Modified Diet

Dietary modifications are changes made during food preparation, processing, and consumption to increase the bioavailability of micronutrients—and reduce micronutrient deficiencies—in food at the commercial or individual/household level (Beck and Heath 2013).

Definition of Modified Diet

A modified diet is any diet altered to include or exclude certain components, such as calories, fat, vitamins and minerals, according to “Nutrition Essentials for Nursing Practice” by Susan G. Dudek. Diets are typically modified for therapeutic reasons, including treatment of high blood pressure, low body weight or vitamin and mineral deficiencies. Talk to your physician about diet modifications that may help your condition, and follow up with a nutritionist to help you make the best dietary choices.

Concept

Dietary modifications are changes made during food preparation, processing, and consumption to increase the bioavailability of micronutrients—and reduce micronutrient deficiencies—in food at the commercial or individual/household level (Beck and Heath 2013).

Dietary Modifications

1. **Standard diet**: a diet that includes all foods and meets the nutrient needs of healthy people; also called a regular diet.

2. **Modified diet**: a diet that is altered by changing food consistency or nutrient content or by including or eliminating specific foods; also called a therapeutic diet.

Examples of Modified Diets

<table>
<thead>
<tr>
<th>Type of Diet</th>
<th>Description of Diet</th>
<th>Appropriate Uses</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Texture and Consistency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mechanically altered diets</strong></td>
<td>Contain foods that are modified in texture. Pureed diets include only pureed foods; mechanical soft diets may include solid foods that are mashed, minced, ground, or soft.</td>
<td>Pureed diets are used for people with swallowing difficulty, poor lip and tongue control, or oral hypersensitivity. Mechanical soft diets are appropriate for people with limited chewing ability or certain swallowing impairments</td>
<td></td>
</tr>
<tr>
<td><strong>Blenderized Liquid Diet</strong></td>
<td>Contains fluids and foods that are blenderized to liquid diet liquid form.</td>
<td>For people who cannot chew, swallow easily, or tolerate solid foods.</td>
<td></td>
</tr>
<tr>
<td><strong>Clear Liquid Diet</strong></td>
<td>Contains clear fluids or foods that are liquid at room preparation for temperature and leave minimal residue in the colon</td>
<td>For bowel surgery or colonoscopy, for acute GI disturbances (such as after GI surgeries), or as a transition diet after intravenous feeding. For short-term use only.</td>
<td></td>
</tr>
</tbody>
</table>

**Therapeutic Modification of the Normal Diet –**

1. **INTRODUCTION**

A therapeutic diet is a meal plan that controls the intake of certain foods. It’s a practice followed in many hospitals as part of the treatment of a medical condition and are normally prescribed by
a physician and planned by a dietician. A therapeutic diet is usually a modification of a regular diet. Diets are modified for consistency, nutrition and new methods of making regular dishes.

The normal diet may be modified:

- to provide a change in the constituents of the diet.
- to maintain, restore or correct nutritional status
- to include all nutrients in the diet
- to increase or decrease the energy value of the diet
- to provide foods bland in flavour.
- to modify the intervals of feeding.

**PRINCIPLES OF THERAPEUTIC DIET**

A well planned diet providing all the specific nutrients to the body helps to achieve nutritional homeostasis in a normal, healthy individual. However, in disease conditions, the body tissues either do not receive proper nutrients in sufficient amounts or cannot utilize the available nutrients owing to faulty digestion, absorption or transportation of food elements, thus affecting the nutritional homeostasis of the sick person. The diet, therefore needs to be suitably modified. However, it is imperative that the basis for planning such modified diets should be the normal diet. Therefore diet therapy is concerned with the modification of normal diet to meet the requirements of the sick individual.

**The general objectives of diet therapy are**

1. To maintain a good nutritional status.
2. To correct nutrient deficiencies which may have occurred due to the disease.
3. To afford rest to the whole body or to the specific organ affected by the disease.
4. To adjust the food intake to the body's ability to metabolize the nutrients during the disease.
5. To bring about changes in body weight whenever necessary.

The advantages of using normal diet as the basis for therapeutic diets are

1. It emphasises the similarity of psychological and social needs of those who are well, even though there is quantitative and qualitative differences in requirements, thus ensuring better acceptability.
2. Food preparation is simplified when the modified diet is based upon the family pattern and the number of items requiring special preparation is reduced to a minimum.
3. The calculated values for the basic plan are useful in finding out the effects of addition or omission of certain foods. e.g; if vegetables are restricted, vitamin A or Vitamin C deficiency can occur.

Factors to consider in planning therapeutic diets

1. The underlying diseased condition which requires a change in the diet.
2. The possible duration of the disease.
3. The factors in the diet which must be altered to overcome these conditions.
4. The patient's tolerance for food by mouth.

In planning meals for a patient, his economic status, his food preferences, his occupation, and time of meals should also be considered.

The four attributes of a therapeutic diet are:
1. Adequacy
2. Accuracy
3. Economy
4. Palatability

### 1.1 MODIFICATION IN CONSISTENCY

These diets are used in the treatment of gastrointestinal tract. These diets can range from a very low residue diet to a very high fibre diet. Method of feeding is oral.

#### a. DIETS WITHOUT SOLIDS

(i) **Liquid Diets**

<table>
<thead>
<tr>
<th>Clear liquid diets are used after surgeries</th>
<th>Liquid diets consist of foods that are liquid at room temperature and are used in:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Febrile states (acute fever)</td>
</tr>
<tr>
<td></td>
<td>• Post operative conditions</td>
</tr>
</tbody>
</table>

#### b. DIETS WITH SOLIDS
## 1. Soft and Low Fibre Diets

Soft diet is between liquid diet and normal diet. Soft diet includes both liquid and solid foods which contain restricted amount of indigestible carbohydrates and no tough connective tissue. The diet can be made soft by cooking, mashing, pureeing the foods used in a diet under normal conditions. One could also use of refined breads, cereals, vegetables and fruits. This diet is soft in texture and bland to taste.

## 2. Low Residue Diets

The diet is made up of foods which can be completely absorbed, leaving little or no residue for faeces formation. This diet is low in its mineral and vitamin content. Such diets need to be supplemented and foods high in fibre should be omitted. Two cups of milk may be permitted on a daily basis. Fruits and vegetables without skins are allowed. Meat should be tender or ground to reduce connective tissue. The diet is usually used in severe diarrhoea, acute diverticulitis, post operations etc.

## 3. High Fibre Diets

Dietary fibre plays a significant role in colonic function. A high-fiber diet includes foods that have a high fiber content. Fiber is essentially the outer crust of fruits, vegetables, and grains that is not broken down by the body. It helps in excretion of body wastes. Its also well known that fiber regulates the cholesterol levels. Oats, beans, peas, and certain fruits and vegetables (oranges, pears, brussels sprouts, and carrots) are rich sources of fiber. Recommended in case of constipation, or high cholesterol. This is a normal diet with fibre increased to 15–20 gms daily.

## 1.2 MODIFICATION IN NUTRIENTS

Modification or change in the nutrient composition of the diet to increase or decrease the availability of nutrients to suit the body requirements / limitations of a person.
### a. High Calorie Diets

This is a normal diet with an increase in the calorie level to 3000 or more. If appetite is poor, small servings of highly reinforced foods are given. The diet may be modified in consistency and flavour, according to specific needs. Excessive amounts of foods that have a low calorific value and fried foods which disturb the appetite should be avoided. These diets are prescribed for:

- Weight loss
- Fever
- Hyperthyroidism
- Burns

### b. Low Calorie Diet

These diets control calories, carbohydrates, proteins and fat intake in balanced amounts to meet the nutritional needs and control blood sugar and weight. This is a normal diet with energy values reduced to 1500, 1200 or 1000 calories. Protein levels should be at 65 to 100 gms. Supplements of Vitamin A and thiamine are usually required for diets below 1000 calories.

These diets are prescribed for reducing body weight in:

- Diabetes Mellitus
- Cardiovascular diseases
- Hypertension
- Gout
- Gall bladder disease
- Preceding surgery

### c. High Protein Diet

These are diets high in plant and animal proteins; used to treat malnutrition or to increase muscle mass. High protein diet of 100 – 125 g per day may be prescribed for a variety of conditions like:

- Fever
- Hyperthyroidism
- Burns
- After surgery
d. Low Protein Diet

A **low-protein diet** is a diet in which people reduce their intake of proteins. Such a diet is often prescribed to people with kidney or liver disorders. Low protein diets are usually prescribed for conditions like:

- Hepatic encephalopathy
- Acute and chronic glomerulonephrites
- Nephroslerosis
- Acute and chronic renal failure
- In-born errors of metabolism.

In severe liver disorders, when protein cannot be synthesized, excess ammonia cannot be converted to urea for excretion and the patient develops hepatic coma. In this situation protein levels must be decreased or completely restricted for a few days. Patients with Kidney require low protein diets since the kidney cannot excrete nitrogenous wastes. Diets containing 18 to 22 gms of high biological value protein may be needed for the chronic uremic patients who is not being dialysed. Low protein diets are also prescribed for patients with in-born errors of metabolism that result from lack of enzymes of the urea cycle.
### d. Fat Controlled Diet

Fat controlled diets regulate the amount and type of fat allowed. The total calories from fats should give about 30% and 35% of the total calories with 10% from saturated fat and 12 – 14% from polyunsaturated fats. Even the intake of cholesterol also is reduced from the average daily intake of 600 to 300 mg. Usually fat controlled diets are prescribed for—

- Gall bladder diseases
- Nontropical sprue
- Celiac disease
- Cystic fibrosis
- Atherosclerosis
- Myocardial infarction
- Hyperlipidemia etc.

### e. Low Sodium Diet

The mineral content of the diet may also be modified. Four levels of sodium restriction are used — 250, 500, 1000 and 2400 mgs. The diet excludes excess salty foods and salt in cooking and at the table. This diet is used both to prevent and treat edema. Therefore, it is prescribed for congestive heart failure, hypertension, liver and renal diseases. Then sodium must be added back by means of the diet.
Lipids constitute one of the four major classes of compounds that are found in living systems. The lipids of metabolic significance include triacylglycerol, phospholipids and the products of lipid metabolism such as free fatty acids and glycerol.

**Lipases:**

Triacylglycerols or triglycerides undergo hydrolysis by lipases to form glycerol and fatty acids, which undergo further oxidation generating energy.

Lipases have been reported to be present in dry seeds of some species, e.g. castor bean, Scots pine and Douglas fir but at a low level, or absent in others e.g. apple.

In most cases of seeds, following imbibitions, there appears to be a rise in lipase activity but whether this increase is due to the de novo synthesis of the enzyme or activation of existing lipases has not been determined.

A decline in lipase activity is always associated with decline in acylglycerol reserves. In castor bean, as in many other fat-storing seeds, free fatty acids do not accumulate, but are rapidly degraded and converted to carbohydrate within the endosperm. In other seeds such as germinating seeds of oil palm (Elaeis guineensis), a different pattern of fat mobilization can be observed.

The products of lipid catabolism are transported via specialized structures called haustorium through its vascular system.

Lipases are generally non-specific and can hydrolyse a wide variety of triacylglycerols. They initiate digestion by hydrolyzing triacylglycerols to form free fatty acids and 1,2-diacylglycerols. Complete hydrolysis of triacylglycerols produces glycerol and fatty acids. Lipase hydrolyses easily the terminal fatty acids to produce 2-monoacyl glycerol as major products.

Phospholipases are the hydrolytic enzymes acting on phospholipids and splitting into different products. There are four types of phospholipases known as phospholipase A1, phospholipase A2 or B1, phospholipase C and phospholipase D.
**Phospholipase A:**

Phospholipase A is present in large amounts in snake venom and human pancreas. It is also designated as phospholipase A1. It catalyses the hydrolysis of the fatty acids in the 2 or -β position of the phospholipids. Though this enzyme attacks on glycerophosphatides, it is fairly specific for phosphatidyl choline (lecithin). The enzyme is relatively stable to heat (below pH 7.0). The product of the hydrolysis, a lysolecithin, (monoacylephosphoryl choline) has a powerful hemolytic activity.

**Phospholipase B (A2):**

It is otherwise termed as lysophospholipase and widely distributed in nature often in association with phospholipase A. Phospholipase B is also designated as phospholipase A2 since it acts on the lysolecithin (the product obtained from phospholipid by the action of phospholipase A1). The action of this enzyme following that of phospholipase A1 yields glycerophosphoryl choline as the final product.

**Phospholipase C:**

Phospholipase C is mostly found in the plant kingdom but it may also be present in some animal tissues and venoms. It catalyses the liberation of a 1,2-diacylglycerol and phosphorylcholine from phosphatidylcholine. Phosphorylcholine is also liberated from sphingomyelin by this enzyme.
**Phospholipase D:**

Phospholipase D, an enzyme described mainly in plants catalyses the hydrolysis of choline from phosphatidylcholine leaving phosphatidic acid.

**OXIDATION OF FATTY ACIDS**

Fatty acids obtained by hydrolysis of fats undergo different oxidative pathways such as alpha (\(\alpha\)), beta (\(\beta\)) and omega (\(\omega\)) pathways.

**Alpha Oxidation (\(\alpha\)):**

Alpha Oxidation (\(\alpha\)) of fatty acids has been found in certain tissues especially in brain tissue of mammals and plant systems. It does not require CoA intermediates and no high-energy phosphates are generated. This type of oxidation results in the removal of one carbon at a time from the carboxyl end of the fatty acid as observed in many animal tissues.

The physiological role of alpha oxidation (\(\alpha\)) oxidation in plants is not yet fully established but it has been suggested that it may be involved in the degradation of long chain fatty acids as observed in many animal tissues. Alpha Oxidation (\(\alpha\)) is clearly the main source of the odd-carbon fatty acids and their derivatives that occur in some plant lipids. In this process, sequential removal of one carbon at a time from free fatty acids of chain length ranging from C13 to C18 occur.

**Omega Oxidation (\(\omega\)) :**

Omega Oxidation (\(\omega\)) is normally a very minor pathway brought about by hydroxylase enzymes involving cytochrome P- 450 in the endoplasmic reticulum. Fatty acids with oxygen function (alcoholic or carboxyl) at the methyl terminal end omega (\(\omega\)) -oxidation and frequently occur as constituents of cutin and suberin.

The requirements for the oxygenase-mediated conversion of a \(\omega\)-methyl fatty acyl CoA into a \(\omega\)-hydroxymethyl fatty acyl CoA are molecular oxygen, reduced pyridine nucleotide and a non-heme iron protein in higher plants.
Beta (β) Oxidation of Fatty Acids:

In 1904, Franz Knoop made a critical contribution to the elucidation of the mechanism of fatty acid oxidation and demonstrated that most of the fatty acids degraded by oxidation at the β-carbon.

Beta (β)-Oxidation of fatty acids takes place in mitochondria. Fatty acids are activated before they enter into mitochondria for oxidation. Activation of fatty acids. Fatty acids are converted into active intermediate in a reaction with ATP and coenzyme A. A thioester linkage between the carboxyl group of a fatty acid and the sulfhydryl group of coenzyme A is formed with the hydrolysis of ATP. This activation reaction takes place on the outer mitochondrial membrane catalysed by acyl CoA synthetase. Several acyl CoA synthetases, each specific for fatty acids of different chain length are present in the membrane of mitochondria.

Penetration of Long Chain Fatty Acids into Mitochondria:

Long chain acyl-CoA molecules do not readily get into the inner mitochondrial membrane and are carried across the inner membrane by conjugating with carnitine (β-hydroxyl, γ-trimethyl ammonium butyrate), a zwitterionic compound formed from lysine.

Activation of lower fatty acids and their oxidation within the mitochondria occur independently of carnitine, but long-chain acyl CoA will become oxidized unless they form acylcarnitines. The acyl CoA combines with carnitine in the presence of carnitine acyltransferase I, which is bound to the outer mitochondrial membrane.

Acylcarnitine is transported in, coupled with the transport out of one molecule of carnitine. The acylcarnitine then reacts with coenzyme-A, catalyzed by carnitine palmitoyl transferase II, located on the inside of the inner membrane. Acyl CoA is reformed in the mitochondrial matrix and carnitine is liberated.

Oxidation

A saturated Acyl CoA is oxidized by a recurring sequence of four reactions i.e. Oxidation in presence of FAD, Hydration, Oxidation in presence of NAD+, and Thiolysis by CoASH. In β-oxidation, 2 carbons are cleaved at a time from Acyl CoA molecules, starting...
from the carboxyl end. The chain is broken between the \( \beta \)-and \( \alpha \) carbon atoms. The two-carbon units formed are acetyl CoA.

1. The first reaction in \( \beta \)-oxidation is the formation of trans \( \Delta^2 \)- enoyl CoA or \( \alpha,\beta \) unsaturated acyl CoA in presence of acyl-CoA dehydrogenase and the coenzyme FAD.
2. The next step is hydration of the double bond between C-2 and C-3 by enoyl CoA hydratase with the formation of \( \beta \) hydroxyl acyl Co-A.
3. In the third step, the \( \beta \)-hydroxy acyl of CoA is dehydrogenated in presence of \( \beta \)-hydroxy acyl CoA dehydrogenase and NAD+ forming \( \beta \)-ketoacyl CoA.
4. In the last step of \( \beta \)-oxidation, \( \beta \) ketoacyl CoA reacts with coenzyme A in the presence of the enzyme, thiolase. The products of this reaction are acetyl CoA and an acyl CoA containing two carbons less than the original acyl CoA molecule that underwent oxidation.

By the above steps of \( \beta \)-oxidation fatty acids are completely degraded to acetyl CoA units. The acetyl CoA formed from fatty acids can be oxidised to carbon dioxide and water via citric acid cycle.

**Energetics of \( \beta \)-Oxidation:**

The energetics or the energy conserved in terms of ATP by oxidation of a molecule of palmitic acid is given below:

Palmitic acid (16 carbons) undergoes \( \beta \)-oxidation forming eight molecules of acetyl co-A by undergoing seven \( \beta \) oxidation spirals. When one cycle of \( \beta \)-oxidation takes place one molecule FADH\(_2\), one molecule of NADH and one molecule of acetyl CoA are produced.

