Core Course 5:unit 3; Food And Nutrition

PROTEINS

Objective: the objective of the course study material is to know about the important macromolecule - proteins which are of prime importance to human health. They are the major component of all animal & plant tissues.

Introduction

Proteins are the most abundant macromolecules in living cells and constitute 50% or more of their dry weight.They are composed of Carbon (50-55%), Hydrogen (6-7%),Nitrogen (15-19%), Oxygen (19-24%), Sulphur(0-4%).

Their molecular weight ranges between 10,000 to more than 10, 00,000.

The term protein is derived from the Greek word ‘proteuo’ meaning **first** suggested by Mulder (1840) who recognized that without it no life is possible.

Proteins are needed for growth, maintenance & repair of body tissue. They regulate key processes in the body.

About 50% of protein is present in muscle, 20% in bone, 10% in skin & the rest is present in other parts of the body.

Based on this background the following aspects are to be studied under proteins:

1) Chemical Composition
2) Physico-Chemical properties
3) Classification of proteins
4) Digestion & Absorption
5) Functions
6) Dietary Sources
7) Deficiency & excess
8) Conclusion

1) CHEMICAL COMPOSITION

On acid hydrolysis proteins yields a group of simple organic molecules of low molecular weight called '**amino acids'** which form the fundamental units of a protein structure.

Out of 300 amino acids known only 20 amino acids can be found in proteins. Unique sequence & length of each protein gives its conformation & make it suitable for its particular function.

Hence all proteins are polymers & are made up of individual amino acidswhich are joined together by an amide linkage called a **'peptide bond'** (fig 1)

In protein molecule the amino acid residues are covalently linked to form very long unbranched chains united in a head to tail arrangement.

The macromolecules called polypeptides may contain hundreds of amino acid units. Some proteins contain one polypeptide & others contain two or more. Each polypeptide chain has a definite molecular weight, chemicalcomposition, sequential order of its amino acids &three dimensional structures (fig 2)

Structure of amino acids:

Amino acids are the basic units for proteins & exist as isomers. Most of the naturally occurring amino acids are of L-form.

Typical amino acid has three features: (fig: 3)

- ✓ Carbon skeleton
- ✓ free amino group (NH_2),
- ✓ free carboxyl group (COOH),
- ✓ Hydrogen atom (H) attached to central carbon.

The amino group(N) of one amino acid is joined to the carboxyl group(C) of another amino acid.

2) PHYSICO-CHEMICAL PROPERTIES OF PROTEINS:

1) Amphoteric behavior: Proteins are ampholytes i.e., they act as both acids & bases. As electrolytes they migrate in an electric field. The direction of migration is determined by the net charge of molecule & influenced by pH. For each protein there is a pH value at which its net charge is neutral & will not move in an electric field. This pH is called the **isoelectric point**.

2) Electrophoresis: The movement of a charged particle in an electric field towards the oppositely charged electrode is called electrophoresis. Proteins migrate in an electric field except at the isoelectric point. Since proteins markedly differ in their isoelectric point, they differ in their electrophoretic mobility at any given pH value. Electrophoretic analysis is used to determine purity of individual proteins & quantitative analysis of complex mixtures.

3) Solubility: Each homogenous protein has a definite & characteristic solubility in a solution of known salt concentration &pH. The solubility of protein is minimum at the isoelectric point & increases with acidity & alkalinity.

4) Colloidal nature: Proteins have large molecular weights & protein solutions are colloids & therefore, do not pass through semi permeable membranes.

3)CLASSIFICATION OF PROTEINS

1) Classification based on conformation & composition

Proteins are divided into three major classes on the basis of their composition: **Simple, Conjugated& derived proteins**(table: 1)

Simple proteins are those which on hydrolysis yield only amino acids & no other major organic or inorganic hydrolysis products.

Conjugated proteins are those yielding not only amino acids but also other organic & inorganic compounds. The non-amino acid portion of a conjugated protein is called the prosthetic group.

In the native state, each type of protein has a characteristic 3 dimensional shape referred to as conformation. Depending on their conformation protein can be placed in two major classes, **fibrous & globular. (Table: 1)**

Fibrous proteins consist polypeptide chains arranged in parallel along a single axis to long fibers on sheets. Globular proteins are tightly folded into compact spherical or globular shapes.

