

Tenualosa ilisha -A Rich Source of omega-3 Fatty Acids

EPA + DHA PUFAs

Fatty acids

B. P. Mohanty
Soma Das
Utpal Bhaumik
A. P. Sharma

EPA + DHA



Fatty acids

PUFAs



Central Inland Fisheries Research Institute (Indian Council of Agricultural Research) Barrackpore, Kolkata-700 120







INDIAN COUNCIL OF AGRICULTURAL RESEARCH FISHERIES DIVISION, KAB-II

Nutrient Profiling and Evaluation of Fish as a Dietary Component

Outreach Activity Consortium # 3



Central Inland Fisheries Research Institute, Barrackpore Lead Institute

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TENUALOSA ILISHA -A RICH SOURCE OF OMEGA-3 FATTY ACIDS

B. P. Mohanty Soma Das Utpal Bhaumik A. P. Sharma



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Barrackpore, Kolkata - 700 120, West Bengal

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B. P. Mohanty Soma Das Utpal Bhaumik A. P. Sharma

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डा. एस. अय्यप्पन सचिव एवं महानिदेशक

DR. S. AYYAPPAN SECRETARY & DIRECTOR GENERAL भारत सरकार

कृषि अनुसंधान और शिक्षा विभाग एवं भारतीय कृषि अनुसंधान परिषद् कृषि मंत्रालय, कृषि भवन, नई दिल्ली – 110 114

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE, KRISHI BHAVAN, NEW DELHI - 110 114
TEL: 23382629; 23386711 FAX: 91-11-23384773
e-Mail: dg.icar@nic.in

FOREWORD

Hilsa is a highly prized food fish of our country. It accounts for 15-20% of the total fish landing of Hooghly estuary. Owing to its rich nutritional quality and taste, hilsa is a highly sought after fish. The fishery is in a decline on account of emergence of obstacles blocking its migration, wanton destruction of juveniles (jatka fishery) besides brooder fishing and recruitment overfishing.

It is a pleasure to see that the team of scientists at CIFRI, Barrackpore have prepared the bulletin entitled "*Tenualosa ilisha* - A Rich Source of omega-3 Fatty Acids". This bulletin outlines the nutrient profile of hilsa and its importance in the human health. Hilsa is a rich source of omega-3 fatty acids and play a major role in providing pharmaceutical elements for physiological maintenance of body tissue. Omega-3 fatty acids play an important role in reducing risk of heart diseases, stroke, hypertension, diabetes, arthritis, cancer in adults; age-related macular degeneration, dementia in elderly and ADHD and childhood asthma in pediatric population. It is also rich in vitamins and minerals which help in preventing deficiencies diseases. The bulletin refers hilsa as `salmon of the east', by comparing the nutritional aspects of both the fishes, but the supply is not enough to sustain the demand. In view of its nutritional and economic importance, there is a need for enhancing the stock of Hilsa by adopting sustainable management practices.

The authors deserve appreciation in bringing out this bulletin on `Hilsa' as a part of the ICAR Outreach Activity-3 Consortium on `Nutrient Profiling and Evaluation of Fish as a Dietary Component'. It is a useful publication which highlights the importance of hilsa and further research can be helpful in providing a complete knowledge on the species.

Dated the 31st March, 2011 New Delhi (S. Ayyappan)

Foreword

Apart from being one of the important fishery resources of our country, hilsa is regarded as a nutritious and highly tasty fish. It is rich in omega-3 polyunsaturated fatty acids, amino acids, vitamins and minerals. The species is in high demand; but its supply is declining each year owing to the excessive fishing of juveniles and brooders. This bulletin on 'Tenualosa ilisha- A Rich Source of Omega-3 PUFAs' as a part of the ICAR Outreach Activity-3 Consortium on 'Nutrient Profiling and Evaluation of Fish as a Dietary Component' has outlined the fishery importance of hilsa, its nutritional components, its role in decreasing the disease impacts and the health benefits. Consumption of hilsa along with our staple food provides a healthy diet and it is highly recommended. Since the availability of hilsa is much less compared to its demand, effective management measures are to be followed in conserving and enhancing the fishery.

I am sure that this bulletin will be a standard reference. More research can be conducted on hilsa in order to get a full insight on its nutritional quality.

(B. Meenakumari)

Deputy Director General (Fisheries), Fisheries Division, Indian Council of Agricultural Research, Krishi Anusandhan Bhavan-II, Pusa Campus, New Delhi-110012



Foreword

ilsa contributes to about 15-20% of the total fish landing of the Hoogly-Matlah estuary and forms an important component of the inland fish resource of our country. Due to many anthropogenic activities like dams and reservoirs, jatka fishery of juveniles and overexploitation of brooders, the Hilsa fishery has shown declining trend over the years. Hilsa is very important in terms of its nutritional quality providing a rich source of proteins, polyunsaturated fatty acids, vitamins and minerals. Owing to its rich content of nutrients, it is recommended as a part of healthy and balanced diets and already being taken as delicacies in West Bengal. The omega-3 fatty acids present in Hilsa helps in preventing the incidence of heart diseases, stroke, arthritis, cancer, diabetes and many other preventable diseases, thus contributing immensely in maintenance of human health. But, unfortunately its supply cannot match the fish demand. This brings the need for strengthening the Hilsa fishery by efficiently managing the resource through various management strategies. In this background, publication of a bulletin on 'Tenualosa ilishaa rich source of omega-3 PUFAs' as a part of the ICAR Outreach Activity-3 Consortium on 'Nutrient Profiling and Evaluation of Fish as a Dietary Component' by the project investigators is worth appreciating and deserves congratulation.

(S. D. Singh)

Assistant Director General (Inland Fisheries)
Fisheries Division, Indian Council of Agricultural Research
Krishi Anusandhan Bhavan-II, Pusa, New Delhi-110012



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TENUALOSA ILISHA – A RICH SOURCE OF OMEGA-3 FATTY ACIDS

INTRODUCTION

The Indian shad hilsa, *Tenualosa ilisha* (Hamilton) belonging to the Family: Clupeidae, is one of the most important tropical fishes of the Indo-Pacific region and has occupied a top position among the edible fishes owing to its taste, flavor and culinary properties. Popularly known as hilsa, it is a fast swimming euryhaline (able to adapt to a wide range of salinities) fish (3) known for its cosmopolitan distribution in brackish water estuaries, marine environment in the Indo-pacific faunistic region and in the riverine environments where it migrates for breeding. Major catch of hilsa, about 95%, comes from Bangladesh, India and Myanmar. Naturally hilsa is in great demand in this part of the world and enjoys very high consumer preference. Its high commercial demand makes it a good forex earner.

Under the Genus: *Tenualosa*, five species have been recognized from the estuaries and coastal waters of the tropical Asian region (Table 1) out of which *Tenualosa ilisha* and to some extent *T. toli* and *T. kelee* are prevalent in the Indian waters. The normal habitat, maximum age and growth and trend of migratory habit differ from species to species. Hilsa is an anadromous clupeid, it migrates to the freshwater riverine environment for breeding and the juveniles migrate to the estuary and sea for feeding and growth; such migration has been attributed to the olfactory memory. Among the five species. *T. ilisha* is the major component of fishery in the Hooghly estuary accounting for 15-20% of the total fish landing.

The anadromous hilsa has a peculiar life cycle, opposite to the catadromous Atlantic eel (Anguilla anguilla). Hilsa shows an upstream migration (up to around 1,200 km) during the breeding season depending largely on the instigation of south-west monsoon (2) and subsequent inundation of the major rivers of India, Bangladesh and Burma. Hence, there is a considerable fluctuation in fish catch based on the intensity of the monsoon during the propagation phase. An optimum temperature of 23°C and a period of 23-26 hours are required for hatching (4).

In general, hilsa shows a relative fecundity with peak breeding season during the full moon in the month of October (6) and produces 2.3 million eggs. The larvae and juveniles find their way downstream to the sea after a period of 5-6 months where they find their feeding ground. Fry grows to a bigger size of 12-20 cm in about 6-10 weeks and becomes jatka (hilsa juveniles). Jatka starts migrating to the sea for further growth and maturity. Hilsa mature in the sea in one year and start their breeding migration towards the river upstream and thus the propagation cycle continues (5). The major rivers in India where the hilsa migration has been recorded are the Ganga, Brahmaputra, Mahanadi, Daya, Godavari, Krishna and Cauvery on the east coast of India; the rivers Narmada, Tapti and Purana Ulhas on the west coast of India.

Hilsa juveniles are plankton feeders; graze upon zooplankton at higher rate for five to six months age in freshwater. They change their food habit based on age and seasonal variability and slowly modified as phytoplankton feeder. During maturation, shads minimize their food intake and stop feeding during spawning migration.