Electrons from these reducing equivalents (FADH\(_2\) and NADH) are transported through the respiratory chain in mitochondria with simultaneous regeneration of high-energy phosphate bonds. Mitochondrial oxidation of FADH\(_2\) eventually results in the net formation of about 1.5 ATP. Likewise, oxidation of electrons from NADH yields 2.5 molecules of ATP. Hence, a total of four ATP molecules are formed per cycle and ten molecules of ATP are formed through Krebs’s cycle from each molecule of acetyl CoA.
<table>
<thead>
<tr>
<th>Reaction Description</th>
<th>ATP Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Acetyl CoA through TCA cycle yield (8x10)</td>
<td>= 80 ATP</td>
</tr>
<tr>
<td>7 β-oxidation spiral reactions yield (7x4)</td>
<td>= 28 ATP</td>
</tr>
<tr>
<td>Total ATP</td>
<td>= 108 ATP</td>
</tr>
<tr>
<td>ATP utilized in the initial step</td>
<td>= 2 ATP</td>
</tr>
<tr>
<td>Number of ATP yielded by complete oxidation of palmitic acid</td>
<td>= 106 ATP</td>
</tr>
</tbody>
</table>

**Oxidation of Monounsaturated Fatty Acids:**

Oxidation of monounsaturated fatty acids follows many of the reactions of saturated fatty acids except the requirement of two additional enzymes, an isomerase and a novel reductase. Reactions of monounsaturated fatty acid are explained by considering the oxidation of a C-16 unsaturated fatty acid, palmitoleic acid, having a single double bond between C-9 and C-10. Palmitoleic acid is activated and transported across the inner mitochondrial membrane in the same way as saturated fatty acids.

Palmitoleoyl CoA undergoes three cycles of degradation as in β-oxidation. But the cis Δ³ decenoyl CoA formed after the third cycle does not serve as a substrate for acyl CoA dehydrogenase. The presence of a double bond between C-3 and C-4 prevents the formation of another double bond between C-2 and C-3. An isomerase converts the cis double bond into a trans double bond and shifts the position of double bond between C-2 and C-3. Thus, the subsequent or follow up reactions are those of the β-oxidation pathway in which the trans Δ² decenoyl CoA is a regular substrate.

**Oxidation of Polyunsaturated Fatty Acids:**

The oxidation of a polyunsaturated fatty acid, linoleic acid, with cis -Δ⁹ and cis-Δ¹²-double bonds, is considered.

The cis-Δ³ double bond formed after three rounds of β-oxidation is converted into a trans double bond by the isomerase. This permits one more round of oxidation.
The acyl CoA produced by four rounds of β-oxidation of linoleic acid contains a cis-Δ^4 double bond, which undergoes dehydrogenation by acyl CoA dehydrogenase yielding trans Δ^2, Δcis^4 dienoyl intermediate. This intermediate is not a substrate for the next enzyme in the β-oxidation pathway. This intermediate is converted into a trans Δ^3 enoyl CoA to the trans Δ^2 form, an intermediate generally found in β-oxidation pathway and results in complete oxidation of the fatty acid.

**Fatty Acid and Triacyl Glycerol Biosynthesis:**

**Biosynthesis of Fatty Acids :**

It was thought that fatty acid biosynthesis occurred by reversal of the β-oxidation pathway. On the contrary, it occurs by a separate pathway that differs from β-oxidation in several ways.

- Synthesis takes place in the cytosol, in contrast with degradation or oxidation, which occurs in the mitochondrial matrix.
- Intermediates in fatty acid synthesis are covalently linked to the sulphydryl group of an acyl carrier protein (ACP) whereas intermediates in fatty acid breakdown are bonded to coenzyme A.
- The enzymes of fatty acid synthesis in animals are joined in a single polypeptide chain called fatty acid synthase. In contrast, the degradative enzymes do not seem to be associated. Plants employ separate enzymes to carry out the biosynthetic reactions.
- The reductant in fatty acid synthesis is NADPH, whereas the oxidants in fatty acid oxidation are NAD+ and FAD. Pathway for the movement of acetyl-CoA units from within the mitochondrion to the cytoplasm for use in lipid and cholesterol biosynthesis. The following seven steps are involved in fatty acid biosynthesis.
Formation of Malonyl CoA:

The synthesis of malonyl CoA from acetyl CoA is catalyzed by acetyl CoA carboxylase having biotin as prosthetic group. The production of malonyl CoA is the initial and controlling step in fatty acid synthesis. In this reaction, bicarbonate serves as a source of CO2. The reaction takes place in two steps, namely carboxylation of biotin involving ATP and transfer of the carboxyl group to acetyl CoA resulting in malonyl CoA. Acetyl CoA carboxylase plays a key role in regulating fatty acid metabolism and the same is inactivated by phosphorylation. 121


ii) Formation acetyl and malonyl ACP

Acetyl transacylase and malonyl transacylase catalyze the formation of acetyl ACP and malonyl ACP respectively. Acetyl transacylase can transfer acetyl as well acyl groups whereas malonyl transacylase is highly specific. Acetyl transacylase Acetyl CoA + ACP → acetyl -ACP + COASH Malonyl transacylase Malonyl CoA + ACP → Malonyl - ACP + COASH

iii) Formation of acetoacetyl -ACP (β-ketoacyl ACP)

Acetyl ACP condenses with malonyl ACP to form acetoacetyl ACP. Carbondioxide is eliminated from malonyl ACP. iv) Reduction of β-ketoacyl ACP to β-hydroxyl acyl ACP. The β- keto group in acetoacetyl ACP is reduced by NADPH- dependent β-ketoacyl reductase. v) Formation of unsaturated acyl ACP. The β-hydroxyl group combines with the hydrogen atom attached to the γ-carbon and a water molecule is removed to form α, β-unsaturated acyl ACP. vi) Formation of Acyl ACP
unsaturated acyl ACP is converted in the next step to a saturated acyl ACP by the enzyme α,β-
unsaturated acyl ACP reductase using NADPH as the coenzyme. The resultant product contains
two carbon atoms more than the starting material. Addition of subsequent acetyl units through
malonyl ACP leads to the formation of 16- carbon palmitate. Stoichiometry of fatty acid
synthesis The stoichiometry of the synthesis of palmitate is given below: Acetyl CoA + 7
malonyl CoA + 14 NADPH + 20 H+ \rightarrow \text{Palmitate} + 7 \text{CO}_2 + 14 \text{NADP}^+ + 8 \text{CoASH} + 6 \text{H}_2\text{O}

The equation for the synthesis of the malonyl CoA used in the above reaction is 7 Acetyl CoA + 7 CO2 + 7 ATP \rightarrow
7 malonyl CoA + 7ADP + 7 Pi + 14 H+ The overall stoichiometry for the synthesis of
palmitate is 8 Acetyl CoA + 7 ATP + 14 NADPH + 6H+ \rightarrow \text{Palmitate} + 14 \text{NADP} + 8
\text{CoASH} + 6 \text{H}_2\text{O} + 7 \text{ADP} + 7 \text{Pi}

Fatty acid synthesis and degradation are reciprocally regulated so that both are not simultaneously active. Elongation of fatty acids or synthesis of long chain
fatty acids Elongation by the fatty acid synthase complex stops upon formation of palmitate
(16\text{C}). Further elongation and the formation of double bonds are carried out by other enzyme systems. The major product of fatty acid biosynthesis is the 16-carbon fatty acid, palmitate. Additional enzymes are required to synthesise longer chain fatty acids. Chain
elongation reactions occur both in mitochondria and in microsomes. Microsomes are small
membrane-enclosed vesicles derived from the endoplasmic reticulum of cells. Mitochondria and
microsomes carry out chain elongation by adding two-carbon units to fatty acids. The
microsomal system has great physiological significance in that it provides the long chain fatty
acids (18-24C) required for the myelination of nerve cells in animal system. Chain elongation
occurs by a cycle of condensation, reduction, dehydration followed by another reduction that
parallels cytosolic fatty acid biosynthesis. The more active elongation system adds two carbons
to palmitoyl-CoA to make it steroyl CoA. The mechanism of elongation is identical with that
known in the synthesis of palmitate except the enzyme systems and the acyl carrier protein.
Biosynthesis of unsaturated fatty acids Palmitate and stearate serve as precursors of the two
most common monounsaturated fatty acids, palmitoleate, 16:1, (Δ9) and oleate, 18:1 (Δ9)
respectively. Each of these fatty acids has a single double bond between C-9 and C-10. The
double bond is introduced into the fatty acid chain by an oxidative reaction catalysed by fatty
acyl-CoA desaturase, which is NADPH-dependent enzyme. The unsaturated fatty acids,
linoleate, 18:2 (Δ9,12) and α-linolenate, 18:3 (Δ9,12,15) cannot be synthesised by mammals; but plants can synthesise both. The desaturases responsible for synthesis of both the above fatty acids are present in the endoplasmic reticulum of plants. The plant desaturases oxidise phosphatidylcholine-bound oleate and produce polyunsaturated fatty acids and do not directly add double bonds to the fatty acids. Once ingested, the linoleate are readily converted to other polyunsaturated fatty acids like γ-linolenate, arachidonic acid etc. in animals and human beings. Biosynthesis of triacylglycerols
Triacylglycerols are not synthesized by reversal of lipolysis. They are synthesized by a different mechanism in which both glycerol and fatty acids are activated by ATP before they are incorporated into acylglycerols.

1. **Activation of Glycerol:**
   Glycerol kinase catalyses the activation of glycerol to glycerol-3-phosphate. If glycerol kinase is found in low quantity or absent, glycerol 3-phosphate will be formed from dihydroxyacetone phosphate obtained from glycolysis and this reaction is catalysed by the enzyme glycerol 3-phosphate dehydrogenase.

2. **Activation of Fatty Acids:**
   Fatty acids are activated to acyl CoA by the enzyme acyl CoA synthetase, utilizing ATP and CoASH. Two molecules of acyl CoA combine with glycerol 3-phosphate to form 1,2-diacylglycerol phosphate. Formation of 1,2-diacyl glycerol phosphate takes place in two stages, catalysed by glycerol 3-phosphate acyl transferase and then by 1-acyl glycerol 3-phosphate acyl transferase. The phosphate group is removed from 1,2-diacyl glycerol phosphate by phosphatidate phosphatase to form 1,2-diacyl glycerol. Triacylglycerols are finally formed by esterification of one or more molecule of acyl CoA with the diacylglycerol.

**Alternative Pathway for Triacylglycerol Biosynthesis:**

In this pathway, dihydroxyacetone phosphate from glycolysis is reduced by NADPH, acylated and converted to lysophosphatidate. This pathway accounts for less than 10% of total triacylglycerol synthesis.

**Reference:**
1. agrimoon.com
2. Text Book of Biochemistry: A.K.Berry
4. Food Science, Fifth Ediction, Norman N. Potter, Joseph H. Hotchkiss
Menu Planning

INTRODUCTION

In recent times, food has emerged as a source of comfort and a potential threat to health. It reflects cultural heritage and gives a feeling of security and pleasure. Healthy food intake is an important part of life. Hence, it is very essential to gain knowledge about food, its planning, preparation and service. Creative meal management for people at different age groups can add pleasure and satisfaction to their lives and ensure healthy living.

Principles of Menu Planning

Menu planning is the process of planning and scheduling intake of meals for general or specific individual requirements. The four food groups permits an individual to plan a menu to achieve nutrient intake as specified by recommended dietary allowances. There are certain Principles in planning menu. They are

**Nutrient Density**: Considering how to ingest enough nutrients without eating too many calories

**Moderation**: Ingesting enough, but not too much, of a food. Control intake of foods that are rich in fat and sugar or do not promote good health

**Variety**: Eating a wide selection of foods within and among the major food groups. Obtain necessary nutrients and trace minerals

**Adequacy**: Sufficient energy, nutrients, and fiber to be healthy

**Balance**: Achieving the proper combination of foods/food groups. Eating foods in proportion to each other and your needs

**Calorie Control**: Eating the right amount of calories to control weight given your
FACTORS AFFECTING MEAL PLANNING

What guidelines do you keep in mind while planning meals? What all do you consider to make your meal planning effective? Yes, there are many factors such as-

1. Nutritional Adequacy

This is the most important factor, which means that the nutritional requirements of all the family members are fulfilled. For example, you know a growing child needs more protein, a pregnant or lactating woman needs calcium, etc. While planning meals you will include food items from various food groups, that is, energy giving foods, body building foods and protective and regulating foods.

2. Age

People normally eat according to their age. You must have observed in your family that the diet of various members of different age groups differs in quantity. A new born baby drinks only milk, a small child’s meal is also of very small quantity, an adolescent eats still more in amount and variety of foods. Similarly, you must have seen your grandfather eating less food and also that they prefer soft and easy to digest foods.

3. Sex

Sex is another factor which determines the dietary intake. Dietary requirement of adolescent and adult males are more than their female counterparts.

4. Physical Activity

The kind of work a person does affects the kind and amount of food they need to take. Do you remember that RDA is different for people engaged in different
activities? A labourer not only eats more quantity but needs more energy because he is engaged in hard work. His body uses up more energy while performing hard work. So, if you have to plan for such a person you will include more energy giving foods in the diet.

5. Economic Considerations

Money available to the family to be spent on food is another major factor. Foods like milk, cheese, meat, fruits, nuts etc. are expensive. However, alternative sources like toned milk, seasonal fruits and vegetables are less costly and at the same time nutritious. You can therefore plan a balanced diet to suit every budget.

6. Time, energy and skill considerations

While planning the meals, you should consider the resources like time, energy and skill available to the family. Meals can be elaborate with different dishes but you can simplify them by cooking a simple but nutritious dish. For example, a working mother could prepare a paushtik pulao, instead of preparing three or four items for dinner.

7. Seasonal availability

Some foods are available in summers while some in winters. The off season foods are expensive and less nutritious, while those in season are fresh, nutritious, tasty and cheap. Hence, while planning seasonal foods should be used.

8. Religion, region, cultural patterns, traditions and customs

Regional factors influence meal planning. For example, if you are a North Indian, you will consume more of wheat, while those near the coastal region, will consume more of coconut, fish, etc. Similarly your staple food would
be rice if you are a South Indian. Religious beliefs prevalent in the family also have an influence. For example, if you are a vegetarian, your diet will not have any meat or meat product, Hindus do not eat beef and Muslims do not eat pork etc.

9. Variety in colour and texture

10. Likes and dislikes of individuals

The food you serve should cater to the likes and dislikes of the individual family members. It is often better to change the form of some particularly nutritious food item, rather than omitting it completely. For example, if someone in your family does not like milk, you can give it in the form of curd, paneer, etc. Similarly, if one does not want to take green leafy vegetables in cooked form, what alternative would you suggest, so that it can be taken in adequate amount? Yes, it can be used in a variety of ways - mixed with flour and made into parant has or poories; or as culets or pakodas. It can also be given in the form of koftas, idlis, vadas, etc.

11. Satiety Value

While planning meals, take care that you select foods which provide satiety value. Meals which produce inadequate satiety, will lead to onset of hunger pangs, which in turn will affect the working capacity and efficiency of a person.
Food, which provides our body all the nutrients such as carbohydrates, fat, protein, vitamins, minerals and water, does influence our health status. Food and nutrition are essential for maintaining good health and to prevent disease. Nutrition is the science that deals with digestion, absorption and metabolism of food, i.e. the utilization of food in the body. It is the result of the kinds of foods supplied to the body and how the body uses the food supplied. It interprets the relationship of food to the functioning of living organism. It includes the uptake of food, liberation of energy, elimination of wastes and all the processes of synthesis essential for maintenance, growth and reproduction.

In nutrition, diet is the sum of food consumed by a person or other organism. Good nutrition provides all essential nutrients in correct balance which are further utilized to promote the highest level of physical and mental health. Such a state of nutrition can be attained through balanced diets. Balanced diet not only meets our day to day nutrient requirements but also provides for an extra allowance of the nutrients to be stored in our body, which can be used in condition of stress.

Good nutrition is a function of both economics and education. The most serious form of nutritional disorder is under-nutrition arising from inadequate purchasing power. However, even when purchasing power is adequate to access balanced nutrition, various forms of imbalance in dietary intake occur due to lack of knowledge.

**Importance of nutrition**

Adequate, optimum and good nutrition are expressions used to indicate that the supply of the essential nutrients is correct in amount and proportion. It also implies that the utilization of such nutrients in the body is such that the highest level of physical and mental health is maintained throughout the life-cycle. Good nutrition can help:

- Reduce the risk of some diseases, including heart disease, diabetes, stroke, some cancers, and osteoporosis
- Reduce high blood pressure
- Lower high cholesterol
- Improve your well-being
- Improve your ability to fight off illness
- Improve your ability to recover from illness or injury
- Increase your energy level
Type of nutrients

There are two main types of nutrients, macronutrients and micronutrients. The main categories of macronutrients include carbohydrate, protein, and fat. The two groups of micronutrients are vitamins and minerals. These are extra molecules that cells need to make energy.

Functions of nutrients

The nutrients found in foods are; carbohydrates, proteins, fats, minerals, vitamins and water. Fibre is also an essential component of our diet. The functions of nutrients are given below.

**Carbohydrates:** Starch found in cereals and sugar in sugarcane and fruits are examples of carbohydrates in foods. The chief function of carbohydrates is to provide energy needed by our body. Those not used immediately for this purpose are stored as glycogen or converted to fat and stored, to be mobilized for energy supply when needed.

**Fats:** Oils found in seeds, butter from milk, and lard from meat, are examples of fats found in foods. Fats are concentrated sources of energy, carriers of fat soluble vitamins and a source of essential fatty acids. If excess fats are taken in the diet, these are stored as fat reserves in the body. Energy taken in excess of body needs, is stored as fat in the body.

**Proteins:** Casein from milk, albumin in egg, globulins in legumes and gluten in wheat, are examples of proteins occurring in foods. The main function of protein is the building of new tissues and maintaining and repair of those already built. Synthesis of regulatory and protective substances such as enzymes, hormones and antibodies is also a function of food proteins. About 10 per cent of the total energy is supplied by proteins in the diet. Protein, when taken in excess of the body’s need, is converted to carbohydrates and fats and is stored in the body.