Proteins can also be divided based on their nature as acidic & basic.

Table 1: Classification of proteins

Based on conformation		Based on composition			Based on nature	
Fibrous	**Globular**	**Simple**	**Conjugated**	**Derived**	**Acidic**	**Basic**
α-keratin	Myoglobin	Albumin	nucleoproteins	Peptone	Blood proteins	histones
β-keratin	Hemoglobin	Globulin	lipoproteins	Small peptides		
Collagen	Lysozyme		glycoprotein	Fibrin		

2) Nutritional classification of proteins: Nutritionally proteins can be divided as ;

Essential & non essential amino acids:

Out of 20 amino acids of protein there are 9 amino acids that cannot be synthesized in the human body, therefore, must be supplied through dietary protein in sufficient amounts(Fig 4)

Non-essential amino acids: The human body can manufacture the remaining 11 amino acids & are therefore referred to as non-essential amino acids (Fig: 4)

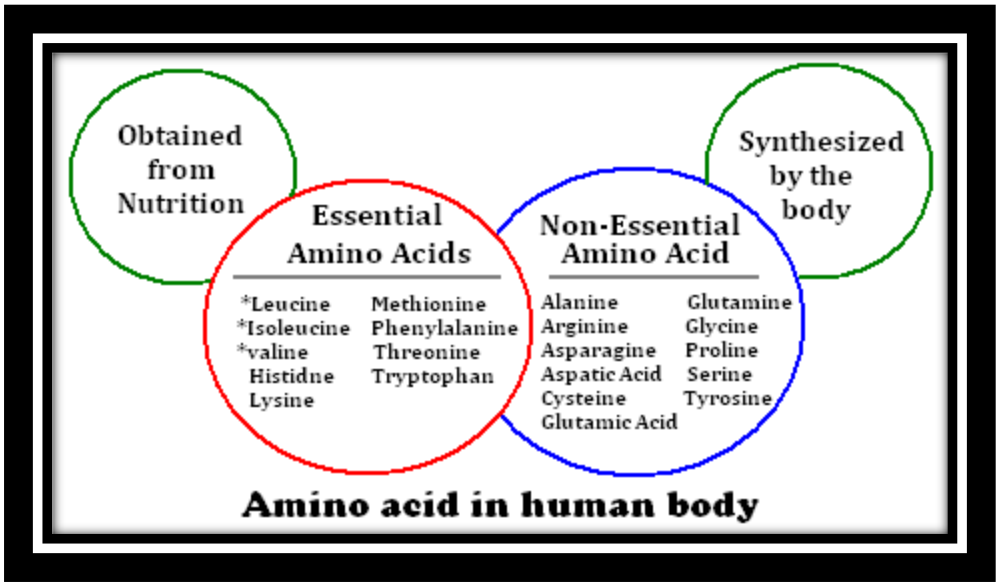

Fig 4: Essential & Non-essential amino acids

4) DIGESTION & ABSORPTION OF PROTEINS:

The first step in using dietary protein is breaking down its long polypeptides chains into amino acids. Digestion of proteins begins in the stomach and requires enzymes from a number of sources.

In the stomach: the hydrochloric acid (HCl) denatures a protein, unfolding it and making the amino acid chain more accessible to the action of enzymes. Glands in the stomach lining produce the proenzyme pepsinogen the inactive precursor of the enzyme pepsin.

When pepsinogen comes in contact with HCl, it is converted to the active enzyme pepsin. Gastric juices must be acidic for this enzyme to be active (the optimum pH must be 2.0). Pepsin, an endopeptidase is responsible for about 10-20% of protein digestion.Since food remains in the stomach for a limited time, pepsin hydrolyses dietary proteins mainly into a mixture of polypeptide. If gastric HCl production is low & not adequate to maintain the pH of the stomach contents between 2 & 3, protein digestion in the stomach is negligible.

In the small intestine: From the stomach, amino acid & polypeptide pass into the small intestine, where most of the protein digestion takes place.

In the small intestine, activated proteases from the pancreas & intestinal lining cells break down large peptides into smaller peptides.

The proteases involved in the digestion are trypsin, chymotrypsin &carboxy peptides & these enzymes act at pH 7.4-8.0.

