CHAPTER-1

Classification of Nutrients

water, carbohydrates, proteins, lipids, minerals and vitamins; role of different nutrients in animals growth, production, reproduction and health

OBJECTIVES

1. To understand the basic role of nutrients in animal body.
2. Classification of nutrients based on their role in animal system.

Introduction

Nutrition is a biological process of chemical and physiological reactions which transform feeds/ fodders into body tissues and activities of organisms. It involves ingestion and digestion food materials, absorption of various nutrients, their transport to all body tissues thereby maintaining growth, repair, production and reproduction and removal of indigestible materials from the body. Feed comprising of water, organic constituents (carbohydrate, protein, fat and vitamins) and inorganic constituents (major and macro minerals) in variable amounts and these are known as nutrients. These nutrients are required for maintenance, growth and repair, reproduction and other body functions in adequate quantity and proportions. The objective of studying the subject is to provide all essential nutrients in adequate quantity and optimum proportions to all organisms.

Every nutrient has its specific functions to play in the biological system. As we know there are six nutrients i.e., water, carbohydrate, protein, fat, minerals and vitamins and each of these have different functions, it will be discussed separately for each nutrients.

Water

Water is the ideal dispersing medium because of its solvent and ionizing powers which facilitates cell reaction and due to its high specific heat which helps to absorb the heat of these reactions with a minimum rise of temperature. Lean adult body contains about 70 percent of water, though the amount varies from embryo to mature animals. In case of animals, the water content is approximately 95 percent for the embryo shortly after conception, 75-80 percent at birth, 65-72 percent at 5 months and 40-65 percent in mature animal which indicates the importance of water in animal body. It is to be noted that India with less than 3 percent water resources harbouring more than 11 percent animals and more than 16 percent human beings. So, we have to use water in judicious way for better future.

Water deprivation: When human is deprive of drinking water in a hot and dry environment, soon exhibits thirst. When deficiency comes to 4-5 percent of body weight there is discomfort, anorexia, when it comes to 6-10 percent, there is headache, lack in coordination, indistinct speeches, dyspnoea and cyanosis. At 12-14 percent level, eye sunken, skin becomes shriveled, there is inability to swallow and delirium occurs. Under hot environment, 12 percent deprivation is fatal to human.

Functions of water

a. By solvent action, it serves as universal medium in which cellular reaction, ionic and other reaction takes place.

b. Lubrication: It acts as lubricant to prevent friction and drying in joints, pleura, conjunctive etc.

c. Hydrolytic action: In this process, H^+ and OH^- ions of water introduced into bigger molecules to facilitate breakdown process.

d. Cell rigidity and elasticity: The body must have a definite form which it can be retain and yet within limits it must be able to change its shape by comprising to some extent to the force applied at any particular point. This is made possible by liquid content of the cell.

e. Transport: It acts as a vehicle for transporting absorbed and reabsorbed of various food materials and excretory products to the definite organ.

f. Heat regulation: As the specific heat of water is high, it is important in heat regulation of body by conduction and distribution, heat loss through urine, feces and respiration as well as sweating.

g. Refractive medium: The aquous humor helps to keep up the shape and tension of the eye ball and acts as the refractive medium of light.

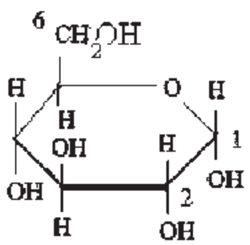
Carbohydrate

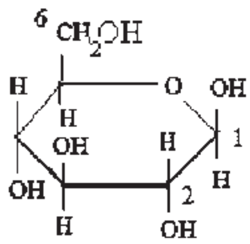
Carbohydrate may be defined as the hydrates of carbon or polyhydroxy aldehyde or polyhydroxy ketone, their polymers and on hydrolysis produces monohydroxy alcohol or ketones i.e. simple sugars. Most plants comprise 60-90 percent carbohydrate and an adult human body comprises about 300-350 g of carbohydrate. Carbohydrates may be represented with a empirical formula $C_n(H_2O)_n$.

Classification: Carbohydrate may be classified into 3 major categories- monosaccharide, oligosaccharide and polysaccharides.

Monosaccharides: These are simple sugars which can not be broken into smaller molecules upon hydrolysis. Monosaccharides again, chemically sub classified into pentoses and hexoses. Important pentoses are arabinose (occur in gum, pectin etc.), xylose (derived from plum, cherries, grapes etc.) and ribose (found every living cell i.e. adenosine di phosphate or ADP, Adenosine tri phosphate ot ATP, riboflabin, nucleic acid of every living cell). Some important hexoses are listed below with their occurance

Glucose: It is the major end product of digestion of carbohydrates by non ruminants and is the primary form to be utilized for energy in which these nutrients circulate in the blood of mammals. Glucose exists in the form of a pyranose ring and is more accurately depicted in the Haworth perspective below. Depending on position of H and OH at C-1, this exists in two form i.e. α and β. α is the precursor of starch and glycogen while, β is the form for cellulose.


α D Glucose


α D Glucose

Fructose: It is the only keto hexose in nature and sweetest of the carbohydrate. It occurs free along with glucose and sucrose in honey, inulin is found in a number of plant where it serves as reserve polysaccharide.

Disaccharide: More than one simple sugars are bound together to form disaccharide. Important disaccharides are maltose occurs in sugar cane, sugar beet in ripe fruits and tree saps, while lactose (galactose and glucose) occurs in milk.

Polysaccharide: Large number simple sugars are polymerized to form polysaccharides which are of high in molecular weight and most of them are insoluble in water. Important polysaccharide is starch which occurs in plant as small granules. These granules are very resistant to rupture but moist heating ruptures them and make them available in gut. Cellulose is a polymer of ß-1,4 glucose. As such the 6^{th} carbon atom is in *trans* position, which results in cellulose being flat band like microfibril. It is highly stable and fibrils held firmly by H bond and makes insoluble and resistant to microbial degradation. It is the most abundant substance in plant kingdom and major cell wall component and combined with lignin. Cotton is one of the purest form of cellulose. Hemicelluloses is not, as name implies, one half of cellulose rather a complex heterogenous mixture of mumber of different polymers of monosaccharide like glucose, xylose, mannose, arabinose and galactose. It is predominantly a xyloglucan. This is linked covalently to the pectic fraction of the cell wall and by H bonding to the cellulose microfibrils, thus adding to significant strength to cell wall. It is also a principal component of cell wall and less resistant to chemical degradation. Nutritionally, carbohydrate may be classified into two- fibrous and non fibrous. Fibrous carbohydrate includes cellulose, hemicellulose and lignin which are responsible for integrity of plants whereas non fibrous carbohydrate includes starch, pectin etc which are mostly the storage part of the plant. These fibrous carbohydrate fermented by microbes in rumen of ruminants, converts them to simpler molecules like acetate, propionate and butyrate which are utilized by the host animal. It is right place to mention that plant fibres are only digested by microbes, no host enzymes can solubilise them.