Hilsa can grow a total length of 60 cm, but commonly found specimens measures from 35-40 cm. A large-sized hilsa weighs about 2.5 kg. Bangladesh India and Myanmar are the countries contribution about 95% of hilsa (4). In India, fishery forms one of the largest share in country's gross production accounting about 75% of the total world catch (7) which is about 25% of the total fish production in Bangladesh (8, 9). There is a huge abundance of hilsa along the mouth of Palk Bay, in the River Godavari, Cauvery Eastuary in Tamil Nadu coast (11), Vishakhapatnam Daya River and Chilka Lagoon along Orissa Coast (7) and especially in Hooghly- Matlah estuary (10) along West Bengal coast. Along west coast, the river mouths of Narmada and Ulhas along Saurashtra coast (12) are the suitable zone for hilsa spawning. There is also report of hilsa catch in the Krishna iver mouth along the east coast in Andhra Pradesh (13). Main catches come from flooded estuaries of Ganges and Mahanadi. 'Sangha jal', gill net and bag net are more popular fishing gears used for hilsa catch mostly during monsoon and winter months. Commercial catch constitute a mean length of 300 to 480 mm during June to August; on the other hand, the lower length of fishes occur in the range of 300-400 mm during January to March.

Hilsa has found a reference in literature, rhymes and religious stories of Bengal. The fish is being offered to Goddess Durga as a sign of happiness at the time of 'Durga Pooia' festival (7). Many of the Hindu Bengali families buy two hilsa fishes (Joda ilish) during Puja festival like Saraswati Puja (The Goddess of Learning and Beauty) in the beginning of Spring and also on the day of Lakshmi Puja (The Goddess of Wealth and Prosperity) in autumn. This shows natural acceptance of the fish as a relished and prized item in the Community. There is a high demand in the market for hilsa, but side by side its supply

is less; hence, it commands a higher price in Bengal (West Bengal of India and Bangladesh) as well as in south-west coast of the Bay of Bengal.

Clupeids contain high lipid percentage (dry wt/wt compared to other tropical fish which is about 58.6% (*T. toli*). Physicochemical characterization of Terubok and Menhaden oils in terms of percentage fatty acid content in menhaden and Terubok hilsa were of 0.49 and 3.52 respectively (17). More than 20 fatty acids types observed in Terubok fish oil. The major saturated fatty acids (SFA) were myristic

acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0). Oleic acid (C18:1), palmitoleic acid (C16:1) and myristoleic acid (C14:1) were contributing in high amount of Mano unsaturated fatty acids (MUFA). The unsaturated fatty acids (PUFA) consist of linoleic acid (C18:2n-6, LA), a-linoleate acid (C18:3n-3, ALA), stearidonic acid (C 18:4n-3, SA), arachidonic acid (C20:4n-6, AA), eicosapentaenoic acid (C20:5n-3, EPA) and docosapnexa acid (C22:6n-3, DHA). Study in fatty acids percentage of Terubok oil can be described in following order USFA>SFA>MUFA>PUFA. Another clupeid Menhaden shows a different order such as USFA>PUFA>MUFA>SFA. Possible causes in variation of fatty acids compositions are geographic location, species, fasting period, type of diet, level of maturity and spawning and maturation cycles (18).

Table 1(a): Hilsa of tropical Asian region

Common name	on name Scientific name		mon name Scientific name Origin	
Terubok	Tenualosa toli	Malaysia		
Terubok	Tenualosa macrura	Indonesia		
Hilsa	Tenualosa ilisha India			
Pha Mak Pang	Tenualosa thibaudeaui	Mekong		
Not known	Tenualosa reevesii	South China		

Source: Blaber et al., 1997.

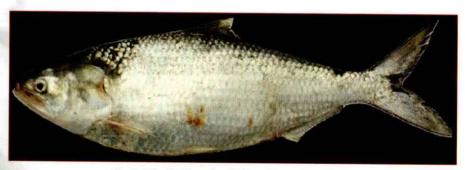


Fig.1. The Indian shad hilsa, Tenualosa ilisha

Table 1(b): Regional/Local name of Hilsa

Tenualosa ilisha	Local names
Bengali	ইলিশ্, Ilish
Odia	ଇଲିଶି, Ilishii
Telegu	పులస . Pulasha, Polasa
Gujarati -	Modenn or Palva
Pakistan (Sindhi)	Pallu Machhi . ي ڇيلو م

Nutritional importance of fish in the diet:

Regular consumption of fish can provide various health benefits which have been established by several clinical investigations and feeding trials. Marine fishes are rich source of omega-3 fatty acids, which are heart-friendly. Studies show that longer lifespan of Japanese and Nordic populations may be partially due to their higher consumption of fish and seafood (Ref. 19). Fish are also good for the skin. Nutritionists recommend that fish be eaten at least 2-3 times a week. Oily fish is claimed to help prevent a range of other health problems from mental illness to blindness (discussed later). Now-a-days the health benefits of eating fish are being increasingly understood.

Massive studies to evaluate the health benefits of eating fish are being taken up globally. Recently, US Government has sponsored probe of \$20-million to evaluate quarantine aspects of fish oil and Vitamin D to prevent heart disease, cancer and a range of other illnesses. The heart benefits of eating fish and oily fish in |Particular, have: been flagged up for years and are insolently used by seafood companies when marketing their products.

Fats and oils:

There are mainly three types of fatty acids: saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and poly-unsaturated fatty acids (PUFAs). The first two are synthesized endogenously, but the third one cannot be synthesized by the humans and therefore must be obtained from the diet.



Figure 2: EPA and DHA oils and pills

The human body cannot synthesize n-3 fatty acids de novo, but it can form 20-carbon unsaturated n-3 fatty acids (like EPA) and 22-carbon unsaturated n-3 fatty acids (like DHA) from the eighteen-carbon n-3 fatty acid α -linolenic acid. These conversions occur competitively with n-6 fatty acids, which are essential closely related chemical analogues that are derived from linoleic acid (LA). Both the n-3 α -linolenic acid and n-6 linoleic acid are essential nutrients which must be obtained from food. Synthesis of the longer n-3 fatty acids from linolenic acid within the body is competitively slowed by the n-6 analogues. Thus accumulation of long-chain n-3 fatty acids in tissues is more effective when they are obtained directly from food or when competing amounts of n-6 analogs do not greatly exceed the amounts of n-3.

Table 2: Fatty acid nomenclature

Systematic name	Trivial name	Short hand notation
Octanoic	Caprylic	8:0
Decanoic	Capric	10:0
Dodecanoic	Lauric	12:0
Tetradecanoic	Myrsitic	14:0
Hexadecanoic	Palmitic	16:0
Octadecanoic	Stearic	18:0
cis-9-Hexadecenoic	Palmitoleic	16:1n-7
cis-9-Octadecenoic	Oleic	18:1n-9
cis-9,12-Octadecadienoic	Linoleic	18:2n-6
All cis-9,12,15-Octadecatrienoic	α-Linolenic	18:3n-3
All cis-6,9,12-Octadecatrienoic	γ-Linolenic	18:3n-6
All cis-8,11,14-Eicosatrienoic	Dihomo-γ-linolenic	20:3n-6
All cis-5,8,11,14-Eicosatetraenoic	Arachidonic	20:4n-6
All cis-5,8,11,14,17-Eicosapentaenoic	Eicosapentaenoic	20:5n-3
All cis-7,10,13,16,19-Docosapentaenoic	Docosapentaenoic	22:5n-3
All cis-4,7,10,13,16,19-Docosahexaenoic	Docosahexaenoic	22:6n-3

Nomenclature: n-3/n-6 (ω-3/ω-6) Fatty acids

n-3 **fatty acids**, popularly referred to as ω **(omega)** -3 **fatty acids**, are a family of polyunsaturated fatty acids (PUFAs) that have in common a final carbon-carbon *double bond* in the *n*-3 position; that is, the third bond from the *methyl* end of the fatty acid (Fig.3). For example, ω-3 18:4 (stearidonic acid) or 18:4 ω-3 or 18:4 n-3 indicates an 18-carbon chain with 4 double bonds, and with the first double bond in the third position from the CH₃ end. So in free fatty acid form, the chemical structure of stearidonic acid is as shown below.

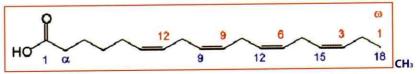
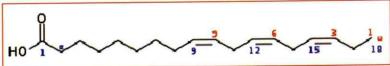


Figure 3: Chemical structure of stearidonic acid showing numbering conventions

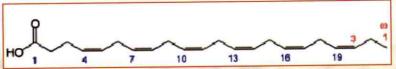
n-3 fatty acids which are important in human nutrition are: α -linolenic acid (18:3, n-3; ALA), eicosapentaenoic acid (20:5, n-3; EPA), and docosahexaenoic acid (22:6, n-3; DHA). These three PUFAs have 3, 5 or 6 double bonds in a carbon chain of 18, 20 or 22 carbon atoms, respectively. All double bonds are in the cis-configuration, i.e. the two hydrogen atoms are on the same side of the double bond (Fig 4). Most naturally-produced fatty acids (created or transformed in animalia or plant cells with an even number of carbon in chains) are in cis-configuration where they are more easily transformable. n-3 compounds are more fragile than n-6 because the last double bond is geometrically and electrically more exposed, notably in the natural cis configuration.



4a.: Alpha (α)-linolenic acid (ALA), an essential n-3 fatty acid.



4b.: Eicosapentaenoic acid (EPA).



