CHAPTER – I

INTRODUCTION
Fish, one of the main sources of protein and fat has become a healthier alternative to meat for the last 50 years. In addition to protein and fat, fish contains several essential amino acids, vitamins and minerals and a larger portion of Omega-3 and other unsaturated fatty acids that are healthier than the saturated fat of red meat (Varlik et al., 2004). However, the chemical composition of fish varies greatly from one species and one individual fish to another depending on age, sex, environment and season. (Huss, 1995) Aqua cultured fish can also vary in composition due to some controlled factors. A fish farmer is able to design, to some extent, the composition of the fish by selecting the farming conditions- the feed composition being the single most pronounced factor to have an impact on the composition of the cultured fish (Lovell, 1988; Roberts, 1989; Winfree, 1992).

The principal composition of fish is 16-21% protein, 0.2-25% fat, 1.2 – 1.5% mineral, 0 – 0.5% carbohydrate and 66 – 81% water (Love, 1970). Furthermore, the variations in proximate composition of fish are closely related to the feed intake. During periods of heavy feeding, the protein content of muscle tissue increases slightly at first and then the fat content shows a marked and rapid increase. On the other hand, fishes have starvation periods for natural or physiological reasons as spawning or migration or because of external factors such as shortage of foods. In that case, fat content gradually decreases and then a decline in protein is also reported (Huss, 1995). Therefore, it is of utmost importance to evaluate the proximate composition of fish and their variations throughout the year.
For many years water quality has been the most important limitation to fish production (Valle and Anguilera, 1991; Theresa et al., 2005). Advances in life support technology have been substantial in recent years and nutrition is increasingly regarded as a key limitation to increase production efficiency as well as the growth and propagation of new species. Commercially prepared diet for channel cat fish and salmonoids have been developed using a great deal of research data on specific nutritional requirement of these species, their production system and their life stages. Some nutritional studies have also been carried out for Tilapia production and fresh water ornamentals (Lovell, 1988; Roberts, 1989; Floyd, 2002).

Various kinds of fish components have been reported to exhibit significant roles in human health and environment. Fish derived compounds have been using in pharmaceuticals as antitumor substance, nutrition substance and also as antifreeze, glycoprotein, amino acid, antioxidation substances, enzymes and antibacterial material (Ruiter, 1995).

Zaboukas et al., (2003) determined the biochemical composition including lipid, crude protein, DNA and RNA of different tissues during seasonal maturation of Bonitos, Sarda sarda from the Aegean sea.

Fishes have received increased attention as a potential source of animal protein and essential nutrients for human diets (Kromhout et al., 1995; Zenebe et al., 1998 (a); Arts et al., 2001; Fawole et al., 2007). Fish meat contains significantly low lipids and higher water than beef or chicken and is favoured over white or red meats (Neil, 1996; Nestel, 2000).
Besides being used as food, the demand for the use of fish as feed is increasingly on the rise. However, information concerning the chemical composition of freshwater fishes in general is valuable to nutritionists seeking readily available sources of low-fat and high protein foods as found in most freshwater fishes (Sadiku and Oladimeji, 1991; Mozaffarian et al., 2003; Foran et al., 2005) and to the food scientists who are interested in developing them into high protein foods, while ensuring the finest quality flavour, colour, odour, texture and safety obtainable with maximum nutritive value. It is also useful to the ecologists and environmentalists who are interested in determining the effects of changing biological and environmental conditions on the composition, survival and population changes within fish species. The nutritional component of the freshwater fish was reported to differ between species, sexes, sizes, seasons and geographical localities (Zenebe et al., 1998 b). It was also reported to influence post harvest processing and affect the shelf-life of the fish (Clement and Lovelli, 1994). Changes in fatty acid and amino acid concentrations were reported to be useful as an index of freshness and decomposition of marinated fish in storage (Ozkan, 2005).