**Minerals:** The minerals calcium, phosphorus, iron, iodine, sodium, potassium and others are found in various foods in combination with organic and inorganic compounds. Minerals are necessary for body-building, for building of bones, teeth and structural parts of soft tissues. They also play a role in regulation of processes in the body, e.g., muscle contraction, clotting of blood, nerve stimuli, etc.

**Vitamins:** Fat-soluble vitamins A, D, E and K and also water-soluble vitamins C and B group are found in foods. These are needed for growth, normal function of the body and normal body processes.
**Water:** It is an essential part of our body structure and it accounts for about 60 per cent of our body weight. Water is essential for the utilization of food material in the body and also for elimination of food waste. It is a regulator of body processes such as maintenance of body temperature.

**Classification of foods based on their functions and major nutrient contributions**

Selection of foods in our meal is important to provide all the essential nutrients for various body functions and to make the diet well balanced. For meal planning, different foods are grouped under three food groups based on their functions and major nutrient contributions which include:

**Energy giving food**

These are rich in carbohydrates, like cereals and their products, starchy roots and tubers and sugars, and those rich in fat like nuts, fats and oils. The energy in our diet is mainly contributed by this group.

**Body building food**

These foods provide proteins that are important for tissue building and maintenance. Foods like pulses, milk and milk products provide proteins of good quality. As these proteins contain all the essential amino acids in right amounts and proportions needed by the body, they have a higher biological utilization.

**Protective food**

This group includes foods that provide sufficient amount of vitamins and minerals for protective and regulatory functions of the body. All vegetables (except starchy roots and tubers included under energy giving foods) and fruits comprise this group. Amongst the vegetables, most of the green leafy vegetables are a good source of iron, calcium, β-carotene, vitamin C and dietary fibre. Deep yellow and orange coloured fruits and vegetables are particularly rich in β-carotene, and citrus fruits in vitamin C.

**Malnutrition**

Malnutrition means an undesirable kind of nutrition leading to ill-health. It results from a lack, excess or imbalance of nutrients in the diet. It is a state of impaired functional ability which may occur due to insufficient food intake or the lack of foods that supply the nutrients. The body is unable to utilize the sufficient food material to provide for proper growth, maintenance and repair. It includes under nutrition and over nutrition. Under nutrition is a state of an insufficient supply of essential nutrients. Malnutrition can be primarily be due to insufficient supply of one or more essential nutrients; or it can be secondary, which means it results from an error in metabolism, interaction between
nutrients or nutrients and drugs used in treatment. Over nutrition refers to an excessive intake of one or more nutrients, which creates a stress in the bodily function.

Disorders of Nutrition

Foods contain a number of nutrients. When sufficient quantities of the right type of foods are not eaten, many essential nutrients are not available in adequate quantities to the body. This leads to the development of several deficiency diseases. Some of the common deficiency diseases found are Protein Energy Malnutrition (PEM), vitamin A deficiency, anaemia due to lack or poor absorption of iron, and vitamin B complex deficiency.

Protein Energy Malnutrition (PEM)

Protein Energy Malnutrition (PEM) or Protein Calorie Malnutrition (PCM) is the name given to various degrees of nutritional disorders caused by inadequate quantities of protein and energy in the diet. This is one of the most widespread deficiency disease in India and covers a broad spectrum ranging from marginal deficiency with loss of weight and poor growth to a severe deficiency in which the body may have developed oedema or may have wasted away. Such deficiency occurs mainly in children below five years of age, when they are weaned from mother's milk and the diet substituted does not supply sufficient protein and energy or protein only. When such lack has been prevalent for a long time in the community, the parents’ may fail to note the low weight and stunted growth of the children.

Diseases associated with protein energy malnutrition

Diseases associated with protein energy malnutrition are ‘Kwashiorkor’ and ‘Marasmus’. Some children eat enough food, but it is wrong kind of food. They get a disease called Kwashiorkor. Other children eat so little food of any kind that they get a disease called Marasmus. Both Kwashiorkor and Marasmus can be complicated with other infections due to intestinal parasites and bacteria. The reasons for the prevalence of protein calorie malnutrition are poverty i.e. the families do not have enough income to purchase the necessary nutritious foods. Ignorance of the relation of foods to health and nutritional well-being is another possible cause of protein calorie malnutrition.

Kwashiorkor occurs when there is not enough protein in the diet but calories or energy in the form of carbohydrates is available in sufficient quantity. Kwashiorkor is characterized by growth failure, swelling of legs and feet (oedema), wasted muscles, a miserable expression and changes in the colour of the skin and hair. The hair changes to a light colour and becomes so soft that it can be easily pulled out. The skin develops rashes and also becomes lighter in colour. In this disease, a child is usually underweight and has swollen feet.
When both protein and energy are insufficient, over prolonged periods, a condition known as 'marasmus' occurs in children. In marasmus, there is also growth failure i.e. there is stunted growth. In addition, because of their being not enough protein and calories in the diet, the protein from the body tissues is used up for energy. Children are always very underweight, and sometimes only weigh half as much as they should do for their age. In other words, a child becomes very thin indeed.

Protein Deficiency (Kwashiorkor)

Protein Deficiency (Marasmus)

**Vitamin A Deficiency**

A direct result of vitamin A deficiency is impairment of vision ultimately leading to blindness. Vitamin A is necessary for growth, and lack of it could result in stunted growth and abnormalities of bones and teeth. Deficiency of the vitamin also leads to dryness of the conjunctiva of the eye and cloudiness of the cornea. At this stage night blindness may be observed. Severe deficiency of vitamin A results in the cornea...
becoming dry and losing its transparency thus having a hazy appearance. The principal causes of vitamin A deficiency is lack of adequate supply in the diet. Vitamin A is present in green leaves, ripe mangoes and other fruits.

Iron Deficiency Anaemia

Iron deficiency anaemia is a major nutritional problem. The age groups affected are women in of reproductive age, pregnant women and pre-school children especially from low income groups. Deficiency of iron causes anaemia, a condition in which there is a decrease in the haemoglobin content of the red blood cells (erythrocytes), and there is an alteration in their size and shape. Hence haemoglobin content of blood has been used to study the incidence of anaemia.

Determination of haemoglobin level in the blood of large numbers of people in different age groups in many parts of the world, has helped to establish standards with which the results of field studies can be compared. Haemoglobin studies of large numbers of school children in India, have shown that more than 50 per cent of them have haemoglobin levels less than 10.8 g per 100 ml. Similarly the haemoglobin levels of more than 50 per cent pregnant women, attending rural health centres, was found to be less than 10 g per 100 ml.

The major cause of anaemia is iron deficiency due to inadequate intake of dietary iron and/or its poor absorption, from the cereal based diets consumed by people. Iron intake in the diets of low socio-economic groups has been found to be around 20 mg per day in adults and 6 mg per day for pre-school children. These amounts of iron intake are considered to be marginal due to the high phytate content of the diets, which render part of the iron unavailable to the body. However, it has been observed that if sufficient amounts of vitamin C and calcium are provided, iron can be absorbed even in the presence of phytates. The incidence of anaemia can be reduced by improvements of
dietary habits. These are inclusion of leafy vegetables, which provide iron; vitamin C and calcium, and pulses, which provide protein, iron and B vitamins.

Iron Deficiency Anaemia

**Vitamin B-complex Deficiency**

Some of the common symptoms of vitamin B-complex deficiency are sore mouth, sore tongue and erosion at the angles of the mouth. Low intake of these vitamins in the diet is the primary cause of deficiency. This is compounded by gastro-intestinal infections, such as diarrhoea and dysentery, in which even the little vitamins ingested, may be flushed out before absorption. During pregnancy and lactation, the need for the B vitamins is increased, if there is no extra intake of the vitamins in the diet, deficiency symptoms may occur. It is observed that chronic alcoholics suffer from thiamin deficiency, as the need for thiamin increases with ingestion of alcohol.

Food processing methods affect the vitamin content of the products. For example, thiamin and niacin are partially lost in refining and polishing of cereals, such as rice and wheat. Beri-beri, which is caused by deficiency of thiamin, can affect children as well as adults. The deficiency of niacin occurs, when the staple cereals are highly refined and intake of dals and legumes is meager. Niacin deficiency is called pellagra (rough skin) and it affects the skin, the gastrointestinal tract and the nervous system.

Thus thiamin deficiency could be corrected by using of rice is either under milled or parboiled. Inclusion of other foods rich in thiamin such as wheat and wheat products could help remove thiamin deficiency. Use of milk and milk products and other foods, which are rich sources of riboflavin could prevent riboflavin deficiency. Groundnuts are a rich source of niacin and very much liked by most people. Use of a combination of cereals, pulses and inclusion of groundnuts, would help prevent B-complex deficiency.
Iodine Deficiency Disorders (IDD)

Iodine deficiency leads to a number of disorders, which include goitre, cretinism, mental retardation, deaf-mutism, neuropsychic retardation and myxoedema in elderly. Goitre results in enlargement of the thyroid gland. Girls and women are more susceptible to goitre than boys and men. The simplest way of eradicating iodine deficiency is by addition of iodine to the diet. Salt is a very convenient vehicle for addition of iodine.
## Nutrient Contribution of five groups

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Food Included</th>
<th>Main Nutrients</th>
<th>Size of Serving</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cereals and their products – Rice, wheat, jowar, bajra, ragi, maize, other millets and their products</td>
<td>Energy, protein, iron, thiamin, niacin, fibre</td>
<td>25 g</td>
</tr>
<tr>
<td>2</td>
<td>Protein foods – Dals, legumes, milk, eggs, fish, poultry, meat and their products</td>
<td>Proteins, energy, calcium, iron, Bcomplex vitamins, invisible fat, fibre</td>
<td>25 g</td>
</tr>
<tr>
<td>3</td>
<td>Protective vegetables and fruits – (a) All green leafy vegetables, orangeyellow fruits and vegetables (b) Vit. C-rich fruits and vegetables</td>
<td>Carotenoids, vitamin C, iron, calcium, folic acid, fibre, Vitamin C, carotene, fibre</td>
<td>50-75 g</td>
</tr>
<tr>
<td>4</td>
<td>Other vegetables and fruits- All gourds, beans, peas, potatoes, onions, etc., all other fruits — banana, apple, melons, grapes, etc.</td>
<td>Supplementary sources of minerals, vitamins and fibre</td>
<td>50-75 g</td>
</tr>
<tr>
<td>5</td>
<td>Oils, fats, sugars and their products – Oils, ghee, butter, vanaspati, sugar, jaggery, jams, syrups</td>
<td>Energy, fat, essential fatty acids Energy</td>
<td>5 g</td>
</tr>
</tbody>
</table>
Food Processing is the set of methods and techniques used to transform raw ingredients into finished and semi-finished products. Food processing requires good quality raw materials to be converted into attractive, marketable and often long shelf-life food products. Food processing is aimed to prevent undesirable changes in nutritive value or quality of food and reduce physical, chemical and physiological changes, while the goal of it is to increase the shelf life of a food for safe storage.

Principles of Food Processing

Foods are affected to physical, chemical and biological deterioration. A number of factors can lead to food deterioration e.g. pests, infestation by insects, inappropriate temperatures used for processing and storage, excessive exposure to light and other radiations, reaction with oxygen, either gain or loss of moisture content and activities of food enzymes and other chemical reactions. Food is also contaminated by microorganisms such as bacteria, fungus and moulds. Food can be spoiled due to degradation by naturally present enzymes (a specific class of protein molecules that act as biological catalysts to accelerate chemical reactions). Moreover, physical and chemical changes in certain constituents of food from plant and animal sources occur soon after harvesting, altering the food quality. Hence, food processing and preservation required to preserve food in edible and safe form. Methods by which food is preserved from contamination are drying, controlled fermentation, pickling, candying, roasting, smoking, baking and using spices as preservatives.

The concepts associated with food processing are reducing microbial activity and other factors that influence food spoilage. The principle of microorganisms that cause food spoilage are bacteria, fungi, yeasts and moulds. Factors influencing microbial growth are nutrient availability, moisture, pH, oxygen levels and the presence or absence of inhibiting substances e.g. antibiotics. So the basic concepts in food processing methods to prevent food spoilage are application of heat, removal of moisture, lowering of temperature during storage, reduction of pH, controlling the availability of oxygen.

Methods of Food processing

The food processing utilizes a variety of technologies such as thermal processing, dehydration, refrigeration, and freezing to preserve food materials. The goals of these food preservation methods include eliminating harmful pathogens, spoilage microorganisms and enzymes present in the food for shelf life extension. The general concepts for processing of foods and preserve quality include asepsis, preservation by
heat temperature (pasteurization and sterilization), aseptic canning, low temperature (cold storage, refrigeration and freezing), chemicals, drying, filtration, carbonation, sugar, fermentation, salt, acids, antibiotics and irradiation etc.

Pasteurization of milk, fruit and vegetable juices, blanching and canning of plant and animal food products are processed with heat addition. Blanching helps for enzyme inactivation. Removal of moisture is another major processing method, is achieved by reducing free moisture in food to limit or eliminate the growth of spoilage microorganisms by drying of foods. Packaging also maintains the product quality by processing of the food.

Asepsis

Asepsis or aseptic means the absence of germs such as bacteria, viruses, and other microorganisms that can cause disease i.e. Asepsis is a process of removal of microorganisms from food. Fruits and vegetables before processing should be washed to eliminate the germs. An aseptic environment can be formed by proper packaging of the product, which separates the internal environment from the surroundings. It provides cleanliness and sanitary conditions during processing of the product from raw material to finished stage. It can help in preventing the entry of microorganisms into the product.

Pasteurization

Pasteurization is a mild heat treatment process, in which liquids, semi-liquids with particulates are heated at a specific temperature (usually below 100 °C) for a stated duration to destroy the pathogenic microorganisms and undesirable enzymes present in the food. Pasteurization is achieved by different temperature-time combinations. In milk pasteurization, heating temperatures – time changes, it uses such combination; low-temperature, long-time heating (LTLT, 63 °C for a minimum of 30 min), high-temperature, short-time heating (HTST, 72 °C for a minimum of 15 sec), ultrapasteurization (135 °C or higher for 2 sec to 2 min). The thermal treatment is also influenced by product pH for a given product; fruit juices having pH <4.5 are generally pasteurized at 65°C for 30 min, whereas other low-acid vegetables are pasteurized at 121°C for 20 –30 min. Mould spores are destroyed by heating at 79 °C for 5 to 10 min whereas yeasts and acid bacteria are readily killed if the juice is heated for a few minutes at about 66 °C.

Blanching

Blanching is a unit operation prior to freezing, canning, or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes; modifying texture; preserving color, flavor, and nutritional value; and removing trapped air. Processing
conditions are usually set up to inactivate enzymes, but other quality parameters also such as color and texture, are commonly monitored.

Blanching is used as a pretreatment to fruit and vegetables by applying the thermal treatment for inactivate enzymes that catalyze degradation reactions. It also destroys some microorganisms. It is achieved by using boiling water or steam for a short period of time, 5–15 min depending on the product for color improvement, removal of air from food tissue and softening plant tissue to facilitate packaging.

Sterilization

Sterilization destructs all viable microorganisms at high temperature (>100°C) for a specified duration. Fruits and tomato products should be heated at 100°C for 30 minutes so that the spore forming bacteria which are sensitive to high acidity may be completely killed. Vegetables being non acidic and containing more starch than sugar, require higher temperature to kill the spore- forming organisms. Continuous heating for 30 to 90 minutes at 116°C is essentials for their sterilization. Before using, empty cans and bottles should also be sterilized for about 30 minutes by placing them in boiling water. Temperature above 100°C can only be obtained by using steam pressure sterilizers such as pressure cookers and autoclaves.

Aseptic canning

Aseptic canning is a process which fills presterilized containers with a sterilized and cooled product and sealed in a sterile atmosphere with a sterile cover. The process keep away from the slow heat penetration inherent in the traditional in-container heating process, thus creating products of superior quality. In other words, Aseptic canning is a technique in which food is sterilized outside the can and then aseptically placed in previously sterilized cans which are subsequently sealed in an aseptic environment. Aseptic processing technologies utilize heat exchangers, ohmic heating or microwave heating. It is currently practiced to improve the flavour of some heat-sensitive products sold in small cans and also to store certain ingredients in large containers. Under this process, product is kept at the temperature of 125 to 140°C.

Microwave heating

Microwave heating is rapid heating process which reduce the time required to achieve the desired temperature, thus reducing the cumulative thermal treatment time and better preserving the food constituents. Heat is generated in dielectric materials by microwave energy ranged from 300–300,000 MHz. A domestic microwave oven uses the 2450 MHz frequency for microwave whereas industrial application, a lower frequency of 915 MHz is selected for greater penetration depth. Microwave heating is used in both batch and continuous (aseptic) operations.
Ohmic heating

Ohmic heating is achieved by electrical resistance heating of food to rapidly heat the food material for improvement of extraction, expression, drying, fermentation, blanching, and peeling. It is one of the novel food processing technologies. It uses an alternating electric current is passed through food materials for heating where heat is internally generated in the material due to electrical resistance when electric current is passed through it. The rate of heating depend electric field strength and the electrical conductivity. The electric field strength can be changed by adjusting the electrode gap or the applied voltage. Moreover, the most important factor is the electrical conductivity of the product and its temperature dependence. The electrical conductivity increases with rising temperature i.e. ohmic heating becomes more effective as temperature increases. Ohmic heating process provides quick and consonant heating, resulting in less thermal damage to the food product.

Drying

Drying is one of the oldest methods of preserving food, which involve changing free water present within the food to vapor form and removing it by passing hot air over the product. In the process the heat is transferred from an external heating medium into the food. Within the food, the moisture moves towards the surface of the material due to the vapor pressure gradient between the surface and interior of the product. Then the moisture is evaporated into the heat transfer medium by hot air. The heat is transferred through conduction, convection or radiation within the food material. The moisture movement utilizes a diffusion process. There are several drying methods used in food processing such as hot air drying, spray drying, vacuum drying, freeze drying, osmotic dehydration, etc. Under hot air drying, heat is transferred through the food either from heated air or from heated surfaces. Vacuum drying is performed by evaporation of water under vacuum or reduced pressures. Freeze drying is performed by removing the water vapor through a process called sublimation which helps to maintain food structure.

