Vitamins

Vitamin A, Vitamin B, Vitamin C, Vitamin D, Vitamin E

Vitamins

Vitamins are similar to hormones in that they control bodily functions in minute amounts, but unlike hormones, which are synthesized in the endocrine system of the human body, they have to be taken as food. Vitamins cannot produce energy like carbohydrates, fat, or proteins, but control various functions of the body. Most vitamins are components of enzymes or coenzymes, which are involved in the metabolism of carbohydrates, fat, protein, and minerals. Enzymes or coenzymes do not directly participate in chemical reactions and are not consumable, so the necessary amount of vitamins are very small. But as enzymes play a vital role in biological reactions, no matter how small the amount necessary, if it is not supplied adequately the metabolism of nutrients cannot be fulfilled appropriately, causing symptoms of deficiency.

Vitamin A (retinol)

Vitamin A is a vitamin related to visual functions, and acts as a growth factor. Vitamin A acts in the form of the light-absorbing molecule retinal in the retina of the eye, and retinal is absolutely necessary for seeing objects in low-light conditions and color vision. Also, vitamin A functions as a growth factor with hormones in places such as the epithelial cells, in the form of retinoic acid which is irreversibly oxidized from retinol.

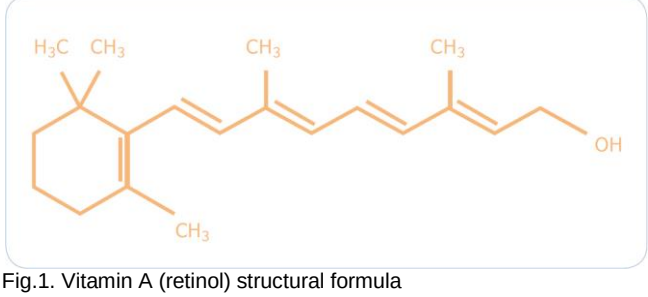

Fig.1. Vitamin A (retinol) structural formula

The human body stores vitamin A in the form of retinol, and converts it into its aldehyde form retinal when necessary to act in the visual system. All forms of vitamin A have an ionone ring with an attached isoprene, which is known as the retinyl group. This structural characteristic is essential in the action of vitamins. Vitamin A is known to perform many functions including visual functions, genetic transcription control, immune functions, embryogenesis and reproduction, bone metabolism functions, hematopoiesis, skin and cellular health, and antioxidative functions. In addition, vitamin A is abundant in liver, carrots, broccoli, sweet potato, butter, kale, spinach, pumpkin, cheese, cantaloupe, eggs, apricot, papaya, mango, peas, and milk.

Vitamin A deficiency can be categorized as primary and secondary deficiency. Primary deficiency is seen in children and adults who haven't ingested enough provitamin A carotenoids from fruits, vegetables, animal products, and dairy products. Early weaning from breast milk may also increase the risk of vitamin A deficiency. Secondary deficiency is caused by chronic lipid malabsorption, poor bile production and secretion, chronic exposure to oxidants such as cigarette smoke, and chronic alcoholism. Also, as zinc is essential as a cofactor in the synthesis of the vitamin A transportation protein and retinol-retinal conversion, zinc deficiency may also result in poor absorption, transportation, and metabolism of vitamin A.

Because retinal acts as a visual chromophore, an initial sign of vitamin A deficiency is night blindness, a type of visual deficit. Continued deficiency may induce blindness due to conjunctival dryness and corneal damage, and other than visual deficits may also cause symptoms such as immunodeficiency and hyperkeratosis.

Vitamin B complexes

Vitamin B complexes are water soluble-vitamins that perform an important role in cell energy metabolism. Vitamin B was known as a single vitamin in the past, but further studies revealed separate types that can be categorized chemically, and detailed names were given.