Fish plays an important role in food security and poverty alleviation in both rural and urban areas of a country, but little is known about the nutritional value of fishes that are consumed by common people in fresh condition. Better knowledge of their nutritional value closely associated with fish species of different or nearby environment, could contribute to the understanding of variability in meat quality of different species. Moreover, the measurement of some proximate
profiles is often necessary to ensure that they meet the requirements of food regulations and commercial specifications (Watermann, 2000).

Fish is much sought after by a broad cross-section of the world population, particularly in developing countries. It is estimated that around 60% of people in many developing countries depend on fish for over 30% of their animal protein supplies, while almost 80% in most developed countries obtain less than 20% of their animal protein from fish. However, with the increased awareness of the health benefits of eating fish and the ensuing rise in fish prices, these figures are rapidly changing.

Fish products are comparable to meat and dairy products in nutritional quality, depending on the methods used in preservation and preparation. The protein content of most fish averages 15% - 20%. Fish also contains significant amount of all essential amino acids, particularly lysine and methionine which are relatively poor in cereals. Fish protein, therefore, can be used to complement the amino acid pattern and improve the overall protein quality of a mixed diet. Fish protein provides a good combination of amino acids which is highly suited to man's nutritional requirements and compares favourably with that provided by meat, milk and egg. Moreover, the sensory property of an otherwise bland diet can be enhanced through fish products, thus facilitating and contributing to greater consumption. Whereas cereal grains are usually low in lysine and sulphur-containing amino acids (methionine and cysteine), fish is an excellent source of these acids. A fish supplement can certainly raise the biological value of a cereal based diet.
The amount of protein in fish muscle is usually somewhere between 15-20%, but values lower than 15% or as high as 28% are occasionally met with in some species (Deuel et al. 1945). All proteins, including those from fish, are chains of chemical units linked together to make one long molecule. These units, of which there are about twenty types, are called amino acids, and certain of them are essential in the human diet for the maintenance of good health. Furthermore, if a diet is to be fully and economically utilized, amino acids must not only be present, but must also occur in the correct proportions.

Among the nutritional components, fish oil plays a significant role. It is one of the most important natural sources of polyunsaturated fatty acids including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which have been proven to have useful effects on human health. (Saaud et al., 2008; Rafflenbeul, 2001). In addition, fish oil is a rich source of vitamins including fat soluble vitamins A, D,E and K and must be taken on a regular basis because of their key roles in human health and metabolism (Kinsella, 1987).

Depending upon the fat content, the fish may be categorized as oily or fatty (fat content more than 8%), average fatty (fat content between 1% - 8%) and lean (fat content less than 1%). Although fat is distributed in all tissues, in some it is present in extraordinary amount which is in far excess of the amount normally required for cell function. Such fats are called depot fats, the principal sites of which are muscle, head tissues, milt, liver, skeletal tissue, subcutaneous connective tissue and viscera (pyloric caeca and mesenteries). Fish liver is often the principal site with large fat deposits. However, brain shows the highest
concentration of fat, heart being the lowest. Liver and kidney rank the intermediate.

There are some twenty fatty acids of which 16% make stable saturated fatty acids. These commonly include palmitic acid, myristic acid, stearic acid etc. The remaining fatty acids, forming a high content are unsaturated fatty acids with low melting point and rather unstable with easily oxidisable and polymerizing characters. These belong to monoenoic acid series such as tetradeconic, zoomeric, oleic acid etc.

Fish oils are chiefly triglyceride esters of fatty acids combined with small amounts of free fatty acids, some vitamins, sterols, hydrocarbons, phospholipids and colour substances. The oil content of marine and fresh water fish differs in relative proportion of various fatty acids. Marine fish oil contains large quantities of the C\textsubscript{18}, C\textsubscript{20} and C\textsubscript{22} acids. Freshwater fish oil, on the other hand, contains large quantities of C\textsubscript{16} and C\textsubscript{18} acid but a smaller amount of C\textsubscript{20} and C\textsubscript{22} acids. In general, fish oil differs from vegetable oils in containing a wider variety of fatty acids particularly of the highly saturated groups.

