SMALL INDIGENOUS FRESHWATER FISHES: A GOOD SOURCES OF MICRO NUTRIENTS IN HUMAN HEALTH

Abstract

This chapter highlights the various importance of micro nutrients viz. macro and micro elements, oil soluble vitamins of Small Indigenous Freshwater Fishes Species (SIFFs) in human health. It is well accepted that fish are the good source of protein and other important mineral elements for the maintenance of healthy body. Like Indian Major Carps (IMCs), large catfish and other food fishes, SIFFS also contribute high quality of animal protein for human nutrition proportional to muscles biomass. Besides this, SIFFS are also rich sources of micronutrients. It consists of vitamins and other essential elements which are depend on other sources. Micronutrients are essential in small amounts however they are indispensable to human body. Generally most small fishes are less preferred than larger fish species however consumption of small fishes as a whole will provides rich amount of micronutrients such as zinc, iron and their bone are excellent sources of calcium are available from consumption of small fishes. Thus, the SIFFs can consider as an important sources micronutrients and good food to combat many micro nutrients deficiencies.

Keywords: Human body, SIFFS, IMCs

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I. INTRODUCTION

India is one of the 17 mega biodiversity hotspot, is native to many freshwater fishes. According to National Bureau of Fish Genetic Resources (NBFGR) about 2,246 species of fin fish are recorded in India, out of these fish species 765 are freshwater fish. India has contributed 27.85% of native fish fauna, followed by China, Indonesia and Myanmar respectively. Out of 765 fish species, about 450 species are classified as SIFFs. Owing to its topographical features of North East India, it provides an ideal habitat for various endemic small fish. As many as 216 species of small fish are recorded itself from North Eastern India. As many as 104 species out of 450 species of SIFFs are highly important as food, aquarium trade and also provides local livelihood security. About 62 species have been categories as food fish. These small fish have occupied enviable and an inseparable relation in the life, livelihood, health and help in economically support especially in poor people.

According to Felts et al., 1996 SIFFs have short life cycle, highly prolific breeder and in mature and adult stage it grow to a maximum size of 25 cm or 9.8 inches in their life cycle. Nevertheless, many small fishes are less than 10 cm or 3.9 inches in length and they are consumed as a whole. They can easily propagate and live in backyard ponds, beels, wetland and can be grown in all types of inland water bodies.

However, SIFFs have not so far been included as a part of aquaculture due to various reason such as culturing of these species is much more difficult than culturing IMC, proper culture technology is not available, lack of interest among the Government and private agencies to promote, no export demand and doubt of culturing these fish species will be profitable by the farmers. However, some initiative has been taken up national as well as international. Kohinoor *et al.,* 2005 have reported the overall production of carp was not affected in the poly-culture stocking with *Puntius sps.* It is also revealed that the shallow and small water bodies may generously be used for culture of SIFFs and have feasibility for good production along with IMCs.

As reported by Mohan, 2010 due to the prolific breeders SIFFs are commonly available in the rural areas. Peoples in that areas are usually consumed small fishes not because of their micronutrients rich rather as these fishes are commonly available and do not have good market demands as compare to the large fishes. Pulses, vegetables and fruits are eaten less frequently as affordability is difficult. Thus, weather by choice or default, they consume more small fishes and get the associate health benefits. However, in urban areas, as the peoples are highly conscious about the health. Therefore, there is high demand of the small fish that got a share in regular fish consumed schedule.

Aquatic foods animal have higher protein content than the terrestrial meat. Moreover protein from aquatic food have higher digestible and rich in several peptides and also provides higher essential amino acids that are limited in terrestrial meat product (Sarvenaz and Sabine, 2018). Despite fish as a good source of protein, fish are also importance source of minerals elements. It is due to ability of fish to absorbed many inorganic elements not only from diets but also from their external environments in both freshwater and seawater. Most of the trace elements are detected in fish tissue and their concentration of minerals in the tissues depends on types of species, food source, stage of development, physiological status and environment where the fish is adapted (Lall, 1995).

In addition to protein and fatty acid, fish is also one of the major sources of oil soluble vitamins in human diet. The oil soluble vitamins are more stable than water soluble vitamins but more prone to degrade at high temperature in the presents of oxygen (Preisley, 1979). Since Small fishes are consumed as whole it is considered as excellent sources of micronutrients. It is also reported that vitamin A is highly accumulated mostly in viscera and around the eyes in some fishes (Roos, et. al., 2002). Many important elements like Ca, Na, P, K, Fe, Cl are known to be indispensible in all living organism and takes part in various metabolic process. The deficiencies of these important minerals induce in many malfunctions and cause many diseases (Roos *et al.,* 2007). In Bangladesh, the small fishes which are highly accumulated with Vitamin A, Ca, Fe and Zn are commonly consumed. The consumption of these small fishes help combat the deficiency of Vit. A among children and play a vital role in supplying rich sources of vitamin A among people. Thus, the consumption of fish is encouraging because of the various benefit outcomes of essential minerals and other nutrients which are mostly available in fish. However, exposure of food fish to high water pollution may increase the metabolic and functional role of toxic elements.

