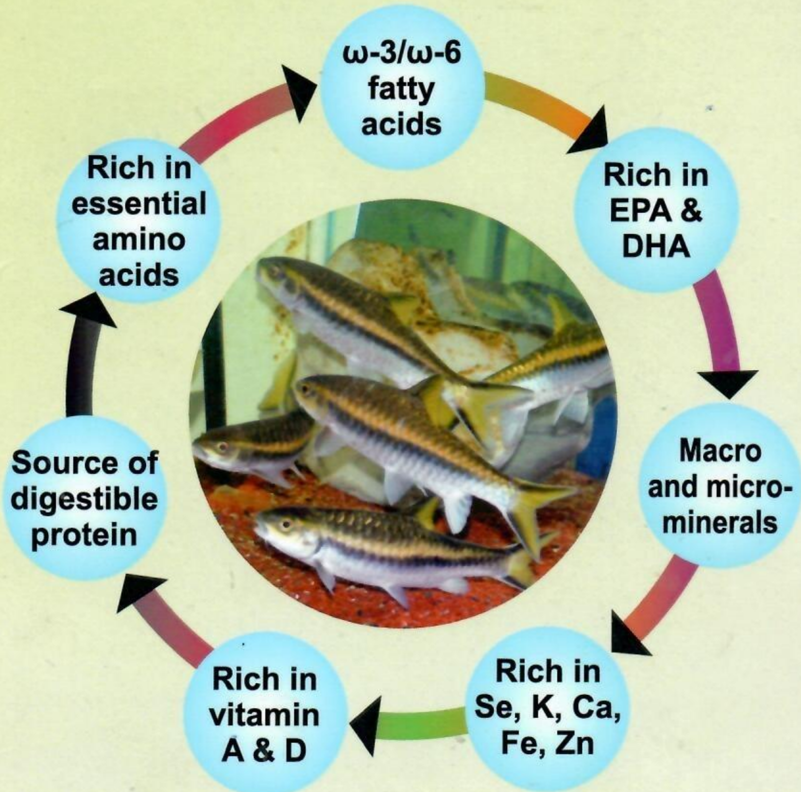
Bulletin No. 29

Nutrient Composition of Coldwater Fishes and Their Prospects in Human Nutrition



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MESSAGE

Coldwater fishes form a significant part of the diet of the India upland population and ensure nutritional security to a greater extent. Fish is one of the important sources of quality proteins and plays a pivotal role in preventing protein and caloric malnutrition in humans. The nutritional quality of fish is associated with its content of essential fatty acids, essential amino acids, minerals and vitamins. The polyunsaturated fatty acids (PUFAs) such as EPA and DHA in fish are efficiently being used in nutraceuticals for preventing coronary heart diseases, osteoarthritis and other age related ailments. There has been dearth of information on nutritive value and nutrient quality of coldwater fish species in India. In this context, ICAR-Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand has taken sincere research efforts to find out the nutrient quality of major Indian coldwater fish species in terms of gross chemical composition, amino acid profile, fatty acids and other macro and micronutrients.

I appreciate the efforts of the authors of this bulletin on *"Nutrient Composition of Coldwater Fishes and Their Prospects in Human Nutrition"* for bringing out the nutritional facts of the coldwater fishes. This bulletin is expected to become instrumental in popularizing fish as a health food and could be useful for common people as well as for dietary recommendations by physicians/dieticians.

(J. K. Jena)

FOREWORD

The concept of healthy or the functional food is becoming popular in global food scenario because of its positive link with spreading of lifestyle diseases. As a consequence of this, the evaluation of nutritional and functional quality of food and food ingredients is becoming indispensable. Worldwide, many food components are being taken up for evaluation of nutritional and functional quality. Among the long array of the functional foods, fish has a long history of preventing humankind from many chronic lifestyle diseases of old ages, and it is taken equally by rich and poor people for their inherent functionality and nutritional potential respectively. Fish not only contains long-chain n-3 polyunsaturated fatty acids (n-3 LC-PUFAs; eicosapentaenoic acid, EPA and docosahexaenoic acid, DHA), it is also a source of other health promoting bioactive components such as vitamin D, B12 and A, selenium, iodine, iron, zinc, choline, taurine, etc. Because of the presence of these intrinsically balanced desirable nutrients and inherent bio-active components, fish comes to everyone's plate irrespective of rich or poor, young or old, healthy or unhealthy.

Considering the importance of fish in human health, ICAR-Directorate of Coldwater Fisheries Research (ICAR-DCFR), Bhimtal took the responsibility of evaluating the nutrient composition of Indian Himalayan fishes under the umbrella of ICAR's network project #3 *"Nutrient profiling and evaluation of fish as a dietary component"* with a view to generate knowledgebase on nutrient quality and to popularize fish consumption. With the sincere efforts of the Directorate, nutrient composition data of 24 coldwater fish species are now available and I am sure the present bulletin *"Nutrient Composition of Coldwater Fishes and Their Prospects in Human Nutrition"* will provide very useful information on the nutrient profile of coldwater fishes and their prospects in human nutrition for consumers. This document will serve as a knowledgebase and an indispensable reference to the physicians, dieticians, scientists, teachers, students and other stakeholders to understand the nutritional significance of coldwater fish species.

The bulletin deserves appreciation and I congratulate the authors for their efforts in bringing such informative document on coldwater fishes of India.

(Debajit Sarma)
Director (Acting)

CONTENTS

Coldwater fishes in India

India has significant aquatic resources in terms of upland rivers, streams, high and low altitude natural lakes, reservoirs, which hold large populations of indigenous and exotic, cultivable and non cultivable fish species. Coldwater fishes occupy an important place amongst the freshwater fishes and its resources spread over the Himalayan and peninsular regions of India encompassing about twelve states. The coldwater resources include around 8243 km long streams and rivers, 20500 ha natural lakes, 50000 ha of reservoirs both natural and manmade and 2500 ha brackish water lakes at high altitude. 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 which eventually affect the nutrient quality of fish. Coldwater fishes form a significant part of the diet of the Indian upland population and ensure nutritional security to a greater extent.

Commercially important coldwater fishes in India

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 belong 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 Indian uplands. Of these, trouts, snow trouts, mahseers, common carp and minor carps are important as sport and food fishes. These species (Table 1) are widely distributed both in the Himalayas and the peninsular plateau. Coldwater fish production is mainly centered in five important hilly states of India namely Himachal Pradesh, Jammu & Kashmir, Sikkim, Arunachal Pradesh and Uttarakhand. Rainbow trout was introduced in early 20th century for the development of recreational fisheries. However, over the years, the exotic rainbow trout has become the most relevant and remunerative coldwater fish farmed in Indian uplands garnering more significance as a source of employment and food security. So far, only rainbow trout is being cultured in an organized manner in the coldwater regions of the country with Himachal Pradesh as the leading producer and the state wise production of rainbow trout in India is given in Figure 1. Presently, coldwater fisheries contribute only 3% to the total inland fisheries sector of India and projected to contribute around 6% by 2025. The low contribution to the total fish production is attributable to several constraints such as low productivity of upland waters, comparatively slow growth rate in majority of fish species, low fecundity and poor landing and marketing facility.

Table 1: Important coldwater fishes

Mahseers	**Exotic trouts**	*Semiplotus semiplotus*
Tor putitora	*Onchorhynchus mykiss*	*Aspidoporia morar*
T. tor	*Salmo trutta fario*	*Bangana devdevi*
T. khudree	*Salvelinus fontinalis*	*Osteobroma balengari*
T. malabaricus	Other exotic species	Barils/Minnows/Catfishes/Loaches

Mahseers	**Exotic trouts**	*Semiplotus semiplotus*
T. mussullah	*Cyprinus carpio* var. *specularis*	*Barilius bendelisis*
T. progeneius	*Cyprinus carpio* var. *communis*	*B. bakeri*
Neolissochilus hexagonolepis	*Cyprinus carpio* var. *nudus*	*B. vagra*
Snow trouts	*Tinca tinca*	*B. barila*
Schizothorax richardsonii	*Carassius carassius*	*Raimas bola*
S. esocinus	*Ctenopharyngodon idella*	*Danio divario*
S. niger	*Hypophthalmichthys molitrix*	*Botia birdi*
S. plagiostomus	**Minor carps**	*B. rostrata*
S. progastus	*Labeo dyochelius*	*Glyptothorax pectinopterus*
S. labiatus	*L. dero*	*G. conirostre conirostre*
S. curvifrons	*Labeo pangusia*	*Sanguina sanguine*
S. longipinnis	*Garra gotyla*	*Macrognathus aral*
S. micropogon	*G. hughi*	*Setipinna phasa*
S. nasus	G. mulya	Clupisoma garua
S. hugelli	Chagunius chagunio	Schistura sp.
S. plannifrons	Puntius ophicephalus	

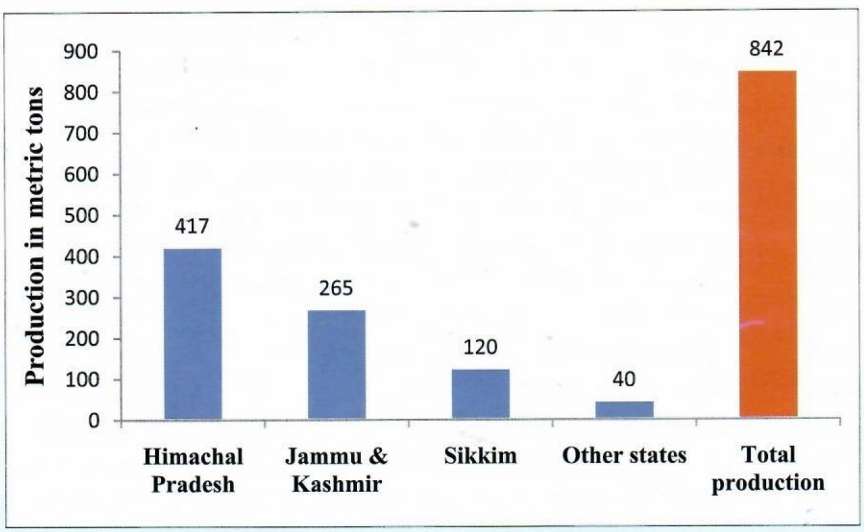


Figure 1: State wise rainbow trout production in India during 2015-2016

Fish as health food

Health and nutrition are the most important contributory factors for human resource development in the country. Presently, the world is facing the dual problems of nutrition; malnutrition (or nutritional deficiency diseases, NDDs) in one hand and the lifestyle diseases (LDs) on the other. Unlike the global decreasing trend of malnutrition, the cases of LDs, in the global scenario, are increasing year after year in an erratic fashion. Therefore, LDs are more of a concern compared to NDDs. They came into being and continuously mushrooming as a result of the advancement of industrialization, urbanization, economic development and globalization; because, expansion of global food market have availed the energy dense food with high saturated fat and carbohydrate, and this in combination with a sedentary lifestyle have further bolstered the cause. Commonly seen such diseases, in our society, include obesity, cardiovascular diseases, hypertension, diabetes, stroke, arthritis, sleep disorders, osteoporosis, arteriosclerosis, dementia, cancer, etc. Irregular and inappropriate eating habits are prime factors responsible for LDs and NDDs. The occurrence of nutrition related death could be avoided through proper dietary formulations or inclusion of fruits, vegetables, whole grains and lean meats, especially fish, in daily human diet (Hasler, 1998).

Among the long array of the functional foods, fish has been considered as an inevitable part of a healthy balanced human diet as it contains good quality proteins of high biological value, vitamins, omega-3 fatty acids and other essential nutrients. The low fat (saturated) content along with high amounts of long chain n-3 polyunsaturated fatty acids (PUFA's) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) makes fish a valuable, cheap source of animal protein and other nutrients. Fish is also a rich source of health promoting bioactive components such as vitamin D, B_{12} and A, selenium, iodine, iron, zinc, choline, taurine, etc. The consumption of fish is popular among health conscious people because of this inherent functionality. The per capita consumption of fish is increasing at a global scenario from 15.7 in 2006 to 17.2 (kg/person/year) in 2010 and projected to reach 18 (kg/person/year) by 2020 (World Bank, 2013). According to Love (1970), principal composition of fish is 16-21 % protein, 0.2-5 % fat and 66-81 % water. The multifarious economic advantages and nutritional significance of fish help to bridge the protein gap in human nutrition (Waseem, 2007). A number of diseases and clinical conditions can be potentially lightened by inclusion of fish/seafood in human diets. The Food and Drug Administration (FDA) and American Heart Association (AHA) urge that seafood is an important part of a healthy diet and advocate consumption of a wide variety of fish and shellfish. The AHA continues to recommend at least two servings of fish (especially oily/fatty fish) per week to achieve cardio-protective effects (Smith and Sahyoun, 2005). Consumption of one fatty fish meal per day could result in an omega-3 fatty acid intake (i.e., EPA and DHA) of approximately 900 mg/day, an amount shown to beneficially affect patients with coronary heart disease (Kris-Etherton et al., 2002). The nutritional value and health benefits of fish consumption are described here under.

Fish as a source of proteins

Fish muscle, the edible portion of fish is an excellent and relatively a cheaper source of animal protein for humans. The great diversity and wide distribution of fish make it available and affordable to every sections of society. Protein is composed of amino acids and human body cannot synthesize nine of these amino acids *viz.*, leucine, isoleucine, valine, lysine, tryptophan, threonine, methionine, phenylalanine and histidine and are hence considered nutritionally essential or indispensable in the human diet (Sheeshka and Murkin, 2002). The quality of protein in terms of its bioavailable indispensable amino acids is a key criterion in deciding the daily protein requirement. Fish contains significant amounts of essential amino acids, particularly lysine which is low in cereals. Fish protein can therefore be used to complement the amino acid pattern and the overall protein quality of a mixed diet (FAO, 2005). Protein supplies nitrogen for the synthesis of non essential amino acids, enzymes, antibodies, peptide hormones, structural and transport proteins (Sheeshka and Murkin, 2002). The quality of a protein is determined mainly by the specific amounts and relative proportions of its essential amino acids, their bio-availability and protein's digestibility (Sheeshka and Murkin, 2002). In general, animal proteins (e.g., dairy products, eggs, meats, fish, and poultry) are of higher quality than plant proteins (e.g., pasta, rice, fruits, and vegetables). The chemical score/amino acid score (comparison of a food's amino acid pattern with that of whole egg protein) and biological value (the percentage of the absorbed nitrogen that is retained by the body for tissue growth and maintenance) of fish are 70 and 76% respectively indicating its protein is of high quality (Sabry, 1990; Sheeshka and Murkin, 2002).

