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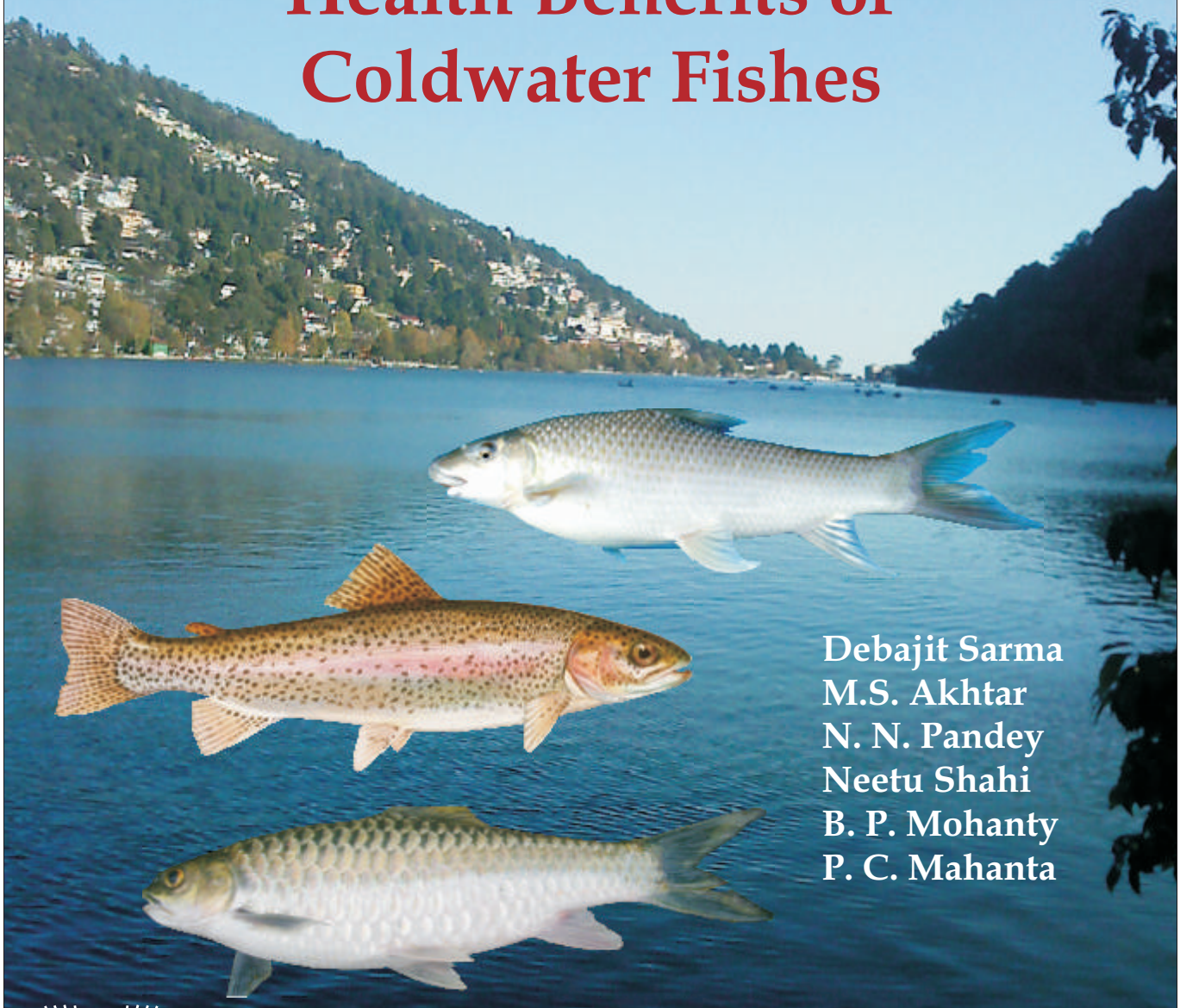
Bulletin No. 17 2011

Nutrient Profile and Health Benefits of Coldwater Fishes



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MESSAGE

Fish constitutes an integral component for the livelihood and food security of large population inhabiting the river basins in Asia. The fish is widely recognized as a health food by virtue of its richness inessential amino acids, minerals, major and minor elements and low fat content. Being a rich source of PUFA, fish adds nutritional value and reduces the risk of cardiovascular ailments.

The Directorate of Coldwater Fisheries Research, Bhimtal initiated a study on nutrient profiling of important coldwater fish species under the outreach activity in a consortium mode with other fisheries Institutes of the ICAR. The bulletin on "Nutrient Composition and Health Benefits of Coldwater Fishes" is an outcome of the multi institutional efforts on coldwater fisheries sector. The partners in the study and authors deserve appreciation for their efforts. It is hoped that the bulletin will prove to be a useful source of reference to the scientists, teachers, students and other stakeholders.

(S. Ayyappan)

Dated 29th March, 2011
New Delhi

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MESSAGE

Fish plays a major role in human nutrition. Importance of fish as a source of high quality, balanced and easily digestible protein is now well understood. Besides, it is also a well-known source of polyunsaturated fatty acids specially, omega-3 fatty acids such as eicosapantaenoic acid (EPA) and docosahexaenoic acid (DHA), which play a central role in the physiology of living system. Regular consumption of omega-3 fatty acids significantly lowers triglycerides and often raises high-density lipoproteins levels, thereby diminishing the risk of heart/cardiovascular diseases. Fish is also known to be a good source of several other nutrients like macro and micro minerals and vitamins and hence, it is being accepted as a healthy and also easily digestively food. Fish is a rich source of calcium and phosphorus and calcium deficiency in children causes decreased growth rate, negative calcium balance in bones. Phosphorus is very essential for the formation of bone and teeth. Other microminerals like coppers, iodine, manganese, cobalt, zinc, fluorine, selenium etc are vital for maintaining the physiological functions of the body. Vitamin A, D and E as well as thiamin, riboflavin and niacin are abundantly found in fish and are important for normal vision, skeletal growth and many other physiological functions, including immunity and disease resistance.

The outreach activity project on nutrient profiling at the Directorate of Coldwater Fisheries Research, Bhimtal, is an attempt to highlight the importance of fish from coldwater regions of India with a view to popularize fish consumption. I am sure the document, "*Nutrient Profile and health benefits of coldwater fishes*" will provide very useful information on the nutrient profile of coldwater fishes and their health benefits for consumers. I would be happy to see that the information being generated in the on-going ICAR Outreach Activity Consortium on ' Nutrient Profiling and Evaluation of Fish as a Dietary Component' on coldwater fishes. The document deserves appreciation and I congratulate the authors for their efforts in bringing such informative document in coldwater fishes of India.

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FOREWORD

Coldwater fisheries resources of India are mainly in the form of upland streams, rivers, high and low altitudinal lakes and reservoirs located in different hill states of India. Diverse population of indigenous and a few exotic coldwater fish species in these mountain water bodies form an immense potential in generating income in rural areas and providing food and nutritional security. The value of fish as health food is well known, but poorly documented. Fish is the cheapest animal protein that is accessible to the poors and it is aptly called the 'rich food of the poor'. Apart from essential fatty acids and protein, fish is rich in vitamins and minerals. By virtue of the presence of PUFA, consumption of fish can prevent cardiovascular diseases. Fish as a protective food assumes greater significance in different regions of India, including Himalayan coldwater regions due to the rich fish and fisheries resources of the country, which can play a pivotal role in mitigating protein deficiency/malnutrition. But in spite of all these advantages of consuming fish, its nutritive value is not well documented, especially for cold water fish from India. Considering that the nutrient profile of fish varies depending on species, size, geographical locations and production systems, available knowledge is not sufficient to enable the physicians and dieticians to prescribe fish as health food. Keeping this gap in mind, ICAR has launched an inter institutional outreach research programme during the 11th plan to investigate all possible fish including coldwater fish species of the country to document their nutritional status.

The Directorate of Coldwater Fisheries Research, Bhimtal, has taken several efforts for documenting the nutrient profile of coldwater fish species under Outreach Activity Consortium on "Nutrient Profiling and Evaluation of Fish as a Dietary Component". This document will become a knowledge base and an indispensable reference to the physicians, dieticians, scientists, teachers, students and other stakeholders to understand the nutritional significance of coldwater fish species.

P. C. Mahanta
Director, DCFR

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1. Coldwater Fishes in India

Coldwater fishes occupy an important place amongst the freshwater fishes, and its resources spread over the Himalayan and peninsular regions of India. Their importance is even far greater in Himalayan uplands, where coldwater fish species have established themselves as important candidate species for sports and food. India has significant aquatic resources in terms of upland rivers, streams, high and low altitude natural lakes, reservoirs, which hold large population of indigenous and exotic, cultivable and non cultivable fish species. The coldwater streams and rivers cover an area of 10,000 km, natural lakes cover 20,500 ha, reservoirs cover 50,000 ha and the brakishwater lakes 2,500 ha.

The coldwater fish fauna range from eurythermal to stenothermal regimes due to differences in microclimatic conditions and habitat variations in aquatic biotopes and their thermal regimes. The fish species continuously inhabiting the different aquatic zones adopts different morphological characters to withstand the fast flowing water currents. The distribution character of hill stream fishes is primarily dependent on water flow, substratum characters, temperature profile, water quality and the availability of natural food. The fish has also, as a taxonomic group, generated unlimited curiosity of naturalist and zoogeographer from the period as early as that of the great Aristotle. Of the 22,000 fish species, over 40% live in fresh water and majority of them live in tropics between latitudes of $23^{0}5'$ N and $23^{0}5'$ S. The coldwater fisheries harbour 258 species belonging to 21 families and 76 genera. Of that, 203 species are found in Himalayas and 91 species are found in Deccan plateau.

The first attempt to introduce trout in Jammu and Kashmir dates back to 1899 when a consignment of eyed-eggs of brown trout ((Salmo *trutta fario*) from England was brought to India. Eyed-eggs of brown trout brought from Kashmir in 1909 hatched successfully at Mahili Hatchery, Katrain, Himachal Pradesh. The cold, clear waters of the Nilgiri hill streams were found to be well suited for planting trout and the early European settlers, tea planters, the game associations, and some foreigners on sojourn from abroad felt it desirable to introduce trout among the game fish to the plateau of TamilNadu. The first attempt to import trout eggs and fry from abroad was made in 1863 by Francis Day. The history of introduction of trout in Kerala dates back to 1909 when the first consignment of eyed eggs of brown trout was brought from United Kingdom.

The term 'coldwater fish' vaguely refers to the members of the family salmonidae, much sought after by the anglers all over the world. In India, however, cyprinids belonging to subfamily cyprininae, which inhabit streams, lakes and

reservoirs receiving snowmelt water directly from their watersheds are also included in this definition. There are a large number of indigenous and a few exotic species of fish, which frequent the rivers, streams, brooks, lakes, ponds etc. in the uplands. Of these, trout, snow trout, mahseer, common carp and minor carps are important as sport and food fishes. These species are widely distributed both in the Himalayas and the Peninsular Plateau.

The coldwater streams and lakes are characterised by high transparency, high dissolved oxygen content and rather sparse biota. Most of the fishes inhabiting the uplands of India, barring a few, are small-sized. They show a distributional pattern that depends on the rate of flow of water, nature of substrata and the availability of food. The principal indigenous fish inhabiting the upland waters of India are (a) loaches (family: cobitidae); (b) snow trouts, mahseers and minor carps (family: cyprinidae; sub-family: cyprininae); (c) barils (family :cyprinidae: sub-family: rasborinae); and (d) cat fishes (family: sisoridae). A few exotic salmonids, common carp and tench (family: cyprinidae) have been transplanted into suitable areas for propagation.

