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Research Article

FISH CONSUMPTION AND EFFECTS ON CARDIO VASCULAR DISEASES IN SRI LANKA

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ABSTRACT

Increasing fish consumption is recommended for intake of omega-3(n=3) fatty acids and to confer benefits for the risk reduction of cardiovascular diseases (CVD). In Sri Lanka coronary heart disease (CHD) is a main cause of morbidity and mortality and reported as first rank of disease among all other diseases (11.69%). Sri Lankan studies suggest concentration of risk factors in urban areas and higher socioeconomic classes with an increasing prevalence among younger people. A diet rich in carbohydrates and saturated fats (coconut is the major supplier of fat energy) but low in protein contribute to the worsening burden of CVD in Sri Lankan community. The fishes have varying amount of Poly unsaturated fatty acids and the consumption of fish varies among people. Herein, the relationship between fish intake and CVD risk reduction as well as the other socio demographics and food habits are described. The multiple factors influencing the consumption pattern with the effects of processing and cooking methods of fish and effects of omega-3 fatty acids are also described. The purpose of this review provides the information on consumption of fish, including current dietary recommendations and intakes which positively affect the health and to meet fish intake and CVD risk reduction Sri Lanka.

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INTRODUCTION

Sri Lanka's coastal fishery contributes a greater share of marine fish production compare to off shore and deep sea production. The total marine fish production as per 2013 was 445, 930 MT where as the inland production was 66,910 MT (MFAD, 2014). Sri Lanka's coastal zone covers around 24 % of land area with about 32% of 19 million people in a critical life line that anchors the countries social economic and environmental development (Fernando, 2002). Major diet of Sri Lankan is rice and fish(FAO, 2012).

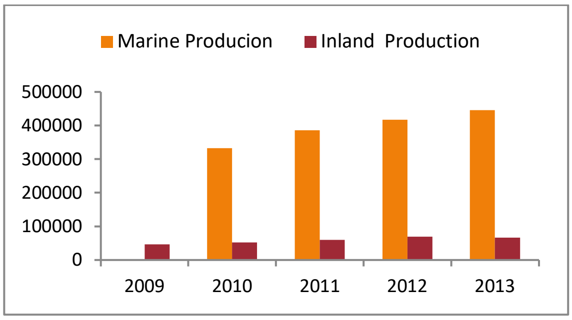

Fig 1a: Annual Marine and Inland Fish Production in MT in Sri Lanka (2009-2013)

Since the marine production was significantly greater than inland fish production as shown in fig,1a,people from the lowland and midland primarily depend on inland fish production. In Eastern part of Sri Lanka, 2/3 of population are living inland areas and they consume the inland fishes mostly. Fig 1b shows the area of the inland water bodies compared to the land in the Eastern Province. A 95 % of Eastern Sri Lankan consume fish as their main protein source in diet and eat fish daily. Although the marine fish production is locally available in Sri Lanka, all Sri Lankan have not received marine fish and they depend on inland fish production and eat fatty fishes. Significant level of CHD patients are reported in Sri Lanka (11.69%). Therefore, this review explores the relationship, type of fish eating, amount of fish eating, demographics of the people with relation to fish consumption and factors related with CVD and fish consumption and lipid profile of fish.

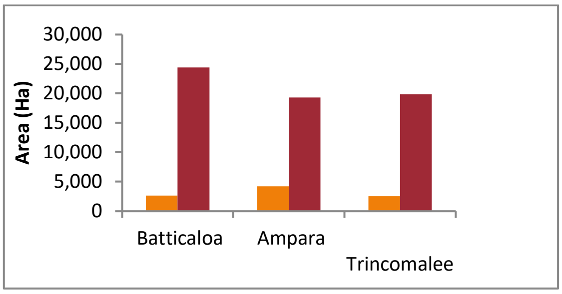

Fig 1b: In Easter Province, Land (blue) and Inland water area (red)

Fish Consumption in World

Capture fisheries and aquaculture supplied the world about 148 millions tonnes of fish in 2010, of which about 128 million was utilized as food for people, and preliminary data for 2011 indicated the increased production of 154 millions tonnes, of which 131 millions tons utilized as food as stated in the (Table 2a, Fig 2a) . Of the 126 millions tones available for human consumption in 2009, fish consumption was lowest in Africa (9.1 millions tonnes with 9.1 kg/per capita), while Asia accounted for two thirds of total consumption, with 85.4millions tonnes (20.7.kg/percapita), of which 42,8 millions tonnes was consumed the outside china (15.4 kg/percapita) (FAO 2013). Fish are particularly important in Asian context where they contribute significantly to human food needs, particularly,to those individuals in densely populated countries at risk of under nutrition and malnutrition conditions.

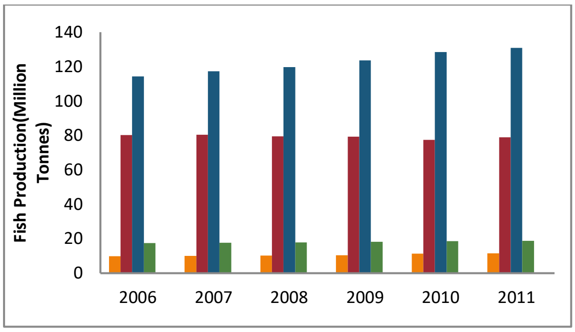

Fig. 2a Changes of Fish Production, Human Consumption, Per capita fish consumption of the world; Inland fish production (blue), Marine fish production (red), Human consumption (green) and Per capita food fish supply (purple)

Fish Consumption in Sri Lanka

The per capita consumption of fish has been increased in the world as seen in fig 2a (FAO, 2009a). The marine fish and inland production in 2013 in Sri Lanka were 445,930 MT and 66,910 MT respectively. Sri Lankans have appetite for fish accounts for the average per capita fish consumption of 22kg/year which accounts for nearly 55 percent of the animal protein intake of the average in Sri Lanka (FAO, 2010). As per the 2012 record, 50.7 g/day is consumed the Sri Lankans averagely (MFARD, 2014). As fish is important and indispensable in the meal, local consumption is gradually increasing in Sri Lanka. Major caught vital fish and seafood species in Sri Lanka are yellow-fin tuna (*Thunnus albacores*), Spanish mackerel (*Scomberomonus commerconi*), trevally (*Caranx ignobilis*), skipjack tuna (*Katsuwonius pelamis*), other tuna species variety of rock fish species (eg: *Lethrinus* sp), shore seine species (*Amplygaster sirm, Stolephorous* spp) and inland species, *Tilapia* spp and cyprinids (FAO, 2004). Sri Lankan are expert in preparing various types of fish dishes using different variety of fish and have their own distinguish style of cooking fish curries. One of the very popular dishes is " Ambul Thiyal" in Sri Lankan context.