II. SIGNIFICANCE OF MICRO NUTRIENTS IN HUMAN HEALTH

Mineral: According to Soetan *et al.,* 2010, minerals are inorganic substances which are present in all fluids and tissues of the body and their present is necessary for the maintenance of physic-chemical processes which are essential in life. Minerals does not yield energy although they plays an important role in many physiological activities in the body (Malhotra, 1998) and help to maintain normal life processes (Ozcan, 2003). Many essential minerals are required in small quantities and are difficult to formulate diets (Lall, 1995). The mineral element in human body are usually content in small amount however deficiency of mineral elements causes many malfunction and causes various diseases such as the osteoporosis, inability of the blood clot, anaemia, etc. (Mill, 1980).

Depending upon the quality, mineral can be classified as macro, micro and the ultra-trace (Eruvbetine, 2003). The macro minerals are requiring in amount >100mg/dl whereas micro is required <100 mg/dl (Murray *et al.,* 2000). Ca, Na, P and Cl are included in macro minerals while K, Fe, Mn, Co, Mg, F, Cu, I, Mo, Zn, Cr, Se and S are included in micro minerals (Eruvbetine, 2003). The ultra-trace elements which include arsenic, boron, nickel, and silicon are essential for animals for proper functioning of the body.

Like essential nutrients viz. proteins, carbohydrates, fats and vitamins, the mineral elements are separately entitle but the needful of minerals by various animals in their diets are demonstrated (Hegsted *et al.,* 1976). The significance of elements for human nutrition and detection of trace element in various foods is still the active areas of research (Soetan *et al.,* 2010). At least fifteen trace elements are considered to be essentials to animals (Lall, 1995) and these deficiencies become major health problem in many developing countries especially risk at infant and pregnant women. Its deficiencies also influence in various degree of impairment in human health including lowered immunity to infections and work capacity, cognitive performance, pregnancy complications such as low weight of babies when birth, reduced psychomotor skills and poor learning capacity (Batra and Seth, 2002).

The definite orders in magnitude of the elements are not observed by many researchers. It might be due to the concentration in local environment and chemical forms of the elements (Window *et al.,* 1987). Its concentration in the body of an aquatic organism depends on the food source, stage of development, environment, physiological status of the organism and species. Most of the trace element are shown higher concentration in first trophic level (Phytoplankton) but Cd, Zn and Cu have higher concentration if zooplankton. Fish feeding on planktons have higher concentration of Cu and Zn than fish feeding on small fish and invertebrates (Lall, 1995). There may have an negative impact on human health on consumption of fish involves exposure to some metals (Uluozlu *et al.,* 2007). The consumption of fish is encouraging because of the various benefit outcomes of essential minerals and other nutrients which are mostly available in fish. However, exposure of food fish to high water pollution may increase the metabolic and functional role of toxic elements.

III. MACRO MINERALS

1. **Calcium (Ca):** Ca is one of the most abundant cations in the body of the fish. The important site of Ca deposition and metabolism in the scale of the fish and the rate of exchange of Ca is three times higher in fish scale than in bone (Berg, 1968). The Ca absorbed is mostly deposited in skin and bone of the fish. The retention and deposition pattern by skeleton and rate of uptake are independent of bone types and seem to be similar in species of marine and freshwater (Lall, 1995).

   Calcium is required for development and normal growth of the skeleton. The average Ca accumulation is 150 mg/day by the body during the growth of skeleton and maturation until early twenties in human. After the menopause in women and 50 years in men, the equilibrium of Ca become imbalance and loss of Ca from skeleton, this loss is associated with rise in fracture. Thus, to achieve optimum bone mass and modified the rate of bone loss, adequate intake of Ca is critical (Strain and Cashman, 2009).

   Many functions such as blood clot formation, muscles contraction, integrity of cell membrane, nerve transmission and activation of various important enzymes such as adenosine triphosphatase (ATPase), adenosine succinic dehydrogenase, lipase etc. are also maintained by Ca other than bone formation and maintenance of skeletal tissue (Lall, 1995). It is also required for contraction of muscle, membrane permeability, in neuromuscular excitability and nerve impulses normal transmission.

