UNIT 10 CHEMISTRY OF FOOD WITH SPECIAL REFERENCE TO CEREALS, PULSES AND OILSEEDS

Structure

10.0 OBJECTIVES

After reading this unit you should be able to:

- understand role of cereals, pulses and oilseeds in food.
- explain different constituents of cereals, pulses and oilseeds and their significance in a food.
- define role of different carbohydrates and lipids in food and its different chemical and metabolic reactions.
- explain basic properties of protein, structure of protein and different sources of protein.
- explain significance and role of essential amino acid in food and its nutritive properties.
- define role of fatty acids in food and its properties.
- define role of different nutrients in human body.

10.1 INTRODUCTION

The Cereals, Pulses and Oilseeds received a boost in production from a starving situation of importing food grains to a position to export after a green revolution in India. The grains are main source of starch in form of energy, proteins, calcium, iron and vitamins of group B in Indian diet. Cereals are the consumed in large quantities and frequently by vast majority of population in the world. Cereals are used as a staple food in large number of countries in world because their cost of production is low and cost: benefit ratio is high in terms of quantity and nutrients.

Cereals are easy to store because of low moisture content, easy to handle and providing blandness to diet.

Legumes are second to cereals as an important source of proteins. As regards consumption, there are basically two groups of legumes. First there is high-protein high-oil group like soybean, groundnut, lupine, etc which are mainly used for processing. It contains high protein content (35%) and oil content varies from 15-45%. The second group comprises the moderate- protein low oil types like cowpea, gram, pea, lentil etc.

Oilseeds are also generally rich source of protein except coconut and fat. Oilseeds are major sources of edible oil. Edible oilseed meals obtain from oilseeds are rich in proteins and have been used for preparation of infants food for feeding infants and school going children in most of the countries in world.

10.2 CHEMICAL COMPOSITION OF FOODS WITH REFERENCE TO CEREALS, PULSES AND OILSEEDS

Cereals

Cereals are of plant origin which yield edible grains which are consumed directly or in modified form as major part of diet and also feed to livestock. Rice and wheat are most important cereals forming part of human food. The major constituents of the principal cereals are listed in Table 1. Cereal grains consist about two third carbohydrates, mainly in form of digestible sugars and starches. These grains are also an important source of several other nutrients such as protein, calcium, iron and vitamin B.

The cost of cultivation and production is low and cost benefits ratio is high in terms of yield and nutrients. Cereals are used as a staple diet in most developing as well as develop countries in world. They can also be stored easily for long periods at low cost, and their moisture levels remain low. They can be consumed in bulk, they provide blandness to diet and hence can be incorporated in diet for infants.

Table 1: Composition of different Grains

Grains	Moisture %	Carbohydrates %	Protein %	Fat %	Fiber %	Kilocalories (per 100 gm.)
Wheat	11	69	13	2	3	340
Rice	11	65	8	2	9	310
Corn	11	72	10	4	2	352
Sorghum	11	70	12	4	2	348
Barley	14	63	12	2	6	320
Oats	13	58	10	5	10	317
Rye	11	71	12	2	2	321
Buck wheat	10	64	11	2	11	318

The major cereals grown in India, in order of their total production are Rice, Wheat, Jowar, Maize, Bajra, Ragi, Barley, etc.

Rice :- In India rice crop is most extensively grown and is accounts for about 22 % of total cropped area and almost 40% of the total area under cereal. Rice production is roughly 46% of total cereals produced.

Composition of rice:- The mature grain or paddy is botanically known as caryopsis and consist of a loose outer husk is enclosing kernel. Husk constitutes about 25 % of the paddy. Kernel is made up of three parts, which are the pericarp (seed coat) with the underlying aleurone layer, the starchy endosperm and the germ. The germ, the pericarp and the aleurone layer are richer in nutrients as compared to endosperm and they contain proteins and vitamins. Germ, pericarp, aleurone layer are separated from the grain during milling along with the husk.

In rice carbohydrates is available in form of starch, which provides energy to body. Rice provides about 350 calories/100 gm, while protein content is only 7 % because it is consumed in large quantity so that total amount of protein which is ingested through rice is significant. The table 2 shows that rice is poor source of minerals, especially calcium, iron and carotene but good source of vitamin B.

Table 2: Chemical Composition of Different kinds of Rice

	Raw rice				**Parboiled rice**	
	Husked	Home-pounded	Under milled	Milled	Home-pounded	Milled
Moisture %	9.7	9.6	9.5	9.7	12.6	13.3
Protein %	7.7	7.3	7.2	6.9	8.5	6.4
Fat %	1.8	1.2	0.95	0.54	0.6	0.4
Carbohydrates %	78.1	80.1	80.95	82.06	77.4	79.1
Crude fiber %	1.1	0.7	0.5	0.2	-	-
Mineral matter %	1.6	1.1	0.9	0.6	0.9	0.8
Calcium, mg./100g.>15.9	13	13	10	10	10	10
Phosphorous mg./100 g.	368	182	146	87	280	150
Iron mg./100 g.	4.0	2.8	2.5	2.2	2.8	2.2
Thiamine, micro g /100 g.	360	210	190	103	270	210
Nicotinic acid mg. /100 g.	3.5	2.5	2.2	1.0	4.0	3.8

Wheat :- Wheat in India is cultivated throughout the major part of the country. There are 18 wheat species out of which only 3 species are very common. Different varieties, forms and hybrids of wheat form the bulk of the crop, and are grown mainly in Punjab, Haryana, northern Rajasthan, Uttar Pradesh and Bihar. In India wheat crop is grown most extensively. Wheat flour is used for making chapattis, and a variety of other preparations.

It is genus of annual and biennial grasses, yielding various types of wheat, native to southwest Asia and the Mediterranean region. Triticum durum, Triticum aestivum, Triticum compactum are most common wheat varieties and cultivated thought a world. Wheat grains, botanically, are the fruits (caryopsis) of the wheat plant. Wheat is the most widely cultivated of all cereals and in most parts of world, it is the principal staple food of mankind.

Starch is the principal carbohydrate of wheat; glucose and fructose are present in small amounts. Starch occurs in the wheat kernel, as granules of varying sizes.

Mature wheat grain or kernel is roughly egg shaped and 4-10 mm in length. The weight of 1000 kernels varies from 33 to 54 g. and the hectoliter weight from 77.5 - 83.8 kg. (values on 10.5 % moisture basis). The kernel consists of three main parts, namely the bran, the endosperm and the germ or embryo. In well-filled kernels, the bran forms 13-14 per cent, the endosperm 84-85 per cent and the germ, 2-3 per cent. The bran is tough because of its fiber content; the endosperm is starchy and friable, and the germ is rich in oil.

The aleurone, which forms the outer periphery of the endosperm and the innermost layer of the bran, accounts for 3-4 per cent of the weight of the kernel; it is usually removed with the bran during milling. The vitamins reported to be present in a sample of wheat are (per 100 g); carotene 64 micro gram; thiamine 0.45; riboflavin 0.17; nicotinic acid 5.5 and choline 206.0 mg. Whole wheat is a good source of thiamine and nicotinic acid, but is relatively poor in riboflavin. Other members of the B-complex present in wheat include pantothenic acid, p-aminobenzoic acid, biotin, choline, folic acid and inositol. Distribution of Carbohydrates in Commercial Wheat Fractions (%)

Composition of wheat:- The chemical composition of the wheat kernel varies widely being influenced by environment, soil and variety.

Composition of Typical Indian Commercial Wheat (%):

	Starch	**Protein**	**Fiber**	**Fat**	**Ash**
Bran	0	20	90	30	67
Endosperm	100	72	8	50	23
Germ	0	8	2	20	10

Bran is rich in fiber, protein and ash. It gives dark colour to flour and is normally used for cattle feed and manufacture for brown bread. Endosperm consists of essential starch, which is embedded in protein matrix. Germ consist of enzyme mainly lipase and lipoxigenase, which breaks fat into fatty acids.