Functions:

a. It provides energy to cell for survival and activity. Glucose through glycolysis and tricarboxylic acid cycle produces 38 moles of ATP which is used for many purposes by the cell. In ruminants, propionate produced in the rumen, goes to liver where it converts to glucose for further use. Again, acetate may enter into the TCA cycle for energy production and at the same time it is required for body fat and milk synthesis. In case of high energy diet (higher amounts of maize, barley even higher cooked rice feeding) acetate level decreases which may lead to milk fat depression.

b. Fibre in ruminants diet is more important as it constitutes around 70 percent, though under tropical situation like in India, animals are raised animals on more than 90 percent roughages. This supplies fibre or cellulose, hemicelluloses for microbial fermentation resulting into production of volatile fatty acids.

c. It has protein sparing effects as intermediates of TCA cycle may produce amino acid which is essential for organisms.

d. Carbohydrates in combination of protein and lipids forms phospholipids and glycolipids which are the part of cell membrane.

e. Part of milk as milk sugar and this lactose is almost constant part of milk.

Protein

As it is the principal constituent of the organs and soft structures of animal body a liberal and continuous supply is needed in the blood throughout life for growth and repair, thus the transformation of food protein into body protein is very important part of nutrition. This is a collective one which embraces an enormous group of closely related but physiologically distinct numbers. Plant protein differ from each other and from animal protein. Each plant and animal species has its own specific protein, even in different organs it is specific one.

The elementary composition of protein is carbon 51-55 percent, hydrogen 6-7 percent, nitrogen 15.5-18.0 percent, oxygen 21-24 percent, sulphur 0.5-2.0 percent and phosphorus 0-1.5 percent. Proteins are the polymers of amino acid which vary in relative amounts and kind from protein to protein. These are the hydrolytic and enzymatic end product of protein. Amino acids are the derivatives of short chain fatty acids and contain a $-NH_2$ group and –COOH group. In acidic pH, it acts as cation and in basic pH, it acts as anion due to presence of NH_2 and COOH group. In the pH, a particular amino acids act as electrically neutral and called as zwitterions and the pH is termed as isoelectric point for that amino acid. Amino acids may be essential and non essential depending on the need of the organism. Amino acids may be mono amino mono carboxylic (glycine, alanine, serine, valine, leucine, isoleucine and threonine), mono amino-dicaboxylic (acidic) acid (aspertic acid and glutamic acid), diamino-monocarboxylic acid (lysine, arginine, citrulline), sulfur containing amino acid (cysteine and methionine), aromatic amino acid (tyrosine, phenyl alanine, thyroxin) and hetero cyclic amino acid (histidine and proline).

Protein are classified primarily on form, physical properties and chemical configuration.

1. Simple protein: Hydrolysis of simple protein yields amino acid or its derivatives.
2. Conjugated protein: When simple protein combined with a non- protein radical- called conjugated protein. Nucleoprotein, phospho-protein, metallo-protein etc, are the examples of conjugated protein.

   b. Structurally it can be fibrous protein which consists of long chains of polypeptide and found in collagen and keratin. Collagen found as components of connective tissue and cornea. Its insoluble and indigestible but upon heating with acid, it becomes soluble, easily digested and the mixture of polypeptides called gelatin. It contains hydroxy- proline but devoid of cysteine or cystine. Elastin, part of tendons, arteries and other elastic tissues and found to contain cystine (22 percent).

   c. Globular protein include enzymes, protein hormone and oxygen carrying proteins. These are soluble in water or aquous mixture of acids, bases or alcohol. Albumins are water soluble and are a significant part of serum protein and egg protein. Globulins are insoluble in water but solubility increases with changes in neutral fat concentration. Immuno-globulins and haemoglobulin in blood, lacto-globulins in milk, myoglobulins in muscles are some of the important examples.

Essential and non- essential amino acids:

Essential amino acids are those which are not synthesized in the body at a required rate by the body for normal functioning. Eight amino acid are dietary essential by all species and 10 are required by one or more species. These ten amino acids must be incorporated in the diet of most of the species and these are histaidine, isoleucine, lysine, leucine methionine, arginine, phenyl alanine, theronine, tryptophan and valine. Some of amino acids are synthesized inside the body, hence not required from the dietary source are called as non essential amino acid. Tyrosine, cystine, alanine, aspartic acid, glutamic acid, citrulline, hydroxy proline etc. are the example of dispensable or nonessential amino acid.

Functions of protein

Proteins perform many different functions in the animal body. Most of body proteins are present as components of cell membrane, in muscle and supportive capacities such as in skin, hair, and hooves.

In addition, plasma proteins, enzymes, hormones and antibodies against any diseases perform specialized functions in the body even though their amount is very low. Collagen gives strength and compact structure to muscles and perhaps you have seen that due to over cooking of meat and meat from older animals becomes tough due to shrinkage as a result of higher proline and hydroxyproline content. It is insoluble in water and resistant to digestive enzymes. Actin, tropomycin B and myosin protein are the major component of muscle responsible for contraction. Blood proteins are albumin, globulins, fibrinogen, hemoglobin and apoproteins works in a variety of physiological function in the organisms. Enzymes or organic catalysts performs a specific function in the system, e.g., digestive enzymes only involves in conversion of large molecules of feed to simple molecules in the gastro-intestinal tract. There are thousands of enzyme present in the cell and performs a specific function. If there is deficiency of energy/ propionate in the circulation, fat and protein comes to play in production of ATP which is required for normal functioning of cell. Like enzymes, hormones antibodies also perform a vital role in protection of animals against specific infections. Antibodies against specific infections can be acquired (passive immunity) by placental transfer to the fetus from the blood of mother, by ingestion and absorption of antibody rich colostrums by the new born or parenteral (not through mouth) injection into the susceptible animals. Exposure of susceptible animals to a pathogen/ antigen stimulates antibody production against particular antigen, resulting in active immunity.

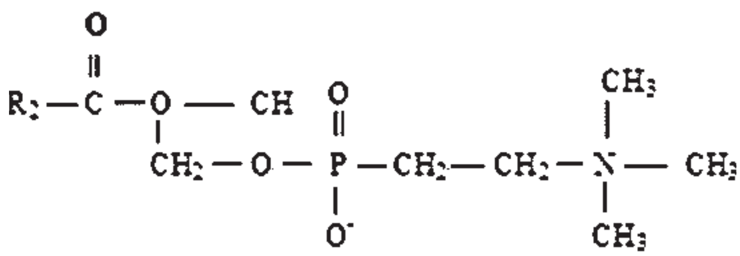
Lipids

It is defined as the substances that are insoluble in water but soluble in ether, chloroform, benzene and other organic solvents. This group includes the fat and a number of closely associated compounds. Fats or lipids play an important role in physiology and nutrition. One of the best example, we can say is cholesterol, which is the precursor of vitamin D and steroid in one hand and the infamous compound of atheromatous plaques of cardio-vascular disease on the other. It acts as the condensed reserve of the body, structural element of tissue and essentials of various reactions in intermediary metabolism.

