INTRODUCTION
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>TCA</td>
<td>Tricarboxylic acid</td>
</tr>
<tr>
<td>CoA</td>
<td>Coenzyme A</td>
</tr>
<tr>
<td>NADPH</td>
<td>Nucleotide diphosphate sugar (reduced form)</td>
</tr>
<tr>
<td>ACC</td>
<td>Acyl CoA carboxylase</td>
</tr>
<tr>
<td>ACP</td>
<td>Acyl carrier protein</td>
</tr>
<tr>
<td>FADH⁺</td>
<td>Flavin adenine diphosphate (reduced form)</td>
</tr>
<tr>
<td>NAD⁺</td>
<td>Nicotinamide adeninedinucleotide</td>
</tr>
<tr>
<td>CDP</td>
<td>Cytidine diphosphate</td>
</tr>
<tr>
<td>PAF</td>
<td>Platelet activating factor</td>
</tr>
<tr>
<td>LDL</td>
<td>Low density lipoprotein</td>
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<tr>
<td>HDL</td>
<td>High density lipoprotein</td>
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<tr>
<td>VLDL</td>
<td>Very low density lipoprotein</td>
</tr>
<tr>
<td>LCAT</td>
<td>Lecithine cholesterol acyl transferase</td>
</tr>
<tr>
<td>EFA</td>
<td>Essential fatty acid</td>
</tr>
<tr>
<td>PUFA</td>
<td>Polyunsaturated fatty acid</td>
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<tr>
<td>MUFA</td>
<td>Monounsaturated fatty acid</td>
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<tr>
<td>SFA</td>
<td>Saturated fatty acid</td>
</tr>
<tr>
<td>EPA</td>
<td>Eicosapentaenoic acid</td>
</tr>
<tr>
<td>DHA</td>
<td>Docosahexaenoic acid</td>
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A constant supply of energy is necessary for all animals to sustain life. Energy for all animal systems comes from the feed eaten or in times of feed deprivation from body stores. The food that we eat is digested and assimilated in the body and used for its maintenance and growth. It furnishes us the energy that is required for normal growth and metabolism. Food chiefly consists of complex organic substances such as lipids, proteins, carbohydrates, vitamins and also the inorganic components like minerals calcium, water etc.

1.1 NUTRIENTS FOR LIFE

Nutrients play an important role in the protection of the host against invading pathogens. Nutrient deficiencies can affect immune function, usually in a negative manner. Certain nutrients are capable of modulating the function of the immune system through a variety of mechanism.

1.1.1 Carbohydrates

Carbohydrates form the most abundant of all the classes of natural organic compounds. They are mostly compounds of carbon, hydrogen and oxygen. Some carbohydrates contain other elements such as nitrogen and sulfur. They are the main source of energy. Carbohydrate molecules range from simple sugars, which are readily digestible by all species, to the complex carbohydrates like cellulose and lignin, which can be digested only by bacteria. Carbohydrate is the least expensive source of energy. The commonly occurring carbohydrates in food are starch, glucose, fructose and lactose. They are the cheapest source of energy. Glucose derived from the digestion of carbohydrates is used as the main source of energy in the body. Hence, the diet should
Several pathways involving sugar metabolism exist in cells. One, the pentose phosphate pathway, known also as the hexose monophosphate shunt or the 6-phosphogluconate pathway, is particularly important in animal cells. Its functions side by side with glycolysis and the tricarboxylic acid cycle for production of reducing power in the form of NADPH and pentose intermediates. Another important function is to convert hexoses into pentoses, particularly ribose 5-phosphate through pentose phosphate pathway (Devlin, 1997). This C5 sugar or its derivatives are components of ATP, CoA, NAD, FAD, RNA, and DNA.

Normal diet contain adequate amount of carbohydrate in order to meet a greater part of the energy needs of a carbohydrate is calculated by using average caloric conversion factors of 4.10 K calories/gm of carbohydrate (Henken et al., 1986).

Benson et al (1993) reported that at an equal dietary energy corn starch decreased the growth suppressive effects of lipopolysaccharide injection of chick relative to diets containing corn oil.

1.1.2 Proteins

Proteins are required for the growth and maintenance of body weight. Proteins also provide energy to a small extent. They constitute about 20 percent of the body
weight. Body proteins are derived from dietary proteins. The body loses continuously
some quantity of proteins and this loss has to be compensated by dietary proteins.
Proteins are made up of simpler chemical substances known as amino acids. The amino
acid contents of proteins have been found to differ from one protein to another (Halver,
1989).

The nutritional value of proteins depends on their amino acid contents. A large
amount of information is available on the nutritive value of dietary proteins and the
protein requirement in farm animals (Halver, 1989).