In addition to the balanced proportions of all EAAs, fish also contains the best combination of non-essential amino acids (NEAAs) such as aspartic acid, asparagine, serine and alanine (Bruke et al., 1997; Buttery and D' Mello, 1994; Dahhar and Elshazly, 1993). Amino acids have high nutritive values and provide several health benefits such as reduction of blood cholesterol and antimutagenicity (Simopoulos, 2002). Certain amino acids like aspartic acid, glycine and glutamic acid are also known to play a role in the process of wound healing (Chyun and Griminger, 1984). Some amino acids like tyrosine, methionine, histidine, lysine and tryptophan are considered to act as antioxidants (Saito et al., 2003). In addition, Kim et al. (1999) reported that aspartic acid, glutamine, proline, glycine and leucine have strong cytotoxic activity against cancer cells.

Fish as a source of polyunsaturated fatty acids

The nutritional quality of fish, to a great extent, is associated with its content of essential fatty acids (EFAs). Among essential fatty acids/polyunsaturated fatty acids, EPA and DHA are found almost exclusively in seafood (Harris, 2004). Approximately 50% of the fatty acids in lean fish (e.g., walleye and yellow perch) and 25% in fattier fish (e.g., channel catfish and rainbow trout) are polyunsaturated fatty acids (Sheeshka and Murkin, 2002). Long chain n-3 PUFA (LCn-3 PUFA) cannot be synthesised by humans and must be obtained from the diet (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002). DHA is the most abundant PUFA in the central nervous system particularly in synaptic plasma membranes (Foot et al., 1982; Cotman et al., 1969; Breckenridge 1972) and in photoreceptor cells (Anderson et al., 1974). Hence, correct acquisition of DHA is essential for normal neurological and visual development during embryogenesis and early postnatal stages of development (Connor et al., 1990; Enslen et al., 1991). Omega-3 fatty acids have probed to have protective effects in preventing coronary heart disease, reducing arrhythmias and thrombosis (Kinsella et al., 1990; Oomen et al., 2000; Kris-Etherton et al., 2002) lowering plasma triglyceride levels (Harris, 1997; Ismail, 2005) and reducing blood clotting tendency (Agree et al., 1997; Din et al., 2004; Ismail, 2005).

There is strong scientific evidence that n-3 PUFA play important roles in the modulation and prevention of human diseases, particularly coronary heart disease, hypertension, inflammation, arrhythmias, psoriasis, aggression, depression, auto-immune disorders and cancer (Simopoulos, 2002) through several actions including the reduction of triglycerides and very low density lipoproteins, prevention of irregularity in the rhythm of heartbeat, prevention of the formation of blood clots in blood vessels and inhibition of inflammation. Fats are valuable sources of energy, fat-soluble vitamins and unsaturated fatty acids, having hypocholesterolemic effect (Fernandez and Venkatrammann, 1993; Ismail, 2005). Omega-3 rich fish oil products under various commercial brand names are available in drug stores for nutraceutical supplementation. However, eating fish as a whole is beneficial than consuming commercially available concentrated nutraceuticals because essential fatty acids, in whole fish, are retained in diluted form in muscle matrix, and thus, they release slowly in the gastrointestinal tract during digestion (Gormley, 2006).

Fish as a source of vitamins and minerals

Vitamins are chemical compounds required by the body in small amounts. Vitamins are essential for numerous body processes and for maintenance of the structure of skin, bone, nerves, eye, brain, blood and mucous membrane. Fish are excellent source of vitamins. Fish represent a very important source of vitamin A and D (both D_2 and D_3) which is essential for proper vision and bone mineralisation respectively. They also contain relatively high levels of vitamin E/tocopherol and vitamin B_{12}. Fish is an excellent source of niacin/vitamin B_3 and pyridoxine/ vitamin B_6. The significant amount of choline and taurine in fish may contribute to the health benefits associated with consuming fish (Lund, 2013).

Minerals are inorganic elements found in body fluids and tissues. They are required for maintenance and integrity of skin, hair, nails, blood and soft tissues. Minerals also govern nerve cell transmission, acid/base and fluid balance, enzyme and hormone activity as well as the blood- clotting processes. Calcium is necessary to maintain 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 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 as a major health problem, especially in young children. Zinc is known to be involved in most metabolic pathways in plants, animals including humans (Hambidge, 2000). Zinc deficiency can lead to loss of appetite, growth retardation, skin changes and immunological abnormalities (Rasoarahona, 2005). Selenium plays a protective role in preventing carcinogenesis and other chronic diseases and act as an antioxidant (Önnig, 2000). Based on the human dietary requirement, minerals are divided into two categories, macro and microminerals; macro-minerals are required in higher concentration and micro-minerals in lower concentration (Mohanty et al., 2016a). Macro-minerals include sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and phosphorus (P); micro-minerals include iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), and selenium (Se) (Mohanty et al., 2016a). Fish in general, is a good source of calcium, phosphrous, iron, zinc and selenium (Fox et al., 2004). Interestingly a novel form of organic selenium, selenoneine, has recently been identified in tuna, the health benefits of which are still to be defined, but initial evidence suggests it has strong antioxidant activity (Yamashita & Yamashita, 2010).

Potential health risks associated with fish/fish oil consumption

Despite the potential health benefits of dietary fish intake, certain species contain metals and organic pollutants arousing health risks for consumers with frequent fish and shellfish consumption. Methylmercury, polychlorinated biphenyls (PCBs) dioxin-like compounds and organochlorine pesticides are the major chemical/organic contaminants present in fish (Wilson, 2004). Additionally, heavy metals such as cadmium, lead and arsenic are also reported to be present in fish. A number of fish species such as tuna and swordfish should not be consumed as per the frequency and meal size recommended by the AHA due to presence of methylmercury (Domingo et al., 2007*)*. Guallar et al. (2002) opinioned that the risk of cardiovascular disease in a population might depend on the balance between omega-3 fatty acids and methylmercury in the fish consumed. These authors reported that high mercury content could diminish the cardioprotective effect of fish intake, which was further corroborated by Virtanen et al. (2005). For pregnant women, nursing mothers, women who may become pregnant, and young children, the US EPA and the US FDA have advised to continue eating fish, but avoiding those species that are higher in mercury (Crawford, 2004). According to US Department of Health and Human Services and the US Environmental Protection Agency (2006), mackerel, shark, swordfish, and tilefish/golden snapper were the marine species with the highest mercury levels, while the lowest levels corresponded to clam, mussel, cuttlefish, shrimp, tilapia, oyster, salmon, hake, and sardine (Domingo et al., 2007). The benefits of eating a seafood rich diet would appear to far outweigh any risk associated with intake of contaminants apart from a few extreme examples (Davidson et al., 2010).

Nutrient composition of coldwater fishes and their significance in human nutrition

Most of the population residing in hilly areas are fish eaters. Coldwater fishes namely rainbow trout, snow trout, golden mahseer, chocolate mahseer, common carp and minor carps are important food fishes for the rural and urban population residing in Indian upland region. It is widely accepted as a healthy food because of its richness in amino acid, fatty acids, vitamins and minerals. 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. The nutritional quality of fish in general is, to a great extent, associated with its content of essential fatty acids, essential amino acids, vitamins and minerals. Fishes are 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 (FAO, 2006). There is a paucity of information on proximate and mineral composition, detailed account of fatty acid especially PUFAs, and amino acid profile in majority of fishes from India, with respect to above variations. Therefore, it is important to generate a sound database on these aspects. 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. Studies carried out in India have 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. 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. 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, making it affordable to the poor.

Among fish, there are differences in nutrient composition; some are lean, while others are fatty; similarly, some have higher functionality than others. Information on nutrient composition of indigenous fishes from different corners of the world is coming to light; consequently, more and more fish species are entering the food fish category (Bogard et al., 2015). However, there is dearth of information on nutritive value and nutrient quality of coldwater fish species in India. Recently, Indian council of agricultural research (ICAR) started a nationwide network project on 'nutrient profiling and evaluation of fish as a dietary component' for bringing compositional information of possibly all Indian fish to the public. Under the umbrella of the same project, ICAR-Directorate of Coldwater Fisheries Research (ICAR-DCFR) took the responsibility of evaluating the nutrient composition of Indian Himalayan cyprinids (IHCs). As a consequence of this, information on nutrient composition of many IHCs came into public domain (Das et al., 2012; Joshi et al., 2017a,b; Sarma et al., 2011, 2013, 2014, 2015; Mohanty et al., 2014, 2016a, b).

Among IHCs, until date mahseers (*Tor putitora* and *Neolissochilus hexagonolepis*), hill carps (*Labeo dero*, *L. dyocheilus* and *L. pangusia*) (Das et al., 2012; Sarma et al., 2011, 2013, 2014, 2015; Mohanty et al., 2014; 2016a, b) and snow trouts (*Schizothorax* spp.) (Joshi et al., 2017a,b) have been evaluated for nutrient composition and functionality. Further, nutrient composition of small indigenous species of Brahmaputra basin from lower Himalayan belt have also been explored (Sarma et al., unpublished data; under review). Among the components of biochemical composition, protein and lipid are nutritionally more important than other; the respective values of protein and lipid are found to fall within the ranges of 16-20 and 2-8 g/100 g of edible parts in coldwater fishes (Joshi et al., 2017a,b; Sarma et al., 2011, 2013, 2014, 2015).

Nutrient profiling of golden mahseer (*Tor putitora*) and chocolate mahseer (*Neolissochilus hexagonolepis*)

Nutritional composition of golden mahseer (*Tor putitora*) from wild and production systems based on seasons, geographical locations and size groups were studied. Further, chocolate mahseer *Neolissochilus hexagonolepis* (220–400 g) from River Kameng at Bhalukpong, Arunachal Pradesh was also analysed for its fatty acid and amino acid composition.

Proximate composition

The proximate analysis of fish from hatchery ponds of ICAR-DCFR, Bhimtal revealed significant seasonal differences. The mean protein content ranged from 15.59 to 7.29 g/ 100 g fish while the ash, crude fat and moisture contents ranged from 1.23 - 1.55, 0.62 - 1.52 and 76.24 - 79.24 g/ 100 g fish, respectively (Table 2). Higher protein (17.29 g/ 100 g) and moderate crude fat (1.50 g/ 100 g) concentrations were observed during June to September i.e. during breeding season. The higher protein level may be attributed to the maturity stage of the fish species in their seasonal life cycle with higher intake of proteinaceous artificial feed in pond environment. The proximate analysis of fish from three geographical locations, hatchery pond Bhimtal, Kosi river and Kameng river revealed 15.59, 21.00 and 17.20 g protein and 1.52, 6.15 and 6.15 g crude fat /100 g fish, respectively (Table 3). Protein and crude fat levels were significantly higher in fish collected from Kosi river. Dempson *et al.* (2004) reported variation in proximate body compositions of Atlantic salmon from two different habitats. The changes of nutritional status may be attributed to substratum adaptation and survival in mountain streams and rivers having different ecological conditions and significant altitudinal variation.

Table 2: Seasonal variation of proximate composition (gm/100 gm) of *T. putitora* of size 110-325 gm from hatchery fish pond, Bhimtal

Parameter	1	2	3
Protein	16.11 ±0.191[a]	15.59 ±0.357[a]	17.29±0.327[b]
Ash	1.23 ± 0.121[a]	1.55 ± 0.050[b]	1.36 ± 0.052[ab]
Crude Fat	0.62 ± 0.089[a]	1.52 ± 0.038[b]	1.50 ±0.008[b]
Moisture	79.24 ±0.397[a]	78.05 ± 0.085[b]	76.24 ± 0.220[c]

Season: 1: October-January; 2: February-May; 3: June-September. Means with different superscripts in table differ significantly (P<0.01)

Table 3: Proximate composition (gm/100gm) of *T. putitora* of size 250-550 gm from different geographical locations

Parameters	1	2	3
Protein	15.59 ± 0.357[a]	21.00 ± 1.000[b]	17.20 ± 0.305[c]

Parameters	1	2	3
Ash	1.55 ± 0.050	1.45 ± 0.045	1.52 ± 0.189
Crude Fat	1.52 ± 0.038[a]	6.15 ± 0.006[b]	6.15 ± 0.312[b]
Moisture	78.05 ± 0.085[a]	73.38 ± 0.024[b]	73.32 ± 0.207[b]

Geo-climatic location: 1: hatchery, Bhimtal; 2: Kosi River, Uttarakhand; 3: Kameng River, Arunachal Pradesh. Means with different superscripts in table differ significantly (P<0.01).

Amino acid composition and amino acid score

The muscle amino acid profiles of *T. putitora and N. hexagonolepis* is given in Table 4. In total, 21 amino acids were identified from the muscle of *N. hexagonolepis* and 17 from *T. putitora*. The most abundant AA was aspartic acid in case of *N. hexagonolepis*, whereas it was glutamic acid for *T. putitora*. The content of aspartic acid was higher in *N. hexagonolepis* while leucine, lysine, phenylalanine and tryptophan contents were higher in *T. putitora*.

To determine the quality of protein in golden and chocolate mahseer, the essential amino acid score (AAS) was calculated using reference amino acid pattern of the pre-school child (FAO, 1985) and presented in Table 5. The presence of higher levels of essential amino acids in golden mahseer and chocolate mahseer makes them a valuable addition to healthy human diet.

Table 4: Amino acid composition (g/ 100 g muscle) of *T. putitora and N. hexagonolepis*

Amino acid	*T. putitora*	*N. hexagonolepis*
Aspartic acid	1.641[a] ± 0.044	3.220[b] ± 0.083
Threonine	0.841[b] ± 0.047	0.476[a] ± 0.099
Serine	0.887[a] ± 0.024	2.206[b] ± 0.009
Glutamic acid	2.079 ± 0.128	2.085 ± 0.084
Proline	1.442[b] ± 0.028	0.448[a] ± 0.053
Glycine	1.609[b] ± 0.034	0.909[a] ± 0.112
Alanine	1.098[a] ± 0.029	1.989[b] ± 0.183
Cystine	ND	0.135 ± 0.048
Valine	0.821 ± 0.038	0.831 ± 0.108
Methionine	0.770 ± 0.010	0.638 ± 0.132
Isoleucine	0.793[b] ± 0.094	0.382[a] ± 0.101
Leucine	1.637[b] ± 0.005	0.956[a] ± 0.033
Tyrosine	1.232[b] ± 0.026	0.445[a] ± 0.055
Phenylalanine	1.189[b] ± 0.022	0.348[a] ± 0.042
Histidine	0.104 ± 0.013	0.481 ± 0.071

Amino acid	*T. putitora*	*N. hexagonolepis*
Lysine	$2.031^{b} \pm 0.119$	$1.009^{a} \pm 0.114$
Arginine	0.912 ± 0.001	1.062 ± 0.135
Tryptophan	$1.397^{b} \pm 0.055$	$0.309^{a} \pm 0.114$
Asparagine	ND	0.054 ± 0.013
Cysteine	ND	0.033 ± 0.013
Ornithine	ND	0.747 ± 0.086

Values are expressed as mean ± SE of three replicates.

Table 5: Essential amino acid score of *T. putitora and N. hexagonolepis calculated using* reference amino acid pattern of the pre-school child (2–5 year; FAO/WHO/UNU, 1985).

