Paper No.: 13
Paper Title: Food Additives
Module 19 Nutrients as food additives-I: Vitamins and Minerals

1. Introduction

The term nutritional additives can be used to mean the addition of vitamins, minerals, amino acids, fatty acids, as well as other pure chemical compounds to food in order to improve or maintain the nutritional quality of foods. However, manufacturers soon discovered that along with an improvement in nutritional qualities, nutritional additives often provide functional qualities.

The earliest use of nutritional additives was to correct dietary deficiencies. In 1833, the French chemist Boussingault recommended the addition of iodine to table salt to prevent goiter. Salt was first iodized in the United States in 1924 when it was shown that the addition of sodium iodine was effective in preventing goiter. Other examples include vitamin D added to milk and vitamin A added to margarine. Nutritional additives can be used to restore nutrients to levels found in the food before storage, packaging, handling, and processing. An early example of this is the enrichment of grain products, corn meal, and rice. Another use of nutritional additives is to improve the nutritional status or correct nutritional inferiority in a food that replaces a more traditional nutritional food, an example would be the fortification of breakfast drink substitutes with folacin and vitamin C. With the advent of nutritional labeling and increased public interest in nutritional properties of food, the food industry rapidly recognized that the addition of nutritional additives can be a selling point. Although it is often thought that the major reason to add nutritional additives to a food supply is to provide nutrients and improve dietary status, nutrients are also added for a variety of other purposes. For example, vitamins C and E may be used for antioxidant properties; beta carotene may be used to provide color. In these cases consumers obtain both a functional and nutrient advantage.

Like all additives, nutritional additives are commercially available in an array of forms such as powders, encapsulated in gelatin, emulsified in oil. The form used depends upon the type of application. Nutrition additives are often protected by protective additives such as antioxidants. Two critical factors in the selection of the form of the additive are stability of the vitamin preparation and its miscibility with the intended food matrix. In order to ensure the second criterion, the point of incorporation of the additive during the food manufacturing process can also be critical.

2. Vitamins as Nutritional additive

Vitamins are organic compounds that facilitate a variety of biological processes. Since the body cannot manufacture vitamins they must be obtained naturally from foods or added to foods. Vitamins are classified as water soluble or fat soluble depending on their characteristics. Water soluble vitamins show poor solubility in water; they are not stored in body tissues in high amounts and excesses are generally excreted in urine. Fat soluble vitamins are linked with lipid metabolism and are generally insoluble or poorly soluble in water. Since fat soluble vitamins can be stored in the human body it is less important to have a daily supply of these vitamins. Excess amounts of fat soluble vitamins can in some cases lead to toxic effects. The fat soluble vitamins are vitamins A, D, E, and K. Vitamins A, C, and E are also classed as antioxidants because they have the capacity to protect the body from free radicals.

2.1 Vitamin A

The active principal component of liver oil is vitamin A. Adequate intake of vitamin A is essential for normal vision, growth, cellular differentiation, reproduction, and integrity of the immune system. Deficiency of vitamin A is commonly seen as night blindness and/or dry and lustreless corneas. Vitamin A is one of the major public health problems in less industrialized countries. In fact, it is the major cause of blindness in the developing world. Inadequate amounts are also associated with protein-calorie malnutrition, low intake of fat, lipid malabsorption syndromes, and febrile diseases.

Toxicity: In amounts several times higher than the recommended dietary allowance, vitamin A will cause Toxicity in humans. With children, signs and symptoms of acute vitamin A Toxicity include anorexia, bulging fontanelles, drowsiness, increased intracranial pressure, irritability, and vomiting.

Occurrence and properties: Preformed vitamin A is found in foods of animal origin, either in storage areas such as the liver or associated with the fat of milk and eggs.

In liquid form, vitamin A is a light yellow to red oil that may solidify on refrigeration. In this form it is very soluble in chloroform and in ether. It is soluble in absolute alcohol and in vegetable oils, but is insoluble in glycerin and in water. In solid form, it may have the appearance of the diluent that has been added to it. It may be nearly odorless or have a mild fishy odor, but it has no rancid odor or taste. In solid form it may be dispersible in water. It is unstable to air and light. Vitamin A should be stored in a cool place in tight containers, preferably under an atmosphere of an inert gas, protected from light.

Commercial forms: Vitamin A is available in pure form by chemical synthesis as vitamin A palmitate or the acetate, or recovered from molecularly recovered fish oil.

2.2 Carotenoids

Although not vitamins per se, carotenoids serve as a precursor to provide vitamin A. This provitamin is converted by the body to vitamin A with various degrees of efficiency. The yellow, red, orange, and violet pigments of carotenoids are largely responsible for the color of many vegetables and fruits. Carotenoids function not only as color and nutrient compounds but also as antioxidants. Although carotenoids may have favorable effects and may reduce the risk of some diseases, since carotenoids are not essential nutrients there is no need to use the term ‘‘carotenoid deficiency’’.