Most of the Sri Lankans who are living low and high land areas eat processed fish like dried or smoked fish whereas the people in urban use canned fish food consumption since the availability of desired species are not available in the market and high price of fish. People living in the midland and low land areas mainly depend on Inland fish and its production reported comparatively with marine production very low. Most popular fish species are fatty species which are namely, *Wallago attu, Etroplus suratensis, Tilapia niloticus, Orecocromis mossabicus,* and *Channa channa*. It is generally known that individuals who eat fish regularly or at least twice a week reduce the risk of heart disease (DGA, 2010). Though the People in Sri Lanka were blessed with sea, it is difficult because it is beyond the average man's income to eat fish regularly since the prices of fish are exorbitant. The people living along the coastal regions benefit much more from eating fish because they can buy fish cheaper than other people in the country and live longer (Ministry of Fisheries, 2013). Tuna, Mackeral, Caranx and Sardines seem to have higher concentrations of omega 3 fatty acids than inland fishes like tilapia (Nezhard, *et al* 2008).

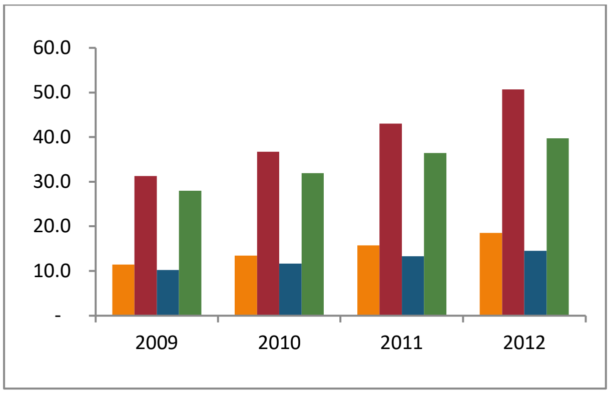

Fig 2b; Fish consumption per day increased during four year period among Sri Lankan; Target (kg/Year) (blue), Target (g/day) (red), Achievement (kg/year) (green) and Achievement (g/day) (purple)

Farmed tilapia is supposed to have higher concentration of omega-6 fatty acids, possibly because they are fed with omega 6 type of foods like corn, which contains omega 6 fatty acids. Omega-6 is required by the body, but most of the foods consumed in Sri Lanka have more omega 6 type fatty acids such as vegetable oils taken for cooking. Too much of omega-6 may lead to unhealthy situations such as heart disease and lowering immune system (Gunatillaka, 2007). Omega-3 forms are an essential fatty acid for our body because it cannot be formed within the body. The essential components of omega-3 fatty acids beneficial to the body are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) which are particularly heart healthy and have cooling effects, sometime referred to as 'anti-inflammatory' effects. Inflammation seems turning out to be at the base of many health problems including heart disease, diabetes, some types of cancers and arthritis. Omega-3 also helps prevent the blood clots which cause many strokes. It is better for health to get the quota of omega-3 through eating fish rather than from the fish capsules. Sivashanthini *et al*., (2011) studied the proximate composition of marine species*, Scomberoides* fish which are consumed by people. Chandrani *et al*.,(2012) reported five species of Leionathidae family contain higher percentages of polyunsaturated fatty acids and also stated the health related fatty acids in different species of fishes in Sri Lanka.

Karunaratna *et al*., (2010) stated that the highest percentage of polyunsaturated fatty acids in white muscle in yellow fin tuna (72.3%) and red muscle (73.49%) in Kawakawa. Edirisinghe *et al*., (1998) stated that sea food plays a very important role in human food and nutrition, Jayasinghe *et al*., (1996) reported that trace amounts of 22: 4n-6 have been in most commercial species of fish in the cold waters in Northern hemisphere.

Factors affecting Fish Consumption

The regular fish consumption is one possible health improving practice (Sidhu, 2003), but actual fish consumption is determined by many factors. The considerable amount of research has shed light on consumers' motives and barriers for fish consumption, relationship between consumption of fish/seafood and attitudes (Olsen, 2003), role of life cycles (Myrland *et al*, 2000), experience and habit (Myrland, 2000; Torendsen, *et al*, 2003), socio-demographic characteristics (Myrland *et a*l, 2000; Olsen, 2003; Torendsen *et al*, 2004), health and diet beliefs (Troendsen *et al* 2005; Verbeke *et al,* 2005), and convenience (Olsen,2003).

A few studies have focused on consumers's fish quality perception and quality evaluation. In a study of Nelson *et al*1997, a qualitative approach was applied a derive quality dimensions of importance to consumers, revealing the desired quality diamension are specially linked with family and well being, thus relating to personal relevance of fish quality. In another study of consumers' evaluation, it was found that many consumers are unable to feel attributes of fresh fish to evaluate the overall expected quality (Juhl and Poulsen, 2000).

Cardiovascular diseases (CVD) in Sri Lanka

When considering deaths due to coronary heart diseases (CHD), large proportion of deaths occurs due to myocardial infarction. Currently, ischemic heart disease (IHD) including myocardial infarction is the leading cause of mortality in hospitals in Sri Lanka. Sri Lanka has observed hospital admission rates due to IHD at 330 hospitals admissions per 100,000. These rates are comparable to those in Organization for Economic Cooperation and Development (OECD) countries (330-1,200 per 100,000). Given that the Sri Lankan population is younger than that of OECD countries, this rate will be higher on an age-standardized basis than admission rates in many developed countries (World Bank 2008). Local statistics confirm that 71% of all annual deaths in Sri Lanka take place due to chronic non communcable diseases (NCDs). The year 2013 has been declared by the Ministry of Health as the Year of NCDs in order to lay emphasis on the impact of NCDs on the country as a whole (Ministry of Health 2013).