Refrigeration and freezing

Refrigeration and freezing receive heat energy from food systems and maintain the lower temperatures throughout the storage period to slow down biochemical reactions. For cold storage, food is cooled about 15°C. In refrigeration, temperature is maintained between 0°C and 5°C by mechanical refrigeration whereas in freezing it is maintained between −18°C and −40°C to slow the physical, microbiological, and chemical activities that cause deterioration in foods. Appropriate temperature control is important in refrigeration and freezing to minimize quality changes and microbial growth. Food products can be frozen using either indirect contact or direct contact systems on the
basis of direct contact between the product and the freezing medium. Freezing media may be cold air or liquid refrigerants. Indirect freezing equipment such as cabinet freezing, plate freezing, scraped surface heat exchanger and direct contact freezing systems such as air-blast, fluidized bed, immersion freezing, and spiral conveyor systems are used in freezing industry.

Preservation by Chemicals

Microbial spoilage of food products is also controlled by using chemical preservatives which do not include salt, sugar, acetic acid, oils, alcohols etc., but only microbial antagonists. The important chemicals preservatives permitted in many industries are sulphur dioxide and benzoic acid for the preservation of juice, pulp, nectar, squash, crush and other products against bacteria and moulds and inhibit enzymes etc. Potassium metabisulphite K₂S₂O₅ is commonly used as stable source of sulphur dioxide. The pH for growth of moulds ranges from 1.5 to 8.5, that of yeasts from 2.5 to 8.0 and of bacteria from 4.0 to 7.5.

Use of high sugar or salt content

By using of a strong sugar solution, water of food product is removed about 68 per cent or more from the microbial cells and thus, inhibits the growth of microbes. Food like murraba, jams, jellies, marmalades, candies etc., are preserved by high sugar concentrations.

Microorganisms do not grow well in acidic solutions, therefore, fruits and vegetables are preserved by adding of salt concentration. This process is known as pickling. Pickling uses the salt combined with acetic acid (vinegar). Some of the fruits and vegetables, which are generally pickled, are raw mangoes, limes, Indian gooseberry (aonla), ginger, turmeric and green chillies.

Food concentration

Liquid foods are preserved by concentration which reduces water activity (aw) and retard the microbial growth and enzymatic reactions. Food concentration is used for many purposes like reduction in volume and weight; reduction in packaging, storage and transport costs; better microbial stability; and convenience. Food like are tomato paste, fruit juice concentrate, soup and condensed milk are preserved by concentration. The rate of heating should be controlled to prevent burning of the product, particularly when it has become thickened towards the end of boiling.

Use of organic acids

Organic acids are used to inhibit growth of many spoilage microorganisms. Bacteria are generally pH sensitive. Organic acids enter the bacteria cell wall and disrupt its normal
physiology and thus preserve the food. For preservation acetic acid, lactic acid, citric acid and malic acid are widely used in food products.

**Irradiation**

Food irradiation is the process of exposing food and food packaging to a carefully controlled amount of energy in the form of high-speed particles or electromagnetic (ionizing) radiation. Food irradiation primarily extends the shelf-life of irradiated foods by effectively destroying organisms responsible for spoilage and food borne illness and inhibiting sprouting. Irradiation includes ionizing radiation such as γ-ray and electron beam. Ionizing radiation penetrates a food and energy is absorbed. Absorbed dose of radiation is presented in grays (Gy), where 1 Gy is equal to an absorbed energy of 1 J/kg. It is used for shelf life extension, control of ripening, and inhibition of sprouting. Radiation is most effective in penetrating through various packaging materials.

The irradiation method depends on the material needing to be treated. Thus, to treat a thin layer of surface or food, usually beta particles (i.e. electrons) will be selected. They are easy to produce electronically but do not have deep penetrating power. To treat a heavy product as a whole sack of spices, one would choose gamma rays or X-rays. Cereals, grains and some fruits, such as papaya and mangoes as a quarantine remedy, to kill insects. Doses of 1 kGy are recommended.

**High-pressure processing**

High Pressure Processing (HPP) is also known as cold pasteurization technique, high hydrostatic pressure processing, ultra high pressure processing or pascalization. In this process, sealed food into a vessel are subjected to a high level of isostatic pressure (300–600MPa/43,500-87,000psi) transmitted by water. This technology applies high pressure to solid or liquid foods to improve their safety and in some cases, organoleptic properties and quality.

Foods must be first pre-packed in vacuum-packs or other flexible packaging such as plastic bottles. Packaging materials such as ceramics, glass or metal cannot be used in HPP. Food should be able to withstand high integrity, without losing seal integrity or barrier properties and without undesirable packaging chemicals in the product.

After packaging, the foods are kept into a specially designed pressure chamber which is sealed and completely filled with water. A pump connected to the pressure chamber pressurises the water and this pressure is then transmitted to the food through its packaging via the water. As the pressure acts instantaneously and is equally distributed, there is no obvious crushing effect on the packaged food. Then the pressure is applied for a set time period from a few seconds up to 20 minutes. On completion of the time period, the chamber depressurizes and the food product can be removed.
**Pulsed electric field processing**

Pulsed electric field (PEF) processing performs a high voltage electrical field (20–70 kV/cm) across the food for a few microseconds. A number of process parameters includes electric field strength, treatment temperature, flow rate or treatment time, pulse shape, pulse width, frequency, pulse polarity, food composition, pH, and electrical conductivity. The temperature of the treated foods increases due to an electrical resistance heating effect and also contribute to the inactivation of microorganisms and other food quality attributes. This process effectively kills a variety of bacteria, but spores are not inactivated at ambient temperatures. PEF process has the potential to pasteurize a variety of liquid foods including fruit juices, soups, milk, and other beverages.

**Preservation by Membrane Filtration**

A membrane process is a kinetics-controlled separation of a fluid mixture using a semi-permeable membrane. The process is rarely spontaneous and usually requires some input of energy. The energy may be supplied in different ways: Mechanical potential gradient, Electrical potential gradient, Chemical potential gradients (concentration or osmotic pressure or vapor pressure) and Heat (T gradient). Membranes use differences in transport rates to separate solutes and solvents (mainly water) or gases using various physical mechanisms. Membrane separation processes are classified into two: physical processes and chemical processes. Chemical processes are: hemodialysis, liquid membranes, active transport, supported membranes and facilitated transport. The physical membrane separation processes are: pressure driven process (microfiltration MF, ultra filtration UF, Nano filtration NF, reverse osmosis RO, gas separation), diffusion process (pervaporation, perstraction, dialysis, membrane extraction and membrane absorption), heat process (membrane distillation, vacuum membrane distillation) and electric processes (electro dialysis, electrostatic pseudo liquid membrane). In this process, juices are clarified by ordinary filters and passed special filters which are capable of retaining yeasts and bacteria. It is used for soft drinking, fruit juices and wines.

**Ultrasound**

Ultrasound technology is as an alternative processing technology over thermal processing techniques. It can be used for pasteurization and preservation of food by inactivation of enzymes and microorganisms at low temperatures. In the ultrasound food processing industry, there are two divisions; low intensity ultra sound (less than 1 W cm-2) and high intensity ultra sound (Between 10- 1000 W cm-2).
High-power ultrasound processing or sonication is another alternative technology that has shown promise in the food industry, especially for liquid foods, in inactivating spoilage microorganisms. Ultrasound is a form of energy generated by sound waves of frequencies above 16kHz; when these waves propagate through compressions and depressions of the medium particles create micro bubbles, which collapse (cavitation) and result in extreme shear forces that disintegrate biological materials. Applications of ultrasound in food processing are cooking, freezing, drying, filtration, emulsification and oxidation etc.

**Fermentation**

Fermentation is a metabolic conversion process of carbohydrate, such as starch or a sugar, into an alcohol or an acid by an organism converts a. In the other words, the process by which microorganisms or enzymes decompose of carbohydrates is known as fermentation. Application for the process is; yeast performs fermentation to obtain energy by converting sugar into alcohol. Bacteria perform fermentation, converting carbohydrates into lactic acid. Fermentation causes desirable biochemical changes in foods in terms of nutrition or digestion, or makes them safer or tastier through microbial or enzyme manipulations. Examples of fermented foods are cheese, yogurt, most alcoholic beverages, beer, and pickles. Representative vegetative bacteria in the fermentations are Lactobacillus, Lactococcus, Bacillus, Streptococcus, and Pseudomonas spp. Yeast and fungi (e.g. Saccharomyces, Endomycopsis, and Monascus) are also used for fermentation.

**Extrusion:**

Extrusion converts raw material into a product with a desired shape and form, such as pasta, snacks, textured vegetable protein, and ready-to-eat cereals, by forcing the material through a small opening using pressure. Advantages of extrusion include high productivity, adaptability, process scale-up, energy efficiency, low cost, and zero effluents. It consists of a screw rotating within a stationary barrel. In this process, thermal and shear energies are applied to a raw food material to transform it to the final extruded product. Pre-ground and conditioned ingredients enter the barrel where they are conveyed, mixed, and heated. Extrusion includes several unit operations such as fluid flow, heat transfer, mixing, shearing, size reduction, and melting. The product comes out from the extruder through a die, where it usually puffs (if extruded at >100 °C and higher than atmospheric pressure) and changes texture from the release of steam and normal forces. Extruded products is subjected to a number of structural, chemical, and nutritional changes including starch gelatinization, protein denaturation, lipid oxidation, degradation of vitamins, and formation of flavors.

**Baking**
Baking uses heat to cook prepared dough into a variety of baked products such as bread, cake, pastries, pies, cookies, scones and crackers. The dough has to go through various stages (mixing, fermentation, punching / sheeting, panning, proofing, among others) before it is ready for baking. Carbon dioxide gas is created from yeast fermentation of available sugars, which could either be added or obtained via amylase breakdown of starch. In this process, heat from the source in an oven is transferred to the dough by convection and conduction. As the heat is conducted through the food, it transforms the dough into a baked food with a firm crust and softer. Heat causes the water to vaporize into steam during baking and gelatinization of flour starch in the presence of water. The gluten holds the structure, while carbon dioxide gas that gives the dough its rise, collapses during baking (at ~450 °C). The product makes in greater size and volume called leavening. Baking temperatures also cause a number of biochemical changes in the dough, containing dissolving sugar crystals, gluten proteins, gelatinizing starch, lose water, and breaks down sugars. Brown color and desired baked flavor are obtained from the process.

**Hurdle technology**

Hurdle technology (combined method technology) requires a suitable combination of different destructive agents to ensure microbial safety, quality, and stability of the processed product. Hurdles such as heat, pressure, acidity, water activity, chemical/natural preservatives, and packaging can be combined to improve the quality of the final processed product. The hurdle approach is quite effective in controlling microbial risk.

It is used for the different purposes such as to make a product shelf-stable, to improve quality and to provide additional safety. The necessities for hurdle technology are for fresh, natural and minimally processed food products and ready to eat foods.

Principle of hurdle technology is preservative factors present in the food product. These factors prevent microorganisms from multiplying and causing them to remain inactive or even die. The hurdle concept is introduced by Leistner in 1976; shows that complex interactions of temperature, water activity, pH etc are significant to the microbial stability.

**Packaging**

Packaging plays a vital role in containment, preservation, handling/transportation and marketing. Packaging maintains the quality and properties of foods attained via processing during storage and protect the food material from microbiological and other environmental factors. It also minimizes loss of moisture. Processing on the basis of various treatments (heat, pressure, radiation dose) not only affects the food material but also alters the barrier properties (moisture and oxygen) of packaging materials and
possibly induces migration of polymer material into the food. Hence, selection of food packaging material is essential for successful food process operation.

**Classification of processed foods on the basis of extent and type of processing**

- **Minimally processed foods**
  - These are processed as little as possible in order to retain the quality of fresh foods. Generally the processes used are cleaning, trimming, shelling, cutting, slicing and storage at low i.e., refrigeration temperatures.

- **Preserved foods**
  - The methods of preservation used do not change the character of the product substantially e.g., frozen peas and frozen vegetables, dehydrated peas, dehydrated vegetables, canned fruits and vegetables.

- **Manufactured foods**
  - In such products, the original characteristics of the raw products are lost and some basic methods of preservation are used, often using various ingredients such as salt, sugar, oil or even chemical preservatives. Examples are pickles, jams, marmalades, squashes, papads, wadis.

- **Formulated foods**
  - These are products prepared by mixing and processing of individual ingredients to result in relatively shelfstable food products such as bread, biscuits, ice cream, cakes, kulfi.

- **Derivative Food**
  - In industry, components of foods may be obtained from the raw product through purification, e.g., sugar from sugarcane or oil from oil seeds. In some cases, the derivative or the component may be processed further, e.g., conversion of oil to vanaspati (the process is called hydrogenation).

- **Functional foods**
  - These are foods that can have a beneficial effect on human health, e.g., probiotics, lycopene.

- **Medical foods**
  - These are used in dietary management of diseases, for example, low sodium salt, lactose–free milk for persons with lactose intolerance.
New Trends in Food Science and Nutrition

Dr. S.S. Shukla and Dr. Priti Jain

Food Science is the application of scientific principles to create and maintain a wholesome food supply. It helps to apply a wide range of scientific knowledge to maintain a high quality, abundant food supply. It allows us to make the best use of our food resources and minimize waste. It is the study of the physical, biological, and chemical makeup of food; the causes of food deterioration; and the concepts underlying food processing.

Most food materials are of biological origin. Their behavior is a complex problem in processing, distribution, storage and preparation. Full awareness of all important aspects of the problem requires broad-based training. Its scope starts at overlap with agricultural science and nutrition and leads through the scientific aspects of food safety and food processing, informing the development of food technology. It brings together multiple scientific disciplines. It incorporates concepts from fields such as chemistry, physics, physiology, microbiology and biochemistry. The basis of the discipline lies in an understanding of the chemistry of food components, such as proteins, carbohydrates, fats and water and the reactions they undergo during processing and storage. The microbiology and the safety aspects of food must also be understood. This study includes food additives, the physico-chemical properties of food, flavor chemistry, product development, food engineering and packaging. Food science integrates this broad-based knowledge and focuses it on food. The science of food encompasses; food science, food technologies, and their applications across the food industry.

Therefore, new trends in food science and nutrients is essential because it contributes to ensuring our food supply. The essential ways are; safe, nutritious, tastes good, economical, abundant, easy to prepare and sustainable. It is used to study the nature of foods and causes of their deterioration. It maintains safe and hygienic conditions during processing, storage and packaging of food. It checks raw ingredients and processed food for nutritional value, safety and quality. It includes research aspects of food processing, food preservation, food quality, food deterioration, packaging, storage and delivery in order to improve them.

Function of Nutrient

A nutrient is a substance used by an organism to survive, grow, and reproduce. The requirement for dietary nutrient intake applies to animals, plants, fungi, and protists. Nutrients can be incorporated into cells for metabolic purposes or excreted by cells to create non-cellular structures, such as hair, scales, feathers etc. Some nutrients can be
metabolically converted to smaller molecules in the process of releasing energy, such as for carbohydrates, lipids, proteins and fermentation products (ethanol or vinegar), leading to end-products of water and carbon dioxide. All organisms require water. The process of digestion and absorption of foods and the body’s use of it for growth and replacement of cells is known as nutrition. It shows the interactions between living organisms and the food they consume. Nutrients are compounds in foods essential to life and health, providing us with energy, the building blocks for repair and growth and substances necessary to regulate chemical processes. Good nutrition is an important part of leading a healthy lifestyle.

Categories of Nutrients

Nutrients are divided into 2 categories: macronutrients and micronutrients. Macronutrients are those nutrients that the body needs in large amounts. These provide the body with energy (calories). Micronutrients are those nutrients that the body needs in smaller amounts. There are six major nutrients: Carbohydrates (CHO), Lipids (fats), Proteins, Vitamins, Minerals, and Water. Macronutrients include proteins, fats and carbohydrates whereas micronutrients include vitamins and minerals. They may protect against diseases.

Importance of enhancing nutritive value of food

- To meet the nutritional requirements of the body.
- To make proper selection and preparation of foods.
- To consume food in a balanced manner.
- To improve the flavour and texture of the food.
- To get variety in food.
- To assist in planning the daily menu, keeping in view the nutrient content of the food.
- To prevent deficiency diseases in the body.
- To develop good food habits.

Methods of Enrichment of Nutrients

There are following methods by which nutrients of food can be enhanced:

1. Combination

   Combination is the process of combining cheaper and commonly available foods from different food groups to improve the quality of nutrients. Combining of foods from different food groups is the easiest way of eating all nutrients. Combination of foods improves the quality of nutrients. The combination of a variety of foods ensures better availability of nutrients.
Combination helps to: i) eat a diet that has good quality nutrients, ii) use cheaper and easily available foods that enhance the nutrient content of food considerably, iii) provide balanced diet to the family.

2. Fermentation

Fermentation is a process in which some micro-organisms are added to the food. They change nutrients already present in the foods into simpler and better forms and also make other new nutrients. Fermentation makes the dough rise and become almost double in quantity. During fermentation the micro-organisms use up some of the nutrients present in the atta and change them into other better quality nutrients. They also make some new nutrients. Curd, bread, khaman, dhokla, idli, etc. are all examples of fermented foods.

Advantages of fermentation are:

a) Fermentation improves the digestibility of foods. The micro-organisms which cause fermentation break the proteins and carbohydrates into smaller parts, which are easier to digest.

b) During fermentation of cereals and foods like peas, beans etc., the minerals, calcium, phosphorus, and iron are changed into better quality ones. These are then easily absorbed by the body.

c) Fermented foods become spongy and soft and are liked by children and adults.

3. Germination

Germination is a process in which small shoots come out of the pulses or cereal when these are kept with small amount of water. The grains and pulses to be sprouted need to be soaked in just enough water so that all of it is absorbed. If the extra water in which they are soaked is thrown away, a lot of nutrients are lost.

Grains like wheat, bajra, jawar, etc. can also be sprouted. These grains can then be dried in shade and roasted lightly on a heated surface. They can be ground and used in many dishes. Pulses are also sprouted first and then steamed and consumed. The time and water which each grain or pulse needs for soaking and sprouting is different. Normally 8-16 hours are needed for soaking and 12-24 hours for sprouting. The cloth in which the soaked pulse seeds are tied should be kept moist all the time. When sprouting is followed by fermentation, the vitamin content becomes much more.
Germination helps to

i) Increase the digestibility of foods
   
   a) Some carbohydrates and proteins are broken down into smaller and easily digestible forms.
   b) Grains and pulses become soft after sprouting, so they take less time for cooking and are easy for you to digest.

ii) Increase the nutritive value of food with no additional cost.