   The excess absorption due to hyperparathyroidism, due to hypervitaminosis D or hypercalcemia, or idiopathic hypercalcemia may lead to high intake of Ca which also shows many toxicity symptoms (Soetan *et al.,* 2010). Intake of excess calcium may cause reduces cardiac activity and leads to cardiac failure which may stop systolic function of heart. However normal level of calcium ions increases the strength of contraction in cardiac muscle (Hays and Swenson, 1985). Human with excess Ca may also risk for the syndrome of hypercalcemia, renal insufficiency with or without alkalosis, kidney stone formation (nephrolithiasis) and absorption of other essential minerals, e.g., Fe, Zn, Mg and P are effected (Strain and Cashman, 2009).

2. **Phosphorus (P):** Phosphorus is known to be an essential constituent of all protoplasm which is uniform across animal tissues and is vitally involved in many metabolic processes (Hays and Swenson, 1985). Commonly phosphorus is occurring in the body of all living organism in its pentavalent form, as phosphate (PO_4^{3-}). Phosphorus is the sixth

most abundant element in human body which comprising about 1.0 – 1.4% of fat - free mass or ~ 12 g (0.4 mol) per Kg in adults. Of this total 85% is in the mineral of teeth and bone and remaining 15% are distributed in soft tissues and blood (Heaney, 2012).

The phosphate regulation is much more critical in fish because of must efficiently absorbed, stored, mobilized and conserved in both freshwater and marine (Strain and Cashman, 2009). Phosphorus plays an important role as a factor for intermediate metabolism, component of genetic materials and in soft tissue as a structural component (Lall, 1995). It also functions as constituents of bone teeth, phosphorylated metabolic, intermediate, nucleic acids and adenosine triphosphate (ATP) (Soetan *et al.,* 2010). Other functional role of phosphorus includes helping to maintain normal pH, the temporary storage and transfer of the energy derived from metabolic fuels by phosphorylation (Strain and Cashman, 2009).

Inadequate phosphorus intake is expressed as hypophosphatemia which effect to various diseases including anemia, paresthesia, anorexia, increased susceptibility to infection, ataxia, rickets and osteomalacia, general debility, bone pain, muscle weakness, confusion, and even death. The expression of hyperphosphatemia is a toxicity symptom due to excess of phosphorus in the body and also the elevation of serum inorganic phosphate in the extracellular fluid (Strain and Cashman, 2009).

3. **Sodium (Na), Potassium (K) and Chlorine (Cl):** The physiological roles of these three elements are closely related and in the body of living organisms they are the most abundant electrolytes. K and Mg are major intracellular cations whereas Na and Cl are major ions of extracellular fluid. They serve as the vital function in controlling acid-base equilibrium and osmotic pressure. The rate of absorption of Na and water by epithelial membrane of gills, gut, kidney and integument controlled the osmotic pressure of the intracellular and extracellular fluid largely through energy-dependent regulation mechanism (Lall, 1995).

Na, K and Cl regulate in acid-base balance, regulation of osmotic pressure of the body fluid, maintain normal irritable of muscle and cell permeability, Na^+/K^+ -ATPase, muscle contraction especially cardiac muscle and conduction of nerve impulse. Moreover, Na help in absorption process of amino acids, monosaccharaides, bile salts and pyrimidine. K is required in glycolysis, help in transfer of phosphate from ATP to pyruvic acid (Soetan *et al.,* 2010). Cl is the major anion of gastric juice and blood, transport of CO_2 and carbonate in the blood by the “chlorine shift” (Lall, 1995).

Na increase in the serum lead to hypernatremia which causes Cushing’s disease, , sex hormone, diabetes insipidus, active sweating and administration of adrenocorticotropic hormone (Malhotra, 1998). Na deficiency cause softening of bones, gonadal inactivity, growth retardation, corneal keratinization, impairment of food utilization and adrenal hypertrophy change in cellular function (Lall, 1995), vomiting, diarrhea, nephrosis severe burns and intestinal obstruction (Malhotra, 1998).

Increase intake of K cause Addison’s disease which lead to shock and dehydration, chronic renal failure, cardiac arrest, small bowel ulcer and dilation of the heart (Soetan *et al.,* 2010). K deficiency occur structural and functional abnormalities including muscular weakness, impaired neuromuscular function of skeleton, smooth and cardiac muscle, paralysis and mental confusion (Murray *et al.,* 2000). Whereas Cl depletion lead to chronic respiratory acidosis, chronic renal disease and renal failure (Strain and Cashman, 2009).