Unhealthy food could be defined as foods that contain high-salt content, high-sugar content, high trans-fatty acids and saturated fat (Ministry of Healthcare and Nutrition,2009). High consumption of fruits and vegetable is strongly associated with better health outcomes. Although the traditional Sri Lankan diet is vegetable based, a large proportion of adults (82%) do not consume adequate amount of vegetable at present. Despite the availability of an abundance and variety of fruit in Sri Lanka, the average consumption is found to be inadequate. Despite a modest consumption of fat (15%-18%) by the Sri Lankans, higher percentage of saturated fats is included in the diet compared to unsaturated fat(Ministry of Healthcare and Nutrition, 2009). Higher saturated to unsaturated fat ratio is an important risk factor for development of cardiovascular diseases. The daily intake of salt (10g /day) and added sugar (60g/day –based on food consumption data, 35 g/day based on individual dietary records) is also high in Sri Lankan diet when compared to WHO recommendations.

Cardiovascular diseases can also be attributed to a large number of modifiable as well as non-modifiable risk factors. While advancing age and heredity or family history are considered non-modifiable risk factors, high blood pressure (hyper tension), abnormal blood lipids, tobacco use physical inactivity, obesity, unhealthy diet and high blood sugar are identified as major modifiable risk factors. (ref)

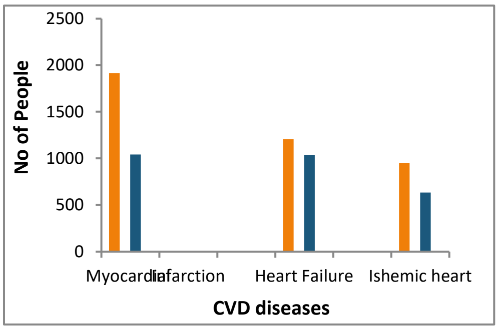

Fig c. shows the death of people due to CVD and it is significantly high compared to population;

Fig c shows the number of death of male and female due to Myocardaial infarction, Heart failure, Ischemic heart disease in 2007 in Sri Lanka. In Sri Lanka, non communicable diseases (NCD) have received considerable global attention, cardio vascular diseases chief among them, since they are largely preventable. It is an alarming trend that 65 % of annual deaths (7 out of 10 deaths) in Sri Lanka are attributed to noncommunicable diseases (NCDs) categorized into cardio vascular diseases, cancers, chronic respiratory diseases and diabetes (Island, 2014). Among these NCDs, 30% is attributed to cardiovascular diseases including ischemic heart disease, stroke and peripheral vascular disease. As the world statistics reveal 80% of cardiovascular diseases is reported from lower and (Randimal Attygale, 2013) middle income countries .

Fish Consumption and Cardiovascular disease

Cardiovascular disease (CVD) is a major cause of morbidity and death in the world. Prevention of CVD is public health goal and comprises several avenues of action, of which one of the most effective may be the inclusion of fish in the diet (Kris-Etherton *et al*., 2002). Fish intake is related to CVD risk reduction in both observational and clinical intervention trials and the 2010 *Dietary Guidelines for American* recommends consumption 8 ounces or more of seafood weekly to provide an average consumption of 1750 mg per week (250 mg per day) which are long chain omega-3 (LCn-3) fatty acids Commonly consumed omega-3 fatty acid "oily fish" are mackerel, tuna, anchovies , salmon and trout. (DGA, 2010).

Table I shows a summary of published CVD related to reported fish intake. Although there are consistencies in results between studies, likely based on study method variability, the overwhelming conclusions that of an association of reduced CVD risk with fish intake, particularly for reduced risk of death from cardiac events. Fish species providing high levels of EPA and DHA may be more protective agent of CVD. Recent data suggest that docosapentaenoic acid (DPA: 22: 5n-3), an intermediate product in the conversion of EPA to DHA, also found in marine sources may have its own particular effects upon CVD –related outcomes . In general, LCn-3 may reduce CVD risk through anti-lipidemic , anti-inflammatory , anti-platelets , and anti-arrhythmic mechanisms.

Table 1: Reported fish consumption and Cardiovascular disease

Reference	Year	Primary Outcomes
Kromhout *et al.,*	1985	An inverse relationship was observed between fish consumption and coronary artery disease death over 20 years of follow up
Burr *et al.,*	1989	Fatty fish intake (≥2-3 times /week) reduce mortalit men after

		myocardial infarction
Dolecek	1991	Consumption of small amounts of fish (reported as n- fatty acids) associated with reduced risk of coronary heart diseases
Siskovick *et al*	1995	Intake of fatty fish (≥1 mean/week) was associated with a 50% reduction in risk of primary cardiac arrest
Ascherio *et al.,*	1995	No significant relationship was observed between fish intake and risk of coronary disease
driguez *et al*	1996	High fish intake (≥2 times /week) among heavy smokers (> 30 cigarettes /day) reduced relative risk of coronary heart disease mortality by half
Daviglus *et al*	1997	An inverse relationship was observed between fish intake and coronary heart disease , especially non-sudden death from myocardial infarction
Albert *et al*	1998	Fish make ≥ weekly associated with reduced sudden cardiac death

Oomen *et al*	2000	Total fish consumption was not associated with coronary heart disease mortality: fatty fish consumption was associated with reduced coronary heart disease mortality.
Iso *et al*	2001	Higher fish consumption (≥1-3 times/month) associated with reduced risk of thrombotic infarction but not related to hemorrhagic stoke
Yuvan *et al*	2001	Men consuming (≥200g of fish /shellfish) weekly had reduced risk of fatal MI compared to those consuming < 50g/week, no risk reduction was observed for stroke or isochemic heart disease.
Hu *et al*	2002	Higher fish consumption (≥1-3 times /month) associated with reduced coronary heart diseases risk among women
He *et al*	2003	Risk of ischemic stroke was significantly lower in men who

		ate fish 1-3 times /month
Hu *et al*	2003	Higher fish consumption (≥1-3 times/month) associated with reduced coronary heart disease risk among women with diabetes
Mozaffarian *et al*	2003	Consuming tuna or other broiled or baked fish ≥3 times/week reduced risk of ischemic heart disease death , reported fried fish / fish sandwich intake showed no association
Osler *et al*	2003	Fish intake of ≥1 time / week compared to < 2 times /month was not associated with the incidence of coronary heart disease
Erkkila *et al*	2004	Consumption of fish (≥2 servings of fish or ≥1 serving of tuna or dark fish weekly) was related to significantly reduced progression of coronary artery stenosis in women with coronary artery disease.
Jarvinen *et al*	2006	Higher fish consumption was associated with a decreased risk of coronary heart disease in women while no association was observed with men
Streppel *et al*	2008	Intake of fatty fish was associated with reduced risk of sudden coronary death
Yamagishi *et al*	2008	An inverse relationship was observed between fish intake and cardiovascular mortality , especially for heart failure
De Goede *et al*	2010	Fish consumption reduced fatal myocardial infarction and coronoary heart disease risk in a close dependant manner , no association was observed with nonfatal myocardial infarction