Minerals - Mineral constituents in Indian wheat on average are as follows :

Minerals	Ca	P	Na	Mg	Fe	K	Cu	S	Cl
Mg/100 g	41.0	306.0	17.1	138.0	4.9	284.0	0.49	128.0	47.0

Maize :- Maize or corn is utilized in more diversified ways than any other cereals. It is extensively cultivated in India in plains as well as in the hills, especially in the areas with hot summer. The states of Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh and Punjab account for majority of production. It consists of high percentage of carbohydrates, lipids and protein and quite nutritious for human consumption. For use as food, maize is ground to flour or whole meal atta and baked into roti or chapatti; it is in this form that maize is consumed in most parts of northern and western India. . The ready to eat breakfast cereal cornflakes is a maize product and also be used in manufacture of starch, dextrin syrup. It is also eaten roasted or boiled on the cob.

Composition of maize:- Maize kernel consists of three main parts, namely hull or bran coat with high fiber content, embryo or germ rich in oil, and starchy endosperm. The proportions of the three kernel parts are approximately as follows

(% of whole kernel); bran, 4.4-6.2 (av. 5.3); germ and scutellum, 10.2-14.1 (av. 11.9); and endosperm, 79.7 – 83.5 (av. 81.9); the tip-cap which is usually removed with the hull in milling, forms 0.8 – 1.1 percent (av, 0.83%).

Proximate composition of Kernel Factions in maize is :

Kernel Faction	Protein (%)	Oil (%)	Starch (%)	Sugars (%)	Ash (%)
Endosperm	9.4	0.8	86.4	0.64	0.31
Germ	18.8	34.5	8.2	10.81	10.10
Bran	3.7	1.0	7.3	0.34	0.84
Tipcap	9.1	3.8	5.3	1.61	1.59
Whole kernel	10.3	4.8	71.5	1.97	1.44

Sorghum:- Sorghum has its origin in Africa. A large variety of sorghums are cultivated in tropical and sub tropical region of the world and known to be an important staple food in many African and Asian countries. In India, sorghum constitutes an important article of food, after rice and wheat. A grain is ground to floor or cooked like rice. In advanced country sorghum is used as an animal feed. Sorghum plants are widely used as fodder, either green or as hay and silage. Sugar content of sweet sorghum is very high and these are used for producing syrups. Sorghum grains is rich source of starch and it is used in fermentation industry for producing industrial alcohols and solvents.

Composition of sorghum:- A chemical composition of sorghum is similar to maize. It consists more protein, lower fat and same amount of carbohydrates as compare to maize. The quantities of riboflavin and pyridoxine are same but pantothenic acid, nicotinic acid and biotin is more as compare to maize. Starch is major carbohydrate in sorghum and simple sugar, cellulose and hemicelluloses are also present.

%	Moisture	Protein	Fat	Carbohydrates	Fiber	Minerals
Sorghum	11.9	10.4	1.9	72.6	1.9	1.6

Amount of Protein present in Sorghum

Protein	albumin	globulin	prolamine	glutelin
%	5.0	6.3	46.4	30.4

Pulses

Pulses are second to cereals as an important source of human food. Approximately 100 species of pulses are considered to be edible from among the over 13,000 pulse species found in world. 39 species of edible pulses information is available on area and methods of cultivation, chemical composition and utilization.

The nutrient composition of edible pulses depends upon species. Protein content in pulses is higher and is commonly more than twice that of cereal grains. The nutritional value of pulses is not just confined to their usefulness as a source of vegetable protein. They are also rich in carbohydrates and are also source of other nutritionally important materials such as vitamins and minerals.

Protein :- Protein content in pulses are usually about 20 % of the dry weight of seeds. Importance of protein not only depends on quantity of protein but also on its quality which in turn depends on the amino acid composition. All pulses have sufficient amount of **leucine** and **phenylalanine.**

Carbohydrates :- Carbohydrate content in pulses are about 55-60 % that includes starch, soluble sugar, fiber and unavailable carbohydrates. The unavailable carbohydrates in pulses include substantial levels of oligosaccharides of the raffinose family of sugars, which are notoriously known for the flatulence production in man and animals.

Lipids :- it consist about 1.5 % of dry matter in pulses mainly polyunsaturated acids and these undergo oxidative rancidity during storage in a number of undesirable changes, such as loss of protein, off-flavour development, and loss in nutritive quality.

Minerals :- Pulses are important source of minerals mainly calcium, magnesium, zinc, iron, potassium, and phosphorous.

A chemical composition of some important pulses per 100 gm edible portion is given below.

1) **Scientific identification:-** *Cajanus cajan*

   Local name & other common names:- Tuver, Red gram dhal (English)

Nutrient	Nutrient Composition/100g (edible portion)	
Pods, tender		Seeds, dry, raw
Energy, Kcal	116	335
Protein, g	9.8	22.3
Fat, g	1	1.7
Carbohydrate, g	16.9	57.6
Fiber, g	6.2	1.5
Minerals, g	1	1.7
Beta-carotene, mg	-	-
Total carotene, mg	469	132
Folic acid, mg	-	103
Vitamin C, mg	25	-
Zinc, mg	3.1	0.9
Iron, mg	1.1	2.7
Calcium, mg	57	73
Phosphorus, mg	164	304
Moisture, g	65.1	13.4

2) **Scientific identification:-** *Dolichos biflours*

Local name & other common names:- Kulad, Horse gram (English)

Nutrient	Nutrient Composition/100g (edible portion)
	Seeds, raw
Energy, Kcal	321
Protein, g	22
Fat, g	0.5
Carbohydrate, g	57.2
Fiber, g	5.3
Minerals, g	3.2
Beta-carotene, mg	-
Total carotene, mg	71
Folic acid, mg	-
Vitamin C, mg	1
Zinc, mg	2.8
Iron, mg	6.8
Calcium, mg	287
Phosphorus, mg	311
Moisture, g	11.8

3) **Scientific identification:-** *Dolichos lablab*

Local name & other common names:- Val papdi, Field bean (English)

Nutrient	Nutrient Composition/100g (edible portion)
	Seeds, raw
Energy, Kcal	347
Protein, g	24.9
Fat, g	0.8
Carbohydrate, g	60.1
Fiber, g	1.4
Minerals, g	3.2
Beta-carotene, mg	0
Total carotene, mg	-
Folic acid, mg	-
Vitamin C, mg	0
Zinc, mg	-
Iron, mg	2.7
Calcium, mg	60
Phosphorus, mg	433
Moisture, g	9.6

4) **Scientific identification:-***Lens esculenta*

Local name & other common names:- Masoor, Lentils (English)

Nutrient	Nutrient Composition/100g (edible portion)
	Seeds, raw
Energy, Kcal	343
Protein, g	25.1
Fat, g	0.7
Carbohydrate, g	59
Fiber, g	0.7
Minerals, g	2.1
Beta-carotene, mg	-
Total carotene, mg	270
Folic acid, mg	36
Vitamin C, mg	0
Zinc, mg	2.8
Iron, mg	7.58
Calcium, mg	69
Phosphorus, mg	293
Moisture, g	12.4

5) **Scientific identification:-** *Phaseolus aureus* Roxb

Local name & other common names:- Moong, Green gram (English)

Nutrient	Nutrient Composition/100g (edible portion)	
Seeds, whole, raw	Seeds, split, raw	
Energy, Kcal	334	348
Protein, g	24	24.5
Fat, g	1.3	1.2
Carbohydrate, g	56.7	59.9
Fiber, g	4.1	0.8
Minerals, g	3.5	3.5
Beta-carotene, mg	-	-
Total carotene, mg	49	94
Folic acid, mg	-	140
Vitamin C, mg	-	-
Zinc, mg	3	2.8
Iron, mg	4.4	3.9
Calcium, mg	124	75
Phosphorus, mg	326	405
Moisture, g	10.4	10.1

6) **Scientific identification:-** *Phaseolus mungo*

Local name & other common names:- Udad, Black gram (English)

Nutrient	Nutrient Composition/100g (edible portion)
Seeds, raw	
Energy, Kcal	346
Protein, g	24
Fat, g	1.4
Carbohydrate, g	59.6
Fiber, g	0.9
Minerals, g	3.2
Beta-carotene, mg	-
Total carotene, mg	38
Folic acid, mg	132
Vitamin C, mg	-
Zinc, mg	3.3
Iron, mg	3.8
Calcium, mg	154
Phosphorus, mg	385
Moisture, g	10.9

7) **Scientific identification:-** *Pisum sativum*

Local name & other common names:- Vatana, Peas (English)

