**Small indigenous freshwater fishes: A good sources of micro nutrients in human health**

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**Abstract**

This chapter highlights the various importance of macro and micro elements and fat 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. SIFFS contribute high quality of animal protein for human nutrition proportional to muscles biomass like Indian Major Carps (IMCs), large catfish and other food fishes. 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. They are consumed in small qualities but these small fishes are consumed as a whole which are particularly rich in micronutrients such as iron, zinc and their bone are excellent sources of calcium. Most fish species are consumed but small fishes are generally being less preferred than larger fish species however these small fishes are consumed as a whole which are particularly rich in micronutrients. Thus, the SIFFs can consider as an important sources micronutrients and good food for monitoring many micro nutrients deficiencies, so consumption of Small Indigenous Fishes should be encouraged.

1. **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 fishare 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. Out of 765 fish species, about 450 species are classified as SIFFs. North East India owing to its topographical features 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.

Small Indigenous Fishes are those fishes which grow to a maximum size of 25 cm or 9.8 inches in the mature or adult stage in their life cycle (Felts *et al.,* 1996). However, many SIS are less than 10 cm or 3.9 inches in length and they are consumed as a whole. These fishes have a short life cycle and they are prolific breeder that needs little or no management and growth in backyard pond, derelict water bodies, beels, wetland and in all such places.

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. Aquaculture of Indigenous Mekong Species (AIMS), a four-country network, aims to develop nine small indigenous species for aquaculture. Kohinoor *et al.,* 2005 have reported that stocking *Puntius sps.* in the polyculture of carps could increase the fish production. The growth of rohu, catla and mrigal was only slightly affected by the presence of *Puntius sps.* but the overall production was not affected. The study also revealed that the small and shallow water bodies may generously be used for SIFFs culture and indicates the feasibility of attaining a good production along with Indian major carps.

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.

It is well accepted throughout the world that fish are the good source of protein and other important mineral elements for the maintenance of healthy body (Andrew, 2001). The nutritional value of fish comprises of moisture, protein, lipid, vitamins, minerals and caloric value of the fish (Steffen, 2006). Fish meat contains essential amino acid as well as having high energy depot in the form of lipid and contains the high amount of polyunsaturated fatty acid which prevents a number of coronary heart diseases (Palani *et al.,* 2014). Besides, fish meat is also a rich source of minerals and the most abundant micro-elements are zinc, Iron and copper (Saadattin *et al.,* 1999). The human body usually contains a small number of minerals and the deficiency of these principal nutritional elements indices a lot of malfunction and causes various diseases such as the inability of the blood clot, osteoporosis, anaemia, etc (Mill, 1980).

Fish can be considered “the poor man’s food” (Kent, 1997) and for large population groups, fish is an irreplaceable animal food source. Most fish species are consumed but small fishes are generally being less preferred than larger fish species and therefore having less market value, this means that small fish species are more accessible to poor particularly in the season of high production (Roos *et al.,* 2007). However, these small fishes have high market value as well as highly esteemed among the people of Manipur. Moreover, micronutrient deficiency, sometimes termed “hidden hunger” since it is difficult to see, and is a big problem in south and Southeast Asia. About 250 million children worldwide are at risk of vitamin A deficiency, and an equal number are at risk of deficiencies of other minerals like iron, zinc and calcium (Sakuntala, 2010). Small fishes are important sources of micronutrients and play an important role to provide essential nutrients. They are consumed in small qualities but these small fishes are consumed as a whole which are particularly rich in micronutrients such as iron, zinc and their bone are excellent sources of calcium (Roos *et al.,* 2006).

Small Indigenous Fishes are consuming as a whole which provide an excellent source of micronutrients. Whole small fish with bones are an extremely Ca rich food (Lersen *et.al.,* 2000) and in some species, vitamin A is richly accumulated around their eyes and viscera (Roos, et.al., 2002). Many of the elements are taking part in various metabolic processes and are known to be indispensible to all living things. Among the elements the most important mineral elements are Ca, Na, P, Fe, K, Cl and many are also needed in trace amount. The deficiency of these important nutritional minerals induces many malfunction as it reduce productivity and causes diseases such as inability of blood clot, osteoporosis, anaemia, etc. Roos *et al*., 2007 have reported that vitamin A, calcium, iron and zinc are abundantly present in commonly consumed small fishes of Bangladesh*.* In Bangladesh small fishes play a pivotal role as rich sources of vitamin A and to combat vitamin A deficiency among the children (Thilsted *et al.,* 1997). In addition to the nutritional values, it is crucial to say that Small Indigenous Fishes plays a vital role in life and economy of vast majority of the fisherman community and poor rural. In addition to the nutritional values, it is crucial to say that Small Indigenous Fishes also plays a vital role in the life and economy of the vast majority of the fisherman community and poor rural people.

1. **Significance of micro nutrients in human health**
	1. **Mineral**

Minerals are inorganic substances, present in all body tissues and fluids and their present is necessary for the maintenance of physicochemical processes which are essential in life (Soetan *et al.,* 2010). Minerals does not yield energy although they have important role to play 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 these principal nutritional elements indices a lot of malfunction and causes various diseases such as the inability of the blood clot, osteoporosis, anemia, etc. (Mill, 1980).