Coldwater fishes are mainly distributed in five important hilly states of India namely Arunachal Pradesh, Sikkim, Himachal Pradesh, Jammu&Kashmir, Uttarakhand and Arunachal Pradesh.

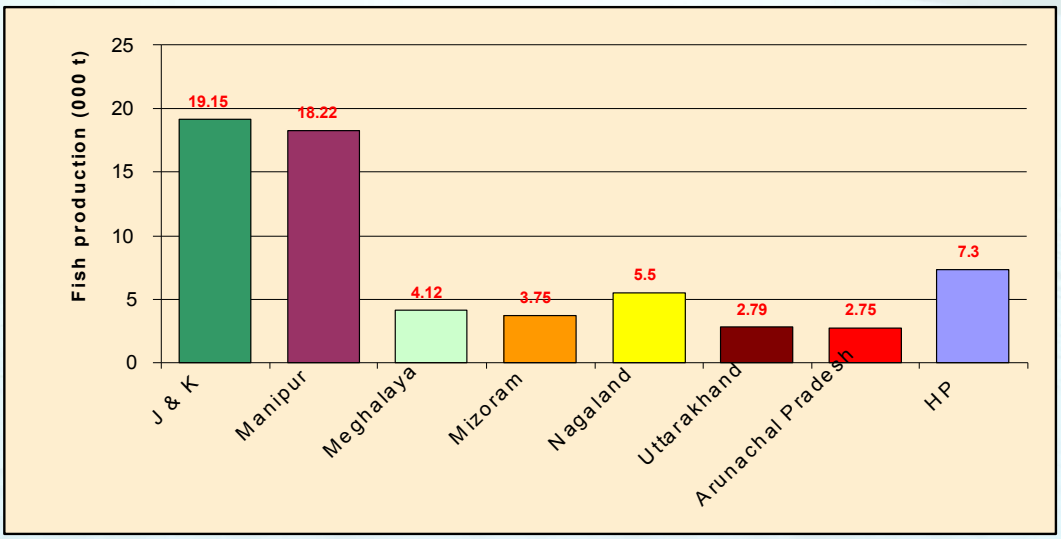


Fig.1. Coldwater Fish Production in India (State wise)

Present contribution in Inland sector - 1.5%

Projected contribution - 6% by 2025

Table 1. Rainbow Trout Production [Annual], 2006

World production	500,000 t
Indian production	500 t
J & K	150 t
H. P.	250 t
Other States	100 t
Production potential	Immense
Export potential	Promising

Table 2. Major Producers of Inland Coldwater Spp. (*Trout and Chars*) and production trends (in MT)

Country	2001	2002	2003	2004	2005	2006
Turkey	36 827	33 707	39 674	43 432	48 033	56 026
Iran	12 170	16 026	23 138	30 000	34 760	46 275
France	46 384	45 059	39 215	35 128	32 353	32 000
Italy	44 000	33 770	38 000	30 238	30 564	30 796
USA	26 109	24 743	23 045	24 975	27 643	28 089
Denmark	33 367	27 340	27 343	31 376	28 154	26 847
Spain	35 384	33 842	33 791	29 308	25 959	25 189
Germany	25 000	24 161	23 256	22 004	19 325	19 011
Poland	11 001	10 711	11 698	14 648	17 104	16 985
Total incl. Others	362 337	342 322	361 063	362 352	371 559	393 959

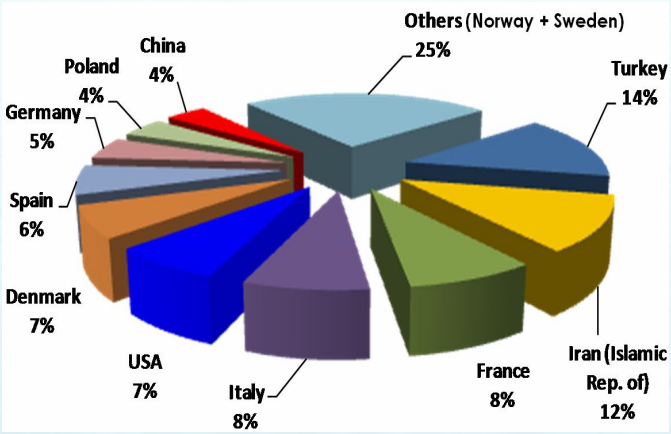


Fig. 2. Top ten producers of trouts and chars (FAO, 2006)

Table 3. Important coldwater fishes

Snow trout	**Exotic trouts**	**Barils/Minnows/Catfishes/ Loaches**
Schizothorax richardsonni	*Onchorhynchus mykiss*	*Barilius bendelisis*
Schizothoraichthys curvifrons	*Salmo trutta fario*	*B. Bakeri*
S. longipinnis	*Salvelinus fontinalis*	*B. Vagra*
S. esocinus	**Other Exotics**	*B. Barila*
S. niger	*Cyprinus carpio var. specularis*	*Raimas bola*
S. plannifrons	*C. carpio var. communis*	*Danio divario*
S. micropogon	*C. Carpio Var. nudus*	*Botia birdi*
S. progastus	*Tinca tinca*	*Glyptothorax pectinopterus*
S. nasus	*Carrasius carrasius*	*G. conirostre conirostre*
S. hugelli	**Minor carps**	
Lepidopygopsis typus	*Labeo dyocheilus*	
Mahseer	*Labeo dero*	
Tor putitora	*Crossocheilus latius latius*	
T. tor	*Gara gotyla*	
T. khudree	*G. hughi*	
T. malabaricus	*Puntius ophicephalus*	
Neolissochilus hexagonolepis		

Table. 4 Important edible fishes of India

Cold water fish Species	**Other Exotics**	**Fish species tranported from plain area**
Snow trout	*Cyprinus carpio var. specularis*	*Hypopthalmichthys molitrix*
Schizothorax richardsonni	*C. carpio var. communis*	*Ctenophraryngodon idella*
S. longipinnis	*H. molitrix*	
S. esocinus	*C. pharyngodon idella*	
S. niger	**Minor carps**	
S. progastus	*Labeo dyocheilus,*	
S. nasus	*Labeo dero*	
Mahseer	*Gara gotyla*	
Tor putitora	*Puntius spp.*	
T. tor	**Barils/Minnows/Catfishes/ Loaches**	
Neolissochilus hexagonolepis	*Barilius spp.*	
Exotic trouts	*Raimas bola*	
Onchorhynchus mykiss	*Danio divario*	
Salmo trutta fario	*Botia birdi*	
Salvelinus fontinalis	*Glyptothorax spp.*	

2. Nutritional Significance of Fish in General

Fish is fundamental for the livelihood and food security of large population groups in the productive and densely populated river basins in Asia. Around 56% of India's population is fish eating. In some states, like Assam and other North- Eastern states, West Bengal, Orissa, Goa and Kerala, more than 90% of the population consumes fish.

Fish is widely recognized as a health food by virtue of its richness in essential amino acids, minerals and trace elements and low fat content. Rich in PUFA, fish adds nutritional value by preventing and fighting cardiovascular ailments. Fish is a rich source of calcium and phosphorus and other microminerals. It is also a well-known source of several other nutrients and hence, fish is being accepted as a healthy food. Fish is known to be one of the cheapest sources of animal protein.

2.1 Fish as a source of omega 3 fatty acids

Fish is the major dietary source of n-3 highly unsaturated fatty acids (HUFA) such as eicosapantaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3), for humans. Omega-3 fatty acids in fish oils have beneficial effects on the symptoms of several health conditions that involve the immune and inflammatory system. Omega-3 fatty acids improve blood circulation, reduce the tendency of blood to clot, improve vascular (blood vessel) function in several ways that reduce the risk of heart disease, and slightly lower blood pressure. Regular consumption of fatty fish or omega-3 fatty acids significantly lowers triglycerides and often raises HDL levels, thereby diminishing the risk of heart disease.

2.2 Fish as a source of amino acids

Fish proteins contain the essential amino acids in the required proportion and thus, improve the overall protein quality of a mixed diet. On a fresh-weight basis, fish contains a good quantity of protein, about 18-20%, and contains all the eight essential amino acids including the sulphur-containing lysine, methionine, and cystine. Glycine, which is one of the major components of human skin collagen, together with other essential amino acids such as alanine, proline, arginine, serine, isoleusine and phenyl alanine form a polypeptide that will promote regrowth and tissue healing. Certain amino acids like aspartic acid, glycine and glutamic acid are also known to play a role in the process of wound

healing (Chyun & Griminger, 1984). Amino acids, not only have high nutritive value, but also provide several health benefits, such as reduction of blood cholesterol, antimutagenicity, reduction of coronary heart disease, and anti-obesity potential.

2.3 Fish and minerals

Minerals occurring in appreciable amounts are called macro elements and those found in minute amounts are called trace elements or microelements. Calcium, phosphorus, sodium, potassium, sulphur, chlorine, Magnesium and Iron are found in appreciable amounts; coppers, iodine, manganese, cobalt, zinc, fluorine, selenium are found in smaller quantities where as cadmium, boron, arsenic, aluminium, lead, nickel are found in trace quantities in different group of fishes.

Calcium deficiency in children produces decreased growth rate, negative calcium balance of calcium from bones. Phosphorus is very essential for the formation of bone and teeth. It forms the linkage in DNA and RNA and constituent of certain co-enzymes. Phospholipids are found in cell membranes and regulate the transport of solutes in and out. Inorganic phosphates in the body act as important constituents in body's buffer system and maintain the neutrality.

Magnesium is the second most abundant intracellular cation in the body. Normally blood serum has 2 to 3 mg percent. Magnesium acts as activator in several enzymes. It together with sodium potassium and calcium maintains fluid balance and is found in some enzymes like co-carboxylase. Magnesium requirement for different age groups are as infants and children 100-150 mg per day, adolescents 150-250 mg per day and adults 250-350 mg per day.

Sodium in our body maintains the normal osmotic pressure and water balance; the 'acid base balance' of the body and the normal irritability of nerves and. muscle contraction. Potassium helps in maintaining acid base balance of the body. It is very essential for synthesis of glycogen and is also required in growth and building of tissues. It is concerned with irritability of nerves and all muscles. Iron is a vital component of hemoglobin with transports oxygen to various tissues of the body. Zinc is primarily intracellular and thus it is proportionate to the lean body mass. Man has about 2 grams zinc in his body. Growth retardation and retarded genital development are seen in children with zinc deficiency.

2.4 Fish and vitamins

Fish oil, especially the one obtained from liver such as the cod liver oil, is a rich source of vitamin A and vitamin D. There are various beliefs surrounding fish oil and vitamin E. Fish oil undergoes oxidation and can become rancid, leading to formation of free radicals. Addition of antioxidants such as vitamin E to fish oil can help prevent the formation of these free radicals. Excessive dosage of fish oil leads to reduction of vitamin E in the human body. This loss of Vitamin E should be supplemented with external Vitamin E supplements. The combination of fish oil and Vitamin E can have added benefit in the treatment of many cancers and heart diseases, than if they are used individually. Preliminary research has been carried out which prove the above beliefs; however, these need to be substantiated with detailed research before drawing strong conclusions on the use of fish oil and vitamin E.