Some vitamins and minerals become more when foods are germinated. Vitamin B becomes almost double in quantity while vitamin C increases almost 10 times.

Classification of Foods

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• **Functional foods**: These are foods that can have a beneficial effect on human health, e.g., probiotics, lycopene.

• **Medical foods**: These are used in dietary management of diseases, for example, low sodium salt, lactose–free milk for persons with lactose intolerance.

• **Super foods**: It offers maximum nutritional benefits for minimal calories. They are packed with vitamins, minerals, and antioxidants.
Processes affecting food nutrient content

Processes that expose foods to high levels of many factors such as heat, pressure, time etc. cause the greatest nutrient loss. A variety of food processing that affect its nutritional content can be summarized as:

1. Milling

Cereals such as wheat can be ground to remove the fibrous husks. The husks contain most of the plant’s dietary fiber, B-group vitamins, phytochemicals and some minerals. Products such as white bread are less nutritious than whole meal varieties, even if they have been artificially fortified with some of the nutrients that were lost after milling. It is impossible to add back everything that is taken out, especially the phytochemicals. The ‘fiber’ that is added back to some products is often in the form of resistant starch, which may not be as beneficial as the fiber removed.

2. Blanching

Before a food is canned or frozen, it is usually heated very quickly with steam or water. The water-soluble vitamins, including vitamin C and B-complex, are sensitive and easily destroyed by blanching.

3. Canning

Food is heated inside the can to kill any dangerous micro-organisms and extend the food’s shelf life. Some types of micro-organisms require severe heat treatment and this may affect the taste and texture of the food, making it less appealing. Preservatives are generally not needed in canned foods. Water-soluble vitamins are particularly sensitive to high temperatures. Many people believe that canned foods are not as nutritious as their fresh counterparts, but this is not always the case, as fresh food often deteriorates more rapidly than canned foods.

4. Freezing

The nutrient value of a food is retained when it is frozen. Any nutrient losses are due to the processing prior to freezing and the cooking once the frozen food is thawed.

5. Pasteurization

Pasteurization involves heating liquid foods such as milk and fruit juices to specific temperatures to destroy micro-organisms. The nutrient value of milk is generally unaffected. In the case of pasteurized fruit juices, some losses of vitamin C can occur.

6. High pressure processing

This alternative preservation method subjects a food to elevated pressures, with or without the use of heat to kill micro-organisms. This method has been used in foods
such as fruit juices. As heat is not required, this process impacts less on the vitamin content, flavour and colour of foods.

7. Dehydrating

Drying out foods such as fruits can reduce the amount of vitamin C they retain, but it can also concentrate other nutrients, particularly fiber in plant foods. Dehydrating food also makes food products more energy dense, which may contribute to weight gain. If a dehydrated food is reconstituted and cooked with water, further nutrients are leached out of the food and lost in the cooking water.

Modern methods of nutritional science

The major difference between traditional and modern food processing is the use of technology that has eased out the processes. Modern method use specific heat energy, microwave energy, UV- light energy, ultra-sound energy, pulsed electric field, high pressure processing, radio-frequency processing, pulsed light processing etc.

1. Microwave heating

Microwave heating is rapid heating process which reduces the time required to achieve the desired temperature, thus reducing the cumulative thermal treatment time and better preserving the food constituents.

2. Ohmic heating

Ohmic heating is achieved by electrical resistance heating of food to rapidly heat the food material for improvement of extraction, expression, drying, fermentation, blanching, and peeling.

3. Refrigeration

Refrigeration receives heat energy from food systems and maintains the lower temperatures throughout the storage period to slow down biochemical reactions.

4. Food concentration

Liquid foods are preserved by concentration which reduces water activity (aw) and retard the microbial growth and enzymatic reactions.
5. **Irradiation**

Food irradiation is the process of exposing food and food packaging a carefully controlled amount of energy in the form of high-speed particles or electromagnetic (ionizing) radiation.

6. **Pulsed electric field processing**

Pulsed electric field (PEF) processing performs a high voltage electrical field (20–70 kV/cm) across the food for a few microseconds.

7. **Extrusion:**

Extrusion is a process that converts raw material into a product with a desired shape and form, such as pasta, snacks, textured vegetable protein, and ready-to-eat cereals, by forcing the material through a small opening using pressure.

8. **Ultrasound**

Ultrasonic method is rapidly emerging techniques that is used to minimize processing, enhance quality, and safeguard the safety of food products. Ultrasound is a form of energy generated by sound waves of frequencies above 16kHz; when these waves propagate through compressions and depressions of the medium particles create micro bubbles, which collapse (cavitation) and result in extreme shear forces that disintegrate biological materials. Applications of ultrasound in food processing are cooking, freezing, drying, filtration, emulsification and oxidation etc.

9. **UV Light for Processing Foods**

It is an alternative to traditional thermal processing. Its applications include pasteurization of juices, post lethality treatment for meats, treatment of food contact surfaces and to extend the shelf-life of fresh produce.

10. **Radio Frequency Processing of Food**

RF processing uses dielectric heating to thermally process foods using electromagnetic waves. Radio frequency (RF) heating is a commonly used food processing technology that has been applied for drying and baking as well as thawing of frozen foods.
Food Safety and Handling

Food Safety refers to handling, preparing and storing food in a way to best reduce the risk of individuals becoming sick from food borne illnesses. The principles of food safety aim to prevent food from becoming contaminated and causing food poisoning. This is achieved through a variety of different avenues, some of which are:

- Properly cleaning and sanitizing all surfaces, equipment and utensils
- Maintaining a high level of personal hygiene, especially hand-washing
- Storing, chilling and heating food correctly with regards to temperature, environment and equipment
- Implementing effective pest control
- Comprehending food allergies, food poisoning and food intolerance
METABOLISM OF CARBOHYDRATE

Introduction:

Carbohydrates are major sources of energy for living organisms. The chief source of carbohydrate in human food is starch, which is the storage form of glucose in plants. Plants may store relatively large amounts of starch within their own cells in time of abundant supply, to be used later by the plant itself when there is a demand for energy production. Glycogen is the glucose storage polysaccharide of animals. It accounts for up to 10% of the mass of the liver and one percent of the mass of the muscle. Glycogen is larger and highly branched than amylopectin.

By the action of several enzymes, such as α-amylase, β-amylase, α (1 → 6) glucosidase and α (1 → 4) glucosidase, starch and glycogen from dietary intake are degraded finally to glucose. Carbohydrate is utilized by cells mainly in the form of glucose. The three principal monosaccharides resulting from the digestive processes are glucose, fructose and galactose. Both fructose and galactose are readily converted to glucose by the liver. Pentose sugars such as xylose, arabinose and ribose may be present in the diet, but their fate after absorption is obscure. Since glucose is the compound formed from starch and glycogen, the carbohydrate metabolism commences with this monosaccharide. The major metabolic processes in carbohydrates are:

1. **Glycolysis:**

   Glycolysis is the sequence of reactions that convert glucose into pyruvate with the concomitant trapping of the energy as ATP.

2. **The Citric Acid Cycle:**

   It is the final common oxidative pathway for carbohydrates, fats and proteins. It is also a source of precursors for biosynthesis of various bio-molecules. The acetyl CoA that enters in this pathway is completely oxidized to carbon dioxide and water with concomitant production of reducing equivalents, namely NADH and FADH2.
3. **The Hexose Monophosphate Shunt:**

   It is an alternative pathway to the glycolytic pathway and the citric acid cycle for the oxidation of glucose to carbon dioxide and water with the generation of reduced nicotinamide adenine dinucleotide phosphate (NADPH) molecules and ribose 5- phosphate.

4. **Gluconeogenesis:** It is a biosynthetic pathway that generates glucose from non-carbohydrate precursors.

5. **Glycogenesis:**

   It is a pathway by which glycogen is synthesized from glucose.

6. **Glycogenolysis:**

   Glycolysis, also called as Embden-Meyerhof-Parnas pathway (EMP pathway), consists of a series of reactions through which glucose is converted to pyruvate with the concomitant production of relatively small amounts of adenosine triphosphate (ATP). It is derived from the Greek stem 'glykys' meaning sweet and 'lysis' meaning splitting. It is the primary pathway occurring in the cytoplasm of all the tissues of biological systems. All the enzymes responsible for the catalysis are found in the extra-mitochondrial soluble fraction of the cells (cytoplasm). In plants, glucose and fructose are the main monosaccharides catabolised by glycolysis although others are also converted into these sugars. Glucose entering the glycolysis is derived from starch or sucrose, and fructose is derived from sucrose. The starch is either from seeds or chloroplasts of matured plants. Glycolysis normally takes place in the presence of O$_2$ in higher plant cells. The enzymes in the cytoplasm catalyze the reactions involved in the conversion of glucose to pyruvate. The series of reactions indicated take place in 3 stages.

**Stage 1 - Conversion of glucose to fructose 1,6-bisphosphate:**

The formation of fructose 1,6-bisphosphate takes place in three steps catalyzed by enzymes. The purpose of these reactions is to form a compound that can be readily cleaved into phosphorylated three carbon units from which, through a series of reactions, ATP is formed. After the first phosphorylation reaction to form glucose 6-phosphate, isomerization of glucose 6-phosphate to fructose-6-phosphate occurs which is conversion of an aldose into a ketose. A second phosphorylation reaction follows the
isomerization, catalyzed by phosphofructokinase resulting in the formation of fructose 1,6-bisphosphate. Phosphofructokinase is the key enzyme in the control of glycolysis.

**Stage 2 - Conversion of fructose 1,6-bisphosphate to 3-phosphoglycerate:**

The splitting of fructose 1,6-bisphosphate occurs in the second stage of glycolysis resulting in the formation of a molecule of glyceraldehyde 3-phosphate and a molecule of dihydroxyacetone phosphate catalyzed by aldolase. The dihydroxyacetone phosphate is isomerized to glyceraldehyde 3-phosphate by phosphotriose isomerase. The isomerisation reaction is rapid and reversible. In the next step, glyceraldehyde 3-phosphate is oxidized to 1,3-bisphosphoglycerate catalyzed by glyceraldehyde 3-phosphate dehydrogenase. The product is further converted into 3-phosphoglycerate and a molecule of ATP is formed. The phosphorylation of ADP to ATP is called substrate level phosphorylation since the phosphate group from a substrate molecule is transferred to ADP.

**Stage 3 - Formation of Pyruvate:**

An intramolecular rearrangement of the phosphoryl group occurs resulting in the formation of 2-phosphoglycerate from 3-phosphoglycerate catalyzed by phosphoglycerate mutase. The 2-phosphoglycerate formed undergoes dehydration forming phosphoenolpyruvate which gives rise to pyruvate and a molecule of ATP (Substrate Level Phosphorylation). The reaction is irreversible and catalyzed by pyruvate kinase. The net reaction in the transformation of glucose to pyruvate is:

\[
\text{Glucose} + 2 \text{Pi} + 2\text{ADP} + 2\text{NAD}^+ \rightarrow 2\text{pyruvate} + 2\text{ATP} + 2\text{NADH} + 2\text{H}^+ + \text{H}_2\text{O}
\]

Once pyruvate is formed, further degradation is determined by the presence or absence of oxygen. Under anaerobic conditions, in one of the pathways, pyruvate undergoes reduction yielding lactic acid. The formation of lactic acid is very rare in plants with exception of potato tubers maintained under anaerobic condition and some green algae. In the second pathway, pyruvate is converted to ethyl alcohol and carbon dioxide. The alcoholic fermentation is the basis of the beer and wine-making industries. Under aerobic conditions, pyruvate is oxidatively decarboxylated to acetyl CoA which is then completely oxidized to CO$_2$ and water through the citric acid cycle.
Energetics of Glycolysis:

From glucose, two molecules of glyceraldehyde 3-phosphate are formed in the second stage of glycolysis from which two molecules of pyruvate are obtained as end products of glycolysis. Hence energetic of glycolysis is calculated by taking into account two molecules of glyceraldehyde 3-phosphate.

Energetics of Glycolysis - Significance of Glycolysis:

Glycolysis is an almost universal central pathway of glucose catabolism occurring in the cytoplasm of all the tissues of biological systems leading to generation of energy in the form of ATP for vital activities. It is the pathway through which the largest flux of carbon occurs in most cells. Some plant tissues which are modified for the storage of starch such as potato tubers and some plants adapted to growth in inundated water such as water cress derive most of their energy from glycolysis.

<table>
<thead>
<tr>
<th>Stages/steps</th>
<th>Enzyme</th>
<th>Method of high energy bond formation</th>
<th>No. of ATP formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation of 1,3-bisphosphoglycerate from glyceraldehydes 3-phosphate</td>
<td>Glyceraldehyde3-phosphate dehydrogenase</td>
<td>Respiratory chain oxidation of 2 NADH</td>
<td>5</td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Formation of 3-phosphoglycerate from 1,3-bisphosphoglycerate</td>
<td>Phosphoglycerate kinase</td>
<td>Phosphorylation at substrate level</td>
<td>2</td>
</tr>
<tr>
<td>Stage 3</td>
<td></td>
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</tr>
<tr>
<td>Formation of pyruvate from phosphoenol pyruvate</td>
<td>Pyruvate kinase</td>
<td>Phosphorylation at substrate level</td>
<td>2</td>
</tr>
<tr>
<td>Allowance for consumption of ATP by reactions catalysed by hexokinase and phosphofructokinase.</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Number of ATP molecules generated by the catabolism of one molecule of glucose under aerobic conditions.</td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Number of ATP molecules generated by the catabolism of one molecule of glucose under anaerobic conditions.</td>
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Significance of Glycolysis:

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In plants, glycolysis is the key metabolic component of the respiratory process, which generates energy in the form of ATP in cells where photosynthesis is not taking place. Many types of anaerobic microorganisms are entirely dependent on glycolysis. Mammalian tissues such as renal medulla and brain solely dependent on glycolysis for major sources of metabolic energy.

The Tricarboxylic Acid Cycle (TCA Cycle):

In 1937, Sir Hans Krebs, an English biochemist proposed a pathway consisting of a cycle of reactions through which acetyl CoA is converted to carbon dioxide and water and hence the cycle was named as Kreb's cycle. All the enzymes catalyzing the reactions of this cycle occur inside mitochondria (mitochondrial matrix) in contrast with those of glycolysis, which occur in the cytosol. Before pyruvate can enter the citric acid cycle, it must be oxidatively decarboxylated to acetyl CoA (active acetate). Three different enzymes working sequentially in a multienzyme complex catalyse this reaction. This formation of acetyl CoA from pyruvate by alpha-oxidative decarboxylation occurs in the mitochondrion following the formation of pyruvate in the cytosol during glycolysis. The reaction involves six cofactors: coenzyme A, NAD+, lipoic acid, FAD, thiamine pyrophosphate (TPP) and Mg2+. 
Reactions of the TCA Cycle:

Acetyl CoA, derived mainly from the oxidation of carbohydrates, lipids and proteins, combines with oxaloacetate to form citrate which is the first reaction of the citric acid cycle. Subsequently, citrate is oxidized in a series of reactions liberating carbon dioxide and reducing equivalents (NADH, FADH2). The oxaloacetate is regenerated and functions therefore in a catalytic manner in the oxidation of acetyl CoA to two molecules of carbon dioxide. The citric acid cycle has eight steps as described below:

1. **Formation of Citrate**

   The first step is the reaction between the four-carbon unit, oxaloacetate and the two-carbon unit, acetyl CoA resulting in the formation of citrate and coenzyme. A catalysed by citrate synthase. The coenzyme A formed in this reaction is recycled.

2. **Formation of Isocitrate via Cis-Aconitate:**

   The isomerization of citrate to isocitrate catalysed by aconitase occurs in two steps with the formation of cis-aconitate as an intermediate. This formation of isocitrate involves both dehydration and hydration. The result is an interchange of hydrogen and a hydroxyl group. In this reaction, fluoroacetate acts as an inhibitor to the enzyme, aconitase. -ketoglutarateα

3. **Oxidation of isocitrate to α –ketoglutarate:**

   The enzyme, isocitrate dehydrogenase oxidatively decarboxylates isocitrate to α –ketoglutarate with simultaneous liberation of carbon dioxide. The intermediate in this α -ketoacid. While bound to the enzyme, it loses β reaction is oxalosuccinate, an unstable α -ketoglutarate. There are two different forms of isocitrate α carbon dioxide to form dehydrogenase (isozymes), one requiring NAD+ and other requiring NADP+. α-ketoglutarate to succinyl CoAα.
4. **Oxidation of α-Ketoglutarate to Succinyl-CoA:** α-ketoglutarate undergoes oxidative decarboxylation forming succinyl-CoA and carbon dioxide in the presence of α-ketoglutarate dehydrogenase complex, an assembly consisting of three kinds of enzymes. The mechanism of this reaction is very similar to the reaction catalyzed by pyruvate dehydrogenase complex. This reaction is irreversible. Arsenite acts as an inhibitor of TCA cycle by inhibiting the action of α-ketoglutarate dehydrogenase complex.

5. **Conversion of Succinyl CoA to Succinate:** Succinate is formed in a reversible reaction from succinyl CoA catalysed by the enzyme, succinyl CoA synthetase or succinate thiokinase with the simultaneous formation of GTP and coenzyme-A. Succinate thiokinase utilises GDP in animal tissues whereas it uses ADP predominantly in plants and bacteria. The formation of GTP in this reaction is a substrate level phosphorylation reaction.

6. **Formation of Fumarate by Oxidation of Succinate:** The succinate formed from succinyl CoA is oxidised to fumarate by succinate dehydrogenase with the participation of FAD. Malonate, an analogue of succinate being a strong competitive inhibitor of succinate dehydrogenase, blocks the citric acid cycle.

7. **Formation of Malate by Hydration of Fumarate:** The reversible hydration of fumarate to L-malate is catalysed by fumarase.

8. **Oxidation of malate to Oxaloacetate:** This reaction forms the last reaction of the citric acid cycle. NAD-linked malate dehydrogenase catalyses the oxidation of L-malate to oxaloacetate.

