PROPERTIES

Amphoteric nature: Amino acids and proteins are amphoteric in nature that is, they act on both acids and bases. Since proteins have electric charges, they migrate in an electric field, the direction of migration depending on the net charge on the molecule. For each protein, there is a pH at which the positive and negative charges will be equal and protein will not move in an electric field. The pH is known as the isoelectric point of the protein.

Solubility: Each protein has a definite and characteristic solubility in a solution of known salt concentration and pH. Albumins are soluble in water. Globulins are soluble in neutral sodium chloride solutions but are almost insoluble in water.

Some proteins like casein are soluble in alkaline pH. The differences in the solubility are made use of in the separation of proteins from a mixture.

Colloidal nature of protein solutions: Proteins have large molecular weights and protein solutions are colloids. They do not pass through semi-permeable membranes. This property of proteins is of great physiological importance.

CLASSIFICATION

Depending on the chemical composition proteins are classified as given in Table 8.1.

Table 8.1: Classification of Proteins

Protein	Characteristics	Example or Occurrence
SIMPLE PROTEINS		
Globular		
Albumins	Soluble in water, dilute salt solutions, dilute acids and bases. Coagulated by heat.	Lactalbumin, egg albumin, serum albumin.
Globulins	Soluble in salt solutions, insoluble in water.	Serum albumin, arachin and conarchin of peanuts, myosin.
Histones	Basic proteins. Soluble in most common solvents, fairly small molecules.	Nucleoprotein.
Fibrous (scleroproteins)		
Collagens	Resistant to digestive enzymes; Insoluble, converted to digestible proteins like gelatins on boiling; contain large amount of hydroxyproline; lack sulfur containing amino acids.	Skin, tendons, bones.
Elastins	Partially resistant to digestive enzymes; contain little hydroxyproline.	Arteries, tendons, elastic tissues.
Keratin	Highly insoluble and resistant to digestive enzymes; high cystine content.	Skin, hair, nails.
CONJUGATED PROTEINS		
Nucleoproteins	Salts or basic protein or polypeptide and nucleic acids.	Chromosomes, nucleoli.
Mucoproteins	Protein or small polypeptide containing muco-polysaccharide; hexosamine less than 4%.	Glycoid of serum alpha globulin; submaxillary and gastric mucoids.
Glycoproteins	Protein or small polypeptide containing muco-polysaccharide; hexosamine less than 4%	Serum alpha, beta, and gamma globulins.

Lipoproteins	Complexes of protein and lipids having solubility properties of proteins.	Cell and organelle membranes, Myelin.
Proteolipids	Complexes of protein and lipids having solubility properties of lipids.	
Chromoproteins	Compounds consisting of proteins and a non-protein pigment.	Flavoproteins, hemoglobin cyto-chromes.
Metalloproteins	Metals attached to protein; metals not part of a non-protein prosthetic group.	Ferritin, Hemosiderin, Transferrin, Carbonic anhydrase.
Phosphoproteins	Phosphoric acid joined in ester linkage to protein.	Casein of milk.
DERIVED PROTEINS		
Primary derived proteins and Coagulated proteins	Denatured proteins produced by heat, acids and alkalis.	Coagulated egg white.
Proteins	Earliest products of protein hydrolysis by enzymes, dilute acids etc., which are insoluble in water.	Fibrin from fibrinogen.
Meta proteins	Second stage products of protein hydrolysis obtained by treatment with slightly stronger acids etc.	
Secondary derived proteins	Progressive hydrolytic products of protein hydrolysis.	Proteoses, peptones, polypeptides and peptides.

NUTRITIONAL CLASSIFICATION OF PROTEINS

The nutritive value of proteins is determined by the composition of essential amino acids. From the nutritional point of view, proteins are classified into 3 categories:

1. **Complete proteins:** These proteins have all the ten essential amino acids in the required proportion by the human body to promote good growth, e.g., egg albumin, milk casein.
2. **Partially incomplete protein:** These proteins are partially lacking one or more essential amino acids and hence can promote moderate growth, e.g., wheat and rice proteins (limiting in lysine and threonine).
3. **Incomplete proteins:** These proteins completely lack one or more essential amino acids. Hence they do not promote growth at all, e.g., gelatin (lacks in tryptophane), zein (lacks in tryptophane and lysine).

Higher quality protein produces a faster growth rate. Such growth rate measurements evaluate the actual factors important in a protein. Pattern and abundance of essential amino acids, relative amounts of non-essential and essential amino acids, digestibility and presence of trypsin inhibitors—all affect the quality of proteins and in turn affect the growth rate.

NUTRITIONAL CLASSIFICATION OF AMINO ACIDS

Essential Amino Acids

Essential amino acids are ones that cannot be synthesised by the body at a rate sufficient to meet the needs for growth and maintenance.