Toxicity: A yellow, jaundice like coloration of the skin is evident in individuals who routinely ingest excessively large amounts of carotenoids.

Occurrence and properties: Provitamin A carotenoids are synthesized exclusively by higher plants and photosynthetic microorganisms. Carotenoids are mainly obtained from plant sources such as carrots, green leafy vegetables, spinach, oranges, and tomatoes. Animal sources include calf liver, whole milk, butter, cheddar cheese, and eggs.

Carotenoids are soluble in most organic solvents but not in water, acids, or alkalis. They are sensitive to oxidation, isomerization, and polymerization when dissolved in dilute solution under light and in the presence of oxygen.

Commercial forms: Beta carotene is available as red crystals or crystalline powder. Carotenoids are highly sensitive to loss by oxidation and should be protected with appropriate packing materials and storage conditions.

2.3 Vitamin D

The primary function of vitamin D is to maintain serum calcium and phosphorus concentrations in a range that supports cellular processes, neuromuscular function, and bone ossification. Vitamin D was found to prevent and cure rickets, a disease associated with malformation of bones. Victims of rickets have traditionally been poor children in industrialized cities where exposure to sunlight has been limited.

Toxicity: Excessive amounts of vitamin D are not normal unless there is excessive use of supplemental vitamins. Toxicity includes hypercalcemia, hypercalciuria, anorexia, nausea, vomiting, thirst, polyuria, muscular weakness, joint pains, diffuse demineralization of bones, and general disorientation.

Occurrence and properties: Food sources are mainly animal products in unfortified foods. Saltwater fish such as herring, salmon, and sardines and fish liver oils are good sources. Other major sources of fortified foods include butter, margarine, cereals, and chocolate mixes. Vitamin D can be produced in the skin after exposure to sunlight. However, in areas with limited sunlight, air pollution, and large cities where buildings block adequate sunlight, the body's ability to synthesize sufficient amounts of vitamin D may be compromised.

Vitamin D is a stable vitamin but is affected by air and by light. Both vitamin D2 and vitamin D3 should be stored in hermetically sealed containers under nitrogen in a cool place and protected from light. Trace metals such as copper and iron will act as prooxidants.

Commercial forms: Both vitamin D2 and vitamin D3 are white, odourless crystals. Commercially available forms include fat soluble crystals for use in high fat content foods and encapsulated, stabilized versions of the fortificant suitable for use in dry products to be reconstituted with water.

2.4 Vitamin E

Vitamin E is the major lipid-soluble, membrane-localized antioxidant in humans. First discovered in 1922, vitamin E acts in foods to prevent the peroxidation of polyunsaturated fatty acids. In the gut, it enhances the activity of vitamin A by preventing oxidation in the intestinal tract. Vitamin E, at the cellular level, also appears to protect cellular and subcellular membrances from deterioration by scavenging free radicals that contain oxygen.

Sources of dietary vitamin E are widely available and as a result deficiencies are relatively uncommon. Deficiencies that do occur are usually associated with malabsorption or lipid transport abnormalities.

Toxicity: Vitamin E is relatively nontoxic. However, large intakes of vitamin E might interfere with absorption of Vitamin A and vitamin K. Doses necessary to elicit Toxicity far exceed those necessary for nutritional sufficiency.

Occurrence and properties: The richest sources of vitamin E are vegetable oils—including soy bean, corn, cottonseed, and safflower—and products made from these oils such as margarine, shortening, and mayonnaise, as well as wheat germ, nuts, and other grains. Meats, fish, animal fat, and most fruits and vegetables contain little vitamin E.

The acetate ester of α-tocopherol, rather than the free alcohol, is used as a food supplement because of its greater stability. Vitamin E is a slightly viscous, pale yellow, oily liquid obtained from molecular distillation of byproducts from vegetable oil refining or by chemical synthesis. The free alcohol form is highly unstable to oxidation and is used in foods as an antioxidant to stabilize the lipid component of foods. Cold water soluble forms have been produced by encapsulation with a suitable matrix.

Commercial forms: Some of the forms available as nutrients and/or dietary supplements are DL-α-Tocopherol, D-α-Tocopherol concentrate, Tocopherols concentrate, mixed, D-α-Tocopheryl acetate, DL-α-Tocopheryl acetate, D-α-Tocopheryl acetate concentrate and D-α-Tocopheryl acid succinate.

2.5 Vitamin K

Vitamin K functions in the liver as an essential cofactor for carboxylase. This enzyme converts specific glutamic acid residues of precursor proteins to a new amino acid, gammacarboxyglutamic acid (Gla). Vitamin K–dependent blood clotting factor prothrombin (factor II) and factor VII, IX, and X are included in the proteins. Vitamin K plays a crucial role in blood clotting activities. Vitamin K is not only associated with coagulation, but also with additional functions in bone, kidney and possibly other tissues.