4c.: Docosahexaenoic acid (DHA).

Figure 4: Chemical structure of ALA, EPA & DHA

Functions of essential Fatty Acids

In the body, essential fatty acids serve multiple functions. In each of these, the balance between dietary ω -3 and ω -6 strongly affects function. They are modified to make: (1) the classic eicosanoids (affecting inflammation and many other cellular functions), (2) the endocannabinoids (affecting mood, behavior and inflammation), (3) the lipoxins from ω -6 EFAs and resolvins from ω -3 (in the presence of aspirin, down regulating inflammation), (4) the isofurans, neurofurans, isoprostanes, hepoxilins, epoxyeicosatrienoic acids (EETs) and Neuroprotectin D, (5) they form lipid rafts (affecting cellular signaling), (6) they act on DNA (activating or inhibiting transcription factors such as NFêB, which is linked to pro-inflammatory cytokine production).

Importance of omega-3 fatty acids in diet

The long chain PUFA (LC-PUFA) (i.e. C20 and C22) that belong to the omega (ω)-3 family, have a number of neutraceutical and pharmaceutical applications. Eicosapentaenoic acid (EPA, 20:5 ω 3) and docosahexaenoic acid (DHA, 22:6 ω 3) are the important ω 3 PUFA. EPA and DHA are important in treatment of arthrosclerosis, cancer, rheumatoid arthritis, psoriasis and diseases of old age such as Alzheimer's and age-related macular degeneration (AMD).

Omega-3 fatty acids are considered a boon to human beings. Body functions are improved by their intake. Brain is a vital organ that keeps the body functions in proper control. These fatty acids increase the volume of grey matter which is associated with mood and regulation of emotions. The risk of dementia and Alzheimer's disease is also checked by them. They also boost the cognitive functions in elderly people, and there is improvement in osteoarthritis by prevention of loss of cartilage that acts as a cushion in the joints and checks inflammation. They protect against prostrate and breast cancer by stimulating the deaths of tumor cells. These fatty acids increase HDL cholesterol and reduce triglycerides, a condition that is favorable for the heart. These keep the blood in fluid state by decreasing platelet aggregation.

Although omega-3 fatty acids have been known as essential to normal growth and health since the 1930s, awareness of their health benefits has dramatically increased in the past few years. The heart-health benefits of the long-chain omega-3 fatty acids - DHA and EPA - are the best known. These benefits were discovered in the 1970s by researchers studying the Greenland Eskimos. The Greenland Eskimos consumed large amounts of fat from seafood, but displayed virtually no cardiovascular disease. The high level of

omega-3 fatty acids consumed by the Eskimos reduced triglycerides, heart rate, blood pressure, and atherosclerosis. As the importance of omega-3 fatty acids to health has received increasing awareness, the number of food products enriched in omega-3 fatty acids has increased. Many manufacturers add fish oil or flax oil into their final product to enrich it in omega-3 fatty acids. Some animal products, such as milk and eggs, can be naturally enriched for omega-3 fatty acids by feeding the animals a diet that is rich in omega-3 fatty acids. Some countries have recognized the importance of DHA and permit the following biological role claim for DHA: 'DHA, an omega-3 fatty acid, supports the normal development of the brain, eyes and nerves.'

Fish oils are the major source of PUFA, and considerable evidence has indicated that $\omega 3$ PUFA in fish oil are actually derived via the marine food chain with zooplankton consuming $\omega - 3$ PUFA-synthesizing micro algae. LA and ALA are predominant in green vegetables and some plant oils. Although some research has derived qualitatively that human can convert the parent ALA to EPA and then to DHA, the most recent consensus is the degree of conversion is 'unreliable and unrestricted'.

The most widely available source of EPA and DHA is cold water oily fish such as Salmon, Herring, Merckerel, Anchovies, and sardines. Oils from these fish have a profile of around seven times as much n-3 as n-6. Other oily fish such as tuna also contain n-3 in somewhat lesser amounts.

Other Clinical interventions of @-3 PUFAs:

Inflammatory bowel disease:

Therapeutic nature of omega 3 PUFA, particularly the fish derivatives have been well studied by several researchers where it applied to alleviate ulcerative colitis, Crohn's disease and inflammatory bowel disease (20). There are many disease conditions with inflammatory component, in which LC-PUFA might be of benefit (Table 3).

Table 3: Diseases and conditions with an inflammatory component in which long chain n-3 fatty acids might be of benefit (21to 41)

Disease	References to the role of inflammation		
Rheumatoid arthritis	Feldmann and Maini, 1999		
Crohn disease	Dignass et al., 2004		
Ulcerative colitis	Dignass et al., 2004		
Lupus	Smolen et al., 2005		
Type 1 diabetes	Donath et al., 2003		
Type 2 diabetes	Donath et al., 2003, Caballero, 2004		
Cystic fibrosis	Dinwiddie, 2005		
Childhood asthma	Lemanske, 2002		
Adult asthma	King, 1999		
Allergic disease	Bochner and Busse, 2005		
Psoriasis	Kreuger and Bowcock, 2005		
Multiple sclerosis	Rostasy, 2005		
Neurodegenerative disease of aging	Rostasy, 2005; Klegeris and McGeer, 2005		
Atherosclerosis	Ross, 1999; Glass and Witztum, 2001		
Acute cardiovascular events	Glass and Witztum, 2001; Plutzky, 1999		
Obesity	Wellen and Hotamisligil, 2003		
Systemic inflammatory response to surgery, trauma, and critical illness	Bone et al., 1997		
Acute respiratory distress syndrome	Bhatia and Moochhala, 2004		
Cancer cachexia	Argiles, 2005		

Mental depression:

Mental depression brings disability and sluggish nature of the physiological nature among young adults. Earlier epidemiological studies have showed the correlation between vitamin D and depression phenomenon. Deficiency of serum vitamin D has been reflected in higher level of depression in human (42). Fish consumption has been considered as a proxy for a healthier lifestyle that protects against depression. Depression episode studied (43) could give a strong support of the hypothesis that high fish consumption protects against depression. It was true for the men but not for the women. Fish

consumption in higher proportion has been suggested to protect against depression among men with high alcohol consumption. This opens a future aspect to study the role of fish consumption as part of the overall diet and lifestyle.

ω-3 vs obesity

Obese individual possess significantly lower plasma concentration of total n-3 PUFA as comparison with healthy weight individuals (44). The study have shown the affect of n-3 PUFA on the weight status and abdominal adiposity. Higher plasma levels of total n-3 PUFA were associated with healthier BMI, waist and hip circumference. Obesity is the consequence of the excessive accumulation of fat in adipose tissue that causes several health problems including cardiovascular disorders such as hypertension, stroke and CHD, conditions associated with insulin resistance such as type 2 diabetes, and certain types of cancers (45, 46) resulting in significant morbidity and mortality. Studies of on health benefits of weight loss showed a weight loss of 5-10% can reduce these risks of obesity (47, 48). Recent studies on effect of n-3 PUFA to improve adherence to weight loss and weight maintenance have been conducted successfully on abdominal adipose tissues. Although it is difficult to maintain weight loss in the long term (49), experimental trials with ω -3 PUFA diet will provide a better horizon.

n-6 Fatty acids

Like n-3 fatty acids, n-6 fatty acids (such as γ -linolenic acid and arachidonic acid) play a similar role in normal growth. n-6 is "better" at supporting dermal integrity, renal function, and parturition. These preliminary findings led researchers to concentrate their studies on n-6, and it was only in recent decades that n-3 has become of interest.

The biological effects of the *n*-6 fatty acids are largely mediated by their conversion to n-6 eicosanoids that bind to diverse receptors found in every tissue of the body. The conversion of tissue arachidonic acid (20:4n-6) to n-6 prostaglandin and n-6 leukotriene hormones provides many targets for pharmaceutical drug development and treatment to diminish excessive n-6 actions in atherosclerosis, asthma, arthritis, vascular disease, thrombosis, immune-inflammatory processes and tumor proliferation. Competitive interactions with the *n*-3 fatty acids affect the relative storage, mobilization, conversion and action of the n-3 and n-6 eicosanoid precursors. This competition was recognized as important when it was found that thromboxane is a factor in the clumping of platelets, which leads to thrombosis. The leukotrienes were similarly found to be important in immune/inflammatory-system response, and therefore relevant to arthritis, lupus, and asthma. These discoveries led to greater interest in finding ways to control the synthesis of *n*-6 eicosanoids. The simplest way would be by consuming more *n*-3 and fewer *n*-6 fatty acids.