Nutrient	Nutrient Composition/100g (edible portion)	
Peas, green, tender		Seeds, dry
Energy, Kcal	93	315
Protein, g	7.2	19.7
Fat, g	0.1	1.1
Carbohydrate, g	15.9	56.5
Fiber, g	4	4.5
Minerals, g	0.8	2.2
Beta-carotene, mg	-	-
Total carotene, mg	83	39
Folic acid, mg	-	7.5
Vitamin C, mg	9	-
Zinc, mg	-	2.3
Iron, mg	1.5	7.05
Calcium, mg	20	75
Phosphorus, mg	139	298
Moisture, g	72.9	16

8) Scientific identification:- *Vigna catjang*

Local name & other common names:- Chowli, Cow peas/pods

Nutrient	Nutrient Composition/100g (edible portion)	
Pods, tender		Seeds, dry
Energy, Kcal	48	323
Protein, g	3.5	24.1
Fat, g	0.2	1
Carbohydrate, g	8.1	54.5
Fiber, g	2	3.8
Minerals, g	0.9	3.2
Beta-carotene, mg	-	-
Total carotene, mg	564	12
Folic acid, mg	-	133
Vitamin C, mg	4	-
Zinc, mg	-	4.6
Iron, mg	2.5	8.6
Calcium, mg	72	77
Phosphorus, mg	59	414
Moisture, g	85.3	13.4

Oilseeds

Oilseeds have been used by for extraction of oil and for purposes of preparation of food for many centuries. These are important source of energy requirement, consists 2.25 times more energy than protein and carbohydrates and helps reduce the bulk of food we take. It also an excellent source of fat soluble vitamins A, E and K and play important role in biosynthesis of several long chain alcohols.

Palm :- Palm oil is native from West Africa, where wild palm is still harvested and the oil is obtained through simple methods in the villages. The oleaginous palm, probably, came to Brazil together with the slaves coming from Africa. The palm trees originated from the seeds brought by the slaves, after bearing fruit and having its seeds dispersed by man or animals formed a wide band along the Brazilian coast. The band between 10 ºN and 10 ºS of latitude is particularly propitious to palm plantation. The oleaginous palm produces fruit bunches. Each bunch holds about 1500 fruits.

Composition of palm:- Palm oil is composed by 44 % of palmitic acid, which is a saturated fatty acid C16 and less hyper-cholesterolemic than saturated fatty acid between C12 to C14. It contains the same amount of saturated and unsaturated fatty acid. The saturated fatty acid proportion in palm oil is: 43 % of palmitic acid and 4.5 % of stearic acid. The mono saturated proportion in palm oil is composed by oleic acid being 41 % of its composition. 10 % of palm oil is composed by linoleum acid (polyunsaturated fatty acid), which is also an essential fatty acid. The stability of the palm oil occurs due to the following factors: (a) presence of a natural antioxidant substance; (b) low percentage (< 0.5 %) of linoleum acid, which is very sensible to oxidation; (c) moderate percentage of linoleum acid (approximately 10 %); (d) the existence of a protection effect to the structure of the unsaturated components. Moreover, palm oil is much less saturated that other oils, such as coconut oil and palm kernel oil. Palm oil can be considered a balanced fat for containing equal quantities of saturated and unsaturated fatty acid.

Palm oil is widely used in the food and other industries. The main application of palm oil in foods is: frying, biscuits, ices cream, snacks, foods for babies, cereals, margarine, milky products, improvers of bread and chemical preparations for cakes, chewing candies, among others. Palm oil and its fractions are also important raw material for soap and oil chemical industries.

Soybean :- Soybeans occur in various sizes, and in several hull or seed coat colors, including black, brown, blue, yellow, and mottled. The hull of the mature bean is hard, water resistant, and protects the cotyledon and hypocotyl (or “germ”) from damage. If the seed coat is “cracked” the seed will not germinate. The scar, visible on the seed coat, is called the hilum (colors include black, brown, buff, gray and yellow) and at one end of the hilum is the micropyle, or small opening in the seed coat, which can allow the absorption of water.

%	Protein	Oil	Carbohydrates	Ash
Soybean	40	20	35	5

Composition of soybean :- It is a remarkable fact that seeds such as soybeans, containing very high levels of soy protein, can undergo desiccation yet survive and revive after water absorption. A. The oil and protein content together account for about 60 % of dry soybeans by weight; protein at 40 % and oil at 20 %. The remainder consists of 35 % carbohydrate and about 5 % ash. The majority of soy protein is a relatively heat-stable storage protein that enables soy food products requiring high temperature cooking, such as tofu, soymilk and textured vegetable protein (soy flour) to be made.

The principal soluble carbohydrates, saccharides, of mature soybeans are the disaccharide sucrose (range 2.5-8.2 %), the trisaccharide raffinose (0.1-1.0 %) composed of one sucrose molecule connected to one molecule of galactose, and the tetrasaccharide stachyose (1.4 to 4.1 %) composed of one sucrose connected to two molecules of galactose. While the oligosaccharides raffinose and stachyose protect the viability of the soybean seed from desiccation, they are not digestable sugars and therefore contribute to flatulence and abdominal discomfort in humans and other monogastric animals. The insoluble carbohydrates in soybeans consist of the complex polysaccharides cellulose, hemicelluloses, and pectin. The majority of soybean carbohydrates can be classed as belonging to dietary fiber. Since soluble soy carbohydrates are found mainly in the whey and are broken down during fermentation. On the other hand, there may be some beneficial effects to ingesting oligosaccharides such as raffinose and stachyose, namely, encouraging indigenous bifidobacteria in the colon against putrefactive bacteria.

Sunflower :- Sunflower was considered as an ornamental flower until 19th century after that it was cultivated as an oil seed plant in Russia. The sunflower is a member of the compositae family. The commercial varieties cultivated for seed purposes are grouped under *Helianthus annuus* variety macrocarpus. The cultivated sunflower contains 34 somatic chromosomes (2n=34).

Sunflower is mainly used for the extraction of oil. Defatted meal is the main byproduct of sunflower oil extraction and it is rich in protein and certain minerals.

Defatted meal is mostly fed to animals and birds. The large seeded non-oil seed varieties normally provide feed for birds and also used as whole roasted seeds similar to peanuts. After de hulling, the kernels are sold as confectionery nuts.

%	Protein	Lipids	Carbohydrates	Ash
Sunflower	20.8	54.8	18.4	3.9

Composition of sunflower :- Sunflower oil has high level of linoleic acid. Linoleic acid is required for the cell membrane structure, cholesterol transportation in the blood and for prolonged blood clotting. Sunflower oil helps to reduce the serum cholesterol levels. The presence of trypsin inhibitor has been observed in sunflower seeds. However, the activity of the inhibitor is extremely low. The inhibitor is heat-labile and inactivated easily.

Check Your Progress 1

Note: a) Use the spaces given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Why Cereals are more consumed in developing countries in a world?

....

....

....

....

2. What are basic constituents of pulses, why pulses are an important source of human food?

....

....

....

....

3. Named important oilseeds, why oils are used as basic component of food?

....

....

....

....

10.3 CARBOHYDRATES AND LIPIDS

Carbohydrates are energy producing food substances made up of carbon, hydrogen and oxygen that make up about half of our food intake. Carbohydrates are organic compounds having plants are the main source add provide the major part of the energy in our diets and assist in the utilization of fats. Carbohydrates are the most abundant class of organic compounds found in living organisms. They originate as products of photosynthesis, an endothermic reductive condensation of carbon dioxide requiring light energy and the pigment chlorophyll.

$$n\ CO_2 + n\ H_2O + \text{energy}\ CnH_2nO_n + n\ O_2$$

As noted here, the formulas of many carbohydrates can be written as carbon hydrates, Cn (H_2O)n, hence their name. The carbohydrates are a major source of metabolic energy, both for plants and for animals that depend on plants for food. Aside from the sugars and starches that meet this vital nutritional role, carbohydrates also serve as a structural material (cellulose), a component of the energy transport compound ATP, recognition sites on cell surfaces, and one of three essential components of DNA and RNA.