The human body has certain limited powers of converting one amino acid into another. This is achieved in the liver by the process of transamination, whereby an amino group is shifted from one molecule across to another under the influence of amino transferases, the co-enzyme of which is pyridoxal phosphate. Inability to synthesise the carbon skeleton of these amino acids is the probable reason why they are dietary essentials. Table 8.2 shows 9 out of 20 amino acids are classified as essential amino acids.

Classified list of amino acids is given in Table 8.2.

Table 8.2: List of Essential, Conditionally Essential and Non-essential Amino Acids

Essential amino acids	Conditionally essential amino acids	Non-essential amino acids
Histidine	Arginine	Alanine
Isoleucine	Cysteine	Asparagine
Leucine	Glycine	Aspartic acid
Lysine	Proline	Glutamic acid
Methionine	Tyrosine	Glutamine
Phenylalanine		Serine
Threonine		
Tryptophan		
Valine		

Non-essential Amino Acids

Non-essential amino acids are ones that the body can make in adequate amounts if nitrogen is available in the diet. They are non-essential only in the sense that they are not essential components of the diet.

Conditionally Essential Amino Acids

These are needed in the diet unless abundant amounts of their precursors are available for their synthesis. The new born may not have enzymes in adequate amounts to synthesise non-essential amino acid or in intestinal metabolic dysfunction arginine may not be synthesised. Hence it becomes conditionally essential amino acid. Amino nitrogen is not freely interchanged between all amino acids. The precursors of conditionally essential amino acids are given in Table 8.3.

Table 8.3: Precursors of Conditionally Essential Amino Acids

Amino acids	Precursors
Cysteine	Methionine, serine
Tyrosine	Phenylalanine
Arginine	Glutamine/glutamate, aspartate
Proline	Glutamate
Glycine	Serine, Choline

Tryptophan

- Nicotinic acid is synthesised from tryptophan. Milk is a good source of tryptophan.
- Precursor of serotonin, 5-hydroxytryptamine, causes vaso constriction. When blood clot occurs, platelets, release 5-hydroxy tryptamine which prevents bleeding by causing vasoconstriction. 5-hydroxytryptamine is also a neurotransmitter.

Proline and Hydroxy Proline

- Present in haemoglobin and cytochromes.
- Prevalent in the collagen of connective tissue.

Leucine, isoleucine and valine

- In the muscle they are oxidized and the nitrogen is used for the formation of alanine.

DIGESTION AND ABSORPTION

The hydrolysis of proteins in the gastro-intestinal tract is accomplished by proteases secreted in gastric juice and pancreatic juice and also by proteases present in the intestinal mucosa.

Gastric digestion: Proteins are denatured by the acid in the stomach. The proteolytic enzyme present in gastric juice is pepsin. The optimum pH is about 2.0. Pepsin is an endopeptidase and it can hydrolyse peptide bonds in the interior of the protein molecule. It hydrolyses mainly peptide bonds containing phenylalanine, tyrosine or tryptophan and also peptide bonds containing leucine and acidic amino acids. Since food remains in the stomach for a limited time, pepsin hydrolyses dietary proteins mainly into a mixture of polypeptides.

If gastric HCl production is low and not adequate to maintain the pH of the stomach contents between 2 and 3, protein digestion in the stomach may be negligible.

Proteolysis in the intestines: The main digestion of polypeptides produced in the stomach takes place in the intestines. The proteases involved in the digestion are trypsin, chymotrypsin and carboxy peptidase secreted in pancreatic juice and amino peptidases present in the intestinal mucosa. Trypsin and chymotrypsin act at pH 7.4 to 8.0. Trypsin hydrolyses mainly peptide linkages containing arginine or lysine and chymotrypsin hydrolyses, peptide linkages containing tyrosine or phenylalanine.

Carboxy peptidase A hydrolyses the end group in peptides containing aromatic or aliphatic amino acid, thus releasing free amino acids. Carboxy peptidase B hydrolyses peptides containing arginine and lysine residues. The intestinal mucosa contains a group of amino peptides which complete the hydrolysis of peptides to amino acids. The intestinal mucosa also contains tripeptidase, dipeptidase etc., which hydrolyse tri and dipeptides.

Absorption of amino acids: Absorption of amino acids takes place in the small intestines. This process requires energy.

The basic amino acids lysine, arginine and histidine share a carrier system with cystine. The dependence of amino acid transport on Na ion suggests a direct interaction between the carrier and Na ion. This is similar to that observed in the absorption of glucose.

According to the available information, the amino acid associates with the carrier and Na ion in the microville and the complex travels to the inner side of the membrane where it

Table 8.5 compares the biological value, NPU and PER values of proteins from different food stuffs.