Amino acid	Reference (mg/g protein)	*T. putitora*	*N. hexagonolepis*
Histidine	14	36.15	183.43
Isoleucine	28	137.73	72.84
Leucine	66	120.66	77.34
Lysine	58	170.40	92.83
Met + Cys[a]	25	149.78	143.30
Phe + Tyr[b]	63	187.00	67.16
Threonine	34	120.29	74.67
Tryptophan	11	618.00	149.98
Valine	35	114.15	126.69

Amino acid score = {sample amino acid / reference amino acid} x 100.
[a] Methionine + Cysteine.
[b] Phenylalanine + Tyrosine.

Fatty acid composition

In total, 23 fatty acids were identified from the muscle of *T. putitora* and 24 from N. *hexagonolepis* (Table 6). The saturated fatty acids (SAFAs) were the most dominant fatty acid in both the species. Among SAFA, palmitic acid (C16:0) was the major fatty acid. Stearic acid (C18:0) constituted 5.87-9.58 % of the total fatty acids. Monounsaturated fatty acids (MUFAs) were the next dominant fatty acid and comprises of 23.95 % and 28.06 % in *N. hexagonolepis* and *T. putitora* respectively. Among the polyunsaturated fatty acids (PUFAs), major contributions were from EPA (C20:5n-3), DHA (C22:6n-3), linolenic acid (C18:3n-3), linoleic acid (C18:2n-6) and arachidonic acid (C20:4n-6).

Table 6: Fatty acid composition (% of total fatty acids) of *T. putitora and N. hexagonolepis*

Fatty acid	*T. putitora*	*N. hexagonolepis*
Saturated fatty acids (SAFAs)		
C12:0	$0.507^{a} \pm 0.041$	$2.473^{b} \pm 0.041$
C13:0	0.083 ± 0.020	0.070 ± 0.023
C14:0	$5.027^{b} \pm 0.026$	$4.670^{a} \pm 0.021$
C15:0	$0.583^{b} \pm 0.026$	$0.413^{a} \pm 0.043$
C16:0	$31.637^{b} \pm 0.041$	$29.780^{a} \pm 0.040$
C17:0	$0.473^{a} \pm 0.035$	$0.590^{b} \pm 0.040$
C18:0	$9.580^{b} \pm 0.150$	$5.873^{a} \pm 0.035$
C19:0	$0.160^{b} \pm 0.064$	$0.100^{a} \pm 0.006$
C20:0	$4.483^{b} \pm 0.098$	$0.323^{a} \pm 0.038$
C22:0	0.437 ± 0.064	ND
Monounsaturated fatty acids (MUFAs)		
C16:1n9	$9.463^{a} \pm 0.119$	$10.897^{b} \pm 0.029$
C16:1n7	0.137 ± 0.046	0.167 ± 0.023
C17:1n7	ND	ND
C18:1n9	$10.457^{b} \pm 0.127$	$9.540^{a} \pm 0.026$
C18:1n7	1.627 ± 0.170	1.383 ± 0.038
C18:1n5	ND	ND
C20:1n9	$5.657^{b} \pm 0.133$	$1.567^{a} \pm 0.027$
C22:1n9	$0.723^{b} \pm 0.150$	$0.397^{a} \pm 0.035$
n-3 polyunsaturated fatty acids (n-3 PUFAs)		
C18:3n3	$0.637^{a} \pm 0.121$	$7.727^{b} \pm 0.035$
C18:4n3	ND	ND
C20:3n3	$0.460^{a} \pm 0.127$	$0.527^{b} \pm 0.035$
C20:4n3	ND	0.620 ± 0.055
C20:5n3	$4.770^{a} \pm 0.115$	$7.430^{b} \pm 0.064$
C22:5n3	ND	0.003 ± 0.003
C22:6n3	$2.727^{a} \pm 0.128$	$5.173^{b} \pm 0.043$
n-6 polyunsaturated fatty acids (n-6 PUFAs)		
C18:2n6	7.430 ± 0.110	7.653 ± 0.061
C18:3n6	0.417 ± 0.090	ND
C20:2n6	ND	0.003 ± 0.003

Fatty acid	*T. putitora*	*N. hexagonolepis*
C20:3n6	ND	ND
C20:4n6	$1.820^{a} \pm 0.112$	$2.063^{b} \pm 0.032$
C22:4n6	ND	ND
Total SAFAs	$52.97^{b} \pm 0.097$	$44.29^{a} \pm 0.20$
Total MUFAs	$28.06^{b} \pm 0.74$	$23.95^{a} \pm 0.032$
Total n-3 PUFAs	$8.69^{a} \pm 0.44$	$21.48^{b} \pm 0.1$
Total n-6 PUFAs	9.67 ± 0.31	9.72 ± 0.1
Ratio of n-3 to n-6 PUFAs	$0.9^{a} \pm 0.01$	$2.21^{b} \pm 0.03$

Values are expressed as mean ± SE of three replicates.

Mineral composition

Macro-mineral estimations showed a significant effect of geographical location on the nutritional quality (Table 7). In general, golden mahseer appeared to be a rich source of calcium (219.33 ± 9.018 - 1951.67 ±3.510 mg/100 g) and potassium (755.33±14.740 - 1523.0±3.000 mg/100 g) while the mean concentration of sodium was comparatively low (99.67±2.082 - 253.33±4.163 mg/100 g). The calcium and potassium content showed a decrease with increase in body weight (Table 7). The findings are in agreement with Nurullah *et al.* (2003) who reported higher mineral content in some selected indigenous fish species of Bangladesh. Fish samples from Kameng river habitat had significantly higher selenium content (1.56 mg/ 100 g) whereas those from Kosi river had significantly higher iron content (1.28 mg/100 g) and moderate manganese (0.16 mg/100 g) and zinc contents (1.19 mg/ 100 g) (Table 8). This may be attributed to the rich concentration of selenium in the water received from anthropogenic sources, from the atmosphere by dry and wet deposition from adjacent water, from surface run off, and from surface drainage in North Eastern Himalayan region (latitude 27048'36" longitude 92026'38" and altitude 2443 masl), and higher levels of iron in the rocky substratum in Kosi river of Western Himalayan region (latitude 29025' to 29039' N; longitude 78044' to 790 07' E and altitude 1960 msl).

Table 7: Macro mineral (mg/100gm) composition of *T. putitora* of size 250-550 gm from different geographical locations.

Macro minerals	1	2	3	4
Na	99.67 ± 2.082^{a}	201.33 ± 6.110^{b}	234.33 ± 4.041^{c}	253.33 ± 4.163^{d}
K	755.33 ± 14.740^{a}	1311.66 ± 7.640^{b}	1252.0 ± 8.544^{c}	1523.0 ± 3.000^{d}
Ca	219.33 ± 9.018^{a}	402.66 ± 2.517^{b}	405.66 ± 16.260^{b}	1951.67 ± 3.510^{c}

Geo-climatic location: 1: Hatchery, Bhimtal; 2: Bhimtal Lake; 3:Kosi River, Uttarakhand; 4: Kameng River, Arunachal Pradesh. Means with different superscripts in table differ significantly (P<0.01).

Table 8: Micro mineral (mg/100gm) composition of *T. putitora* of size 170-550 gm from different geographical locations.

Micro minerals			
	1	2	3
Fe	0.83 ±0.208[a]	1.28 ±0.024[a]	0.68 ±0.005[b]
Mn	0.17 ±0.036[a]	0.16 ±0.013[a]	0.10 ±0.005[b]
Zn	1.43 ±0.153[a]	1.19 ±0.005[ab]	0.99 ±0.072[b]
Se	0.87 ±0.306[a]	0.74 ±0.049[a]	1.56 ±0.009[b]

Geo-climatic location: 1: hatchery pond Bhimtal; 2: Kosi River, Uttarakhand; 3: Kameng River, Arunachal Pradesh. Means with different superscripts in table differ significantly (P<0.01)

Nutrient profiling of rainbow trout (*Oncorhynchus mykiss*) and common carp (*Cyprinus carpio*)

Proximate composition

The results of proximate analysis of rainbow trout are shown in Table 9. *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 (Bennion, 1997). However, the values in the present study are well comparable with the earlier reports in different salmonid species (Testi *et al.*, 2006). 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 (Rasoarahona *et al.*, 2005).

Table 9: Proximate composition (% of total wet weight) of rainbow trout

Estimation	Mean ± SD (n=3)
Crude protein	19.44 ±0.07
Crude ash	1.37 ± 0.08
Crude fat	5.18 ± 0.22
Moisture	74.00 ± 0.30

Amino acid composition and score

The muscle amino acid profiles of the rainbow trout and common carp is given in Table 10.

In total, 20 from amino acids were identified from the muscle of *C. carpio* and 17 from *O. mykiss*. The most abundant AA was aspartic acid in case of *C. carpio*, whereas it was proline for *O. mykiss*. Rainbow trout protein had a well balanced amino acid composition, with high amounts of proline (1.67 g/100g muscle), aspartic acid (1.48 g/100g muscle), tyrosine (1.44 g/100g muscle), glycine (1.21 g/100g muscle), serine (1.16 g/100g muscle), arginine (1.13 g/100g muscle), isoleucine (1.12 g/100g muscle) and tryptophan (1.07 g/100g muscle).

To determine the quality of protein the essential amino acid score (AAS) was calculated using reference amino acid pattern of the pre-school child and presented in Table 11. In case of rainbow trout, the highest amino acid score was observed for tryptophan (574) followed by isoleucine (236) while it was highest for histidine (132) followed by valine and isoleucines (95 each) in common carp. According to the amino acid score, the amounts of leucine and lysine were the lower amongst amino acids in rainbow trout. However, in this study, cysteine was not detected which may be due total loss of cysteine when the muscle tissue was hydrolyzed without performing acid oxidation.

Table 10: Muscle amino acid composition of rainbow trout and common carp (values expressed as g/ 100 g muscle)

Amino acid	*Rainbow trout*	*Common carp*
Aspartic acid	$1.479^{a} \pm 0.014$	$2.721^{b} \pm 0.083$
Threonine	$1.033^{b} \pm 0.027$	$0.401^{a} \pm 0.024$
Serine	$1.156^{a} \pm 0.026$	$2.441^{b} \pm 0.105$
Glutamic acid	$0.857^{a} \pm 0.028$	$1.903^{b} \pm 0.109$
Proline	$1.672^{b} \pm 0.017$	$0.491^{a} \pm 0.029$
Glycine	$1.213^{a} \pm 0.022$	$1.497^{b} \pm 0.114$
Alanine	$1.056^{a} \pm 0.007$	$1.553^{b} \pm 0.045$
Cystine	ND	ND
Valine	$0.855^{b} \pm 0.015$	$0.528^{a} \pm 0.034$
Methionine	$0.548^{b} \pm 0.013$	$0.321^{a} \pm 0.056$
Isoleucine	$1.120^{b} \pm 0.012$	$0.421^{a} \pm 0.061$
Leucine	$0.994^{b} \pm 0.020$	$0.763^{a} \pm 0.076$
Tyrosine	$1.444^{b} \pm 0.006$	$0.236^{a} \pm 0.087$
Phenylalanine	$0.523^{b} \pm 0.016$	$0.337^{a} \pm 0.048$
Histidine	0.185 ± 0.025	0.292 ± 0.124
Lysine	0.602 ± 0.010	0.537 ± 0.073
Arginine	1.132 ± 0.017	1.011 ± 0.109
Tryptophan	$1.070^{b} \pm 0.007$	$0.065^{a} \pm 0.026$

Amino acid	*Rainbow trout*	*Common carp*
Asparagine	ND	0.123 ± 0.052
Cysteine	ND	0.027 ± 0.010
Ornithine	ND	0.154 ± 0.046

Table 11: Amino acid score of rainbow trout and common carp *calculated using* reference amino acid pattern of the pre-school child (2–5 year; FAO/WHO/UNU, 1985)

Amino acid	Reference (mg/g protein)	*O. mykiss*	*C. carpio*
Histidine	14	78.01	131.84
Isoleucine	28	236.13	95.04
Leucine	66	88.91	73.03
Lysine	58	61.27	58.47
Met + Cys[a]	25	129.28	87.86
Phe + Tyr[b]	63	184.31	57.89
Threonine	34	179.27	74.46
Tryptophan	11	573.95	37.35
Valine	35	144.12	95.27

Amino acid score = {sample amino acid / reference amino acid} x 100.
[a] *Methionine + Cysteine.*
[b] *Phenylalanine + Tyrosine*

Fatty acid profile

The fatty acid profile of the rainbow trout and common carp is presented in Table 12. The fatty acids analyzed were grouped as saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). Fatty acid profile showed that total MUFA were the highest followed by SFAs and PUFAs in both the species. Palmitic acid (C16:0) was the predominant fatty acid followed by stearic acid (C18:0). Among MUFAs, oleic (C18: 1) and palmitoleic (16:1) acids were the predominant fatty acids. 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. The results are in agreement with Yanar *et al.*, (2006) and contrary to Testi *et al.*, (2006) who reported that PUFA was the highest in rainbow trout followed by MUFA and SFA. This may be due to 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 (González *et al.*, 2006). Simopoulus (1999) suggested that n-3/n-6 ratio of 1:1 is optimal for nutritional purposes and the n-3/n-6 ratio of rainbow trout and common carp muscle was found to be 0.77 and 0.70 respectively.

Table 12: Muscle fatty acid profile of rainbow trout and common carp (values expressed as percentage of total fatty acids)

Fatty acid	*O. mykiss*	*C. carpio*
Saturated fatty acids (SAFAs)		
C12:0	0.599[b] ± 0.007	0.167[a] ± 0.038
C13:0	0.129[b] ± 0.008	0.063[a] ± 0.029
C14:0	3.464[b] ± 0.035	2.270[a] ± 0.026
C15:0	0.354[a] ± 0.006	0.470[b] ± 0.035
C16:0	21.838[a] ± 0.056	35.190[b] ±0.040
C17:0	0.535[a] ± 0.007	0.687[b] ± 0.041
C18:0	7.614[b] ± 0.088	6.723[a] ± 0.049
C19:0	ND	0.233 ± 0.050
C20:0	ND	0.383 ± 0.043
C22:0	ND	ND
Monounsaturated fatty acids (MUFAs)		
C16:1n9	ND	9.567± 0.448
C16:1n7	8.200 ± 0.012	ND
C17:1n7	0.239[b] ± 0.007	0.003[a] ± 0.003
C18:1n9	24.289[b] ± 0.057	14.843[a] ± 0.095
C18:1n7	ND	2.337 ± 0.072
C18:1n5	ND	0.133 ± 0.030
C20:1n9	1.157[a] ± 0.054	3.940[b] ± 0.107
C22:1n9	0.816[b] ± 0.027	0.177[a] ± 0.030
n-3 polyunsaturated fatty acids (n-3 PUFAs)		
C18:3n3	4.839[b] ± 0.040	0.003[a] ± 0.003
C18:4n3	ND	0.070 ± 0.025
C20:3n3	ND	1.430 ± 0.084
C20:4n3	ND	ND
C20:5n3	2.337 ± 0.039	ND
C22:5n3	ND	3.173 ± 0.041
C22:6n3	6.438[b] ± 0.018	5.133[a] ± 0.211
n-6 polyunsaturated fatty acids (n-6 PUFAs)		
C18:2n6	13.790[b] ± 0.016	10.043[a] ± 0.060

Fatty acid	*O. mykiss*	*C. carpio*
C18:3n6	ND	0.243 ± 0.049
C20:2n6	0.822[b] ± 0.044	0.003[a] ± 0.003
C20:3n6	0.764 ± 0.021	ND
C20:4n6	2.399[a] ± 0.004	3.620[b] ± 0.075
C22:4n6	ND	0.003 ± 0.003
Total SAFAs	34.53[a] ± 0.093	46.19[b] ± 0.27
Total MUFAs	34.7[b] ± 0.01	31.00[a] ± 0.37
Total n-3 PUFAs	13.61[b] ± 0.06	9.81[a] ± 0.35
Total n-6 PUFAs	17.77[b] ± 0.08	13.91[a] ± 0.18
Ratio of n-3 to n-6 PUFAs	0.77 ± 0.005	0.7± 0.017

Values are expressed as mean ± SE of three replicates.

