UNIT 3 PROTEINS

Structure

3.0 OBJECTIVES

After reading this unit, you will be able to:

- tell about proteins and their functions;
- identify food items rich in proteins and diseases associated with low protein intake;
- explain the types of proteins that make up meat; and
- describe the applications/uses of enzymes.

3.1 INTRODUCTION

The word Protein is derived from Greek word *Proteus,* which means "to come first"[1]. They are most abundant biological macromolecules/substances present in all types of cells constituting the major components of our muscle mass. Nearly half of the dry weight of a typical animal cell is protein. All proteins contain carbon, hydrogen, oxygen and nitrogen. It also contains sulphur with occasional occurrence of phosphorus. Average composition of protein shows 50 per cent of Carbon, 7 per cent of Hydrogen, 23 per cent of Oxygen, 16 per cent of Nitrogen, 0-3 per cent of Sulphur and 0-3 per cent of Phosphorus. Proteins are made up of small building blocks called *amino acids*. The amino acids are chemical compounds that contain both an acidic carboxyl (-COOH) and a basic amino ($-NH_2$) group (Fig. 3.1).

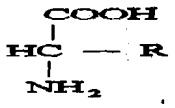

Fig. 3.1: General structure of an amino acid

Different proteins have different sizes depending on the number of amino acids they contain. They represent molecules through which genetic information is expressed. Proteins perform diverse functions and are therefore important part of our diet. Some foods are rich in protein whereas some have low protein content. Low protein diet results in many disorders that may impair our abilities to perform well. Some specialized proteins called **enzymes** perform chemical reactions in the body. Enzymes referred as biocatalyst also have industrial applications.

3.2 IMPORTANCE AND FUNCTIONS

Proteins are major component of our body cell and play various important roles. Major functions of proteins are detailed out below:

a) **Tissue building (growth) and maintenance:** This is the main function of dietary proteins. Many proteins are involved in body tissue formation. For example, proteins myosin and actin contribute significantly to muscle structure. Collagen and keratin are other structural proteins.

b) **Physiological role:** Proteins play a vital role in functionary of body. Enzymes being biocatalyst in nature, are among the most important proteins in the body. They act as catalyst and increase the rate of chemical reactions in the body. Various hormones are of proteinous nature and similar to enzymes regulate metabolic reactions. Besides this, the breakdown product of protein i.e., amino acids, di-peptides, polypeptides are utilized for synthesis of much needed bio-compounds inside body. Tryptophan, an essential amino acid is used to build Niacin (Vitamin B_3) and serotonin acts as neurotransmitter. Acid-base balance is important for all physiological activities and is maintained by the buffering action of the proteins. The pH of the blood is slightly alkaline (pH 7.3-7.4). A drastic alteration in blood pH would be fatal. The blood pH is maintained by the buffering actions of proteins, which can accept and release H^+essential for pH maintenance. Besides this, blood pigment haemoglobin that helps in transport of gases posses a protein globulin portion. Several lipoproteins are also engaged in transportation work. Protein provides defence to body in the form of antibodies. These proteinous substances are also responsible for gene regulatory, detoxicating and hemostatic function in body.

c) **Energy source**: Body does not use proteins as main source of energy. Protein rich foods are expensive. However, proteins can be used for energy requirements during fasting, long distance running but not in fed state. Protein is also utilized as reserve material for nutrition of developing cells. One gram of protein releases 4.08 Kcal of energy. It is estimated that close to 58 per cent of dietary protein may be used up for energy production.

3.3 PROTEINS: BUILDING BLOCKS, TYPES AND SOURCES

Each protein is a collection of several amino acids and these amino acids are called building block of proteins. Depending upon these building blocks, nature

of the protein varies. Building blocks, types and sources of different proteins are described below:

3.3.1 Building Blocks of Protein – Amino acids

There are 22 amino acids that usually makeup/form proteins. Amino acids are covalently linked in proteins in a linear fashion by a linkage called peptide bond.