3. Nutritional Importance of Coldwater Fishes

Coldwater fishes namely rainbow trout, snow trout, golden mahseer, chocolate mahseer and common carp etc are important food in the rural and urban upland population in India. Most of the population residing in hilly areas are fish eaters. It is widely accepted as a healthy food because of its richness in amino acid, fatty acids, vitamins and minerals. Coldwater fishes like trout and mahseer contain high PUFA compared to other fresh water fishes.

The geographical location (tropical/temperate/cold climate and hill-stream/downstream), seasons, ecosystems, management practices (cultured vs. wild stock) etc. are important factors, which influence the growth, body composition and nutritive value of fish. There is paucity of information on proximate composition, detailed account of fatty acid and amino acid profile in majority of fishes from India, with respect to above variations. Therefore, there is a pressing need to generate a sound database on these aspects so that in linkage with human nutritionists/clinicians feeding trial can be carried out to see the impact of incorporation of better fishes with superior nutritional value in diet on human health. There is a prime need to initiate work on nutrient profiling of selected edible fishes from different aquatic ecosystems. It is necessary to find out the varieties of fishes consumed and their consumption rate by different sections of fish eating population. Child health and low birth weight are important social problems and have often been correlated with fish consumption profile. It is also

important to generate information on nutritional value of different food fish species in terms of fatty acid, especially PUFAs, profile and amino acid profile.

The recommended daily amount of omega 3 fatty acids from fish is 200–600mg. The approximate amounts of omega 3 fatty acids per 60g serve from varieties of fish. Those are salmon (fresh Atlantic) 1,200mg; smoked salmon 1,000mg; canned salmon 500mg; sardines 1,500mg; trout (fresh rainbow) 350mg; gem fish 300mg; blue-eye, shark (flake), salmon, squid 250mg; scallop or calamari 200mg; sea mullet, abalone 170mg; canned tuna 145mg and sea perch 7mg. omega 3 fatty acids come from green leaves then why are fish a good source of omega 3 fatty acids. The reason is that fish eat the green plants. There's no doubt that fish is the best source of concentrated omega 3 fatty acids. One ounce of salmon fish oil contains 9,887 milligrams of omega 3 fatty acids.

Atlantic salmon - 6 ounces raw farm raised (omega 3 fatty acids - 4,260 milligrams; calories 354, total Fat 22 grams, dietary fiber 0). Atlantic salmon - 6 ounces dry heat cooked farm raised (omega 3 fatty Acids - 3,842 milligrams; Calories 350, Total Fat 20 grams, dietary fiber 0). Rainbow Trout - 6 ounces raw farm raised (Omega 3 Fatty Acids -1,676 milligrams; Calories 234, Total Fat10 grams, dietary fiber 0). Rainbow trout 6 ounces dry heat cooked farm raised (omega 3 fatty acids - 2,102 milligrams; calories 288, total fat 12 grams, dietary fiber 0).

Coldwater fishes are also rich source of calcium and phosphorus. Unlike other sources of animal protein, such as chicken, mutton, pork, etc, fish as a group comprises a large number of species and varieties. Except a few, most of the 1300 marine and 720 inland fish species present in Indian waters are edible, but they vary widely in their proximate, fatty acid and mineral composition. Child health and low birth weight are important social problems and have often been correlated with fish consumption profile. It is also important to generate information on nutritional value of different food fish species in terms of fatty acid, especially PUFAs, profile and amino acid profile. Studies carried out in India have also shown that the incidence of low birth weight (<2500 gms) deliveries among the poor is around 25-30% and nearly 50% of children less than three year of age are stunted. Studies have shown that apart from correction of anemia, supplementation with foods rich in n-3 fatty acids could significantly reduce the low birth weight incidence. It has been suggested that the longer lifespan of Japanese and nomadic populations may be partially due to their higher consumption of fish and seafood. 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. In comparison to the other sources of dietary proteins of animal origin, the unit cost of production of fish is much cheaper. Fish also come in a wide range of prices making it affordable to the poor. A common man can afford to meet the family's dietary requirement of animal proteins because he has the option to choose from a fairly large number of fish species available.

The study of mineral elements present in fish is of biological importance; since many of such elements take part in some metabolic processes and are known to be indispensable to all living things. The body usually contains small amount of these minerals, some of which are essential nutrients, been components of many enzymes system and metabolic mechanisms, and such as contribute to the growth of the fish. The most important mineral salts are that of calcium, sodium, potassium, phosphorus, iron, chlorine while many others are also needed in trace amounts. The deficiency in these principal nutritional mineral elements induces a lot of malfunctioning; as it reduces productivity and causes diseases, such as inability of blood to clot, osteoporosis, anemia etc. Therefore, considering the various health risk and the nutritional benefits associated with fish consumption ;it has therefore become important that, fish's mineral and proximate composition and their health status be assessed in order to establish the safety level of the table sized species prior their consumption. In rainbow trout, variations in lipid and moisture content were found both in cranio-caudal and in dorso-ventral directions. Low intakes of micronutrients such as iron, zinc and magnesium, are widespread, causing retarded growth and mental development in children, as well as high morbidity rates and increased risk of early death in other vulnerable population groups, such as women at the reproductive age.

4. Coldwater Marine Species vs. Coldwater Species from Freshwater

The proximate composition of fishes varies from one habitat to another. There are some significant differences in the overall body composition of coldwater marine and coldwater fishes from landlocked freshwater (Table 1 and 2). Difference in the PUFA and sodium concentration of the fishes found in these two different habitat is shown in table 3 and 4. Farmed and wild fishes differ in proximate composition, fatty acid etc. Generally wild fishes are more rich in n-3 fatty acids than its culture counter part, which may be due to the fact that the fish feed contain more of n-6 and saturated fatty acid, but less of n-3 fatty acids (table 5 and 6).

Table 5. Proximate composition values of various coldwater marine species worldwide*

Scientific name	Location	Water content (% wet body weight)	Ash content (% wet body weight)	Protein content (% wet body weight)	Fat content (% wet body weight)
Dicentrarchus labrax	*Greece*	72-75	1.5	19.2-21.1	1.4-5.2
Engraulis encrasicolus	*Atlantic ocean*	64.93-74.32	1.68-1.38	NA	16.32-6.49
Salvelinus alpinus	Arctic Bay	68.2	NA	24.5	7.7
Gadus morhua	NW Atlantic	82.9	1.52	4.06	1.9
Gadus macrocephalus	NE pacific	81.8	1.06	17.1	0.78
Epinephelus morio	Maxico	77.97	1.2	21.71	0.88
Clupea harengus	Canada	63.6	3.3	19.7	9.9
Scomber japonicus	Florida	73.73	2.66	21.08	3.07
Brevoortia patronus	Gulf of maxico	64.55	4.55	16.25	15.54
Mugil cephalus	Gulf of maxico	80.56	0.84	14.19	1.89
Esox lucius	Canada	78.6	1.2	19.5	1.1
Oncorhynchus tshawytscha	NE pacific	73.1	1.2	19.5	1.1
Coregonus artedii	Finland	69.3	1	18.7	NA
Salmo gairdneri	Alaska	68.9	1.31	21.1	9.02
Salvelinus namaycush	America	72.4	1.1	18.6	7.2
Salvelinus malma	Bristol bay	74.1	1.2	19.8	1.2
Salmo clarki	Alaska	78.2	1.37	19.9	1.8

* Ref- Krzynowek and Murphy 1987

Table 6. Proximate composition values of various coldwater freshwater species worldwide*

Scientific name	Location	Water content (% wet body weight)	Ash content (% wet body weight)	Protein content (% wet body weight)	Fat content (% wet body weight)
Salmo trutta	*Norway*	66.00-81.50	2.40-2.8	14.0-17.50%	02.00-07.70
Salmo garidneri	*Norway*	NA	NA	12.60-19.10	1.50-12.80
Cyprinus carpio	Michigan	69.95	0.96	13.55	15.56
Oncorhynchus nerka	*Pacific ocean*	NA	2.1-4.2	15.8-18.7	2-4.1
Aristichthys nobilis	*Black Sea*	73.86-84.54	2.65-5.52	09.43-16.54	00.18-06.37
Lota lota	Finland	64.5	1.4	16.2	9.4
Salmo salar	Canada	75-82	NA	13-17	NA
Peprilus triacanthus	NW Atlantic	80.4	1.45	NA	1.6
Salvelinus fontinalis	N america	74.3	1.3	21.5	3.4
Oncorhynchus keta	NE pacific	74.1	1.18	21.3	3.86
Pomatomas saltatrix	Virginia	70.16	1.12	19.56	2

* Ref- Naeem and Salam 2010

Table 7. PUFA, sodium and cholesterol composition values of various coldwater marine species worldwide*

Scientific name	Location	PUFA (% of total fat)	Sodium (mg %)	Cholesterol (mg%)
Ambloplites rupestris	*America*	42.9	50%	90
Coregonus hoyi	*Michigan*	NA	700	NA
Gadus morhua	*Scotia*	32	NA	NA
Brosme brosme	*Canada*	NA	36	NA
Eleginus gracilis	*Japan*	42.4	NA	NA
Anguilla rostrata	*America*	30.4	NA	NA
Epinephelus morio	Mexico	41.15	NA	46.7
Seriolella brama	NewZealand	19	45	NA
Merluccius bilinearis	NewZealand	NA	15.75	18.8
Brevoortia patronus	Nova Scotia	44.16	NA	NA
Coregonus clupeaformis	Atlantic	35.7	NA	NA
Coregonus artedii	Finland	53.4	NA	1.4

*Krzynowek and Murphy 1987

Table 8. PUFA, sodium and cholesterol composition values of various coldwater freshwater species worldwide*

Scientific name	Location	PUFA (% of total fat)	Sodium (mg %)	Cholesterol (mg%)	Reference
Salmo gairdnerie	Scotland	34.4	NA	NA	Hinderson et al 1982
Salmo gairdnerie	Newyork	53	30	50	Kinsella et al 1977
Salvelinus namaycush	Newyork	NA	5.11	40	Mai et al 1978
Salvelinus fontinalis	Ireland	NA	60	68	Kinsella et al 1977
Oncorhynchus nerka	Alaska	2.54	42.7	NA	Dubrow et al 1976
Aplodinotus grunniens	Newyork	25.8	60	64	Kinsella et al 1977

*Ref- Krzynowek and Murphy 1987

Table 9. Fatty acids concentration in farmed and wild salmon and trout worldwide

Fats	*O mykiss* (Akhan et al., 2010)		*O kisutch* (Nettleton & Exler 1992)		*Salmo salar* (Bell et al., 2003)	
	Wild	**Farmed**	**Wild**	**Farmed**	**Wild**	**Farmed**
Fat	3.46	5.4	5.93	7.67	6.34	10.85
18:3n-3	0.119	0.858	0.157	0.075	0.295	0.094
20:5n-3	0.167	0.26	0.429	0.385	0.321	0.618
22:6n-3	0.42	0.668	0.656	0.821	1.115	1.293
22:5n-3	0.106	0.001	0.232	NA	0.287	NA
18:2n-6	0.234	0.71	0.206	0.349	0.172	0.586
PUFA	1.237	1.805	1.992	1.861	2.53	3.931