The lipid fraction is the component of fish showing the greatest variation. Often, the variation within a certain species can display characteristic seasonal changes with a minimum value around the time of spawning. Some tropical fish show a marked seasonal variation in chemical composition. West African shad (*Ethmolosa dorsalis*) shows a range in fat content of 2 - 7% (wet weight) over the year with a maximum in July (Watts, 1957). Corvina (*Micropogon furnieri*) and pescada foguete (*Marodon ancylodon*) captured on the Brazilian coast had a fat content range of 0.2 - 8.7% and 0.1 – 5.4% respectively (Ito
and Watanabe, 1968). It has also been observed that the oil content of these species varies with size, larger fish containing about 1% more oil than smaller ones. Watanabe (1971) examined freshwater fish from Zambia and found a variation from 0.1 to 5.0% in oil content of four species including both pelagic and demersals.

The lipids present in teleost fish species may be divided into two major groups- the phospholipids and triglycerides. The phospholipids make up the integral structure of the unit membranes in the cells, thus, they are often called structural lipids. The triglycerides are lipids used for storage of energy in fat depots, usually within special fat cells surrounded by a phospholipid membrane and a rather weak collagen network.

The white muscle of a typical lean fish (e.g. Cod) contains less than 1% lipids. Of this, phospholipids make up about 90% (Ackman, 1980). The phospholipid fraction in a lean fish muscle consists of about 69% phosphatidyl choline, 19% phosphatidyl ethanolamine and 5% phosphatidyl serine. In addition, there are several other phospholipids occurring in minor quantities. Achionye-Nze and Omoridion (2002) studied the lipid composition of *Heterotis niloticus, Brycenus nurse, Gnathonemus cyprinoids* and *Sarotherodon galilaeus* and observed that the common neutral lipids were cholesterol, free fatty acids and cholesterol esters, while diphosphatidyl glycerol, phosphatidyl glycerol and phosphatidyl ethanolamine were the most predominant phospholipids.

The phospholipids are all contained in membrane structures, including the outer of cell-membrane, the endoplasmic reticulum and
other intracellular tubule systems as well as membranes of the organelles like mitochondria. In addition to phospholipids, the membranes also contain cholesterol, contributing to the membrane rigidity. In lean fish muscle cholesterol may be found in a quantity of about 6% of the total lipids. This level is similar to that found in mammalian muscle.

Fish species are categorized as lean or fatty depending on how they store lipids for energy. Lean fishes use the liver as their energy depot, and the fatty species store lipids in fat cells throughout the body. The fat cells making up the lipid depots in fatty species are typically located in the subcutaneous tissues, in the belly flap muscle and in the muscles responsible for the movement of the fins and tail. In some species with extraordinary high amount of lipids, the fat may also be deposited in the belly cavity. Depending on the amount of polyunsaturated fatty acids, most fish fats are more or less liquid at low temperature.

Fat depots are also reported to be typically spread throughout the muscle structure. The concentration of fat cells appears to be highest, close to the myocommata and in the region between the light and dark muscle (Kiessling et al., 1991). The dark muscle contains some triglycerides inside the muscle cells even in lean fish, as this muscle is able to metabolize lipids directly as energy. The corresponding light muscle cells are dependent on glycogen as a source of energy for the anaerobic metabolism.
The phospholipids may also be mobilized to a certain extent during sustained migrations, although this lipid fraction is considered to be conserved much more than the triglycerides (Love, 1970).

In Elasmobranchs, such as sharks, a significant quantity of the lipid is stored in the liver and may consist of fats like diacyl-alkyl-glyceryl esters or squalene. Some sharks may have liver oils with a minimum of 80% of the lipid as unsaponifiable substance, mostly in the form of squalene (Buranudeen and Rajadurai, 1986).