Deficiencies in vitamin K status are relatively uncommon. However, since newborns do not have the necessary menaquinones, due to poor vitamin K placenta transfer, administration of vitamin K to newborns has become common practice.

Toxicity: There is no known Toxicity associated with the administration of high doses of vitamin K1. However, administration of vitamin K3 to infants is associated with hemolytic anemia and liver Toxicity.

Occurrence and properties: Green leafy vegetables, especially broccoli, cabbage, turnip greens, and lettuce, have large amounts of vitamin K. Other vegetables, fruits, cereals, dairy products, eggs, and meat contain smaller amounts. A significant amount of vitamin K is formed by the bacterial flora of the human lower intestinal tract.

Vitamin K is fairly resistant to heat. Compounds tend to be unstable in the presence of alkali and light.

Commercial forms: Vitamin K is a clear, yellow to amber, very viscous liquid that is stable in air but decomposes when exposed to sunlight. It is slightly soluble in alcohol, and soluble in dehydrated alcohol, in chloroform, in either, and in vegetable oils. It is insoluble in water.

2.6 Vitamin C

Vitamin C is the antiscorbutic vitamin. First described during the Crusades and a common plague of early explorers and voyagers, scurvy is now virtually eliminated with the presence of vitamin C in adequate diets. Vitamin C, or ascorbic acid, has many functions as either a coenzyme or cofactor. Because of its ease of losing or taking on hydrogen, it is essential in metabolism. It is well recognized for its role in enhancing the absorption of iron. Vitamin C maintains the integrity of blood vessels. Vitamin C also promotes resistance to infection.

Toxicity: Since vitamin C is one of the most commonly used supplements, excessive intake may occur. Symptoms may include diarrhea, abdominal bloating, iron over-absorption, nausea, and kidney stones.

Occurrence and properties: The best sources of vitamin C are fruits and vegetables, preferably acidic and fresh. These sources include citrus fruits, raw leafy vegetables, tomatoes, broccoli, strawberries, cantaloupe, cabbage, and green peppers. Content of ascorbic acid in fruits and vegetables varies with the conditions under which they are grown and degree of ripeness when harvested.

Ascorbic acid is a stable, odorless, white solid which is soluble in water, slightly soluble in alcohol, and insoluble in organic solvents.

Commercial forms: l-Ascorbic acid is white or slightly yellow crystals or powder. It will gradually darken on exposure to light, and is reasonably stable in air when dry but will rapidly deteriorate in solution in the presence of air. It has to be stored in tight light-resistant containers. Ascorbate is available in vitamin tablets and many multivitamin supplements contain ascorbate.

2.7 Thiamin

Also known as vitamin B1, thiamin has been known as the vitamin which prevents beriberi. Thiamin is essential in energy transformation and membrane and nerve conduction as well as in the synthesis of pentoses and the reduced coenzyme form of niacin. First identified in 1897 it was not until 1936 that the vitamin was synthesized. There are two major forms, thiamine pyrophosphate (TPP) and thiamin triphosphate (TTP). In the TPP or diphosphate form it is required for the oxidative decarboxylation of pyruvate to acetyl CoA, providing entry of oxidizable substrates into the Krebs cycle for energy. Thiamin is most strongly linked with carbohydrate metabolism even though it is also needed to metabolize fats, proteins, and nucleic acids.

Severe thiamin deficiency in humans leads to impairment of the auditory and visual pathways in the brain stem as well as impairment of the endocrine pancreas and the heart. In addition, clinical features of thiamin deficiency experienced by the chronic alcoholic includes ataxia and altered memory and alcoholic peripheral neuropathy.

Toxicity: Even in high oral doses, thiamin has been found to have no toxic effect other than possibly gastric upset.

Occurrence and properties: Food sources include meat, fish, whole cereal grains, fortified cereal and bakery products, nuts, legumes, eggs, yeast, fruits, and vegetables.

Thiamin esters are relatively stable in the dried state if stored at low temperatures in the dark. In solution thiamin is stable at pH 2–4, and Thiamin pyrophosphate (TPP) is stable at pH 2–6 at low temperature. All thiamin vitamers are unstable at elevated temperatures and under alkaline conditions.

Commercial forms: Thiamin mononitrate is available as white to yellowish white crystals, or crystalline powder, usually having a slight characteristic odor. It is slightly soluble in alcohol and in chloroform. Thiamin mononitrate should be stored in tight, light-resistant containers. Thiamin hydrochloride is also available as white to yellowish white crystals or crystalline powder.

2.8 Riboflavin

Deficiencies of riboflavin are usually in combination with deficiencies of other water soluble vitamins. Intake of riboflavin must be low for several months in order for signs of deficiency to develop. Pellagra like symptoms including skin lesions around the mouth, nose, and ears occur when there is a riboflavin deficiency.