The important functions of dietary proteins are:

1. To replace the daily loss of body proteins
2. To provide amino acids for the formation of tissue proteins during growth
3. To provide amino acids necessary for the formation of enzymes, blood
   proteins and certain hormones of protein nature, and
4. To provide amino acids for growth of the fetus and also for the production
   of milk proteins.

The studies conducted by Osborne and Mendel (1913) showed that rats fed on a
synthetic diet containing 'zein' (a protein contained in Maize) as the only source of
protein failed to grow. Chemical analysis of zein showed that it did not contain
tryptophan or lysine. When these two amino acids were added to zein, animals grew
normally.
Experiments conducted on chicks have shown that amino acids like methionine acid are very essential in the growth of chicks and turkeys. Methionine was able to replace part of the glycine in the diet (Takashahi et al, 1994).

Diet supplemented with lysine and methionine gives better growth performance with better protein retention and efficacy ratio in fish (El-Danhar and El-Shazly, 1993).

Bhargava et al (1970) found that methionine deficiency resulted in increased antibody level. While Tsiagbe (1987) suggested that the requirement for methionine for maximum antibody titres was greater than that for growth.

The protein or the amino acids are channelized for the energy yielding purpose. The amino acids through various transaminases and glutamate dehydrogenase enzyme convert into keto sugars, which enter in the TCA cycle for yielding energy. Besides, ammonia is been produced as a nitrogenous waste in the body which may directly be excreted out or converted into less toxic substances like urea and uric acid and then excreted out from the body (Lehninger, 1984). The energy content of the food is calculated by using the average caloric factor 5.65 K calories per gram for protein (Henken et al, 1986).

The important factors affecting the utilization of dietary proteins are:

➢ Calorie intake
➢ Digestibility coefficient of proteins and
➢ Biological and nutritive value of proteins.
For the maximum utilization of dietary proteins, the calorie intake should be adequate. If the calorie intake is inadequate, a part of the dietary protein will be wasted in meeting the energy requirements and the protein need will not be satisfied. In the utilization of dietary protein, a part of the protein is lost in digestion and metabolism. Thus, protein should be supplemented in the diet from different sources like oil seeds, cereals, pulses, nuts etc.

1.1.3 Lipids

The lipids are a group of organic substances of fatty nature, which are insoluble in water but soluble in organic solvents like ether, alcohol, chloroform and benzene. In general, lipids are the esters of fatty acids with glycerol or with other organic compound.

Lipids rarely exist in an organism in the free state but are usually associated with proteins or combined with polysaccharides. They are important dietary constituents providing energy, vitamins, essential fatty acids and often give flavor and palatability to food. Lipids act as lubricants and insulators and the fat stores in the adipose tissue of the body are rich source of energy. Combination of the lipids and proteins are of particular cellular importance especially in membrane structures and also as a means of transporting lipids in the blood. The steroid hormones are derived from cholesterol and very small amounts of these exert potent physiological effects.

Apart from these, fats also help in forming the structural materials for cells and tissues such as cell membrane and other organal components. The fatty acids and glycerol react with alkali present in the small intestine to form their salt. These salts
being water soluble are readily absorbed by the blood and carried to the body cells (Gurr and James, 1976). The energy content of the food is calculated by using the average caloric factor 9.45 K calories per gram of lipid (Henken et al, 1986).

1.1.4 Vitamins

Vitamins are ordinarily defined as substances that act in trace amounts. Hence, the definition includes only substances with catalytic functions. Vitamins are classified as either fat soluble or water soluble. They are essential food components just as the essential amino acids are. Vitamins are indispensable for the growth and maintenance of the organism and occur both in animals and plants. A deficiency of certain vitamins is reflected in characteristic disturbances (deficiency diseases). Such diseases are the consequences of unbalanced nutrition. Pantothenic acid, one of the vitamins of vitamin B2 complex, can prevent or cure a specific type of dermatitis (chick pellagra) in chicks (Swaminathan, 1986). Vitamin E deficiency in rats results mainly in atrophy of the testes and dystrophy of muscles (Halver, 1989). In animal experiments, vitamin A deficiency is manifested first by cessation of growth and in man the deficiency leads to night blindness (Karlson, 1970). In animal experiments, a deficiency of riboflavin impairs normal growth and causes symptoms of skin impairment and in man the principal symptoms are dermatitis ("pellagra sine pellagra") and inflammations around the mouth (Karlson, 1970).
1.1.1 Minerals

The body contains about 24 minerals, all of which are derived from diet. The important minerals are, the anions like phosphate, chloride, iodide, fluoride and the cations viz., calcium, potassium, sodium, magnesium, iron, zinc, copper, manganese, cobalt and possibly others. Among the heavy metals, iron and zinc occupy the top slots. The minerals are essential for various body functions, as indicated below.

i. Sodium, potassium and chloride are essential for maintaining water balance in the body.