Fish lipids differ from mammalian lipids, the main difference being that fish lipids include up to 40% of long chain polyunsaturated fatty acids (14-22 carbon atoms). Mammalian fats rarely contain more than two double bonds per fatty acid molecule while the depot fats of fish contain several fatty acids with five or six double bonds (Stansby and Hall, 1967).

The percentage of polyunsaturated fatty acids with four, five or six double bonds is slightly lower in the lipids from freshwater fish (approximately 70%) than in the corresponding lipids from marine fish (approximately 88%). However, the composition of the lipids is not completely fixed but can vary with the feed intake and season (Stansby and Hall, 1967).

In human nutrition, fatty acids such as linoleic and linolenic acids are regarded as essential since they cannot be synthesized by the organism. In marine fish, these fatty acids constitute only around 2% of the total lipids, which is a small percentage compared with many vegetable oils. However, fish oils contain other polyunsaturated fatty acids regarded as “essential” are useful to prevent skin diseases in the
same way as linoleic and arachidonic acid. As members of the linolenic acid family, they also have neurological benefits in growing children. Eicosapentaenoic acid has recently attracted considerable attention because Danish scientists have found this acid high in the diet of a group of Greenland Eskimos virtually free from arteriosclerosis. Investigations in the United Kingdom and elsewhere have documented that eicosapentaenoic acid in the blood is an extremely potent antithrombotic factor (Simopoulos et al., 1991).

Various reports on the study and identification of fish liver oil having high potential of pharmacological activities as hypolipidemic agent (Castro et al., 1997; Van Vligman et al., 1998), antiarthritic agent (Ariza et al., 1988; James et al., 1997, Gonnerman et al., 1998) and preventing renal damage (Manitius et al., 1997; Dillon, 1997; Folch et al., 1957) may also the outcome of study dealing with the fatty acid and lipid characterisation of liver oils.

Different workers have reported their own views in the variable values of varied fatty acids in fishes living both in fresh and marine water bodies. In a study by Cakli (1994), the average annual palmitic acid values in gilthead seabream were reported as 23.39%. Stearic acid contents were also higher in wild type (7.26%) than the culured (5.11%). Average percent values of myrictic, oleic, palmiteloic and docosahexaenoic acids were reported to be higher. On the other hand, eicosapentaenoic acid level remained same in wild-type and gilthead seabream. Higher docosahexaenoic acid levels were also reported by Wassef and Snehata (1991) in cultured red snapper.
Aoki et al., (1991) showed significantly higher lipid content in cultured red seabream (Pagrus major) compared to wildtype counterparts. Similarly, Funuyama et al., (1991) reported 12.4 – 40.7% fat content in cultured striped jack (Pseudocaranx dentex) as oppose to 7.9 – 22.2% in wild type. Nakagawa et al., (1991) compared amount of fatty acids in ayu (Plecoglossus altivelis) collected from nine different regions of Japan. They detected more than twice as much fat (8.2±2.5%) in cultured ayu than its wild types (3.4±1.7%). In addition, Hatae et al., (1989) reported higher fat contents in both cultured pory (Pagellus erythrinus) and Japanese amber jack (Seriola quinqueradiata) than their wild types, but not between cultured and wild type flounder (Platichthys flesus). Kunisaki et al., (1986) reported 10-20 fold high fat content in cultured horse mackerel than wild type.

Chanmugam et al., (1986) reported a higher n-3 fatty acid presence in cultured cat fish. Various muscle fat contents were also investigated by Cakli and Celik (1995) in wild and cultured gilthead seabream. Nettleton et al., (1994) also reported 5 fold higher fatty acid consisting mostly of monounsaturated fatty acid levels in cultured catfish. Similar results were also reported in Red seabream by Novarro et al., (1990). Other authors also reported higher linolenic acid levels in cultured carps and rainbow trout (Suzuki et al., 1986).