Table 8.5: Nutritive Value of Proteins of Some Food Stuffs

Food	B.V.	NPU	PER	Limiting amino acid*
Egg	96	96	3.8	Nil
Milk	90	85	2.8	SAA
Meat	74	76	3.2	SAA
Fish	80	74	3.5	Tryp
Rice	80	77	1.7	Lys, Thr
Wheat	66	61	1.3	Lys, Thr,
Maize	50	48	1.0	Lys, Thr, Tryp
Bengal gram	74	61	1.1	SAA
Redgram	72	54	1.7	SAA, Tryp
Groundnut	55	–	–	Lys, SAA and Thr
Gingelly seeds	62	–	–	Lys

Source: Gopalan, C., B.V. Rama Sastri and S.C. Balasubramanian, 1989, *Nutritive Value of Indian Foods*, National Institute of Nutrition, ICMR, Hyderabad.

*Swaminathan M., 1988. *Essentials of Food and Nutrition*, Bappco, Bangalore.

Scoring Systems

Amino Acid Scores

A chemical grading of the quality of a protein can be made by comparing its amino acid content with that of a reference protein. The FAO/WHO (1973) suggested 'Amino acid pattern of reference' based on needs for each amino acid. Hen's egg protein is also recommended as reference protein because egg proteins contain all essential amino acids in adequate amounts. Chromatographic, chemical and microbiological methods are used for estimating the amino acid content of proteins. Food composition tables can also be used to know the amino acid content.

$$\text{Amino acid score} = \frac{\text{mg of amino acid in 1 g test protein}}{\text{mg of amino acid in 1 g reference protein}}$$

The score should be calculated for all the essential amino acids using the above formula and the lowest score is taken. In practice, the scores need to be calculated only for lysine, the sulphur-containing amino acids and tryptophan, as one or other of these, is the limiting amino acid in common foods. The chemical score is the ratio between the content of the most

SOURCES

Animal foods like meat, fish and egg and plant foods like pulses, oil seeds and nuts are good sources of protein. Milk can also be classified (though it contains 3–4 per cent) under this category as it has good quality protein and due to high content of water it can be consumed in large quantities.

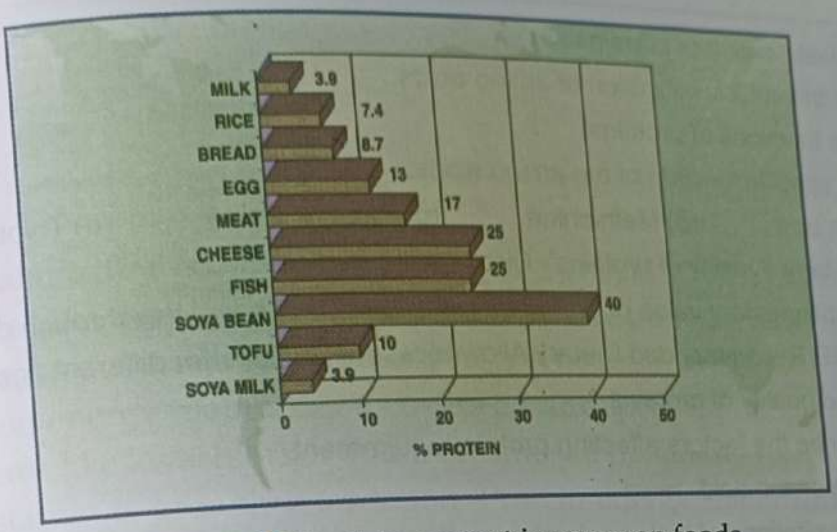

Figure 8f: Protein content in common foods.

Table 8.13: Protein Content of Foods

Animal sources	Protein g/100 g	Plant sources	Protein g/100 g
Skimmed milk powder (Cow's milk)	38	Soya bean	43
Whole milk powder (Cow's milk)	26	Watermelon seeds	34
Fowl	26	Wheat germ	29
Cheese	24	Groundnut	25
Herring, India	20	Green gram dhal	24
Liver goat	20	Peas, dry	20
Prawn	19	Bengal gram whole	17
Mutton	18	Wheat whole	12
Egg, hen	13	Agathi	8
Milk buffalo's	4	Rice	7

Soya bean is the richest source containing 40 per cent protein. Defatted oil seed cakes contain 50–60 per cent protein. Cereals and millets are moderate sources of protein as they contain about 10 per cent protein. Rice contains less protein than wheat but its quality is better. However, the cereals as they are consumed in large amounts daily contribute a considerable amount of protein to the daily intake. Leafy vegetables, fruits, roots and tubers are generally poor sources of protein as they contain less than 2 per cent protein.