Table 10. Fatty acids concentration in farmed and wild coldwater fishes*

Species	*Dicentrarchus labrax*		*O. kisutch*		*I. punctatus*		*Salmo gairdnerri*	
Fatty Acids	*Cultured*	*Wild*	*Cultured*	*Wild*	*Cultured*	*Wild*	*Cultured*	*Wild*
Total saturated	29.2	33.4	1.84	0.77	2.48	0.56	1.5	1.22
Total monoenoic	34.6	19.4	2.88	1.02	5.72	0.82	1.49	1.27
n-6 series	9.3	11.8	0.46	0.06	1.56	0.22	0.71	0.29
n-3 series	26.8	35.6	1.42	0.9	0.37	0.28	1	1.13
Total polyenoic	36.1	47.4	1.87	0.96	2.02	0.5	1.74	1.44
n-3:n6	2.88	3.02	3.1	14	0.2	1.3	1.4	4.2
Total PUFA	NA	NA	6.88	2.9	10.4	1.98	4.92	4.17

* Nettleton & Exler 1992

5. Nutrient Profile of Golden Mahseer

Seasonal effect on estimated average proximate composition (protein, ash, crude fat and moisture) from Hatchery pond was found statistically significant different and the above average estimates ranged between 15.59-17.29 gm/100gm, 1.23-1.55 gm/100gm, 0.62-1.52 gm/100gm and 76.24-79.24 gm/100gm respectively (Fig. 4). From the estimated average values, higher protein (17.29 gm/100gm) and moderate crude fat (1.50 gm/100 gm) levels were observed during June to September (breeding season). The higher protein level reflected might be accountable due to the maturity stage of the fish species in their seasonal life cycle having higher intake of proteineous artificial feed in pond environment. This agrees with observations made by Berg and Bremset (1998), who reported that significant changes in body composition of young riverine Atlantic salmon and brown trout with the concentration of fat and protein level declined greatly in winter but were replenished rapidly in Spring.

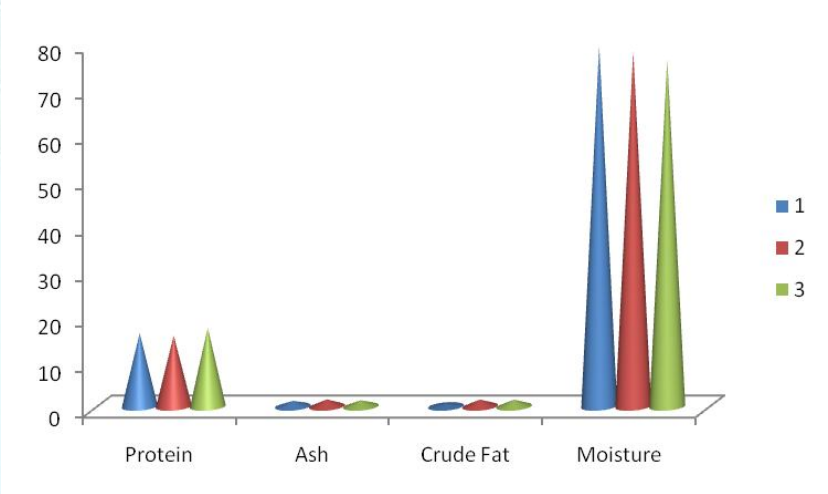


Fig. 4. Seasonal variation of proximate composition (gm/100gm) of *Tor putitora*, 110 - 325gm from Hatchery Fish Pond, Bhimtal

Season: 1=October-January; 2=February-May & 3=June-September.

Protein, ash, crude fat and moisture concentration of three geographical locations were recorded (Fig. 5). The average protein content of hatchery pond, Kosi river and Kameng river were 15.59, 21.00 and 17.20 gm/100 gm respectively. Similarly, average crude fat levels were 1.52, 6.15 and 6.15 gm/100 gm from hatchery pond, Kosi river and Kameng river respectively. Results from the present

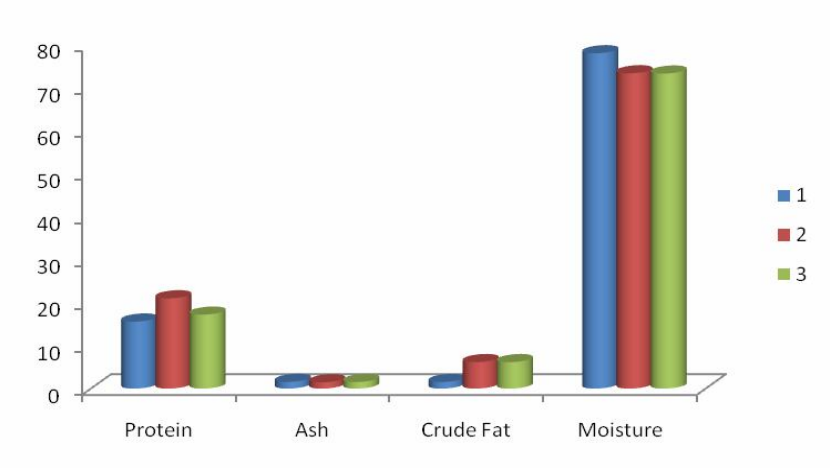


Fig. 5. Proximate composition (gm/100gm) of *Tor putitora* of size 250-550gm in different geographical location

Geo-climatic location: 1=Hatchery, Bhimtal; 2=Kosi River, Uttarakhand & 3=Kameng River, Arunachal Pradesh.

study revealed that protein and crude fat levels of the above fish species collected from Kosi river was found highest among different geographical locations considered. The changes of nutritional status may be attributed due to substratum adaptation and survival in mountain streams and rivers having different ecological conditions and significant altitudinal variation. Significant differences in macro minerals content was observed among four different geographical locations of hatchery pond, Bhimtal lake, Kosi river and Kameng river (Fig. 6). The average values of sodium, potassium and calcium concentration in golden mahseer for Hatchery pond, Bhimtal lake, Kosi river and Kameng river are presented in Fig. 6.. Results of these analyze showed that golden mahseer contains significantly higher concentration of calcium, potassium but low in sodium concentration. Further, concentration of calcium and potassium decreases with the increase in body weight (Fig. 7). It may be concluded that Himalayan mahseer is a good source of minerals. The above finding agrees with the observation made by Nurullah *et al*.2003, that reported higher minerals content in some selected indigenous fish species of Bangladesh. Fishes collected from the habitat of Kameng river has significantly higher concentration of selenium (1.56 mg/100gm), whereas Himalayan mahseer of Kosi river has significantly higher concentration of iron (1.28 mg/100 gm) and moderate estimates of manganese and zinc (0.16 and 1.19

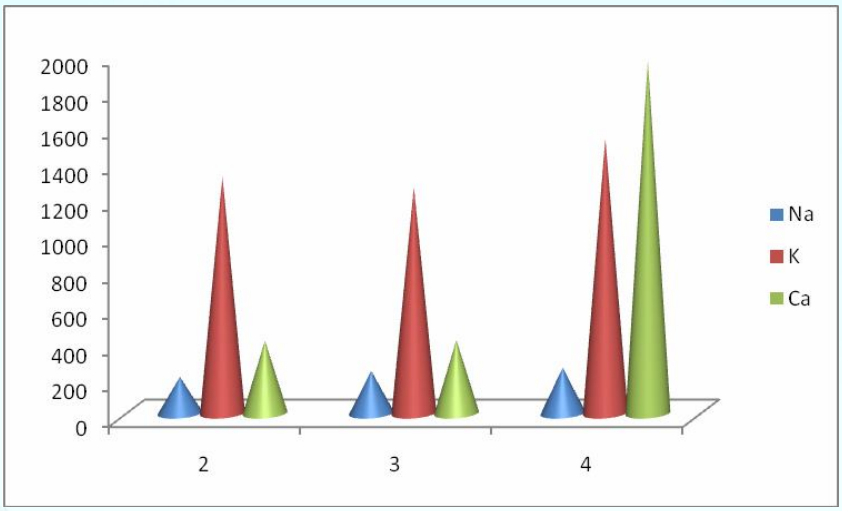


Fig.6. Macro mineral (mg/100gm) composition of *Tor putitora* of size 250-550 gm in different geographical location

Geo-climatic location: 1=Hatchery, Bhimtal; 2=Bhimtal Lake; 3=Kosi River, Uttarakhand & 4=Kameng River, Arunachal Pradesh.

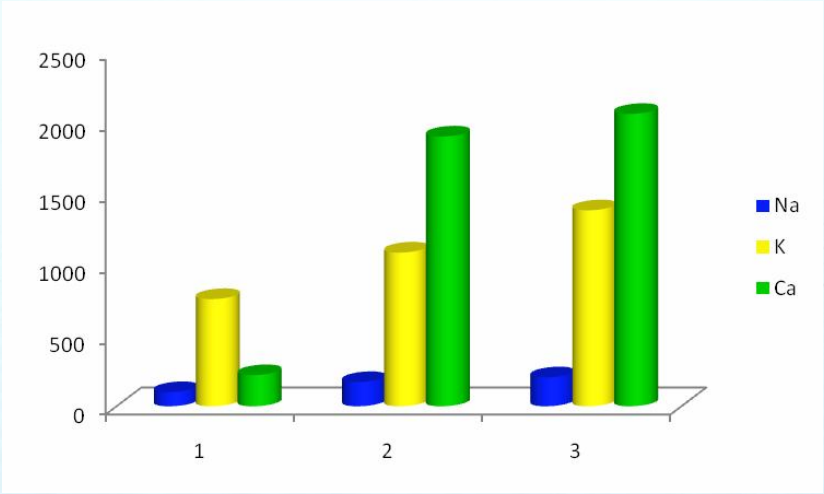


Fig.7. Macro mineral (mg/100gm) composition of *Tor putitora* from Hatchery Pond, Bhimtal in different fish size

Fish size: 1=325-500 gm; 2=115.3-170 gm & 50-174.5 gm.

mg/100 gm) respectively (Fig. 8). The higher concentration of selenium in the body composition of mahseer of Kameng river is attributed due to the rich concentration of selenium in water received as a process of anthropogenic sources from the atmosphere by dry and wet deposition from adjacent water, from surface run off, and from surface drainage in the North Eastern Himalayan region (latitude $27^0$48″36′ longitude $92^0$26″38′ and 2443 m. asl). Similarly, the rocky substratum in Kosi river of Western Himalayan region (latitude $29^0$25″ to $29^0$39″ N; longitude $78^0$44″ to 79^0 07″ E and 1960 m. asl) which contains higher levels of iron mineral have had positive co-relation with the increased body concentration of iron of golden mahseer benefiting the human health.

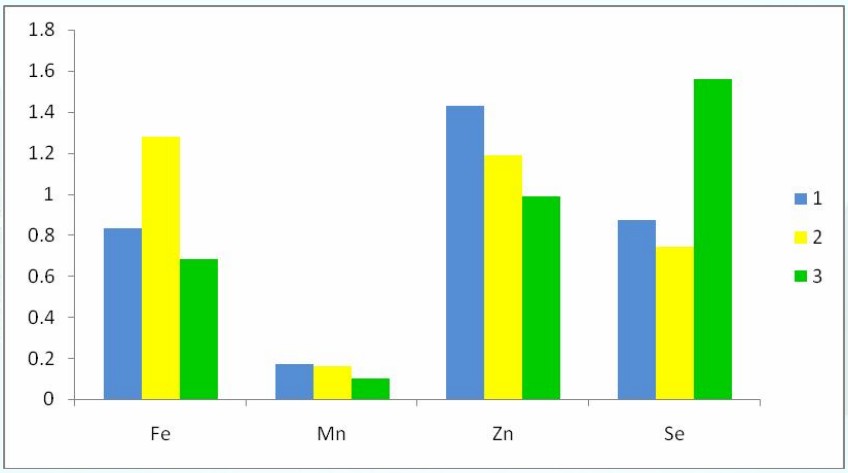


Fig.8. Micro mineral (mg/100gm) composition of *Tor putitora* of size 170-550 gm in different geographical location

Geo-climatic location: 1=Bhimtal (Hatchery Pond); 2=Kosi River, Uttarakhand & 3=Kameng River, Arunachal Pradesh.