Table 4: List of com	mon n-3 and n-6 fatt	y acids found in nature
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Common name	Lipid name	Chemical name	Abbre- viation
Common n-3 (ω-3) Fatty	y Acids		
α -Linolenic acid	18:3 (n-3)	all-cis-9,12,15- octadecatrienoi acid	ALA
Stearidonic acid	18:4 (n-3)	all-cis-6,9,12,15- octadecatetraenoic acid	STD
Eicosapentaenoic acid	20:5 (n-3)	all-cis-5,8,11,14,17- eicosapentaenoic acid	EPA
Docosapentaenoic acid	22:5 (n-3)	all-cis-7,10,13,16,19- docosapentaenoic acid	DPA
Docosahexaenoic acid	22:6 (n-3)	all-cis-4,7,10,13,16,19- docosahexaenoic acid	DHA
Common n-6 (ω-6) Fatty	Acids		
Linoleic acid	18:2 (n-6)	9,12-octadecadienoic acid	LA
Arachidonic acid	20:4 (n-6)	5,8,11,14-eicosatetraenoic acid	AA
Docosadienoic acid	22:2 (n-6)	13,16-docosadienoic acid	DDA
Docosapentaenoic acid	22:5 (n-6)	4,7,10,13,16-docosapentaenoic acid	DPA

Some medical research suggests that excessive levels of n-6 fatty acids, relative to n-3 fatty acids, may increase the probability of a number of diseases and depression. Modern Western diets typically have ratios of n-6 to n-3 in excess of 10 to 1, some as high as 30 to 1. The optimal ratio is thought to be 4 to 1 or lower. Excess n-6 fats interfere with the health benefits of n-3 fats; in part because they compete for the same rate-limiting enzymes. A high proportion of n-6 to n-3 fat in the diet shifts the physiological state in the tissues toward the pathogenesis of many diseases: prothrombotic, proinflammatory and proconstrictive. Chronic excessive production of n-6 eicosanoids is associated with heart attacks, thrombotic stroke, arrhythmia, arthritis, osteoporosis, inflammation, mood disorders and cancer.

Many of the medications used to treat and manage these conditions work by blocking the effects of the potent *n*-6 fat, arachidonic acid. Many steps in formation and action of n-6 hormones from n-6 arachidonic acid proceed more vigorously than the corresponding competitive steps in formation and action of n-3 hormones from n-3 eicosapentaenoic

acid. The Cyclooxygenase (COX)-1 and COX-2 inhibitor medications, used to treat inflammation and pain, work by preventing the COX enzymes from turning arachidonic acid into inflammatory compounds. Many of the anti-mania medications used to treat bipolar disorder work by targeting the arachidonic acid cascade in the brain. Linoleic acid (18:2, n-6), the shortest-chained n-6 fatty acid, is an essential fatty acid. Arachidonic acid (20:4) is a physiologically significant n-6 fatty acid and is the precursor for prostaglandins and other physiologically active molecules.

Like *n*-3 fatty acids, *n*-6 fatty acids (such as g-linolenic acid and arachidonic acid) play a similar role in normal growth. *n*-6 is "better" at supporting dermal integrity, renal function, and parturition. These preliminary findings led researchers to concentrate their studies on *n*-6, and it was only in recent decades that *n*-3 has become of interest.

Figure 5: Biosynthesis of Prostanoids from the different fatty acids (Ulbricht and Southgate, 1991; Calder 2008)

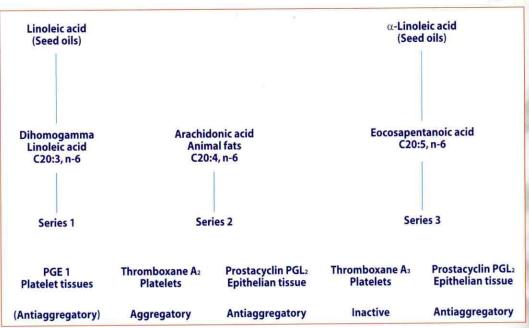
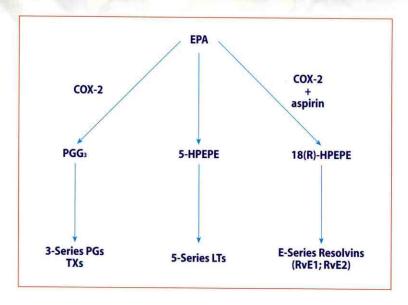


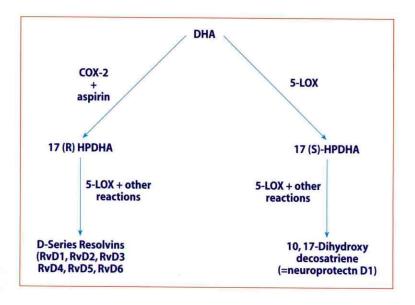
Figure 6: Outline of the pathways of synthesis of resolvins and related mediators.

COX: cyclooxygenase; HPDHA: hydroperoxy docosahexaenoic acid;

HPEPE: hydroperoxy-eicosapentaenoic acid; LOX: lipoxygenase; LT: Leukotriene;

PG: Prostaglandin; Rv: Resolvin; TX: Thromboxane (Calder, 2010)





Needs for essential fatty acids and PUFAs:

Therapeutic values of PUFA studies in fish Showed that omega-6 (@-6) groups provide nourishments for healthy skin, migraine and multiple sclerosis also for premenstrual syndrome (52). Since human and vertebrates can produce only saturated and ω -9 fatty acids (53), ω -3 fatty acids must be taken through foods. Marine seaweeds, fungi, bivalves land sponges which are able to synthesise ω -3 fatty acids (54, 55) such as Green algae Cladophora rupestris (56); red seaweed Ptilota filicna and green seaweed Anadyomene stellata contains conjugated EPA and DHA (57,58). Marine bivalve Megangulus zyonoensis is a valuable food resource in Japan, and Megangulus venulosus contain typical NMI dienoic acids, 22:2 D7, 13 and 22:2 D7, 15, identified in mainly the mantle, also in muscle, but not in the viscera (59). Hardshell clam Mercenaria mercenaria (60); Sponge (Microciona prolifera) (61) have also been studied for characterizing non-methylene-interrupted fatty acids to observe their structural and functional role in development of biological membrane and also to describe the inhibitory activity towards cancer cell lines. Fatty Acids Derived from Royal Jelly Are Modulators of Estrogen Receptor Functions (62). Marine fish can neither synthesis ω -3 fatty acids nor from shorter chain precursors such as ALA, thus ω -3 fatty acids are important in fish. In fact, fish needs PUFA for maintaining chemical composition and physiological function of cell membrane such as osmoregulation, and eicosanoid metabolism (63, 64).

Nutritional importance of hilsa

This fish is endowed with valuable fatty acids and lipids which play a major role in providing pharmaceutical elements for physiological maintenance of body tissue. Polyunsaturated omega-3 fatty acids (ω -3 PUFAs) EPA and DHA especially obtained from fish oil are reported to be potential in curing coronary heart diseases, stroke, hypertension, cardiac arrhythmias, diabetes, rheumatoid arthritis, brain development, photoreception system, cancer and depression (65, 66, 67). A 100 g hilsa contain 22.0 g Protein, 19.5 g Fat, 180 mg calcium and 250 mg of Phosphorus along with other nutrients . Highest fat content of 20% has been observed in hilsa captured from Mahanadi river mouth, while it was lower in Narmada catches along Indian coast. The crude fat content (Table 5) and fatty acid composition (Table 6, Figure 8) of different size groups of hilsa have been studied in detail. Fatty acids profiling of small pelagic fishes of Srilanka have shown highest amount of saturated fatty acids in hilsa shad (5844.5 mg per l00g fish and palmitic acid contributed 3345 mg/100g fish as compare to the other pelagics in North-West coast of Srilanka (68).

Table 7: One and three letter codon of Amino acid

A	Ala	Alanine	
В	Asx	Asparagine or Aspartic acid	
С	Cys	Cysteine	
D	Asp	Aspartate	
E	Glu	Glutamate	
F	Phe	Phenylalanine	
G	Gly	Glycine	
Н	His	Histidine	
1	lle	Isoleucine	
К	Lys	Lysine	
L	Leu	Leucine	
М	Met	Methionine	
N	Asn	Aspargine	
Р ,	Pro	Proline	
Q	Gln	Glutamine	
R	Arg	Arginine	
S	Ser	Serine	
Т	Thr	Threonine	
V	Val	Valine	
w	Trp	Tryptophan	
X		Unknown or nonstandard amino acid	
Υ	Tyr	Tyrosine	
Z	Glx	Glutamine or Glutamic acid	

Asx and Glx are used in describing the result of amino acid analytical procedures in which Asp and Glu are not readily distinguished from their amide counterparts, Asn and Gln.

(Source: Biochemistry, Lubert Stryer, 1995)

Table 8: Total amino acid profiles (in % of total amino acid) of Tenualosa ilisha.