**Energetics of Tricarboxylic Acid Cycle (TCA Cycle):**

From one molecule of glucose, two molecules of pyruvate are formed which in turn give rise to two molecules of acetyl CoA. When two molecules of acetyl-CoA undergo oxidation through TCA cycle, the following number of high-energy bonds (ATPs) is produced.

**Significance of the TCA cycle**

1. The major significance of the citric acid cycle is to act as the final common pathway for the oxidation of carbohydrates, lipids and proteins, since glucose, fatty acids and many amino acids are all metabolized to acetyl CoA.
2. This cycle serves as the mechanism by which much of the free energy liberated during the oxidation of carbohydrate, lipids and amino acids is made available.

3. TCA cycle is of further significance since it has dual or amphibolic role thus providing precursor compounds for biosynthesis of other bio-molecules (amino acids, fatty acids, and glucose.

**Glyoxylate cycle**

Plants, especially seedlings, can use acetate as the only source of carbon for all carbon compounds they produce. Acetyl CoA, which enters the TCA cycle, is completely oxidized to two molecules of CO2. Thus it would not be possible for the cycle to produce the massive amounts biosynthetic precursors needed for acetate based growth unless alternative reactions were possible. Plants and bacteria employ a modification of the TCA cycle called the Glyoxylate Cycle to produce four carbon dicarboxylic acids from acetyl CoA. The Glyoxylate cycle bypasses the Decarboxylations of the TCA Cycle. The enzymes of the Glyoxylate Cycle in plants are present in Glyoxysomes. Isocitrate lyase and malate synthase are the additional enzymes required for this cycle in addition to TCA cycle enzymes. Glyoxysomes do not contain all the enzymes needed for the glyoxylate cycle. The enzymes succinate dehydrogenase, fumarase and malate dehydrogenase are absent. Hence glyoxysomes, with the help of mitochondria run their cycle. Succinate molecules formed in glyoxysomes are transported to mitochondria where it is converted to oxaloacetate with the help of TCA cycle enzymes. The oxaloacetate is then converted to asparate and transported to glyoxysomes where it is transaminated to oxaloacetate. The oxaloacetate is converted to malate through glyoxylate cycle. The malate then enters the cytosol and converted into glucose via gluconeogenesis pathway. The existence of glyoxylate cycle is important for the germinating seeds where photosynthesis is not possible. Triacylglycerols rich in oilseeds are degraded to acetyl CoA. Glyoxysomes formed during germination convert the acetyl CoA to oxaloacetate, which is then utilised for the conversion to glucose through gluconeogenesis. Once the growing seedling begins their photosynthesis to produce carbohydrates, the Glyoxysomes disappear.
**Electron Transport Chain and Oxidative Phosphorylation:**

The mitochondrion is the aerobic organelle in which the final stage of the oxidation of food occurs. It is the site of the citric acid cycle, fatty acid oxidation and oxidative phosphorylation, processes that are responsible for the formation of ATP under aerobic condition. The two most important energy transductions in the biological systems are the oxidative phosphorylation (ATP synthesis driven by electron transfer to oxygen) and photophosphorylation (ATP synthesis driven by light). Oxidative phosphorylation is the process in which ATP molecules are formed as a result of the transfer of electrons from the reducing equivalents, NADH or FADH2 (produced by glycolysis, the citric acid cycle and fatty acid oxidation) to oxygen by a series of electron carriers in the form of a chain located in the inner membrane of mitochondria. This is the final reaction sequence of respiration. Since the electrons are transferred by a series of electron carriers in the form of a chain, it is known as electron transport chain (ETC). In plants, ATP is mainly derived through photosynthesis utilizing the energy derived from the sun. In non-photosynthetic tissues, ATPs are derived through respiration. The electrons are transferred along a set of cytochromes in the form of a chain in steps from the more electronegative components (NADH/FADH2) to the more electropositive oxygen. The respiratory chain consists of a number of protein complexes that are remarkably complicated in nature. They are known as NADH-ubiquinone reductase, succinate-ubiquinone reductase, ubiquinone-cytochrome c reductase and cytochrome c oxidase. These complexes are also called as NADH dehydrogenase, succinate dehydrogenase, cytochrome b-c complex and cytochrome c oxidase respectively or as complexes I - IV. All the three reductases are also known as iron-sulphur proteins since they contain Fe-S centres as their critical components. Iron in these enzyme complexes can exist in two forms as Fe$^{2+}$ and Fe$^{3+}$. Each cytochrome in its oxidised form (Fe$^{3+}$) accepts one electron and becomes reduced to Fe$^{2+}$ form. Fe$^{2+}$ donates electron to the next carrier. Oxidation of one molecule of NADH results in generation of 2.5 molecules of ATP whereas oxidation of one molecule of FADH2 generates 1.5 molecules of ATP.

**Sites of ATP Formation**

When electrons are transported along the respiratory chain, due to high amount of energy released, ATP molecules are synthesised at the following three sites.
1. Transfer of electrons from NADH to ubiquinone via flavoprotein (FMN).
2. Transfer of electrons from cyt b to cyt c.
3. Transfer of electrons from cyt a to cyt a3.

**Mechanism of ATP Formation:**

Two principal hypotheses have been proposed for the mechanism of oxidative phosphorylation.

1. Chemical hypothesis
2. Chemiosmotic theory

**Chemical Hypothesis:**

Many attempts have been made since 1920 to identify an energy-rich metabolite linking oxidation and phosphorylation. No such intermediates was isolated and in 1960, Peter Mitchell suggested that no possibility of existence of such an intermediate compound. So, the chemical hypothesis has become discredited.

**Chemiosmotic Theory:**

The chemiosmotic theory states that the coupling of oxidation to phosphorylation is indirect. According to this, the hydrogen ions (protons) generated by the oxidation of components in the respiratory chain are ejected to the outside (matrix) of the inner membrane. The electrochemical potential difference resulting from the asymmetric distribution of the hydrogen ions (protons or H$^+$) is used to drive a membrane-located ATP synthase which in the presence of Pi + ADP forms ATP. Inhibitors of respiratory chain inhibitors, which inhibit respiratory chain, may be grouped as follows:

1. Inhibitors of electron transfer
2. Inhibitors of ATP Synthase
3. Uncouplers of oxidative phosphorylation

Inhibitors that arrest respiration by blocking the respiratory chain act at three sites. Compounds such as barbiturates, amytal, rotenone prevent the transfer of electron from FeS centre to ubiquinone. Carboxin specifically inhibits transfer of reducing equivalents from succinate dehydrogenase to ubiquinone. Antimycin A blocks electron transfer from cytochrome b to cytochrome c1. Substances such as cyanide (CN-), azide (N3-) and carbon monoxide inhibit cytochrome c oxidase by binding to heme group and are extremely
poisonous. Oligomycin inhibits ATP synthase. In the presence of the uncouplers such as dicoumarol and 2,4-dinitrophenol, oxidation proceeds without phosphorylation (dissociation of oxidation in the respiratory chain from phosphorylation) releasing energy in the form of heat rather than in the form of ATP.

**The Hexose Monophosphate Shunt:**

The hexose monophosphate shunt (HMP shunt), also called as pentose phosphate pathway (PPP) and phosphogluconate pathway is an alternate pathway for the oxidation of glucose. In 1930, Otto Warburg discovered the first evidence for the existence of this pathway, which was later, elucidated in 1950 by Frank Dickens group. The pathway is important during the hours of darkness and in non-photosynthetic tissues such as differentiating tissues and germinating seeds. In animal system, it occurs in certain tissues, notably liver, lactating mammary gland and adipose tissue in addition to the Embden - Meyerhof pathway. The enzymes of the shunt pathway are found in the extra mitochondrial soluble portion of the cell. It is in effect, a multicyclic process whereby three molecules of glucose 6-phosphate give rise to three molecules of CO2 and three 5-carbon residues. The latter are rearranged to regenerate two molecules of glucose 6-phosphate and one molecule of glyceraldehyde-3-phosphate. Since two molecules of glyceraldehyde 3-phosphate can regenerate a molecule of glucose 6-phosphate by reactions, which are essentially a reversal of glycolysis, the pathway can account for the complete oxidation of glucose. Here oxidation is achieved by dehydrogenation using NADP and not NAD as in Embden-Meyerhof's glycolytic pathway. This pathway consists of a series of reactions taking place in three stages Stage I. Formation of NADPH and ribulose 5-phosphate The first three reactions of the pathway, catalysed by glucose-6-phosphate dehydrogenase, phosphogluconolactonase and phosphogluconate dehydrogenase ultimately result in the formation of ribulose 5-phosphate and NADPH. Stage II. In this stage, the ribulose 5-phosphate is converted to ribose 5-phosphate by ribulose 5-phosphate isomerase and then to xylulose-5 phosphate by ribulose 5- phosphate epimerase. The ribose 5-phosphate is essential precursor in the biosynthesis of nucleotides. Stage III. In the third stage, three molecules of the 5-carbon sugars are converted to two molecules of 6-carbon sugars and one molecule of 3-carbon sugar, glyceraldehyde 3- phosphate catalysed by two enzymes, transaldolase and transketolase. Transketolase catalyses the transfer of a C2 unit from
xylulose 5-phosphate to ribose 5-phosphate yielding glyceraldehyde 3-phosphate and sedoheptulose 7-phosphate. Transaldolase catalyses the transfer of a three carbon unit from sedoheptulose 7-phosphate to glyceraldehyde 3-phosphate yielding erythrose 4-phosphate and fructose 6-phosphate. Control of the HMP shunt Ribose 5-phosphate and NADPH are the principal products of the HMP shunt. In this pathway, excess amount of ribose 5-phosphate is converted into glycolytic intermediates when the need for NADPH exceeds that of ribose 5-phosphate in nucleotide biosynthesis. If ribose 5-phosphate is needed more than NADPH, fructose 6-phosphate and glyceraldehyde 3-phosphate are used for the synthesis of ribose 5-phosphate by reversal of the transaldolase and transketolase reactions. The rate of NADPH formation in the pathway is controlled by the rate of the glucose 6-phosphate dehydrogenase reaction. Metabolic significance of the HMP Shunt

1. Major function of HMP shunt appears to be the production of reduced NADP (NADPH) required by anabolic (synthetic) processes such as fatty acid synthesis outside the mitochondria.
2. The pathway provides ribose for nucleotide and nucleic acid synthesis.
3. It also provides erythrose required for the synthesis of phenolics and other aromatic compounds through shikimate pathway.

Glucose 6-phosphate can be used as a substrate either for glycolysis or for the pentose phosphate pathway. On the basis of the cell's needs, it makes this choice for biosynthesis and for energy from catabolism. If glucose 6-phosphate is channeled into glycolysis, ATP is produced in abundance; but if it is channeled into pentose phosphate pathway. NADPH and ribose 5-phosphate are produced. The fate of glucose 6- phosphate is determined to a large extent of phosphofructokinase and glucose-6 P. There are four principal possibilities in which, depending upon the cell's need, HMP shunt operates.

1. More ribose 5-phosphate than NADPH is required Most of the glucose 6-phosphate is converted into fructose 6-phosphate and glyceraldehyde 3-phosphate by the glycolytic pathway. Two molecules of fructose 6-110 phosphate and one molecule of glyceraldehyde 3-phosphate are converted into three molecules of ribose 5-phosphate by a reversal of reactions catalysed by transaldolase and transketolase reactions.
2. Both ribose 5-phosphate and NADPH are needed by the cell In this, the first four reactions of the pentose phosphate pathway predominate. Ribose 5-phosphate is the
principal product of the metabolism and NADPH is also produced. The net reaction for these processes is

$$\text{Glucose 6 P} + 2 \text{NADP}^+ + \text{H}_2\text{O} \rightarrow \text{Ribose 5-Phosphate} + \text{CO}_2 + 2 \text{NADPH} + \text{H}^+$$

3. More NADPH than ribose 5-phosphate is needed by the cell. Under this situation, glucose 6-phosphate is completely oxidized to carbon dioxide. Three reactions are active. First, two NADPH and one ribose 5-phosphate are formed by the oxidative branch of the pentose phosphate pathway. Then, ribose 5-phosphate is converted into fructose 6-phosphate and glyceraldehyde 3-phosphate by transketolase and transaldolase. In the final reaction, glucose 6-phosphate is resynthesized from fructose 6-phosphate and glyceraldehyde 3-phosphate by the gluconeogenic pathway. The sum of these reactions is

$$\text{Glucose 6-phosphate} + 12 \text{NADPH}^+ + 7\text{H}_2\text{O} \rightarrow 6 \text{CO}_2 + 12 \text{NADPH} + 12\text{H}^+ + \text{Pi}$$

4. Both NADPH and ATP are needed by the cell. In this, fructose 6-phosphate and glyceraldehyde 3-phosphate derived from ribose 5-phosphate enter the glycolytic pathway and form pyruvate. ATP and NADPH are concomitantly generated and five of the six carbons of glucose 6-phosphate emerge in pyruvate.

$$3 \text{Glucose 6-phosphate} + 6 \text{NADP}^+ + 5\text{NAD}^+ + 5 \text{Pi} + 10\text{ADP} \rightarrow 5 \text{pyruvate} + 3\text{CO}_2 + 6\text{NADPH} + 5\text{NADH} + 10\text{ATP} + 2\text{H}_2\text{O} + 10\text{H}^+$$

**Comparative Account of glycolysis and HMP Shunt:**

These two major pathways are meant for the catabolism of glucose. They have little in common, e.g. the presence of metabolites like glucose 6-phosphate. The major differences are

1. ATP is not generated in the HMP pathway, whereas in glycolysis, ATP molecules are generated.
2. Pentose phosphates are generated in the HMP pathway but not in glycolysis.
3. NADH is produced in glycolytic pathway whereas NADPH is produced in HMP shunt.

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Chapter- 1

Metabolism of Protein

Amino acids are simpler forms of protein. Since proteins are necessary for growth, repair and maintenance of the human body, amino acids also participate in these functions. Good food sources of protein are pulses, cereals, milk and red meat. Amino Acids are of two types: essential (Amino acids which are required by the body but cannot be synthesized by the body, so it depends on food sources.) and non-essential (Amino acids which are required by the body and the body can synthesize them).

Functions of Amino Acids:

1. Amino acids are fundamental units and are building blocks of proteins.
2. Amino acids also act as precursors of important bio-molecules such as hormones, purines, pyrimidines, porphyrins, and some vitamins.
3. When amino acids are used as fuel, they undergo de-amination reactions.
4. Left over carbon gets converted to glucose or oxidizes to CO₂ through the TCA cycle.

Central dogma: It is a simple transfer of information from DNA to RNA to Protein. It is summarized in the following figure. The replication process on the left consists of passing information from a parent DNA molecule to daughter molecules. The middle transcription process copies this information to an mRNA molecule. Finally, this information is used by the chemical machinery of the ribosome to make polypeptides.
Central dogma consists of 3 major processes in the preservation and transmission of genetic information.

1. **Replication**: In this process each strand of parent DNA molecule forms 2 identical daughter DNA molecules.

2. **Transcription**: In this process genetic message in DNA is transcribed (copied) into the form of mRNA (Messenger RNA).

3. **Translation**: It is the process by which the information transcribed from DNA to mRNA directs the specific amino acid sequence and protein synthesis occurs. This flow of genetic information was proposed by Crick is the Central Dogma of molecular biology.

The machinery of protein biosynthesis consists of DNA, mRNA, tRNA, ribosomes, and a large number of enzymes and cofactors. The whole machinery operates in cytoplasm and is closely connected to endoplasmic reticulum.

**Ribosomes**: It is a kind of platform on which the protein synthetic machinery is formed. It has two sites

1. Amino Acyl or A site
2. Peptidyl or P site.

The initiating codon AUG is at P site. When elongation occurs, all the incoming amino Acyl tRNAs bind to A site. Ribosomes of prokaryotes (Old Cells) have sedimentation coefficient of 70 S. During translation, 70S ribosome continuously dissociates to form 50S and 30 S subunits. mRNAs and tRNAs cannot bind directly to 70 S subunit, therefore first bind to 30 S subunit which then combines with 50 S subunits. Eukaryotes (New Cells) have 80 S sedimentation coefficient (40S & 60 S).

**mRNA**: The key component of translation is mRNA. It carries the genetic information (message) from DNA to the site of protein biosynthesis where protein synthesis occurs i.e ribosome. mRNA contains codons. Codon is the unit that gives code for a given amino acid and consists of 3 nucleotides.

**Genetic Code**: Through DNA replication, complementary base pairs are formed. RNA with 4 specific bases (Each base is denoted by an alphabet. Together, the bases and its arrangements form a code of RNA) is translated to the amino acids (Base with twenty alphabets). Clearly, there
could not be a direct one-to-one correlation of bases to amino acids, so the nucleotide letters must form short words or codons that define specific amino acids. The features of genetic code are as follows:

1. The code/codon is a triplet (as singles & doublets are insufficient to code 20 amino acids)
2. The genetic code is universal. The same code dictionary is used by all organisms (both prokaryotes & eukaryotes)
3. Comma, space and punctuation is not used in the genetic code.
4. Overlapping is not permitted. The nucleotide sequence of two consecutive amino acids does not overlap.
5. It is degenerate. With the exception of codes for Methionine & tryptophan, all the amino acids are encoded by more than one codon.

**tRNA:** tRNA has a structure of clover leaf (Three leaf). The molecule is asymmetrically folded to yield a compact structure with anticodon arm at one end and amino acid arm at the other end. Anticodon is the nucleotide triplet in tRNA. It is present in the central petal of tRNA. Anticodon is complimentary to the corresponding codon in mRNA. tRNAs are small in size and consist of 70-90 nucleotides.

**Translation (Biosynthesis of Protein):**

Though protein synthesis is a complex biosynthetic mechanism, proteins are made at a high speed. A polypeptide chain of 100 amino acid residues is synthesized in few seconds. Protein synthesis is tightly regulated. Translation consists of following 3 major steps.

1. Chain initiation
2. Chain elongation &
3. Chain termination.

In addition to these steps, activation of amino acids, prior to their incorporation into polypeptides and post translational processing of completed polypeptide, constitute 2 additional stages.