Lipids are one of the largest groups of organic compounds, which are of great importance in the food we eat because they are readily digested and utilized in body and are widely distributed and almost every natural food. Lipids consist of numerous fat like chemical compounds that are insoluble in water but soluble in organic solvents. Lipid compounds include monoglycerides, diglycerides, triglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, and fatty acids. Dietary fats supply energy, carry fat-soluble vitamins (A, D, E, K), and are a source of antioxidants and bioactive compounds. Fats are also incorporated as structural components of the brain and cell membranes.

Most of Fruits and Vegetables contains between 0.1 and 1 percent total lipids, Whole grain cereals have from 1 percent for whole barley on the dry basis to 7.4 percent for dry oatmeal, while nuts are very rich in lipids.

Foods supply carbohydrates in three forms: starch, sugar, and cellulose (fiber). Starch and sugar are major and essential sources of energy for humans. A lack of carbohydrates in the diet would probably result in an insufficient number of calories in the diet. Cellulose furnishes bulk in the diet.

Since the tissues of the body need glucose at all times, the diet must contain substances such as carbohydrates or substances, which will yield glucose by digestion or metabolism. For the majority of the people in the world, more than half of the diet consists of carbohydrates from rice, wheat, bread, potatoes, and macaroni.

10.4 CHEMICAL REACTIONS OF CARBOHYDRATES

Carbohydrates serve as the primary source of energy in the cell, and carbohydrate metabolism is central to all metabolic processes

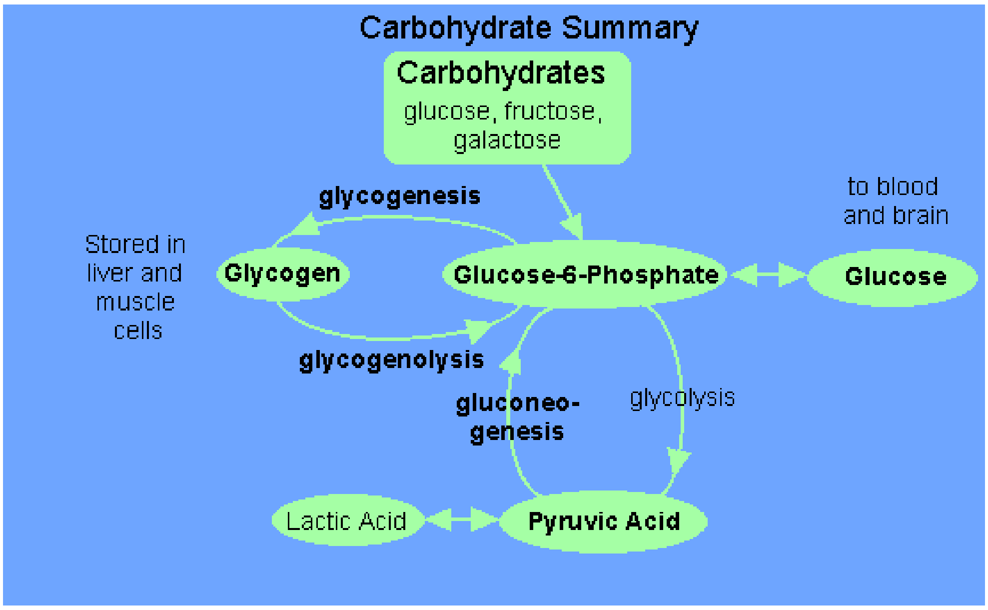


Fig. 1: Carbohydrate Summary

Carbohydrates have been given non-systematic names, although the suffix **ose** is generally used. The most common carbohydrate is **glucose** ($C_6H_{12}O_6$). Applying the terms defined above, glucose is a monosaccharide, an aldohexose (note that the function and size classifications are combined in one word) and a reducing sugar. The general structure of glucose and many other aldohexoses was established by simple chemical reactions. The Fig. 2 illustrates the kind of evidence considered, although some of the reagents shown here are different from those used by the original scientists.

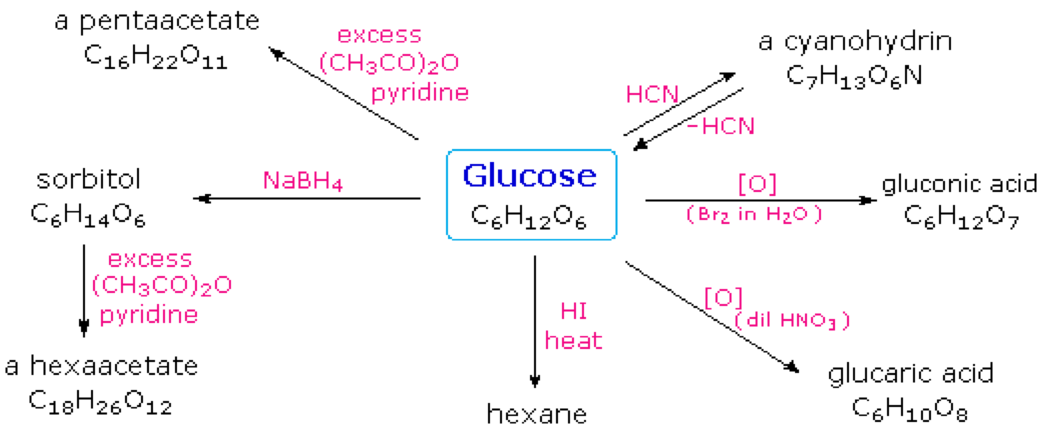


Fig. 2

Hot hydriodic acid (HI) was often used to reductively remove oxygen functional groups from a molecule, and in the case of glucose this treatment gave hexane (in low yield). From this it was concluded that the six carbons are in an un branched chain. The presence of an aldehyde carbonyl group was deduced from cyanohydrin formation, its reduction to the hexa-alcohol sorbitol, also called glucitol, and mild oxidation to the mono-carboxylic acid, glucuronic acid. Somewhat stronger oxidation by dilute nitric acid gave the diacid, glucaric acid, supporting the proposal of a six-carbon chain. The five oxygen's remaining in glucose after the aldehyde was accounted for were thought to be in hydroxyl groups, since a penta-acetate derivative could be made. These hydroxyl groups were assigned, one each, to the last five carbon atoms, because geminal hydroxy group are normally unstable relative to the carbonyl compound formed by loss of water.

Glucose and other saccharides are extensively cleaved by periodic acid, because of abundance of vicinal diol moieties in their structure. This oxidative cleavage, known as the **Malaprade reaction** is particularly useful for the analysis of selective O-substituted derivatives of saccharides, since ether functions do not react. The stoichiometry of aldohexose cleavage is shown in the following equation.

$$HOCH_2(CHOH)_4CHO + 5\ HIO_4 \longrightarrow H_2C{=}O + 5\ HCO_2H + 5\ HIO_3$$

Glucose is metabolized by a stepwise oxidative process according to the balanced equation. this process can be accomplished either anaerobically or aerobically, resulting in the synthesis of adenosine triphosphate (ATP). An overview of the process of glucose oxidation appears in the figure below.

Glycolysis Reaction :- The pathway of glycolysis can be seen as consisting of 2 separate phases. The first is the chemical priming phase requiring energy in the form of ATP, and the second is considered the energy-yielding phase. In the first phase, 2 equivalents of ATP are used to convert glucose to fructose 1,6-bisphosphate (F1, 6BP). In the second phase F1, 6BP is degraded to pyruvate, with the production of 4 equivalents of ATP and 2 equivalents of NADH.