Amino Acid	Small Size	Medium Size	Large Size
Essential			
Threonine	ND	6.32 ±0.17a	7.10 ±0.03a
Valine	6.58 ± 0.81a	6.35 ± 0.21a	5.80 ±0.81a
Methionine	3.30 ±0.29a	1.63 ±0.10b	2.72 ±0.02c
Iso leucine	5.35 ±0.12a	6.20 ±0.21b	4.69 ±0.58a
Leucine	9.25 ±0.33a	9.33 ±0.35a	8.03 ±0.06b
Phenylalanine	4.16 ±0.14a	3.71 ±0.42b	3.43 ±0.38b
Histidine	6.31 ±0.10a	5.47 ±0.41b	5.94 ±0.21a
Lysine	3.22 ±0.03a	2.35 ±0.25b	10.15 ±0.05c
Arginine	1.25 ±0.13a	0.94 ±0.03b	0.72 ±0.01c
ΣΕΑΑ	39.42	42.3	48.58
Non-essential			
Aspartic acid	10.48 ± 0.04a	11.25 ±0.40	10.21 ± 0.06
Serine	6.56 ± 0.13a	7.02 ±0.31b	5.99 ±0.13c
Glutamic acid	15.16 ± 0.47a	15.39 ±0.22a	13.06 ±0.06b
Glycine	8.46 ± 0.39a	9. <mark>01</mark> ±0.21b	8.22 ±0.25a
Alanine	9.34 ± 0.28a	9.59 ±0.15a	8.45 ±0.04b
Tyrosine	1.92 ± 0.54a	1.39 ±0.16a	0.84 ±0.16b
Proline Proline	0.20 ± 0.05a	1.34 ±0.39b	0.91 ±0.10b
Cysteine	0.32 ± 0.03a	0.95 ±0.04b	2.11 ±0.06c
ΣΝΕΑΑ	52.44	55.94	49.79
EAA/NEAA	0.75	0.76	0.98

Values are shown as average \pm standard deviation

Beside fatty acids, hilsa is also sude in amino acids (Table 8, Figure 7). A high plasma EAAto-NEAA ratio is considered to be an index of positive protein nutritional status (70). There is significant contribution of low protein intake along with rise in NEAA to the ratio of EAA to NEAA. The favorable ratio of EAA to NEAA, about 0.70, indicates high quality protein content (71) studied semi-intensive reared sea bream and wild sea bream (72 The ratio for medium sized hilsa was 0.76 which was lying in optimal range. The EAA/NEAA ratio has significant impact for the nutritional aspect of fish feed formulation to determine the physiological growth of fish and shellfish fry or fingerlings in the aquaculture farm. The highest value recorded for squid's roe (0.93) and was lowest for sea urchin roe (0.65). For Fin fish mullet's roe had the lowest EAA/NEAA ratio (0.67) and the roe of chum salmon had the highest ratio (0.82). The EAA/ NEAA ratios for immature (0.78) and mature salmon (0.84) studied biochemical prosperities of chinook salmon based on maturity (73) which was also of similar as reported previously for immature Pollock (0.77) and chum salmon (0.82), respectively (74,75). Amino acid metabolism also depicts the physiological function of rat plasma and erythrocyte EAA-to-NEAA ratio showed a positive correlation to IGF-I and insulin whereas an inverse correlated to IGFBP-1 (76).

The paramount importance of the hilsa in nutritional point of view, is all the more enhanced by the presence of minerals. These micronutrients play a major role in the metabolic activity of the human body, by serving as co-factors of enzymes (9). The microelements (viz. Na, Mg, K and Ca) and trace elements (viz. Mn, F, Cu, Zn) are present in hilsa in good amount and their concentration per 100 g wet weight of Tenualosa hilsa are given in table 10. These minerals are highly 'bioavailable' meaning that they are easily absorbed by the body.

The mineral Fe is important in the synthesis of heamoglobin in red blood cells which is important for transporting oxygen to all parts of the body. Iron deficiency is associated with anemia, impaired brain function and in infants is associated with poor learning ability and poor behaviors. Due to its role in the immune system, its deficiency may also be associated increase risk of infections. Calcium is required for strong bones (formation and mineralization) and for the normal functioning of muscles and nervous system. Ca is also important in the blood clotting process. Zn is required for biological functioning of body as it occurs together with proteins in essential enzymes required for metabolism. Zn plays an important role in growth and development as well as in proper functioning of immune system and for healthy skin.

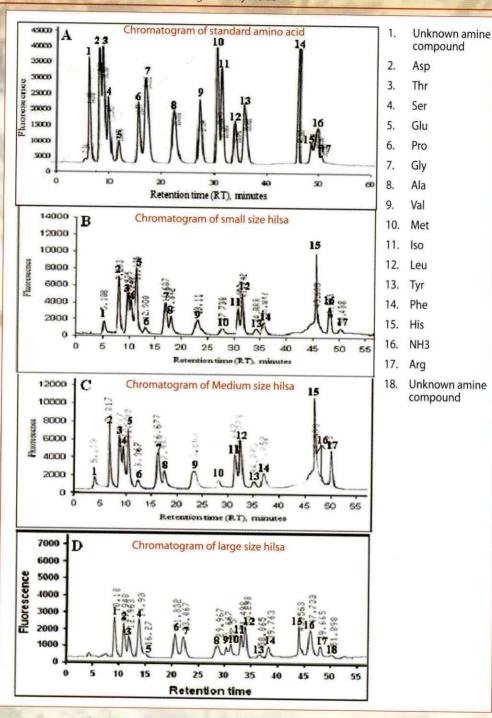


Figure 7: Chromatograms of the amino acid standards (A), small size (B), medium size (C) and large size fish (D).

Table 9: Some important minerals that Serve as Cofactors for Enzymes

Cu ²⁺	Cytochrome oxidase	
Fe ²⁺ or Fe ³⁺	Cytochrome oxidase	
	Catalase, peroxidase	
K ⁺	Pyruvate kinase	
Mg ²⁺	Hexokinase	
	Glucose 6- phosphate	
	Pyruvate kinase	
Mn ²⁺	Arginase	
	Ribonucleotidase reductase	
Мо	Dinitrogenase	
	Nitrate reductase	
Ni ²⁺	Urease	
Se	Glutathione peroxidase	
Zn ²⁺	Carbonic anhydrase	
	Alcohol dehydrogenase	
	Carboxypeptidases A & B	
	DNA polymerase	

Table 10 : Concentration of macro and trace elements per 100 g wet weight of *Tenualosa ilisha*

ELEMENTS	Small	Medium	Large
Macro elements			
Na	47.95 ±0.04a	44.97 ±0.01b	34.35 ±0.02c
Mg	2.59 ±0.07a	0.84 ±0.02b	-
K	42.43 ±0.05a	41.88 ±0.03b	0.97 ±0.02c
Ca	331.16±0.10a	261.67 ±0.09b	252.05 ±0.03c
Trace elements			
Mn	0.13 ±0.02a		0.34 ±0.03c
Fe	0.14 ±0.03a	0.21 ±0.02b	0.16 ±0.02c
Cu	0.21 ±0.04a	0.13 ±0.02b	
Zn	0.51 ±0.02a	0.47 ±0.02b	0.27 ±0.02c

Values are shown as average \pm standard deviation; (-): data absent

Table 5: Crude fat content of different size groups of Hilsa

Different size group	Crude fat (g/100g w/w)
Small	15.33 ± 0.12
Medium	16.35 ± 0.07
Large	19.15 ± 0.29

(Source: Mohanty et al., 2011)

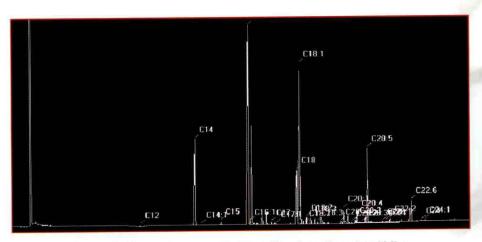


Figure 8: Chromatogram of Fatty Acids of medium-sized hilsa

Table 6 :	Table 6: Fatty acid composition of different size group				
Fatty Acid	Small Size	Medium Size	Large Size		
Saturated					
8:0 (%)	0.05 ± 0.04	0.03 ± 0.03	0.03 ± 0.01		
10:0 (%)	0.06 ± 0.02	0.05 ± 0.01	0.02 ± 0.01		
12:0 (%)	0.41 ± 0.01a	0.37 ± 0.23a	0.09 ± 0.03b		
13:0 (%)	0.24 ± 0.25a	0.05 ± 0.01a	0.02 ± 0.01a		
14:0 (%)	37.78 ± 0.12a	37.77 ± 0.02a	9.67 ± 0.48b		
15:0 (%)	1.69 ± 0.04a	1.48 ± 0.01b	0.34 ± 0.12c		
16:0 (%)	0.81 ± 0.05a	0.21 ± 0.06b	38.26 ± 0.05c		
17:0 (%)	0.82 ± 0.03a	1.05 ± 0.03b	0.19 ± 0.05c		
18:0 (%)	0.24 ± 0.02a	0.26 ± 0.06a	8.86 ± 0.16b		
20:0 (%)	0.62 ± 0.06a	0.67 ± 0.03b	0.20 ± 0.02c		
22:0 (%)	0.48 ± 0.09a	0.45 ± 0.02a	0.22 ± 0.09b		
24:0 (%)	0.43 ± 0.02a	0.44 ± 0.04a	0.11 ± 0.05b		
Σ SFA (%)	43.64 ± 0.46	42.82 ± 0.39	57.99 ± 0.68		
Monounsaturated					
14:1 (%)	0.26 ± 0.05a	0.18 ± 0.08a	0.07 ± 0.04b		
15:1 (%)	0.08 ± 0.02a	0.05 ± 0.02a	0.01 ± 0.01b		
16:1n-7 (%)	0.06 ± 0.01a	0.48 ± 0.05b	0.22 ± 0.06c		
17:1	0.25 ± 0.08a	0.29 ± 0.09a	0.07 ± 0.05b		
18:1n-9 (%)	27.55 ± 0.51a	30.66 ± 0.19b	25.42 ± 0.25c		
20:1n-9 (%)	3.47 ± 0.06a	2.27 ± 0.36b	1.23 ± 0.40c		
22:1n-9 (%)	0.38 ± 0.06a	0.64 ± 0.02b	0.09 ± 0.04c		
24:1 (%)	0.55 ± 0.13a	0.78 ± 0.05b	0.20 ± 0.13c		
Σ MUFA (%)	32.60 ± 0.48a	35.36 ± 0.65b	27.59 ± 0.79c		

Table 6: (Contd.)