**Activation of Amino Acids:**

This process takes place in cytoplasm. Each amino acid is attached to a specific tRNA and the reaction is catalyzed by amino acyl tRNA synthetase.
Amino Acid + tRNA + ATP $\rightarrow$ Amino Acyl-tRNA + AMP + ppi

This reaction occurs in two steps.

ATP + Amino Acid $\rightarrow$ Amino Acyl Adenylic Acid + Pyrophosphate.

Amino Acyl Adenylic Acid + tRNA $\rightarrow$ Amino Acyl-tRNA + Adenylic Acid

Generally methionine is first attached to tRNA and then formyl group is transferred finally forming fMet tRNA.

**Initiation:**

Polypeptide synthesis begins from the amino terminal end. This stage requires 1) 30S & 50S subunits 2) mRNA 3) fMet tRNA 4) a set of initiation factors IF1, 2 & 3 and 5) GTP, Mg++. The formation of initiation complex is divided into three steps.

In the first step, 30S subunit binds to IF 3 which prevents the premature union of 30S & 50S. Then binding of mRNA to 30S sub-unit takes place in such a way that the initiation codon AUG binds to a precise location on 30S.

In the second step, complex of 30S, IF3 & mRNA forms a still larger complex by binding IF2 (which is already bound to GTP) & the fMet tRNA. The anticodon of this tRNA pairs correctly with the initiation codon.

In the third step this large initiation complex of 30S subunit will combines with 50S subunit. Simultaneously GTP is hydrolyzed to GDP +Pi. IF2 & IF3 depart from ribosomes. This elaborate initiation process is required to ensure that the initiating aminoacyl- tRNA is bound at the peptidyl site and positioned at the initiation codon AUG, so that the ribosomes start translation at the correct point on the mRNA. Translation of the codons of mRNA take place in the 5’ $\rightarrow$ 3’ direction.

**Elongation:**

This stage requires the complex formed above, the next amino acyl tRNA, a set of elongation factors EFTu, TS, G & GTP.

a) **Binding of incoming amino acid:** Elongation factor EF is made up of two subunits ie: Tu and Ts. As along as Tu and Ts are associated the next amino acid cannot bind to this complex. Once the two factors separate out then GTP will bind to Tu and forms a complex Tu-GTP and this
complex will bind with the next amino acyl tRNA. This entire complex is bound to A site of ribosome and the energy released by GTP hydrolysis will facilitate the correct binding of the amino acid. GDP & EF are released.

b) **Formation of the peptide bond:** A new peptide bond is formed between the amino acids at A&P sites. This occurs by the transferring formyl methionyl group from its tRNA to the amino group of second amino acid, which is at A site. The A site alpha amnio acid acts as a nucleophile and formation of peptide bond takes place. The dipeptide thus formed is bound to A site leaving P site with uncharged tRNA at P site. Peptidyl transferase enzyme will participate in this reaction. For the formation of one peptide bond four ATP molecules are utilized.

c) **Translocation:** Finally the ribosome moves by a distance of one codon towards 3’ end of mRNA, thus shifting dipeptidyl tRNA from A site to P site. Now A site is free for the incoming amino acyl tRNA. The uncharged tRNA is released from P site back into cytoplasm. The ribosome moves from codon to codon along mRNA towards 3’ end, adding one amino acid at a time to the growing chain. Elongation continues until the ribosome adds the last amino acid, completing the polypeptide coded by the mRNA.
**Termination:**

This stage is signaled by one of the 3 termination codons in mRNA – UAA, UAG, and UGA. The termination codon first occupies A site. Then the release factors 1, 2 & 3 contribute to the following:

1. Hydrolysis of terminal peptidyl tRNA bond.
2. Release of free polypeptide and last tRNA from P site.
3. Dissociation of 70S subunit into 30S & 50S which are ready to start a new cycle of protein biosynthesis.

In bacteria RF1 recognizes the termination codons UAG and UAA, and RF2 recognizes UGA and UAA. RF1 or RF2 binds at a termination codon and induces peptidyl transferase to transfer the growing peptide chain. The specific function of RF3 has not been firmly established. In eukaryotes, a single release factor called eRF recognizes all three termination codons.

**Inhibitors of Protein Biosynthesis:**

Protein synthesis being a long complex process is vulnerable to inhibition at many points. Some inhibitors of protein synthesis are

1. Streptomycin – inhibits initiation & causes misreading (binds to 30S subunit)
2. Tetracycline – in bacteria it inhibits by binding to amino acyl tRNA
3. Chloramphenicol – in bacteria it inhibits peptidyl transferase activity.
4. Puromycin – causes premature release of peptide, as it has a structure very similar to the 3’ end of an aminoacyl-tRNA.
5. Cycloheximide – n blocks the peptidyl transferase of 80S eukaryotic ribosome
6. Ricin: inactivates 60S subunit of eukaryotic ribosome
7. Diphtheria toxin: it inactivates eukaryotic elongation factor eEF2

**Post Translational Modifications:**

After synthesis, the nascent polypeptide chain is folded & processed into its biologically active form. It assumes its native conformation i.e secondary, tertiary & quaternary structure. Some newly made proteins do not attain their final biologically active conformation until they have been altered by one or more processing reactions called posttranslational modifications. The post translational changes can be grouped under following sub headings:

1. Amino terminal and Carboxyl terminal modification: Protein synthesis is initiated by formyl-methionine or methionine which has to be removed enzymatically, the N terminal amino acids is acetylated.
2. Loss of signal sequence: 15 to 30 residues at the amino-terminal end of some proteins play a role in directing the protein to its ultimate destination in the cell. Such signal sequences are ultimately removed by specific peptidases.
3. Modification of individual amino acids: The hydroxyl groups of certain amino acids like serine, threonine and tyrosine residues of some proteins are enzymatically phosphorylated by ATP. Carboxyl groups of glutamic acid are methylated, lysine is methylated Hydroxylation of Proline to hydroxy proline etc

4. Attachment of carbohydrate side chain: Carbohydrate side chain of glycoproteins is attached covalently during or after the synthesis of the polypeptide chain.

5. Addition of isoprenyl groups: A number of eukaryotic proteins are isoprenylated, a thioether bond is formed between the isoprenyl groups and a cysteine residue of the protein. In some cases, the isoprenyl group serves to help anchor the protein in a membrane.

6. Addition of prosthetic groups: Many prokaryotic and eukaryotic proteins require covalently bound prosthetic groups for their activity. These are attached to the polypeptide chain after it leaves the ribosome. Eg. The attachment of heme group to the cytochrome c

7. Proteolytic processing: Some viral proteins and proteases are initially syntheisied as larger inactive precursor proteins called as zymogens which have to be trimmed to produce finally active forms Eg: trypsin is synthesized as trypsinogen

8. Formation of disulfide cross-links: Proteins to be exported from eukaryotic cells, after undergoing spontaneous folding into their native, conformations, are often covalently cross-linked by the formation of intrachain and interchain disulfide bridges between Cysteine residues. The cross links formed in this way help to protect the native conformation of the protein molecule from denaturation in an extracellular environment that can differ greatly from that inside the cell.

**Degradation of proteins into amino acids:**

Proteins are hydrolyzed by proteases and the amino acids are released. These amino acids under go catabolism in the following ways:

1. Transamination
2. Oxidative deamination.
3. Non oxidative deamination
4. Decarboxylation
Transamination:

This reaction involves the transfer of an amino group from a donor amino acid to an acceptor α-keto acid to yield the α-ketoacid of the donor amino acid and the amino acid of the original α-keto acid. The reaction is catalyzed by an enzyme called aminotransferase or transaminase that requires PLP as co-enzyme for its activity.

Types of Deamination:

Oxidative Deamination:

Amino group from amino acid is oxidatively removed in this process. Glutamate dehydrogenase enzyme catalyses the following reaction.

Non oxidative Deamination:

Non oxidative deamination takes place in absence of water and the corresponding unsaturated dicarboxylic acid is formed

Aspartic acid + H2 → Fumaric acid + NH3

Structural formulae for the above reactions need to be written & explained in the class.
Decarboxylation:

In decarboxylation reactions, the CO$_2$ from the corresponding amino acids are removed and biologically active amines are formed.

Amino Acid Carbon Skeletons:

The remainder of the amino acid is referred to as the "carbon skeleton". Depending on the particular amino acid being catabolised, its carbon skeleton will be converted to acetyl coA, or pyruvate and or a citric acid cycle intermediate. Those carbon skeletons which end up as acetyl CoA are committed to energy production. They will be oxidised via the citric acid cycle.

Ammonia Assimilation:

The ammonia released during metabolism of amino acids is toxic to the cells if it is not incorporated into synthetic processes. There are three reactions that can catalyze the incorporation of the nitrogen atom as NH$_3$ into organic compounds. These reactions are those catalysed by glutamic dehydrogenase, glutamine synthetase and carbamyl phosphate synthetase.

\[
\text{CO}_2 + 2\text{ATP} \rightarrow \text{Carbomyl phosphate} + 2\text{ADP} + \text{H}_3\text{PO}_4
\]
Balanced/ Modified diets

Balanced diets

A balanced diet is one which provides all the nutrients in required amounts and proper proportions so that the need for calories, proteins, minerals, vitamins and other nutrients are adequately met. It can be easily achieved through a blend of four basic food groups. The nutrient requirements vary with age, gender, physiological status and physical activity. A balanced diet provides (i) 50-60% of total calories from carbohydrates, (ii) about 10-15% from proteins (iii) and 20-30% from both visible and invisible fat. In addition, a balanced diet should provide other non-nutrients such as dietary fiber, antioxidants and phytochemicals.

Definition

A balanced diet is one which contains different types of foods in such quantities that the individual’s need for the various nutrients is adequately met, and some amounts of nutrients are stored in the body to withstand short periods of low dietary intake.

Importance of balanced diet

To help maintain a healthy weight and have the best chance to stay in good health, balance is key. The WHO (the World Health Organization) has given recommendations in 5 points that summarize the basis of nutrition:

- Eat roughly the same amount of calories that your body uses. Healthy body weight = “calories in”-“calories out”.
- Eat a lot of plant foods: vegetables, legumes, whole grains, fruits and nuts.
- Limit your intake of fats, preferring the healthier unsaturated fats to saturated fats and trans fats.
- Limit your intake of granulated sugar, ideally less than 10g/day.
- Limit salt / sodium consumption from all sources
- A balanced diet is important because your organs and tissues need proper nutrition to work effectively. Without good nutrition, your body is more prone to disease, infection, fatigue, and poor performance.
- A balanced diet is vital for your body and all of its systems to function properly, by having good nutrition it will help you maintain a healthy weight, reduce body fat, provide your body with energy, promote good sleep and generally make you feel better.
- The Importance of Eating Healthy for Students. Research has shown that students are able to learn better when they’re well nourished, and eating healthy meals has been linked to higher grades, better memory and alertness, and faster information processing.
- A healthy diet can protect the human body against certain types of diseases, in particular noncommunicable diseases such as obesity, diabetes, cardiovascular diseases, some types of cancer and skeletal conditions. Healthy diets can also contribute to an adequate body weight.
- A well-balanced diet provides important vitamins, minerals, and nutrients to keep the body and mind strong and healthy. Eating well can also help ward off numerous diseases and health complications, as well as help maintain a healthy body weight, provide energy, allow better sleep, and improve brain function.
- For being physically active and healthy-Nutrient -dense low fat foods
For maintaining health, productivity and prevention of diet-related disease and to support pregnancy/lactation—Nutritionally adequate diet with extra food for child bearing/rearing

For growth spurt, maturation and bone development—Body building and protective food

For growth development and to fight infections—Energy rich, Body building and protective foods (milk, vegetables and fruits).

For growth and appropriate milestones—Breast milk, energy rich foods (fat and sugar).

**Recommended Dietary Allowance (RDA)**

RDA for Indians—Most countries have derived their own set of dietary guidelines for requirements, which are periodically revised. Improved tools and methodology, developments in understanding the role of nutrients and updated database of population intake, health status and food tables necessitate a revision. The guidelines for India were first drawn by the Expert Committee of Indian Council of Medical Research (ICMR) in 1944 and the latest revision was made in 2010.

**Definition**—Recommended dietary allowance (RDA) the amount of nutrient and calorie intake per day considered necessary for maintenance of good health, calculated for males and females of various ages and recommended by the Food and Nutrition Board of the National Research Council.

**Recommended Dietary Allowances (RDA) for Indian Population**

For the Indian population, the dietary standards have been computed by the Indian Council of Medical Research (ICMR). These recommendations have been published as "Nutrient Requirements and Recommended Dietary Allowances for Indians" (ICMR 2010). The recommendations are constantly revised whenever new data is available. The last recommendations were revised in 2010, based on the new guidelines of the International Joint FAO/WHO/UNU Consultative Group and based on the data on Indians that had accumulated after 1989 recommendations. To help you understand these recommendations here are a few highlights:

- RDA for Indians are presented for the different age categories: 0-6 months, 7 to 12 months, 1 – 3 years, 4 – 6 years, 7 – 9 years, 10 – 12 years, 13 – 15 years, 16 – 18 years, adult man and women.
- Recommendations are given for energy and all other nutrients including proteins, visible fat, calcium, iron, retinol, Beta Carotene, thiamine, riboflavin etc.
- Recommended dietary allowances for adults are based on sex (male, female), body weight and physical activity level (i.e. Sedentary, Moderate and Heavy work).
- RDA for energy is expressed in kilocalories (Kcal), for proteins, fats in grams (g), and for calcium, iron, vitamins and minerals in milligram (mg) or microgram.
- RDA for protein is based on body weight. The relationship can be expressed as 1g protein per kg body weight in the case of adults. It varies for other age categories.
- RDA for energy and protein are given as additional intakes in pregnancy and lactation, indicated by a (" + " sign). This requirement is over and above the normall requirement of adult women. RDA for other nutrients are given as total intake figures.
- In infancy RDA's for energy, protein, iron, thiamin, riboflavin and niacin are expressed as per kg body weight (expected for a healthy, normal growing infant of a particular age).
• RDA for Vitamin A have been given in terms of retinol or alternatively in terms of Beta Carotene.
## Recommended Dietary Allowances for Indians

<table>
<thead>
<tr>
<th>Group</th>
<th>Particulars</th>
<th>Body weight</th>
<th>Net energy Kcal/d</th>
<th>Protein g/d</th>
<th>Visible fat g/day</th>
<th>Calcium mg/d</th>
<th>Iron mg/d</th>
<th>Vitamin μg/kg</th>
<th>Thiamine mg/d</th>
<th>Riboflavin acid mg/d</th>
<th>Nicotinic acid mg/d</th>
<th>Pyridoxine mg/d</th>
<th>Ascorbic acid mg/d</th>
<th>Free folic acid µg/d</th>
<th>Vit B12 µg/d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Man</strong></td>
<td>Sedentary work</td>
<td>60</td>
<td>2425</td>
<td>60</td>
<td>20</td>
<td>400</td>
<td>28</td>
<td>600</td>
<td>2400</td>
<td>1.2</td>
<td>1.4</td>
<td>16</td>
<td>2</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Moderate work</td>
<td></td>
<td>2875</td>
<td></td>
<td></td>
<td>3800</td>
<td></td>
<td></td>
<td></td>
<td>1.4</td>
<td>1.6</td>
<td>18</td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.6</td>
<td>1.9</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pregnant woman</td>
<td></td>
<td>+300</td>
<td>+15</td>
<td>30</td>
<td>1000</td>
<td>38</td>
<td>600</td>
<td>2400</td>
<td>+0.2</td>
<td>+0.2</td>
<td>+2</td>
<td>2.5</td>
<td>40</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Lactation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Woman</strong></td>
<td>Sedentary work</td>
<td>50</td>
<td>1875</td>
<td>50</td>
<td>20</td>
<td>400</td>
<td>30</td>
<td>600</td>
<td>2400</td>
<td>0.9</td>
<td>1.1</td>
<td>12</td>
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<td>100</td>
</tr>
<tr>
<td></td>
<td>Moderate work</td>
<td></td>
<td>2225</td>
<td></td>
<td></td>
<td>3800</td>
<td></td>
<td></td>
<td></td>
<td>1.1</td>
<td>1.3</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy work</td>
<td></td>
<td>2925</td>
<td></td>
<td></td>
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<td></td>
<td>1.2</td>
<td>1.5</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pregnant woman</td>
<td></td>
<td>+300</td>
<td>+15</td>
<td>30</td>
<td>1000</td>
<td>38</td>
<td>600</td>
<td>2400</td>
<td>+0.2</td>
<td>+0.2</td>
<td>+2</td>
<td>2.5</td>
<td>40</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Lactation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infants</strong></td>
<td>0-6 months</td>
<td>50</td>
<td>+550</td>
<td>+25</td>
<td>45</td>
<td>1000</td>
<td>30</td>
<td>950</td>
<td>3800</td>
<td>+0.3</td>
<td>+0.3</td>
<td>+4</td>
<td>2.5</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>6-12 months</td>
<td></td>
<td>+400</td>
<td>+18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+0.2</td>
<td>+0.2</td>
<td>+3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Children</strong></td>
<td>0-6 months</td>
<td>5.4</td>
<td>108/kg</td>
<td>2.05/kg</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55 µg/kg</td>
<td>65 µg/kg</td>
<td>710 µg/kg</td>
<td>0.1</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>6-12 months</td>
<td>8.6</td>
<td>98/kg</td>
<td>1.65/kg</td>
<td></td>
<td>350</td>
<td>1200</td>
<td>50 µg/kg</td>
<td>60 µg/kg</td>
<td>650 µg/kg</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td>1-3 years</td>
<td>12.2</td>
<td>1240</td>
<td>22</td>
<td>12</td>
<td>400</td>
<td>18</td>
<td>400</td>
<td>1600</td>
<td>0.6</td>
<td>0.7</td>
<td>8</td>
<td>0.9</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>4-6 years</td>
<td>19</td>
<td>1690</td>
<td>30</td>
<td>25</td>
<td>400</td>
<td>18</td>
<td>400</td>
<td>1100</td>
<td>0.9</td>
<td>1</td>
<td>11</td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7-9 years</td>
<td>26.9</td>
<td>1950</td>
<td>41</td>
<td>26</td>
<td>600</td>
<td>2400</td>
<td>1</td>
<td>1200</td>
<td>1.2</td>
<td>1.2</td>
<td>13</td>
<td>1.6</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td><strong>Girls</strong></td>
<td>10-12 years</td>
<td>35.4</td>
<td>2190</td>
<td>54</td>
<td>22</td>
<td>600</td>
<td>34</td>
<td>600</td>
<td>2400</td>
<td>1.1</td>
<td>1.3</td>
<td>15</td>
<td>1.6</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13-15 years</td>
<td>31.5</td>
<td>1970</td>
<td>57</td>
<td>19</td>
<td>600</td>
<td>34</td>
<td>600</td>
<td>2400</td>
<td>1.1</td>
<td>1.3</td>
<td>15</td>
<td>1.6</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td>13-15 years</td>
<td>41.7</td>
<td>2450</td>
<td>70</td>
<td>22</td>
<td>600</td>
<td>41</td>
<td>600</td>
<td>2400</td>
<td>1.2</td>
<td>1.5</td>
<td>16</td>
<td>2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16-18 years</td>
<td>57.1</td>
<td>2640</td>
<td>78</td>
<td>22</td>
<td>500</td>
<td>50</td>
<td>600</td>
<td>2400</td>
<td>1.3</td>
<td>1.6</td>
<td>17</td>
<td>2</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td><strong>Girls</strong></td>
<td>16-18 years</td>
<td>49.9</td>
<td>2060</td>
<td>63</td>
<td>30</td>
<td>600</td>
<td>30</td>
<td>600</td>
<td>2400</td>
<td>1</td>
<td>1.2</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The knowledge of recommended dietary allowances and composition of food is necessary for the selection of an adequate diet. But if we start doing this, it will be a tedious process. Therefore, it is necessary to translate the nutritional needs into kinds and amounts of food that we should eat. Such an information can then be used in everyday meal planning exercise. This is achieved by dividing/categorizing all food items into various groups called **food groups**.