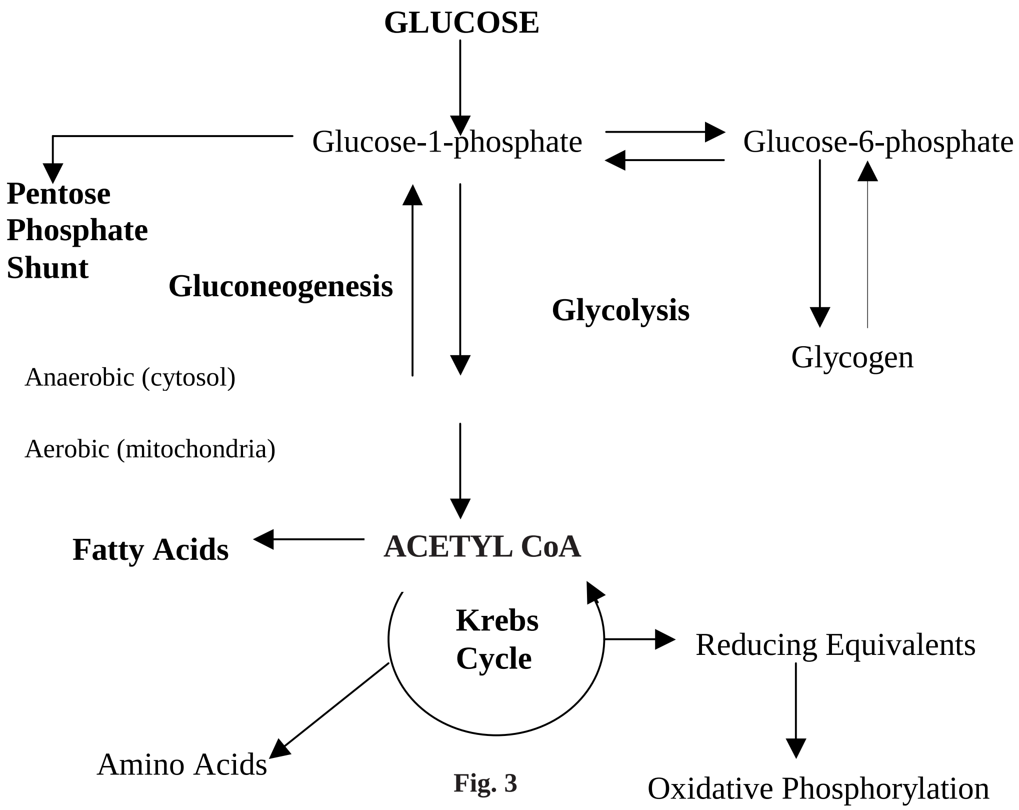
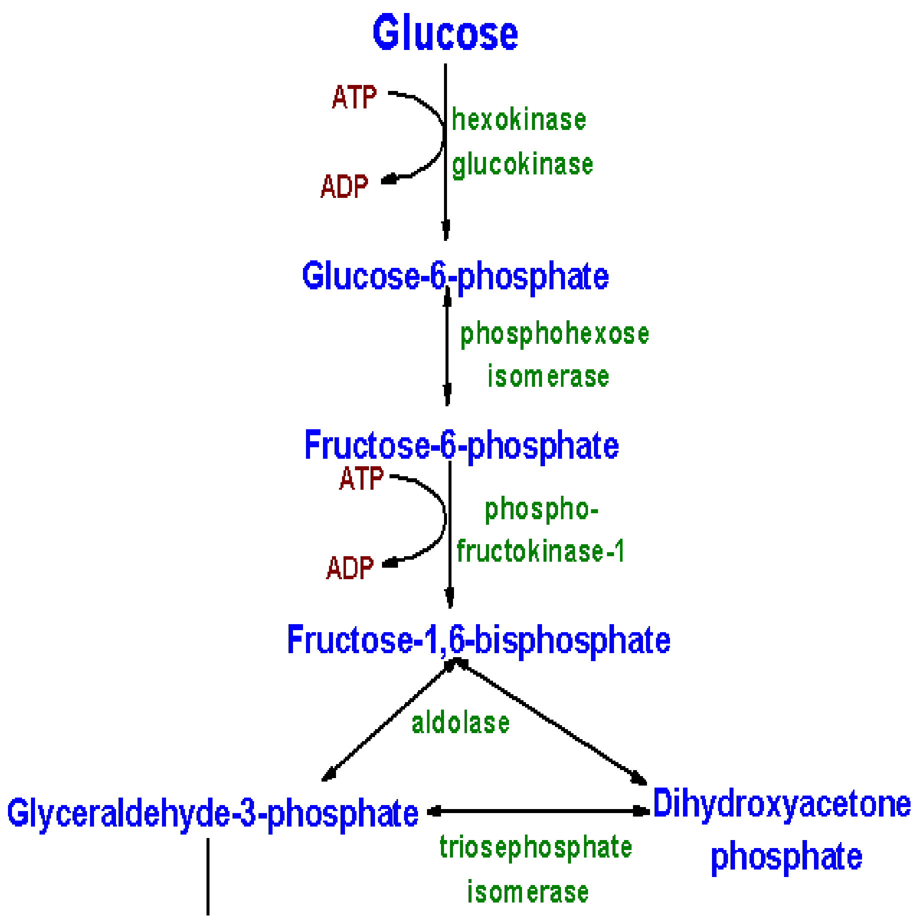


Fig. 3

$C_6H_{12}O_6$ + 2 NAD+ + 2 ADP + 2 P ——> 2 pyruvic acid, $(CH_3(C{=}O)$ COOH + 2 ATP + 2 NADH + 2 H+

At this time, concentrate on the fact that glucose with six carbons is converted into two pyruvic acid molecules with three carbons each. Only a net "visible" 2 ATP are produced from glycolysis. The 2 NADH will be considered separately later.



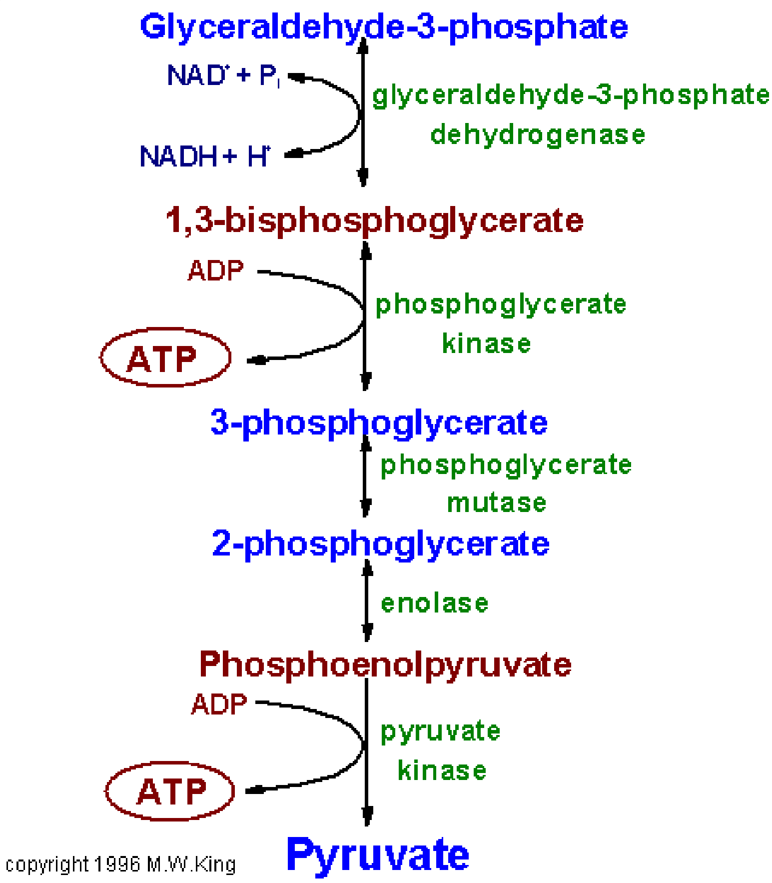


Fig. 4

The major steps of glycolysis are outlined in the graphic. There are a variety of starting points for glycolysis; although, the most usual ones start with glucose or glycogen to produce glucose-6-phosphate. The starting points for other monosaccharides, galactose and fructose, are also shown.

Once glucose is phosphorylated to G-6-P, a six carbon phosphosugar, it can enter the pentose phosphate shunt, or be converted to glycogen (a storage form of glucose). G-6-P can also be oxidized to the three carbon intermediate pyruvate. Pyruvate can be reversibly converted to lactate, which is the final step in the anaerobic oxidation of glucose. Everything described so far is anaerobic and occurs in the cytosol. The process of anaerobic glucose metabolism results in the net formation of ATP.