Fatty Acid	Small Size	Medium Size	Large Size
Polyunsaturated			
18:2n-6 (%)	0.66 ± 0.12a	0.88 ± 0.03b	0.29 ± 0.45a
18:2tr (%)	2.66 ± 0.11a	1.84 ± 0.66b	0.59 ± 0.15c
20:2n-6 (%)	0.13 ± 0.02a	0.12 ± 0.03a	$0.03 \pm 0.02b$
22:2n-6 (%)	0.07 ± 0.01a	0.07 ± 0.01a	0.63 ± 0.21 b
18:3n-3 (%)	2.61 ± 0.06a	2.23 ± 0.04b	0.59 ± 0.13c
18:3 tr (%)	0.86 ± 0.16a	$0.68 \pm 0.05a$	0.54 ± 0.77a
20:3n-6 (%)	1.11 ± 0.06a	0.14 ± 0.004b	$0.36 \pm 0.06c$
20:3 & 21 (%)	0.13 ± 0.02a	0.17 ± 0.03b	0.02 ± 0.01c
20:4n-6 (%)	4.66 ± 0.03	4.14 ± 0.06	1.21 ± 0.33
20:5n-3 (%)	2.49 ± 0.03a	2.87 ± 0.09b	8.22 ± 0.25c
22:6n-3 (%)	8.41 ± 0.01a	8.95 ± 0.03b	2.02 ± 0.42c
ΣPUFA (%)	23.78 ±0.07a	22.11 ± 0.58b	14.75 ± 1.280
ΣPUFA -3 (%)	13.51± 0.09a	14.06 ± 0.05a	10.83 ± 0.68b
ΣPUFA -6 (%)	6.62 ± 0.12a	5.36 ± 0.09a	1.76 ± 0.37b
EPA + DHA (%)	10.90 ± 0.03a	11.83 ± 0.09b	10.24 ± 0.57a
Σ PUF ω-3/ Σ PUFA ω-6	2.48 ± 0.05a	2.73 ± 0.03a	7.44 ± 2.36b
ΣΡυγΑ /ΣςγΑ	0.54 ± 0.01a	0.52 ± 0.02a	0.25 ± 0.02b
TI	0.63 ± 0.01	0.58 ± 0.01	1.04 ± 0.03
Al	2.96 ± 0.05	2.78 ± 0.03	2.29 ± 0.57

Different letters within a row correspond to statistical differences (p<0.05) between size groups.

Amounts of EPA+DHA in fish and the amount of fish consumption required to provide ~1g of EPA+DHA per day.

^{*} Thrombogenic index (TI)=(14:0+16:0+18:0)/[0.5xΣMUFA+0.5xΣPUFA (n-6)+3xΣPUFA(n-3)+ (n-3)/(n-6)]

^{*} Atherogenic index (AI) = $(12:0+4*14:0+16:0)/[\Sigma MUFA+\Sigma PUFA(n-6)]$ and (n-3)]

Table 11: Amount of EPA + DHA in fish & fish oils and the amount of fish consumptions required to provide ~ 1 g of EPA + DHA per day

Fish	EPA+DHA content,g/3-oz serving fish (Edible portion)	Amount required to provide ~1 g of EPA+DHA per day, oz (fish)
Tuna	0.26	12
Cod	0.24	12.5
Salmon	1.48	2
Herring	1.81	1.5
Mackerel	0.34 - 1.57	2 - 8.5
Hilsa (medium size) Mohanty <i>et al.</i> , 2011	1.32	2.27

¹ oz (Ounce) = 28.35 g

Table 12: Fatty acid profile (comparison with other marine fishes of tropical and temperate water)

Components	PUFA	Σ ω-3	Σω-6	ω-3/ ω-6	EPA+DHA	Reference
Herring	24.21	20.59	2.93	7.02	17.32	Huynh <i>et al.,</i> 2007
Salmon	42.1	39.3	3.2	12.3	36.4	Blanchet et al., 2005
Indian Mackerel	39.44	11.2	31.32	0.35	6.42	Marchamy et al., 2009
Hilsa	22.11	14.06	5.14	2.73	11.83	Mohanty et al., 2011 communicated

a. (Kris-Etherton et al., 2002)

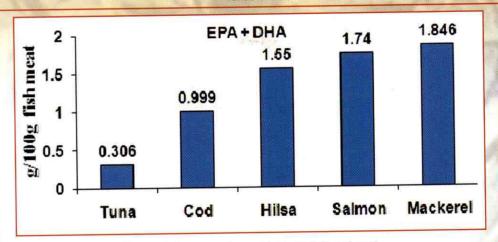
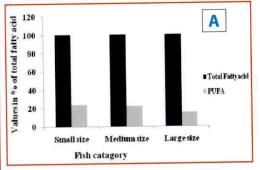


Figure 9: Comparative analysis of EPA and DHA (Kris-Etherton *et al.*, 2002)



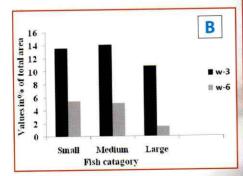


Figure 10: Total fatty acid and PUFA content of fish *T. ilisha* (A) ω -3 and ω -6 poly unsaturated fatty acids content in different size of *T. ilisha* (B)



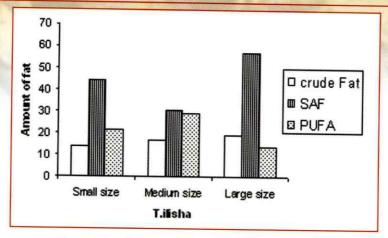


Figure 11: ω -3/ ω -6 ratio in three different size fish

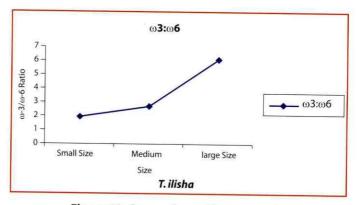


Figure 12: Comparison of fat content in three different size fish

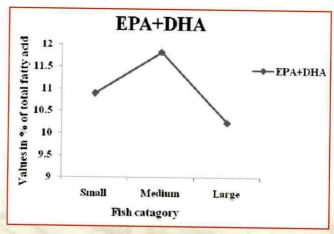


Figure 13: Comparative analysis of EPA and DHA between three size groups of *T. ilisha*

Table 13: Fatty acid composition (weight %), and Atherogenic and Thrombogenic Indices of some fish and shellfish meat (Valfre, et al., 2003)

r attv acide			Fish				Shel	Shellfish	
	Anchovy (Engraulis encrasicolus)	Eel (Anguilla anguilla)	Rainbow trout (Oncorhynchus mykiss)	Sea bass (Dicentrarchus Iabrax)	Cod (Gadus morhua)	Mussel (Mytilus edulis)	Shrimps (Penaeus kerathurus)	Lobster (Palinurus vulgaris)	Octopus (Octopus vilgaris)
C14:0	5.5	5.5	3.3	5.5	2.3	2.9	5.6	0.0	3.9
C16:0	39.9	17.4	18.6	14.8	18.6	16.8	17.8	22.1	27.5
C18:0	5.1	3.3	4.4	3.1	4.7	10.4	5.6	7.6	8.6
C14:1	0.0	0.7	0.0	0.0	0.0		1		ı
C16:1	4.0	8.7	9.9	9.3	2.3	9.2	4.4	0.0	2.0
C18:1	6.7	28.8	21.9	18.3	14.0	9.2	21.1	18.6	7.8
C20:1	0.4	6.2	2.2	0.9	4.7	10.4	=	0.0	3.9
C22:1	0.4	1.2	2.7	1:1	4.7	7.5	3.3	3.5	5.9
C18:2 n-2	2.8	6.3	8.7	0.9	0:0	2.9	2.2	0.0	0.0
C18:3 n-3	0.4	0.3	0.0	0.3	0.0	2.3	1.1	0.0	0.0
C20:4 n-2	0.2	3.2	1.1	0.9	2.3	6.4	0.0	9.0	1.0
C20:5 n-3	10.7	5.0	0.9	7.8	7.0	15.6	17.8	14.5	17.6
C22:6 n-3	20.6	8.7	21.3	12.7	34.9	6.4	20.0	25.6	21.6
SFA	50.6	26.2	26.2	23.5	25.6	30.1	28.9	29.7	41.2
MUFA	15.8	45.6	33.3	34.7	25.6	36.4	30.0	29.7	19.6
PIEA	33.6	28.2	40.4	41.8	48.8	33.5	41.1	40.7	39.2
	0.45	0.32	0.37	0.25	E	0.12	0.01	0.01	0.01
	1 35	0.94	0.57	0.45	0.55	0.40	0.56	0.31	0.73