Mineral composition

The mineral contents of the rainbow trout are summarized in Table 13. Among the minerals analyzed, K was the highest followed by Ca, Na, Fe, Zn, Se and Mn. The mineral analysis data showed that rainbow trout is an excellent source of minerals especially K (1447.0 mg g/100 g), Ca (359.33 mg/100g), Na (208.0mg/100g) and Fe (5.17mg/100g). The selenium content (1.66 mg/100g) in rainbow trout was higher than those present in many other species such as sea bass, 0.227 mg/kg, herring, 0.347 mg/kg; mackerel, 0.498 mg/kg; turbot, 0.473 mg/ kg and flounder, 0.371 mg/kg (Önnig, 2000).

Table 13: Mineral (mg/100 gm whole body sample) composition of rainbow trout

Minerals	Mean ± SD (n=3)
Sodium (Na)	208.00± 9.00
Potassium (K)	1447.00 ± 7.55
Calcium (Ca)	359.33 ±12.01
Iron (Fe)	5.17 ± 0.02
Manganese (Mn)	0.19 ± 0.01
Zinc (Zn)	1.79 ± 0.02
Selenium (Se)	1.66 ± 0.029

Nutrient profiling of snow trout (*Schizothorax* spp.)

Snow trout, *Schizothorax* spp. (family cyprinidae, sub-family schizothoracinae) have contributed a large share of commercial landings in the Himalayan belts for a long time (Jhingran, 1982). In India, these fishes are distributed in the cold waters from Jammu and

Kashmir to Arunachal Pradesh (Jhingran, 1982). Among several species under this genera, *S. niger*, *S. progastus*, *S. plagiostomus*, *S. curvifrons*, and *S. esocinus* are the common food fish for the local people of the entire Himalayan belt (Jhingran, 1982).

Proximate composition

Proximate composition in terms of moisture, lipid, protein, and ash percentages on wet weight basis is presented in Table 13. Protein percentage, in all five fish, did not differ statistically ($P > 0.05$), and value was restricted to 15-18%. The nutrients that differed prominently were moisture (75-82%) and lipid (1.5-8%). Moisture and lipid values in fish muscle were found to be in inverse proportion; fish with significantly high moisture had low lipid (*S. progastus* and *S. plagiostomus*). This relationship is reported in several fish (Jabeen and Chaudhry, 2011; Sharma et al., 2010). Further, these two fish showed the best nutritional combination, i.e., high-moisture, high-protein and low-lipid compared to the other three fish. The ash content was found to vary significantly among different species, yet the value remained in and around 1%. Moreover, the overall biochemical composition of all five snow trout species remained more or less similar to other Indigenous Himalayan Cyprinids (IHCs) (Sarma et al., 2011, 2014).

Table 13: Proximate composition (g/100 g on wet weight basis) of five snow trout (*Schizothorax* spp.)

Composition	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
Moisture	75.20 ± 1.67^{a}	79.74 ± 1.12^{ab}	75.39 ± 0.85^{a}	82.74 ± 0.66^{b}	82.29 ± 0.08^{b}
Ash	0.96 ± 0.21^{ab}	0.89 ± 0.084^{ab}	1.18 ± 0.05^{b}	0.89 ± 0.08^{a}	0.92 ± 0.01^{ab}
Protein	16.15 ± 0.29	16.55 ± 1.10	15.43 ± 0.55	17.17 ± 0.43	16.98 ± 0.33
Crude fat	7.98 ± 0.64^{d}	4.25 ± 0.12^{b}	5.90 ± 0.28^{c}	2.21 ± 0.15^{a}	1.66 ± 0.10^{a}

Results are expressed as mean ± SD (n=3). Values in the same row with different superscripts differ significantly (p< 0.05).

Protein and amino acid composition

The amino acid profile of seven species of snow trout *S. labiatus*, *S. plagiostomus*, *S. progastus*, *S. esocinus*, *S. curvifrons*, *S. richardsonii* and *S. niger* are presented in Table 14. The preponderance of protein content (Figure 2) was observed in the order of *S. labiatus* > *S. plagiostomus* > *S. progastus* > *S. esocinus* > *S. curvifrons* > *S. richardsonii* > *S. niger*. Statistically, *S. labiatus* was found to be significantly superior in comparison with *S. progastus*, *S. esocinus*, *S. curvifrons*, *S. richardsonii* and *S. niger*. Similarly, the DV% of protein for pre-school children was found to be in the same order, *S. labiatus* showed the highest value. In total, seventeen amino acids were identified and quantified. The concentrations of each amino acid were found to be significantly different among all the fishes. Overall, the most abundant amino acid was alanine in the case of *S. curvifrons*, *S. esocinus*, *S. niger*, and *S. plagiostomus*, whereas it was leucine for *S. labiatus*, *S. progastus* and *S. richardsonii*. Totally, nine essential amino acids (EAAs) were found in the fish samples. Among essential amino acids, leucine was found to be in highest concentration in all the fish. In general, snow trout may prove to be the good source of dietary leucine, the important EAA, which has several physiological importance such as the induction of muscle protein synthesis and reduction of stress conditions such as trauma, burn, sepsis etc. The second highest EAA was found to be phenylalanine another EAA with significant role in immune strengthening, neurotransmission, regulation of blood pressure and regulation of metabolism. Similarly, Isoleucine (branched-chain amino acid) which has a vital role in growth, muscle formation and renal function was recorded as the third abundant EAA. Other than these, valine, arginine and threonine were also found in considerable percentage. The EAAs which were found to be limiting were methionine, lysine and histidine, similar to those reported by Sarma et al. (2013). The quality of protein in terms of amino acid score (AAS) (for pre-school children) of all seven species of snow trout is shown in Table 14. Most of the EAAs in all the seven species of snow trout, were scored more than 100 or around 100 (leucine in *S. curvifrons* is 90). Among all the snow trout, *S. labiatus* showed the highest and second highest AAS for leucine, isoleucine and lysine, and phenylalanine, threonine and valine respectively. More importantly, scoring for lysine (the limiting EAA) was found to be highest in *S. labiatus*. Seven NEAAs were also detected in and among these NEAAs, alanine *in S. niger, S. progastus, S. curvifrons, S. esocinus* and *S. plagiostomus,* and glycine in *S. richardsonii* and *S. labiatus* were the most predominant. Other than these, glutamic acid and aspartic acid were also found in appreciable amount.

Table 14: Amino acid composition (g/100 g protein) of seven species of snow trout (*Schizothorax* spp.)

Amino acids	*S. curvifrons*	*S. esocinus*	*S. labiatus*	*S. niger*	*S. plagiostomus*	*S. progastus*	*S. richardsonii*
Essential							
Methionine	1.26±0.002^{a}	2.03±0.004^{b}	2.96±0.003^{e}	2.20±0.004^{d}	2.06±0.002^{c}	3.098±0.004^{f}	3.57±0.002^{g}
Arginine	3.78±0.005^{a}	5.01±0.004^{c}	4.95±0.004^{b}	5.70±0.004^{e}	5.05±0.004^{d}	6.17±0.004^{g}	5.93±0.003^{f}
Threonine	3.33±0.004^{a}	4.45±0.005^{b}	6.27±0.005^{f}	5.16±0.005^{c}	4.45±0.003^{b}	5.57±0.002^{e}	5.31±0.004^{d}
Valine	4.57±0.003^{a}	5.29±0.004^{b}	6.91±0.003^{f}	6.25±0.004^{d}	5.39±0.003^{c}	6.64±0.004^{e}	7.49±0.003^{g}
Isoleucine	5.04±0.003^{a}	5.60±0.002^{b}	10.00±0.003^{g}	7.01±0.004^{d}	5.71±0.003^{c}	7.47±0.001^{e}	8.39±0.003^{f}
Lysine	2.45±0.001^{d}	2.07±0.004^{c}	3.94±0.004^{g}	1.98±0.003^{a}	2.53±0.004^{e}	2.00±0.003^{b}	3.86±0.005^{f}
Leucine	10.38±0.003^{a}	12.51±0.003^{c}	20.57±0.002^{g}	14.63±0.004^{d}	12.24±0.003^{b}	15.72±0.004^{e}	17.61±0.004^{f}
Phenylalanine	6.81±0.003^{a}	11.72±0.003^{d}	16.93±0.003^{g}	12.76±0.003^{e}	9.91±0.003^{b}	13.48±0.004^{f}	10.69±0.003^{c}
Histidine	1.22±0.006^{a}	2.15±0.005^{d}	2.36±0.004^{e}	2.097±0.003^{c}	1.97±0.004^{b}	7.31±0.003^{f}	2.16±0.008^{d}
Non-essential							
Aspartic acid	3.06±0.007^{b}	3.40±0.008^{c}	0.40±0.009^{a}	6.186±0.008^{f}	4.23±0.003^{e}	3.47±0.006^{d}	3.06±0.005^{b}
Serine	2.83±0.005^{b}	3.42±0.004^{c}	4.14±0.007^{f}	2.45±0.006^{a}	3.46±0.004^{d}	4.07±0.004^{e}	4.31±0.005^{g}
Glutamic acid	4.68±0.003^{c}	5.31±0.007^{d}	4.44±0.005^{b}	4.06±0.006^{a}	6.81±0.003^{f}	6.07±0.006^{e}	7.82±0.003^{g}
Glycine	5.48±0.004^{c}	6.90±0.006^{f}	6.41±0.002^{d}	6.71±0.004^{e}	5.40±0.003^{b}	3.06±0.003^{a}	8.03±0.004^{g}
Alanine	37.48±0.006^{g}	22.62±0.007^{e}	4.97±0.004^{a}	15.63±0.004^{d}	23.38±0.003^{f}	10.28±0.006^{c}	7.33±0.003^{b}
Proline	3.51±0.010^{g}	2.43±0.006^{e}	1.88±0.014^{c}	2.38±0.004^{d}	2.83±0.003^{f}	1.24±0.008^{b}	0.92±0.002^{a}
Tyrosine	4.14±0.003^{c}	5.10±0.003^{g}	2.86±0.005^{a}	4.81±0.005^{f}	4.57±0.004^{e}	4.373±0.002^{d}	3.52±0.004^{b}

Values are expressed as mean ±SD of three replicates. Mean values bearing different superscripts (a, b, c, d, etc.) in the same row vary significantly ($p < 0.05$).

Table 15: Amino acid scores of seven species of snow trout (*Schizothorax* spp.) for the pre-school children (2–5 year; Sarma et. al., 2013)

AAS	Reference (mg/g)	*S. curvifrons*	*S. esocinus*	*S. labiatus*	*S. niger*	*S. plagiostomus*	*S. progastus*	*S. richardsonii*
Histidine	14	133.57	188.14	208.36	238.93	141.29	544.21	160.79
Isoleucine	28	276.11	244.89	441.36	399.46	205.14	278.29	312.25
Leucine	66	90.00	231.88	384.92	353.48	186.38	248.41	277.95
Lysine	58	64.86	43.74	83.83	54.36	43.91	36	69.31
Phe + Tyr[a]	63	266.86	326.79	388.11	444.71	230.97	295.49	235.02
Threonine	34	150.35	160.12	227.76	242.03	131.50	170.91	162.65
Tryptophan	11	nd	nd	nd	nd	nd	nd	nd
Valine	35	200.69	184.91	243.97	284.89	154.83	197.94	223.03
Met + cys[b]	25	77.32	99.56	146.40	140.60	82.92	129.24	148.84

AAS = Sample amino acid/Reference amino acid x 100, [a]Phenylalanine + tyrosine and [b]Methionine + cysteine

Total fat, triglyceride and cholesterol content

Total fat, cholesterol, and triglyceride contents of five species of *Schizothorax* are presented in Table 16. Total fat content was between 2.73 and 6.54%, more or less in the same range. According to Henderson and Tocher (1987) the total fat content may vary from from 0.7 to 25.8% in different fish species. Values for all snow trout examined also came within this range. According to the fat-based fish classification system by Rahnan et al. (1995), *S. niger* and *S. curvifrons* can be categorized as a medium-fat fish (containing 5-10% fat), and *S. esocinus*, *S. plagiostomus*, and

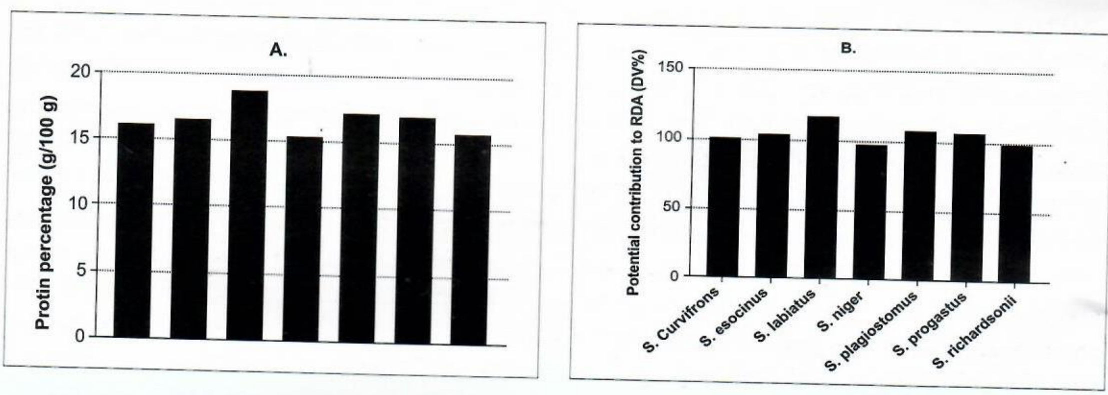


Figure 2: Graphical representation of protein content (A) of seven species of snow trout (*S. curvifrons*, *S. esocinus*, *S. labiatus*, *S. niger*, *S. plagiostomus*, *S. progastus* and *S. richardsonii*), and their contribution potential to recommended dietary allowance (RDA) or daily value percentage (DV%) of pre-school children (B; with RDA 16 g).