Pyruvate is an important junction point in glucose metabolism. It can be converted to lactate, as described above, in the cytosol (an anaerobic process). Alternatively, pyruvate can be converted to the two carbon metabolite acetyl CoA, which enters into an aerobic process known as the Krebs cycle (A.K.A. the tricarboxylic acid cycle). Since acetyl Co A can be converted into fatty acids, or into amino acids via the Krebs cycle, it serves as a third major branch point in metabolism. The Krebs cycle produces the reducing equivalents NADH and FADH2, which are oxidized in the electron transport chain to produce three ATP's per molecule in a process known as oxidative phosphorylation. All of the steps of aerobic glucose metabolism occur in the mitochondria.

One molecule of glucose passing through glycolysis, the Krebs cycle and the process of electron transport/oxidative phosphorylation will produce 38 molecules of ATP.

10.5 FATTY ACIDS AND THEIR PROPERTIES

Fats are concentrated sources of energy because they give twice energy as compare with carbohydrates or protein on a weight basis. The functions of fats are to: make up part of the structure of cells, form a protective cushion and heat insulation around vital organs, carry fat soluble vitamins, and provide a reserve storage for energy.

Natural fats are mixture of mixed glycerides in which the three fatty acids esterifying glycerol differ from each other. Three unsaturated fatty acids, which are **essential** include: linoleic, linolinic, and arachidonic and have 2, 3, and 4 double bonds respectively. Saturated fats, along with cholesterol, have been implicated in arteriosclerosis, "hardening of the arteries". For this reason, the diet should be decreased in saturated fats (animal) and increased in unsaturated fat (vegetable). The chemical names and descriptions of some common fatty acids are given in table 3.

Table 3

Chemical Names and Descriptions of Some Common Fatty Acids				
Common Name	*Carbon Atoms*	*Double Bonds*	*Scientific Name*	*Sources*
Butyric acid	4	0	butanoic acid	butterfat
Caproic Acid	6	0	hexanoic acid	butterfat
Caprylic Acid	8	0	octanoic acid	coconut oil
Capric Acid	10	0	decanoic acid	coconut oil
Lauric Acid	12	0	dodecanoic acid	coconut oil
Myristic Acid	14	0	tetradecanoic acid	palm kernel oil
Palmitic Acid	16	0	hexadecanoic acid	palm oil
Palmitoleic Acid	16	1	9-hexadecenoic acid	animal fats
Stearic Acid	18	0	octadecanoic acid	animal fats
Oleic Acid	18	1	9-octadecenoic acid	olive oil
Vaccenic Acid	18	1	11-octadecenoic acid	butterfat
Linoleic Acid	18	2	9,12-octadecadienoic acid	grape seed oil
Alpha-Linolenic Acid (ALA)	18	3	9,12,15-octadecatrienoic acid	flaxseed (linseed) oil
Gamma-Linolenic Acid (GLA)	18	3	6,9,12-octadecatrienoic acid	borage oil
Arachidic Acid oil	20	0	eicosanoic acid	peanut oil, fish
Gadoleic Acid	20	1	9-eicosenoic acid	fish oil
Arachidonic Acid (AA)	20	4	5,8,11,14-eicosatetraenoic acid	liver fats
EPA	20	5	5,8,11,14,17-eicosapentaenoic acid	fish oil
Behenic acid	22	0	docosanoic acid	rapeseed oil
Erucic acid	22	1	13-docosenoic acid	rapeseed oil
DHA	22	6	4,7,10,13,16,19-docosahexaenoic acid	fish oil
Lignoceric acid	24	0	tetracosanoic acid	small amounts in most fats

Apart from flavour fats are used as shortening, tenderizing, lubricants, frying media, whipping agents and for other purpose. Fats are important source of our energy requirement, they furnish 2.25 times more energy than proteins and carbohydrate. They are good source of fat soluble vitamins like A, D, E and K and play a part in biosynthesis of several long chain alcohols.

Essential fatty acids are the component member of living cell and used by the body to make prostaglandin's involved in a large variety of vital physiological functions and these acids play a very important role in immunity. Decreased availability of these acids leads to impaired growth and diminished mental and physical capacities.

Fats delays the pangs of hunger because they are slow in leaving the stomach and hence retard the digestion. They are utilized up to 95-98%, the difference in digestibility/utilization is depends on melting point. Those who have a melting point below 43 ^{O}C are completely digested, whereas those melting point above 43 ^{O}C are slowly digested and less completely absorbed.

The consumption of fats and oils in India is very low, as per estimate our per capita consumption is 4-5 kg/annum compared with 40-50 kg/annum in advanced countries. So, due to low intake of fats, it causes malnutrition mainly in children. FAO/ WHO expert groups has recommended that 30-50 % of our total calories requirement must be met by oils and fats and ratio of saturated to polyunsaturated fatty acids should be 1:1.

Check Your Progress 2

Note: a) Use the spaces given below for your answers.

b) Check your answers with those given at the end of the unit.

1. Write a importance of carbohydrates and lipids?

   ....

   ....

   ....

   ....

2. Define Glycolysis cycle.

   ....

   ....

   ....

   ....

3. Why fats are good source of energy? Name three essential fatty acids.

   ....

   ....

   ....

   ....

10.6 PROTEINS

Proteins are polymers of amino acids joined together by peptide bonds. There are 20 different amino acids that make up essentially all proteins on earth. Each of these amino acids has a fundamental design composed of a central carbon (also called the alpha carbon) bonded to:

- a hydrogen
- a carboxyl group
- an amino group
- a unique side chain or R-group

Thus, the characteristic that distinguishes one amino acid from another is its unique side chain, and it is the side chain that dictates an amino acids chemical properties. All life requires protein since it is the chief tissue builder and part of every cell in the body. These are polymers of amino acids covalently linked through peptide bonds into a chain. Amino acids are made up principally of carbon, hydrogen, oxygen, and nitrogen. Proteins are essential to all life. . Proteins are principal constituents of the protoplasm of all cells. Twenty different amino acids are commonly found in proteins and each protein has a unique, genetically defined amino acid sequence that determines its specific shape and function. Protein is one of the basic components of food and makes all life possible. Among other functions, proteins help to: make hemoglobin in the blood that carries oxygen to the cells; form anti-bodies that fight infection; supply nitrogen for DNA and RNA genetic material; and supply energy.

They provide for the transport of nutrients, oxygen and waste throughout the body. They helps to form protective and supporting to all animals like cartilage, skin, nails, hair and muscles. They are major constituents of enzymes, antibodies, hormones and blood. Within and outside of cells, proteins serve a myriad of functions, including structural roles (cytoskeleton), as catalysts (enzymes), transporter to ferry ions and molecules across membranes. Proteins are necessary for muscular growth and cellular repair and are also functional component of enzymes, hormones, etc. it use for energy only when carbohydrates and fats are not available. They provide the structure and contracting capability of muscles. They also provide collagen to connective tissues of the body and to the tissues of the skin, hair and nails. Proteins are essential for growth and repair. They play a crucial role in virtually all biological processes in the body. All enzymes are proteins and are vital for the body's metabolism. Muscle contraction, immune protection, and the transmission of nerve impulses are all dependent on proteins. Proteins in skin and bone provide structural support. Many hormones are proteins. Protein can also provide a source of energy. Generally the body uses carbohydrate and fat for energy but when there is excess dietary protein or inadequate dietary fat and carbohydrate, protein is used. Excess protein may also be converted to fat and stored. Foods with the best quality protein are listed in diminishing quality order: whole eggs, milk, soybeans, meats, vegetables, and grains.

Many of proteins present in plant are deficient in one or more of the essential amino acids like **zein,** one of the protein of corn, lacking in lysine and tryptophan, while **gliadin** one of the protein of wheat is low in lysine. However, both wheat and corn contains other proteins that possess these amino acids. So, wheat and corn is supplemented with protein that are relative rich in lysine.

10.7 PROTEIN FROM DIFFERENT SOURCES

Most foods contain at least some protein. Good sources of protein for vegetarians include nuts and seeds, pulses, Soya products (tofu, Soya milk and textured Soya protein such as Soya mince), cereals (wheat, oats, and rice), free-range eggs and some dairy products (milk, cheese and yogurt). Proteins are large compounds that are formed when amino acids combine. They contain carbon, hydrogen, and oxygen like carbohydrates and lipids, but they also contain nitrogen. Some proteins may also contain sulfur, phosphorus and iron. Proteins are the building blocks or cells, tissues, and organs. Plants are the source for protein. However, not all compounds in the plant that contain nitrogen are proteins. Most foods contain at least some protein. Good sources of protein for vegetarians include nuts and seeds, pulses, Soya products (tofu, Soya milk and textured Soya protein such as Soya mince), cereals (wheat, oats, and rice), free-range eggs and some dairy products (milk, cheese and yogurt).