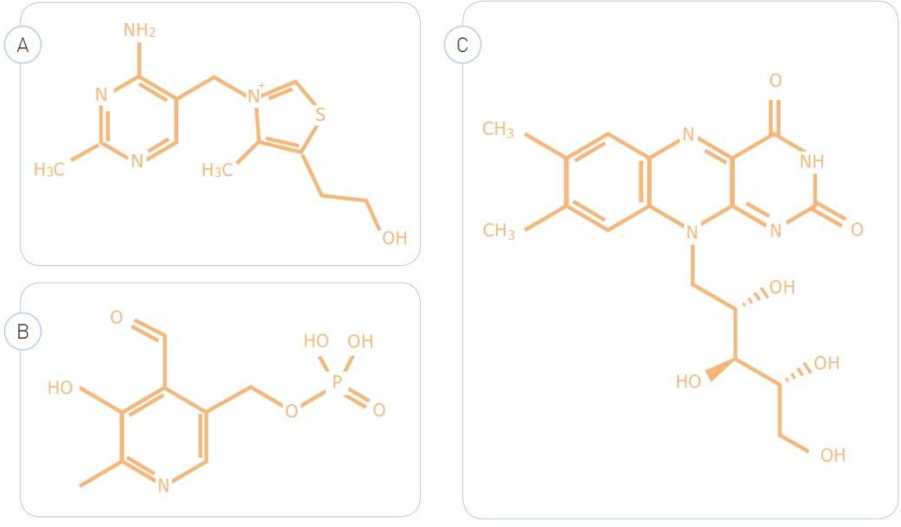

Fig.2.
Vitamin B complex structural formula
(A) Vitamin B1 (thiamin),
(B) Vitamin B6 (pyridoxine)
(C) Vitamin B2 (riboflavin)

1. **Vitamin B1 (thiamine)**
   Thiamine or vitamin B1 are molecules involved in carbohydrate metabolism and are abundant in yeast and grains, especially in the germ of a grain. Thiamine is transported in the form of a coenzyme in erythrocytes in its intact form in the blood, and as it is not stored easily, excess intake is excreted immediately through urine. Also, 80% of vitamin B1 in the body exists in the form of thiamin pyrophosphate (TPP), which is a type of thiamin coenzyme, and is involved in energy metabolism including carbohydrate metabolism. Because all cells require energy, thiamin deficiency affects all bodily organs, and is also necessary for nerve and muscle activity. TPP acts as a coenzyme for the enzyme that participates in the pentose phosphate pathway necessary for the synthesis of DNA and RNA, and is involved in nucleic acid synthesis. Thiamine deficiency may result in Beriberi disease, Wernicke-Korsakoff syndrome, cataracts, Alzheimer's disease, and heart failure.

2. **Vitamin B2 (riboflavin)**
   Riboflavin (lactoflavin) or vitamin B2 is abundant in meat, eggs, milk, cheese, yogurt, leaf vegetables, and whole grains, and its deficiency is rare with a balanced diet. But as it is water soluble, it is continuously excreted through urine and if continuous intake is not done, deficiency may arise. Riboflavin deficiency may also be caused by other causes such as liver disorders or adverse events of drugs. Riboflavin deficiency may lead to growth arrest, early aging, keratitis, dermatitis, alopecia, glossitis, angular stomatitis, stomatitis, sore throat, gastrointestinal disorders, ocular hyperemia and disorders.

3. **Vitamin B6 (pyridoxine, pyridoxamine, pyridoxal)**
   Many forms of vitamin B6 are known, and pyridoxal 5'-phosphate (PLP) is its active form. It is a cofactor in many amino acid metabolic reactions such as transamination, deamination, and decarboxylation. Also, PLP is necessary for enzymatic reactions that control glucose release from glycogen. PLP is a type of vitamin B6 activated through metabolic activity, and it is associated with various bodily functions such as the metabolism of large amounts of nutrients, synthesis of neurotransmitters, synthesis of histamine, synthesis of hemoglobin, and gene expression.

   Vitamin B6 is synthesized by gut flora and deficiency is very rare, but for people with absorption disorders such as lactose intolerance or celiac disease, diabetic patients, the elderly, pregnant women, and women taking oral contraceptives, there is a risk of deficiency. Vitamin B6 can be ingested as pills, capsules, and syrup, and can be used as a nasal spray or for injection in liquid form. Adults can safely ingested up to 200 mg of vitamin B6 every day, but long-term excessive ingestion may result in neurologic deficits such as loss of sensation in the legs and imbalance, and paresthesia of hands and feet.

Vitamin C (ascorbic acid)

Vitamin C is a water-soluble vitamin and is an essential coenzyme for energy metabolism in living organisms, and is also involved in anti-oxidation. Some animals can synthesize it in the body, but synthesizing enzymes are deficient in primates including humans and guinea pigs, a type of rodent, and it must be ingested through food externally. Because it is water soluble, ingestion of large amounts does not lead to accumulation in the body, and remaining amounts are excreted through urine. Therefore, it is relatively safer than fat-soluble vitamins when taken in excess.

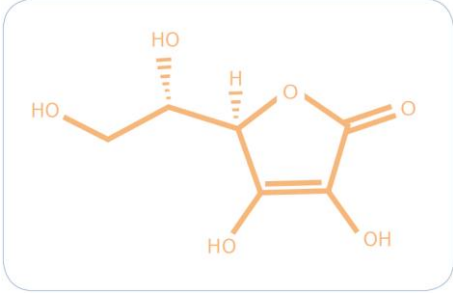

Fig.3. Vitamin C structural formula

Vitamin C deficiency may lead to scurvy. In the early 20th century, fresh fruits and vegetables, which are the major sources of vitamin C, were lacking and scurvy was common in the navy or among sailors. But these days, fruits and vegetables are relatively easy to come by and vitamin C deficiency is rare. But irregular eating habits may lead to ingestion falling short of the daily recommended dose, and care should be taken. Vitamin C is structurally destroyed if heated over 70℃ due to its characteristic five-sided ring structure, and it is desirable to eat raw fruits and vegetables.