Toxicity: There are no known effects from Toxicity.

Occurrence and properties: Riboflavin is widely distributed in small amounts. The best sources are milk, cheddar cheese, and cottage cheese. Other good sources include eggs, lean meats, broccoli, and enriched breads and cereals.

Vitamin B2 is heat- , oxidation- , and acid-stable but is sparingly soluble in water and disintegrates in the presence of alkali or light, especially ultraviolet. Very little riboflavin is lost in cooking and processing of foods.

Commercial forms: The commercial form is a yellow to orange yellow crystalline powder having a slight odor. It melts at about 280^{o}C with decomposition, and its saturated solution is neutral to litmus. When dry it is not affected by diffused light, but in solution light induces deterioration. It is less soluble in alcohol than in water. In ether and in chloroform it is insoluble but very soluble in dilute solutions of alkalies. It should be stored in tight, light-resistant containers.

2.9 Niacin

Niacin is a generic term used for nicotinic acid and its derivatives that exhibit the biological activity of niacinamide. These function as a component of the coenzymes nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP), which are present in all cells. These coenzymes are essential in oxidation–reduction reactions involved in the release of energy from carbohydrates, fats, and proteins. The coenzyme NAD is also used in glycogen synthesis. Niacin was identified as a result of the search for the cause and cure of pellagra. Clinical signs of pellagra are commonly referred to as the 3 Ds; diarrhea, dementia, and dermatitis. The most characteristic sign is a pigmented rash that develops symmetrically in areas of the skin exposed to sunlight.

Toxicity: High doses of niacin may be toxic to the liver. Large doses of nicotinic acid have been shown to reduce serum cholesterol concentrations. However, there are side effects that include flushing of the skin, hyperuricemia, hepatic and ocular abnormalities, and occasional hyperglycemia.

Occurrence and properties: Niacin is widely distributed in plant and animal foods. Good sources include meats (including liver), dairy products, cereals, legumes, and seeds. Green leafy vegetables and fish, especially shellfish, as well as enriched breads and cereals, also contain appreciable amounts.

Niacin in general is one of the more stable vitamins. Free forms of the vitamin are white stable crystalline solids. Nicotinamide is more soluble in water, alcohol, and ether than is nicotinic acid. Nicotinic acid's stability is pH independent.

2.10 Vitamin B6

There are six nutritionally active B6 vitamers occurring in foods. Its original form is pyridoxine (PN), pyridoxal (PL), pyridoxamine (PM), and the corresponding 5′-phosphate esters pyridoxine phosphate (PNP), pyridoxal phosphate (PLP), and pyridoxamine phosphate (PMP). The esters PLP and PMP function primarily in transamination and other reactions related to protein metabolism. The former is also necessary for the formation of the precursor of heme in hemoglobin. Vitamin B6 is essential in the metabolism of tryptophan and its conversion to niacin. The immune responses of young and elderly humans are also affected by the nutritional status of vitamin B6. Signs of deficiency in adults include stomatitis, cheilosis, glossitis, irritability, depression, and confusion.

Occurrence and properties: Best sources of vitamin B6 are yeast, wheat germ, pork, liver, whole grain cereals, legumes, potatoes, bananas, and oatmeal.

Vitamin B6 is considered relatively labile with its degree of lability influenced by pH. All forms are relatively heat stable in acid medium and are heat labile under alkaline conditions. In aqueous solution, most forms are light sensitive.

Commercial forms: Vitamin B6 is available commercially in the form of pyridoxine hydrochloride as a colorless or white crystal or a white crystalline powder. It is stable in air and slowly affected by sunlight.

2.11 Pantothenic acid

Pantothenic acid was first synthesized in 1940. As a primary constituent of coenzyme A, it is involved in many areas of cellular metabolism including the synthesis of cholesterol, steroid hormones, vitamin A, vitamin D, and heme A. It is involved in the release of energy from carbohydrate and in the degradation and metabolism of fatty acids.

Pantothenic acid is widely available so deficiencies are rare. When there are conditions of severe malnutrition, deficiencies may be detected that mainly affect the adrenal cortex, nervous system, skin, and hair. Insufficiency is characterized by a burning sensation in the soles of feet.

Occurrence and properties: Pantothenic acid is widely distributed in nature. Rich dietary sources include meat, fish, poultry, eggs, whole grain products, and legumes.

Pantothenic acid is relatively stable at neutral pH. Strong acids, alkalis, or thermal processing will hydrolyze pantothenic acid. Calcium pantothenate occurs as a slightly hygroscopic, white powder. It is odorless, has a bitter taste, and is stable in air.