ii. Iron and copper are required for the formation of hemoglobin and

iii. Iodine is needed for the normal functioning of thyroid glands (Halver, 1989)

These substances are also metabolized. They are taken up in food and eliminated again in urine, feces and sweat. The metabolism of inorganic ions or simply “mineral metabolism” differs from the metabolism of other substances. In contrast to proteins, carbohydrates or fats, minerals are neither produced nor consumed in the organism. Their intake from food can be regulated only very roughly, if at all. Most animal species, nevertheless, in the course of evolution have developed the ability to keep the concentration of ions constant in the body fluids, thus providing a constant “milieu interne”. Several ions have special depots, which can be mobilized in periods of insufficient intake (Karlson, 1970).
Copper deficiency can decrease antibody response, mitogen induced blastogenesis and mixed - lymphocytes reaction in mice and addition of copper to poultry diets increased primary antibody response. Zinc deficiency also has been demonstrated to suppress immune function in mammals and poultry (Cook, 1991).

1.2 CHEMISTRY OF LIPIDS

Lipids are structurally diverse. They contain much lower proportion of oxygen atom than do carbohydrates and broadly classified into fats, oil and wax. The function of lipids are to maintain structural integrity of membrane, to supply energy for physiological activities, transport of various metabolites in and out of the cells and regulation of physiological functions through secondary metabolites of lipid (Lehninger, 1984). The major dietary lipid components are namely, triglycerol, phospholipid, cholesterol, glycolipid and fatty acid.

1.2.1 Fatty Acids

Fatty acids are building block components of most lipids. They are long chain organic acids having from 4 – 24 carbon atoms; they have a single carboxyl group and a long, non popular hydrocarbon “tail” which gives most lipids their water insoluble and oily or greasy nature. Many different kinds of fatty acids have been isolated from the lipids of various species. They differ from each other in chain length and in the presence, number and position of their double bonds; some fatty acids also have methyl group branches. Fatty acids that contain no carbon carbon double bonds are termed saturated fatty acids; those that contain double bonds are unsaturated fatty acids. Unsaturated
fatty acids are further classified as **monounsaturated fatty acids** (e.g. Palmitic acid, Stearic acid) and **polyunsaturated fatty acids** (dienoic, trienoic, tetraenoic).

Polyunsaturated fatty acids are also classified into two major groups, **n3 or ω3** and **n6 or ω6** series depending upon the position of last double bond from methyl end.

The fatty acid biosynthesis occurs in the cytoplasm through a multistep reaction catalyzed by a set of enzymes commonly termed as **fatty acid synthase system**. The fatty acid synthase system catalyses the following overall reaction, in which one molecule of acetyl-CoA and seven molecules of the 3-carbon malonic acid, in the form of its CoA thioester, malonyl-CoA are assembled in succession to make a molecule of the 16-carbon palmitic acid, with release of seven molecules of CO₂.

\[
\text{Acetyl-CoA} + 7 \text{malonyl-S-CoA} + 14 \text{NADPH} + 20\text{H}^+ \rightarrow (\text{CH}_3(\text{CH}_2)_{14}\text{C}00^+ + 7\text{CO}_2 + 8\text{CoA-SH} + 14\text{NADP} + 6\text{H}_2\text{O}
\]

The reducing power required to make the singly bonded hydrocarbon backbone of fatty acids is furnished by NADPH.

The fatty acids produced by fatty acid synthase system do not contain any double bond between carbon – carbon atoms. The desaturation of the fatty acid occurs in the endoplasmic reticulum and catalyzed by a group of enzymes known as desaturation system. In mammals desaturation system comprises of 3 proteins, viz., cytochrome b5, cytochrome b5 reductase and fatty acyl CoA desaturases (Lehninger, 1984).
The fatty acids of the body fat are also channelized for yielding energy through β oxidation pathways, which occurs in the mitochondrial matrix. The oxidation of fat involves a reduction of FADH⁺ and NAD⁺. Through this pathway fatty acids are oxidized by successive loss of two carbon fragments. The fatty acid components of lipids furnish a large fraction of the oxidative energy in animals. Free fatty acids are first activated by esterification with CoA to form acyl-CoA esters. Four reaction steps are required to remove each acetyl-CoA residue from the carboxyl end of saturated fatty acyl-CoAs.

1.2.2 Acyl Glycerols

The most wide spread acyl glycerol is triacylglycerol, also called triglyceride or neutral lipid. Triacylglycerides are composed of a glycerol backbone to which 3 fatty acids are esterified.

\[
\begin{align*}
\text{H}_2\text{C} & - \text{O} - \text{C} - \text{R} \\
\text{H}_2\text{C} & - \text{O} - \text{C} - \text{R'} \\
\text{H}_2\text{C} & - \text{O} - \text{C} - \text{R''}
\end{align*}
\]

[R, R' & R'' are acyl chains esterified to glycerol backbone]
Fatty acids are stored for future use as triacylglycerols in all cells, but primarily in adipocytes of adipose tissue. Diacyl glycerols and monoacyl glycerols do not occur in appreciable amounts in nature but are important intermediates in a number of biosynthetic reactions.