 Out of 90 naturally occurring elements, 29 are known to be essential for animal life and greater proportion of living matter consist of six basic elements such as carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur (Lall, 1995). Depending upon the quality, mineral can be classified as macro (major), micro (trace) 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). The macro-minerals include calcium, phosphorus, sodium and chloride, while the micro-elements include iron, copper, cobalt, potassium, magnesium, iodine, zinc, manganese, molybdenum, fluoride, chromium, selenium and sulfur (Eruvbetine, 2003). The ultra-trace elements include boron, silicon, arsenic and nickel which have been found in animals and are believed to be essential for these animals.

 The minerals elements are separately entitled from the others essential nutrients like proteins, fats, carbohydrates, and vitamins. However, mineral needed by the various animals in their diets are demonstrated (Hegsted *et al.,* 1976). The significance and importance of mineral elements for animals and human nutrition and detection of trace elements as essential nutrients is still the active areas of research (Soetan *et al.,* 2010). Fifteen trace elements are considered to be essentials to animals (Lall, 1995) and these deficiencies are 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 cognitive performance, lowered work capacity, lowered immunity to infections, pregnancy complications such as babies with low birth weight, poor learning capacity and reduced psychomotor skills (Batra and Seth, 2002).

 Fish are importance source of minerals elements since unlike other animals, fish have the ability to absorbed some 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 food source, environment, species, stage of development and physiological status (Lall, 1995). 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.

Moreover, different concentration of minerals were detected and the concentrations of macro and micro elements are in decreasing order as follows; Ca>K>Mg>Na and Fe>Zn>Mn>Cu respectively. Bhouri *et al.,* (2010) reported in decreasing order of K>Na> Mg>Ca>Zn>Fe>Mn>Cu in the muscle of wild Sea bass. Hei and Sarojnalini (2012) in smoke dried Hill Stream Fishes of Manipur observed the concentration of macro and micro elements in the order of K>P>Mg>Na>Ca> and Fe>Co>Cu>Zn>Ni>Mn>Cr respectively. The composition of macro and micro mineral of some SIFFs reported by shantosh and sarojnalini (2018a, 2018b) and Mohanty, et al., 2011 are shown in table 1 and 2 respectively.

 Many researchers did not observe any definite order in magnitude of the elements. This variation in concentration of elements is due to the chemical forms of the elements and their concentration in the local environment (Window *et al.,* 1987). Moreover, the concentration of minerals in the body of an aquatic organism depends on the food source, environment species and stage of development and physiological status of the organism. Most of the trace element are shown higher concentration in first trophic level (Phytoplankton) but Cd, Cu and Zn have higher concentration if zooplankton. Fish feeding on planktons have higher concentration of Cu and Zn than fish feeding on invertebrates and small fish (Lall, 1995).

Therefore, the consumption of fish involves exposure to some metals that may have a negative impact on human health (Uluozlu *et al.,* 2007). Significance of various essential mineral elements in human health is reviewed.

* + 1. **Macro minerals**
			1. ***Calcium (Ca)***

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

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

Despite the importance of Ca in bone formation and maintenance of skeletal tissue, it is also help in maintenance of other functions such as muscles contraction, blood clot formation, nerve transmission, cell membrane integrity and activation of several important enzymes such as adenosine triphosphatase (ATPase), succinic dehydrogenase, lipase etc. (Lall, 1995). It is also required for membrane permeability, involved in muscle contraction, normal transmission of nerve impulses and in neuromuscular excitability.

The toxicity symptom occurs when high intake of Ca from the diet or excess absorption due to hypervitaminosis D or hypercalcemia due to hyperparathyroidism, or idiopathic hypercalcemia (Soetan *et al.,* 2010). Excess calcium depresses cardiac activity and leads to respiratory and cardiac failure; it may cause the heart to stop in systole, although, normally, calcium ions increase the strength and duration of cardiac muscle contraction (Hays and Swenson, 1985). Human with excess Ca may also risk for kidney stone formation (nephrolithiasis), the syndrome of hypercalcemia and renal insufficiency, with or without alkalosis (referred to historically as milk alkali syndrome associated with peptic ulcer treatments) and the effect on absorption of other essential minerals, e.g., iron, zinc, magnesium and phosphorus (Strain and Cashman, 2009).

* + - 1. ***Phosphorus (P)***

Phosphorus is an essential constituent of all known protoplasm which is uniform across animal tissues and is vitally concerned with many metabolic processes, including those involving the buffers in body fluids (Hays and Swenson, 1985). Commonly phosphorus is occurring in the body of all living organism in its pentavalent form, as phosphate (PO43-). Phosphorus is the sixth most abundant element in the human body, comprising in adults about 1.0 – 1.4% of fat - free mass or ∼ 12 g (0.4 mol) per kilogram. Of this total 85% is in the mineral of bones and teeth, with 15% distributed through the blood and soft tissues (Heaney, 2012).