Table 1: Composition of the Macro Element (mg/100g) of some SIFFS

Mg/100g				
Name of the species	**Ca**	**Mg**	**Na**	**K**
*Devario yuensis **	2077.0	112.6	87.5	54.9
*Glossogobius giuris **	2244.0	125.8	84.99	149.8
*Hipsibarbus myitkyinae **	1864.3	67.25	85.0	47.49
*Tariqilabeo burmanicus **	1759.0	96.00	79.56	104.9
*Puntius chola **	1932.8	115.7	102.4	124.9
Pangio pangia ¥	905.0	73.5	45.0	57.5
Lepidochephalichthys guntea ¥	2150.0	131.7	112.5	87.33
Syncrossus berdmorei ¥	680.33	77.0	64.99	90.81
Chanda nama †	955	110	--	750
Gudusia chapra †	1063	120	--	860
Etroplus suratensis †	315.30	--	126.90	296.70
Oreochromis niloticus †	585.20	--	--	--
Esomus denricus †	891	--	--	--
Corica soborna †	476	100	--	520
Amblypharyngodon mola †	853	120	--	630
Puntius sophore †	1171	100	--	860
Channa punctatus †	766	--	--	--
Channa straitus †	82.20	--	44.86	153.80
Puntius sarana †	30.32	--	34.36	121.28
Heteropneutus fossilis †	42.61	--	57.58	247.29
Barbus sps. †	47.96	--	76.98	244.93
Clarius batrachus †	76.52	--	76.52	280.44
Osteobrama cotio †	140	110	--	920
Mystus tengra †	190	110	--	840
Puntius stigma †	120	110	--	650
Chela phulo †	170	130	--	670
Chela bacalia †	160	110	--	880
Chanda ranga †	150	100	--	990
RDA* (31-50 years) (mg/d)	1200	320	1500	2600
TUIL* (31-50 years)(mg/d)	2500	350	ND*	ND*

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RDA: Recommended Daily Allowance; UL: Tolerable Upper Intakes Level, RDA* and TUIL*: Food and Nutrition Board, (1997, 1998, 2000, 2001, 2019),

IV. MICRO MINERALS

1. **Magnesium (Mg):** In fish most of the Mg is found in the bone and remains is found within the cell of soft tissue. Fish red blood cell contains significantly higher level of Mg. Mg ion in freshwater fishes is derived either from dietary sources or by active uptake from the environment (Lall, 1995). In many enzymatic reactions Mg is an essential cofactor of intermediary metabolism. It also plays an important role in the development and maintenance of bone, chromosomal condensation in the regulation of gene activity and enhances condensation of chromatin (Strain and Cashman, 2009). It is also an essential activator for phosphate transferring enzyme viz. diphosphopyridine nucleotide kinase, myokinase and creatine kinase, activate pyruvic acid carboxylase and pyruvic acid oxidase (Soetan *et al.,* 2010).

   Mg depletion result in excessive vomiting and diarrhea. Deficiency of Mg causes various diseases includes malabsorption, vasodilation, increase hyperirritability neuromuscular and may be eventually followed by cardiac arrhythmia and generalized tremors (Soetan *et al.,* 2010). Mg deficiency also causes vertebrae deformity, disintegration of muscle fibers and calcinosis of kidney, and (Lall, 1995), disintegration of muscle fibers, progressive reduction in plasma magnesium and red blood cell magnesium. Excess potassium resulting hypocalcemia may lead to negative abnormal neuromuscular function and potassium balance (Strain and Cashman, 2009).

2. **Iron (Fe):** Iron is an essential nutrient for humans and participates in many metabolic processes as a cofactor, essential for sustaining life including deoxyribonucleic acid (DNA) synthesis, oxygen transport and electron transport (Anderson, et al., 2007). It is found in the body as heme compounds in myoglobin and haemoglobin, heme enzyme such as mitochondrial and microsomal cytochromes catalyze, peroxidase etc., and non heme compound like iron containing flavoprotein, transferrin and ferritin (Lall, 1995). Heme is the major iron containing substance. It is found in haemoglobin, cytochrome, myoglobin and many enzymes associated with iron are cytochrome C reductase, succinate dehydrogenase, cytochrome A, B, C, F_{450}, peroxidases, choline dehydrogenase, xanthine oxidases, glucose 6 phosphate dehydrogenase, catalases and tryptophan pyrrolase (Prashanth *et al.,* 2015).