The glycerol backbone of triacylglycerols is activated by phosphorylation at the C-3 position by glycerol kinase. The fatty acids incorporated into triacylglycerols are activated to acyl-CoAs through the action of acyl-CoA synthetases. Two molecules of acyl-CoA are esterified to glycerol-3-phosphate to yield 1,2-diacylglycerol phosphate (commonly identified as phosphatidic acid). The phosphate is then removed, by phosphatidic acid phosphatase, to yield 1,2-diacylglycerol, the substrate for addition of the third fatty acid. Intestinal monoacylglycerols, derived from the hydrolysis of dietary fats, can also serve as substrates for the synthesis of 1,2-diacylglycerols (Lehninger, 1984).

Generally triacylglycerol biosynthesis and oxidation occur simultaneously in a steady state, so that the amount of body fat stays relatively constant over long periods although there may be minor shortterm changes as the caloric intake fluctuates. However, if carbohydrate, fat or protein is consumed in excess above normal energy needs, the excess calories are stored in the form of triacylglycerols. Both carbohydrates and carbon chains of amino acids can give rise to acetyl CoA required for the net biosynthesis of fatty acids and triacylglycerols.
The rate of triacylglycerol biosynthesis is profoundly altered by the action of several hormones like insulin, pituitary growth hormone, adrenal cortical hormones and glucagon.

1.2.3 Phospholipids

The basic structure of phospholipid is very similar to that of the triacylglycerides except that the position of the glycerol backbone is esterified with phosphoric acid.

\[
\begin{array}{c}
\text{O} \\
\text{H}_2\text{C} \quad \text{O} \quad \text{C} \quad \text{R}_1 \\
\text{O} \\
\text{H} \quad \text{O} \quad \text{C} \quad \text{R}_2 \\
\text{O} \\
\text{H}_2\text{C} \quad \text{O} \quad \text{P} \quad \text{O} \quad \text{X} \\
\text{O}^-
\end{array}
\]

[Backbone of Phospholipid; X – Head alcohol group]

The building block of the phospholipid is phosphatidic acid, which results when the X substitution in the basic structure shown in the Figure above is a hydrogen atom (Gurr and James, 1976). Substitutions include ethanolamine (phosphatidyl ethanolamine), choline (phosphatidyl choline, also called lecithins), serine (phosphatidyl serine), glycerol (phosphatidyl glycerol), \textit{myo}-inositol (phosphatidyl inositol, these compounds can have a
variety in the numbers of inositol alcohols that are phosphorylated generating polyphosphatidyl inositols), and phosphatidylglycerol (diphosphatidylglycerol more commonly known as cardiolipins).

Phospholipids are the basic lipid components of all membranes. The biosynthetic enzymes are associated with the endoplasmic reticulum (eukaryotic cells) or plasma membrane (prokaryotic cells). Phospholipids can be synthesized by two mechanisms. One utilizes a CDP-activated polar head group for attachment to the phosphate of phosphatidic acid. The other utilizes CDP-activated 1,2-diacylglycerol and an inactivated polar head group.

1.2.4 Sphingolipids

Sphingolipids are composed of a backbone of sphingosine which is derived itself from glycerol. Sphingosine is N-acetylated by a variety of fatty acids generating a family of molecules referred to as ceramides (Lehninger, 1984).

\[
\begin{align*}
\text{CH}_3\text{-(CH}_2\text{)}_{12}\text{C=CH}_2\text{CH}_2\text{OH} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{OH} & \quad \text{NH}_2
\end{align*}
\]

Sphingosine

Sphingolipids predominate in the myelin sheath of nerve fibers. Sphingomyelin is an abundant sphingolipid generated by transfer of the phosphocholine moiety of
phosphatidylcholine to a ceramide, thus sphingomyelin is a unique form of a phospholipid.

The other major class of sphingolipids (besides the sphingomyelins) are the glycosphingolipids generated by substitution of carbohydrates to the sn1 carbon of the glycerol backbone of a ceramide. There are 4 major classes of glycosphingolipids:

- **Cerebrosides**: contain a single moiety, principally galactose.
- **Sulfatides**: sulfuric acid esters of galactocerebrosides.
- **Globosides**: contain 2 or more sugars.
- **Gangliosides**: similar to globosides except also contain sialic acid.