A. Classification

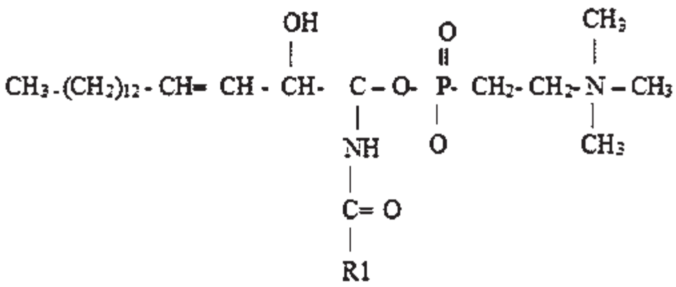
Lipids are relatively insoluble in water and relatively soluble in organic solvents and performs various important functions in animals. It is classified as the saponifiable and non saponifiable fat. Saponifiable again classified as the simple fat and waxes whereas the compound fat as the glycolipids and phospholipids. Simple fats and oils are esters of fatty acids with glycerol. Terpenes, steroids and prostaglandins are the example of nonsaponifianble lipids. Waxes are lipids resulting from combination of fatty acids and higher monohydroxy and di- hydroxy- alcohols. These have higher melting point and sufficiently difficult to saponify that these are not readily digested by animals. Common example is bee wax, a combination of palmitic acid and myricyl alcohol. Wax occurs as secretion and excretion in animals and insects and as protective coatings of plant. They are removed the in ether extract, thus, overestimates the nutritive significance of the assay.

Compound lipids: In biological system lipids contain a hydrophobic (non polar) end and a hydrophilic (polar) end which is essential for transportation. Examples of compound lipids are phospholipids, sphingolipids etc. Phospholipids consists of glycerol in which the 1 and 2 positions are esterified with long chain fatty acids. Saturated fatty acid in 1 and unsaturated fatty acid in position 2 , whereas, position 3 is esterified with phosphoric acid and turn to a nitrogen base. If the nitrogen base is choline, the phospholipids is lecithin, if it is ethnolamine, the phospholipids is cephalin. Both the lipids are component of cell membrane and involves in transport of lipid in plasma eg. chilomicrons and lipoproteins.



R2 - Fatty acid chain in the C3 position of glyceraldehydes

Shingolipids don't contain glycerol but consists of amino alcohol sphinosine to which is added a fatty acid phosphate and either choline or ethanolamine. In animals, these are found predominantly in brain and nerve tissues and called sphingomyelin. One special component of sphingolipid has the choline replaced with glucose and is called as the cerebroside, as shown below.



Prostaglandins: This group is non saponifiable and containing 20 carbon atom with cyclic structure between 8th and 12th carbon atom. These are found in almost all mammalian tissue and synthesized from linoleic acid. Their name comes from prostate gland, from where it was first identified. Though, recent advances of medical research shows that these are not confined to male genitalia but can be detected in several tissues of both sexes and are found to function as regulator of various tissue metabolism. These are often called as local hormone due to their activity within cells or nearby cells from where secreted. They work together with other established hormone to modify the chemical messages that other hormones brings to cell, though complete understanding requires research to conclude, even today.

From the standpoint of nutrition, it is the fact that main component of fat/ lipids are fatty acid. These are may be saturated and unsaturated fatty acid. Saturated fatty acids are those have no double or triple bond, on the contrary, the later have one or more double and triple bond. Polyunsaturated fatty acids have important role to play in various physiological functions.

Example of saturated fatty acids are butyrate (C4:0), palmitic (C16:0), stearate (C18:0), whereas the example of unsaturated fatty acid are oleic acid (C18: $1^{\Delta 9}$), linoleic acid (C18: $2^{\Delta 9:12}$), linolenic acid (C18: $3^{\Delta 9:12:15}$) and arachidonic acid (C20: $4^{\Delta 5:8:11:14}$).

Fat analysis and characterization

In routine feed analysis, lipids are determined as ether extract and it includes plant pigments, some essential oils thus ether extract in the feeds and fodder is not fully accurate which feed or fodder contains and available to the animal. There are some typical characteristics of food or feed fat required for routine analysis or identifying the origin of fat. Some of which are listed below.

a. **Melting point (or solidifying point)**: Number of carbon atom when increased in saturated fatty acid, melting point increased, whereas, in unsaturated fatty acid melting point decreased with increasing carbon numbers of fatty acids.

b. **Iodine number**: It is defined as the number of grams of iodine absorbed by 100 g of vegetable or animal fat to be evaluated. It readily unites with the unsaturated fat at the double bond, two moles of iodine per double bond.

c. **Saponification number**: The number of milligrams of alkali (KOH) is required to saponify 1.0 g of fat is called the saponification number of that particular fat. As one mole of K^+ reacts with each fatty acid, the larger the saponification number, the smaller the average chain length.

d. **Rancidity**: It may be of 2 type, viz., hydrolytic and oxidative depending on type of reaction with the fat. When unsaturated fat or butter are stored they become rancid due to hydrolytic activity of the microbes. These secrete lipase which splits triglyceride to mono and di- glyceride, glycerol and free fatty acid. Low molecular fatty acids give bad flavour and odour to the particular fat. This type of rancidity can be reduced by refrigeration, exclusion of water or by destroying hydrolytic microbes. In case of oxidative rancidity, hydrogen, oxygen and halogens are combined with unsaturated fatty acids. This reaction of hydrogen with fats and oils is used commercially to produce hydrogenated fats.

Functions

The functions of lipids can be listed broadly as follows

1. Supply energy for maintenance and production: Hydrolysis of triglyceride or neutral fat yields glycerol and fatty acid which serve as the source of energy. Most of the variation among fat sources in the amount of utilizable energy they contain related to their digestibility. Though high fat diet in ruminants may interfere with the rumen fermentation due to fact that fatty acids have antimicrobial activity resulting in reduction of feed intake. All the energy needed by the animals, may not require energy from fat but it is the source of essential fatty acid and fat soluble vitamins, hence fat intake must be there for every organism.

2. Serve as the source of essential fatty acids: Linoleic and linolenic acid apparently can not be synthesized by animal tissues and needs to supplement through dietary source to prevent some pathological changes. Exact mechanism is not clear how these works but assumes that they are the integral part of lipid – protein structure of of cell membrane and they appear to play an important part in the structure of several components called eicosanoids that play a role in the release of hypothalamic and pituitary hormones. Eicosanoids include thromboxane, leucotines and prostaglandins. Deficiency symptoms of essential fatty acids are dermatitis or skin lesions, growth failure, reproductive failure and deposition of tissue fluids between cells (oedema) etc.

3. Serve as the source of fat soluble vitamins: Absorption of fat soluble vitamins (A, D, E and K) is a function of digestion and absorption of fats.