Pancreatic enzymes completely digest proteins into individual amino acids; enzymes on the surface of the small intestines spilt the remaining larger polypeptides into tripeptides& dipeptides &individual amino acids.

5) FUNCTIONS OF PROTEINS:

1)Structural & Mechanical functions: Structures such as bone, skin & hair are made up of collagen, the most abundant protein in mammals. It gives elasticity to these structures. Hair & nails are made up of keratin, another important protein.

2)**Immune function**: Proteins are responsible for fighting invasion & infection by foreign substances. Antibodies are blood proteins that attack & inactivate bacteria & viruses that cause infection.

3)**Enzymes**: Enzymes are proteins that catalyze, or speed up, chemical reactions without being destroyed in the process. Every cell contains thousands of enzymes each with its own purpose. Cellular enzymes release energy from the nutrients to fuel thousands of body processes. Enzymes also trigger the reactions that built muscle & tissue.

4)**Hormones**: Hormones are chemical messengers that are made in one part of the body but act on cells in other parts of the body. Protein hormones perform many important regulatory functions(example- insulin, is a protein hormone that plays a key role in regulating the amount of glucose in blood. It is released from the pancreas in response to rise in blood glucose levels & works to lower those levels).

5)**Acid base balance**: Proteins help in maintaining pH balance in the body fluids by serving as buffers. They pick up extra hydrogen ions when conditions are acidic, and they donate hydrogen ions when conditions are alkaline.

If proteins are not available to buffer acidic or alkaline substances, the blood can become too acidic or too alkaline, resulting in either acidosis or alkalosis. Both conditions can be serious & can lead to coma or death.

6)Transport functions: Many substances pass in & out of cells through proteins that cross cell membranes & act as channels & pumps. Proteins also act as carriers, transporting many important substances in the blood stream for delivery throughout the body (example- they transport lipid components like triglycerides, cholesterol & phospholipids by complexing with them forming lipoproteins).

Serum albumin carries free fatty acids. Specific proteins act as carriers for fat soluble vitamins; retinol binding proteins carries retinol (VitaminA). Iron is stored in the liver & bone marrow as ferritin which is a complex of iron with a protein.

7)Fluid balance: Fluids in the body are found inside cells (intracellular fluid) or outside cells (extracellular fluid). There are two types of extracellular fluids- fluid between cells called intracellular fluid or interstitial fluid & fluid in the

blood (intravascular fluid). Protein in the blood helps to maintain appropriate fluid levels in the vascular systems.

8)Source of energy & glucose: Although our body prefers to burn carbohydrate & fat for energy, if necessary it can use protein for energy or to make glucose. Thus, carbohydrates & fat are protein- sparing; they spare amino acids from being burned for energy & allow them to be used for protein synthesis. Normally metabolism yields about 6-12% of the body's energy needs.

6) DIETARY SOURCES OF PROTEINS

Animal foods like meat, fish & egg are good sources of proteins. Plant foods include pulses, oil seeds &nuts. Milk is also a good quality protein. Cereals & millets are moderate sources of protein as they contain about 10% of protein. Soybean is the richest source among plant based protein which has 40% protein & is ideal source of proteins for vegetarians. Leafy vegetables, roots & tubers are generally poor sources of protein as they contain less than 2% protein.

Protein content of common foods are tabulated in the table: 2

Animal sources	g/100g	Plant sources	g/100g
Milk, cow's	3	Rice	10
Milk, buffalo's	4	Wheat	14
Egg , hen	13	Corn, whole	9.2
Fowl	26	Groundnuts	25
Cheese	24	Peas, dry	20
Liver, goat	20	Bengal gram (whole)	17
Prawn	19	Green gram dhal	24
Mutton	18	Soya bean	43
Fish, katla	19	Wheat germ	9

Source reference : National Institute of Nutrition (NIN, Hyderabad)

7) PROTEIN DEFECIENCY: As proteins plays a vital role in many body processes, its deficiency results in great damage to the numerous body systems. Protein deficiency occurs when energy & or protein intake is inadequate. Sufficient energy intake spares dietary & body proteins as they can be used for protein synthesis.