1.2.5 Glyceryl Ethers (Plasmalogens)

Plasmalogens are glycerol ether phospholipids. They are of two types, alkyl ether and alkenyl ether. Dihydroxyacetone phosphate serves as the glycerol precursor for the synthesis of glycerol ether phospholipids. Three major classes of plasmalogens have been identified: **choline**, **ethanolamine** and **serine plasmalogens**. Ethanolamine plasmalogens is prevalent in myelin. Choline plasmalogens is abundant in cardiac tissue. One particular choline plasmalogen (1-alkyl, 2-acetyl phosphatidylcholine) has been identified as an extremely powerful biological mediator. This molecule is called **platelet activating factor**, PAF (Gurr and James, 1976). These are found in varying portions in marine organisms and other animal species.
1.2.6 Cholesterol

Cholesterol is complex and fat soluble having four fused isoprene rings. It has a polar head group, hydroxyl group at position 3. The rest of the molecule is a relatively rigid non-polar structure.

![Cholesterol structure](image)

Cholesterol is an extremely important biological molecule that has roles in membrane structure as well as being a precursor for the synthesis of the steroid hormones and bile acids. Both dietary cholesterol and that synthesized de novo are transported through the circulation in lipoprotein particles. The same is true of cholesteryl esters, the form in which cholesterol is stored in cells.

The synthesis and utilization of cholesterol is tightly regulated in healthy animals in order to prevent over-accumulation and abnormal deposition within the body. The abnormal deposition of cholesterol and cholesterol-rich lipoproteins in the coronary arteries is of particular importance clinically. Such deposition, eventually leading to atherosclerosis, is the leading contributory factor in diseases of the coronary arteries.
Cholesterol synthesis occurs in the cytoplasm and microsomes from the two-carbon acetate group of acetyl-CoA.

The process has five major steps:

1. Acetyl-CoAs are converted to 3-hydroxy-3-methylglutaryl-CoA (HMG-CoA)
2. HMG-CoA is converted to mevalonate
3. Mevalonate is converted to the isoprene based molecule, isopentenyl pyrophosphate (IPP), with the concomitant loss of CO$_2$
4. IPP is converted to squalene
5. Squalene is converted into lanosterol and then to cholesterol.

\[
\text{Acetyl-CoA} + \text{Acetoacetyl-CoA} \rightarrow \text{HMG-CoA} \xrightarrow{(2) \text{ NADPH}} \text{mevalonate}
\]

The cellular supply of cholesterol is maintained at a steady level by three distinct mechanisms (Lehninger, 1984):

1. Regulation of HMGR activity and levels
2. Regulation of excess intracellular free cholesterol through the activity of acyl-CoA: cholesterol acyltransferase, ACAT
3. Regulation of plasma cholesterol levels via LDL receptor-mediated uptake and HDL-mediated reverse transport.
Regulation of HMGR activity is the primary means for controlling the level of cholesterol biosynthesis. The enzyme is controlled by four distinct mechanisms: feedback inhibition, control of gene expression, rate of enzyme degradation and phosphorylation-dephosphorylation.

The first three control mechanisms are exerted by cholesterol itself. Cholesterol acts as a feedback inhibitor of pre-existing HMGR as well as inducing rapid degradation of the enzyme. The latter is the result of cholesterol-induced polyubiquitination of HMGR and its degradation in the proteosome.

Cholesterol is transported in the plasma predominantly as cholesteryl esters associated with lipoproteins. Dietary cholesterol is transported from the small intestine to the liver within chylomicrons. Cholesterol synthesized by the liver, as well as any dietary cholesterol in the liver that exceeds hepatic needs, is transported in the serum within LDLs. The liver synthesizes VLDLs and these are converted to LDLs through the action of endothelial cell-associated lipoprotein lipase. Cholesterol found in plasma membranes can be extracted by HDLs and esterified by the HDL-associated enzyme LCAT. The cholesterol acquired from peripheral tissues by HDLs can then be transferred to VLDLs and LDLs via the action of cholesteryl ester transfer protein (apo-D), which is associated with HDLs. Reverse cholesterol transport allows peripheral cholesterol to be returned to the liver in LDLs (Gurr and James, 1976).
1.3 DIETARY ROLE OF LIPID

Lipid metabolism in animals can no longer be considered to be simply a matter of dietary fatty acids. The dynamics of membrane structure and function depend upon the complex role of lipid and help the organism to adapt a new environment (Hazel, 1984; Cossins, 1983; Dey et al., 1993; Farkas et al., 1994; Roy et al., 1997). The interrelationship between the dietary fatty acid, membrane fluidity and membrane integrity and metabolic pathways in animal are evident and the state of the lipids in the animal is in a constant flux.

The main function of fats in the body is to provide a steady energy. Fats provide twice as much energy as that provided by the same amount of carbohydrate, because fats molecule contain higher percentage of carbon and hydrogen, but less percentage of oxygen than that of carbohydrates. Fats are the richest source of energy to the body but they are more expensive than carbohydrates.