Transport of oxygen required Fe, a critical for cellular respiration as it is present in haemoglobin but in myoglobin, Fe is needed for the storage of oxygen in the muscles. In many number of enzymes, Fe act as a cofactor involved in synthesis of neurotransmitter and also required for proper myelination of spinal cord and cerebellar folds of white matter in brain (Larkin and Rao, 1990). The redox reaction of Fe takes an essential part in electron transport chain which is responsible for the generation of ATP during oxidation of substances (Strain and Cashman, 2009).

The absorption of iron is inhibiting by profuse diarrhea, malabsorption syndrome, achlorhydria and partial or total gastrectomy (Malhotra, 1998). This inhibition may lead to various iron deficiency disease including anemia, pathophysiology of restless legs syndrome (Tan, et al., 2006), may impact brain functioning like neurotransmitter metabolism, organogenesis and protein synthesis due to alteration of many metabolic processes of Fe (Beard,1999). However, due to excessive accumulation of iron in pancreas a disease haemosiderosis accompanied by bronze pigmentation in the skin, lungs, liver, heart and others tissue is causes (Soetan *et al.,* 2010).

3. **Manganese (Mn):** In tissue of fish and animal, Mn is widely distributed, of which the higher concentration is found in bone, but significant amount is also found in gonadal tissues, muscle, liver, skin and kidney (Lall, 1995). Mn is a co-factor of large numbers of enzymes such as hydrolase, decarboxylase, transferase (Murray *et al.,* 2000) and is the component of mitochondria superoxide dismutase. It is also a part of enzymes involved in pyruvate metabolism, glucotransferase of connective tissue biosynthesis and urea formation. Manganese activate large numbers of enzymes that includes lyases, kinases, oxidoreductases, hydrolases, ligases, transferases and decarboxylases (Nielsen, 2012).

   The deficiency of Mg causes a variety of effects depending on the animal species. Testicular degeneration, slipped tendons or perosis, depressed growth, severe glucose intolerance, seizures, osteodystrophy ataxia and skeleton abnormalities are causes dur to difeciency of Mg (Nielsen, 2012). However, overexposure to Mn may have severe effects on mood and fuction of central nervous system. Toxicity disease by enhalation of Mg poisoning may cause psychotic symptom and parkinsonism (Soetan *et al.,* 2010).

4. **Zinc (Zn), Copper (Cu) and Selenium (Se):** With accumulation of higher than 95% of the body intracellular, zinc become most abundant intracellular trace element (Strain and Cashman, 2009). The main function of the Zn is based on its taking part in integral component of numbers of metalloenzymes and as a catalyst for regulation the activity of specific Zn-dependent enzymes (Lall, 1995). In macronutrient metabolism and cell replication, Zn dependent enzymes are involved. In many enzymes like glutamic dehydrogenase, lactate dehydrogenase, alkaline phosphatase, alcohol dehydrogenase, carbonic anhydrase, carboxypeptidase, DNA and RNA polymerase, retinene reductase and superoxide dismutase Zn act as a cofactor (Hays and Swenson, 1985).

   Severe zinc deficiency in humans is rare however interests are mostly focused on marginal zinc deficiency. The deficiency of Zinc can be the result of chronic alcoholism and malabsorption syndromes (Tuerk and Fazel, 2009). Severe zinc deficiency in humans shows many clinical manifestations that includes dermatitis, alopecia, skeletal and sexual immaturity, growth retardation, loss of appetite, neuropsychiatric disturbances, diarrhea and increased susceptibility to infections (Strain and Cashman, 2009).

In all animal including fish Cu is an essential trace element. Cu is a component of several enzymes such as catalase, amine oxidase, cytochrome c oxidase, uricase, ascorbic acid oxidase, peroxidase, cytochrome oxidase, cytosolic superoxide dismutase, erythrocuprin (ceruloplasmin), lactase, tyrosinase, plasma monoamine oxidase etc. and it plays an important role in absorption of Fe (Chandra, 1990). It is also a component of various cofactor and proteins in the body. It is an essential micro nutrient necessary for the hematological and neurological system (Tan, et al., 2006). Cu is necessary for the regulation of mitochondrial and other gene expression (Strain and Cashman, 2009), supports in the transfer of Fe from tissues to the plasma formation of myelin sheaths in the nervous systems, in the absorption of iron from the gastrointestinal tract (GIT), growth and formation of bone, helps in the incorporation of iron in haemoglobin (Murray *et al.,* 2000).