Protein quality is usually defined according to the amino acid pattern of egg protein, which is regarded as the ideal. As such, it is not surprising that animal proteins, such as meat, milk and cheese tend to be of a higher protein quality than plant proteins. This is why plant proteins are sometimes referred to as low quality proteins. Many plant proteins are low in one of the essential amino acids. For instance, grains tend to be short of lysine whilst pulses are short of methionine. This does not mean that vegetarians or vegans go short on essential amino acids. Combining plant proteins, such as a grain with a pulse, leads to a high quality protein, which is just as good, and in some cases better, than protein from animal foods. Soya is a high quality protein on its own which can be regarded as equal to meat protein.

The limiting amino acid tends to be different in different proteins. This means when two different foods are combined, the amino acids in one protein can compensate for the one lacking in the other. This is known as protein complementing. Vegetarians eating a well-balanced diet based on grains, pulses, seeds, nuts and vegetables will be consuming a mixture of proteins that complement one another naturally without requiring any planning. Beans on toast, cheese or peanut butter sandwich and rice with peas or beans are all common examples of protein complementing.

Sources of protein (single servings)					
Good sources		**Fair Sources**		**Poor sources**	
Chick peas (200g or 7oz)	16.0g	Brown rice (200g or 7oz)	4.4g	1 Carrot	0.4g
Baked beans (225g or 8oz)	11.5g	Broccoli (100g or 3½oz)	3.1g	1 Apple	0.3g
Tofu (140g or 5oz)	10.3g	Potatoes (200g or 7oz)	2.8g	Cream, double (20g or 2/3oz)	0.3g
Cow's milk (½ pint)	9.2g	Porridge [water] (160g or 6oz)	2.4g	Butter/margarine	None
Lentils (120g or 4¼ oz)	9.1g	-	-	Vegetable oil	None
Soya milk (½ pint)	8.2g	-	-	Sugar or syrup	None
Muesli (60g or 2¼oz)	7.7g	-	-	-	-
Egg, boiled	7.5g	-	-	-	-
Peanuts (30g or 1oz)	7.3g	-	-	-	-
Bread, (2 slices)	7.0g	-	-	-	-
Hard cheese (30g or 1oz)	6.8g	-	-	-	-

List of high protein foods from natural sources

High Protein Food	Protein	Carbs
Eggs (1 medium size)	6 grams	0 g
Milk (1 pint or 568ml)	19 grams	24 g
Milk (1 glass)	6.3 grams	8 g
Soya Milk Plain (200 ml)	6 grams	1.6 g
Tofu (100 g)	8 grams	0.8 g
Low-fat Yoghurt (plain) 150g	8 grams	10 g
Low-fat Yoghurt (fruit) 150g	6 grams	27 g
Fish (cod fillets 100g or 3.5 ounces)	21 grams	0 g
Cheese cheddar 100g (3.5 ounces)	25 grams	0.1 g
Roast Beef (100g or 3.5 ounces)	28 grams	0 g
Roast Chicken 100g (3.5 ounces)	25 grams	0 g
Other Meats Average (100g or 3.5 ounces)	25 grams	0 g

Different foods contain different proteins, each with their own unique amino acid composition. The proportions of essential amino acids in foods may differ from the proportions needed by the body to make proteins. The proportion of each of the essential amino acids in foods containing protein determines the quality of that protein. Dietary proteins with all the essential amino acids in the proportions required by the body are said to be a high quality protein. If the protein is low in one or more of the essential amino acids the protein is of a lower quality. The amino acid that is in shortest supply is called the limiting amino acid.

10.8 PROTEIN STRUCTURE

Proteins are highly complex molecules comprised of linked amino acids. Amino acids are simple compounds containing carbon, hydrogen, oxygen, nitrogen and occasionally sulphur. There are about 20 different amino acids commonly found in plant and animal proteins. Amino acids link together to form chains called peptides. A typical protein may contain 500 or more amino acids. Each protein has it's own unique number and sequence of amino acids which determines it's particular structure and function. Proteins are broken down into their constituent amino acids during digestion, which are then absorbed and used to make new proteins in the body. However, the essential amino acids cannot be made and so they must be supplied in the diet. The eight essential amino acids required by humans are: leucine, isoleucine, valine, threonine, methionine, phenylalanine, tryptophan, and lysine. For children, histidine is also considered to be an essential amino acid.

Proteins are large polypeptides of defined amino acid sequence. The sequence of amino acids in each protein are determined by the gene that encodes it. The gene is transcribed into a messenger RNA (mRNA) and the mRNA is translated into a protein by the ribosome. Structural features of proteins are usually described at four levels of complexity:

1) Primary structure: the linear arrangement of amino acids in a protein and the location of covalent linkages such as disulfide bonds between amino acids. Primary structure is sometimes called the "covalent structure" of proteins because, with the exception of disulfide bonds, all of the covalent bonding within

proteins defines the primary structure. In contrast, the higher orders of proteins structure involve mainly non covalent interactions.

2) Secondary structure: areas of folding or coiling within a protein; examples include alpha helices and pleated sheets, which are stabilized by hydrogen bonding. Secondary structure is "local" ordered structure brought about via hydrogen bonding mainly within the peptide backbone. The most common secondary structure elements in proteins are the alpha (a) helix and the beta (b) sheet (sometime called pleated sheet).

3) Tertiary structure: the final three-dimensional structure of a protein, which results from a large number of non-covalent interactions between amino acids. Tertiary structure is the "global" folding of a single polypeptide chain. A major driving force in determining the tertiary structure of globular proteins is the hydrophobic effect. The polypeptide chain folds such that the side chains of the no polar amino acids are "hidden" within the structure and the side chains of the polar residues are exposed on the outer surface. Hydrogen bonding involving groups from both the peptide backbone and the side chains are important in stabilizing tertiary structure. The tertiary structure of some proteins are stabilized by disulfide bonds between cysteine residues.

4) Quaternary structure: non-covalent interactions that bind multiple polypeptides into a single, larger protein. All types of non covalent interactions: hydrogen bonding, van der Walls interactions and ionic bonding, are involved in the interactions between subunits. Hemoglobin has quaternary structure due to association of two alpha globin and two beta globin polyproteins. Quaternary structure involves the association of two or more polypeptide chains into a multi-subunit structure. Quaternary structure is the stable association of multiple polypeptide chains resulting in an active unit. Not all proteins exhibit quaternary structure. Usually, each polypeptide within a multi sub unit protein folds more-or-less independently into a stable tertiary structure and the folded subunits then associate with each other to form the final structure.

10.9 ESSENTIAL AMINO ACIDS

These are nitrogen-containing compounds that are the building blocks of proteins. There are 22 different amino acids from which every protein in the body is made up of. There are 10 so-called essential amino acids that are not manufactured by the body and must come from the diet. Humans can produce 12 of the 22 amino acids. The others must be supplied in the food. Failure to obtain enough of even 1 of the 10 essential amino acids, those that we cannot make, results in degradation of the body's proteins—muscle and so forth—to obtain the one amino acid that is needed. Unlike fat and starch, the human body does not store excess amino acids for later use—the amino acids must be in the food every day.

Eight amino acids are generally regarded as essential for humans: tryptophan, lysine, methionine, phenylalanine, threonine, valine, leucine, isoleucine. Two others, histidine and arginine are essential only in children. These amino acids are required in the diet. Plants, of course, must be able to make all the amino acids. Humans, on the other hand, do not have all the enzymes required for the biosynthesis of all of the amino acids.