Two ways of classifying food into groups-

**A. Classification Based on Physiological Functions**

**B. Classification Based on Nutrients**

**A. Classification Based on Physiological Functions** - However, foods may also be classified according to their functions.

<table>
<thead>
<tr>
<th>Major nutrients</th>
<th>Other nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Rich foods</strong></td>
<td><strong>Carbohydrates and fat</strong></td>
</tr>
<tr>
<td>Whole grain, Cereals, millets</td>
<td>Protein, Fibre, minerals, Calcium, Iron &amp; B-complex, vitamins</td>
</tr>
<tr>
<td>Vegetables oils, Ghee, butter</td>
<td>Fat soluble vitamins, essential fatty acids</td>
</tr>
<tr>
<td>Nuts and oilseeds</td>
<td>Protein, Vitamins, minerals</td>
</tr>
<tr>
<td>Sugar</td>
<td>Nil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major nutrients</th>
<th>Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body building foods</td>
<td>Pulses, nuts and oilseeds, milk and milk product, meat, fish, poultry</td>
</tr>
<tr>
<td></td>
<td>B-complex, vitamins, invisible fat, fibre, calcium, vitamin A, Riboflavin, Vitamin B12, B-complex, Vitamins, iron, iodine, fat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major nutrients</th>
<th>Vitamins and minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective foods</td>
<td>Green leafy vegetables</td>
</tr>
<tr>
<td></td>
<td>Antioxidants, Fibre, and other carotenoids</td>
</tr>
<tr>
<td>Other vegetables and fruits</td>
<td>Fibre, sugar and antioxidants</td>
</tr>
<tr>
<td>Egg, milk and milk products, Flesh foods</td>
<td>Protein and fat</td>
</tr>
</tbody>
</table>

**Classification of essential nutrients**

Based on the amount of the nutrients that each person needs to consume on a daily basis, these nutrients are categorised into two groups. These are macronutrients, which should be consumed in fairly large amounts, and micronutrients, which are only required in small amounts.

**Macronutrients**

‘Macro’ means large; as their name suggests these are nutrients which people need to eat regularly and in a fairly large amount. They include carbohydrates, fats, proteins, fibre and
water. These substances are needed for the supply of energy and growth, for **metabolism** and other body functions.

Metabolism means the process involved in the generation of energy and all the ‘building blocks’ required to maintain the body and its functions.

Macronutrients provide a lot of calories but the amount of calories provided varies, depending on the food source. For example, each gram of carbohydrate or protein provides four calories, while fat provides nine calories for each gram.

**Micronutrients**

As their name indicates (‘micro’ means small) micronutrients are substances which people need in their diet in only small amounts. These include minerals and vitamins. Although most foods are mixtures of nutrients, many of them contain a lot of one nutrient and a little of the other nutrients.

**What are nutritional requirements?**

The amount of each nutrient needed is called the nutritional requirement. These are different for each nutrient and also vary between individuals and life stages, e.g. women of childbearing age need more iron than men.

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals and millets</td>
<td>60</td>
</tr>
<tr>
<td>Body –building foods</td>
<td>15</td>
</tr>
<tr>
<td>Other vegetables and fruits</td>
<td>10</td>
</tr>
<tr>
<td>Protective foods</td>
<td>10</td>
</tr>
<tr>
<td>Energy group</td>
<td>05</td>
</tr>
</tbody>
</table>
Food exchange list

Food Exchange: Foods are classified into different groups for exchange. Each “exchange list” includes a number of measured foods of similar nutritive value that can be substituted interchangeably in meal plans.

Food Exchange List

List 1 - Cereal Exchange
30 gm provide: Carbohydrate 20 gm, Protein 2 gm

<table>
<thead>
<tr>
<th>Cereals</th>
<th>Household Measures</th>
<th>Wt/Vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Wheat flour</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Dalia</td>
<td>1/2 katori cooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Sago</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>White flour</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Bread</td>
<td>2 slices</td>
<td>40 gms</td>
<td></td>
</tr>
<tr>
<td>Chapati</td>
<td>1.5 [approx. 5-6” diameter]</td>
<td>44 gms</td>
<td></td>
</tr>
<tr>
<td>Jowar roti</td>
<td>0.5</td>
<td>55 gms</td>
<td></td>
</tr>
<tr>
<td>Ragi</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Rice flakes</td>
<td>1 katori</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Oat meal</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Vermicelli</td>
<td>1/2 katori cooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Corn flakes</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Maize dry</td>
<td>30 gms uncooked</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Marie biscuit</td>
<td>8 No.</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Monaco biscuit</td>
<td>4 No.</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Idlis</td>
<td>2 No.</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Poha</td>
<td>1/2 katori</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Upma</td>
<td>1/2 katori</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Dosa ordinary</td>
<td></td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

1 Katori-volume 150 ml.

List 2 - Fat Exchange
50 gm Calories; Fat 5.5 gm

<table>
<thead>
<tr>
<th>Fats</th>
<th>Household Measures</th>
<th>Wt.[gm.]</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter</td>
<td>1 1/2 teaspoon</td>
<td>7.5</td>
<td>50</td>
</tr>
<tr>
<td>Ghee</td>
<td>1 teaspoon</td>
<td>5.5</td>
<td>50</td>
</tr>
<tr>
<td>Hydrogenated fat [Vanaspati]</td>
<td>1 teaspoon</td>
<td>5.5</td>
<td>50</td>
</tr>
<tr>
<td>Oil [Coconut, Mustard]</td>
<td>1 teaspoon</td>
<td>5.5</td>
<td>50</td>
</tr>
</tbody>
</table>
Sunflower, Corn, Groundnut, Cotton seed, Til, Palm
Cashewnuts 10 50
Groundnuts, roasted 10 50
Walnuts 7.5 50
Pistachio 7.5 50
Almonds 7.5 50

List 3 - Milk & Milk Products
50 Calories; Protein 2.5 gm

<table>
<thead>
<tr>
<th>Milk &amp; Milk Products</th>
<th>Household Measures</th>
<th>Wt./Vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curd</td>
<td>2/3 glass</td>
<td>105 gm</td>
<td>50</td>
</tr>
<tr>
<td>Butter Milk</td>
<td>3 glasses</td>
<td>375 ml</td>
<td>50</td>
</tr>
<tr>
<td>Cheese</td>
<td>1 ice cube</td>
<td>15 gm</td>
<td>50</td>
</tr>
<tr>
<td>Milk [Buffalo]</td>
<td>1/3 glass</td>
<td>45 ml</td>
<td>50</td>
</tr>
<tr>
<td>Milk [Cow]</td>
<td>2/3 glass</td>
<td>90 ml</td>
<td>50</td>
</tr>
<tr>
<td>Milk, Skimmed*</td>
<td>1 glass</td>
<td>130 ml</td>
<td>50</td>
</tr>
<tr>
<td>Milk, Skimmed, powder*</td>
<td></td>
<td>15 gm</td>
<td>50</td>
</tr>
<tr>
<td>Coffee Nescafe+75 ml milk [without sugar]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea + 75 ml milk</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Khoya</td>
<td>15 gm</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>1 medium glass 150 ml</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
*provides 5 gm protein

List 4 - Vegetable Exchange
50 Calories; Carbohydrate 10 gm

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Household Measures</th>
<th>Wt. (gm)</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beetroot [Chukander]</td>
<td>75</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Carrot</td>
<td>1-2 No.</td>
<td>105</td>
<td>50</td>
</tr>
<tr>
<td>Colocasia [arbi]</td>
<td>45</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Onion [big]</td>
<td>1 No.</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Onion [small]</td>
<td>2 No.</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Potato</td>
<td>1/2 No.</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>30</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Fruits</td>
<td>Size/No.</td>
<td>Wt. (ml)</td>
<td>Calories</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Tapioca</td>
<td></td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Yam [Zimikand]</td>
<td></td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Broad beans</td>
<td></td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Cluster beans</td>
<td></td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Double beans</td>
<td></td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Jack, Tender</td>
<td></td>
<td>105</td>
<td>50</td>
</tr>
<tr>
<td>Jackfruit seeds</td>
<td></td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Leeks</td>
<td></td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Peas</td>
<td></td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Singhara</td>
<td></td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Sambar</td>
<td>1/4 katori</td>
<td>35 ml</td>
<td>50</td>
</tr>
<tr>
<td>Cooked vegetable</td>
<td>1/2 katori</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>1 katori: volume 150 ml</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**List 5 - Fruit Exchange**

**50 Calories; Carbohydrate 10 gm**

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Size/No.</th>
<th>Wt. (ml)</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>1 small</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Amla</td>
<td>20 medium</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Banana</td>
<td>1/4 medium</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Cashew fruit</td>
<td>2 medium</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Custard apple</td>
<td>1/4</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Dates</td>
<td>3</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Figs</td>
<td>6 medium</td>
<td>135</td>
<td>50</td>
</tr>
<tr>
<td>Grapes</td>
<td>20</td>
<td>105</td>
<td>50</td>
</tr>
<tr>
<td>Grape fruit</td>
<td>1/2 big</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Jack fruit</td>
<td>3 medium pieces</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Mango</td>
<td>1 small</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Melon</td>
<td>1/4 medium</td>
<td>270</td>
<td>50</td>
</tr>
<tr>
<td>Orange</td>
<td>1 small</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Lemon</td>
<td>1 medium</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Papaya</td>
<td>2 medium</td>
<td>120</td>
<td>50</td>
</tr>
<tr>
<td>Peach</td>
<td>1 medium</td>
<td>135</td>
<td>50</td>
</tr>
<tr>
<td>Pear</td>
<td>1 medium</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Plums</td>
<td>4 medium</td>
<td>120</td>
<td>50</td>
</tr>
<tr>
<td>Pineapple</td>
<td>1 1/2 slices (round)</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Fruit</td>
<td>Quantity</td>
<td>Calories</td>
<td>Fat</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
<td>----------</td>
<td>-----</td>
</tr>
<tr>
<td>Strawberry</td>
<td>40</td>
<td>105</td>
<td>50</td>
</tr>
<tr>
<td>Sweetlime</td>
<td>1 medium</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td>Tomato</td>
<td>4 medium</td>
<td>240</td>
<td>50</td>
</tr>
<tr>
<td>Watermelon</td>
<td>1/4 small</td>
<td>175</td>
<td>50</td>
</tr>
</tbody>
</table>

**List 6 - Legume and Pulse Exchange**

*30 gm provide: Carbohydrate 15 gm, Protein 6 gm*

<table>
<thead>
<tr>
<th>Pulse [uncooked]</th>
<th>Household Measures</th>
<th>Wt. (gm)</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bengal gram</td>
<td>3/4 katori cooked</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Bengal gram, roasted</td>
<td></td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Bengal gram-flour [Besan]</td>
<td></td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Cow gram</td>
<td>1 katori cooked</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Horse gram</td>
<td></td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Kabuli Channa [white gram]</td>
<td></td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Lentils</td>
<td>3/4 katori cooked</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Moth beans</td>
<td></td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Peas, dried</td>
<td>1 katori cooked</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Rajmah [kidney beans]</td>
<td>3/4 katori cooked</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Red gram</td>
<td>3/4 katori cooked</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

1 katori-volume 150 ml

**List 7 - Flesh Food Exchange**

*70 Calories; Protein 10 gm*

<table>
<thead>
<tr>
<th>Flesh Foods</th>
<th>Household Measures</th>
<th>Wt. (gm)</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Hen</td>
<td>2 No.</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Fish</td>
<td>1 piece</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Liver, sheep</td>
<td></td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Mutton, muscle</td>
<td>3 piece</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Pork</td>
<td>1 slice</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Prawn</td>
<td>5-7 pieces</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Chicken</td>
<td>1 breast</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Crab</td>
<td>120 gm</td>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Beef</td>
<td>1 slice</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>
List 8 - Vegetable Exchange
These vegetables may be used as desired. Carbohydrates and calories are negligible

<table>
<thead>
<tr>
<th>Leafy Vegetables</th>
<th>Other Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitter gourd [Karela]</td>
<td>Curry leaves</td>
</tr>
<tr>
<td>Amaranth</td>
<td>Fenugreek leaves</td>
</tr>
<tr>
<td>Brussels sprouts</td>
<td>Mint</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Spinach</td>
</tr>
<tr>
<td>Coriander leaves</td>
<td>Mango, green</td>
</tr>
<tr>
<td>Brinjal</td>
<td>Cauliflower</td>
</tr>
<tr>
<td>Onion stalks</td>
<td>Drumstic</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>Tomato, Green</td>
</tr>
</tbody>
</table>

Drinks*

<table>
<thead>
<tr>
<th>Drinks</th>
<th>Household Measures</th>
<th>Vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange juice</td>
<td>1 big glass</td>
<td>200 ml.</td>
<td>30</td>
</tr>
<tr>
<td>Tomato juice</td>
<td>1 big glass</td>
<td>200 ml</td>
<td>30</td>
</tr>
<tr>
<td>Apple juice</td>
<td>1 big glass</td>
<td>200 ml</td>
<td>100</td>
</tr>
<tr>
<td>Grape juice</td>
<td>1 big glass</td>
<td>200 ml</td>
<td>80</td>
</tr>
<tr>
<td>Mango juice</td>
<td>1 big glass</td>
<td>200 ml</td>
<td>150</td>
</tr>
</tbody>
</table>

Fast Food*

<table>
<thead>
<tr>
<th>Fast Food</th>
<th>Household Measures</th>
<th>Vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft drink</td>
<td>1 bottle</td>
<td>300 ml</td>
<td>120-135</td>
</tr>
<tr>
<td>Potato wafers</td>
<td></td>
<td>50 gm</td>
<td>430</td>
</tr>
<tr>
<td>Samosa</td>
<td>1</td>
<td>40 gm</td>
<td>130</td>
</tr>
<tr>
<td>Veg. cutlet</td>
<td>1</td>
<td>100 gm</td>
<td>140</td>
</tr>
<tr>
<td>Vada</td>
<td>1</td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

Cakes & Pastries*

<table>
<thead>
<tr>
<th>Cakes &amp; Pastries</th>
<th>Wt/vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cake plain</td>
<td>50 gm</td>
<td>150</td>
</tr>
<tr>
<td>Chocolate cake</td>
<td>50 gm</td>
<td>250</td>
</tr>
<tr>
<td>Sponge cake</td>
<td>50 gm</td>
<td>150</td>
</tr>
<tr>
<td>Pastry</td>
<td>50 gm</td>
<td>250-400</td>
</tr>
</tbody>
</table>
### Desserts*

<table>
<thead>
<tr>
<th>Household Measures</th>
<th>Wt/vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custard</td>
<td>150 gm</td>
<td>360</td>
</tr>
<tr>
<td>Fruit salad</td>
<td>150 gm</td>
<td>150</td>
</tr>
<tr>
<td>Fruit salad with cream</td>
<td>150 gm</td>
<td>300</td>
</tr>
<tr>
<td>Icecream</td>
<td>150 gm</td>
<td>380</td>
</tr>
<tr>
<td>Carrot halwa</td>
<td>1 medium katori</td>
<td>100 gm</td>
</tr>
<tr>
<td>Badami halwa</td>
<td>100 gm</td>
<td>570</td>
</tr>
</tbody>
</table>

### Sweets*

<table>
<thead>
<tr>
<th>Household Measures</th>
<th>Wt/vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut burfi</td>
<td>25 gm</td>
<td>110</td>
</tr>
<tr>
<td>Gulabjamun</td>
<td>25 gm</td>
<td>200</td>
</tr>
<tr>
<td>Laddo</td>
<td>30 gm</td>
<td>160</td>
</tr>
<tr>
<td>Rasgulla</td>
<td>150 gm</td>
<td>140</td>
</tr>
<tr>
<td>Jam</td>
<td>2 tablespoon</td>
<td></td>
</tr>
<tr>
<td>Honey</td>
<td>2 tablespoon</td>
<td></td>
</tr>
</tbody>
</table>

### Beverages**

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beer</td>
<td>150 ml</td>
</tr>
<tr>
<td>Wine dry</td>
<td>30 ml</td>
</tr>
<tr>
<td>Wine dessert</td>
<td>30 ml</td>
</tr>
<tr>
<td>Whisky, brandy, gin, rum</td>
<td>30 ml</td>
</tr>
<tr>
<td>Vodka</td>
<td>30 ml</td>
</tr>
<tr>
<td>Ginger ale</td>
<td>30 ml</td>
</tr>
</tbody>
</table>