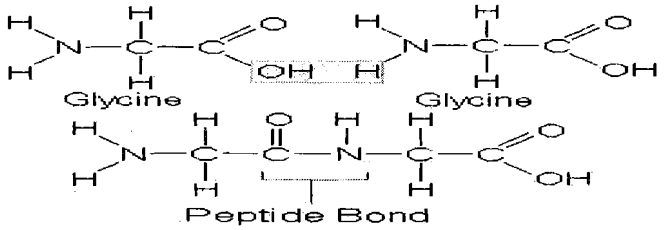

Fig. 3.2: A molecule of water is removed from two glycine amino acids to forma peptide bond

It is remarkable that though different proteins contain the same set of amino acids, they differ in their arrangement in linear chain to give rise to proteins with diverse functions such as enzymes, antibodies, hormones etc. As the name indicates, amino acids contain at least an amino and a carboxyl group. Based on their chemical properties, amino acids can be grouped into five classes: non-polar, polar, aromatic, basic and acidic. However, on nutritional basis they are classified as essential amino acids and non-essential amino acids (*Table 3.1*). There are eight amino acids that are grouped under essential amino acids. These are required in the diet because body cannot synthesize them. The remaining amino acids can be synthesized in the body and are therefore non-essential in the diet. However, this classification is ambiguous as all the 22 amino acids are necessary for building body's tissue proteins.

Table 3.1: Classification of amino acids

i) **Based on Chemical Properties**				
Non Polar Amino acids	**Polar**	**Aromatic**	**Positively Charged**	**Negatively Charged**
Glycine Alanine Valine Leucine Isoleucine Methionine	Serine Threonine Cysteine Proline Aspargine Glutamine	Phenylalanine Tyrosine Tryptophan	Lysine Arginine Histidine	Aspartic Acid Glutamatic Acid

ii) **Based on Nutritional Requirements**		
Essential amino acids	**Semi-essential amino acids**	**Non-essential amino acids**
Isoleucine Leucine Lysine, Methionine Phenylalanine Threonine Tryptophan,Valine	Arginine Histidine	Alanine, Aspargine, Tyrosine, Aspartic acid, Cysteine, Glutamic acid, Glycine, Proline, Serine, Hydroxylysine, Glutamine, Hydroxyproline

3.3.2 Types of Proteins and their Sources

According to the nutritional requirements, proteins are classified as complete or incomplete. This classification is based on the amount of essential amino acids

present in a protein. Complete proteins are those that contain all the essential amino acids in sufficient amount and ratio to meet the body's requirements. Proteins of animal origin such as those in egg, meat and milk are considered as complete proteins, whereas proteins derived from plant products such as grains and legumes are incomplete proteins. Poultry, fish, meat, peanuts, wheat germ, cheese are most concentrated protein foods on weight basis. Milk has 3.0 - 3.5 per cent protein whereas cereals such as rice and oat meal and potatoes have only about 2.0 per cent protein. Vegetables and fruits have low protein concentrations.

The nutritive value of plant proteins can be improved by complementation. By combining a plant source low in one amino acid with another supplying that amino acid, we can complement or mutually supplement proteins. Vegetarians should use a combination of complementary protein in their diet. For example, beans, peas are rich in lysine but low in sulphur containing amino acids such as methionine and cysteine which can be complemented by including cereals (wheat) in the diet.

Check Your Progress 1

1) What are the essential amino acids?

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2) Name any two sources of complete proteins.

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3) Enlist the functions of proteins.

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3.4 MEAT PROTEINS: STRUCTURE AND CLASSIFICATION

Meat in true sense refers to the flesh of animals used as food. It includes muscles (musculature), organs such as liver, kidney, brains and other edible tissues. The term *carcass* is used in meat industry and represent the portion of body left after removal of the blood, head, feet, hides, internal organs (digestive tract, intestine, bladder, heart, trachea, lungs, kidneys, spleen etc.) and adhering fatty tissues.

3.4.1 Chemical and Biochemical Constituents of Muscle

The approximate composition of meat is: 75 per cent water, 19 per cent protein, 3.5 per cent of soluble non-protein substances and 2.5 per cent fat. It must be remembered that meat is the resultant product of a complicated post mortem changes of a tissue (*Table 3.2*).

Table 3.2: Chemical composition of a typical adult mammalian muscle (before post-mortem changes)