Intake of fish varies due to regional, economic cultural and personal factors on the other hand, there are national and global production forces that influence availability and price. Widespread increases in the intake of fish to meet recommendations for CVD risk reduction will only be possible if there are adequate fish supplies to satisfy the demand (Norday, 2001). The supply of seafood from global capture fisheries has plateaued and is unlikely to supply adequate amounts of additional sea food to the world's growing population (Branch *et al.*, 2011) and thus aquaculture production is essential to meet the shortfall (FAO, 2012).

Coronary Heart Disease (CHD)

As reviewed by Stone (1996) three prospective epidemiological studies within populations reported that men who ate at least some fish weekly had a lower coronary heart disease (CHD) mortality rate than that of men who ate none (Kromhout *et al*., 1995; Daviglus *et al*., 1997). More recent evidence that fish consumption favorably affects CHD mortality, especially non sudden death from myocardial infarction (MI), has been reported in a 30-year follow-up of the Chicago Western Electric Study (Zhang *et al*., 1999). Men who consumed 35 g or more of fish daily compared with those who consumed none had a relative risk of death from CHD of 0.62 and a relative risk of nonsudden death from myocardial infarction (MI) of 0.33. In an ecological study conducted by Zhang *et al*, 1999) fish consumption was associated with a reduced risk from all-cause, ischemic heart disease and stroke mortality across 36 countries. In addition, in a study of Japanese living in Japan or Brazil, Mizushima *et al*., (1997) reported a dose-response relationship between the frequency of weekly fish intake and reduced CVD risk factors (eg, obesity, hypertension, glycohemoglobin, ST-T segment change on the ECG). Until recently, little information was available about the effects of fish and omega-3 fatty acids and risk of CHD in women. A study conducted with women in the Nurses' Health Study (Hu et al., 2002) reported an inverse association between fish intake and omega-3 fatty acids and CHD death. Compared with women who rarely ate fish (less than once per month), the risk for CHD death was 21%, 29%, 31%, and 34% lower for fish consumption 1 to 3 times per month, once per week, 2 to 4 times per week, and >5 times per week, respectively (*P* for trend=0.001). Comparing the extreme quantities of fish intake, the reduction in risk for CHD deaths seemed to be stronger for CHD death than for nonfatal MI (RR 0.55 versus 0.73).

Recommendation of Fish Intake

Fish provides 72 percent of the animal protein requirements of the Sri Lankan population. The per capita fish intake of Sri Lanka has increased from 22 grams per day in 2009 to 45 grams per day in 2014, but it is still far below the target of 60 g/ day, based on WHO recommendations to prevent malnutrition (MOF). The current *Dietary guidelines for Americans 2010* (DGA) recommendation for fish intake is "at least 8 ounces of cooked seafood per week", and to "select some seafood that is rich in omega-3 fatty acids, such as mackerel, sardines, anchovies, salmon, trout (DGA,2010). The American Heart Association (AHA) 2002 recommendation is the consumption of fish two times weekly for risk reduction of CVD. In individuals with established CVD, the recommendation is for approximately 1 g and EPA and DHA daily, preferably from oily fish. European recommendations for n-3 fatty acids and fish, primarily for the prevention on CVD, are approximately 250-500mg/day through consumption of oily fish (NDA, 2012). The estimated average intake of LCn-3 (EPA, DPA and DHA) for Americans 60-170mg/day, mostly through fish consumption (Whelan *et al.,* 2009). There are no identifiable differences by race or ethnicity in intake patterns, although intakes are highest among the top income tertile (UDA, 2012; 37-39). In the US, no Dietary Reference Intake (DRI) for EPA and DHA currently exists; but based upon recent research, there is strong support in the US for the establishment of a DRI of 250-500 mg/day of EPA and DHA for CVD risk reduction (Harris *et al.*, 2009; Kris-Etherton *et al*., 2009). At best, EPA and DHA intake in the US is only 20% of the proposed DRI level.

Omega – 3 Fatty Acids : Background and Metabolism

Omega-3fatty acids are essential, polyunsaturated fatty acids (PUFAs), i.e. they cannot be synthesized *in vivo*. In diet, large quantities are found naturally in fish oil, flaxseed and some nuts. They derive from alpha-linolenic acid and mainly occur as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are both anti-inflammatory (Goldberg & Katz ,2007).

These are then converted to active metabolites, in particular, molecules known as resolvins and protectins. Omega-3- polyunsaturated fatty acids (PUFAs) are long chain PUFAs found in plants and marine sources such as fish, mussel, oyster, shrimp but primarily cold water fish (Friedman & Moe, 2006) but also exist in a wide range of plant products such as nuts, especially English walnuts, seeds, namely sesame (Namiki, 2007), flax seed and vegetable oils such as soybean and canola besides olive (Whelan & Rust, 2006). Omega-3-fatty acids, unlike saturated fatty acids, have been associated with various health benefits relating to treatment of rheumatoid arthritis (Rennie *et al.,*2003) and coronary artery disease (Freeman, 2000) whilst improving blood pressure control and preserve renal function even in hypertensive heart transplant recipients (Holm *et al*., 2001). The effects of omega-3- PUFAs on various cancers and also on other clinical disorders including oedema, rheumatoid arthritis, cardiovascular disease and others, is closely related to their metabolism. Hence replacement of saturated fat with unsaturated fatty acids for the protection against metabolic diseases and disorders, omega-3- PUFAs have been widely accepted as one of the cornerstones of healthy lifestyle and nutrition.