Recently, the lipids in fish muscle have received much interest as a source of EPA and DHA fatty acids in human diets. Lipid and fatty acid compositions of many marine fish and shell-fish as well as the effect of different diets on lipid compositions of these marine species have been investigated (Ackman and Takeuchi, 1986; Viswanathan and Gopakumar, 1984; Halver, 1980). Suzuki et al., (1986); Viola et al.,
Bieniarz et al., (2000) have investigated some of the factors causing changes in the composition of fatty acids in various fish species. For years, the American Heart Association (AHA) has recommended eating an average of two to three fish meals each week to help in reducing the cholesterol, high blood pressure and hardening of arteries. Research shows that consuming fish increases high quality protein with fewer calories, and it is rich in omega-3 fatty acids. Omega-3 fatty acids help to reduce the risk of coronary artery disease, in the treatment of bipolar disorder and helps to reduce inflammation in autoimmune diseases. In addition, fish oil also helps to prevent brain aging and Alzheimer’s disease (Kyle, 1999).

The amount of vitamins in fish is species-specific and can vary with season. Fish provides vitamin A, B, D and E which are all essential vitamins of human diet. Liver is particularly rich in B-complex vitamins, A and D. B-Complex includes thiamine, riboflavin and nicotinic acid. The distribution of vitamins however, is not uniform in the body. Vitamins A and D occur more in inner organs of the body. Vitamin B occurs more in liver, eyes, skin, kidney, spleen, pyloric caeca and intestine. The content of different vitamins also varies due to age, sex as well as fishing regions. Nettleton and Exler (1992) reported very similar concentration variations in ascorbic, pantothenic, folic, thiamine, riboflavin and niacin levels in channel catfish, cohosalmon and rainbow trout.

Vitamins A, D and E are fat soluble and these vitamins are essential nutrients controlling a diversity of biologically important processes in human body. Vitamin A rich fishes are found more where
there is abundant plankton (diatoms and flagellates). Freshwater fish contains high amount of vitamin A\textsubscript{2} (dehydroretinol); whereas marine fish contain vitamin A\textsubscript{1} or retinol. Both the retinols are the conversion products of carotene. Several carotenoids depict a wide variety of colouration like red, orange, yellow, pink, greenish etc in both fresh and marine water fish. Vitamin – A helps in photoreception and regulates gene expression and cell-division, bone growth, teeth development, reproduction etc. The biologically active isomer of Vitamin – E – alphatocopherol acts as an antioxidant, protecting membrane structures, essential fatty acids and vitamins A and C from oxidation. Fat soluble vitamins in the flesh of fish are affected by the level of fat. The flesh of lean fish contains 7.5 to 15\( \mu \text{g}/100\text{g} \) vitamin A, while in the fatty species vitamin A ranges from 30 to about 1350\( \mu \text{g}/100\text{gm} \) (Sikorski \textit{et al.}, 1989). In this range, common carp (23.52 \( \mu \text{g}/100\text{g} \)) and European catfish (6.30\( \mu \text{g}/100\text{g} \)) are classified in medium and low content of vitamin A respectively. The contents of vitamin-E in the edible parts of fish range from 0.2 to 270 mg/100g wet weight (Sikorski \textit{et al.}, 1989). Vitamin –E content of lean fish evaluated is on the low level. This is due to low fat level in the muscle tissue of these fishes, since vitamin E is a fat soluble vitamin.

Being one of the major sources of Omega-3 PUFA and fat soluble vitamins A, D\textsubscript{3} and E, fish production by fish farming attains great economical importance. On the other hand, due to the worldwide decline of marine fisheries stock has provided impetus for rapid growth in fish and shell fish aquaculture (Rosamond \textit{et al.}, 2000).
Vitamins of B-group are water soluble. These include Thiamin (B<sub>1</sub>), Riboflavin (B<sub>2</sub>), vitamin B<sub>6</sub>, vitamin B<sub>12</sub> etc. Other water soluble vitamins found in fishes are niacin, pantothenic acid, folic acid, choline and ascorbic acid (vitamin-C). Red muscles of fish contain greater quantities of vit B<sub>1</sub>, B<sub>2</sub>, B<sub>12</sub> and pantothenic acid than the white muscles. On the other hand, white muscles contain larger quantities of folic acid than the red muscles.