Linus Carl Pauling, who won the Nobel Prize twice, claimed vitamin C was all-powerful and insisted on high-dose therapy. Some researchers in Korea also claimed its potency as an anti-cancer substance, but the number of samples are insufficient, long-term research is lacking, and there is lack of research on the appropriate dose, which hindered its wide recognition. There is some research that shows that continuous ingestion of vitamin C, even if not in large amounts, may prevent the oxidation of cholesterol and help patients with cardiovascular diseases and aid in the enhancement of the immune system, such as preventing colds. But excess ingestion of vitamin C may lead to diarrhea, stone formation, and hemolysis, and the WHO does not recommend long-term high dose therapy. Reputable organizations such as the U.S. FDA, American Medical Association, UK Foods Standards Agency, and Korean Nutrition Society have recommended a daily maximum dose of 2000 mg, and daily ingestion over 1000 mg is not recommended.

Vitamin D (cholecalciferol, ergocalciferol)

Vitamin D is a fat-soluble vitamin that helps the absorption of calcium in the colon and kidneys, which is necessary for skeletal formation, and acts with the parathyroid hormone and calcitonin to regulate calcium in the body and bone mineralization.

Vitamin D deficiency leads to huge deficits in bone growth and maintenance. A recent study has shown that vitamin D acts on various organs and its deficiency is related to various diseases such as reduced immunity, malignant tumors and its metastasis, allergy and asthma, anomalies in hormonal metabolism, decreased brain functions, generation of cardiovascular diseases, and reduced renal functions.

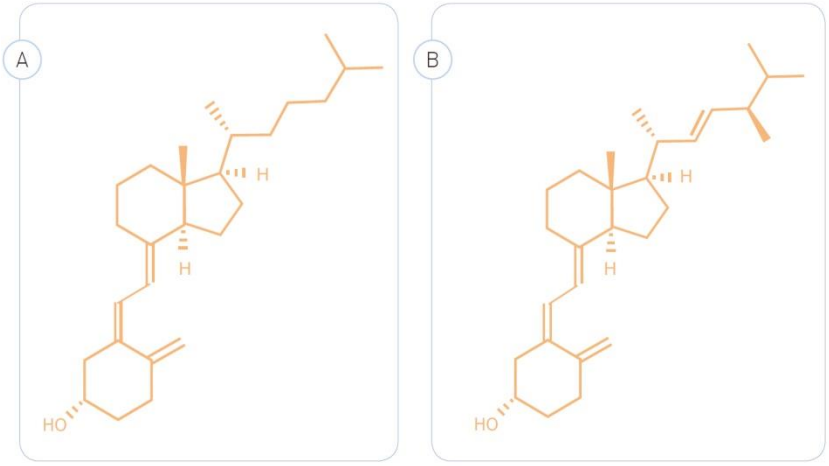

Fig.4. Vitamin D structural formula
(A) Vitamin D3
(B) Vitamin D2

Vitamin D forms more than 50 metabolites in the body. It exists in two major metabolite forms, which are 25(OH)D2 (vitamin D2), ingested through food, and 25(OH)D3 (vitamin D3), which is synthesized in the skin from ultraviolet rays. 1,25-dihydroxyvitamin D (1,25(OH)2D) is an active hormone, has a short half-life and low blood levels, and is measured when diseases with excessive production of vitamin D such as sarcomatosis or some types of lymphomas are present. To evaluate the general vitamin D nutrition status, 25(OH)D is mainly measured.

Many tests on 25(OH)D do not distinguish between D2 and D3, and reports as total 25(OH)D. But tests such as liquid chromatography-tandem mass spectrometry can distinguish between 25(OH)D2 and D3 and can quantify them, and the sum of the two values can be reported as total 25(OH)D.

Vitamin E (tocopherols, tocotrienols)

Vitamin E is a term that includes four types of tocopherols and tocotrienols, α, β, γ, and δ. Tocopherol is present in plant seeds and green leaf vegetables, and seed oils are a major food source. The main function of vitamin E is its action as an antioxidant, and it is well-known for its role in inhibiting damage to lipids from reactive oxygen species. Most studies on vitamin E were done on the investigation of α-tocopherol, and the effects of α-tocopherol are perceived as representing the functions of vitamin E, but other types of tocopherols and tocotrienols are known to have similar effects.