The amino acid composition (% of total protein) is presented in (Fig. 9). The major amino acids were aspartic acid (7.606%), glutamic acid (9.631%), proline (6.684%), glycine (7.456%), leucine (7.585%), and lysine (9.411%). Levels of different amino acids were ranging from 0.482-9.631%. Thus, golden mahseer could be a good source of minerals as it contains higher concentration of micro and macro minerals (potassium, calcium, iron, manganese, zinc and selenium), which helps in metabolic process of development stages and are known to be indispensable to the human beings. Moreover, the values of proximate composition obtained were highly pronounced most especially the protein and crude fat, thereby the fish may provide an alternate source of protein for the upland population of developing countries. It is concluded that the size of fish, seasons

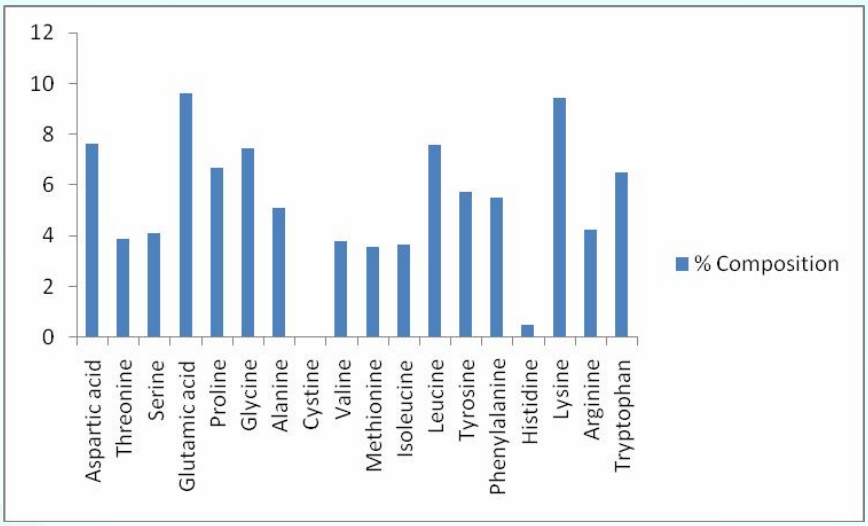


Fig.9. Amino acid composition of *Tor putitora* (%)

Cystine not detected

and geographical locations are the prominent factors in making a choice for consumption of coldwater fish species especially of golden mahseer for benefiting the human health.

6. Nutrient Profiling of Rainbow Trout

6.1 Proximate analyses

The results of proximate analysis of rainbow trouts are shown in Fig 10. The moisture, crude protein, crude lipid and ash contents of the rainbow trout were 74.00, 19.44, 5.18 and 1.37%, respectively. These values are almost similar to those for *Salmo gairdneri*, reported as 76.23, 18.57, 3.71 and 1.47%, for moisture, protein, fat and ash, respectively except crude lipid content which was slightly higher (5.18%). Based on the moisture and fat contents, the rainbow trout is a medium-fat fish, with a fat content of 5–10% by weight. However, the values in the present study are well comparable with the earlier reports in different salmonid species. Conversely, González-Fandos *et al.* (2004) reported higher lipid content (6.55%) and lower protein content (16.04%) in rainbow trout (*O. mykiss*) when compared to findings of the present study. This may be due to geographical location or maturity stage of rainbow trout as it has been indicated that the lipid content

of fish changes due to species, gender, maturity stage, geographical location and season.

6.2 Amino acid composition and score

The amino acid composition of rainbow trout muscle is shown in Fig 14. Rainbow trout protein had a well-balanced amino acid composition, with high amounts of proline (96.37 mg/g crude protein), aspartic acid (85.23 mg/g crude protein), tyrosine (83.84 mg/g crude protein), glycine (69.87 mg/g crude protein), serine (66.63 mg/g crude protein), arginine (65.26 mg/g crude protein), isoleucine (64.56 mg/g crude protein) and tryptophan (61.63 mg/g crude protein). Amino acids, not only have high nutritive value, but also provide several health benefits, such as reduction of blood cholesterol, anti-mutagenicity, reduction of coronary heart disease, and anti-obesity potential. Certain amino acids like aspartic acid, glycine and glutamic acid are also known to play a role in the process of wound healing (Chyun & Griminger, 1984). Proline, which is one of the major components of human skin collagen, together with other amino acids such as glycine, alanine, arginine, serine, isoleucine and phenyl alanine form a polypeptide that will promote regrowth and tissue healing where as tyrosine, methionine, histidine, lysine and tryptophan are considered to act as antioxidants for humans. It is reported that aspartic acid, glutamine, proline, glycine and leucine have strong cytotoxic activity against cancer cells. The protein in rainbow trout muscle was well balanced in essential amino acid composition and is of high quality.

6.3 Fatty acid profile

The fatty acid profile of the rainbow trout is presented in Fig. 11. The fatty acids analyzed were grouped as saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). In the present study, fatty acid profile showed that total monounsaturated fatty acids (MUFA) were the highest (35.88%) followed by saturated fatty acids (34.51%) and polyunsaturated fatty acids (31.39%). Palmitic acid (C16:0) was the predominant fatty acid in rainbow trout, accounting for about 63.28% of all SFAs followed by stearic acid (C18:0) (22%). Among MUFAs, oleic (C18: 1) and palmitoleic (16:1) acids were the predominant fatty acids, accounting for almost 67.69 and 22.85% of total MUFA, respectively. Linoleic acid (C18: 2n-6), docosahexaenoic acid (DHA) (C22: 6 n-3), linolenic (C18: 3n-3), arachidonic acid (AA) (C20: 4n-6) and eicosapantaenoic acid (EPA) (C20: 5 n-3) were the dominant PUFAs which were accounted for 43.93, 20.52, 15.42, 7.65 and 7.45 % of total PUFAs respectively. There is the fact that the lipid and fatty acid compositions of fish differ depending

on a variety of factors such as the species, maturity period, size and age of the fish, seasonal conditions and geographical location. In general, the fatty acid composition distribution of the rainbow trout analyzed is in agreement with the data available on the fatty acid composition of the same fish species. Studies have shown that freshwater fish generally contain lower proportions of n-3 PUFA than marine fish. Among PUFAs, DHA and EPA have an important role in nutrition for human health. It is reported that arachidonic acid is a precursor for prostaglandins and thromboxanes, which influence clotting of blood and the healing process. Apart from this function, it also plays a role in growth. Therefore, fish have been suggested as a key component for a healthy diet of humans. In the present study, we observed that DHA, AA and EPA accounted for 20.52, 7.65 and 7.45 % of the total PUFAs in the muscle of the rainbow trout.

6.4 Minerals

Fig 12 & 13 summarizes the mineral contents of the rainbow trout. Among the minerals analyzed, K was the highest followed by Ca, Na, Fe, Zn, Se and Mn. The results, especially K (1447.0 mg g/100 g), Ca (359.33 mg/100g), Na (208.0mg/100g) and Fe (5.17mg/100g) values, show that rainbow trout is suitable for human nutrition. All macro-mineral data fell within the range reported by the USDA for rainbow trout (*S. gairdneri*) meat. The main functions of essential minerals include skeletal structure, maintenance of colloidal system and regulation of acid-base equilibrium. Minerals also constitute important components of hormones, enzymes and enzyme activators. Calcium is necessary to maintain an optimal bone development. Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell hemoglobin, as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues. Adequate iron in the diet is very important for decreasing the incidence of anemia, which is considered a major health problem, especially in young, children. Iron deficiency occurs when the demand for iron is high, e.g., in growth, high menstrual loss, and pregnancy, and the intake is quantitatively inadequate or contains elements that render the iron unavailable for absorption. In the present study, it is revealed that rainbow trout muscle is reasonably a good source of iron, supplying 5.17mg/100 g muscle. Zinc is known to be involved in most metabolic pathways in plants, animals including humans. Zinc deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities (National Research Council Recommended dietary allowances, 1989). In the present investigation, zinc level of rainbow trout was found to be 1.79mg/100g of muscle, which is sufficient to maintain good health in humans.

Selenium plays a protective role in preventing carcinogenesis and other chronic diseases and act as an antioxidant in man. The selenium content (1.66 mg/100g) in rainbow trout in our study is higher than many other species like sea bass, 0.227 mg/kg, herring, 0.347 mg/kg; mackerel, 0.498 mg/kg; turbot, 0.473 mg/kg; flounder, 0.371 mg/kg. This suggests the nutritional good quality of rainbow trout muscle.