S. progastus as low-fat fish (containing 1-5% fat). None of the species of *Schizothorax* fell in the high-fat category (>10%). The cholesterol content varied from 21.31 to 25.76 mg/100 g, and was low in *S. esocinus* and high in *S. curvifrons*. The cholesterol content in wild freshwater fishes, according to Moreira et al. (2001), did not exceed 50 mg/100 g. In snow trout, the cholesterol values were also within this range; the maximum value was half of the upper limit set by Moreira et al. (2001). The triglyceride values on the other hand, were not significantly different among all five species, but numerical values varied from 298.89 (*S. plagiostomus*) to 342.22 mg/100 g (*S. esocinus*).

Table 16: Total fat, cholesterol and triglycerides of five snow trout (*Schizothorax* spp.)

Lipid class	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
Total fat (g/100 g)	6.539 ± 0.57^{c}	4.92 ± 0.60^{b}	5.64 ± 0.57^{bc}	3.005 ± 0.38^{a}	2.73 ± 0.25^{a}
Cholesterol (mg/100 g)	25.76 ± 1.97^{b}	21.31 ± 0.47^{a}	23.54 ± 1.49^{ab}	21.43 ± 0.63^{a}	22.82 ± 0.88^{ab}
Triglyceride (mg/100 g)	302.22±12.57	342.22±106.07	304.17±12.96	298.89±69.93	317.5±29.46

Results are expressed as mean ± SD (n=3). Values in the same row with different superscripts differ significantly (p< 0.05).

Fatty acid composition

The absolute fatty acid composition (mg/100 g fish muscle) of five snow trout species is presented in Table 17. The trend of fatty acids in all five fish species was SFAs>MUFAs>PUFAs (n-6>n-3). A similar pattern was also found in other IHCs (*Tor putitora* and *S. richardsonii*, Sarma et al., 2013) and other wild caught cyprinids (Jabeen and Chaudhry, 2011; Sharma et al., 2010). The level of PUFAs compared to SFAs and MUFAs, in freshwater fishes, are reported to be generally lower (Jabeen and Chaudhry, 2011; Sarma et al., 2013; Sharma et al., 2010). The prevalence of low PUFAs in the edible parts of these fish is possibly due to the low PUFAs in their natural food (Ackman, 1967). Further, preponderance of n-6 fatty acids, especially linoleic (C18:2 n-6) and arachidonic (ARA; 20:4 n-6) acids, over n-3 fatty acids was observed. This finding is similar to previous reports on other freshwater fishes (Ackman, 2002; Jabeen and Chaudhry, 2011; Sarma et al., 2013; Sharma et al., 2010). The predominance of n-6 fatty acid over n-3 in freshwater (even fresh-cold water) fish species is either due to their metabolic conservation over n-3 PUFAs (De Silva et al., 2004) or possible contribution from their natural food (Ackman, 1967). The abundance of SFAs in all five fish species was found to be in the order of *S. curvifrons>S. niger>S. esocinus>S. progastus>S. plagiostomus*. The major contributors in SFAs, in order, were C16:0>C14:0>C18:0>C20:0. The order of abundance of C16:0 and C14:0, the two principal contributors, in all these fish species was the same as SFAs. The trend of preponderance of MUFAs also followed more or less the same pattern, *S. curvifrons>S. niger>S. esocinus>S. plagiostomus>S. progastus*, with major contributors being C16:1>C18:1>C20:1. The sum of all PUFAs includes both n-6 and n-3. Assessing the PUFAs separately as n-6 and n-3 gives a better idea of lipid quality than collective assessment because these fatty acids have different roles and different degree of importance in human nutrition (FAO, 2010). The order of abundance of n-3, n-6 PUFAs, and n-6/n-3 ratios in all five fish species was found to be *S. esocinus>S. curvifrons>S. niger>S.*

progastus>S. plagiostomus, *S. niger>S. curvifrons>S. esocinus>S. plagiostomus>S. progastus*, and *S. plagiostomus>S. niger>S. curvifrons>S. progastus>S. esocinus*, respectively. The major n-6 long chain PUFA identified was arachidonic acid, and the major n-3 long chain PUFAs were EPA and DHA. As a precursor of biologically active molecules such as prostaglandin and thromboxane, which facilitate in blood clotting, wound healing, etc. (Bowman and Rand, 1980), AA is considered an important fatty acid. Rare but more panaceaic fatty acids, the n-3

PUFAs have several beneficial attributes such as cardio-protection, anti-atherosclerosis, anti-thrombosis, anti-inflammatory, anti-rheumatoid arthritis, anti-depression, and anti-aging (Lund, 2013; Tocher, 2003, 2015). The ratio of n6/n3, in all snow trout except *S. plagiostomus* (4.17), was found to be lower (lowest in *S. esocinus*) than the maximum value (4) recommended by UK Department of Health (HMSO, 1994). However, no such dietary recommendation is made on this ratio by FAO (2010) or ICMR (2010). The sum of all n-3 PUFAs, in general, and DHA, in particular, is involved in the development of foetal brain, eye retina, and cognition (Tocher, 2015). The incorporation of these vital fatty acids in pregnant and lactating women's (PLW) diet is therefore very much essential. An estimation of the potential contribution of an individual fish's (DV%) n-3 PUFAs to meet RDA (300 mg/day) for PLW may provide quantitative information for incorporation of these fish species in their diet. Therefore, the DV% of all five snow trout species against RDA of PLW was estimated (Figure 3). Based on these calculated values, *S. curvifrons*, *S. esocinus*, and *S. niger* showed more than 50% of potential contribution to RDA for PLW. Further, based on this finding, 200 g/day of *S. curvifrons*, *S. esocinus*, and *S. niger* can be recommended for PLW to meet their n-3 PUFAs requirement for better nourishment of babies. The lipid quality indices (Figure 4), such as AI and TI, of fish muscle provide some indication of their nutritional quality (Grigorakis, 2007). The abundance of MUFAs and PUFAs is considered effective in decreasing atherosclerosis and thrombosis; however, the mechanism of the anti-atherosclerosis pathway of such fatty acids is complicated and yet to be fully confirmed (Nasopoulou et al., 2007). The value of AI was found to be in the range of 1.87 (*S. esocinus*) to 3.02 (*S. niger*). Some tropical freshwater fishes of South America, such as *Prochilodus reticulatus magdalenae* (2.89) and *Tilapia roza* (1.99), exhibited high AI (Filho et al., 2010); in contrast, lipid from marine fishes have AI less than 1 (Grigorakis, 2007). Similarly, TI is not reported above 1.49 (Filho et al., 2010); however, snow trout values reached up to 2.58 (*S. progastus*). No rational conclusion can be drawn for the high values of AI and TI based on a one-time post-spawning sampling of snow trout. A deliberate seasonal sampling may be required to explain this anomaly.

Table 17: Fatty acids composition of five snow trout (*Schizothorax* spp.)

Fatty acids	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
C8:0	nd	0.48±0.45	0.57±0.55	0.29±0.27	0.55±0.05
C10:0	5.79±1.20[b]	1.52±0.68[a]	1.69±0.17[a]	0.61±0.31[a]	0.55±0.05[a]
C11:0	0.65±0.06	0.49±0.06	0.54±0.54	nd	nd
C12:0	13.66±2.04[b]	9.88±1.70[b]	11.91±2.33[b]	10.00±1.13[b]	2.20±0.44[a]

Fatty acids	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
C13:0	3.33±1.36^{c}	3.39±0.56^{c}	2.85±0.83^{bc}	0.60±0.08^{a}	0.85±0.57^{ab}
C14:0	886.09±78.32^{c}	479.00±59.61^{b}	749.23±73.78^{c}	283.32±34.84^{a}	284.99±25.46^{a}
C15:0	79.75±7.24^{c}	63.72±4.79^{b}	80.60±7.64^{c}	14.71±2.22^{a}	16.68±2.01^{a}
C16:0	2815.19±248.23^{c}	2000.94±245.64^{b}	2776.68±285.22^{c}	1248.51±155.03^{a}	1276.07±117.00^{a}
C17:0	61.22±2.17^{d}	46.12±3.79^{bc}	54.77±7.18^{cd}	12.99±2.73^{a}	35.77±3.40^{b}
C18:0	145.05±11.45^{b}	203.94±27.06^{c}	3.92±0.38^{a}	184.57±23.86^{bc}	168.96±14.94^{bc}
C19:0	0.63±0.59a	nd	3.95±0.73b	nd	nd
C20:0	18.25±1.17^{d}	10.88±2.01^{bc}	14.10±1.62^{c}	7.52±1.21^{ab}	5.21±0.95^{a}
C21:0	3.28±0.81^{b}	0.52±0.56^{a}	1.09±0.47^{a}	0.60±0.08^{a}	0.27±0.02^{a}
C22:0	4.58±0.40^{b}	1.95±0.81^{a}	4.99±1.08^{b}	5.15±1.18^{b}	1.37±0.32^{a}
C23:0	8.44±0.40^{c}	4.50±1.43^{b}	13.48±0.88^{d}	0.86±0.45^{a}	0.82±0.29^{a}
C24:0	1.96±0.17^{a}	1.00±0.51^{a}	4.52±0.77^{b}	6.28±0.54^{c}	5.72±0.62^{bc}
∑SAFAs	4047.88±347.24^{c}	2828.34±346.70^{b}	3724.90±378.18^{c}	1776.03±221.41^{a}	1800.01±165.38^{a}
C14:1	nd	0.49±0.06^{a}	13.05±2.66^{b}	1.48±0.22^{a}	1.34±0.49^{a}
C16:1	937.48±78.35^{c}	614.09±79.02^{b}	929.82±94.63^{c}	299.71±35.11^{a}	372.99±35.00^{a}
C18:1	675.37±57.83^{b}	879.29±103.63^{c}	70.54±8.10^{a}	557.53±67.11^{b}	215.62±18.76^{a}
C20:1	100.61±8.06^{e}	61.16±9.08^{c}	79.94±6.44^{d}	33.59±3.53^{b}	14.94±0.73^{a}
C22:1	1.93±0.53^{a}	0.68±0.38^{a}	0.56±0.06^{a}	12.42±2.89^{b}	0.53±0.25^{a}
C24:1	0.65±0.06^{a}	2.97±1.01^{b}	2.25±0.54^{ab}	5.74±1.32^{c}	0.55±0.05^{a}
∑MUFAs	1716.06±143.32^{c}	1558.68±192.71^{c}	1096.17±111.73^{b}	910.48±109.52^{ab}	605.97±53.45^{a}
C18:2	123.57±10.59^{bc}	1.011±0.609^{a}	140.68±10.48^{c}	114.82±14.70^{b}	0.27±0.25^{a}
C18:3n6	224.34±20.61^{b}	184.64±23.27^{b}	229.44±22.55^{b}	106.38±13.41^{a}	217.24±18.60^{b}
C20:4n6	255.02±22.26^{c}	179.25±23.08^{b}	283.05±28.55^{c}	34.26±4.45^{a}	25.64±1.98^{a}
C20:5n3	7.18±1.18	4.46±0.98	6.16±0.67	5.14±1.25	5.48±0.98
C22:6n3	162.67±11.72^{b}	166.48±21.90^{b}	158.54±17.62^{b}	56.20±7.38^{a}	75.97±8.18^{a}
∑n3	169.84±12.24^{b}	170.94±22.83^{b}	164.70±17.53^{b}	61.34±8.55^{a}	81.45±9.08^{a}
∑n6	602.93±53.41^{c}	364.90±46.80^{b}	653.18±61.16^{c}	255.47±32.49^{ab}	243.15±20.45^{a}
∑PUFA	772.7756±65.57^{c}	535.84±69.60^{b}	817.88±78.68^{c}	316.81±40.87^{a}	324.60±29.52^{a}
∑n6/n3	3.547152±0.071^{c}	2.135603±0.019^{a}	3.969287±0.050^{d}	4.170283±0.142^{d}	2.991±0.078^{b}

Indices: SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids. Results (mg/100g) are expressed in means± S.D (n = 3). Values in the same row with different superscripts differ significantly (p< 0.05).

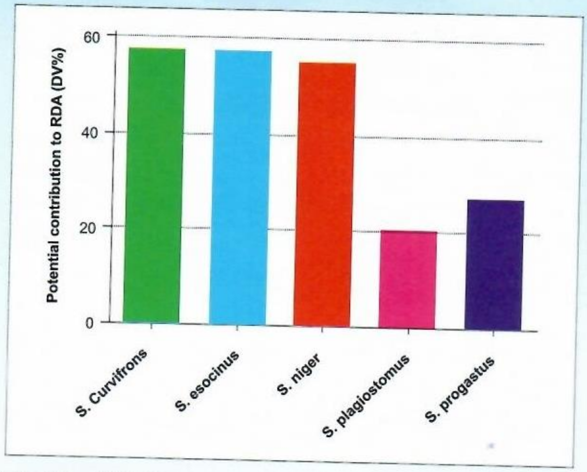


Figure 3: Potential contribution (DV%) to recommended daily allowance (RDA; 300 mg/day; based on Indian council of medical research, ICMR, 2010) of n-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs) for pregnant and lactating women (PLW) by different snow trout species. In calculation, 100 g of fish muscle is considered as per serving value.

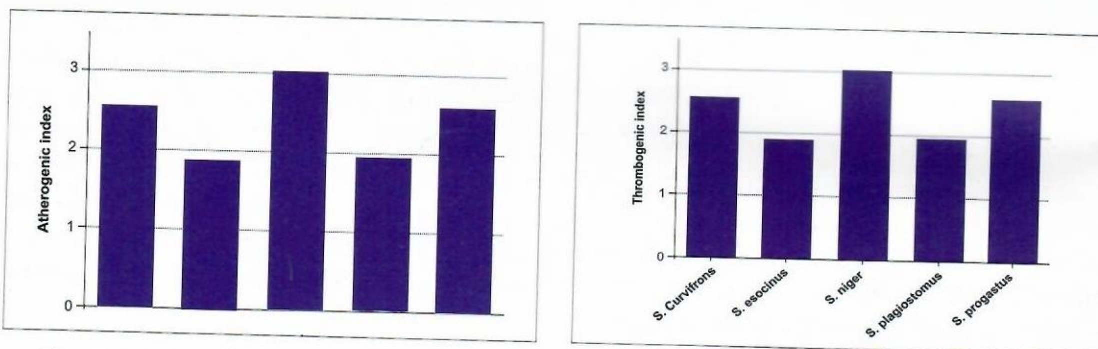


Figure 4: Index of lipid quality, atherogenic (top) and thrombogenic indices (bottom) of lipid from five different species of snow trout.