Identification of PUFAs

The very long chain PUFAs (C18, C20 and C22) include the two essential fatty acids; linoleic acid (LA) [18:2 (omega-6)] and a-linolenic acid (a-LN) [18:3 (omega-3)] and are most commonly found in large amounts in some certain fish species (Poisson, 1990). These two essential fatty acids (EFAs) are the only sources for the production of important longer chain PUFAs such as prostaglandins; dynamic but short compounds that control blood vessels and other body functions. Arachidonic acid (AA) (20:4 n-6) (Pereira *et al*., 2004), a member of the n-6 PUFA, is another source of prostaglandins (PG). Eicosapentaenoic acid (EPA) (20:5 n-3), LN and docosahexaenoic acid (DHA) (C22) and EFAs are called three PUFAs or n-3 omega PUFAs (n-3 series) (Pereira *et al*., 2004). In addition, dietary LN can be converted to the EPA and DHA. AA, LN and LA, long chain and highly unsaturated fatty acids are truly essential, while C18 compounds, stearic and palmitic acids, abundant in animal fat, should be considered as conditionally essential (Trautwein, 2001).

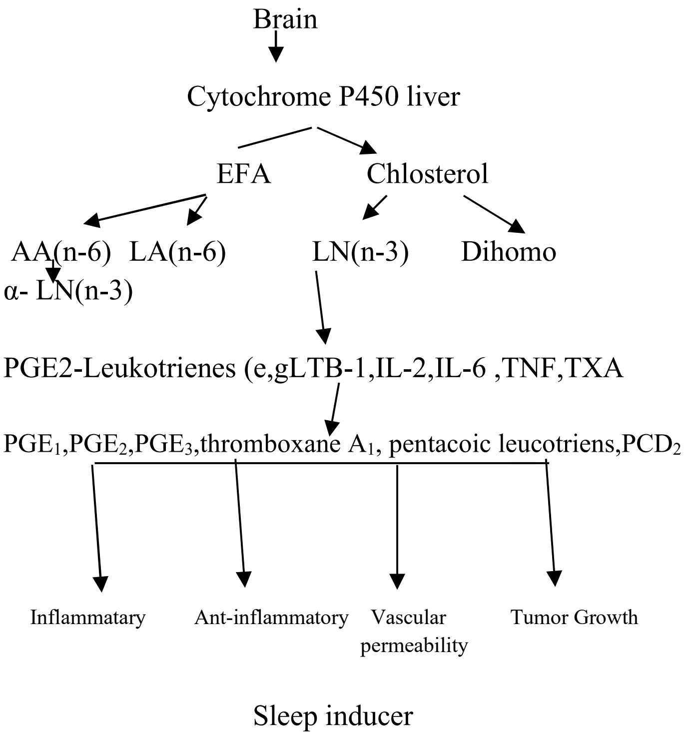

Fig d; Biochemical pathways of omega-3 and omega-6 fatty acids with their effects on metabolism

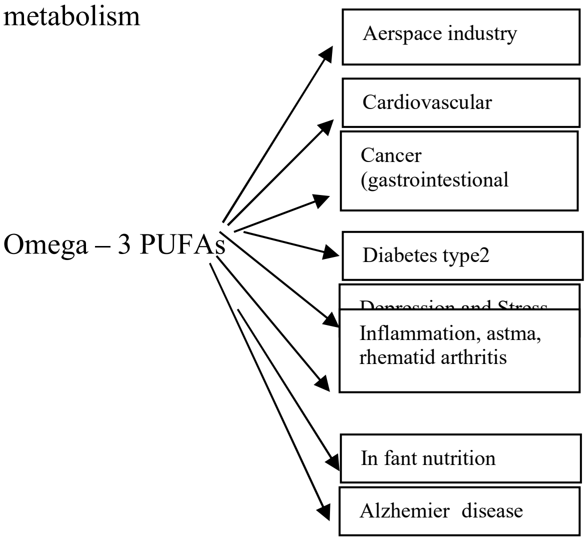

Fig e: Current application fields of omega -3 PUFAs

Cardiovascular disease and omega -3 PUFAs

Besides the anti-inflammatory effect of omega-3 PUFAs, the other beneficial and protective effect of these fatty acids is on the cardiovascular system. Trans fatty acids, cholesterol and saturated fats are mainly responsible for atherosclerosis. On the contrary, omega-3 PUFAs are beneficial in reducing cholesterol and thus the risk of myocardial infarction (Zyriax & Windler, 2000). Another cause of cardiovascular disease formation is the hypertriglyceridaemia, an increase in the serum triglyceride in blood serum level, can also be reduced by the addition of omega-3 (fish oil) to the diet (Hau *et al*., 1996). The modern sciences of dietetics and nutrition studies the relationship between nutrition and health so that people can protect themselves from diseases or ameliorate the adverse effects of these diseases by means of appropriate diets (Table 1). According to Harris *et al*. (2003), of all known dietary factors, long-chain omega 3 fatty acids may be the most protective against death from coronary heart disease (CHD), by increasing the omega-3 intake of an individual with coronary artery disease by approximately 1 g day (Tables 2 and Table 3). The best prevention of cardiovascular diseases appears to be achieved by replacing saturated fats with omega-3 PUFAs (Temple, 1996). Such replacement appears to have a direct effect on the intrinsic ability of a cardiac muscle fibre to contract at a given fibre length. These effects indicate to the beneficial and protective effects of omega 3 fatty acids in preventing sudden death following myocardial infection (Bhatnagar & Durrington, 2003). Eicosanoid synthesis from n-3 omega PUFAs minimizes the production of PGE2 and thromboxane A2, IL-1, IL-2 and IL-6 (Fig. 1). Specifically, minimising the production of thromboxane A2 and IL-1, IL-2 and IL-6 by n-3 omega PUFAs protects the individual's health by protecting cardiac tissue from clot formation, platelet aggregation and thrombosis risk (Arkhipenko & Sazontova, 1995; Wahlqvist, 1998). A further benefit for the cardiovascular system is the lowering of total cholesterol by omega-3 PUFAs (Kusunoki *et al*., 2003). Indeed, daily supplementations of 3 g in men and EPA containing soy phospholipid at 10% level in rat can decrease total serum cholesterol and LDL (bad cholesterol, which sticks free cholesterol in blood onto the walls of blood vessels) whilst slightly increasing high density lipoprotein (Lox, 1990) (HDL: good cholesterol, which is claimed as protective against hypertension and calcification since it can take bound cholesterol from the walls of vessels and return it to blood stream). Supportive data is found in a study in rats in which a soybean oil containing 5% EPA showed a significant decrease in serum triglyceride (TG) levels (Dasgupta & Bhattacharyya, 2007).