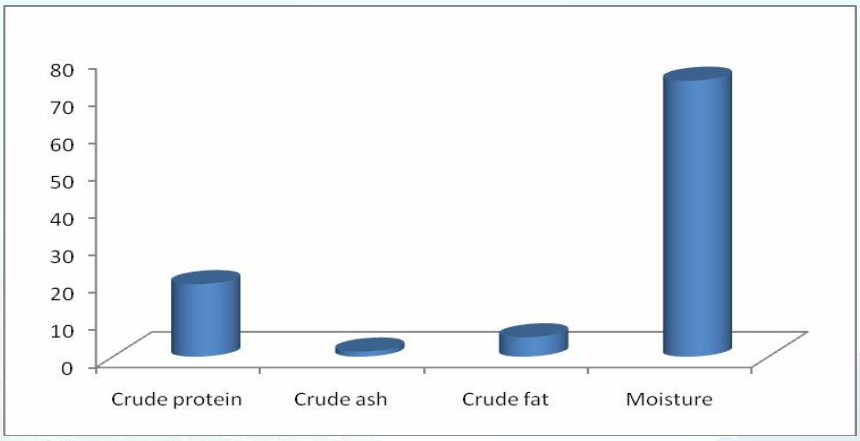


Fig.10. Proximate composition (gm/100gm) of *Oncorhynchus mykiss*

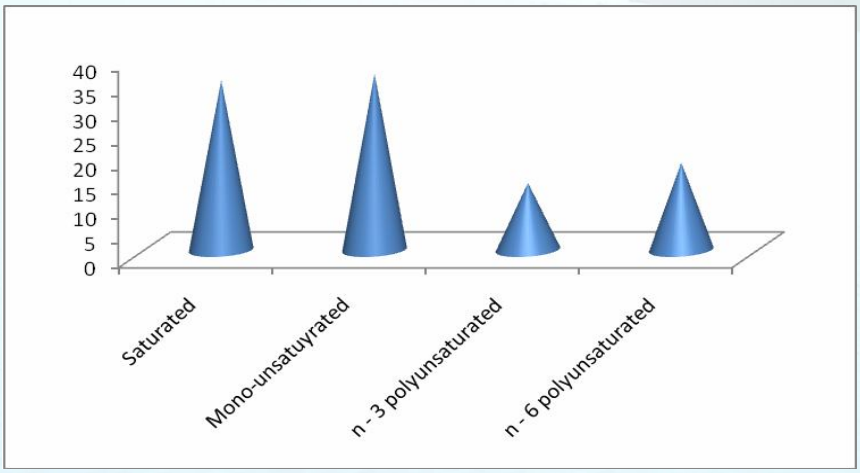


Fig. 11. Fatty acid profile of *Oncorhynchus mykiss*

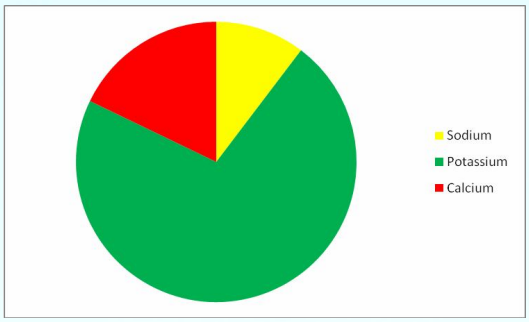


Fig.12. Macro mineral (mg/100gm) composition of *Oncorhynchus mykiss*

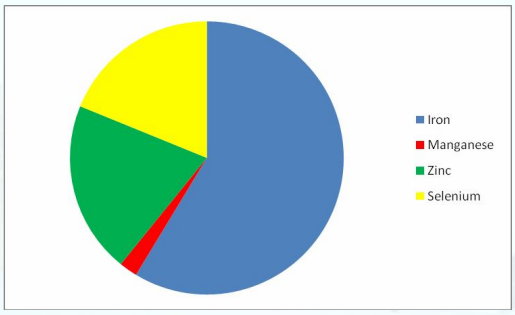


Fig.13. Micro mineral (mg/100gm) composition of *Oncorhynchus mykiss*

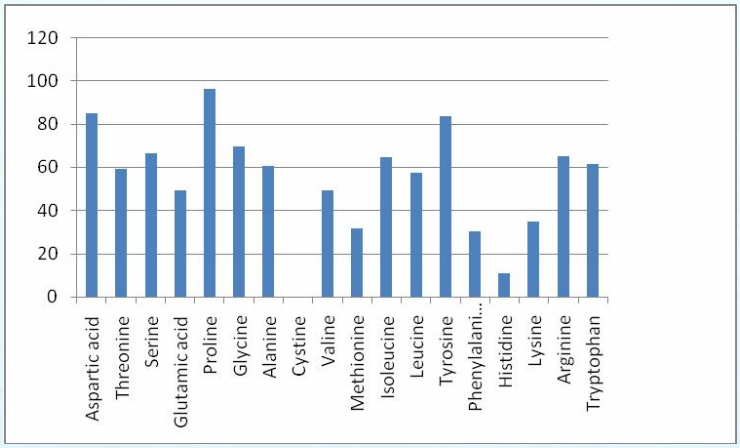


Fig.14. Amino acid composition in muscle of rainbow trout (values expressed as mg/g crude protein)

Cystine not detected

7. Fattyacid Profile of Important Coldwater Fish Species

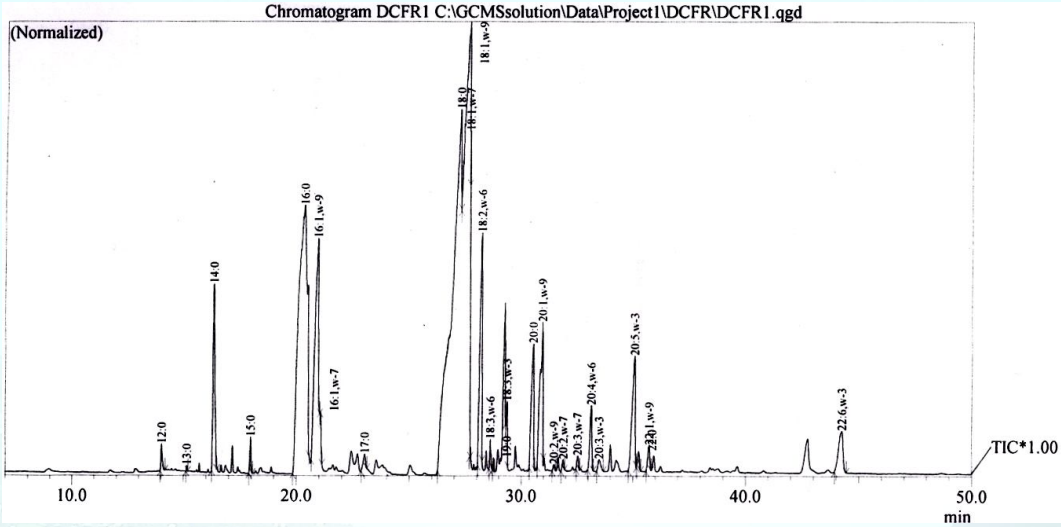


Fig. 15: Chromatogram of fatty acids of golden mahseer.

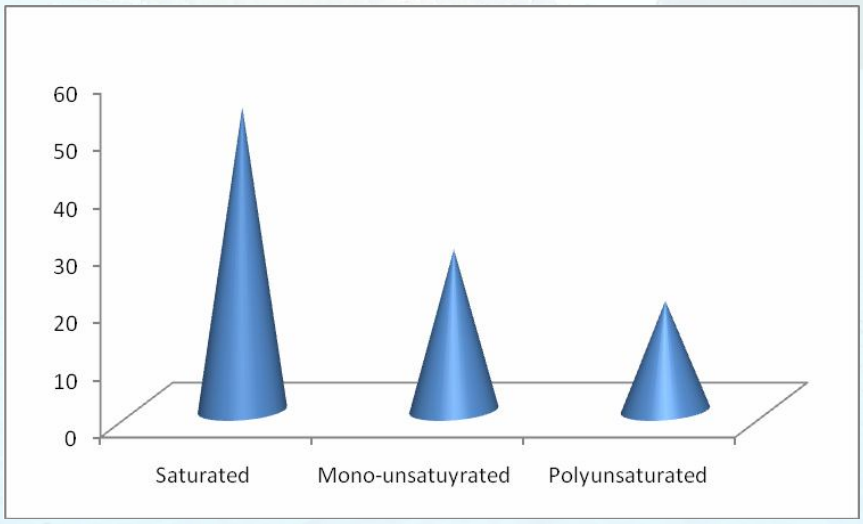


Fig. 16: Fatty acid profile (% of total fatty acid) of *Tor putitora* (golden mahseer)

Chocolate Mahseer

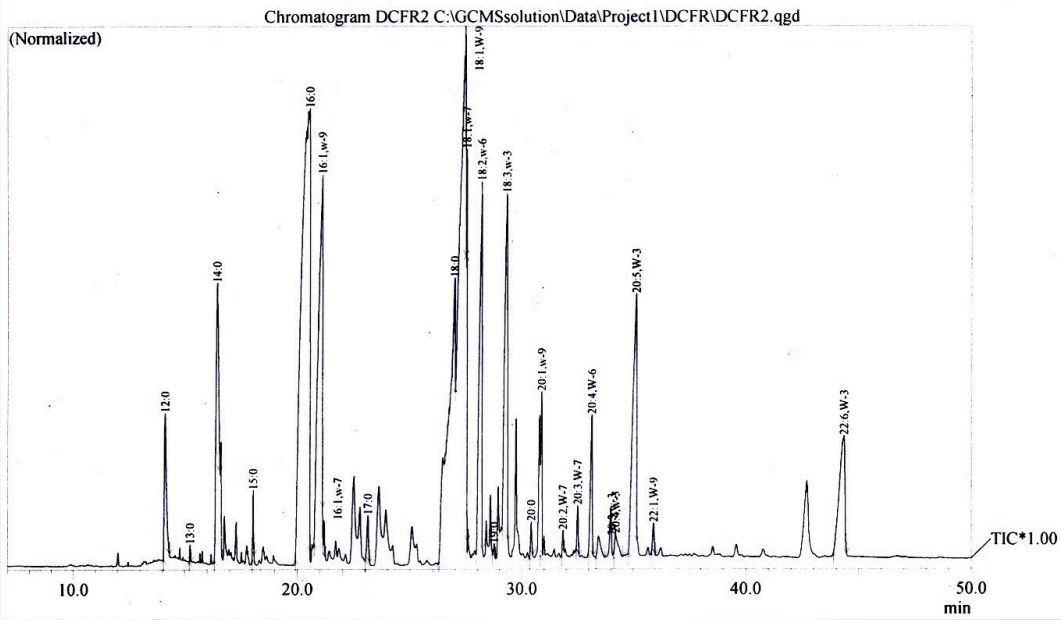


Fig. 16: Chromatogram of fatty acids of chocolate mahseer.

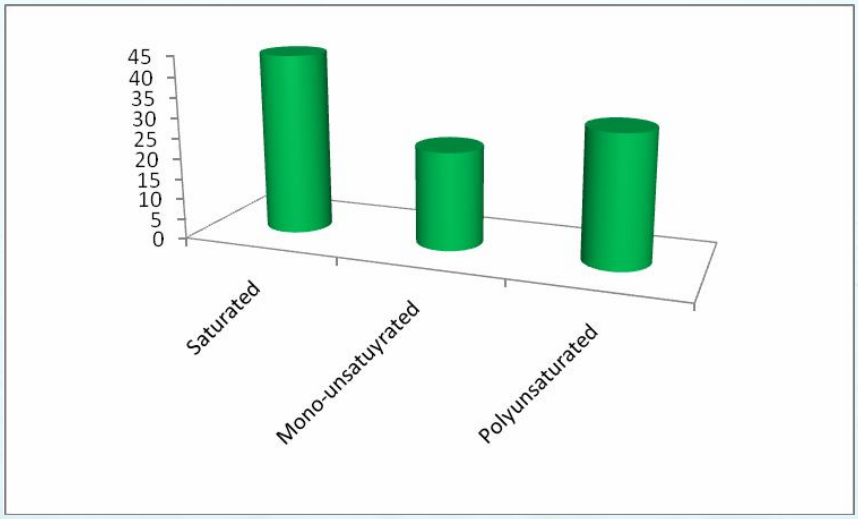


Fig. 17: Fatty acid profile (% of total fatty acid) of *Neolissocheilus hexagonolepis* (chocolate mahseer)

Common carp

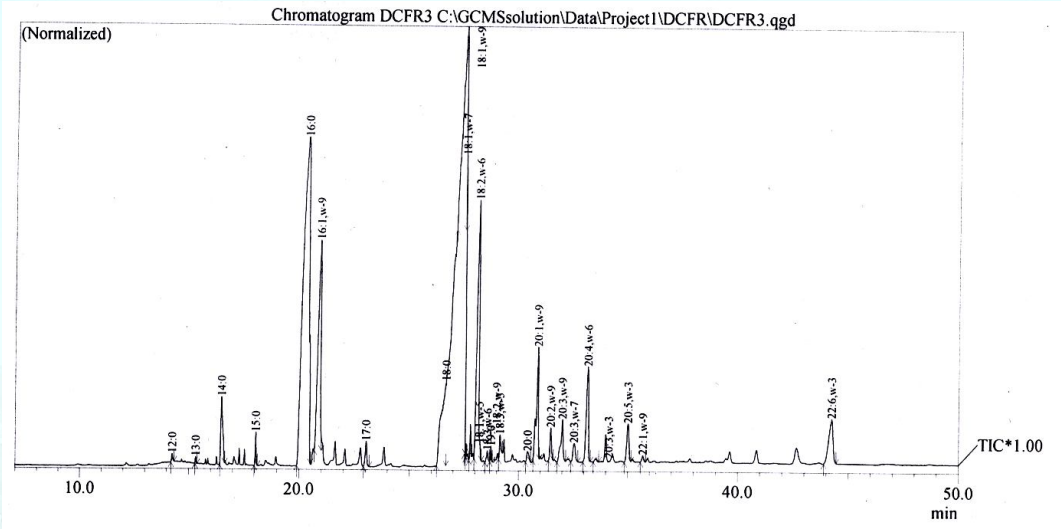


Fig. 18: Chromatogram of fatty acids of *Cyprinus carpio*.