Component	Per cent
WATER (range 65 to 80)	75.0
PROTEIN (range 16 to 22)	19.0
A) Myofibrillar	11.5
Myosin	5.5
Actin	2.5
Tropomyosin	0.6
Troponin	0.6
M protein and C protein	0.2
α , β and γ actinin	0.5
Desmin, F and I protein etc.	0.4
B) Sarcoplasmic	5.5
Soluble sarcoplasmic and mitochondrial enzyme	4.5
Myoglobin	0.3
Haemoglobin, Cytochromes and flavoproteins	0.7
C) Stroma	2.0
Collagen and reticulin	1.0
Elastin	0.05
Other insoluble proteins	0.95
LIPIDS (variable range 1.5 to 13.0)	2.5
Neutral lipids, Phospholipids, Cerebrosides	2.0
Cholesterol	0.5
NON-PROTEIN NITROGENOUS SUBSTANCES	1.65
Creatine and Creatine phosphate	0.55
Free amino acids	0.35
Peptides (anserine, carnosine etc.)	0.35
Other [creatinine, urea, inosine monophosphate (IMP), adenosine triphosphate (ATP), adenosine diphosphate (ADP), nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP)]	0.4
CARBOHYDRATES (range 0.5 to 1.5)	1.2
Glycogen (variable range 0.5 to 1.3), Glucose, Intermediate products of cell metabolism [hexose and triose phosphates, lactic acid, citric acid, fumaric acid, succinic acid, acetoacetic acid etc.]	
INORGANIC CONSTITUENTS	0.65
Potassium	0.35
Total phosphorus [phosphates and inorganic phosphorus]	0.2
Magnesium	0.02
Sodium	0.05
Others [including, calcium, iron, cobalt, copper, zinc, nickel, manganese etc.]	0.03
VITAMINS (various fat and water soluble vitamins, quantitatively minute).	

Muscle proteins can be broadly classified into three types depending on their solubility properties:

i) **Sarcoplasmic proteins:** These are readily extracted in aqueous solution of low ionic (0.15 or less) strength i.e., soluble in water or very dilute salt solutions. It constitutes about 5.5 per cent of total muscle mass. There are about 50 sarcoplasmic proteins. It includes myoglobin, hemoglobin, enzymes associated with glycolysis, the tricarboxylic acid cycle and the electron transport chain, flavour proteins.

ii) **Myofibrillar proteins:** These are soluble in concentrated salt solutions and require higher (0.3 or greater) ionic strength solutions of sodium or potassium salts for their extraction. Since they are extracted by salt solutions, they are called salt-soluble proteins. They constitute about 11.5 per cent of muscle mass. The myofibrillar proteins are further classified into three categories.

a) **Contractile Proteins:** Actin and myosin constitute the major contractile proteins. They are named so because of their role in muscle co: traction. Actin constitutes approximately 20 per cent of the myofibrillar proteins whereas myosin, fibrous in nature constitutes 45 per cent of the myofibrillar protein. Actin forms the thin filament whereas myosin forms thick filament. The monomeric unit for actin is globular actin or G actin and it links to form fibrous actin or F actin. In F actin, the G actin monomers are linked together in strands, much like beads on a string of pearls. Super helix, a characteristic of actin filament is formed as result of spiral coiling of two strands of F actin around each other. As far as myosin is concerned, proteolytic enzyme degradation reflects two fractions — light meromyosin and heavy meromyosin. The structure of the myosin molecule is an elongated rod shape with a thickened portion at one end called head, thin backbone called tail and a connecting between two is neck. Myosin has six subunits (polypeptides): two heavy chains and four light chains. The heavy chains are extended and wrapped around each other in a coiled manner. Molecules of myosin aggregate in muscles to form thick filaments which act as the basic contractile unit.

b) **Regulatory proteins:** These are involved in regulation of actin-myosin interaction during muscle contraction and in maintenance of myofibril integrity. The chief regulatory proteins are tropomyosin, troponin, α-actinin and β-actinin. Tropomyosin is approximately five per cent of myofibrillar protein and lies in close contact with actin filament Tropomysoin exerts inhibition on crossbridge formation between actin and myosin except during contraction. Troponin is another regulatory protein, approximately five per cent of myofibrillar protein and also found in close association to actin. It is responsible for picking up the Ca^{2+} available in sarcoplasm because of action potential. The calcium bind to troponin and this calcium activated troponin relieve inhibition being exerted by tropomyosin to facilitate contraction. The other two protein α and β-actinin constitute approximately two per cent and one per cen respectively and found in Z disc and free end of thin filaments within A band.

c) **Cytoskeleton protein:** They serve as the template and / or provide th scaffold for the alignment of myofilaments during myofibril an sarcomere formation. In mature muscle, these are responsible fc

maintenance of overall longitudinal and lateral alignment as well as structural integrity of myofibrils. Cytoskeleton proteins includes titin, nebulin, C-protein, myomesin, M-protein, desmine, filamin, vinculin, synemin, Z-protein, creatinine kinase.

iii) **Stromal protein:** They are of fibrous nature and not soluble even in high ionic strength salt solutions. These are refered as insoluble protein fraction of muscle. As such in muscle fiber they are approximately two per cent but more in connective tissue. The major stromal proteins are collagen, elastin and reticulin. Collagen is the most abundant protein in animal body, about 20-25 per cent of total body protein. The tropocollagen is the structural unit of collagen fibril. Collagen is a glycoprotein which is a most abundant amino acid and one third of collagen is glycine. The relative insolubility and high tensile strength of collagen fibers results from intermolecular cross-linkages which influence meat tenderness. Elastin is rubbery protein present throughout the body in ligament and arterial walls. It comprises of high content (about 90 per cent) of non-polar amino acids responsible for its extreme insolubility. Being resistant to digestive enzyme and cooking, it contributes little or nothing to nutritive value of meat. Reticulin is another stromal protein which gives black with ammonical silver. It is different from collagen in having intimate association with lipids containing myristic acid.