The oily fish hilsa is known worldwide for its unique flavor and delicious taste that last for long time. It possesses an aroma of its own. The unique taste of hilsa was due to the presence of certain fatty acids like steareic acid, oleic acid and poly unsaturated fatty acids. The amount of fat ranges from 22 percent to 36 percent and the more the quantity of fat, the tastier is the fish. Salmon protein is one of the best animal proteins and among which get digested and absorbed easily in human body tissue. Breeding behavior of salmon is semelparous; lay their eggs at river mouth, eggs hatch there, develop into fry and start migrating towards seas. They grow in the seas into adult salmons and again go back to the rivers to reproduce, where most of them die after laying eggs. It is well known and very favourite fish for its easily digestible proteins (amino acids), fatty acids like Omega-3 fatty acids triglyceride, vitamins like vitamin-D, vitamin-A and some members of vitamin-B family and minerals like selenium, zinc, phosphorus, calcium and iron. Like salmon, hilsa is also a rich source of omega-3 fatty acids such as EPA and DHA, although the PUFA content is low as compared to salmon. Salmon is also rich in some of the very essential minerals like iron, calcium, selenium and phosphorus and vitamins like A, B and D. Selenium, which is very necessary for building up of tissues, hair, nails. Calcitonin obtained from Salmon ultimobranchial tissue can provide phylogenetic interest, also generate information on the structural requirements for hypocalcemic activity of the hormone (84). The fish salmon known for its lingering delicious taste and smell and also for colored meat similar to hilsa in India. sodium, magnesium, potassium, calcium, manganese, iron, cupper and zinc were also reported from hilsa fresh muscles (82). Like Salmon is popular in the western world, hilsa is known for its mouth watering, appetizing and culinary properties. It is also rich in PUFAs, especially ω -3 PUFAs and proteins and minerals and is quite nutritious. Although ω -3 fatty acids and EPA+DHA content of salmon is more than two times higher than hilsa, the later is quite popular in the eastern world especially in South-East Asian countries owing to its taste and flavor and nutrient richness. Hence, hilsa can be termed as 'salmon of the east'.

Table 14: Comparing amino acid pro	rofile of Salmon and hilsa
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Amino acids	Salmon ^a	Hilsa ^b
Essential		
Thr	4.9 ± 0.56	6.32 ± 0.17
Val	6.4 ± 1.45	6.35 ± 0.21
Met	2.8 ± 0.55	1.63 ± 0.10
lle	6.2 ± 1.17	6.20 ± 0.21
Leu	7.4 ± 0.24	9.33 ± 0.35
Phe	5.8 ± 1.14	3.71 ± 0.42
His	2.1 ± 0.20	5.47 ± 0.41
Lys	6.8 ± 0.01	2.35 ± 0.25
Arg	6.5 ± 0.99	0.94 ± 0.03
EAA	42.4	42.3
Non-essential		
Asp	6.7 ± 1.89	11.25 ± 0.4
Ser	5.4 ± 0.54	7.02 ± 0.31
Glu	10.0 ± 0.2	15.39 ± 0.22
Gly	1.8 ± 0.44	9.01 ± 0.21
Ala	5.2 ± 1.0	9.59 ± 0.15
Tyr	4.4 ± 0.88	1.39 ± 0.16
Pro	8.7 ± 3.54	1.34 ± 0.39
Cys	1.5 ± 0.08	0.95 ± 0.04
NEAA	50.4	55.94
TAA	92.8	98.24
TSAA	4.3	2.58
TAAA	10.2	5.1
EAA/NEAA	0.84	0.76

a. Bekhit et al., 2009

b. Mohanty et al., 2011

Table 15: Proximate com	nocition and fatter i-	profile of Salmon and hilsa
rubic 15.11 toxilliate Colli	position and fatty acid	profile of Salmon and hilsa

Components	Salmon	Hilsa ^c
Protein (g/100g)	19.84	21.35
Fat (lipids) (g/100g)	6.34	16.35 (w/w)
PUFA 42.1	22.11	
18:3n-3	0.295ª	2.23
20:5n-3	0.321ª	2.87
22:6n-3	1.115 ^a	8.95
18:2n-6	0.172 ^a	0.88
Σω-3	39.3 ^b	14.06
Σω-6	3.2 ^b	5.14
ω-3/ ω-6	12.3 ^b	2.73
EPA+DHA	36.4 ^b	11.83

- a. Bell et al., 2003
- b. Blanchet et al., 2005
- c. Mohanty et al., 2011

Health Advisory

Seafood products provide high percentages of long-chain fatty acids and also low percentages of short-chain fatty acid. An exhaustive study on cardiovascular diseases in Eskimo in relation to their food habits have been taken by Danish researchers in Greenland, which illustrated positive effect of large amounts of fish eating communities where there is a 10% incidence of heart attacks among the inhabitants (86, 87). Lower mortality rate due to ischemic heart disease and cerebrovascular were reported as a consequence of the high intake of fish in families of fishermen living along the coast in comparison with farming families (88). Both EPA and DHA have an anti-thrombotic effect, and it was shown in a clinical test that high concentrations (1.8 g per day for 4 weeks) of eicosapentaenoic acid ethyl ester made from sardine oil were able to suppress platelet aggregation (88). Thrombogenic effects have been exhibited by saturated Fatty Acids with a chain length of 14, 16 or 18 C atoms (89). Both (MUFA) and ω -6 PUFA reduces plasma total cholesterol and low-density-lipoprotein cholesterol (LDL-C) concentrations (90). Long chain ω -3 PUFA shows minimal effect on plasma cholesterol level but reduce plasma triacylglycerols thromboxane B, and platelet activity. It also repairs prolong bleeding time and heparinthrombin clotting time (HTCT) (91).

A Line of Caution: Environmental Contaminants like Hg and As

Fish and shellfish concentrate mercury in their bodies, often in the form of methyl mercury by the process of biomagnifications. Methyl mercury is a highly toxic organic compound of mercury. Species of fish that are long-lived and higher in the food-chain such as tuna, shark, king mackerel, northern pike and lake trout contain higher concentrations of mercury than others. The presence of mercury in fish can be a health issue, particularly for women who are or may become pregnant, nursing mothers, and young children. Mercury poisoning leads to Minamata disease; methylmercury and high levels of elemental mercury can be particularly toxic to a fetus or young children. Mercury accumulation in hilsa flesh has not been reported from Hooghly river and estuary; however, regular surveillance and monitoring is necessary. Arsenic (As), another toxic environmental contaminant, is a big public health problems in parts of West Bengal and Bangladesh; however, As level in hilsa from the Hooghly and associated rivers are within safe limits.

Some Common Dietary Indices

Atherogenicity and Thrombogenicity indexes are the two dietary indices which can foretell Ischaemic Heart Disease (IHD) i.e. atherosclerosis and thrombosis risk in a community sample of men aged 45-59 years. This study has been carried out (92). The main highlight of the research was men with higher atherogenicity or thromhogenicity scores at baseline tended to have a higher risk of subsequent IHD. The type of dietary fat consumed may contribute to both of these processes, some fatty acids having a greater role in atherogenesis while others have a greater role in thrombogenesis. Saturated fatty acids (SFAs) of 12, 14 or 16 C atoms shows a cholesterol-raising effect and are thus atherogenic (93, 94). SFA with a chain length of 14, 16 or 18 C atoms are thrombogenic (89). Both monounsaturated fatty acids (MUFA) and n-6 polyunsaturated fatty acids (n-6 PUFA) can be used to reduce plasma total cholesterol and low-density-lipoprotein cholesterol (LDL-C) concentrations (90). Long chain n-3 polyunsaturated fatty acids (n-3 PUFA) have minimal effect on plasma cholesterol level but reduce plasma triacylglycerols thromboxane B, and platelet activity and prolong bleeding time and heparin-thrombin clotting time (HTCT) (91). Even though this indices were the weak predictor of the IHD risk but these scores would be a better analyst of intakes of total saturates in human body.

PUFA n-3 and PUFA n-6 have been equally subjected to estimate Atherogenic Index (AI). Even though n-6 PUFA seems to have similar anti-atherogenic effects to n-3 PUFA, there are some important differences in functional activities two series, linoleic acid and linolenic acid and their longer-chain homologues such as arachidonic, EPA and DHA, which occur in fish. MUFA are applicable in similar way as PUFA n-3 and PUFA n-6 and thus as beneficial effects of MUFA interprets foods of different origin suggesting the index value.

Atherogenic Index

Atherogenic (AI) = $(12:0+4*14:0+16:0)/[\Sigma MUFA+\Sigma PUFA (n-6) \text{ and } (n-3)]$

Where, 12: Dodecanoic (Lauric) acid; 14: Tetradecanoic acid (Myrsitic acid); 16: Hexadecanoic (Palmitic) acid.