4. Serve as the integral part of cell membrane.

Minerals

There are immensely important elements which require for various life processes as they are the basic component of all forms of life. Large number of elements of the periodic table has been found to be present in living cells but so far 25 minerals have been found to be dietary essential on the basis of their proven role in various metabolic function in the animal body. These are required in very small quantity as compared to carbohydrate, protein, fat, and water but deficiency may cause harmful effect in the body and some time may lead to death of the animals.

Classification

Depending on requirement of animal the minerals are classified in to two major classes viz., major or macro and micro or trace minerals. There are 7 minerals viz., Ca, P, Mg, S, Na, K and Cl which are termed as major as these are needed in relatively higher quantity (i.e. in grams) and others *viz*., Cu, Co, Zn, Fe, I, F, Mn, Ni, Si, Sn, V, Cd, Hg, Pb, Cr, As, Sc and Se are termed as trace mineral as these are needed relatively lower quantity (in microgram or even less) for large ruminants. In addition to these listed minerals there are 30 or so minerals that are needed for normal functioning of the animal body but exact role yet to be established.

Most of the minerals are distributed throughout the body where they exist in variety of functional combination and in characteristic concentrations which must be maintained within quite narrow limits if the functional and structural integrity of the tissue is to be safeguarded with the growth, health and productivity of the animal. Continued ingestion of diets, that are deficient, imbalanced or excessively high in a particular element invariably induce changes in the functioning forms, activities or concentration of that element in the body tissues or fluids. Under these circumstances, biochemical defects develop, physiological functions are affected and structural disorders may arise in ways which vary with different elements, with the degree and duration of the dietary deficiency or toxicity and with age, sex and species of animal involved. However, there is generally a varying degree of gap between the essential and apparently toxic levels of intake.

Bioavailability of minerals

Bioavailability of any mineral relates to the degree to which an ingested mineral is absorbed and so is available to the body of the animal. While minerals are present in a feed, they are not available unless the body can absorb and utilize them. The ability to absorb minerals from a diet depends on many factors. A value listed in the feed composition table is just a starting point for estimating the true contribution a feed makes to the animals' mineral needs. Bioavailability in true sense, therefore, could be defined as the proportion of an ingested element i.e. absorbed, transported to the site of action and converted to the physiologically active species.

In the country like India, animals are fed diets consisting of dry fodders, legumes and non- leguminous fodders, tree leaves, shrubs, crop residue and cereal byproducts. In such diets mineral content is generally low and their availability is not known. Ruminant reared mostly on roughages mainly crop residues and animals need supplementation of minerals. But most of the farmers are not aware of the fact and there is immediate need to consider mineral supplementation to the dairy animals for better productivity.

General functions of minerals

Mineral nutrition is a complex one, since there is lot of interactions between the various minerals and some of them function in combination. However, a few general functions are given below.

a. Electrochemical: The elements are concerned in the maintenance of acid base balance, osmotic pressure and membrane permeability of cell in the body.

b. Catalytic: Nearly all essential elements are believed to have one or more catalytic functions in the cell as they are constituents of various enzymes and co- enzymes.

c. Structural: Large number of elements has a structural role in integrity of cell and the body as a whole. The frame work of the body (skeleton) and synthesis of structural protein are also dependant on so many minerals.

A number of elements have a unique functions e.g. calcium and phosphorus besides being a major constituent of bone and teeth are involved in wide range of metabolic reactions, in gain or loss of energy and almost every form of energy exchange in the cell including the making and breaking of high energy phosphate bonds. It is also an integral part of protein molecules of the soft tissues of the body and of the nucleic acid and their derivatives that are involved in cell replication and transmission of the genetic code. Iron is the constituent of haem and play an important role in respiration. Co is a component of vitamin cyanocobalamin (B_{12}) and it is an constituent of thyroxine. Both the elements and vitamin are nevertheless concerned in a variety of metabolic processes. In ruminants, Co is necessary for the growth of certain bacteria which synthesizes vitamin B_{12} essential to the host animal.

Major elements

Calcium is the most abundant mineral in the body as its the major constituent of bone, teeth, in which almost 99 percent of total body Ca is found. It is the essential component of all living cell and tissue fluids. Blood contains about 9-12 mg/ dl in mammals but in laying hens it is about 30-40 mg/ dl. Bone ash contains about 36 percent of Ca,17 percent of phosphorus and 1 percent of Mg. The bone or skeleton is not the stable organ chemically rather dynamic especially during growth, lactation, laying in poultry depending on nutritional status of the animal. If the animal is fed on low Ca diet, bone Ca will liberate and parathyroid hormone plays an important role in it through absorption from gut, which is a gene mediated action by formation of Ca binding protein. Deficiency symptom in young is known as rickets whereas in the adult its known as osteomalacia. Phosphorus has more known functions in the living organism than any other mineral content because of its association with Ca in bone and skeleton formation and energy metabolism. It occurs in phophoproteins, nucleic acids and phospholipids. In the bone and skeleton 80-85 percent P is found as compared to Ca (99 percent). Normal blood level is 4-9 mg/ dl in mammals. Pica or deprived appetite is noted in ruminants due to deficiency of P in their ration with the symptoms of chewing hard objects like wood, bones, rags and other solid object. Magnesium is also associated with Ca and P in formation of bone skeleton. 70 percent of total body Mg is found in skeleton whereas rests are found in body fluid and soft tissues. It is the commonest enzyme activator i.e, phosphate transferases, pyruvate carboxylase, pyruvate oxidase etc. in addition it is involved in cellular respiration and formation of AMP, ADP and ATPs. In adult ruminants a condition called hypomagnesaemic tetany with low Mg content in blood due to intake of lush, green pasture which is low in Mg content.

K, Na and Cl are associated with acid base balance in body. Failure to maintain the correct electrolyte balance within cell means that metabolic pathways are unable to work efficiently and resources are diverted to achieving homeostasis at the expense of growth. The diet is important in maintenance of correct intracellular electrolyte balance owing to the metabolizable anions and cations that it contains, which consume or generate acid during metabolism. Dietary influence in this respect may be assessed by measuring the quantity of sodium, potassium and chlorine ions per unit weight. Alteration in electrolyte balance influence the metabolism of energy, amino acid, vit D and Ca, hence it has an effect on growth and lactation.

Most of the sulphur in the animal body occurs in the proteins containing amino acids cysteine, cystine and methionine. Vitamins – biotin and thiamin; insulin hormone and coenzyme A contains sulphur. The structural compound chondroitin sulphate is a component of cartilage, bone, tendons and the walls of blood vessels. Inorganic S present in the body in small quantities and wool rich in cystine and contains about 4 percent S. The ration should contain about 10-15: 1 N to S ratio and narrower the ratio, better will be the production performance of animals. Tissue protein and milk have the N:S ratio is 15:1, whereas in wool its around 5:1. Traditionally, little attention has been given to the importance of S in animal nutrition as the intake of this element is mainly in the form of protein, and a deficiency of S would indicate the deficiency of protein.