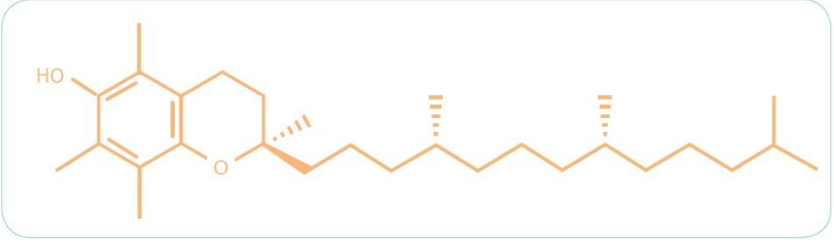

Fig.5. Vitamin E structural formula

Table 1. Major Vitamins

Vitamin generic descriptor name	Vitamin chemical name(s) (list not complete)	Deficiency disease	Overdose disease	Food sources
Vitamin A	Retinol, retinal	Night-blindness, Hyperkeratosis, and Keratomalacia	Hypervitaminosis A	Liver, orange, ripe yellow fruits, leafy vegetables, carrots, pumpkin, squash, spinach, fish, soy milk, milk
Vitamin B1	Thiamine	Beriberi, Wernicke-Korsakoff syndrome	Drowsiness or muscle relaxation with large doses.	Pork, oatmeal, brown rice, vegetables, potatoes, liver, eggs
Vitamin B2	Riboflavin	Ariboflavinosis, Glossitis, Angular stomatitis	-	Dairy products, bananas, popcorn, green beans, asparagus
Vitamin B3	Niacin, niacinamide	Pellagra	Liver damage (doses > 2g/day) and other problems	Meat, fish, eggs, many vegetables, mushrooms, tree nuts
Vitamin B5	Pantothenic acid	Paresthesia	Diarrhea; possibly nausea and heartburn	Meat, broccoli, avocados
Vitamin B6	Pyridoxine, pyridoxamine, pyridoxal	Anemia, peripheral neuropathy	Impairment of proprioception, nerve damage (doses > 100 mg/day)	Meat, vegetables, tree nuts, bananas
Vitamin B7	Biotin	Dermatitis, enteritis	-	Raw egg yolk, liver, peanuts, leafy green vegetables
Vitamin B9	Folic acid, folinic acid	Megaloblastic anemia and Deficiency during pregnancy is associated with birth defects, such as neural tube defects	May mask symptoms of vitamin B12 deficiency; other effects.	Leafy vegetables, pasta, bread, cereal, liver
Vitamin B12	Cyanocobalamin, hydroxycobalamin, methylcobalamin	Megaloblastic anemia	Acne-like rash [causality is not conclusively established]	Meat and other animal products

Vitamin generic descriptor name	Vitamin chemical name(s) (list not complete)	Deficiency disease	Overdose disease	Food sources
Vitamin C	Ascorbic acid	Scurvy	Vitamin C megadosage	Many fruits and vegetables, liver
Vitamin D	Cholecalciferol, Ergocalciferol	Rickets and Osteomalacia	Hypervitaminosis D	Fish, eggs, liver, mushrooms
Vitamin E	Tocopherols, tocotrienols	Deficiency is very rare; sterility in males and abortions in females, mild hemolytic anemia in newborn infants	Increased congestive heart failure seen in one large randomized study	Many fruits and vegetables, nuts and seeds
Vitamin K	Phylloquinone , menaquinones	Bleeding diathesis	Increases coagulation in patients taking warfarin	Leafy green vegetables such as spinach, egg yolks, liver

➢ Test information

Test name	Specimen	Test date /Analytical time (day)	Method
Vitamin A (retinol) (GC Labs code: C405)	Serum 1.0 mL	Tue, Thu / 2	HPLC
Vitamin B1 (thiamine) (GC Labs code: C612)	EDTA WB 2.0 mL	Mon, Wed, Fri / 2	HPLC
Vitamin B2 (riboflavin) (GC Labs code: C614)	EDTA WB 3.0 mL	Thu / 2	HPLC
Vitamin B6 (pyridoxine) (GC Labs code: C610)	EDTA P 0.5 mL	Mon, Thu / 2	HPLC
Vitamin B12 (cyanocobalamin) (GC Labs code: C402)	Serum 0.5 EDTA P 0.5 Heparin P 0.5	Mon-Sat / 1	ECLIA
Vitamin C (ascorbic acid) (GC Labs code: C693)	Serum 1.0 mL	Tue, Thu / 2	HPLC
Vitamin E (tocopherol) (GC Labs code: C533)	Serum 1.0 mL	Tue, Thu / 2	HPLC
25-OH Vitamin D2 & D3 (GC Labs code: K209)	Serum 1.0 mL	Mon, Wed, Fri / 3	LC-MS/MS

➢ Contact

Business Strategy Team Tel:+82-31-280-9908 E-mail: gclabsob@gclabs.co.kr

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