Commercial forms: Commercial available forms of pantothenic acid are Calcium pantothenate, racemic Calcium pantothenate, Calcium chloride double salt of DL- or D-calcium panthothenate, Dexpanthenol (dextrorotatory isomer of the alcohol analog of pantothenic acid and occurs as a clear, viscous, somewhat hygroscopic liquid having a slight odor) and DL-Panthenol.

2.12 Folate

Folate is a generic term for a group of compounds chemically and nutritionally similar to folic acid. Essential to cell division, folate plays an important role in the synthesis of the purines guanine and adenine and the pyrimidine thymine, which are compounds utilized in the formation of nucleoproteins deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Folate is also essential for the formation of both red and white blood cells and serves as a single carbon carrier in the formation of heme. Low levels of plasma folate and vitamin B12 lead to elevated plasma homocysteine, which has been associated with increased risks of coronary heart disease. Deficiency of folate results in poor growth, megaloblastic anemia, and other blood disorders elevated blood levels of homocysteine, glossitis, and gastrointestinal tract disturbances.

Occurrence and properties: Folates are ubiquitous in nature and are present in nearly all natural foods. However, they are highly susceptible to oxidation and folate content in foods and may be destroyed by protracted cooking or processing, such as canning. Best sources are legumes such as kidney beans, lima beans, lentils, fresh dark green leafy vegetables, especially spinach, asparagus, turnip greens, and broccoli.

Crystalline folic acid is yellow. The free acid is almost insoluble in cold water, and the disodium salt is more soluble. Folic acid is destroyed at a pH below 4, but is relatively stable above pH 5.

Commercial forms: Folic acid is a yellow or yellowish orange, odorless crystal or crystalline powder. It is insoluble in acetone, in alcohol, in chloroform, and in ether, but dissolves in solutions of alkali hydroxides and carbonates.

2.13 Vitamin B12

Initially vitamin B12, also known as cobalamin, was identified as the extrinsic factor of food that is effective in the treatment of pernicious anemia. Vitamin B12 is synthesized by bacteria. It is essential for normal function in the metabolism of all cells, especially cells of the gastrointestinal tract, bone marrow, and nervous tissue. It participates, along with folic acid, choline, and methionine, in the transfer of methyl groups in the synthesis of nucleic acids, purines, and pyrimidine intermediates. Vitamin B12 and folate are closely related with each depending on the other for activation. With vitamin B12 deficiencies, impaired DNA synthesis results leading to megaloblastic anemia, glossitis, hypospermia, and gastrointestional disorders. Lack of vitamin B12 also results in subacute degeneration of cerebral white matter, optic nerves, spinal cord, and peripheral nerves with resulting symptoms of numbness, tingling, burning of the feet, stiffness, and generalized weakness of the legs.

Toxicity: No toxic effects are known.

Occurrence and properties: Vitamin B12 is found almost exclusively in foods derived from animals. Usual dietary sources are meat and meat products and to a lesser extent milk and milk products. Richest sources are liver and kidney. Plant products have very little vitamin B12. Fermented soy products and some sea algae do not provide an active form of vitamin B12. Megadoses of vitamin C may adversely affect the availability of vitamin B12 from Food.

Cyanocobalamin crystals are dark red, and the substance absorbs water. Cobalamins are destroyed by heavy metals and strong oxidizing or reducing agents. Aqueous solutions are neutral with maximum stability at pH 4.5 to 5.0.

Commercial forms: Vitamin B12/cyanocobalamin are dark red crystals or amorphous or crystalline powder. In anhydrous form it is very hygroscopic and when exposed to air it may absorb about 12% of water. Packaging and storage should be in well-closed containers.

2.14 Biotin

Biotin was first isolated in 1936 and synthesized in 1943. First named vitamin H, it was later proved to be the same as a potent growth factor in yeast known as coenzyme R and was renamed biotin. It functions as the coenzyme for reactions involving the addition or removal of carbon dioxide to or from active compounds. These coenzymes are involved in gluconeogenesis, synthesis, and oxidation of fatty acids, degradation of some amino acids, and purine synthesis. The absorption of both dietary biotin and any biotin synthesized by intestinal bacteria is thought to be prevented by dietary avidin, a glycoprotein found in raw egg white. Thus the name ''egg-white injury'' given to the syndrome of severe dermatitis, hair loss, and neuromuscular dysfunction.

Occurence and Properties: Biotin is widely distributed with major food sources including liver, rice, egg yolks, and vegetables. It may also be found in seeds of many cereals and oilseeds, however it is largely unavailable in this form. Avidin reduces the bioavailability of biotin. Biotin will occur in food as free biotin but is usually bound to protein.

Biotin is soluble in water. It is more soluble in hot water and in dilute alkali and four times more soluble in 95% ethanol than in cold water. It is not soluble in other organic solvents. Biotin does not fluoresce nor is it a UV absorber.