Mineral composition

Concentration of nine elements (Na, K, Ca, Mg, P, Fe, Zn, Mn and Cu) estimated in the muscle sample of five *Schizothorax* species are given in Table 18. The pattern of abundance of macrominerals in most of the fish was in the order of P>K>Ca>Na>Mg. The highest P, K, Na, and Mg levels were found in *S. plagiostomus*, while high Ca level was found in *S. niger* and *S. curvifrons*. The order of abundance of minerals, based on the report of Mohanty et al. (2016a), in Indian major carps (IMCs, cyprinids; *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*) was K>Ca>Na>P.

In *S. richardsonii* (one among the Indian Himalayan snow trout), the order of abundance was K> Na>Ca; P was not included in the analysis (Mohanty et al., 2016a). The DV% of calcium and phosphorus, on average, appeared promising in all five species of snow trout (Figure 5). Further, among these two minerals, DV% of phosphorus (around 100 of all four fishes and 118 of *S. plagiostomus*) is even better than calcium (around 50%). Based on the preponderance of these two macrominerals in the studied fish species, consumption may prove to be beneficial to PLW (RDA of Ca and P is 1200 mg/day), adolescent boys/girls, and postmenopausal women (RDA of Ca and P is 800 mg/day; ICMR 2010). The DV% of these fish species for other minerals, such as sodium, potassium, and magnesium, did not appear to be promising. All fish species displayed micromineral content in the order of Fe>Zn>Cu>Mn, except *S. esocinus*, which showed slightly higher Mn than Cu. This trend of microminerals is not consistent in other IHCs (*Tor putitora* and *S. richardsonii*; Mohanty et al., 2016a) and IMCs (Bogard et al., 2015; Mohanty et al., 2016a). The inconsistency in mineral (both macro and micro) content is possibly due to differences in the habitat, physiological state, and feed or natural food of the fish. The decreasing order of DV% for *S. niger*, *S. progastus*, *S. plagiostomus*, and *S. esocinus* was found to be Cu>Fe Mn>Zn, whereas in *S. curvifrons*, it was in the order of Fe> Zn>Cu>Mn. Based on the RDA and DV% plot of microminerals (Figure 5), it is clear that Fe (>60) and Cu (>80) contributed to RDA as described by ICMR (2010). For Cu, the maximum DV% providing fish species were *S. progastus* (134) and *S. niger* (128), and for Fe, *S. progastus* (74) contributed the highest. In India, anemia is a major public health problem, mainly due to Fe deficiency. It affects a significant portion of the population (50-70%), including infants, children, adolescent boys and girls, women of childbearing age, pregnant women, and even adult men (ICMR, 2010). Based on the DV%, all analyzed snow trout (with DV% 67-69), *S. progastus* in particular (with DV% 74), prove to help contribute Fe to pregnant (RDA 35 mg/day), lactating women (RDA 25 mg/day), and adolescent boys and girls (RDA averaged to 25 mg/day) (RDA obtained from ICMR 2010). Similarly, *S. progastus* and *S. niger* can contribute significantly to RDA of Cu to curb the incidence of Cu deficiency diseases such as anemia, osteoporosis, liver, and kidney problems (ICMR, 2010).

Table 18: Mineral composition of five snow trout (*Schizothorax* spp.).

Minerals	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
Macro					
Sodium	150±1.08[c]	140±0.89[b]	140±0.70[b]	180±0.61[d]	70±0.36[a]
Potassium	460±8.25[a]	480±2.00[b]	580±4.43[c]	700±3.04[d]	450±9.81[a]
Calcium	430±1.11[d]	410±1.25[c]	430±1.02[d]	360±1.80[b]	350±1.25[a]
Magnesium	90±0.95[c]	70±1.30[a]	100±1.32[d]	150±1.74[e]	80±1.80[b]
Phosphorus	640±1.02[b]	680±3.28[d]	670±2.53[c]	830±1.64[e]	580±1.38[a]

Minerals	*S. curvifrons*	*S. esocinus*	*S. niger*	*S. plagiostomus*	*S. progastus*
Macro					
Micro					
Iron	11.82±0.11[b]	11.54±0.10[a]	11.45±0.05[a]	11.83±0.05[b]	12.59±0.09[c]
Zinc	6.45±0.08[e]	4.62±0.10[b]	6.03±0.07[d]	2.64±0.09[a]	5.40±0.03[c]
Manganese	0.43±0.04[a]	1.43±0.00[d]	1.62±0.01[e]	1.02±0.00[b]	1.26±0.01[c]
Copper	0.72±0.03[a]	1.24±0.08[b]	1.73±0.01[c]	1.14±0.06[b]	1.81±0.09[c]

Results (mg/100g) are expressed in means± S.D (n = 3). Values in the same row with different superscripts differ significantly (p< 0.05).

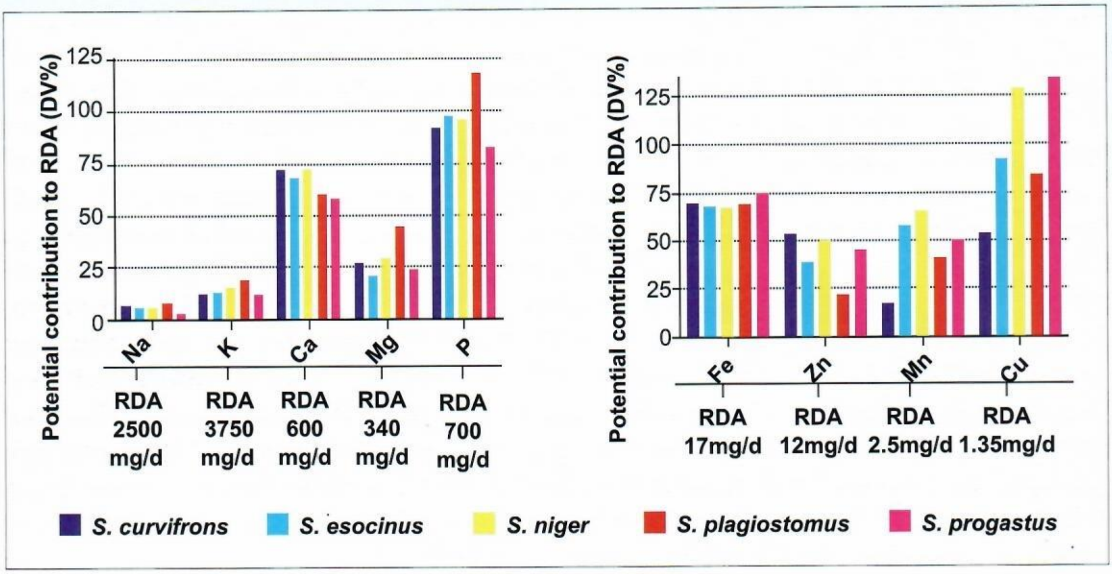


Figure 5: Potential contribution (DV%) to recommended daily allowance (RDA; based on Indian council of medical research, ICMR, 2010) of macro (top) and microminerals (bottom) for adult man (60 kg) by different snow trout species. In calculation, 100 g of fish muscle is considered as per serving value.

Nutrient profiling of selected coldwater fishes of North Eastern Indian upland region

The nutritional quality of selected coldwater fishes of north eastern Indian upland region viz., *Barilius bendelisis, Garra mulya, Labeo dero, Labeo dyocheilus, Labeo pangusia, Sanguina sanguine, Tor tor, Salmo trutta, Semiplotus semiplotus* and *Neolissocheilus hexagonolepis* were studied in terms of proximate and mineral composition to assess their nutritional quality.

Proximate composition

The proximate composition of the ten studied coldwater fish species are given in Table 19. One way Analysis of Variance (ANOVA) showed that there is a marked significant difference in moisture, crude protein, crude fat and ash contents among different species. The fishes had moisture content ranging from 71.41 to 78.27%, lowest being in *Semiplotus semiplotus* and highest in *Labeo dero*. Their crude protein levels ranged from 16.67 to 19.98%, crude fat 9.60 to 1.54% and ash 3.52 to 0.99%. The analyzed fish samples manifested highest to lowest levels of crude fat (CF) in the order of *S. sanguine* > *S. semiplotus* > *G. mullya* > *B. bendelisis* > *L. pangusia* > *T. tor* > *L. dyochelius* > *N. hexagonolepis* > *S. trutta* > *L. dero*. An inverse relationship has been found between crude fat and moisture contents. The results showed that *L. dero* is a 'low lipid-moderate protein' fish with the highest amount of moisture, while *S. sanguine* is a 'high lipid-low protein' fish and contains the least amount of moisture. The nutritional elements showed variable values in all the fishes analyzed; with crude protein recording the highest values and lipid recording the lowest. This makes these fishes important living resources of dietary protein as other sea and freshwater fish (Zuraini et al. 2006). High lipid fishes had less water and more protein than low-lipid fishes. This is in-line with the earlier report that protein forms the largest quantity of dry matter in fish (Steffens 2006; Sarma et al., 2011). Fish can be grouped into four categories according to their fat content as lean (<2 %), low (2-4 %), medium (4-8 %) and high (>8 %) fat fish (Ackman 1989). In terms of the lipid content, *L. dero* can be considered as a lean fish, *S. trutta* and *N. hexagonolepis* as low fat fish and *B. bandelesis, G. mullya, L. dyochelius, L. pangusia, S. sanguine, T. tor, S. semiplotus* as medium fat fishes.

Table 19: Whole body proximate composition (% wet weight basis) of ten coldwater fish species from North Eastern Himalayan region

Fish species	Proximate composition			
	Moisture	Crude fat	Crude protein	Ash
Barilius bendelisis	$73.42^{ab}\pm0.32$	$7.00^{de}\pm0.34$	$16.90^{a}\pm0.39$	$3.45^{c}\pm0.08$
Garra mulya	$73.09^{ab}\pm0.44$	$7.59^{e}\pm0.52$	$17.70^{ab}\pm0.46$	$3.51^{c}\pm0.07$
Labeo dero	$78.27^{d}\pm0.11$	$1.54^{a}\pm0.01$	$18.10^{ab}\pm0.79$	$1.73^{b}\pm0.02$
Labeo dyocheilus	$75.40^{bc}\pm0.98$	$5.79^{c}\pm0.12$	$18.7^{ab}\pm1.17$	$1.67^{b}\pm0.06$
Labeo pangusia	$76.07^{cd}\pm1.23$	$6.65^{cd}\pm0.18$	$16.67^{a}\pm1.40$	$3.52^{c}\pm0.37$
Sanguina sanguine	$72.46^{a}\pm0.90$	$9.60^{f}\pm0.31$	$17.44^{a}\pm0.94$	$3.18^{c}\pm0.02$

Fish species	Proximate composition			
Tor tor	$73.03^{ab}\pm0.56$	$6.12^{cd}\pm0.14$	$16.88^{a}\pm0.13$	$1.03^{a}\pm0.01$
Salmo trutta	$73.56^{ab}\pm0.89$	$2.27^{ab}\pm0.23$	$19.98^{b}\pm0.25$	$0.99^{a}\pm0.03$
Semiplotus semiplotus	$71.41^{a}\pm1.97$	$7.73^{e}\pm0.91$	$18.48^{ab}\pm0.46$	$1.16^{a}\pm0.09$
Neolissocheilus hexagonolepis	$76.19^{cd}\pm1.23$	$3.33^{b}\pm0.02$	$18.73^{ab}\pm0.23$	$1.21^{a}\pm0.01$
P-values	0.001	0.001	0.097	0.001

Mean values bearing different superscripts in the same row vary significantly ($p<0.05$). Data expressed as Mean ± SE (n =10).

Mineral composition

The mineral contents of the ten fishes are presented in Table 20 and 21. All the minerals investigated (sodium, potassium, calcium, iron, zinc, manganese and selenium) were presented in all the studied species. The average sodium, potassium and calcium content ranged from 92-309, 692-1435, 467-2021 mg/100g respectively. *Labeo pangusia* had the highest calcium (2021.91 mg/100g) while *T. tor, S. trutta and S. semiplotus* recorded the least calcium content. Potassium ranged from 1435.74 mg/100g in *L. dero* to 692.49 mg/100g in *T. tor*. The highest amount of sodium was observed in S. *sanguine* (309.61 mg/100g) while *T. tor* contained the least amount of sodium (92.22 mg/100g). The results revealed that the most abundant macro mineral in *L. dero, L. dyocheilus, S. sanguine, T. tor, S. trutta* and *S. semiplotus* was potassium, while calcium was the most abundant macro mineral in *B. bendelisis, G. mullya, L. pangusia* and *N. hexagonolepis*. Among the micro minerals, the highest amount of iron was observed in *L. dero* (21.32 mg/100g) while *S. sanguine, N. hexagonolepis, L. pangusia* and *S. trutta* contained the least amount of iron. *B. bendelisis* has the highest manganese (1.22 mg/100g) while *L. pangusia* recorded the least manganese content. Zinc ranged from 3.84 mg/100g in *G. mullya* to 0.10 mg/100g in *S. sanguine*. The highest amount of selenium was observed in *S. sanguine* (177.53 mg/100g) while *T. tor, S. semiplotus, N. hexagonolepis* and *S. trutta* contained the least amount of selenium. The results of the present study revealed that the coldwater fishes are rich source of macro and micro minerals. The species examined contained appreciable concentrations of potassium, sodium, calcium and selenium suggesting that these fish species could be used as good sources of minerals.

Table 20: Macro-mineral (mg /100g) content of ten coldwater fish species from North Eastern Himalayan region

Fish species	Macro-minerals (mg/100g)		
	Sodium	Calcium	Potassium
Barilius bendelisis	$152.58^{c}\pm20.4$	$965.74^{c}\pm58.2$	$851.58^{b}\pm29.1$
Garra mulya	$113.88^{ab}\pm4.2$	$819.49^{b}\pm7.5$	$711.53^{a}\pm16.24$
Labeo dero	$152.93^{c}\pm11.5$	$1423.74^{e}\pm27.5$	$1435.74^{d}\pm40.5$
Labeo dyocheilus	$116.65^{ab}\pm11.1$	$1017.03^{c}\pm19.7$	$1079.28^{c}\pm25.9$

Fish species	Macro-minerals (mg/100g)		
	Sodium	Calcium	Potassium
Labeo pangusia	123.92^{bc}±3.4	2021.91^{f}±48.6	1118.09^{c}±46.9
Sanguina sanguine	309.61^{d}±11.4	854.02^{b}±10.2	897.00^{b}±16.0
Tor tor	92.22^{a}±10.4	509.37^{a}±30.0	692.49^{a}±22.7
Salmo trutta	159.19^{c}±10.5	547.01^{a}±35.2	807.64^{ab}±41.3
Semiplotus semiplotus	133.56^{bc}±5.6	467.45^{a}±18.5	701.48^{a}±16.2
Neolissocheilus hexagonolepis	105.00^{ab}±12.3	1175.0^{d}±14.8	810.33^{ab}±11.8
P-values	0.001	0.001	0.001

Mean values bearing different superscripts in the same row vary significantly (p<0.05). Data expressed as Mean ± SE (n =10).