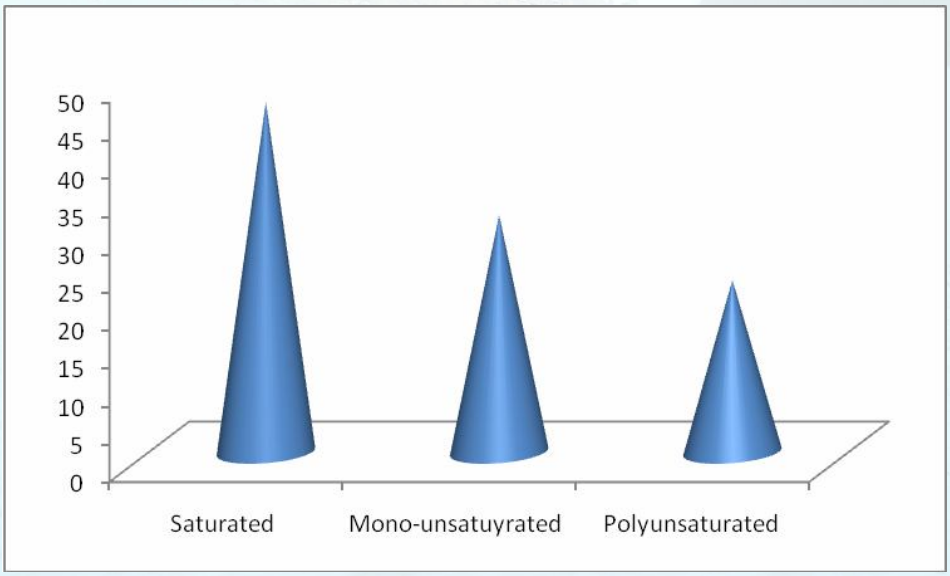


Fig. 19: Fatty acid profile (% of total fatty acid) of *Cyprinus carpio* (Common carp)

Snow trout

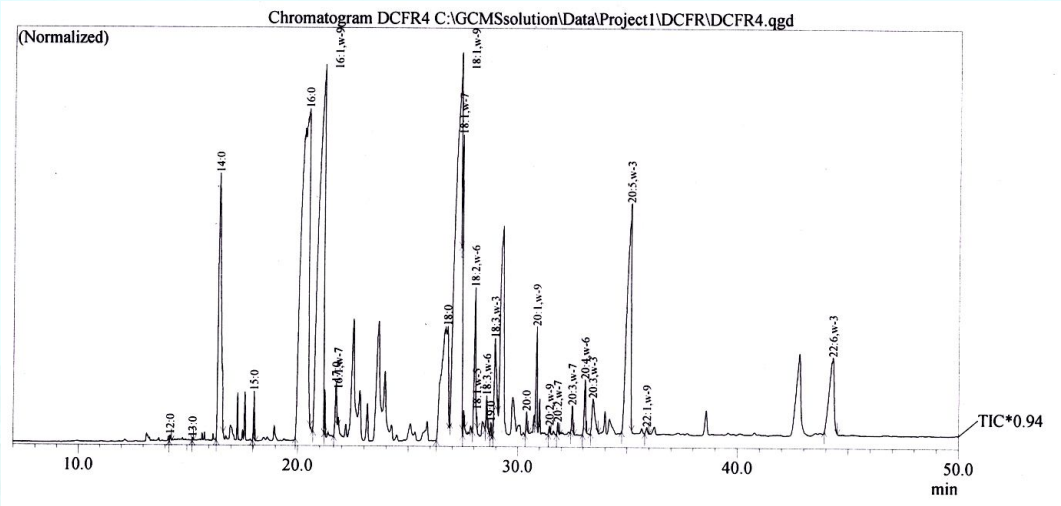


Fig. 20: Chromatogram of fatty acids of snow trout (*Schizothorax richardsonii*).

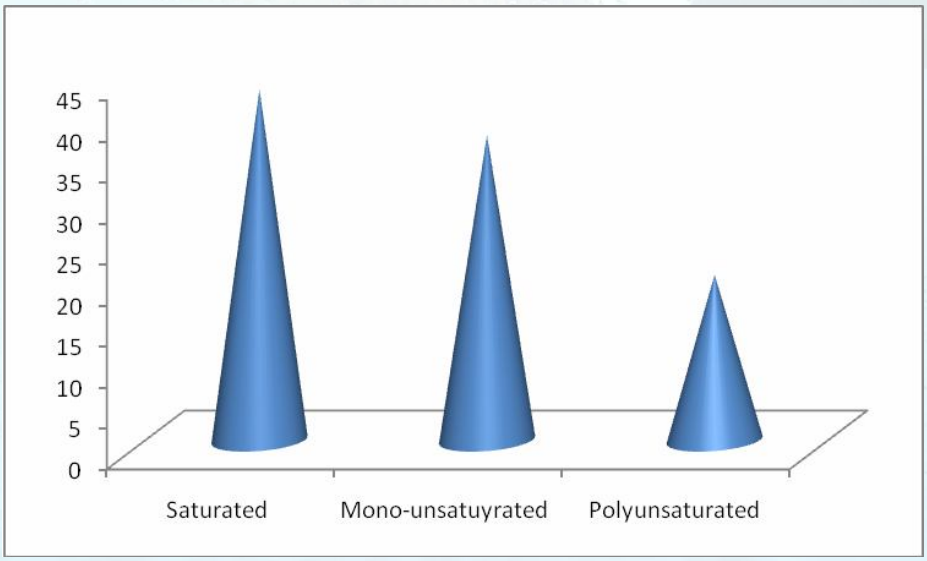


Fig. 21: Fatty acid profile (% of total fatty acid) of *Scizothorax richardsonii* (snow trout)

Angura (*Barilius bendelisis*)

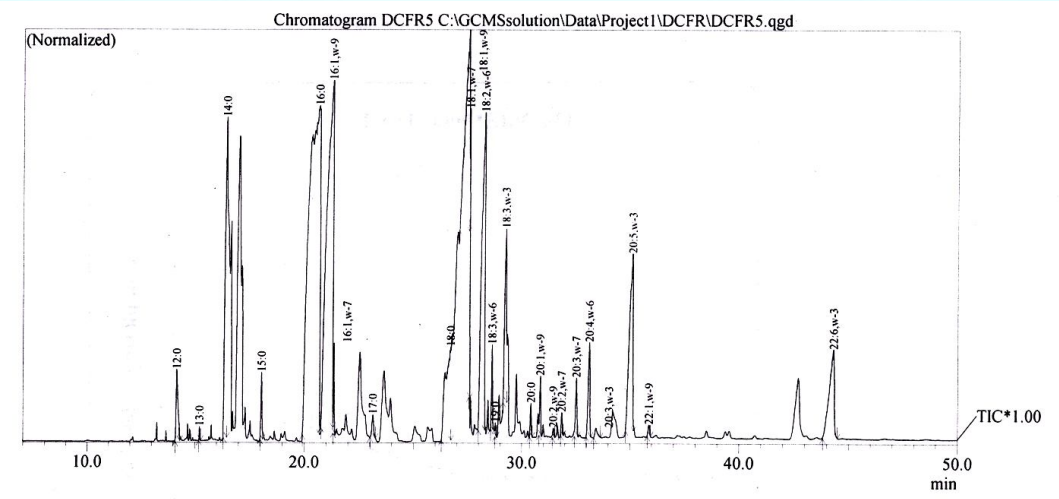


Fig. 22: Chromatogram of fatty acids of Angura.

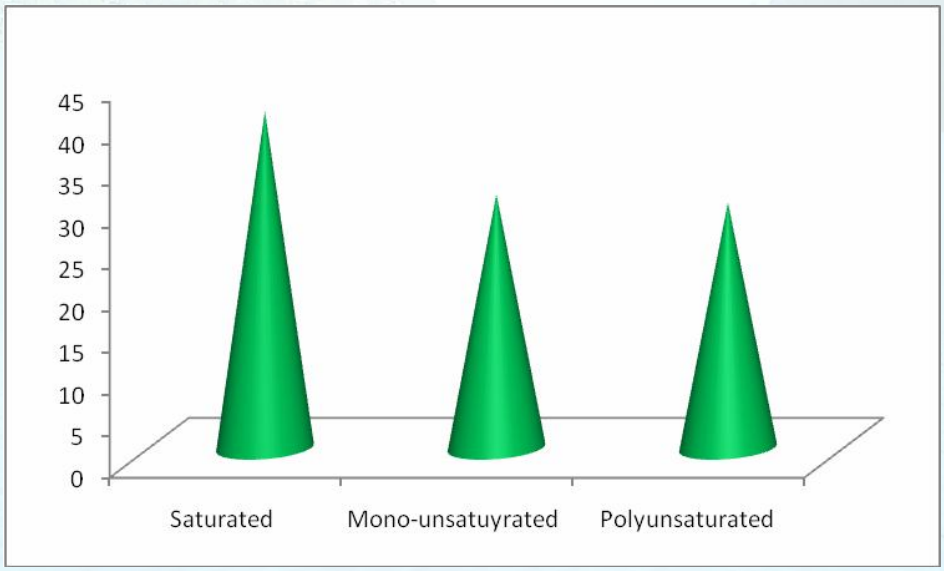


Fig. 23: Fatty acid profile (% of total fatty acid) of *Barilius bendelisis* (Angura)

Semiplotus (*Semiplotus semiplotus*)