Minor/ trace elements

Zinc

Zinc is widely distributed throughout the body and plays an essential role in many body processes. Zinc on oral supplementation or through intravenous route reaches peak concentration in the liver within a few days, but concentrations in red blood cells, muscle, bone and hair do not peak for several weeks. Zinc is present in many enzyme systems that are concerned with the metabolism of feed constituents. For example, zinc is a constituent of carbonic anhydrase, carboxy peptidase A and B, several dehydrogenase, alkaline phosphateses, ribonuclease and DNA polymerase. Zinc is required for normal protein synthesis and metabolism and it is also a component of insulin, so it functions in carbohydrate metabolism. Common sources of supplemental zinc include zinc sulfate, zinc oxide, zinc chloride, zinc carbonate and zinc chelates.

Zinc deficiency in bulls and lactasing animals results in a lack of appetite, reduced growth, impaired growth of testes, cessation of spermatogenesis and poor milk production.

Iron

Approximately two-thirds of body iron is present in hemoglobin in red blood cells and myoglobin in muscle, 20% is in labile forms in liver, spleen and other tissues with the remainder in unavailable forms in tissues such as myosin and actomysin and in metallo enzymes. In hemoglobin, which contains 0.34% iron, an atom of ferrous iron in the centre of a porphyrin ring connects heme, the prosthetic group, with globin, the protein. The iron in hemoglobin is essential for the proper function of every organ and tissue of the body. Iron also plays a role in other enzymes involved in oxygen transport and the oxidative process, including catalase, peroxidases, flavoprotein enzymes and cytochromes. Iron in blood plasma is bound in the ferric state (Fe+++) to a specific protein called transferrin. Transferrin is the carrier of iron in the blood and is saturated normally only to 30-60% of its iron binding capacity.

Anemia may occur at any stage of life due to deficiency of iron, but it is likely to occur during the suckling period, since milk is very low in iron. Iron is very low in the milk of cows, goats and sows. It varies from 0.5 to 1.0 ppm. The magnitude of growth rate imposes a greater demand on iron needs than occurs with young ruminants. There is little evidence of an iron deficiency occurring with calves, lambs and kids raised under grazing conditions, except when blood loss or disturbance in iron metabolism occurs because of parasitic infection or disease. This is because they start early to eat food other than mother’s milk. Iron supplementation is needed, however, when young ruminants are fed an exclusive whole milk diet. Young nursing calves and lambs, receiving no supplemental source of iron, have responded to intra musculature injections of iron-dextran by improved hemoglobin levels and growth rate.

Copper

Copper is required for the activity of enzymes associated with iron metabolism, elastin and collagen synthesis, melanin production and the integrity of the central nervous system. It is required for normal red blood cell formation by allowing iron absorption from the small intestine and release of iron in the tissue into the blood plasma. Ceruloplasmin is the copper-containing transport protein.

Copper is required for bone formation by promoting structural integrity of bone collagen and for normal elastin formation in the cardiovascular system. Copper is required for normal myelination of brain cells and spinal cord as a component of the enzyme cytochrome oxidase which is essential for myelin formation. Maximum immune response is also dependent on copper as indicated by depressed titers in deficient animals. The process of normal hair and wool pigmentation requires copper. It is believed that copper is a component of polyphenyl oxidase which catalyzes the conversion of tyrosine to melanin and for the incorporation of disulfide groups into keratin in wool and hair. A minimum requirement for copper cannot be given with great accuracy, since copper absorption and utilization in the animal can be markedly affected by several mineral elements and other dietary factors. Zinc, iron, molybdenum, inorganic sulfate and other nutrients can reduce copper absorption.

Copper deficiency in suckling lambs results in a lack of muscular coordination, partial paralysis of the hindquarters, a swayback condition, degeneration of the myelin sheath of nerve fibers, and weak lambs at birth that may die because of their inability to nurse. Anemia, bone disorders and a lack of fertility also occur with a copper deficiency. Sheep produce 'steely' wool, which is lacking in crimp, tensile strength, affinity for dyes, and elasticity. Black sheep show depigmentation of the wool.

Iodine

Around 1900, scientists first recognized that iodine was required for the proper functioning of the thyroid gland and that an iodine deficiency caused goiter. Shortly thereafter, iodized salt became widely accepted as a means of preventing goiter in man and animals. The thyroid gland contains the highest concentration (0.2% to 5% on a dry weight basis) of iodine in the body; between 70% and 80% of the total body stores. Approximately 90% of the iodine which passes through the thyroid gland is captured by that organ. Iodine is then combined with tyrosine in the thyroid to form diiodotyrosine. Two molecules of this compound are then combined to form thyroxine. Approximately, 80% of the thyroxine entering the circulation is broken down through de-iodinization by the liver, kidney and other tissues. Deficiency of iodine, related to improper brain development and basal metabolism in the animal.

Cobalt

The only known animal requirement for cobalt is as a constituent of Vitamin B_{12}, which has 4% cobalt in its chemical structure. This means that a cobalt deficiency is really a vitamin B_{12} deficiency. Microorganisms in the rumen are able to synthesize vitamin B_{12} to fulfil needs of ruminants if the diet is adequate in cobalt. Normally, cobalt is not stored in the body in significant quantities. The small amount that is stored does not easily pass back into the rumen or intestinal tract where it can be used for vitamin B_{12} synthesis. Therefore, ruminants must consume cobalt frequently in the diet for adequate B_{12} synthesis. Traditionally, a breakdown in propionate metabolism at the point in the metabolic pathway where methymalony-CoA is converted to succinyl-CoA was thought to be the reason for the depression in appetite is controlled by Vit B_{12}. It has been well documented that changes in the rumen microbial population occurs in cobalt deficient ruminants. It now appears that a cobalt deficiency causes a vitamin B_{12} deficiency which inhibits propionate producing bacteria such as *Selenomonas ruminantium*.

Manganese

Manganese was first recognized as a necessary nutrient for animals in the early 1930s. Because manganese is found in many different feeds, a deficiency is less likely than with most of the other trace minerals. However, manganese deficiency does occur in sufficient magnitude to justify consideration in this text. Bone, kidney, liver, pancreas, and pituitary gland are the sites of highest manganese concentration. Relative concentration is quite low compared to the other trace minerals. For example, in humans, total body manganese is approximately 1% of the zinc and 20% of the copper. Although concentrations are low, it is a critical nutrient for several functions. Manganese is essential for chondroitin sulfate synthesis, which is critical to the organic matrix of bone. Many enzymes required for the synthesis of polysaccharides and glycoproteins need manganese to be active. Manganese is a key component of the metalloenzyme, pyruvate carboxylase, a critical enzyme in carbohydrate metabolism. Lipid metabolism is also dependent on manganese to allow the liver to convert mevalonic acid to squalene.