Table 21: Micro-mineral content (mg/100g) of ten coldwater fish species from North Eastern Himalayan region

Fish species	**Micro-minerals (mg/100g)**			
	Iron	Manganese	Zinc	Selenium
Barilius bendelisis	8.86^{e}±0.25	1.22^{g}±0.01	0.35^{b}±0.04	125.63^{d}±4.74
Garra mulya	6.07^{d}±0.12	0.09^{ab}±0.01	3.84^{f}±0.05	156.33^{e}±3.65
Labeo dero	21.32^{f}±0.67	0.04^{ab}±0.01	0.33^{b}±0.02	61.32^{c}±3.75
Labeo dyocheilus	8.35^{e} ±0.22	0.67^{e}±0.03	0.30^{b} ±0.03	66.33^{c}±2.29
Labeo pangusia	1.90^{a}±0.17	0.02^{a}±0.01	0.26^{ab}±0.02	50.77^{b}±2.22
Sanguina sanguine	1.38^{a}±0.13	0.84^{f}±0.03	0.10^{a}±0.02	177.53^{f}±2.52
Tor tor	3.08^{b} ±0.08	0.21^{c}±0.04	0.89^{c}±0.09	1.30^{a}±0.13
Salmo trutta	1.83^{a} ±0.09	0.31^{d}±0.03	1.16^{d}±0.08	0.96^{a}±0.10
Semiplotus semiplotus	4.03^{c}±0.17	0.21^{c}±0.01	1.67^{e}±0.16	1.23^{a}±0.04
Neolissocheilus hexagonolepis	1.87^{a}±0.02	0.10^{b}±0.01	1.60^{e}±0.02	1.89^{a}±0.02
P-values	0.001	0.001	0.001	0.001

Mean values bearing different superscripts in the same row vary significantly (p<0.05). Data expressed as Mean ± SE (n =10).

Nutrient profiling of small indigenous fishes from Brahmaputra river

Six small indigenous fish species (SIFs) namely *Macrognathus aral*, *Setipinna phasa*, *Clupisoma garua*, *Aspidoporia morar*, *Barillius bendelisis* and *Semiplotus semiplotus* were collected from Brahmaputra river & its tributaries and their nutritional value was assessed in terms of proximate composition, fatty acids profile, total cholesterol and mineral composition.

Proximate composition

The proximate composition of studied SIFs is shown in Table 22. The preponderance of principal edible nutrients such as protein and lipid in descending order appeared as *C. garua* > *S. semiplotus* > *B. bendelisis* > *M. aral* > *A. morar* > *S. phasa* and *S. phasa* > *S. semiplotus* > *B. bendelisis* > *A. morar* > *M. aral* > *C. garua* respectively. The protein contents in these fish ranged from 15.65% in *S. phasa* to 20.88% in *C. garua;* conversely the fat content was highest in *S. phasa* (13.23±0.25) and lowest in *C. garua* (2.91±0.12). Highest crude fat in *S. phasa* is because of the fact that its belongingness to the family engraulidae under which the anchovies, the high fat containing fish, also belong. According to fat based fish classification system, *S. phasa* can be categorized as high fat fish (>10%), *B. bendelisis* and *S. semiplotus* as medium-fat fish (containing 5-10% fat), and *M. aral, C. garua* and *A. morar* as low-fat fish (containing 1-5% fat). Highest moisture was found in *M. aral* and lowest in *S. phasa,* the pattern was more or less opposite to the crude fat content, as was reported in several fishes. The highest amount of ash was found in *S. phasa* and lowest in *C. garua.* In fish, the ash content approximates to 1.25%, with range from 1-1.5%, and in some cases the ash content can be erroneously go higher because of inclusion of bones.

Table 22: Proximate composition of different SIFs (g/100 g on wet weight basis)

Composition	*M. aral*	*S. phasa*	*C. garua*	*A. morar*	*B. bendelisis*	*S. semiplotus*
Moisture	77.75 ± 0.46^{d}	69.31 ± 0.54^{a}	75.36 ± 0.57^{cd}	77.42 ± 0.36^{d}	73.42 ± 0.56^{bc}	70.91 ± 2.97^{ab}
Ash	2.61 ± 0.22^{b}	3.46 ± 0.06^{c}	0.82 ± 0.02^{a}	2.36 ± 0.15^{b}	3.45 ± 0.13^{c}	1.21 ± 0.24^{a}
Protein	16.87 ± 0.87^{ab}	15.65 ± 0.78^{a}	20.88 ± 0.09^{c}	16.71 ± 0.70^{ab}	16.90 ± 0.67^{ab}	18.12 ± 0.85^{b}
Crude fat	3.90 ± 0.23^{b}	13.23 ± 0.25^{d}	2.91 ± 0.12^{a}	4.96 ± 0.39^{b}	7.00 ± 0.60^{c}	7.72 ± 1.58^{c}

Results are expressed as mean ± SD (n=3). Values in the same row with different superscripts differ significantly ($p < 0.05$).

Fatty acid composition

Out of the six fish analyzed, the fatty acids abundance trend (Table 23) of three fish, namely *C. garua, A. morar* and *B. bendelisis* was SFAs > MUFAs > PUFAs. The fatty acids abundance trend of other three fish, namely *M. aral, S. phasa* and *S. semiplotus* was SFAs > PUFAs > MUFAs. Among SFAs, myristic acid (C14:0) in *M. aral* and *S. phasa,* and palmitic acid (C16:0) in *C. garua, A. morar, B. bendelisis and S. semiplotus* were found to be dominant. Similarly among MUFAs, palmitoleic (C16:1) in *M. aral, A. morar, B. bendelisis* and *S. semiplotus*, and oleic acid (C18:1) in *S. phasa* and *C. garua* were dominant. The total PUFAs were found to be in order as *S. semiplotus* > *S. phasa* > *B. bendelisis* > *M. aral* > *A. morar* > *C. garua.*

Assessing the PUFAs separately as n-6 and n-3 gives a better idea of lipid quality than collective assessment because these fatty acids have different roles and different degree of importance in human nutrition. Among PUFAs, *S. semiplotus* > *S. phasa* > *B. bendelisis* showed more n-3 than n-6 (in other words, better n-3/n-6 ratio) and *M. aral* > *C. garua* > *A. morar* showed the reverse (non preferable n-3/n-6 ratio). However, no optimal or preferable recommendation on n-3/n-6 is given by FAO (2010) and ICMR (2010). Among n-3, *S. semiplotus* had high alpha linolenic acid

(C18:3n-3) and high EPA (C20:5n-3), and *S. phasa* had high DHA (C22:6n-3). Among n-6, in some fishes (*M. aral, C. garua, and A. morar*) arachidonic acid (AA; C20:4n-6) and in others (*B. bendelisis, S. semiplotus*) linoleic acid (C18:2n-6) were predominating (exception, *S. phasa*). Arachidonic acid, as a precursor of biologically active molecules such as prostaglandin and thromboxane, which facilitate blood clotting and wound healing is considered as an important fatty acid in human nutrition. Contrarily, rare but more panacea fatty acids, the n-3 long chain PUFAs on the other hand, have several beneficial attributes such as cardio-protection, anti-atherosclerosis, anti-thrombosis, anti-inflammatory, anti-rheumatoid arthritis, anti-depression, anti-aging, etc. The sum of all n-3 long chain PUFAs, in general, and DHA in particularly are involved in the development of fetal brain, eye retina and cognition (Tocher, 2015). The incorporation of these vital fatty acids in pregnant and lactating women's (PLW) diet is therefore very much essential. An idea on the potential contribution of n-3 LC-PUFAs to RDA (300 mg/day) for PLW of individual fish (DV%) may provide a quantitative information for incorporation of these fish in their diet to meet the RDA. Therefore, the potential contribution value (DV%) of all these fish against RDA for PLW was estimated (Figure 6). Based on these calculated values, *S. phasa, S. semiplotus* and *B. bendelisis* showed more than 100% potential to contribution to RDA for PLW.

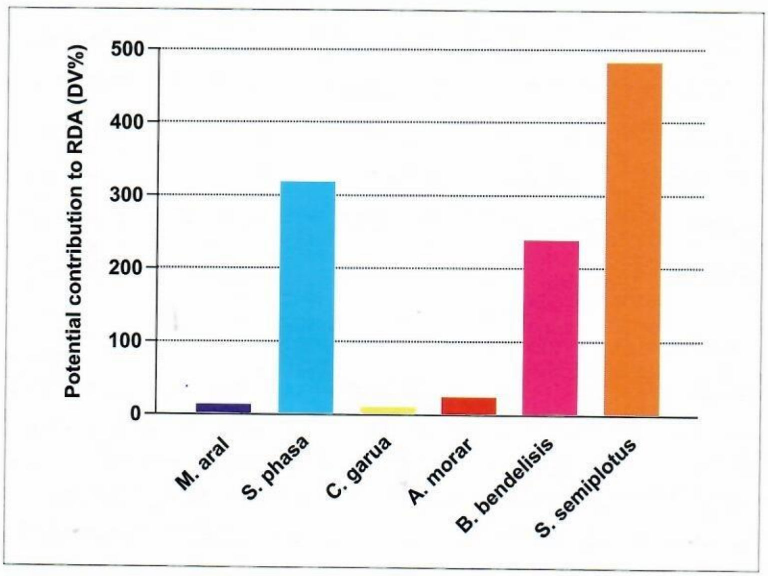


Figure 6: Potential contribution (DV%) to recommended daily allowance (RDA; 300 mg/day; based on Indian council of medical research, ICMR, 2010) of n-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs) for pregnant and lactating women (PLW) by ten coldwater fish species from North Eastern Himalayan region. In calculation, 100 g of fish muscle is considered as per serving value.

Cholesterol and lipid quality

Diverse group of fat soluble chemical compounds are fall under lipids, of which the sterol, especially cholesterol is very important and hence we assessed in our study. Our results showed that cholesterol content ranged from 32.82 mg/100g in *S. phasa* to 10.07 mg/100g in *B. bendelisis* (Table 23). The range of cholesterol content in our fish of interest was similar to the findings reported by Moreira et al. (2001) and Osman et al. (2001) that is below 50mg/100g. The cholesterol content of the food, these days, is considered to be an important nutritional issue; consumers generally prefer low cholesterol food, and for them, fish can be a good choice which can assure better health.

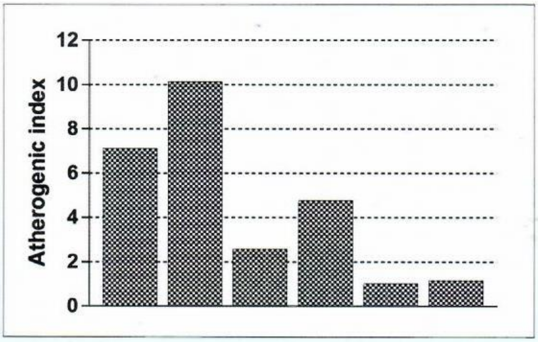
The lipid quality indices (Figure 7) such as AI and TI of fish muscle provide some information of their nutritional quality. The abundance of MUFAs and PUFAs are considered effective in decreasing atherosclerosis and thrombosis; therefore, the AI and TI were also assessed. A high value for AI and TI were obtained in our findings, although AI and TI values are preferred to be low. No concluding rational can be drawn for high value of AI and TI with one time sampling of SIFs. A further deliberate seasonal sampling may required to explain this anomaly.

Table 23: Fatty acid and cholesterol concentration of different SIFs (mg/100g)

Fatty acids	*M.aral*	*S. phasa*	*C. garua*	*A.morar*	*B. bendelisis*	*S. semiplotus*
C 6:0	0.43±0.43a	1.16±0.00b	ND	ND	ND	ND
C 7:0	ND	1.16±1.16	ND	ND	ND	ND
C8:0	1.28±0.21a	19.75±1.17b	0.50± 0.25a	0.83 ± 0.42a	ND	ND
C9:0	1.07±0.56	2.32±2.01	0.25±0.43	ND	ND	ND
C10:0	3.62±0.37	3.48±3.07	0.25 ± 0.25	0.41±0.41	ND	ND
C11:0	16.20±1.88b	1.16 ± 2.01a	0.25± 0.00a	ND	ND	ND
C12:0	271.49±0.52d	1.16±1.16a	7.74± 0.99b	4.13 ±4.13ab	69.184±2.52c	6.0±1.20ab
C13:0	143.00±0.43b	1.16±0.00a	1.00± 0.66a	2.48 ±1.49a	3.41 ±1.97a	ND
C14:0	771.21±0.62d	6404.51±9.36e	141.02±1.04a	495.39 ±1.07c	325.023 ±29.80 b	352.70±66.40b
C15:0	299.83±0.92c	909.45±6.82d	25.71±0.71a	105.36±0.44b	34.13±4.43a	34.30±8.11a
C16:0	1.07±0.43a	1367.09±3.05b	1448.92±2.83b	2281.10±3.18cd	1847.91 ±152.80bc	2392.94±448,18d
C17:0	1.28±0.56a	1.16±1.16a	24.46±0.46b	40.08 ±0.38c	20.33 ±1.09b	73.84±12.28d
C18:0	5.54±0.56a	2.32±0.00a	7.24±1.14a	270.21 ±0.95b	258.16 ±26.86b	1042.49±157.25c
C19:0	0.64±0.43a	ND	1.25±0.90a	ND	5.90±2.141b	8.82±3.12b
C20:0	26.21±0.98	3.48±2.32	17.47±6.60	8.26 ±7.15	52.40±58.48	14.78±3.70
C21:0	17.47±0.55b	5.81 ±5.33a	2.30±0.67a	1.24 ±0.41 a	ND	ND
C22:0	46.24±0.51c	60.40±4.21d	17.47±5.0b	8.68±1.10a	ND	ND
C23:0	10.87±0.43b	164.93±3.06c	7.99±0.65b	3.31 ±1.10a	ND	ND
C24:0	41.34±1.18a	ND	10.48±0.49a	15.29±1.89b	ND	ND
ΣSFAs	1658.77±5.20a	8950.52 ±15.70d	1715.00±10.74a	3236.74±11.81bc	2616.44 ±176.40b	3925.86±681.75c
C14:1	1.07±0.77a	5.81±3.07a	ND	1.24 ±1.09a	ND	15.88±2.77b
C16:1	161.32±1.0a	166.09±1.18a	115.07±1.09a	679.66 ±1.44b	1154.13±37.94c	1019.47±148.37c