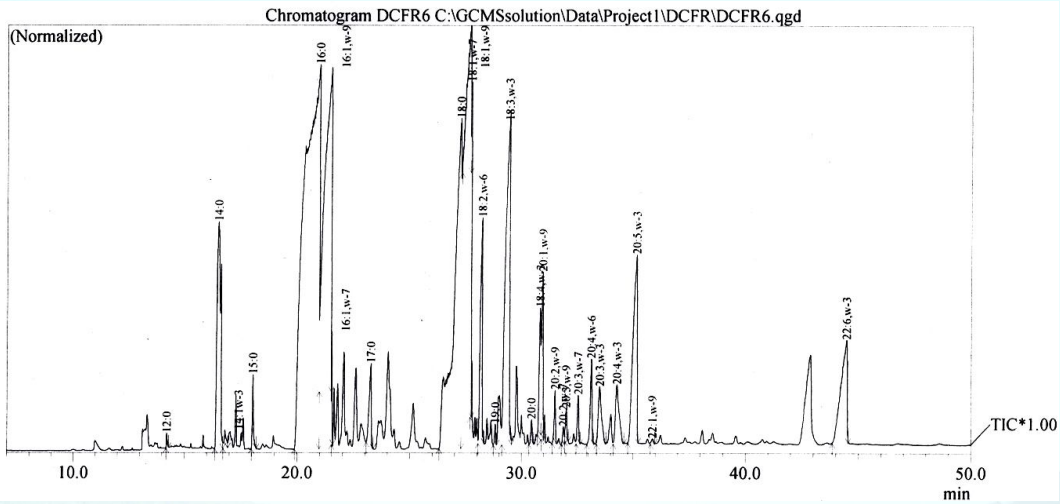


Fig. 24: Chromatogram of fatty acids of *Semiplotus semiplotus*

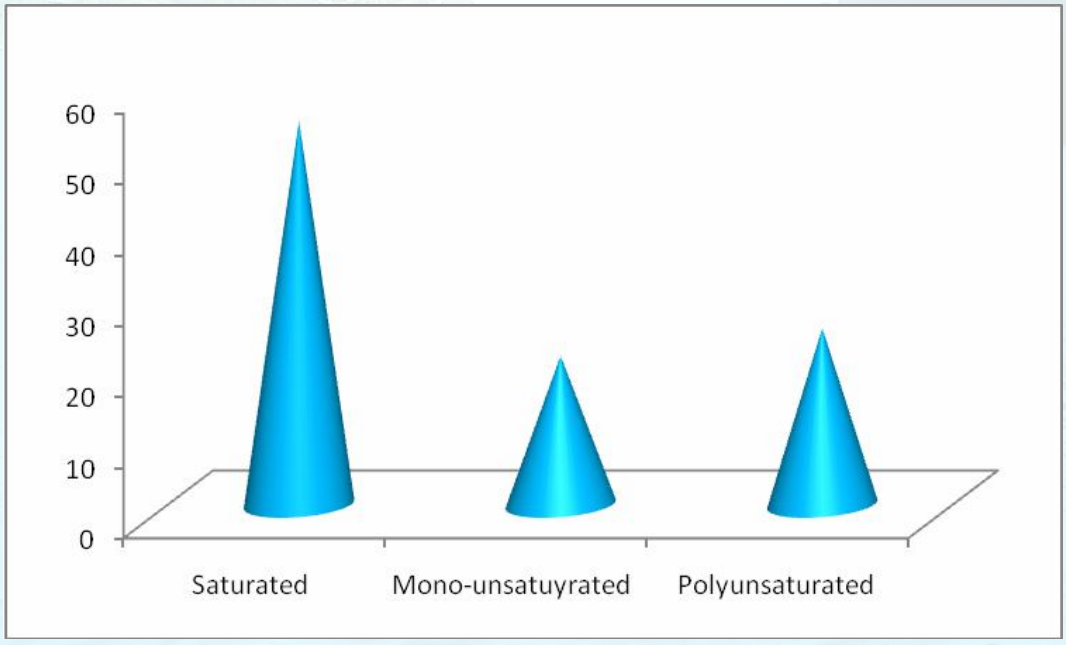


Fig. 25: Fatty acid profile (% of total fatty acid) of *Semiplotus semiplotus*

8. Medicinal and Therapeutic Value of Coldwater Fishes

Fish is not only to eat and relish, it has huge medicinal values and can be used as a medicine for various diseases. Example: Cod liver oil is used extensively as medicine. Seafood contains essential oils that are an important part of our diet. Oils provide the source of energy we need and they are also great flavor enhancers. More importantly, they are source of significant fatty acids such as omega-3 and omega -6 fatty acids. Oils derived from seafood help prevent some of the most deadly diseases today, including Alzheimer's disease, asthma, arteriosclerosis, bipolar disorder, bronchitis, cancer, heart diseases and more. The omega-3 oils decrease the risk of heart diseases, high blood pressure and rheumatoid arthritis. They are also beneficial to infants' brain and eye development.

Shark cartilage is used as a medicine for cancer. The study has shown that omega 3 fatty acids is present in fish, thus it is advised that the pregnant women must eat fish to avoid the risk of brain disease in their offspring.

Halibut is also known as a good source of vitamin B12, vitamin B6 and folic acid that lower levels of homocysteine, a compound that can damage artery walls. It is also a very good source of magnesium, a natural calcium channel blocker, which lessens resistance and improves the flow of blood, oxygen and nutrients throughout the body. Apart from theses the halibut provides protection against ovarian and digestive tract cancers.

Few people talk about the health benefits of eating roe. Roe is a rich source of vitamins A and D, very long-chain fatty acids, and zinc. Since deficiencies of all of these compounds during pregnancy can cause birth defects, primitive peoples valued roe as a superfood, necessary for healthy children. Indians of the Andes went to great trouble to carry dried fish roe from sea level to high in the Andes, to provide those of childbearing age with a food that insured they would have healthy babies. Salmon roe is known to be beneficial in chronic liver diseases such as hepatitis, as it contains phosphatidylcholine.

Seafood diet of haddock and cod, which are low in fat and calorie, can also help us to reduce weight. For years, seafood has been part of many weight loss programs. This is because, unlike diet pills, seafood is natural and has beneficial properties to people. Shellfishes are very much rich in zinc, thus consumed for healthier skin, muscle and fertility.

In earlier days those who suffered from goiter were given marine seafood especially cod, haddock, sea bass and perch to supplement the iodine in body. The pacific sea cucumber (*Stichopus* species) has been revered by Chinese cooks since ancient times. In particular, sea cucumber meals have been offered on special

occasions, especially New Year celebrations. The sea cucumber is valued-along with several other delicacies, such as shark's fin, ginseng, cordyceps, and tremella-as a disease preventive and longevity tonic. It was listed as a medicinal agent in the *Bencao Congxin* (New Compilation of Materia Medica) by Wu Yiluo in 1757.

The Atlantic sea cucumber, *Cucumaria frondosa*, has been collected primarily for food, but has recently been researched as a source of medicinal components. Sea cucumber, having a cartilagenous body, serves as a rich source of mucopolysaccharides, mainly chondroitin sulfate, which is well known for its ability to reduce arthritis pain, especially that of osteoarthritis. As little as 3 grams per day of the dried sea cucumber has been helpful in significantly reducing arthralgia. Chondroitin's action is similar to that of glucosamine sulfate, the main building block of chondroitin. Long-chain sulfated polysaccharides, like chondroitin, also inhibit viruses; there is a Japanese patent for sea cucumber chondroitin sulfate for HIV therapy based on this action, and other sulfated polysaccharides from seaweeds have been patented as inhibitors of herpes viruses. Chondroitin is usually obtained in commercial quantities from bovine trachea or shark cartilage (including the shark fin), while glucosamine sulfate is obtained from shells of shrimp and crab. These compounds are also found in deer antler, which is not a practical source for extraction due to its rarity and cost, but it is likely that glucosamine and chondroitin are significant contributors to the medicinal action of deer antler. Russian, Japanese, and Chinese studies reveal that sea cucumbers also contain saponins (triterpene glycosides). These compounds have a structure similar to the active constituents of ginseng, ganoderma, and other famous tonic herbs. Pharmacology studies indicate anti-inflammatory and anticancer properties of the sea cucumber saponins.

In addition, the sea cucumber oil contains two anti-inflammatory fractions. One fraction has fatty acids characteristic of those found in fish; they can be used as a substitute for fish oil in reducing inflammatory byproducts of fat metabolism, and to nourish the brain and heart. The other oil fraction is a mixture of branched chain fatty acids, mainly 12-MTA (methyltetradecanoic acid). This compound, and the more widely studied variant, 13-MTA, are potent inhibitors of the 5-LOX (lypoxygenase) enzyme system. 5-LOX inhibitors are one of the key areas of modern drug development, with plans evolving to use the compounds in treatment of asthma, ulcerative colitis, and arthritis. In addition, cancer-inhibiting effects have been observed in preliminary studies with prostate cancer cell lines and other human cancer cells These fatty acids are thought to be produced by bacteria that live within the sea cucumbers; they are also produced by bacteria in other marine organisms, such as sponges and tunicates.

Oncorhynchus mykiss

Schizothorax richardsonii

Salmo trutta fario

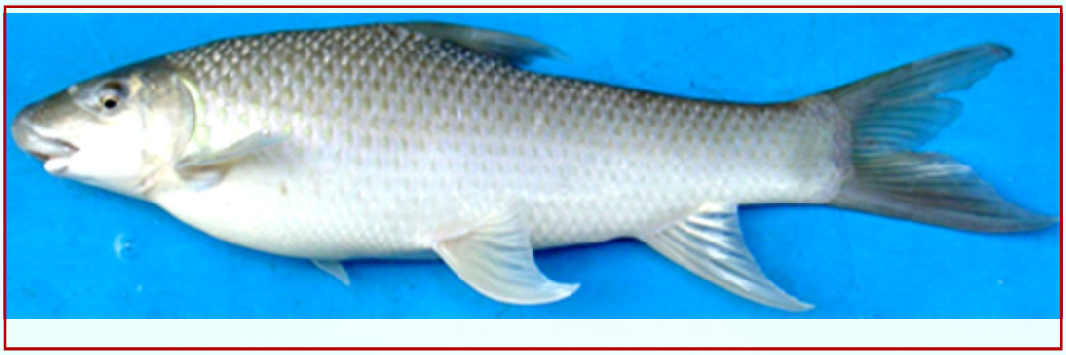
Plate 1 : Important edible coldwater fishes of India

Neolissocheilus hexagonolepis

Tor putitora

Tor khudree

Plate 2 : Important edible coldwater fishes of India



L. pangusia

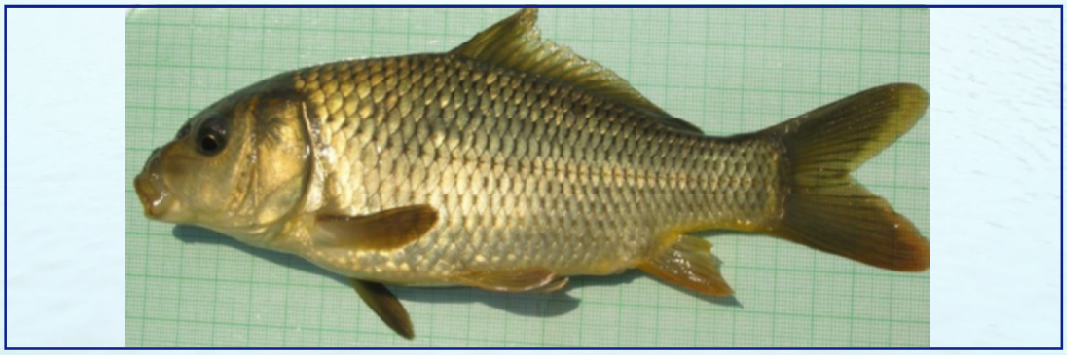
Labeo dero

Labeo dyocheilus

Plate 3 : Important edible coldwater fishes of India

Felsosomogy Mirror carp

Ropsha Scaly Carp



Common carp

Plate 4 : Important edible coldwater fishes of India

Silver carp

Grass carp

Semiplotus semiplotus

Plate 5 : Important edible coldwater fishes of India

Garra sp.

Botia sp.

Osteobroma balengari

Barilius bendelisis

Plate 6 : Important edible coldwater fishes of India

Pseudochinies sp.

Botia dario

Botia rostrata

Plate 7 : Important edible coldwater fishes of India

Schistura sp.

Glyptothotax sp.

Parambassis sp.

Plate 8 : Important edible coldwater fishes of India

10. Suggested Reading

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