The deficiency of Cu cause more frequent symptoms such as neutropenia, bone fractures and anaemia, while less frequent symptoms are hypopigmentation, impaired growth, abnormalities of glucose, increased incidence of infections and cholesterol metabolism (Strain and Cashman, 2009). Cu deficiency is also incorporated with cardiac hypertrophy and sudden cardiac failure (Lall, 1995). However, due to excess dietary of Cu a phenomenon of higher accumulation of Cu in the liver with a decrease in blood haemoglobin concentration and packed cell volume. Cu poisoning may adversely affected liver function and cause erythrocyte haemolysis which result to jaundice and this may lead to death unless treatment is started (Merck, 1986).

The biochemical role of Se took part in integral of glutathione peroxidase which act as the defence system that protect the living organism from harmful action of free radical. Organic Se act as a prooxidant provoking oxidative damage and glutathione oxidation to the DNA. It is also a synergistic antioxidant with vitamin E and functions in preventing certain diseases that have associated with vitamin E deficiency. The activities of thioredoxin reductase and selenoenzymes glutathione peroxidase (GSH-Px) is the important metabolic activity of the Se (Soetan *et al.,* 2010).

Se deficiency is associated with a high incidence of retained placenta, resulting in delayed onset of estrus cycle and impaired conception (Hays and Swenson, 1985), illness of white muscles that cause high mortality, myopathy that affect both heart and skeleton muscles, interfere with normal growth, disruption in normal reproduction process, affect ovulation and fertilization (Soetan *et al.,* 2010). It is also been reported that many diseases such as the Keshan's disease, a cardiomyopathyis developed that affects children and women of child-bearing age in China is due to low amounts of selenium in the food chain. Low selenium in the body may influence many deleterious conditions, and most remarkably the increased incidence of virulence or many disease progressions of viral infections (Strain and Cashman, 2009).

Table 2: Composition of the Micro Element (mg/100g) of some Small Indigenous Fishes

Mg/100g				
Name of the Species	**Mn**	**Cu**	**Zn**	**Fe**
Devario yuensis *	0.53	0.16	0.90	25.3
Glossogobius giuris *	0.42	0.31	0.36	11.88
Hipsibarbus myitkyinae *	0.65	0.26	0.29	10.39
Tariqilabeo burmanicus *	0.77	0.35	1.19	8.61
Puntius chola *	1.26	0.24	1.77	17.6
Pangio pangia ¥	0.27	0.29	1.59	20.53
Lepidochephalichthys guntea ¥	1.15	0.47	3.05	13.55
Syncrossus berdmorei ¥	1.26	0.22	1.40	28.61
Chanda nama †	4.24	1.82	2.3	1.8
Gudusia chapra †	4.76	1.97	2.1	7.6
Etroplus suratensis †	--	--	--	1.80
Oreochromis niloticus †	--	--	--	1.50
Esomus denricus †	--	--	2.1	12.0
Corica soborna †	7.01	6.14	2.1	2.8
Amblypharyngodon mola †	4.21	2.67	3.2	5.7
Puntius sophore †	7.39	1.16	3.1	3
Channa punctatus †	--	--	1.5	1.8
Channa straitus †	--	--	--	1.88
Puntius sarana †	--	--	--	2.55
Heteropneutus fossilis †	--	--	--	4.86
Barbus sps. †	--	--	--	0.84
Clarius batrachus †	--	--	--	2.21
Osteobrama cotio †	4.42	2.28	13.6	39.7
Mystus tengra †	5.31	3.20	17	14.5
Puntius stigma †	5.68	3.98	11.3	32.6
Chela phulo †	4.72	1.23	10	30.8
Chela bacalia †	4.32	1.20	12.8	33.2
Chanda ranga †	3.26	1.15	14.6	24.7
RDA (31-50 years) (mg/d)*	1.8	0.9	8	18
UL (31-50 years)(mg/d)*	11.0	10	40	45

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V. OIL SOLUBLE VITAMINS

Vitamin A, D, E and K is fat soluble vitamins since they are soluble in organic solvent and absorbed and transport as a manner similar to that of fat. These fat-soluble vitamins are required in small amount in the diet to promote growth, reproduction, and health. The reviews on the importance of fat-soluble vitamins are discussed. The content of fat soluble composition of some SIFFs of Manipur is shown in table 3.

1. **Vitamin A:** Vitamin A is fat soluble vitamin that is essential for animals and human. Vitamin A comprises a family of methyl substituted cyclohexenyl ring (beta-ionone ring) and a tetraene side chain with a carboxylic acid group (retinoic acid), or ester group (retinyl ester), hydroxyl group (retinol) at carbon- 15 and aldehyde group (retinal). The term vitamin A includes carotenoids, provitamin A that are dietary precursors of retinol (Food and Nutrition Board, 2001). Liver is the riches sources of Vit. A as in the form of Retinyl esters and is the only form of Vit. A found in foods of animal origin. Carotenes are found in yellow, green, red fruits and vegetables as well as in liver, milk products and margarine (David, 2009).