Fatty acids	M.aral	S. phasa	C. garua	A.morar	B. bendelisis	S. semiplotus
C18:1	11.01±0.65a	703.87±8.09d	499.53±4.26c	3.03 ±0.86a	555.37 ±19.14c	379.11±52.37b
C20:1	18.97±0.23ab	106.86±3.08c	19.72±0.88ab	12.81 ±0.82a	31.66 ±0.86b	99.00±13.29c
C22:1	1.065±0.74a	4.65±0.00b	4.74±0.44b	2.07±0.83a	9.19±1.21c	3.47±1.37ab
C24:1	3.20±0.93	ND	3.99±0.25	2.07 ±1.49	ND	ND
ΣMUFAs	196.62±1.02a	987.27 ±7.93c	643.05±4.25b	700.87±3.5b	1750.35 ±55.26d	1516.93±215.25d
C18:2n6	15.77 ±0.43 a	34.84 ±20.11a	44.18±0.74a	0.41±0.00a	533.59±23.13c	188.19±27.54b
C18:3n6	11.29±0.43a	627.21±30.59c	28.45±0.91ab	50.82±1.13b	43.88 ±4.11ab	ND
C18:3n3	ND	ND	ND	ND	161.67±7.63a	597.90±87.28b
C18:4n3	ND	ND	ND	ND	ND	88.93±12.75
C20:4n6	228.23±0.39d	61.56±3.10ab	56.66±1.00a	74.78±0.45bc	81.64±1.58c	65.54±12.06ab
C20:3n3	ND	ND	ND	ND	11.69±0.78a	80.66±10.66b
C20:4n3	ND	ND	ND	ND	ND	92.12±13.34
C20:5n3	13.85±1.12a	ND	8.49±0.67a	4.13±0.00a	316.80 ±14.45b	319.49±45.81b
C22:6n3	6.18±0.56a	950.11 ± 2.88e	0.75±0.25a	64.87±1.06b	226.64 ±10.59c	273.69±39.39d
ΣPUFAs	275.33±2.65a	1673.72±47.24c	138.53±2.38a	195.02±0.93a	1375.91±60.34b	1706.45±246.95c
Σothers	ND	ND	ND	ND	58.58 ±3.30a	91.37±15.25b
Σn-3	20.03±1.66a	950.11±2.88b	9.24±0.45a	69.00±1.06a	716.80 ±31.88b	1452.80±208.72c
Σn-6	255.29 ±1.17b	723.61 ±49.24c	129.29±2.02a	126.02±1.33a	659.11±28.60c	253.66±38.47b
Σn-3/n-6	0.078±0.01a	1.32±0.089d	0.07±0.00a	0.55±0.013b	1.09±0.01c	5.73±0.12a
Cholesterol	18.90±0.81c	32.82±0.10e	16.60±0.52b	23.70±0.72d	10.07±0.42a	25.71±0.34d

Indices: SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids. Results (mg/100g) are expressed in means± S.D (n = 3).Values in the same row with different superscripts differ significantly ($p < 0.05$). the sum of other fatty acid includes C20:2n9, C20:2n7, C20:3n9, C20:3n7.



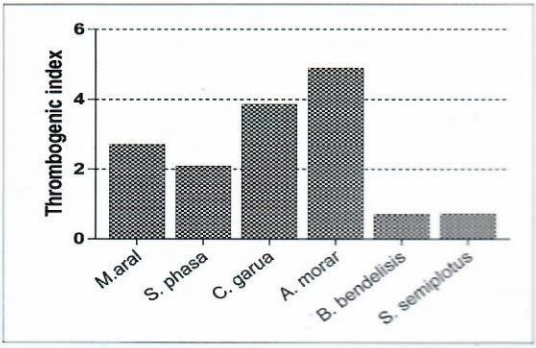


Figure 7: Index of lipid quality, atherogenic (top) and thrombogenic indices (bottom) of lipid from ten coldwater fish species from North Eastern Himalayan region

Mineral composition

Concentrations of six elements (Na, K, Ca, Fe, Zn, and Mn), estimated in the muscle sample of six SIFs are given in Table 24. The trend of the abundance of macrominerals in most of the fish of our interest was in the order of K > Ca > Na, except *B. bendelisis* (Ca > K > Na). The highest K and Na recorded were in *M. aral*. The trends of occurrence of macrominerals were similar to other SIFs (*A. coila, A. mola, G. chapra* and *P. sophore*) and freshwater cyprinids (*Labeo rohita* and *Catla catla*).

Table 24: Minerals estimation of different SIFs (mg/100g)

Minerals Macro	*M. aral*	*S. phasa*	*C. garua*	*A. morar*	*B. bendelisis*	*S. semiplotus*
Sodium	311.61±13.86^{c}	127.256±11.31^{a}	128.37±30.87^{a}	215.87±15.81^{b}	152.58±35.50^{a}	133.41±1.51^{a}
Potassium	1110.48±20.25^{d}	492.35±25.38^{a}	474.96±117.86^{a}	611.87±32.39^{ab}	851.58±50.32^{c}	701.29±11.01^{bc}
Calcium	858.51±37.75^{b}	445.12±15.21^{a}	407.30±58.80^{a}	438.14±15.42^{a}	965.74±100.81^{b}	467.12±15.00^{a}
Micro						
Iron	18.84±1.00^{d}	111.4±0.07^{e}	13.38±1.09^{c}	16.92±0.98^{d}	8.7±0.44^{b}	4±0.78^{a}
Zinc	6.69±1.11^{b}	7.2±0.03^{b}	6.31±0.73^{b}	7.31±1.31^{b}	0.35±0.13^{a}	1.7±0.3^{a}
Manganese	2.57±0.58^{bc}	3.2±0.03^{c}	1.32±0.10^{ab}	2.03±0.97^{bc}	1.2±0.7^{ab}	0.21±0.03^{a}

Results are expressed as mean ± SD (n=3). Values in the same row with different superscripts differ significantly ($p<0.05$).

Although macro-minerals like K and Na were detected significantly in all fish, however, the DV% (the extent to which, in terms of percentage, the particular mineral from individual fish can contribute to RDA) of calcium only, appeared more than 50% potential to contribute to RDA (Figure 8). Particularly, *M. aral* and *B. bendelisis* appeared to contribute 143% and 161% respectively to RDA of adult human. Based on the preponderance of calcium in the studied SIFs, the consumption of these SIFs may prove to be beneficial to adult men/ women (600 mg/day), PLW (RDA of Ca is 1200 mg/day), adolescent boys/girls and postmenopausal women (RDA of both Ca and P is 800 mg/day; ICMR 2010). The DV% of these fish for other minerals such as sodium and potassium did not appeared to be promising.

Amongst the micro-minerals, all fish investigated exhibited the abundancy in following order Fe > Zn > Mn, except *B. bendelisis* (with slightly higher Mn than Zn, possibly due to differences in their habitat, physiological state and natural food). This trend of microminerals is similar to that reported by Mohanty et al. (2016a) (in *A. coila, A. mola, G. chapra, P. sophora, L. rohita* and *C. catla*) and Bogard et al. (2015) (in *M. armatus, G. chapra, M. pancalus, C. batrachus, A. mola*, etc.). The decreasing order of DV% for all SIFs was found to be Fe > Mn > Zn. Based on DV% plot of microminerals (Figure 8), it is clear that Fe (>100%) and Mn (>100%) in *M. aral* and *S. phasa* respectively, and to some extent in *A. morar* (99.5% for Fe and 81% for Mn) appeared promising to contribute to RDA recommended by ICMR (2010). Among the fish investigated, *S. phasa* followed by *M. aral* exhibited the highest DV% for Fe (655% and 110%), and Mn (128% and

102%). In India, anaemia is a major public health problem, mainly driven by Fe deficiency, and it is affecting a significant chunk of the population (50-70%). Based on the DV%, all analyzed SIFs (*S. phasa*, prominently) in general (with DV% around 50-650), except *S. semiplotus* (with DV% 24), prove to be promising in contributing Fe to pregnant (RDA 35 mg/day), lactating women (RDA 25 mg/day), and adolescent boys and girls (RDA averaged to 25 mg/day) (RDA obtained from ICMR (2010). Similarly, *S. phasa* and *M. aral* can contribute significantly to RDA of Mn to curb the incidence of Mn deficiency diseases such as neurological symptoms in epilepsy ICMR (2010).

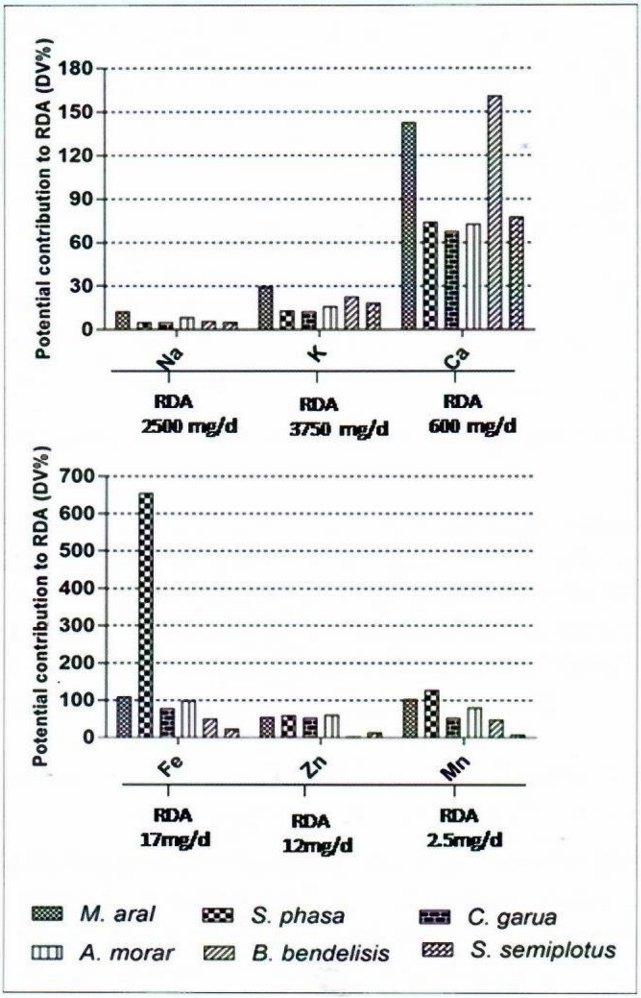


Figure 8: Potential contribution (DV%) to recommended daily allowance (RDA; based on Indian council of medical research, ICMR, 2010) of macro (top) and micro minerals (bottom) for adult man (60 kg) by ten coldwater fish species from North Eastern Himalayan region. In calculation, 100 g of fish muscle is considered as per serving value.

Conclusion

In conclusion, all the studied coldwater fishes were good in one way or the other in their nutrient load and dietary nutrient contribution potential with slightest interspecies differences. Among the common edible coldwater food fishes, namely rainbow trout (*Oncorhynchus mykiss*), golden mahseer (*Tor putitora*), snow trout (*Schizothorax richardsonii*), chocolate mahseer (*Neolissochilus hexagonolepis*) and common carp (*Cyprinus carpio*), snow trout followed by chocolate mahseer are the best in term of n-3/n-6 fatty acid ratio (Sarma et al., 2011, 2013). Among various species of snow trouts, namely *S. curvifrons, S. esocinus, S. labiatus, S. niger, S. plagiostomus, S. progastus* and *S. richardsonii, S. labiatus* is the superior fish with best nutritional attributes (in terms of protein content, leucine, phenylalanine, isoleucine, lysine, threonine, MUFAs, n-3 fatty acids, calcium, phosphorus and zinc, and lowest contents of TAG, and n-6/n-3 ratio) (Joshi et al, 2017a,b). *S. richardsonii* is the second best with abundant loads of methionine, valine and lysine, and limited content of fat, SAFAs, n-6 fatty acids and n-6/n-3 ratio. Similarly, *S. progastus* (due to best in arginine, histidine and iron content) and *S. esocinus* (with lowest cholesterol) respectively are the third and the fourth best.

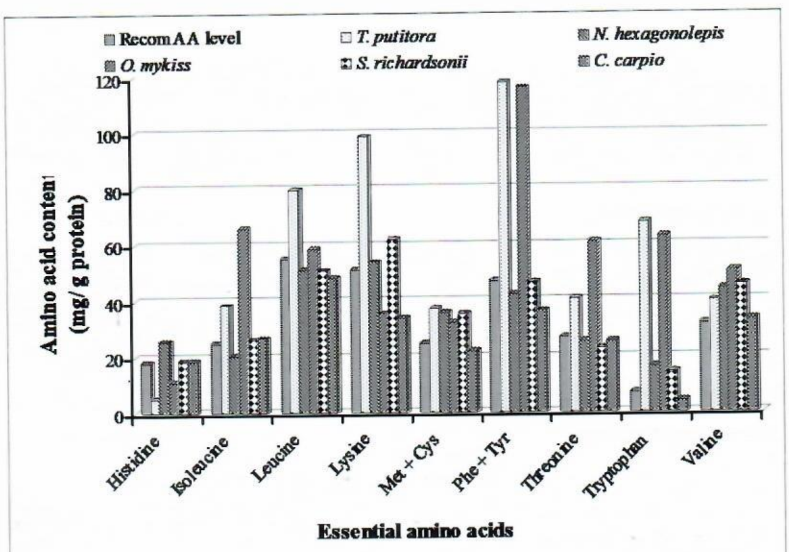


Figure 9: Essential amino acid contents (mg/ g protein) of *T. putitora, N. hexagonolepis, O. mykiss, S. richardsonii and C. carpio from Indian upland Himalayan region as compared to the amino acid content (mg/ g protein)* as recommended by *Food and Nutrition Board of Institute of Medicine, Washington, DC, USA (Data source of recommended amino acid contents:* http://nutritiondata.self.com/help/analysis-help*).*

Plate: Nutrient profiling of the following fish species is reported in this bulletin

Tor putitora

Neolissochilus hexagonolepis

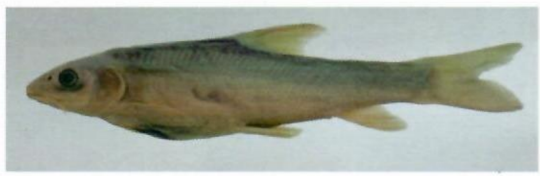
Tor tor

Schizothorax richardsonii

Schizothorax esocinus

Schizothorax niger

Schizothorax progastus



Schizothorax labiatus

Schizothorax curvifrons

Schizothorax plagiostomus

Labeo dyocheilus

Labeo dero

Labeo pangusia

Garra mulya

Oncorhynchus mykiss

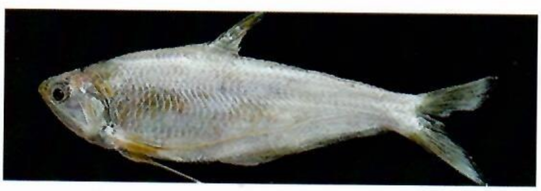
Salmo trutta

Semiplotus semiplotus

Aspidoporia morar

Barilius bendelisis

Macrognathus aral



Setipinna phasa

Clupisoma garua

Cyprinus carpio

(Photos reproduced from Mahanta et al., 2011 and Fishbase.org)

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