Check Your Progress 2

1) Define meat.

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2) What is collagen?

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3) How many types of muscle proteins are there?

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3.5 PROTEIN DEFICIENCY DISEASES

You all studied earlier that protein constitutes the major portion of our body mass after water. There are a number of diseases related to protein metabolism and its deficiency in diet. For better understanding its better to deal deficiency diseases in correlation to functional importance of protein. The subject has been dealt here under different headings.

3.5.1 Protein Turnover

Tissue proteins are continuously being broken down into amino acids and are then rebuild into tissue proteins. This process is called *protein turnover* and varies in different tissues. High protein turnover is observed in the intestine (epithelium), liver, pancreas and kidney whereas; muscle, brain and skin have low. Structural tissues such as collagen and bone have very low turnover. Dietary deficiency of protein may lead to structural and functional alteration of these important body parts.

3.5.2 Protein Balance

Body proteins exist in two compartments: Tissue proteins and plasma proteins. Balance between the two compartments is maintained by dietary protein intake. There is a give and take relationship between the two compartments at times. During growth, the protein synthesis is higher so that the new tissues could be formed whereas during ageing, tissue breakdown exceeds that of synthesis and the body gradually deteriorates.

Criteria to assess a person's state of protein balance are the measurement of total nitrogen. Total body nitrogen includes, protein nitrogen and non-protein nitrogen represented by compounds such as urea, ammonia, uric acid etc. It is an indication of all nitrogen gains and losses in the body protein. A net negative nitrogen balance is not a healthy sign and reflects increased loss of body protein and low input of food protein. It is observed during long illness, starvation or hyper metabolism (higher body activity).

3.5.3 Protein Requirements

The primary purpose of protein in the diet is to supply amino acids in sufficient quantity for growth and tissue maintenance. There is an enhanced protein requirement during growth. Also important is the nature of protein in the diet and its amino acid composition. Sufficient non-protein foods in the diet are also essential so that proteins are not used up for energy production. This is called *protein-sparing effect*. The digestibility and absorbability of the protein is affected by cooking methods and other factors. The recommended amount of protein per day (RDA) amounts to about 60-65 grams/day for a healthy man and 50 grams/ day for a woman, which increases during pregnancy and lactation. The nutritive value of a food protein is often expressed in terms of its *chemical score*, a value reflecting its amino acid composition. The chemical score of a protein is calculated by comparing its amino acid composition with that of egg protein, taken as a standard, having a value of 100. Other criteria that are also considered during the calculation of chemical score of a protein are:

- Biological value (BV) based on nitrogen balance.
- Net protein utilization (NPU) based on biological value and degree of digestibility
- Protein efficiency ratio (PER) based on weight gain of a growing test animal divided by its protein intake.

As we discussed in the protein function that it plays a vital role in the regulation of body process. Deficiency may lead to hormonal imbalance, poor immune status, anemia, wasting condition as well as impairment of several body processes because of lack of necessary enzymes.

3.5.4 Protein Calorie Malnutrition (PCM)

Growing children require a higher amount of protein and energy (Kcal) per kilogram of body weight than adults. Breast milk usually provides these needs during infancy (first six months). After that, weaning foods adequate in calories, protein, vitamins and minerals need to be added to the breast milk diet for growth.

Protein calorie malnutrition (PCM), a nutritional deficiency, is prevalent among infants and small children particularly in underdeveloped poor countries. PCM is characterized by poor growth and is manifested in two forms: ***Marasmus***, a chronic state with severe wasting of the body tissues and ***Kwashiorkor***, in which edema occurs.

Marasmus is seen in young children (three months to three years) and kwashiorkor occurs in the age group of one to five years. Marasmus is due to low calorie low protein diet whereas kwashiorkor develops due to protein deficiency even though there are sufficient kilocalories in the diet.

Check Your Progress 3

1) What is protein turnover?

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2) Name the tissues with high protein turnover.

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3) Define protein-sparing effect.

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4) What is chemical score of a protein?

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5) What is protein calorie malnutrition?