   In the retina, retinyl esters are converted to 11-cis-retinol and then oxidized to 11-cis-retinal which binds with the protein opsin, forming rhodopsin (in rods) and iodopsin (in cones) which is responsible for the dim-light vision (Barua, et al., 2011). 11-cis-retinal is isomerized to all-trans-retinal when rhodopsin is exposed to a photon of light which triggers the signalling to neuronal cells associated with the brain's visual cortex (David, 2009). The integrity of epithelial cells throughout the body required Vitamin A. Moreover, the development of the heart, limbs, ears and eyes is also help by Retinoic acid (Dickman and Smith, 1996) and maintaining of adequate level in circulating natural killer cells that have antiviral and anti-tumor activity (Zhao and Ross, 1995). Carotenoids have potentially useful antioxidant action and help in lowering the incidence of cardiovascular disease and cancer. Moreover rate of growth, development and tissue differentiation is also regulated by 9-cis-retinoic acid and all-trans-retinoic acid (David, 2009).

   Deficiency of vitamin A is lead to poor growth and vision, haemorrhage in anterior chamber of eye, night blindness, keratinization of epithelial tissue, abnormal bone formation, nerve degeneration (John, 2013). Regular and prolong intake of more than about 7.5–9 mg/day by adults causes signs and symptoms of toxicity affecting the liver: hyperlipidemia, hepatomegaly with histological change in the liver and increased collagen formation; central nervous system: anorexia, nausea, headache and ataxia which is associated with increased cerebrospinal fluid pressure; the skin: scaling, desquamation, excessive dryness, alopecia and chapping of the skin; bones: calcification of soft tissues, joint pains, hypercalcemia and thickening of the long bones (David, 2009).

2. **Vitamin D:** In higher animals, Vitamin D is essential for life and it is also the most important biological regulators of calcium homeostasis. Several form of vitamin D occurs in the form of D_2 or ergocalciferol and D_3 or activated 7-dehydrocholesterol (John, 2013). 1, 25-dihydroxyvitamin D_3 is an active form of vitamin D (Ali and Ronda, 2016). Vitamin D is produced photo-chemically in the epidermis of higher animals from the pro-vitamin D by the action of sunlight or artificial ultraviolet light (Anthony and Helen, 2009). The main sources of vitamin D are fish oil, liver, eggs and butter. In some country the modest amounts of Vitamin D is available as fortified milk containing ergocalciferol (David, 2009).

Calcitriol influences the action of parathyroid hormone on bone, promotes intestinal absorption of calcium and homeostatic of calcium and phosphate are the principle function of Vitaamin D (John, 2013), mobilization of bone mineral. Low-grade chronic inflammation associated with obesity of especially abdominal, insulin resistance and non-insulin dependent diabetes mellitus and impaired glucose tolerance is associated with low Vitamin D level in the body (David, 2009). The deficiency of vitamin D lead to the bone disease termed rickets in children or osteomalacia in adults (Anthony and Helen, 2009).

Table 3: Oil Soluble Vitamins of SIFFs in *µg/100g*

	µg/100g			
Species	**Vitamin A***	**Vitamin D_3***	**Vitamin E***	**Vitamin K**
D. yuensis	16.78±0.19^{f}	5.29±0.16^{b}	0.24±0.04^{a}	7.33±0.11^{b}
G. giuris	13.12±0.28^{b}	6.32±0.10^{c}	1.65±0.11^{e}	12.76±0.19^{g}
H. myitkyinae	7.26±0.17^{a}	3.70±0.12^{a}	1.67±0.07^{e}	7.31±0.21^{b}
L. guntea	15.78±0.38^{e}	6.13±0.38^{c}	0.50±0.59^{b}	12.19±0.19^{f}
P. chola	13.80±0.16^{c}	7.59±0.24^{d}	0.51±0.07^{b}	7.63±0.08^{c}
P. pangia	18.50±0.27^{g}	5.97±0.18^{bc}	1.26±0.09^{d}	6.94±0.16^{a}
S. berdmorei	14.70±0.17^{d}	3.48±0.22^{a}	0.50±0.04^{b}	10.10±0.10^{e}
T. burmanichus	13.77±0.19^{c}	12.89±0.16^{e}	0.84±0.07^{c}	8.30±0.03^{d}