Arginine:- A bitter tasting amino acid found in proteins and necessary for nutrition; its absence from the diet leads to a reduced production of spermatozoa

Histidine:- An essential amino acid found in proteins that is important for the growth and repair of tissue

Isoleucine:- An essential amino acid found in proteins; isomeric with leucine

Leucine:- A white crystalline amino acid occurring in proteins that is essential for nutrition; obtained by the hydrolysis of most dietary proteins

Lysine:- An essential amino acid found in proteins; occurs especially in gelatin and casein

Methionine:- A crystalline amino acid containing sulfur; found in most proteins and essential for nutrition

Phenylalanine:- An essential amino acid found in proteins and needed for growth of children and for protein metabolism in children and adults; abundant in milk and eggs; it is normally converted to tyrosine in the human body

Threonine:- A colorless crystalline amino acid found in protein; occurs in the hydrolysis's of certain proteins; an essential component of human nutrition

Tryptophan:- An amino acid that occurs in proteins; is essential for growth and normal metabolism; a precursor of niacin

Valine:- An essential amino acid found in proteins; important for growth in children and nitrogen balance in adults

Amino acids play central roles both as building blocks of proteins and as intermediates in metabolism. The 22 amino acids that are found within proteins convey a vast array of chemical versatility. The precise amino acid content, and the sequence of those amino acids, of a specific protein, is determined by the sequence of the bases in the gene that encodes that protein. The chemical properties of the amino acids of proteins determine the biological activity of the protein. Proteins not only catalyze all (or most) of the reactions in living cells, they control virtually all cellular process. In addition to the tissues, your digestive and regulatory enzymes, hormones, blood sugar, blood proteins and brain chemicals are also composed of amino acids. So, depending on the specific formula you choose, either to support muscle growth, fat regulation, brain stimulation, or dietary fortification, your expectations can be realized.

In addition to being the building blocks of structure, amino acids in effect turn on and off the "chemical switches" that control our metabolism and body function.

1) Amino acids are necessary for growth and cellular replication throughout the body.
2) Amino acids are a major constituent for muscle, blood, skin, and internal organs.
3) Amino acids control the pathway that allows hormones and enzymes to be released.

Check Your Progress 3

Note: a) Use the spaces given below for your answers.
b) Check your answers with those given at the end of the unit.

1. Write a short note on proteins. Mention at least five good source of proteins for vegetarians.

   ....

   ....

   ....

   ....

2. Role of amino acids to control our metabolism and body function.

   ....

   ....

   ....

   ....

3. Mention a name of essential amino acids.

   ....

   ....

   ....

   ....

10.10 LET US SUM UP

Food Science consists of basic sciences and engineering to study the fundamental physical, chemical, biological, biochemical and behavioral science to nature of food, principles of food processing and marketing of food.

A basic aim of food science is to provide a food, which consists not only processing of food to maintain its nutritive value but also consider to increases shelf life of a food. It also consists of different evaluation of food product to maintain a better quality and reduce spoilage of food and its wastage. Basic aim is also to develop new techniques of preservation and keeping quality of food and to develop new products having good nutritive value and quality with help of different branches of science and engineering.

10.11 KEY WORDS

Legumes	:	Legumes are important source of human food, world wide distributed and every area has its local ‘pea’ or ‘bean’.
Essential Amino Acids	:	Amino acids which are not manufactured by the body, essential for o growth of body, must come from the diet.
Essential Fatty Acids	:	The three fatty acids which esterifying glycerol differ from each other are called essential fatty acids these are linoleic, linolinic, and arachidonic.
Proteins	:	They are polymers of amino acids joined together by peptide bonds.

10.12 SOME USEFUL REFERENCES

1. Lillian Hoagland Meyer, Food Chemistry, CBS Publication & Distributors.
2. Norman N. Potter, Joseph H. Hotchkiss, Food Science, CBS Publication & Distributors.
3. S Ranga, Hand book of Analysis and Quality control for fruits and Vegetables, Tata Mac Graw Hill Publication.

4. Govindrajan US, Ginger- chemistry, technology and quality evaluation: Part I, Food Sci : Nutrition 1982:17(1):1-96.
5. Vijaya Khader, Text book of food science and technology, Indian Council of Agriculture Research.
6. Drewnowski, "Taste Preferance And Food Intake" Annual Review Of Nutrition, vol.17:237-253(volume publication date July 1997)
7. Harry H. Sister, Calvin A. Vonder Werf, Food Chemistry, Van Reinhold Company.

10.13 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. Cereals grains consist about two third carbohydrates, mainly in form of digestible sugars and starches and are also important source of several other nutrients such as protein, calcium, iron and vitamin B. Cereals consumed as feed to livestock are converted into meat, milk, egg etc. Rice and wheat form most important human food in world followed by other grains.

   The cost of cultivation and production of cereals are low and cost: benefits ratio is high in terms of yield and nutrients, cereals are used as a staple diet in most developing as well as developed countries in world. They can also stored easily for long periods at low cost, and their moisture level remains low.

2. Protein content in pulses is usually about 20% of the dry weight of seeds. All pulses have sufficient amount of good value protein like **leucine** and **phenylalanine.** Carbohydrate content in pulses is about 55-60% that includes substantial levels of oligosaccharides. Lipids consist about 1.5% of dry matter in pulses mainly polyunsaturated acids. Pulses are also important source of minerals mainly calcium, magnesium, zinc, iron, potassium, and phosphorous.

   Protein content in pulses are commonly more than twice that of cereal grains. Pulses are useful source of vegetable protein. Pulses contain carbohydrates of the raffinose family of sugars, which are notoriously known for the flatulence production in man and animals. They are also rich in carbohydrates and are also source of other nutritionally important materials such as vitamins and minerals.

3. The important oil seeds are Palm, Soybean, Sunflower, Coconut, Mustered etc. These are important source of energy requirement, consists 2.25 times more energy than protein and carbohydrates and helps reduce the bulk of food we take. It also consists of and is excellent source of fat soluble vitamins A,D,E and K and play important role in biosynthesis of several long chain alcohols.

Check Your Progress 2

1. The carbohydrates are a major source of metabolic energy, both for plants and for animals that depend on plants for food. Aside from the sugars and starches that meet this vital nutritional role, carbohydrates also serve as a structural material (cellulose), a component of the energy transport compound ATP, recognition sites on cell surfaces, and one of three essential components of DNA and RNA.

   Lipids have great importance in the food because they are readily digested and utilized in body. Lipids consist of numerous fat like chemical compounds that are insoluble in water but soluble in organic solvents. Lipids supply energy, carry fat-soluble vitamins (A, D, E, K), and are a source of antioxidants and bioactive compounds. Fats are also incorporated as structural components of the brain and cell membranes.

2. First phase of glycolysis reaction is requires energy in the form of ATP, and in second phase is called as a energy-yielding phase. In the first phase, 2 equivalents of ATP are used to convert glucose to fructose 1,6-bisphosphate (F1, 6BP). In the second phase F1, 6BP is degraded to pyruvate, with the production of 4 equivalents of ATP and 2 equivalents of NADH.

   C6H12O6 + 2 NAD+ + 2 ADP + 2 P ——> 2 pyruvic acid, (CH3(C=O) COOH + 2 ATP + 2 NADH + 2 H+

   At this time, concentrate on the fact that glucose with six carbons is converted into two pyruvic acid molecules with three carbons each. Only a net "visible" 2 ATP are produced from glycolysis. The 2 NADH will be considered separately later.

3. Fats are sources of energy because they provide twice the energy as compared with carbohydrates or protein on a weight basis. The basic functions of fats are to make up part of the structure of cells, form a protective cushion and heat insulation around vital organs, carry fat soluble vitamins, and provide a reserve storage for energy.

   The three essential fatty acids are linoleic, linolinic, and arachidonic. These are unsaturated fatty acids.

Check Your Progress 3

1. All life requires protein since it is the chief tissue builder and part of every cell in the body. These are polymers of amino acids covalently linked through peptide bonds into a chain.

   Good sources of protein for vegetarians includes nuts and seeds, pulses, Soya products (tofu, Soya milk and textured Soya protein such as Soya mince), cereals (wheat, oats, and rice), free-range eggs and some dairy products (milk, cheese and yogurt).

2. A basic role of amino acids is to control our metabolism and body function as under:

   1) Amino acids are necessary for growth and cellular replication throughout the body.

   2) Amino acids are a major constituent for muscle, blood, skin, and internal organs.

   3) Amino acids control the pathway that allows hormones and enzymes to be released.

3. There are Eight amino acids which are generally regarded as essential amino acids for humans: tryptophan, lysine, methionine, phenylalanine, threonine, valine, leucine, isoleucine. Two others, histidine and arginine are essential only in children.