Commercial forms: cis-Hexahydro-2-oxo-1H-thieno[3,4]imidazole-4-valeric acid and d-biotin is a practically white crystalline powder. It is stable to air and heat. Packaging and storage should be done in tight containers.

3. Minerals as nutritive additive

Minerals are inorganic elements that retain their chemical identity when in a food product. Minerals can be divided into two groups, the major minerals and the trace minerals. Major minerals are those present in amounts larger than 5 g in the human body. The seven major minerals include calcium, phosphorus, potassium, sulfur, sodium, chloride, and magnesium. Sulfur, however, is not traditionally used as a nutritional additive. There are more than a dozen trace minerals. Some of the most important trace mineral nutritional additives include iron, zinc, copper, iodine, manganese. Minerals cannot be destroyed by heat, air, acid, or mixing, and only little care is needed to preserve minerals during food preparation. The ash that remains when a food is burned contains the minerals that were in the food originally. Aside from price considerations, the choice of the source depends on three factors:

1. Bioavailability of the mineral in a particular salt form.
2. Solubility and/or mixability.
3. Potential effects on final product properties.

3.1 Calcium

Calcium is needed to form bones and to keep bones strong. Bones and teeth are the major storage units of calcium of one's body. Bones are continually torn down and built back as the body works to meet its calcium needs. If calcium needs are not met through dietary intake, the body will pull greater amounts of calcium from bones. Without adequate intake of calcium, use of stored calcium will lead to porous bones and eventually to the crippling bone disease osteoporosis. Dairy products are an excellent source of calcium. Other sources include dark green leafy vegetables, broccoli, spinach, sardines, canned salmon,and almonds. Recommended Dietary Allowances for calcium have been increased to 1300 mg for ages 9–18, 1000 mg for ages 19–50, and 1200 mg for age 50 and older.

Calcium is commercially available in several forms as a nutrient in foods which includes Calcium phosphate, monobasic, Calcium phosphate, tribasic, Calcium acid pyrophosphate, Calcium carbonate, Calcium glycerophosphate, Calcium oxide, Calcium lactobionate, Calcium pyrophosphate, Calcium phosphate dibasic and Calcium sulphate. Other commercial forms of calcium exist: calcium silicate, calcium acetate, calcium bromate, calcium chloride, calcium gluconate, calcium hydroxide, and calcium peroxide. However, in the Federal Commercial Codex, their functional use in foods does not include the term nutrient.

Calcium is determined using either atomic absorption spectrometry or inductively coupled plasma spectroscopy.

3.2 Phosphorus

Following calcium, phosphorus is the second major component of bone and teeth. Besides working with calcium, phosphorus is important as a major regulator of energy metabolism in one's body organs and generates energy in every cell of one's body. Phosphorus also plays an important role in DNA and RNA. Most foods contain phosphorus. However, good sources are protein-rich foods including milk, meat, poultry, fish, and eggs. Legumes and nuts are good sources as well. Carbonated beverages also contain phosphorus. With such an abundance of availability to phosphorus, deficiencies are rare. Should deficiency occur, symptoms would include loss of appetite, bone loss, weakness, and pain. Calcium and phosphorus can have an inhibitory effect on the absorption of iron from food.

Excessive intake of phosphorus, the level of calcium in blood may be reduced. This may be a potentially serious problem in those that already have low calcium intake. Patients with advanced renal failure often become hyperphosphatemic as renal failure progresses. The current recommendations for males and females 9 to 18 years of age is 1250 mg and that for 19 years of age and beyond is 700 mg.

Commercially phosphorus is available in combination with other minerals: calcium phosphate, calcium pyrophosphate, calcium glycerophosphate, ferric phosphate, ferric pyrophosphate, magnesium phosphate, manganese glycerophosphate, potassium glycerophosphate, sodium phosphate, sodium ferric pyrophosphate, and sodium pyrophosphate.

3.3 Magnesium

Magnesium is an intracellular cation largely found in bone, followed by muscle, soft tissues, and body fluids. It is important for the part that it plays in more than 300 body enzymes. Enzymes regulate body functions, including producing energy, making body protein, and enabling muscle contractions. Magnesium also plays a part in neuromuscular transmission and activity and works with or against the effects of calcium. Excess magnesium will inhibit bone calcification.

Dietary sources high in magnesium include seeds, nuts, legumes, and unmilled cereal grains. Green vegetables are also good sources. Diets high in refined foods, meats, and dairy products are low in magnesium. In the processing of foods like flour, rice, and sugar, magnesium is lost and not returned in the enrichment process. Because magnesium is relatively common, deficiencies are rare. In cases where the body does not absorb magnesium appropriately, deficiency symptoms of irregular heartbeat, nausea, weakness, and mental derangement may result. Magnesium deficiencies are common in short bowel syndrome where there is binding of calcium and magnesium, as well as with diseases that cause prolonged vomiting or diarrhea. Excessive intakes of magnesium do not appear to be of concern unless kidney disease exists.