Values are mean of three replicates.
Mean (±SD) followed the same small letter are not significantly different ($P \leq 0.05$)
*(Food and Drugs administration {FDA}):1 IU Vitamin A = 0.3 µg retinol (1 µgRAE = 1 µg retinol); 1 IU Vitamin D = 0.67 mg d–alpha–tocopherol; 1 IU Vitamin E = 0.025 µg

3. **Vitamin E:** Vitamin E is the collective term given to a group of fat-soluble compounds which is known as tocopherols and are derivatives of tocol (John, 2013) and are generic descriptor for two families of compounds, the tocopherols and the tocotrienols (David, 2009). Vitamin E is present in fat containing food and as they have fat soluble property, they were store within the fat tissue in the animals and human (Saliha *et al.,* 2014).

As many as eight naturally occurring forms of vitamin E viz. the alpha, beta, gamma and delta classes oftocotrienol and tocopherol which are synthesized by plants from homogentisic acid (Saliha, et al., 2014). In the serum and the red blood cells, the alpha- and gamma-tocopherols are found with alpha-tocopherol present in the highest concentration (Chow, 1975) and are most active of all the tocopherol (David, 2009). Beta- and delta- tocopherols are found in plasma in minute concentration. The rich sources of Vitamin E are Vegetable oils however significant amounts are also found in a variety of fish, most green leafy vegetables, nuts and seeds (David, 2009).

Vitamin E is the potent antioxidant in the cell membrane and plasma lipoprotein that inhibits the production of reactive oxygen molecules (Burton *et al.,* 1983). The inhibitions of newly form free radicals are mainly controlled by Alpha-tocopherol, while trapping and neutralizing the existing free radicals are done by gamma-tocopherol (Saliha *et al.,* 2014). Along with selenium and ascorbic acid in the enzyme glutathione peroxidase and superoxide dismutase the Vitamin E functions stop the chain reaction of polyunsaturated fatty acid peroxidation (David, 2009). Vitamin E is necessary for maintaining proper skeletal muscle homeostasis and promotes plasma membrane repair (Szczeklik *et al.,* 1985).

Many conditions including affected of nervous system, that include the development of necrosis in central nervous system and axonal dystrophy, affected of skeletal and cardiac muscle, atrophy and degeneration of the germinal epithelium of the seminiferous tubules, affected of integrity of blood vessel walls with leakage of blood plasma, necrotizing myopathy and muscular dystrophy is resulted due to deficiencies of Vitamin E (David, 2009).

4. **Vitamin K:** The word vitamin K was derived from Danish word coagulation (koagulation) by Dam, in 1935. Vitamin Phylloquinone (K_1) in plant source and menaquinones (K_2) produced by bacterial flora in animals are two naturally occurring forms of the vitamin which had been isolated from alfalfa and putrefied fish meal respectively (Suttie, 2009). Phylloquinone (K_1), menaquinones (K_2) and menadiol are the three compounds of vitamin K which have biological activity (David, 2009). The excellent source of vitamin K includes green leafy vegetable such as broccoli, Brussels sprouts, cauliflower, lettuce and spinach. Alfalfa leaves are one of best sources (John, 2013). Liver and fish meal are also good animal sources of the vitamin K (McDowell, 2000).

The major function of the vitamin K is to maintain normal blood-clotting rate. The vitamin is required for the synthesis of the active form of many plasma clotting factors viz. factor- II, -VII, -IX, and -X (McDowell, 2000). It also acts as cofactor for the carboxylation of glutamate residues in the post synthetic modification of proteins to form the unusual amino acid γ- carboxyglutamate (David, 2009). It may involve in coenzyme Q-type compounds which function between flavoprotein and cytochromes in electron transport mechanism (David, 2009). Vitamin K lower the risk of bone fracture, positively associated with risk factors for atherosclerosis, associated with lower levels of the tumor necrosis factor receptor 2, lowering of proinflammatory markers IL-6, C-reactive protein and intracellular adhesion molecule-1 (Ferland, 2009), menaquinones is associated with reduced risk of cancer and mortality (Nimptsch *et al.,* 2008)

Clinically deficiency of vitamin K is associated with an increase in internal hemorrhage and anemia, lowering blood-clotting due to blood loss, gastrointestinal disorders associated with fat malabsorption including cystic fibrosis and liver disease, bile-duct obstruction, inflammatory bowel disease, chronic pancreatitis, , suppression of menaquinone synthesizing organisms in the gut, risk of bleeding in infants in the first weeks of life, increased risk of leukemia and many forms of cancer in children (Ferland, 2009).

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