Fish muscle lipids contain several n-3 PUFA with nutritional requirements. This has been discussed and much attention is given to n-3 fatty acids of freshwater fish from Southern Brazil (Andrade et al., 1995). Similarly the freshwater fishes of present study also revealed considerable amounts of PUFA like ALA, EPA and DHA in the muscle and liver tissues. Hence, besides marine fish which showed higher levels of PUFA in the muscle and liver, the freshwater fishes also have PUFA in the form of ALA, EPA and DHA and these freshwater fishes (Indian major carps) catla, rohu and mrigal can also be recommended as sources of PUFA and we can include these for nutritional requirements.

The importance of these PUFA to infant nutrition is particularly relevant because both EPA and DHA are important for foetal and infant normal development (Carlson, 1995; Jumpsen and Clandinin, 1995). In earlier studies, controlled experiments (Henderson et al., 1992) have used a maternal dietary supplement of marine fish oil as also evident from the study on mackerel to enrich human milk in DHA. In Brazil, there is a substantial freshwater fish industry and during pregnancy this PUFA rich food could be recommended as desirable to build up the DHA in the mother. Therefore, the presence of PUFA in freshwater fishes of our country is confirmed by the Brazilian studies (Andrade et al., 1995). This is also true to EPA, usually associated with adult health problems such as cardiovascular disease and hence freshwater fish lipids may also be an important source of PUFA in the diet. Hence, PUFA indispensable for human development and health and they need to be consumed as part of the diet observations on Eskimos in 1970’s sparked great interest in n-3 PUFA research.

The pioneering studies of Bang and Dyerberg (1972) showed that the low rates of mortality from CHD despite high fat intake in Eskimos could be due to relatively large intakes of LC n-3 PUFA from marine ponds in their diets. Since then other epidemiological studies confirmed that regular consumption of fish reduces the risk of
CHD. When humans consume fish or fish oils the ingested EPA and DHA partially replace the n-6 PUFA in cell membranes and lead to decreased production of thromboxane a precursor of blood clot.

From the foregoing discussion, it is clear that there is a need to increase n-3 PUFA intake in Indians. A specific recommendation to eat fish once or twice a week, before conception, during pregnancy and lactation and breast feeding may significantly contribute to growth and development of babies and ensure good health.

Both marine and brackish water fish of the present investigation are found to be rich sources of PUFA (Table 9 and Figure 13). In marine fish, the total PUFA is 12.268 and 7.060gm/100gm wet wt in muscle and liver respectively and in the brackish water fish, it is 9.880 and 6.320gm/100gm wet wt in muscle and liver respectively. Next to these fish, freshwater fishes show significantly lower level of PUFA in catla, 2.058 and 1.311gm/100gm wet wt in muscle and liver respectively, in rohu, 2.451 and 1.505gm/100gm wet wt in muscle and liver respectively, and in mrigal, 1.579 and 0.955gm/100gm wet wt in muscle and liver respectively. Thus fish is a more healthy food than pork, mutton, beef. This is due to the presence of n-3 PUFA fatty fish stored lipids in muscle and fish has less cholesterol than animal food.

Marine lipids contain a larger number of unsaturated fatty acids with 16-carbon to 22-carbon chain length up to 6 double bonds. Phytoplankton, the base for food chain in the ocean synthesizes EPA and DHA. Marine zooplankton which ingest these phytoplanktons retain the n-3 PUFA. Since fish feed on algae and zooplanktonic crustaceans, they become rich sources of EPA and DHA. The best source of n-3 PUFA is the muscle or the liver of fish (Cowey, 1998).

Mobile fat is in the form of minute oily droplets known as chylomicrons, which travel in the blood stream. Chylomicrons are made up of neutral fats and also consist of
phospholipids, cholesterol and cholesterol esters of fatty acids. The liver absorbs the
chylomicrons where they are hydrolyzed giving rise to free glycerols and fatty acids.
Mobilization of fats can be conveniently observed incase of starving animals. After
starvation for a short period, the glycogen reserve of the liver is depleted since no more
of carbohydrates are synthesized (except by way of gluconeogenesis), the liver doesn’t
receive its carbohydrate supply. Under such conditions, large amounts of fats are
transported to the liver, which take part in metabolism.