The marine fishes of India are rich in vitamins like B<sub>1</sub> B<sub>2</sub> and D. Niacin is particularly rich in the muscles of Indian shad, pomfret and clarius. Choline is known for its medicinal value in treating hunger edema in underfed patients is found in large quantities in freshwater fishes.

The vitamin composition of a few species of fish e.g. pike perch, common carp and European catfish was reported by Lall and Parazo, (1995). According to them, the vitamin –E content of these three species was found to be 1.91 mg /100 g, 1.14 mg/100gm and 2.15 mg/100g respectively. Similarly, Souci et al., (1994) reported that vitamin B<sub>1</sub> level for some marine and freshwater fish species were 0.02 mg/100g. Vitamin B<sub>2</sub> content of pike perch was significantly higher than common carp and European catfish (P<0.05). Lall and Parazo (1995) also reported that the average folic acid content of fish and shellfish was 0.5 - 10 μg/100g in flesh. For this reason, pike perch, common carp and European catfish can be a good source of folic acid.

As for mineral elements, fish meat is regarded as a valuable source of Ca, Mg, K, Na, P, Fe, S, Cl, Cu, Mn, I, besides having traces of Sr, Zn, Ba, Al, Pb, Mo, Co, Ni, Hg, As, Cd etc. Minerals constitute
1-2% of fish flesh composition. The bulk is concentrated in fish bones. Like vitamins, minerals also do not provide calories and are only required in relatively small amounts. Minerals are essential for the body which generally needs 15 different minerals, out of which the maximum can be expected from fish source.

Although iron is essential for carrying oxygen throughout the body and is important to prevent anaemia, yet fish contains less iron than the normal amount found in red-meat; however, iron in white fish is well absorbed, so is a useful source of iron. On a weight for weight basis, shellfish contains as much iron as lean meat. Most of the fishes, specially small ones containing small bones are a very rich source of calcium. Calcium is important for bone health and teenagers and young people who have not reached their peak bone mass sometimes go short of this mineral.

Fish is one of the few reliable sources of iodine that has some very significant physiological importance as biosynthesis of thyroid hormones, which control many of the body’s metabolic processes. Insufficient iodine in the diet causes lethargy and swelling of the thyroid gland, forming a goiter. Iodine is also required for normal neurological development and for energy metabolism.

High protein food generally contains high amount of zinc. Fish and fish food provide a significant amount of zinc that can be easily absorbed. Zinc is needed for the body’s defensive (immune) system. It plays a major role in cell-division, cell-growth, wound healing and the breakdown of carbohydrates.
Fish contains calcium, the most abundant mineral in our body. The majority of the calcium in our body is found as hydroxyapatite, the hard mineral that provides strength to teeth and bone. Other calcium in our body aids in cellular signaling, used to support proper cellular functioning and also aids in the conduction of electrochemical nerve impulses. Calcium is found in a number of other organisms belonging to shellfish including crab, lobster and shrimp.

Magnesium represents another type of essential mineral found in fish. Magnesium together with calcium form the bone constituting minerals in our body. In addition, magnesium aids in proper muscle function, maintaining the health of heart and may prevent the development of type-2 diabetes, according to the University of Maryland Medical Center.