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3.6 APPLICATIONS OF ENZYMES

As mentioned earlier most enzymes are proteins and carry out different metabolic functions in the body. They have numerous applications. Some important ones are given below:

3.6.1 Role in Medicines

One of the important applications of enzymes is in disease diagnosis. Alterations in the blood levels of certain enzymes occur during diseased conditions and are listed in *Table 3.3*. Measuring the levels of these enzymes would tell us the health status of a person.

Table 3.3: Enzymes of clinical importance

Serum enzymes	Diagnostic application
Serum glutamate-oxaloacetate transaminase/Serum glutamate-pyruvate transaminase	Viral hepatitis, Myocardial infarction
Amylase	Acute pancreatitis
Ceruloplasmin	Hepatolenticular degeneration
Creatine kinase	Muscle disorders, myocardial infarction
Lipase	Acute pancreatitis
Acid phosphatase	Metastatic carcinoma of the prostrate
Alkaline phosphatase	Bone disorders, obstructive liver diseases

Enzymes also have applications in medical therapy. *Streptokinase* is an enzyme, which breaks down fibrinogen as well as plasminogen. Plasmin formed from the latter helps in dissolving clot. This enzyme is now used to dissolve blood clots in the body to prevent heart ailments.

3.6.2 Industrial Applications

In meat industry, enzymes are used for tenderization, a process that makes muscle tissue soft. Some of these enzymes are from plant sources: papain (papaya), ficin (fig), bromelein (pineapple). Bacterial and fungal enzymes are: hydrolase D, protease 15 and rhozyme. Details of tenderization are given else where in this course. In milk industry, rennet, an enzyme obtained from calf intestinal linings, is used for cheese preparation.

Check Your Progress 4

1) Name two industrial applications of enzymes.

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2) Name two enzymes that are affected during liver diseases.

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3) Name the enzyme that is used to dissolve blood clots.

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3.7 LET US SUM UP

Proteins are an important constituent of our body and perform diverse functions. Amino acids are the building blocks of proteins. Food items like meat, egg, milk, fish, nuts are rich source of proteins. Proteins like myosin and actin are involved in muscle contraction whereas collagen a stromal protein of muscle is mainly associated with connective tissues. Specialized proteins called enzymes carry out chemical reactions in the body and have many industrial uses.

3.8 KEY WORDS

Amino acids : It is the building blocks of protein.

Collagen : Collagen is an abundant connective tissue protein.

Enzymes : They are specialized proteins that carry out chemical reactions in the body.

Myofibril : Myofibril is the structural unit of muscle.

Myofilaments : These are muscle filament actin called as thin filament and myosin called as thick filament.

Protein : Protein means to come first which is an important component of body tissues.

Protein turnover : It is the breakdown and rebuilding of tissue proteins.

Sarcomere : It is the functional unit of muscle.

Z-Disc : It forms the separation line of one sarcomere with another.

3.9 SOME USEFUL BOOKS

Lawrie, R.A. (1998). *Meat Science*, 6th edition, Wood head Publishing Ltd., Cambridge, England.

Nelson, D.L. and Cox, M.M. (2000). *Principle of Biochemistry,* Worth Publishers Inc., New York, U.S.A.

Williams, S.R. (1990). *Essentials of nutrition and diet therapy*, Times Mirror Mosby College Publishing, St. Louis, Missouri, U.S.A.

Williams, E.R. and Caliendo, M.A. (1984). *Nutrition- Principles, issues and applications*, McGraw-Hill Book Company, New York, U.S.A.

3.10 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) Essential amino acids are required in the diet as body cannot make them.

2) Meat and egg are two complete proteins.

3) Proteins do many functions, the major being tissue building and other being energy source, physiological roles.

Check Your Progress 2

1) Meat is defined as those animal tissues that are suitable for use as food.

2) Collagen is the major connective tissue protein with high tensile strength.

3) Muscle proteins are classified into three types based on their solubility properties. These are sarcoplasmic, myofibrillar and stromal proteins.

Check Your Progress 3

1) Breakdown and rebuilding of tissue proteins is called protein turnover.

2) Intestine, liver, pancreas, kidneys have high protein turnover.

3) Consumption of sufficient non-protein diet to avoid use of proteins as energy source is called protein sparing effect.

4) Comparison of the amino acid composition of a protein with that of egg protein taken as a standard is called its chemical score.

5) PCM is a nutritional deficiency due to low calorie, low protein diet.

Check Your Progress 4

1) In meat industry for muscle tenderization and in milk industry for cheese preparation by rennet.

2) SGOT and SGPT levels are altered during liver disorders.

3) Streptokinase is used to dissolve blood clot.