Although most studies define omega-3 PUFAs as lowering cholesterol and LDL as reducers, a few studies suggest that long term use of omega-3-PUFAs results in increase in LDL. Schacky *et al.* (1999) found a 7% increase in LDL, following a period of 2 years during which subjects consumed 3 g of EPA and DHA daily. Similarly, 3 g /kg/7 day use of EPA and DHA, was shown to lower the amount of VLDL (Very Low Density Lipoprotein, which is claimed as more harmful than LDL because of its greater ability to bind free cholesterol on to the walls of blood vessels), while enhancing the production rate of LDL. The cholesterol reducing and HDL increasing effect of omega, n-3 PUFAs makes them one of the most effective substances in the prevention of atherosclerosis, comparable to niacin, statins, and fibres (Barbeau *et al*., 1997; Rader, 2003). Omega n-3 PUFA supplementation of the diet has also been seen to lower the blood pressure in rats (Yahia *et al*., 2003).

Table 2. Amounts (g) of some foods which should be consumed to provide 1 g EPA and DHA

Fish/Sea food	Gamday-1 to provide 1g EPA and DHA per day

Fresh tuna	70-360
Sadines	60-90
Salmon	60-135
Mackeral	60-250
Herring	45-60
Rainbow Trout	90-105
Halibut	90-225
Cod	375-750
Haddock	450
Catfish	450-600
Flounder	210
Oyter	75
Lobster	225
Crab	255
Shrimp	330
Clam	375
Scallop	525

Table 3. Fat content /EPA+ DHA(g /100g and fat content/ α – linolenic acid (g/100g) ratio of some various fish , marine products.

Fish/Sea Food	Fat content (g/100 g)	EPA+DPA (g/100 g)	Fat content (EPA*DHA) (g/100g)
Eel	24.5	0.83	29.51
Herring	17.8	2.72	6.54
Sprat	16.6	3.23	5.14
Tuna	15.5	3.37	4.60
Salmon	13.6	2.86	4.76
Mackeral	11.9	1.75	6.8
Carp	4.8	0.30	16
Sardine	4.5	1.39	3.24*
Sword	4.4	1.79	2.45*
fish	2.7	0.59	4.58
Trout	1.7	0.51	3.33*
Halibut	0.6	0.18	3.33*
Cod	0.6	0.16	3.75*
Haddock	1.9	0.20	9.5
Lobster	1.4	0.30	4.66
Shrimp	1.4	0.15	9.33
Mussels	2.3	0.50	4.60
Ancovy	13.9	2.44	5.70
Sardine			

*Source Sauci et al,(1994). * Food which appears as perfect from the point of omega-3 content.*

The protective effect of omega-3 PUFAs on the cardiovascular system, can easily be increased by niacin, bile acid, resins, sport and exercise, which highlights the importance of life style and nutrition on health. Similarly, increased intakes of marine omega-3- PUFAs can result in decreased triglycerides, fibrinogen and platelet aggregation, which are considered to be beneficial for cardiovascular diseases (Wijendran & Hayes, 2004). It was found in a study by Sweeney *et al.* (1999) that Japanese students who had relocated to USA showed higher serum triglyceride, cholesterol levels and a high risk of cardiovascular diseases when compared with the general population of Japan. The apparent explanation of this difference is that the native Japanese diet is high in omega-3-PUFAs whilst the American diet is not. The fact that higher serum triglyceride, cholesterol levels and high risk of cardiovascular diseases found in Japanese students, following their moving to the USA, can be compared with the lower triglyceride and cholesterol levels of the general population of Japan, is a clear example, showing the significance of n-3 omega fatty acids as cardio protectors (Sweeney *et al*., 1999). Liu *et al*., (2001) added omega-3-PUFAs to bread, as one of the most commonly consumed food products and this enrichment lowered serum triglyceride level and also total serum cholesterol by increasing HDL. Russo (2009) recommends the intake of 1 g /day of EPA and DHA for treatment of post Myocardial Infarction (MI) and prevention of sudden cardiac death and other cardiovascular dysfunctions. Omega-3- PUFAs also inhibit protein kinase C and increase in nitrous oxide release, which inhibits platelet adherence to the collagen and thus eases blood circulation (Schoene, 2001; El-seweidy *et al*., 2002).

Thus, supplementation of the diet with n-3 omega PUFAs is very effective and protective against cardiovascular diseases, such as hypertension and atherosclerosis (Shoda *et al*., 1996; Temple, 2002) and even in the reduction of the incidence of sudden cardiac death (Villa *et al*., 2002). Omega-3 PUFA supplementation of the diet of rats, decreased the mortality rate, caused by myocardial infarction (MI) while decreasing creatine phosphokinase as the indicator for MI. In contrast, an increased mortality rate was observed when the rat diets were supplemented by saturated fat from coconut oil (Nageswari *et al*., 1999). Mente *et al*. (2009) conducted a systematic search of Medline for cohort studies on randomized trials investigating dietary exposures in relation to CHD.

The protective effects of n-3 omega PUFAs on cardiovascular health, very surprisingly may accelerate heart beat, cause adverse effects and even be life threatening according to the findings of Raitt *et al.* (2005). In their randomised controlled trial involving 200 patients, 1.8 g daily fish oil supplementation caused significantly important accelerations of the heart beat in patients with ventricular tachycardia (VT), an accelerated heart beat initiated within the ventricular that may prevent heart from pumping enough blood and ventricular fibrillation (VF), a heart failure due to sudden cardiac death. The findings are seriously important since it indicates that patients with VF and VT should rather avoid omega-3 PUFAs.