The study of mineral elements present in living organisms is always of biological importance; since many of such elements take part in some metabolic processes and are known to be indispensable to all living beings (Shul’man, 1974). The body usually contains small amount of these minerals, some of which are essential nutrients, being components of many enzyme system and metabolic mechanisms, and as such contribute to the growth of the fish. The deficiency in principal nutritional elements induces a lot of malfunctioning; as it reduces productivity and causes diseases such as inability of blood clot, osteoporosis, anaemia etc. (Mills, 1980). In addition, one of the major pollution sources that poses serious health risk and environmental concern results from heavy metals (Neil et al. 1995). All living organisms require these mineral elements and some of these biochemical attributes at moderate levels; but when they exceed metabolic demand or
requirement, they tend to become accumulated in tissues of organisms such as fish which can only metabolise it to a lesser extent, because most of these heavy metals are non-biodegradable (Lenntech, 2006). Therefore, considering the various health risks and the nutritional benefits associated with fish consumption, it has become important that fish’s mineral and proximate composition and their health status should be assessed in order to establish the safety level of the species prior to their consumption.

Metals such as iron, copper, zinc and manganese are essential since they play an important role in biological systems (Narin et al., 2000; Soylak et al., 2005; Ghaedi et al., 2005, 2006, 2008; Ibrahim et al., 2009 a,b; Rutkiewicz and Namiesnik, 2009; Sounderajan et al., 2009). The main roles of these elements can be described as functional and structural. From the functional standpoint, they play a catalyzing role in enzymatic systems by binding their ions to substrates, thereby favouring various reactions, through reversible changes in the oxidation state of the metal ions (Hlihor and Gavrilescu, 2009; Kadi, 2009; Ibrahim et al., 2009 a,b; Mikiashvilli and Isikhuemhen, 2009). Structurally, they stand out for their role as integrators of the body’s organic compounds, such as iron in haemoglobin and cobalt in vit-B_{12}, whereas mercury, lead and cadmium are non-essential metals as they are toxic (Hilton, 1989; Watanabe et al., 1997; Tuzen et al., 2004; Turkmen and Ciminli, 2007; Neves et al., 2009; Ganjavi et al., 2010). The heavy metals can also produce toxic effects at high concentrations and low or high trace element imbalances can be considered as risk factors for several diseases (Khaled, 2009; Shah et al., 2009 a,b; Tepe, 2009; He et al., 2009).
Industrial wastes, geochemical structure and mining of metals create a potential source of heavy metal pollution in the aquatic environment (Lee and Stuebing, 1990; Gumgum et al., 1994; Turkmen et al., 2005; Shah et al., 2009 a,b). Over the last few decades both the fresh and marine environment have been contaminated by persistent pollutants of agriculture and industrial origin.

Metal pollution of a water body is always more severe than any other type of pollution and the effects on the ecosystems and humans are very intensive (Schoerder, 1965; Inskip and Piotrowski, 1985; Nishihara et al., 1985; Kurieshy and D’ Silva, 1993; Naruaes, 2002; Khansari et al., 2005, Ozyurt et al., 2009; Erkan et al., 2009). Fishes are the major part of the human diet, because fishes have low risk of coronary heart disease, hypertension and cancer. Fish also have been popular targets of heavy metal monitoring programs, because sampling, sample preparation and chemical analysis are usually simpler, more rapid and less expensive than alternative choices such as water and sediments (Rayment and Borry, 2000; Turkmen et al., 2005). The distribution of metals varies between fish species, depending on age, development status and other physiological factors (Kagi and Schaffer, 1988; Khansari et al., 2005).

Everyday, human life is bound by the consumption of food. Many of our foods have recently come to light as potential health hazards due to their significant traces of arsenic. In fish the toxic accumulation of arsenic is thought to stem from environmental bioaccumulation. Arsenic is a metalloid element that is widespread in the aquatic environment as a result of both geogenic and anthropogenic processes (Sanders et al., 1994; Reimer et al., 2002). Arsenic is lethal
for most organisms at high concentrations, while chronic intake of arsenic at concentrations as low as 5-10 ppb is associated with increased risk of cancer, damage to organs, diabetes and cardiovascular disease (Hughes, 2002). As a result, arsenic is considered the number one substance of concern. Most research has focused on the effects of arsenic on fishes which may be particularly vulnerable to aquatic arsenic as they take it up continuously through gill respiration and ingestion of contaminated food. Indeed, when arsenic levels increase substantially in aquatic fish habitats, die-off and compromised health have been reported (Gilderhus, 1966; Sorenson, 1991; Reimer et al., 2002; Larsen and Francesconi, 2003; Liao et al., 2003) However, mechanisms of sublethal toxicity of environmentally relevant arsenic levels on fish are not well understood.