Liver has a key role in the metabolism of fats. It has been proved beyond doubt
that in conditions of carbohydrate depletion, most of the fat of the body is metabolized to
the liver to provide an alternative source of energy. Liver is not normally an accumulator
of fats as it is for carbohydrates. The fat content in the liver is maintained uniformly
constant between 3 and 8 percent. Thus excess of fat deposits is transformed by the liver
into useful substances through various interconversions. Besides interconversion of
proteins, fats and carbohydrates which goes on in the liver, it is also responsible for
transformation of lipids into phospholipids and cholesterol, desaturation of fatty acids,
oxidation of fatty acids etc.,. The sluggish function of the liver results in several
metabolic disorders, which may be normally due to the effect of certain positions, far-
rich diet, protein-poor diet, deficiency of vitamins and a host of other causes. Therefore,
the synthesis of these PUFA in liver of all the fishes of the present study is testimony to
the above metabolic changes.

Animal foods provide a good source of protein of high biological value (high
content of methionine and lysine). There are some differences between fish muscle and
the muscle of land animals. Fish muscle has less connective tissue than muscle of
terrestrial animals, resulting in a more tender texture. Therefore, cooking time and
digestibility of fish protein is high, as compared to other meats. In a nutritionally
balanced diet, vegetarians get animal proteins from milk and milk products, where as non-vegetarians get them from a wide range of other animal foods in addition. Animal foods contain high amounts of fat, SFA and cholesterol. Being structural lipids, the lean meats contain arachidonic acid (AA) as the major n-6 PUFA. Organ meats contain very high amounts of cholesterol and LC PUFA of both n-6 and n-3 series. However, the fat content and fatty acid composition of animal foods varies with animal feed as well as the proportion of depot fats with in and around the meats. Fish can be categorized in to white lean fish and oil rich fatty fish. Lean fish have high fat in the liver, where as fatty fish store lipids in muscle. Fish has less cholesterol than other animal foods. The dark muscles, which are found in the flesh along the lateral line, have more lipids than the light muscle. Further, the lipid content of muscle increases from the tail portion towards the head (Ghafoorunissa, 2001). The higher levels of PUFA in the dorsal muscle of these experimental fishes of the present investigation supported with the above statement of the lipids in the dark muscle of fishes.

**PUFA VS. SERUM CHOLESTEROL:**

The major focus for preventing CHD by diet was on lowering serum total cholesterol and its principal carrier LDL cholesterol by reduction of total fat, saturated fat and cholesterol and increase in PUFA. Dietary fish oils are implicated in reducing the incidence of coronary heart disease in that n-3 PUFA in fish oils produce changes in lipid ordering and dynamics with in high density lipoprotein (HDL) (Ghafoorunissa, 2001).

Generally, fish has less cholesterol and is a rich source of n-3 PUFA and fish have fat in the liver from which fish liver oils are prepared and this is also evident from the results on PUFA vs. serum cholesterol (Table 11 and Figure 15). These are good sources of n-3 PUFA and vitamins A and D and most of the fishes have fat stored in the
muscle in greater concentration than the liver as also noticed in the present study and
greater fish PUFA concentrates are found in their flesh (Ghafoornissa, 1998; Basha Mohideen et al., 2003).

Although many tissues of the body synthesize cholesterol, liver is considered to be the main site. It is synthesized from 2-carbon compounds in the form of acetyl co-A, which is a product of carbohydrate metabolism or fatty acids. Two molecules of acetyl co-A condense to form acetoacetyl co-A, which again reacts with another molecule of acetyl co-A and forms β-hydroxymethyl glutaryl co-A. This compound is broken down by a series of steps forming several intermediates and ultimately yields cholesterol. Cholesterol is converted in the liver to cholic acid to be excreted in the bile. High cholesterol levels in the blood are responsible for creating gallstones, hypertension and atherosclerosis.