Fats fulfill important functions in our diet. It is a source of essential fatty acids and carries lipid soluble vitamins. The amount and type of fat consumed is the focus of much interest on maintaining the good health. Fat is important for slowing the digestive process so one does not feel hungry an hour after eating a meal. One role of fat in the diet is to aid in the absorption of fat soluble vitamins, which include vitamins A, D, E and K.
Polyunsaturated fatty acids cannot be synthesized de novo by animals (Henderson and Tocher, 1987) as the animals lack the enzymes (Δ12 and Δ15 desaturases) required for the addition of extra double bond to monoenoic or oleic acid towards the methyl end to synthesize linoleic (9,12, Octadecaenoic acid) and linolenic (9,12, 15 Octadecatrienoic acid) acids respectively.

Because these two fatty acids are essential to body function they must be obtained through diet. Therefore they called essential fatty acids (EFA). Animals do possess the machinery to synthesize other long chain polyunsaturated fatty acids, once these two essential fatty acids are supplied to the body. These EFAs are used as parts of cell membranes and in the synthesis of hormone like substances.

The natural distribution of these two fatty acids is not in a same order. Synthesis of linoleic acid from oleic acid is very common among the terrestrial plants where as the linolenic acid, which is further a desaturated product of linoleic acid by Δ15 desaturase enzyme is very restricted in terrestrial ecosystem.

These two fatty acids are very important for animal beings in terms of producing other ω3 and ω6 series of PUFAs and are involved in temperature adaptation and production of secondary metabolites (Lands, 1987).
Fats with a high content of saturated fatty acids (SFA) include tropical oils like coconut oil, palm kernel oil, cocoa, butter, palm oil etc. SFA can increase blood cholesterol levels. Higher levels of blood cholesterol increase the risk of heart disease.

Foods high in PUFA include corn oil, safflower oil, soybean oil, sunflower oil, cotton seed oil, walnuts, and seafood. Foods like olives oil, canola oil, peanuts, almonds, hazelnuts, cashew nuts are rich in monounsaturated fatty acid (MUFA). MUFA and PUFA both have a blood cholesterol lowering effect and can lower the risk of heart disease.

PUFAs are very essential for the growth and development and maintenance of cellular functions in animals. EPA and DHA are important for normal growth and development in children and are also active in brain and eye development; these fatty acids may also be important in the prevention and treatment of heart disease, hypertension, arthritis and cancer, especially in adults (Simopoulos, 1991; Salem et al., 1996).

Fish oil and fish meal, rich sources of ω3 fatty acids are the most effective means of correcting the dietary balance of ω6: ω3 fatty acids in terms of the improvements seen in health and fertility (Allen and Dandorth, 1988).
The ω6 and ω3 series of fatty acids play a significant role to maintain physiological homeostasis in animals. The secondary metabolites viz., prostaglandin and thromboxane produced from PUFA regulate the various metabolic and physiological functions in animals (Lands, 1987).

Each PUFA synthesize different prostaglandin and thromboxane. Dietary linoleate is converted to arachidonate, which is further converted to prostaglandin required for biosynthesis of steroid. On the other hand, the eicosanoid produced from n3 PUFA act as anti-inflammatory mediators. All eicosanoid use same biosynthetic pathway (i.e. cyclooxygenase or lipoxygenase pathway) but they work in antagonistic fashion. Eicosanoid of one group work as competitive inhibitor for the production of other eicosanoid. It is important to recognize that linoleic acid will not substitute alpha linolenic acid in providing n3 PUFA to various tissues (Mantzioris et al, 1995).

1.4 LITERATURE SURVEYED:

Investigations to determine the essential fatty acid requirement of poultry bird began in 1950 and in 1960 linoleic acid requirement was established for chickens. Presently a dietary level of 1% linoleic acid is recommended for adequate growth of Chickens, Turkeys and Quails (National Research Council, 1984). Even though essential fatty acid requirement is known, little information is made available to the practical nutritionist regarding the metabolic and physiological importance of essential fatty acid in poultry. Essential fatty acid deficiency symptom in chicks include retarded growth,
increased water consumption, reduced resistance to disease, enlarged liver with increased lipid content and alteration of tissue fatty acid composition (Balnava, 1971). Linoleic acid requirement for growing quail as determined by maximum growth rate and minimum liver size, was estimated to be about 1% of the diet but the requirement of the same for egg production was estimated to be about 0.70% of the diet (Murai et al, 1994). Although linoleic acid is accepted as essential fatty acid for the poultry birds, linolenic acid is also essential for the normal development and growth of poultry birds as in other animals. Linoleic acid cannot be synthesized de novo by animals (Henderson and Tocher, 1987), it is to be consumed along with the food. Hence, it is also known as essential fatty acid in animals including the poultry birds. It is important to recognize that linoleic acid will not substitute linolenic acid in providing n3 PUFA to various tissues. The long chain n3 PUFA, derived from linolenic acid, is present in the retina and nervous tissue (Rezenka, 1998). The recognized deficiency symptoms of n3 fatty acid in mammals include defective vision (Neuringer et al., 1998) and impaired learning ability (Yamamoto et al., 1987, Bourre et al., 1989). Although dietary linoleic acid may protect chicks from nutritional encephalomalacia induced by vitamin E deficiency (Budowski and Crawford, 1986), an absolute requirement for a linolenic acid in poultry has not been demonstrated. Both linoleic and linolenic acid are readily absorbed through the intestinal wall where resynthesis of triacylglycerol and the packaging of lipid into proto microns occur for transport to the liver (Krogdahl, 1985). Metabolic machinery of birds altered during post hatching development depending upon the type and proportion of metabolite consumed along with the diet (Asnani and Pilo, 1991). Halle (1999) reported that the
fertility, hatchability and the growth of progeny of poultry birds depend upon the dietary fatty acids.