In the aquatic environment, inorganic arsenic is predominantly present as arsenite (As$^{3+}$) and arsenate (As$^{5+}$). Once inside the cell, arsenite binds to protein sulfhydryl group, while arsenate completely interferes with phosphorylation reactions (Hughes, 2002; Andrew et al., 2003). Since organisms cannot avoid exposure to arsenic, most of them have evolved mechanisms for biotransformation of arsenic into less harmful forms.

In fishes, arsenic speciates into two oxidation states, methylated species, arseno sugars and arsenolipids which differ in toxicity. The combination of forms found in the tissue is thought to be responsible for the overall pathophysiological effects of arsenic (Phillips, 1990; Yamauchi and Fowler, 1994; Francesconi and Admonds, 1998; Wrobel et al., 2002). Little is known about the mechanism of sublethal arsenic toxicity in fish (Allen and Rana, 2004); however, physiological
processes affected at low arsenic concentrations typically involved stress-mediated pathways. For instance, when harmful arsenic amount is increased in fish – abnormal growth, decreased acclimation ability to changes in salinity and temperature, changes in reproduction and ion-regulation are observed (Holland et al., 1964; Sorensen et al., 1980, Nichols et al., 1984, Pedlar et al., 2000 a,b; Kotsanis, 1999). These pathways are directly or indirectly mediated by the hormone activated glucocorticoid receptor suggesting the possibility that arsenic may interrupt normal stress-mediated gene expression.

Being an agro-based state with vast inland water bodies in the form of rivers, ponds, canals, ditches, beels etc., Assam provides a conducive ecological condition for the propagation of fish. Many different indigenous fishes are abundant in almost all the freshwater bodies of the state. These species have an importance for their food value as well as for their taste. Analysis of biochemical composition including protein, fat, vitamins and minerals is very important to evaluate food value as the composition varies from species to species and with the same species from different habitats as well as in different seasonal climatic conditions of the year (Stansby et al. 1962). Moreover, biochemical analysis is an index of nutritive value only because the fractions it isolates are correlated with some of the properties of organisms that are nutritionally significant. Considering the various health risk and the nutritional benefits associated with fish consumption, it has therefore become important to evaluate and assess the proximate composition of fishes along with some elements in order to establish the food value, quality and safety level of fish consumption from particular habitats and seasons. But the reports of detailed
Aim and Objective:

This study is aimed to examine the seasonal changes in certain nutrients of the fish species from lotic and lentic habitats taking *Labeo gonius* as a representative index model of the local fish fauna with an objective of exploring the scope for applicability of the proposed research outcome for equilibrating the nutrient status of this food fish in particular with the habitat nutriome.

Thus, the aim of the present investigation – A study on the seasonal variation of certain nutrients of *Labeo gonius* (Ham) from different habitats has been taken with the following objectives –

- To estimate the Protein and Essential amino acid content of the experimental fish in different seasons from lotic and lentic habitats.

- To estimate the amount of Total lipid, Cholesterol and Triglyceride of the experimental fish in different seasons of the year under lotic and lentic habitats.
• To estimate the Vitamin-E, Vitamin-B complex group (B₁, B₂, Folic acid and B₃) and Vitamin-A (retinol and dehydroretinol) of the studied fish from four different seasons and two different habitats.

• To estimate certain Heavy metals (Cu, Zn, Cd, Pb, Ni, As and Mn) of the experimental fish in different seasons from lotic and lentic habitats to assess the effect of pollution.

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