairy products (milk, organic yogurt and raw, organic cheese, Cheddar cheese), baked turkey breast, boiled eggs; <i>Other:</i> Iodized salt, bread, baked potatoes, canned tuna, canned corn	A vital component of hormones produced by the thyroid gland which are responsible for a number of key activities in body, including growth, development, metabolism, reproduction, nerve and muscle function, production of blood cells, adjustment of body temperature and generally the speed of body processes
Iron (Fe)	<i>Vegetable/Fruit:</i> Squash and pumpkin seeds, nuts (cashew, pine, hazelnut, peanut, almond), beans and pulses (white beans, lentils), whole grains, bran, dark leafy greens (spinach, Swiss chard), dried fruits; <i>Animal:</i> Liver (chicken), seafood (oysters, mussels, clams), beef and lamb (lean chuck roast), eggs, poultry; <i>Other:</i> Dark chocolate, cocoa powder, Fe-enriched breads and cereals, tofu	Needed for the formation of hemoglobin in red blood cells, which carries oxygen from the lungs to the body cells; Needed for energy metabolism; A transport medium for electrons within cells; An integrated part of important enzyme systems in various tissues
Manganese (Mn)	<i>Vegetable/Fruit:</i> Nuts (hazelnuts), seeds (pumpkin), beans (butter/lima beans, cooked), spinach (cooked), whole grains (brown rice), tea (black, brewed); <i>Animal:</i> Seafood (mussels, cooked), fish (bass, cooked); <i>Other:</i> Bread (whole-wheat), tofu (firm, raw) <i>General:</i> Widespread in foods, especially plant foods	Part of many enzymes; Important for the normal functioning of the brain and proper activity of nervous system throughout the body; Vital for proper and normal growth of human bone structure; Useful for post-menopausal women and preventing osteoporosis
Molybdenum (Mo)	<i>Vegetable/Fruit:</i> Legumes (beans, peas, lentils), whole grains, chokeberry, leafy vegetables (spinach), Swiss chard, nuts, sunflower seeds, wheat flour, cucumber; <i>Animal:</i> Eggs, liver, milk, cheese, organ meats (lamb); <i>Other:</i> Pasta, breads	Cell protection through activation of enzymes that have antioxidant roles in blood; Needed for permitting cells to generate energy within the mitochondria, or powerhouse of the cells, with the help of broken-down macronutrients; To activate enzymes required to remove waste in the body

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