Selenium

Selenium is present in all cells of the body, but the concentration is normally less than 1 ppm. Toxic concentrations in liver and kidney are normally between 5 and 10 ppm. Selenium is an important part of the enzyme glutathione peroxidase. This enzyme destroys peroxides before they can damage cell membrane. Vitamin E is also effective as an antioxidant. Therefore, both selenium and vitamin E prevent peroxide damage to body cells. This aids the defense mechanisms against stress. Most feeds contain compounds that can form peroxides. Unsaturated fatty acids are a good example. Rancidity in feeds causes formation of peroxides that destroy nutrients. Vitamin E for example, is easily destroyed by rancidity. Selenium spares vitamin E by its antioxidant effect as a constituent of glutathione peroxidase. Selenium and vitamin E are interrelated in metabolic action. Both are needed by animals and both have metabolic roles in the body in addition to an antioxidant effect. In some instances, vitamin E will substitute in varying degrees for selenium, or vice versa. However, there are deficiency symptoms that respond only to selenium or vitamin E. Although selenium cannot replace vitamin E in nutrition, it reduces the amount of vitamin E required and delays the onset of E deficiency symptoms.

Selenium plays a critical role in increasing the immune response in animals. Selenium is important in sulfur containing amino acid synthesis. Sulfur containing amino acids protect animals against several diseases associated with low intakes of selenium and vitamin E. This protection is believed to be due to the antioxidant activity of selenium and vitamin E. Therefore, the sulfur containing amino acids, methionine and cystine, can spare vitamin E and selenium through their antioxidant role. Selenium can be added to diets of all food animals. Either sodium selenite or sodium selenate can be used. Selenium is added to feed as follows: Up to 0.1 ppm in complete feed for ruminants and poultry.

Vitamins

Vitamins are usually defined as the organic compounds which are required in small quantity compared to other nutrients for normal functioning and the physiological processes of body. The term vitamin is derived from 'vital amines' as it was thought that some food factors which contain amine nitrogen are essential for normal health. Later on it was known that certain vitamins contain amines. Many of the vitamins are not very stable and are destroyed by oxidation which is speeded up by certain metals, heat and light. These are the important things to be remembered during the formulation of ration and processing of feeds for animal. Most of the commercial companies are marketing the vitamins claiming to be stabilized. Though there are almost 15 vitamins known to be essential but not all of them are not dietary essential for dairy animals as some of them are synthesized by the microbes in rumen and available to the host animals.

Classification

The vitamins are classified into fat soluble and water soluble vitamins on the basis of solubility in a particular solvent. Fat soluble vitamins are A, D_2, D_3, E and K whereas the water soluble vitamins are thiamin (B_1), riboflbin (B_2), niacin, pyridoxine (B_6), pantothenic acid, biotin, folic acid, chlorine, cyanocobalamin (B_{12}) and ascorbic acid or Vitamin C.

General functions of different vitamins

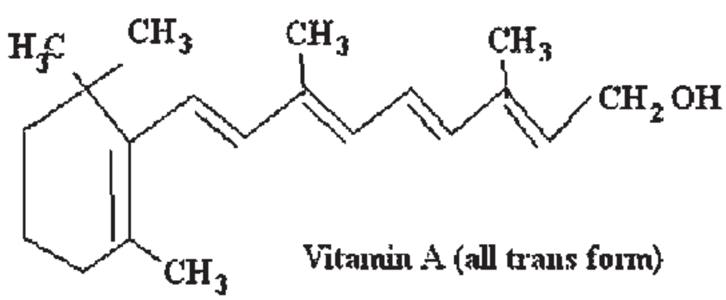
There are number of vital functions in the system regulated by vitamins which are summarized in the following table (Table 1.1).

Table 1.1. General functions of vitamins and deficiency symptoms

Name of the vitamin	Chemical name	Metabolic activity
Vitamin A	Retinol Retinal Retonoic acid	Oxidation- reduction cycle, visual cycle. Necessary for chondroitin sulphate. Maintenance of placenta in 2nd trimester
Vitamin D_2 Vitamin D_3	Ergocalcipherol Cholecalcipherol	Absorption of Ca, P from gut. Necessary for calcification of bone matrix
Vitamin E	α Tocopherol	Acts as antioxidant. Normal phosphorylation of ATP
Vitamin K	Phylloquinone	Blood coagulation
Water soluble vitamins	Not required by the ruminants as these are synthesized in rumen and indirectly the requirement fulfils.	

Vitamin A

Vitamin A is chemically known as retinol is an unsaturated monohydric alcohol with the following formula.



Vitamin A (all trans form)

The vitamin is yellow crystalline solid, insoluble in water which is readily destroyed by oxidation on exposure to air and light. A related compound with two hydrogen molecule less originally found in fish, has been designated as vitamin A_2. Vitamin does not exist in plant, but is present as precursor or provitamins of vitamin A. At least 600 naturally occurring carotenoids are known but only few of those are precursors of vitamin A. Carotenoids have yellow, orange or red colour and are responsible for many varied and natural colours which occur in carotenoids, insects, birds and fishes. They are also found in egg yolk, butterfat and body fat of cattle and horses but not in pig and sheep. They also occur in plants, but their colour is frequently masked by the green colour pigment chlorophyll. Conversion of carotenoids to vitamin can occur in liver but usually takes place in intestinal mucosa. Theoretically, one molecule of ß carotene yields two molecules of vitamin A (retinol).

Function: Vitamin A appears to play two different roles in the body according to whether it is acting in the eye and or in the general system. In the retinal cells of the eye, vitamin A (all trans retinol) is oxidized to aldehyde (all trans retinaldehyde) which is converted into 11 cis isomer. The later then combines with the protein opsin to form rhodopsin (visual purple) which is the photo receptor for vision at low light intension or dim light vision. Deficiency symptoms involve night blindness, softening and cloudness of cornea and development of xerophthalmia

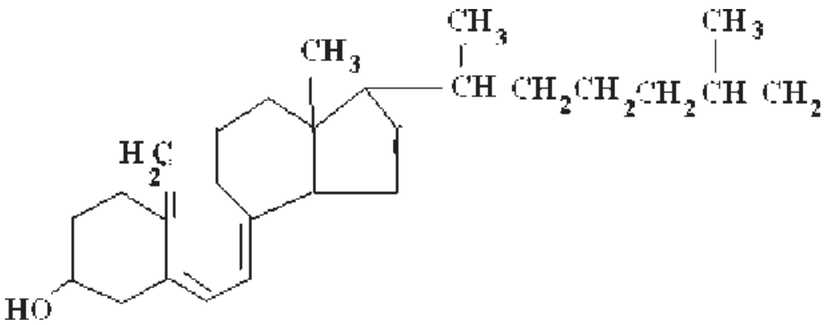
In its second role, it is involve in the formation and protection of epithelial tissues and mucus membranes. Deficiency disorder causes rough skin or toad skin, reproductive failure etc. In breeding animal vitamin A deficiency leads to infertility and in pregnant animals it leads to abortion or still birth.

Sources: Vitamin A accumulates in liver, hence this organ is likely to be a good source, the amount present varies greatly. Oils from livers of certain fish especially cod and halibut have long been used as an important dietary source of the vitamin. Egg yolk and milk fat are also rich source of vitamin A.