Studies (Bang *et al*., 1971; Kromann & Green, 1980) have shown that the diet is high in omega-3 polyunsaturated fats (PUFAs) from sea mammals and fish has a protective effect. In one study, which obtained information on deaths from different diseases for 2005 from US National Center for Health Statistics, Danaei *et al*. (2009) examined lifestyle and metabolic risk factors in death and determined a deficiency of Omega-3 PUFAs as the eighth highest killer in death for people living in USA. Deficiency of omega-3 PUFAs with 84 000 death /year even beat out nutrition rich in trans fat with 82 000 deaths annually as a causative factor. The same study findings also suggested that the huge number of annual deaths (84 000 /year) in USA is mainly depended on deficiency of Omega-3 PUFAs, i.e EPA & DHA, which can also be prevented by omega-3-PUFA supplementation and a change in nutrition style to a diet rich in omega-3 PUFAs. Thus, the study indicates to the importance of increasing consumer awareness of the dangers of about the drastic deficiency of omega-3- PUFAs. A recent meta-analysis of ramdomised controlled studies of omega-3 fatty acid supplementation of the diet by Preiss & Sattar (2009) confirmed that this treatment had a cardiovascular benefit but suggested that more data would be needed to support use in clinical practice. However according to Lee & Lip (2003), the use of omega -3 PUFAs should be considered as a part of comprehensive secondary prevention strategy in patients following myocardial infarction. It has also been proposed that ischemia-induced arrhythmias may be prevented by n-3 PUFA supplementation (Leaf *et al*., 2003). In spite of many studies, indicating the protective effect of omega-3 PUFAs on cardiovascular system, the minimum dose which shows this effect, was not established until the studies by Weber & Raederstorff (2000). They stated that, 1g /dayomega-3 PUFA (in the form of fish oil) is sufficient to show this serum triglyceride and LDL lowering effect whilst a daily intake of 3 g of EPA and DHA is regarded as safe by Food and Drug Administration (O'Keefe & Harris, 2000). Similarly, Retterstol *et al*., (1996) claimed the serum triglyceride and LDL lowering effect of omega-3-PUFAs,, but as combined with drugs to treat hypercholesterolemia. On the other hand, an insufficiency of mega-3- PUFAs and high amounts of omega-6- PUFAs may also increase the atherogenic effects of environmental chemicals such as polychlorinated biphenyls (PCB), leading to dysfunction of the vascular endothelium. In spite of the cardiovascular protective effects of omega-3 PUFAs, omega-6 PUFAs do not appear to be correlated with cardiovascular benefits even though they lower LDL and cholesterol (Lecerf, 2009).

The effects of LA or PCB are contrary to those of omega-3-PUFAs, disrupting the endothelial barrier function. Cellular enrichment with LA can amplify PCB induced endothelial cell dysfunction, which brings about a cardio toxic effect (Slim et al., 2001). These findings underline the importance of omega-3-PUFAs supplementation in daily nutrition in the prevention of diseases associated with high cholesterol levels. There appears to be significant evidence that n-3 omega PUFAs have a protective effect on the cardiovascular system and evidence of an inhibitory effect on inflammation. This evidence made omega-3-PUFA rich foods, especially fish meat, as the most popular meat option when compared with other meats. Among red meat options, beef cut (round) may be advised with a higher a-LN content (32 mg /100 g) (as the indicator of omega-3 PUFAs) and lower palmitic acid content (958 mg/100 g)followed by beef cut (leg) with 22 mg/ 100 g alpha- LN content and 2804 mg/ 100 g palmitic acid content and dark chicken meat with 25 mg/ 100 mgmLN content and 1097 mg /100 g palmitic acid content (Almeida *et al*., 2006). Linseed oil with 55% LN content may be considered as the optimum plant oil being the richest among others although it is often neglected by the media.

It is possible that the cardioprotective effect of omega-3 PUFAs is dependent on the anti-inflammatory properties. The anti-inflammatory properties are due to the incorporation of EPA and DHA into cell membranes. NADPH oxidase, the main producer of cell membranes, is also activated by n-3 omega PUFAs. Only after this activation, does the enzyme regulate the cell membrane production and make it more durable and cells become more resistant to extrinsic and intrinsic destructive factors, especially inflammatory agents. This protection against inflammation is the same for the cells of blood vessels and the heart (Heine et al., 1999). On the other hand, when omega 3 fatty acids are provided, there is partial replacement of arachdonic acid in cell membranes by EPA as one of the important members of n-3 omega PUFAs which results in strengthening of the cell (Calder, 2003a, b). The anti-inflammatory and cardioprotective functions of omega-3 PUFAs improve the immune system. This improvement which is very important for immune system diseases such as HIV/AIDS, requires nutrients to power the immune system and support maximum cellular protection and function for long term survival.

It can be clearly stated that, omega-3 PUFAs have potential as an immune system defenders and enhancers in immune system deficiencies (Zimmerman, 1997).

Lipid Profile in Fish

Pattern of fatty acids profile in fish lipids

When FA profiles of zander fish in Egirdir Lake Turkey were investigated by Celik *et al* ., (2005), it was noted that the propotionof PUFA was greater in comparison of saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA). Testi *et al.,* (2006) and Ozden, (2005) differently found that PUFA was the highest in rainbow trout followed by MUFA and SFA. During the analysis of FA composition for the rainbow trout by Celik *et al*., (2008) MUFA was the highest followed by SFA and PUFA. Similar pattern of FA for rainbow trout and other fresh water fish species has been accounted by Pirestani *et a*l., (2010); Yanar *et al*., (2006) and Rahman *et al*., (1995). Blanchet *et al*., (2005) and Haliloglu *et al*., (2004) again in the same fish species, determined different results than those of other studies. The researchers concluded that the lipid and FA proportion of fish differ depending on a variety of aspect for instance the species, maturity period, age and size, seasonal conditions and geographical status of the (Gonzalez *et al*., 2006 ; Gulsun *et al.,* 2005; Gokce *et al*., 2004; Steffens).

Masaki et al.,(2000) reported PUFA content in four freshwater fish species (grass carp, Chinese bass, swamp eel and bluntnose black bream muscle) from China ranged from 10.5.to 44.2%. It was observed that EPA and DHA accounted for 7.18 and 5.39% of the total FA in rainbow trout muscle lipid. The level of 22:6 DHA and 20:5 n-3 EPA for different species of fresh water (swamp eel, Chinese bass, grass carp, bluntnose black bream muscle) from China was ranged from 0.2-4.7%, such observed range from DHA and 20 EPA were lesser in comparison of marine fish (Masaki et al., 2000; Kaneniwa,*et al*., 1997). Conversely other six fish species (Chinese sea bass, crucian carp, snake head fish, silver carp, common carp and big head carp) of Chinese fresh water in which DHA and EPA contents ranged from 1.8-23.4%. The contents of DHA was 5% higher than of the those of marine fish. The level of omega-3 PUFA for example AA (arachidonic acid , 20:4 n-6), DHA and EPA was also found high in Lake Biwa freshwater in Japan, there was some deviation in the FA profile for different fish species (Masaki *et al*., 2000 and Kojima *et al*., 1986 a,b).