Broadhurst et al (2002) proved that polyunsaturated fatty acid is dietary essential for brain intellectual growth and development. Watts and Browse (2002) proved that PUFA are important membrane component and precursor of signaling molecules. The long chain PUFA during infancy has been related to neonatal growth and development (Patrix and Gerard, 2002). Polyunsaturated fatty acid derived from essential fatty acid plays an important role in prenatal visual and neural development. It was found that in malnourished infants a nutrient formula enriched with long chain fatty acid of n6 and n3 series could be helpful to achieve erythrocyte fatty acid pattern and a visual function similar to that obtained in a breast fed infant (Marin et al., 2000). Bell et al., (1994) showed that diet rich in PUFA influences the growth as well as the production of secondary metabolites like prostaglandin and thromboxane in juvenile trouts.

The metabolic utilization of dietary fat affects the carcass composition and meat quality in farmed animals (Doreau et al., 1997) including the poultry birds (Hartfiel, 1995; Mieczkowska et al, 1999). Klinger et al (1996) suggested that dietary lipid effect several hematological factors of culture channel cat fish. Fish fed with fish oil diet had significantly lower hematocrits, higher thrombocyte count and higher serum iron concentration. Dietary lipid affects the fatty acid composition of blood leucocytes and plasma eicosanoid concentration in European Sea Bass (Farndale et al., 1999). It was proved that deficiency of EFA in chicks lead to cessation of growth and loss of feathers.
on the body (Swaminathan, 1986). Shafey and Cham (1994) showed that by manipulating hen’s diet the cholesterol and fatty acid content of the eggs can be altered for better human consumption. The dietary fatty acid influence the fatty acid composition of egg yolk fatty acid and the utilization of essential fatty acid by developing chick embryo (Lin et al., 1991). Rinogi et al (2000) showed that, the daily heat production of cocks fed the diet with fish oil rich in long chain PUFA was found to be higher than that in those fed with control diet containing soya bean oil and linseed oil. This result suggests that also in poultry long chain PUFA induces thermogenesis, particularly during daylight.

Dietary fat induced changes in tissue lipid parameters have already been reported in various animals including mammals and non-mammals. The undigested fraction of soya bean protein supplemented with 10% safflower oil induces the changes in leukotrienes and prostaglandin E production in the spleen of hamsters (Gatchalian et al., 1994). However, when the hamster was fed on safflower oil with soybean protein diet leukotriene B4 production was not influenced (Gatchalian et al., 1995). 1% conjugated linoleic acid supplemented diet significantly increases the body mass gain along with the increased ratio of HDL – Cholesterol and total cholesterol ratio in rat (Szymczyk et al., 2000). Similarly, conjugated linoleic acid did not modify the performance parameter (weight gain and feed conversion ratio), but altered the fat and protein content of the tissues in chicks (Simon et al., 2000). Work done by An Byong et al (1997) showed that dietary fat, the degree of unsaturated fat, plays a very important role in the growth of chicks, when the four weeks old chicks were fed with fat varying in
saturated and unsaturated index from different sources and the metabolism in the growing chicks was significantly affected. Lopez et al (2001) reported that high fish oil concentration decreases the saturated and monoenoic fatty acid content in the thymus sample. Production of platelet thromboxane A2 and aortic prostacyclin decreased in rat with higher intake of n3 fatty acid (Yamada, 1996). DHA and EPA prevent atherosclerosis development by reducing hypercholesterolemia and modifying the platelet function in rat (Ikeda et al., 1996,1998; Adan et al., 1999). Castillo et al (2000) showed that fish oil produced a significant reversion of the hyper cholesterolemia previously induced by coconut oil feeding. Fish oil also produces a clear decrease in plasma triacylglycerine level. PUFA reduces the incident of NEC (nectorizing enterocolitis) by modulating PAF (platelet activating factor) metabolism and endotoxin trans location.