Vitamin D

A number of forms of vitamin D are known, although not all these are naturally occurring compounds. The two most important forms are ergocalcipherol (D_2) and cholecalcipherol (D_3). This vitamin is insoluble in water but sulphate derivatives in milk are water soluble. Both D_2 and D_3 are resistant to oxidation.

Ergosterol and 7 dehydrocholesterol, are the precursors of vitamin D_2 and D_3, respectively. The provitamins, as such have no vitamin value and must be converted to calcipherols before they are of any use to the animals. For this conversion it is necessary to impart a definite quantity of energy to the sterol molecule and this can be brought about by the ultra violet light present in the sunlight, by artificially produced radiant energy or by certain kind of physical treatment. The chemical transformation occurs in the skin and also in the skin secretions, which are known to contain the precursor. Absorption of the vitamin can take place from the skin, since deficiency can be treated successfully by rubbing codliver oil on the skin. Most biologically active form of the vitamin is 1, 25- dihydroxycholecalcipherol. This compound is transported in the blood to various target tissues, intestine, bones. The



Cholecalcipherol

compound acts in a similar way to a steroid hormone, regulating DNA transcription in the intestinal microvilli, including the synthesis of specific messenger RNA, which is responsible for the synthesis of Ca binding protein. This protein is involved in the absorption of Ca from the intestinal lumen.

The amount of 1,25- dihydroxycholecalcipherol produced in the kidney is controlled by parathyroid hormone. When the level of Ca in the blood is low, the parathyroid gland is stimulated to secrete more parathyroid hormone, which induces the kidney to produce 1, 25 dihydroxy cholecalcipherol which in turn enhances the intestinal absorption of calcium. In addition to increasing intestinal absorption of Ca, 1, 25 dihydroxycholecalcipherol increases the absorption of phosphorus from the intestine and also enhances calcium and phosphorus reabsorption from the kidney and bone.

Deficiency symptoms: A deficiency of vitamin D in the young animals results in rickets a disease if growing bone in which the deposition of Ca and P is disturbed, as a result the bones are weak and fragile and legs may be bowed. In young animals, the symptoms like swollen knee and hocks and arching the back. In older animals, deficiency causes osteomalacia in which there is reabsorption of bones already laid down. Although the similar condition may be seen in pregnant and lactating animals and thus require more vitamin D or Ca and phosphorus.

Sources: The vitamins are limited in distribution. They rarely occur in plants except in sun dried roughages and the dead leaves of growing plants. In the animal kingdom vitamin occurs in small amounts and in certain tissues and is abundant only in some fishes. Egg yolk is also a good source of the vitamin, but cow milk is generally a poor source, though colostrum is 6-10 times richer than ordinary milk.

Vitamin E

Vitamin E is a group name which includes a number of closely related active compounds. Eight naturally occurring forms are available of vitamin E, among which α, β, γ, Δ are important and most active form is the 1st one. This vitamin act as biological antioxidant, in association with Se containing enzyme glutathione peroxidase, protects cell against damage caused by free radicals. Free radicals formed during cell metabolism and as they are capable of damaging cell membranes, enzymes and cell nuclear materials, they must be converted in to less reactive substances if the animal is to survive. This protection is essential in preventing the oxidation of polyunsaturated fatty acids which functions as primary constituent of subcellular membrane and precursor of prostaglandins. Oxidation of poly-unsaturated fatty acid (PUFA) produces hydro-peroxides which also damage the cell and tissues, so preventing such oxidation is highly essential for life process. There are two main defense line against these oxidation process, first is free radical is scavenged by vitamin E and second, glutathione peroxidase destroys any peroxidides formed before they can damage the cell. Vitamin E also plays an important role in development and function of immune system.

Deficiency symptoms: Deficiency of vitamin E is known as muscular degeration or myopathy, nutritionally also known as muscular dystrophy. The disease found in calves when turned out in to dry grasses suddenly. Symptoms are manifested by weak leg muscle, difficulty in standing and after standing trembling and staggering gait. Eventually the animals are unable to rise and weakness in neck muscle prevents them from raising their head. This condition is also known as white muscle disease. Heart muscle is also affected and death may occur.

Sources: Vitamin E is not stored in animal body in larger quantity. Fortunately it is distributed in feeds. Green fodders and young grasses are rich source of tocopherols. Mature herbage is poor source of this vitamin and leaves contain 20-30 times as much vitamin E as stems. Losses during hay making as high as 90 percent but losses during ensiling and artificial drying is very low. Cereals are good sources of vitamin E. wheat and barley contains a tocopherols but maize contains in addition to α tocopherol and γ tocopherols. Animal products are relatively poor sources of the vitamin.

Vitamin K

During the time when discovered this vitamin called as ‘Koagulation Factor’, knowing its role in blood coagulation. Chemically the vitamin K is known as phylloquinone, vitamin K_1 or 2 methyl, 3 phytyl, 1-4 naphthoquinone. The compound is originally isolated from purified fishmeal and designated as vitamin K_2 is now known to be only of a series of K vitamins with unsaturated side chain synthesized by bacteria and referred to as menaquinones. Vitamin K is necessary for synthesis of prothrombin in liver which is a inactive precursor of thrombin, an enzyme that converts fibrinogen to fibrin (insoluble fibrous protein that holds clots together). Prothrombin normally binds to Ca ions before it can be activated. If the supply of the vitamin is inadequate prothrombin molecule is deficient in γ carboxyglutamic acid, a specific amino acid responsible for Ca binding. Proteins containing this amino acid, dependent on vitamin K for their formation are also present in bone, kidney and other tissues.

Sources: Phylloquinone is present in most leafy vegetables, lucerne, cabbage and kale being good sources. Egg yolk, liver and fishmeal are good sources of this vitamin. Other feed materials are moderate source of the vitamin. Menaquinones are synthesized by bacteria in the digestive tract of animals.

Water soluble vitamins

Vitamin B complex

All the vitamins are soluble in water and not stored in body (except cyanocobalamin), hence exogenous supply is essential on regular basis. In dairy animals, all the water soluble vitamins are synthesized by the microbes in rumen and provides the satisfactory amount of vitamin required for animals.

Thiamin: This is a complex nitrogenous base containing a pyrimidine ring joined to a thiazole ring. Because of the presence of hydroxyl group at the end of the side chain, thiamin can form esters. Thiamin pyrophosphate is coenzyme involved in the oxidative decarboxylation of pyruvate to acetyl coenzyme A and α keto glutarate to succinyl CoA, in TCA cycle. Under some circumstances, bacterial thiaminase destroys the vitamin, resulting in deficiency symptoms called as cerebrocortical necrosis. This condition is characterized by circling movement, head pressing, blindness, muscular tremor etc. Thiaminase activity of bracken fern and some carp fish have been established and needs careful attention in case of deficiency.

Source: It is concentrated in outer layers of seeds, germ, in the growing areas of roots, leaves and shoots. Fermentation products like brewers' yeast are rich source of thiamin. Animal source is also rich in thiamin.