When the protein intake-either in terms of quantity or quality or both is not sufficient during the growth period, the child suffers from the disease known as **Protein Energy Malnutrition** (**PEM)**. It is prevalent among children& contributes to one-third of all deaths worldwide. In more than 50% of deaths in children, malnutrition is the direct or indirect cause. PEM is a silent killer in many children.

It is a condition resulting from long term inadequate intakes of protein & energy that can lead to wasting of body tissues & increased susceptibility to infection.

Many factors contribute to PEM, including poverty, insufficient food intake, poor food quality, unsanitary living conditions, & improper feeding of infants & young children. Although it can occur at all stages of life, PEM is most common during childhood, when protein is needed to support rapid growth.

It can also occur in elderly people, hospitalized patients, with other conditions such as anorexia nervosa, AIDS, cancer, or malabsorption syndromes. Symptoms of PEM can be mild or severe& exist in either acute or chronic forms.

Types of PEM

Severe protein deficiency is called **kwashiorkor**, whereas severe calorie deficiency is called **marasmus**. Fig: 5

Marasmus: The word marasmus is derived from the Greek word “marasmos”, which means “to waste away” or “withering”. It develops more slowly than kwashiorkor & results from chronic PEM.

Protein, energy, & nutrient intakes are all grossly inadequate, depleting body fat reserves & severely wasting muscle tissue, including vital organs like the heart. Growth slows or stops & children are both short & very thin for their age. Metabolism slows & body temperature drops as the body tries to conserve energy. Marasmus occurs most often in infants &in children 6 to 18 months of age. It can also occur in adults who have cancer or are experiencing starvation.

The signs & symptoms observed in marasmic child are as follows:

- Severe growth retardation

- Loss of subcutaneous fat
- Severe muscle wasting
- Child appears very thin & short for its age
- Shriveled body
- Wrinkled skin
- Dehydration
- Associated with vitamin deficiencies
- Irritability & apathy is common

Kwashiorkor: The term kwashiorkor is a Ghanian word that describes the ‘evil spirit that infects the first child when the second child is born”.

In many cultures, babies are breastfed until the next baby comes along. When the new baby arrives, the first baby is weaned from nutritious breast milk to watery down version of the family’s diet.

In areas of poverty, this diet is often low in protein, or the consumed protein is not digested & absorbed easily. In these conditions the child is not able to adapt to the stress of inadequate diet, infection & separation from mother due to subsequent pregnancy.

It occurs in children between 18 to 24 months of age. Its onset can be rapid & is often triggered by an infection or illness that increases the child’s protein needs.

The signs & symptoms observed in kwashiorkor are as follows:

- Edema or swelling of body tissue (feet & legs)
- Bloated belly
- Stunted weight & height
- Increased susceptibity to infection
- Dry & flaky skin
- Dry, brittle & unnaturally blonde hair
- Changes in skin color
- Mental development is affected
- Diarrhoea.

EXCESS DIETARY PROTEIN:In developed countries, an excess of protein & energy is more common than the deficiency. Diets rich in animal protein are often associated with various diseases like kidney problems, osteoporosis, heart disease & cancer.

Normal intake of protein is **1g/kg body weight** recommended by Indian Council of Medical Research (ICMR, 2010) for the normal Asian population. Any excess protein can be harmful & encountered with various health issues.

1) **Kidney problems**: High protein intake can strain kidney function & is especially harmful for people with kidney disease or diabetes. To prevent dehydration, it is important to drink plenty of fluids to dilute the byproducts of protein breakdown for excretion.

2) **Osteoporosis**: The link between high-protein diets & osteoporosis is based on studies showing that a high protein intake increases calcium excretion, which could then contribute to bone mineral losses.

3) **Obesity**: Studies have shown a correlation between high protein intake & body fatness. High-protein foods often are high in fat. A diet high in fat & protein may provide too much energy, contributing to obesity.

4) **Heart diseases**: Research has linked high intake of foods rich in animal protein to high blood cholesterol levels & increased risk of heart disease. Foods high in animal protein are also high in saturated fat & cholesterol.

5) **Cancer**: Diets high in animal protein have been linked to pancreatic, colon, kidney, breast & prostate cancer. Prolonged consumption of both red meat (beef, pork) & processed meat (ham, smoked meats, sausage, bacon) has been associated with increased colon cancer risk.