Fish mitochondria with high levels of the ω-3 PUFA and very low levels of ω-6 fatty acids are very similar to mammalian mitochondria with respect to cytochrome content, β-oxidation of fatty acids, operation of the tricarboxylic acid cycle, electron transport and oxidative phosphorylation. The EFA play another role in the mitochondria. In addition to their importance in membrane structure, the EFA are important in some enzyme systems. Unsaturated fatty acids play an important role in the transportation of other lipids. It has been repeatedly shown that feeding PUFA will lower the cholesterol levels in animals with above normal blood lipid and cholesterol levels. Fish oils are more effective in lowering cholesterol levels than are most dietary lipids. The major portion of the fatty acids absorbed across the intestinal mucosa is transported as protein-lipid complexes stabilized by phospholipids. The low body temperature in fish probably results in a greater importance for unsaturation in transport of lipids than in homeothermic animals.
About one-third to one-fourth of blood cholesterol is carried by high-density lipoprotein (HDL). HDL cholesterol is known as the “good cholesterol” because a high level of it seems to protect against heart attack. Low HDL cholesterol levels (less than 40mg/dL) increase the risk for heart disease. Medical experts think that HDL tends to carry cholesterol away from the arteries and back to the liver, where it is passed from the body. Some experts believe that HDL removes excess cholesterol from plaque in arteries, thus showing the build-up.

Further, it has been shown that insulin action in skeletal muscle and adipose tissue can be modified by PUFA composition of membranes (Storlien et al., 1996). Since the n-3 acids from fish and fish oils down regulate several of the factors which have atherogenic potential and enhance factors which have antiatherogenic potential, these contribute to cardiovascular wealth. The current emphasis thus, is that human diets should provide a) Low SFA trans-fatty acids (present in hydrogenated oils) and cholesterol, b) Adequate absolute levels as well as an optimal balance of n-6 and n-3 fatty acids and c) Adequate antioxidants.

Fish is a good source of n-3 fatty acids, fish containing low fat (<2 percent), medium fat (2-5 percent) and high fat (>5 percent) furnishes about 0.2, 0.9 and 1.2 gm n-3 fatty acids/100gm muscle respectively.

Since the levels of LA in the diet were similar, it was possible to compare the increase in LC n-3 PUFA after 3 weeks of ALNA supplementation with the increase after Max EPA. This shows that 3.7gm dietary ALNA may have biological effects similar to about 0.3gm LC n-3 PUFA or one capsule of Max EPA. This works out to an equivalence of 11gm ALNA for 1gm LC n-3 PUFA. Hunter et al., (1992) has compared a number of studies under varying experimental conditions and arrived at an equivalence
of 10gm ALNA to 1gm of EPA. However, dose response effects with varying intakes of ALNA need to be done.

Wang et al., (1990) reported that Lake Superior fish were excellent sources of polyunsaturated fatty acids (PUFA). The amount of constituent fatty acids varies widely among the species and C_{16:0} and C_{18:0} are the most predominant saturated acids. This observation was not totally surprising because Ackman and Eaton (1966) have pointed out that C_{16:0} is a key metabolite in fish. Wang et al., (1990) show that the level of C_{16:0} in Lake Superior fish was in the range of 68-79%. Ackman (1967) reported that high values of C_{16:1α-7} is one characteristic of freshwater fish.

It has been reported (Budowski, 1981; Leaf and Weber, 1988) reported that eicosapentaenoic acid (EPA) (C_{20:5α-3}) and docosahexaenoic acid (DHA) C_{22:6α-3}) are the most important ω-3 fatty acids and also the specific effect of each one.

The EPA and DHA contents of the various species revealed many interspecies differences, as we pointed out previously for the total PUFA ω-3 content. Nevertheless, the observed biological effects of C_{20:5α-3} acid, would seem to justify the practice of reporting the content of both acids in assessing the ω-3 composition of fish.