Recommended dietary allowances for males 19 to 30 years old is 400 mg, and from 31 years on is 420 mg. Recommendations for females 19 to 30 years old is 310 mg, and from 31 years is 320 mg.

Commercials forms of magnesium includes Magnesium gluconate, Magnesium phosphate dibasic, Magnesium phosphate tribasic and Magnesium sulphate. An integrated analytical scheme involving flame atomic absorption and flame emission spectrometry can be used to determine magnesium elements in foods.

3.4 Potassium, Sodium and Chloride

These three minerals are known as electrolytes because of their ability to dissociate into positively and negatively charged ions when dissolved in water. These ions, in delicate balance, help to regulate fluids in and out of body cells. Potassium, the major cation of intracellular fluid, is present in small amounts in extracellular fluid. With sodium, potassium maintains normal water balance, osmotic equilibrium and acid–base balance. Besides helping to regulate fluids in and out of body cells, potassium is also important, along with calcium, in the regulation of neuromuscular activity. Potassium promotes cellular growth and helps maintain normal blood pressure. Muscle mass and glycogen storage are related to muscle mass. During times of muscle formation an adequate supply of potassium is essential. Muscle contractions require potassium.

A wide range of food sources provide potassium including bananas, whole milk, turkey, haddock, okra, oranges, and tomatoes. Concerns involving too much potassium are rare except in cases where the kidneys are unable to excrete excess, which may lead to heart problems. In cases of excessive vomiting and diarrhea, potassium deficiency may result. Deficiency symptoms may include weakness, appetite loss, nausea, and fatigue. Low potassium (hypokalemia) is one of the most common electrolyte abnormalities encountered in clinical practice.

There are no established recommended dietary allowance levels for potassium. Commercial forms of potassium include potassium chloride, potassium gluconate, Potassium glycerophosphate and Potassium iodide. Both atomic absorption spectrometry and inductively coupled plasma spectroscopy are used to determine potassium in foods.

The most common form of sodium is sodium chloride or table salt. Processed foods are high in sodium and only a small amount of sodium occurs naturally in foods. In the 1960s sodium restriction began to gain acceptance as a dietary practice to reduce hypertension. Both chloride and sodium amounts and concentrations are responsible for regulation of extracellular fluids. Excessive chloride, like excessive sodium, may play a role in high blood pressure.

3.5 Iron

Iron is important as a carrier of oxygen in the hemoglobin of red blood cells. Hemoglobin takes oxygen to body cells where it is used for energy production. The resulting byproduct of energy production, carbon dioxide, is removed by hemoglobin. Iron can exist in different ionic states and therefore can serve as a cofactor to enzymes involved in oxidation– reduction reactions. As energy production proceeds, iron gets recycled protecting against iron deficiency. Iron is also important for its roles in protecting from infections, in converting beta carotene to vitamin A, in helping produce collagen, and in helping make body proteins. Iron is widely available in foods from a variety of sources, both animal and plant. Iron found in plants is only nonheme iron. Iron found in meat, poultry, and fish contains both heme and nonheme iron in a ratio of about 40 to 60. Heme iron is more rapidly absorbed in the body then nonheme iron. Absorption of nonheme iron can be increased with consumption of vitamin C sources. Hinderances to nonheme iron absorption can be caused by oxalic acid in spinach and chocolate, phytic acid in wheat bran and legumes, tannins in tea, and polyphenols in coffee.

Recommended Dietary Allowances for males ages 11 to 18 is 12 mg, and for males 19 and older is 10 mg. For females 11 to 50 years old the recommended amount is 15 mg. Despite its wide availability, iron deficiency is one of the most common nutritional deficiencies, especially among children and women during childbearing years. Deficiencies can be caused by injury, hemorrhage, or illness and can be aggravated by poorly balanced diet containing insufficient vitamins and minerals. Anemia occurs as a result of iron deficiency and symptoms include fatigue, weakness, and general poor health. Excessive iron overload may be caused by hereditary hemochromatosis or transfusion overload. Iron toxicity or poisoning is a short-term disorder that occurs following ingestion of large doses of therapeutic iron. Iron toxicity can lead to severe organ damage and death within hours or days.

Commercial forms of iron include Ferric ammonium citrate, Ferric phosphate, Ferric pyrophosphate, Ferric fumerate, Ferric gluconate, Ferric lactate, Ferric sulphate, etc. Near-infrared spectroscopic analysis has been used to determine heme and nonheme iron in raw muscle meats.

3.6 Zinc

Zinc is second only to iron in its abundance. Zinc assists in the promotion of cell reproduction, tissue growth, and tissue repair. Over 70 enzymes have zinc as a part of them. Zinc is an essential nutrient for normal wound healing. Zinc is also involved in reactions to either synthesize or degrade major metabolities such as carbohydrates, lipids, proteins, and nucleic acid.