8) CONCLUSIONS

Proteins are the macromolecules composed of carbon, hydrogen, oxygen, nitrogen & sulphur. They are made up of amino acids linked together by peptide bonds.

The amino acid sequence of a protein determines its shape & function.
Out of 20 amino acids that are commonly present in proteins, nine are called essential amino acids & have to be supplied through diet.
Dietary protein is found in meats, dairy products, legumes, nuts & grains.
In general, animal foods contain higher quality protein than plant foods.
Protein needs are highest when growth is rapid, such as infancy, childhood & adolescence.
Protein deficiency is most common in developing countries & often results in marasmus & kwashiorkor.
Excess protein is also harmful & may affect risk for heart diseases & cancer.

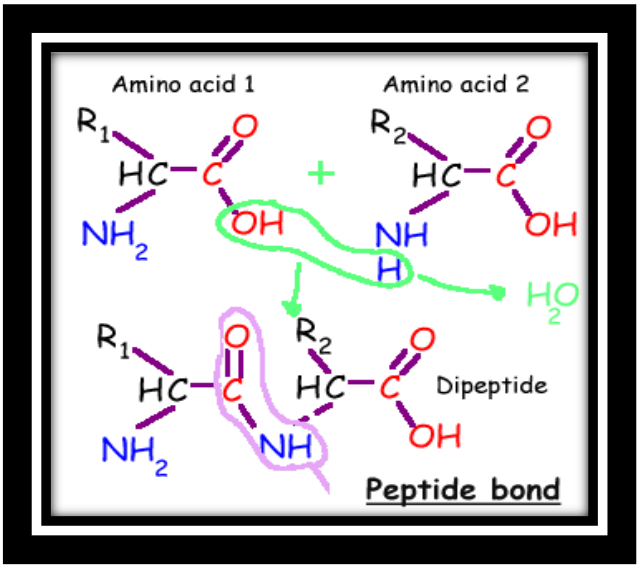

Fig :1 Peptide bond

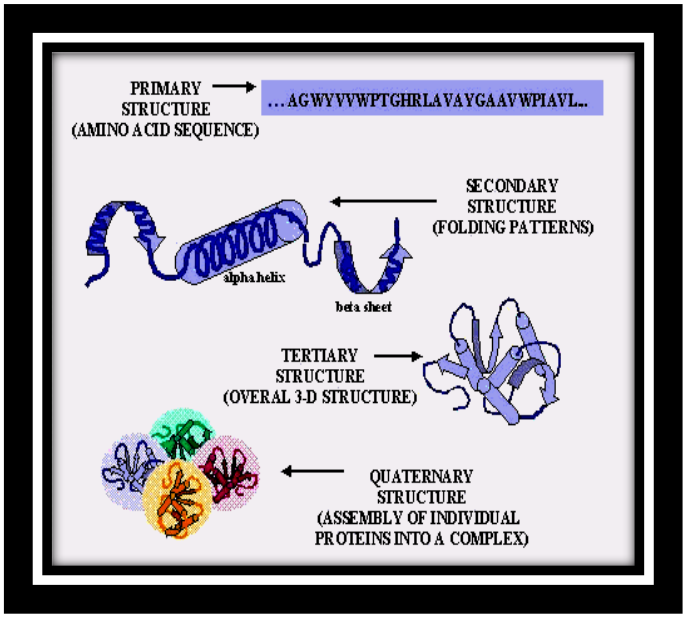

Fig : 2 Structure of proteins

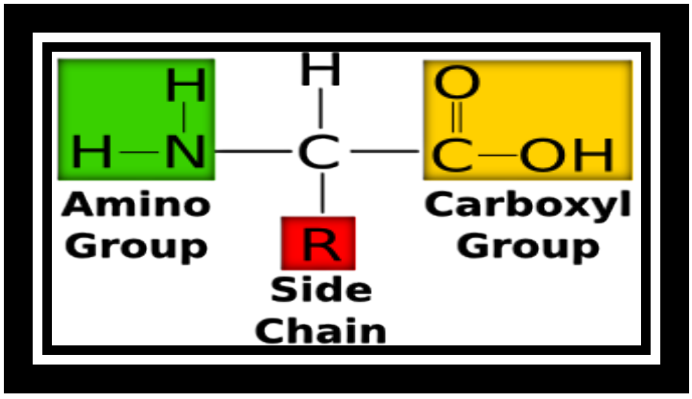

Fig : 3 Basic structure of amino acid

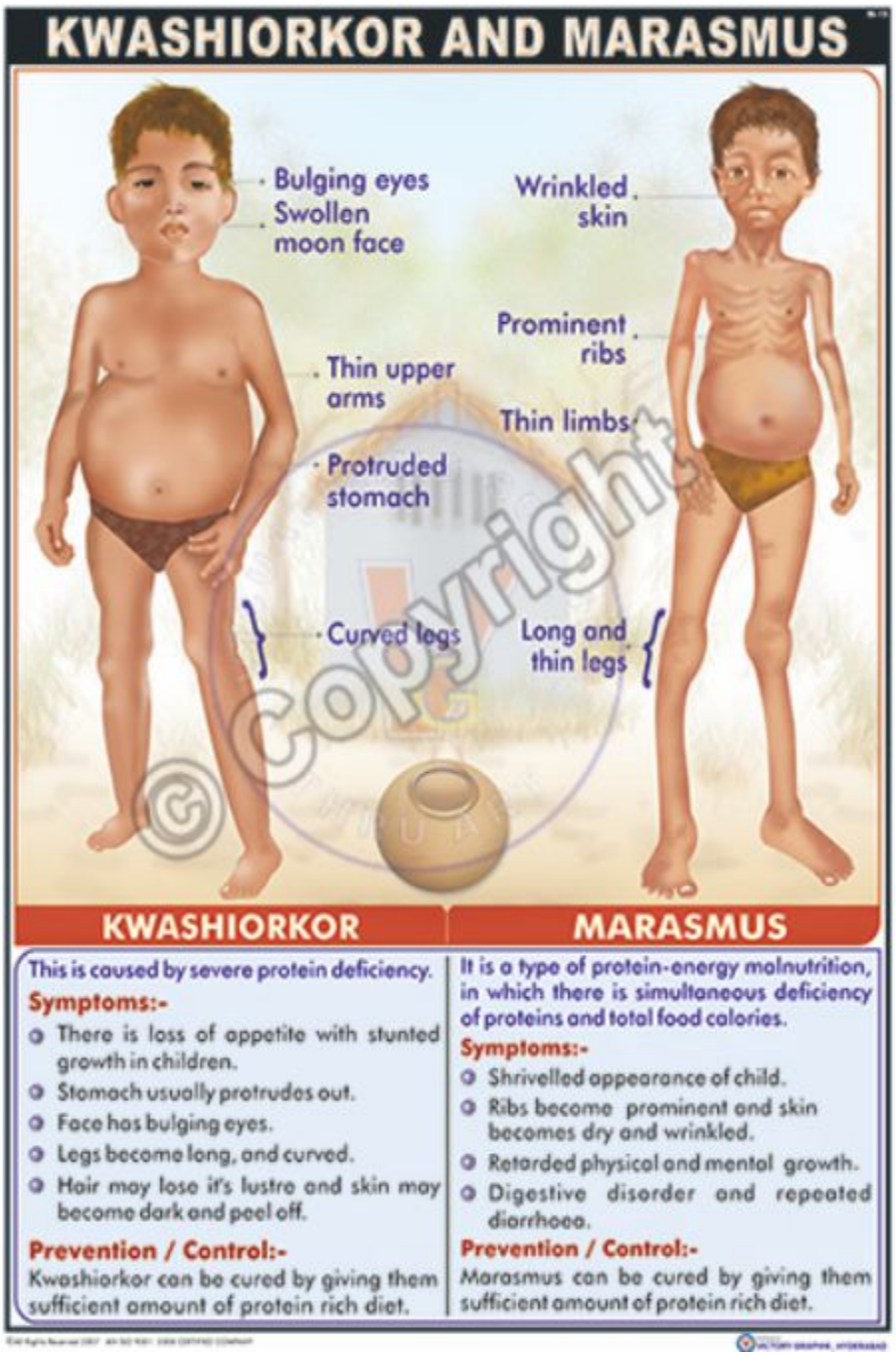

Fig : 5 Differences between marasmus &kwashiorkar