Watkins (1995) reviewed the dietary and hormonal control of PUFA formation and the role of PUFA in eicosonoid production during cell differentiation, oviposition and bone cell metabolism of poultry bird. Dietary administration of γ - linolenic acid increased in vitro production of prostaglandin E1 derived from dehomo γ - linolenic acid but did not significantly influenced the production of prostaglandin - E2 derived from Arachidonic acid in rat (Quoc et al., 1996). Although the capability of fat digestion increased with dietary supplementation of lipase, the feed intake in terms of crude protein remain unaltered in broiler chicks (Ala-Marazooqi and Leeson, 1999). Cholesterol metabolism of the growing birds varies with age of the growing birds (Innariea et al., 1992).
Marine bacteria are known to produce wide range of compounds, which have potential applications as bioactive compounds, probiotics and nutritional supplements. These organisms are now being screened for the production of polyunsaturated fatty acids as well as specific fatty acids (Watanabe et al., 1996 & 1997; Yazawa, 1996). The concept of using microorganisms in feed or enriching the feed with some specific microorganisms in fish is well established in Asian countries. The use of living microbial supplementation in diet as an additional ingredient for enhancing growth of animal has been the thrust area of nutritionist in the recent past. The probiotics have multiple effects on intestinal microflora and act as health promoting microorganisms (Yano et al., 1994).

1.5 OBJECTIVES

So far, the nutritional studies carried out with respect to fish nutrition, poultry nutrition, cattle nutrition or human nutrition is focused on the requirement of dietary protein and how best this could be supplemented. Only very recently the emphasis is given on requirement of EFA in the nutritional biochemistry work. From the literature review it has been observed that both the linoleic and linolenic fatty acids are required in the diet for better growth of animal. It is been suggested that only 5% of lipid should be supplemented in the diet either in the form of linoleic or linolenic acid or both. There is absolute dearth of knowledge about what is the exact quantity of the linoleic and linolenic acid should be there in the diet in order to maintain animal in a well being condition.
Poultry products like chicken meat, eggs are in great demand as it provides protein rich comparatively low priced non-vegetarian diet, which is unique and tasty. It becomes an essential substitute of protein for human consumption. Although the poultry science in India and other countries is well established with regard to improvement of the meat and production of eggs through dietary manipulation, feed formulation of the poultry has not been aimed to improve the health of the consumer (human beings) as well as poultry bird itself.

The work that has been carried out so far on importance of dietary lipids (as reviewed in section 1.4) depicted that fatty acid profiles of tissues depend on dietary lipids. But how the dietary lipids are influencing PUFA composition has not been studied. The effect of dietary cholesterol on serum and tissue lipid composition on the different organism has been worked out but how dietary cholesterol modulates lipid composition is not studied. Mostly scientists have worked on poultry birds of 14 days age and above and there is no information about the requirement of dietary lipid in neonatal period. Although much work is done to increase sustainable level of n3 PUFAs, in fish, poultry birds and other animals, the requirement of particular fatty acids as growth promoter are not known.

The concept of enriching the feed with some specific microorganisms in fish and other animals is well established in Asian countries. These act as additional ingredient for enhancing growth of animal and have multiple effects on intestinal microflora and acts as health promoting factors.
It has been observed that most of the available commercial poultry diets contain 35-40% crude protein and 5-10% of crude fat, out of which 60-70% is linoleic acid and 2-3% is linolenic acid. Since, varying the dietary levels of essential fatty acids will modify the composition of long chain PUFA of both \( \omega 6 \) and \( \omega 3 \) series in the tissues of poultry birds, enriching poultry meat with specified PUFA can be done to meet the consumer demand. Furthermore, the changes in the types of PUFA in the tissues of bird may offer potential benefits to the birds by modulating eicosanoid production which would help the birds to be in a "well being state" and so also the human beings.

In the present research work, poultry bird, *Gallus domesticus* is used as an experimental model. The emphases were laid on the quality and quantity of lipid in a diet. The main aim of the study was to increase the sustainable level of n3 and \( \omega 6 \) PUFA so that the consumer of these animals get benefit by synthesizing sufficient amount of metabolically active compounds required for being in a "well being state."

Efforts were taken to see the effect of dietary lipids on poultry bird during post hatching development from 1\textsuperscript{st} day to 35\textsuperscript{th} day, to see change in pattern of lipid metabolism during this period and also to find out the amount of EFA required for them to be in healthy state during this period.
The assumed Ph.D. work is based on the following broad objectives:

1. To study the lipid profiles in the growing birds during post hatching development.

2. Role of some dietary lipids (some oils) in the tissues of poultry bird during growth and development (post hatching)

3. To find out whether some marine bacteria can be used as an alternative source of ω- linolenic acid (n-3 fatty acid).