Zinc is primarily found in meat, fish, poultry, milk, and milk products. Whole grain products, wheat germ, black-eyed peas, and fermented soybean paste (miso) are also good sources of zinc. Recommended Dietary Allowances for males 11 years and older is 15 mg, and for females 11 years and older is 12 mg.

Deficiencies in zinc can cause retarded growth, loss of appetite, skin changes, and reduced resistance to infections. During pregnancy, zinc deficiencies can cause birth defects. High calcium diets have been found to significantly reduce zinc absorption and zinc balance in postmenopausal women. Zinc toxicity, although rare, can cause deficiency in copper. Toxic levels can also be harmful to the immune system. Commercial forms include zinc gluconate, zinc oxide, and zinc sulphate. Using atomic absorption with a flame mode is found to be efficient and accurate in determination of zinc in foods.

3.7 Copper

Copper is involved as a part of many enzymes and helps the body to produce energy in cells. Copper also helps make hemoglobin and is needed to carry oxygen in red blood cells. Studies have found that copper is required for infant growth, host defense mechanisms, bone strength, red and white cell maturation, iron transport, cholesterol and glucose metabolism, myocardial contractility, and brain development.

Sources of copper in food are highly variable. Rich sources include organ meats, oysters, seafood, nuts, chocolate, and seeds. Milk is a poor source of copper although human breast milk has a higher content than cow milk. Drinking water will also have a variable amount of copper depending on the natural mineral content and pH of the water and the plumbing system.

Deficiencies of copper can result from decreased copper stores at birth, inadequate dietary copper intake, poor absorption, elevated requirements induced by rapid growth, or increased copper losses. Clinical manifestations of copper deficiency are anemia, neutropenia, and bone abnormalities. Overt toxicity from dietary copper sources is rare. Wilson’s disease is a rare inherited disease which causes copper to be accumulated slowly in the liver and then released and taken in by other parts of the body. Estimated safe and adequate daily dietary intake level for adults is 1.5 to 3 mg/day.

Copper gluconate and copper sulphate are commercial forms of copper. Atomic absorption in the flame mode can be used efficiently, accurately, with low inter-laboratory co-efficients of variation for copper estimation in foods.

3.8 Iodine

Iodine functions as a part of the thyroid hormone, thyroxin. The thyroid regulates the rate that one's body uses energy. It is involved in the regulation of metabolic activities of cells, especially of the brain during fetal and early postnatal life. When requirements are not met, functional and developmental abnormalities can occur.

Iodine found in foods is rapidly absorbed as iodide. Iodized salt is the main source of this element. Iodine in milk is influenced by the source of animal feed and the sanitizing solutions used in the dairy industry.

Deficiencies of iodine can occur at all stages of development. During pregnancy, infancy, or early childhood, deficiency may lead to endemic cretinism in an infant or child. Cretinism is not reversible. Goiters, the more commonly known iodine deficiency symptom, can be reversed by providing adequate iodine intake. Iodine can also be toxic. Graves' disease is the most common form of hyperthyroidism. Calcium and vitamin D losses may occur in cases of hyperthyroidism, and supplementation with a multivitamin is recommended.

The iodine recommended allowance for adults is 150 mg/day. During pregnancy, an additional 25 mg/day is recommended and an additional 50 mg/day is recommended for lactating women. Kelp, a dehydrated seaweed, is used as a source of iodine.

3.9 Manganese

Manganese functions as a part of several enzymes. Besides magnesium, manganese can also activate numerous enzymes. Manganese is associated with the formation of connective and bony tissues, growth and reproduction, and carbohydrate and lipid metabolism.

Sources of manganese include nuts, seeds, tea, and whole grains. Small amounts are found in meats, dairy products, and sugary and refined foods.

Manganese deficiency symptoms include poor reproductive performance, growth retardation, congenital malformations in offspring, abnormal formation of bone and cartilage, and impaired glucose tolerance. However there are no reported cases of deficiency in humans. The lungs and brain are the primarily affected by overdose of manganese. No RDA exists for manganese. However, the estimated safe and adequate daily dietary intake for adults is 2.0 to 5.0 mg/day.

Commercial forms include Manganese chloride, manganese gluconate, Manganese glycerophosphate, Manganese hypophosphite, Manganese sulphate and Manganese citrate.

Atomic spectroscopy and neutron activation analysis are two methods believed to have the most sensitivity and greatest potential for accurately measuring manganese.

5. Conclusion

Vitamins and minerals are trace elements but are vital for several body functions including cell metabolism, energy transformation, tissue repair, part many enzymes, etc and thus it is impossible to have normal life without these minor nutrients. Many deficiency disease encountered can be alleviated by supplementation with recommended dosage level.