Riboflavin: Its yellow crystalline compound, which has a yellowish green fluorescence in aquous solution. It is heat stable, acid and neutral solutions but destroyed in alkali, sparingly soluble in water. It is the important component of flavin mononeucliotide and flavin adnine dineucleotide. There are several other flavoproteins which are involved in reaction of transport of hydrogen. The vitamin is synthesized in rumen and deficiencies in fully functional ruminants are unlikely to occur. However, young calves and lambs have been demonstrated with riboflavin deficiency. The symptoms are loss appetite, diarrhoea and lesions in the corner of mouth.

Sources: Rich sources of riboflavin are yeast, liver, milk (whey), green leafy crops. Cereal grains are poor sources of riboflavin.

Nicotinamide: It is a stable vitamin which is not easily destroyed by heat, acid, alkali or oxidation. It is functions as active group of two coenzymes, nocotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). These are involved in hydrogen transfer in ATP production. Requirement of the vitamin is being fulfilled by rumen microbes and deficiency symptoms not seen in dairy aniamls under normal condition.

Sources: It can be synthesized from tryptophan in the body tissues and since, animals can convert the acid to the amide containing coenzymes, it follows that if the diet is adequately supplied with protein sources rich in tryptophan, dietary requirement will be low. Rich sources are liver, yeast, groundnut, sunflower meals. Although the cereals containing this vitamin but due to bound form, it is not available to the animal. Milk and egg are almost devoid of the vitamin, although, they contain the precursor of the vitamin.

Vitamin B_6: The vitamin exists in three form which are inter-convertible in the body tissue. The parent substance is pyridoxine, corresponding to aldehyde derivative pyridoxal and amine is pyridoxamine. All three forms describes the vitamin B_6. The amine and aldehyde derivatives are less stable than pyridoxamine and are destroyed by heat. It plays the central role as a coenzyme in reactions by which a cell transforms nutrient amino acid into mixture of amino acids and other nitrogenous compounds required for its own metabolism. These reactions involve activities of transaminase and decarboxylases. The lesions primarily of amino acid metabolism and growth rate will hamper.

Sources: The vitamin present as pyridoxine in plants, whereas in the animal products it is available as pyridoxal and pyridoxamine. Pyridoxine and its derivatives are widely distributed in yeast, cereal grains, liver and milk.

Pantothenic acid: It is an amide of pantoic acid and b alanine and is a precursor of coenzyme A which is important coenzyme of acyl transfer. In addition to the component of coenzyme A, pantothenic acid is also a structural component of acyl carrier protein, involved in cytoplasmic synthesis of fatty acid.

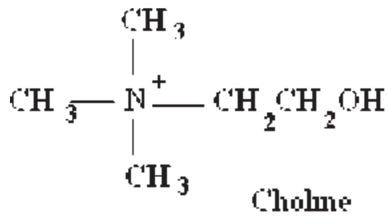
Folic acid: Chemically folic acid is pteroylmonoglutamic acid and made up of three moieties: p- aminobenzoic acid, glutamic acid and a pteridine nucleus. Several active derivatives of the vitamin are known to occur, these containing upto 11 glutamate residues in the molecule. It is reasonably stable in food stored under dry conditions but it is readily degraded by moisture, particularly at high temperature. It is destroyed by ultraviolet light. Folic acid is converted into tetrahydrofolic acid after absorption which functions as a coenzyme in the mobilization and utilization of single carbon groups that are added to, or removed from, such metabolites as histidine, serine, glycine, methionine and purines.

Source: Folic acid widely distributed in nature, green leafy vegetables, cereals and extracted oilseed meals are good source of the vitamin.

Biotin: A part of the vitamin B complex, biotin is chemically 2-keto 3, 4 imidazolido-2 tetrahydrothiophen-n- valeric acid. Biotin serves as the prosthetic group of several enzymes which catalyze the transfer of carbon dioxide from one substrate to another. In animals there are three biotin dependent enzymes of particular importance: pyruvate carboxilase, acetyl coenzyme A carboxilase and propinyl coenzyme A carboxilase. In ruminants, like other B complex vitamins, it is synthesized by the gut mocosa, hence not required.

Source: It is widely distributed in foods; liver, milk, yeast, oilseeds and vegetables are rich sources. However, in some feeds much of the bound vitamin may not be released during digestion and hence is unavailable.

Choline: Chemically the structure is given below:



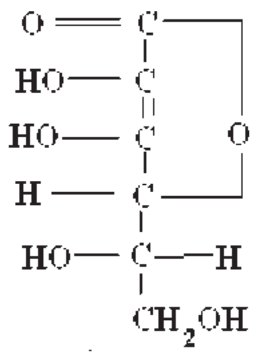
Choline

Unlike the other B vitamins, it is not a metabolic catalyst but forms an essential structural component of body tissues. It is a component of lecithins which play role in cellular structure and activity. It also plays an important role in lipid metabolism in the liver by preventing the accumulation of fat in this organ. It serves as a donor of methyl group in trans-methylation reaction and is a component of acetylcholine which is responsible for transmission of nerve impulses. Choline can be synthesized in liver from methionine and the exogenous requirement for this vitamin is therefore influences by the methionine in the diet.

Vitamin B_{12}: It is also known as cyanocobalamin and has the complex structure of all vitamins. The basic unit is corrin nucleus which consists of a ring structure comprising four five membered rings containing nitrogen. In the active centre of the nucleus is a cobalt atom. A cyano group is usually attached to the cobalt as an artifact of isolation and, as this is the most stable form of the vitamin, it is the form in which the vitamin is commercially produced. Before vitamin B_{12} can be absorbed from the intestine it must be bound to a highly specific glycoprotein, termed intrinsic factor, which is secreted by the gastric mucosa. In man, intrinsic factor may be lacking which leads to poor absorption of the vitamin and results in a condition known as percinious anaemia. The coenzyme forms of vitamin B_{12} function in several important enzyme system. These include isomerases, dehydrases and coenzymes involved in biosynthesis of methionine from homocysteine. Of special interest in ruminant nutrition is the role of vitamin B_{12} in the metabolism of propionic acid into succinic acid. In this pathway, the vitamin is necessary for the conversion of methyl malonyl CoA into succinyl CoA.

Vitamin C

Chemically this is L- ascorbic acid and has the following formula:



L-Ascorbic acid

It involves in various oxidation reduction mechanism in living cell. It is necessary for maintenance of normal collagen metabolism. It also plays an important role in the transport of iron ions from transferrin, found in the plasma, to ferritin which acts as store of iron in the bone marrow, liver and spleen. It also acts as antioxidant like vitamin E and glutathione peroxidase. In the ruminants it not dietary essential but under climatic stress poultry needs to be supplemented with this vitamin.

Review Questions

1. Why water is necessary for animals?
2. What is antioxidant and which nutrient plays the role of antioxidant.
3. Why water soluble vitamins not required through diet by the ruminants?
4. What is essential fatty acid and importance of it in human nutrition.
5. Role of forage in dairy animals. What is the precursor of glucose in dairy animals?
6. Role of cyanocobalamin in animals?