The risk of cardiovascular disease is more prominent in communities consuming more of dairy products like butter as comparison with other lipid preparation, since it contain considerable amount of lauric, myristic, and palmitic acids and a lower proportion of unsaturated fatty acids (95). According to Ulbricht and Southgate (1991) Index of Atherogenicity (IA) is the sum of the proportion in the fat of lauric and palmitic acids and four times myristic acid divided by the proportion of total unsaturated fatty acids. This explains the effect of various fatty acids on serum cholesterol and low- and high-density lipoprotein concentrations. The equation illustrates that only saturated fatty acids with chain lengths of 12 to 16 are atherogenic and myristic acid is considered four times more atherogenic than other two. All unsaturated fatty acids actively participate in minimizing atherogenicity, in spite of number of double bond, position, or configuration.

Table 16: Al values calculated in western diets

Diets	Al values	Reference
Coconut oil	13 - 20	Leaflet (2004)
Palm kernel oil	7	do
Cocoa butter	0.7	do
Other vegetable oils	<0.5	do
Meat fats	0.5 - 1	do
Milk and dairy products	2.0	do
Beef	0.50-0.86	Marques et al., 2010
Pork	0.44-0.86	do
Chicken	0.43	do
Rabbit	1.11	do
Hilsa	2.78	(Mohanty et al., 2011)

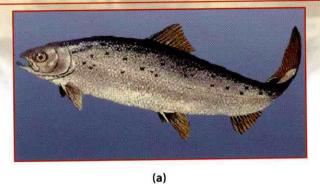
Thrombogenic Index

Thrombogenic index (TI) = $(14:0+16:0+18:0)/[0.5 \times \Sigma MUFA+0.5 \times \Sigma PUFA (n-6)+3 \times \Sigma PUFA (n-3) + (n-3)/(n-6)]$

Where, 14: Tetradecanoic acid (Myrsitic acid); 16: Hexadecanoic (Palmitic) acid; 18: Octadecanoic (Stearic) acid.

Saturated fatty acid and polyunsaturated fatty acids have been extensively studied to check the anti-thrombogenic effect in human and also in laboratory animals. The crude outcomes of the research were long chain saturated fatty acids (C14:0, C16:0 and C18:0) can accelerate thrombosis formation.

ω-3 fatty acids like ecosapentanoic acid and docosahexoic acid exerts a powerful antithrombogenic effect (97). They inhibit the conversion of arachidonic acid to thromboxane A₂. The similar effect has been noticed in the diets containing significant quantities of oily fish and capsule fed with purified form of fish oils. N-6 series of fatty acids also play a key role in reducing platelet aggregation and also by increasing the fluidity of platelet membrane (98). Infusible platelet membrane (IPM) exhibits clinical potential as a substitute for platelets in the treatment of bleeding in the Wessler rabbit model due to thrombocytopenia. The estimated thrombogenicity index value of the medium sized of 800 -1000g hilsa was 0.58 as mentioned in the table no. 11 (82) which lies in prescribed range of up to 0.6 and it is acceptable clinically. Chao *et al* (1996) studied in wessler rabbit model by administering Infusible platelet membrane (IPM) prepared from human platelets helps in enhancement in the thrombogenicity index and a substantial reduction in the bleeding time (99).



(b)

Figure 14: (a) Atlantic salmon (Salmo salar) and (b) Indian shad (Tenualosa ilisha)



Growth over-fishing and recruitment over-fishing play a key role in capture fisheries resource management which causes stock depletion and stock collapse. Thus it brings a clear attention to the researchers to conserve the resource to sustain the future generation. Recruitment over-fishing is the indiscriminate catching of the brood stock to the point that they did not have the reproductive capacity to replenish themselves. Growth over-fishing occurs when animals are harvested at an average size smaller than the size that would produce the maximum yield per recruit. Thus, fishing mortality rate causes depletion in total yield. Hilsa population has dwindling status because wanton killing in most landing centers which hilsa juvenile contributes maximum percentage of the total catch. Hence less fishing practices would produce higher landings for conserving the resources even when the resource is abundant. In general growth over-fishing is more common concern than recruitment over-fishing. In hilsa, there is an intensive catch of brood fishes which causes depletion in new recruits and side by side artisanal fishermen also harvest juvenile fishes before they reach a marketable size.

Mono-filament mesh of 80-85 mm or below are being employed to harvest hilsa juveniles below 500 g Fraserganj along Hooghly Matlah estuary which alters number of new recruits to the fishery (10). Upstream migration causes huge loss of brood fishes in estuarine rivers where they are being caught using gill and seine net. Moreover construction of dams, weir, anicuts in the rivers to impound water for irrigation (in India) had topped the fish in their migration. Not only did this interfere with migration but it also rendered stock prone to excessively heavy exploitation at location where migration was impeded, the barriers are so many and the fishing methods so efficient that the potential breeders are ruthlessly exterminated, during the past 20 to 25 years in India. As a result the stock is available in huge amount in Bangladesh. But unfortunately once more this particular stock is being exploited, with over fishing and natural barrier in their migratory route due to heavy siltation in inland rivers. Therefore conservation and management of this population in Bangladesh has become important for utilizing this resource in future. Population dynamics study at meghna reservoir has reported overfishing (E>0.5) of Jatka in Meghna river (105). Juveniles are caught in large amount using current nets of small mesh size during their grazing period in rivers as well as in sea shore. Based on a survey published through Bangladesh Fisheries Research Institute, over 3700 metric tons of Jatka are caught annually during their nursery season from inland rivers.

Construction of dam and barrage, lack of proper mesh size regulation, ineffective fish pass, loss of habitat and man made pollution and anthropogenic activities causing the depletion in hilsa catch in present decade (10). There is absolutely no control measure taken on fishing efforts and also observing the closed season to compel gear restriction owing to open access of the catch, poor management measures and surveillance and also lack of social awareness. In order to maintain increase in production and sustainable yield, implementing selective mesh size regulation (gill net mesh size of 100 mm) will be one of the effective methods. This will ensure a fish catch of 340 mm in length and 550 g in weight when it attains the first maturity. Therefore, an urgent need to formulate the policy measures and proper implementation by declaring closed seasons to stop fishing practices during the spawning periods should given a prior notice as a conservation measures. Technical measure to improve catching methods and an increase in official fishing ban period have become mandatory at West Bengal coast to avoid indiscriminate catching of brood fishes.



Figure 15: Wanton killing of hilsa juveniles

To conclude, hilsa is highly prized food fish and is in great demand in the South-East Asian countries owing to its taste, flavor and other culinary properties. It is a high forex earner for the countries where is available in plenty. As the nutrient profile has shown the fish is rich in PUFAs, especially ω -3 PUFAs, EPA and DHA, proteins and minerals. Fatty fishes are heart-friendly, and as recommended by nutritionist. A regular diet with fishes also reduces the risk of cardiovascular disease in Eskimos. Studies show that longer lifespan of Japanese and Nordic populations may be partially due to their higher consumption of fish and seafood. Physicians recommend also a fish diet with at least 2-3 times a week. Oily fish is claimed to help prevent a range of other health problems from mental illness to blindness. There is a gap between demand and supply. Therefore, there is urgency in bringing hilsa into domestication; for this culture and management aspects need to be established and strengthened. Hilsa can be a good food supplement for meeting the ω -3 fattyacids requirement. It needs to be promoted as the 'Salmon of the east'....

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ACRONYMS

Al Atherogenic Index

DHA Docosahexaenoic acid

EAA Essential Amino acids

EPA Eicosapentaenoic acid

HDLC High-density-lipoprotein cholesterol

HTCT heparin-thrombin clotting time

HUFA Highly unsaturated fatty acids

IGFBP-1 IGF-binding protein

IGF-I insulin-like growth factor 1

LDL-C low-density-lipoprotein cholesterol

MUFA Mono-unsaturated fatty acids

NEAA Nonessential Amino acids

PUFA Poly-unsaturated fatty acids

SFA Saturated fatty acids

TAA Total amino acid

TAAA Total aromatic amino acid

TC Total cholesterol

TI Thrombogenic Index

TSAA Total sulfur amino acid

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Publications from Outreach Activity (#3):

Nutrient Profiling and Evaluation of Fish as a Dietary Component

Contribution No.	Publication details	
1.	Fish as Health-Food (Folder), CIFRI, Barrackpore, 2010	
2.	Nutritional Significance of Small Indigenous Fishes in Human Health. B. P. Mohanty, B. K. Behera and A. P. Sharma. Bulletin No. 162, CIFRI, Barrackpore. p.73. 2010. ISSN 0970-616X.	
3.	Nutrient Profiling of Fish. T. V. Sankar, S. Mathew, R. Anandan, K. K. Asha and B. P. Mohanty. CIFT, Cochin. p.61. 2010. ISBN 978-81-905878-3-9.	
4.	Therapeutic Value of Fish. B. P. Mohanty, D. Sudheesan, T. V. Sankar, M. K. Das, A. P. Sharma. Bulletin No. 170, CIFRI. Barrackpore. 2011. ISSN 0970-616X.	