Yanar *et al*., (2006) and Haliloglu *et al*., (2004) showed that among MUFAs, oleic and pamitoleic acids were the predominant FA in lipid of Rainbow trout , accounting for almost 64 and 26% of total MUFA. The eicosanoic (20:0. Arachidic acid) and docosanoic (22: 0, Behenic acid) MUFA are leading in few marine fish for instance herring , sardine , capelin , sand lance and salmon and low levels were observed in fresh water fish (Masaki *et al* .,2000). In literature several researchers (Kaneniwa *et al*., 1997; Ota *et al*., 1990 Sasaki *et al* 1989) suggested that eicosanoic and docosanoic MUFA were included in lipids of marine fish diets originate from Copepoda. However lower rank of both MUFA, such as in marine fish diet (Ratnayake and Ackman, 1979a,b).

Ozogul *et al*., (2007) reported major FA of fish captured from freshwater Lake (Seyhan Dam) in Adana, Turkey were myristic acid (14:0), palmitic acid (16:0), palmitoleic acid (16:1) , heptadecanoic acid (17:0) , stearic acid (18:0) , oleic acid (18: 1 n-9cis) , linoleic acid (18:2 n-6) , linolenic acid (18:3 n-3), cis-8 , 11,14 eicosatrienoic acid (20:3 n-6), cis - 5,8,11,14, 17 –eicosapentaenoic acid (EPA, 20:5 n-3) and cis -4,7,10,13,,16,19-docosahexaenoic acid (DHA , 22:6 n-3) . FA profile of freshwater fish composed of 23.2-43.8% PUFA, 10.7-22.7 % MUFA and 28.0-34.6% SFA.

The most abundant individual FA in fish studied were palmitic , oleic eicosapentaenoic , and docosahexaenoic acid . Celik *et al* ., (2005) calculate the overall amount 30.5% of SFA in lipids of Zander fish from Egirdir Lake Turkey. Generally, fish have quite lower percentage <30% of SFA , excluding certaine fish species (Gular *et al.,* 2008; Nettleton and Exler, 1992). Masaki *et al* .,(2000) examined the fresh water fish species from China and calculated 17.3-34.5 % of total SFA (Alasaver *et al* 2002). Palmitic acid content in Zander fish were approximately 65% of total SFA composition and in Rainbow trout , accounting about 62% of all SFA s . Wang et al ., (1990) illustrated the Palmitic acid level in Lake Superior fish ranged from 68 to 79 % and Jesu Verglio *et al* .,(2007) also calculated the level of this acid for Brazilian fish ranged from 54 to 63 % of the SFA , Cleik *et al*., (2005); Jankowska *et al*., (2003); Halioglu (2002) and Rahman *et al*., (1995) reported comparable results for few fresh water fish species as well as for wild Zander fish.

Cooking of Fish and Fatty acids

The cooking of fish improves their digestibility, enhances palatability, and provides a safe eating by killing harmful bacteria, other microorganisms, and parasites (Gokoglu *et al.,* 2004), enhance its flavor and taste (Unusan 2007). Traditionally, there are numerous fish cooking methods varying among different countries and even within the same country, depending on the species of the fish (Gokoglu *et al.,* 2004). During cooking, chemical and physical reactions occurred therefore digestibility is increased due to protein denaturation but the content of thermo labile compounds and polyunsaturated fatty acids is often reduced (Finot 1997). Modifications in the fatty acid profiles by different culinary technologies, such as frying, boiling, roasting, microwave cooking, grilling or cooking with steam, have been studied in some fish species (Gladyshev *et al.,* 2005). Since most fish species are consumed cooked, the nutritive value of the final cooked product is of major importance for human health.

Unfortunately, polyunsaturated fatty acids (PUFAs) are susceptible to oxidation and to thermal damage due to excessive heat. Modifications of fatty acids during cooking could be related to three mechanisms: oxidation, loss of fatty acids by diffusion (in roasting) or fatty acid exchange between fish and oil (in frying). The nutritive value of fish can be affected by processing or cooking methods. The effects of different processing and cooking methods on nutritive values of different fish species have been previously studied (Garcia-Arias *et al.,* 2003). Polyunsaturated fatty acids are known to be highly susceptible to oxidative breakdown (Sant'ana and Mancini-Filho 2000) and heat catalysts strongly for the initiation of lipid peroxidation (Kingston *et al.,* 1998). The oxidation and changes in lipid profile of the fish lipid resulting during cooking can lead to certain medical disorders such as higher risk of atherosclerosis (Modugo *et al.,* 2011), oxidative stress, and exacerbate atherogensis by incorporating into lipoproteins (Penumetcha. 2000). It has been recognized that lipid oxidation product exert toxic carcinogenic and mutagenic effects (Yang *et al.,* 1998) and causing a decrease of fatty acid digestibility and adsorption as a result of cross-linking reactions of secondary lipid oxidation with protein (Kirk 1984). Several studies have shown that cooking methods effect on fatty acid compositions and the lipid class composition of fish (Garcia-Arias *et al.,* 2003). The effect of cooking methods on the fatty acid profile has been studied however, there were moisture and lipid losses during cooking amongst the different methods. The fatty acid profile showed only minor differences between the methods apart from an increase in PUFAs in the deep fried salmon due to linoleic acid uptake from the frying oil (Danae *et al.,* 2010). Most of cooking methods such as poach, steam, microwave and oven baked showed good preservation of ω-3 fatty acids, and this is attributed to internal protection of ω-3 fatty acids in king salmon. It also was the effect of heating on fish lipid sprat, herring and bream. Furthermore, the increasing of peroxide value was proportional to heating temperature. DHA increased by 20% after 1 h heating at 100°C ; a 45% decrease after 15 min heating at 160°C and a 70% loss after 1 hr at the same temperature. EPA under the same conditions reported losses of less than 20% (Kolakowska *et al.,* 2010).

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