The human brain is one of the largest consumers of DHA. A normal adult human brain contains more than 20gm of DHA. Low DHA levels have been linked to low levels of brain serotonin, which again are connected to an increased tendency to depression, suicide and violence. A high intake of fish has been linked to a significant decrease in age-related memory loss and cognitive function impairment and a lower risk of developing Alzheimer’s disease. A recent study found that Alzheimer’s patients given an omega-3-rich supplement experienced a significant improvement in their quality of life (Levine, 1997). An enormous amount of medical literature testifies to the fact that
fish oils prevent and may help to ameliorate or reverse atherosclerosis, angina, heart
attack, congestive heart failure, arrhythmias, stroke and peripheral vascular disease. Fish
oils help maintain the elasticity of artery walls, prevent blood clotting, reduce blood
pressure and stabilize heart rhythm (Flaten et al., 1990; Simopoulos, 1991; Simon et al.,
1995; Christensen, 1996). Hence the present fish fauna are good and useful sources of
PUFA and may be included in human diet.

Researchers at the University of Cincinnati have found that supplementing with
as little as 2gm/day of fish oil (410mg of EPA plus 285mg of DHA) can lower diastolic
pressure by 4.4mm Hg and systolic pressure by 6.5mm Hg in people with elevated blood
pressure. Enough to avoid taking drugs in cases of borderline hypertension. Several
other clinical trials have confirmed that fish oils are indeed effective in lowering high
blood pressure and that they may work even better if combined with a program of salt
restriction (Radack, 1991; Lawrence and Sorrell, 1993).

A dose response relationship exists between ω-3 fatty acid intake and triglyceride
lowering. Postprandial triglyceridemia is especially sensitive to chronic ω-3 fatty acid
composition (Harris et al., 1988) with quite small intakes (<2gm/day) producing
significant reductions. A critical review by (Harris, 1989) has clarified the discrepancy
among fish oil studies reporting effects on LDL cholesterol (LDL-C). He noted that in
the majority of studies reporting reductions in LDL-C levels, the saturated fat intake was
lowered when subjects switched from the control diet to the fish oil diet. When fish oil
is consumed and saturated fat intake is constant, LDL-C levels either do not change or
may increase.

The strongest evidence indicating a beneficial effect of fish intake on CHD came
from the Diet and Reinfarction Trial (DART) in which men who were instructed to eat
fish after Myocardial Infarction (MI) had a 29% decline in all cause mortality as compared with those in the placebo group (Burr et al., 1989).

When considering cardiovascular health, it seems premature to recommend general usage until compelling evidence for the beneficial action of fish oil supplements is at hand. Although doses of 3 to 8 gm of n-3 PUFA per day in those with CHD were not associated with significant adverse effects in recent clinical trials, (Leaf, 1994; Eritsland et al., 1995) evidence for beneficial effects in CHD patients is either lacking or needs additional study. Currently, fish oil capsules can only be recommended for the infrequent patients with severe treatment resistant hypertriglyceridemia who are at increased risk for pancreatitis. Potential side effects should be kept in mind. On the other hand, inclusion of marine sources of the n-3 PUFA in the diet seems reasonable because they are good sources of protein with out the accompanying high saturated fat seen in fatty meat products. More over, as Harris has noted, the potential for benefit remains high, since dietary fish oils affect “a myriad of potentially atherogenic processes” (Harris, 1996). This requires the continued support of cardiovascular research on the n-3 PUFA.

Thus, the findings of the present study of all the five species of fish analyzed for PUFA in muscle and liver indicate that fish species like mackerel and mullet are high PUFA type fish, where as freshwater fish species like catla, rohu and mrigal are low PUFA type fish and the brackish water fish like mullet is of intermediate level of PUFA. DHA is the most abundant PUFA in all the five species followed by EPA and ALA. DHA was nearly twice the amount of EPA and nearly five times high to that of ALA. All these n-3 PUFA have been reported to have beneficial effects in human health as reported earlier (Ghafoorunissa, 2001). Therefore, all the five species studies would be suitable for inclusion in the human diet for reducing cholesterol level in the blood.