 The regulation of phosphate is much more critical in fish because of must effectively absorbed, stored, mobilized and conserved in both freshwater and marine (Strain and Cashman, 2009). The fish belonging to Pleuronectidae family exceeds 100mg/100g in phosphorus content (De Clercq, 1932). In the study of Chilean fishes, Thyrsites aiun phosphorus has the higher amount (Schimidt-Hebbel, 1950).

 Phosphorus plays an important role in soft tissue as a structural component, a factor for intermediate metabolism and component of genetic materials (Lall, 1995). It also functions as constituents of bone teeth, adenosine triphosphate (ATP), phosphorylated metabolic, intermediate and nucleic acids (Soetan *et al.,* 2010). Other functional role of phosphorus includes buffering of acid or alkali excesses, hence helping to maintain normal pH, the temporary storage and transfer of the energy derived from metabolic fuels by phosphorylation, and hence activation of many catalytic proteins (Strain and Cashman, 2009).

Inadequate phosphorus intake is expressed as hypophosphatemia which effect to various diseases including anorexia, anemia, muscle weakness, bone pain, rickets and osteomalacia, general debility, increased susceptibility to infection, paresthesia, ataxia, confusion, and even death. Toxicity symptom of excess phosphorus in the body is expressed as hyperphosphatemia and the adverse effect of excess phosphorus are owing to elevation of serum inorganic phosphate in the extracellular fluid (Strain and Cashman, 2009), low serum Ca2+-P ratio and bone loss (Murray *et al.,* 2000).

* + - 1. ***Sodium (Na), Potassium (K) and Chlorine (Cl)***

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

 Na, K and Cl regulate in plasma volume and acid-base balance, regulation of osmotic pressure of the body fluid, maintain normal irritable of muscle and cell permeability, muscle contraction especially cardiac muscle, conduction of nerve impulse and Na+/K+ -ATPase. Moreover, Na help in absorption process of monosaccharides, amino acids, pyrimidine and bile salts. 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 carbon Dioxide and carbonate in the blood by the “chlorine shift” (Lall, 1995).

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

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

*\**Shantosh Mayanglambam and Sarojnalini Chungkham (2018) Macro and trace mineral elements of five small indigenous fishes of Manipur, India. *Journal of Fisheries and Life Sciences.* 4(1):1-8.

*¥*Shantosh Mayanglambam and Sarojnalini Chungkham (2018) Nutritional Quality of Three Cobitid Fishes of Manipur, India: With Special Reference to Essential Mineral Elements. *International Journal of Scientific Research in Biological Sciences.* 5(2), Pp. 24-33.

*†*Bogard, J.R., Thilsted, S.H., Marksa, G.C., Wahab, M.A., Hossain, M.A.R., Jakobsen, J., Stangoulise, J. (2015) Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. *Journal of* *Food Composition and Analysis*.42:120-133.

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

* + 1. **Micro minerals**
			1. ***Magnesium (Mg)***

In fish most of the Mg is located in the bone and the remainder is found within the cell of soft tissue. Fish red blood cell contains significantly higher level of Mg. Freshwater fish derive Mg ion either by active uptake from the environment or from dietary sources (Lall, 1995). Mg is the essential cofactor in many enzymatic reactions in intermediary metabolism. It also plays an important role in the development and maintenance of bone, enhance the condensation of chromatin, and given the role of chromosomal condensation in the regulation of gene activity (Strain and Cashman, 2009). It is also an essential activator for phosphate transferring enzyme myokinase, diphosphopyridine nucleotide kinase 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 calcinosis of kidney, vertebrae deformity and disintegration of muscle fibers (Lall, 1995), progressive reduction in plasma magnesium and red blood cell magnesium, hypocalcemia and hypocalciuria. Hypocalcemia resulting from excess potassium excretion leading to negative potassium balance and abnormal neuromuscular function (Strain and Cashman, 2009).

* + - 1. ***Iron (Fe)***

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

 Iron is required for the transport of oxygen, 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. It is also a component of various tissue enzymes, such as cytochromes that are critical for energy production and immune system functioning. 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).

Iron is also required for proper myelination of spinal cord and white matter of cerebellar folds in brain and is a cofactor for a number of enzymes involved in neurotransmitter synthesis (Larkin and Rao, 1990). Iron is involved in synthesis and packaging of neurotransmitters, their uptake and degradation into other iron-containing proteins which may directly or indirectly alter brain function (Beard, 2001).

The absorption of the 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), alteration of many metabolic processes that may impact brain functioning like neurotransmitter metabolism, protein synthesis, organogenesis (Beard,1999). However excessive accumulation of iron in liver, pancreas, heart, lungs and others tissue causes hemosiderosis accompanied by bronze pigmentation in the skin (Soetan *et al.,* 2010).

* + - 1. ***Manganese (Mn)***

Mn is widely distributed in fish and animal tissue of which the higher concentration is found in bone, however significant amount is also present in liver, muscle, kidney, gonadal tissues and skin (Lall, 1995), depressed reproductive function, and defects in lipid and carbohydrate metabolism (Strain and Cashman, 2009). 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 urea formation, pyruvate metabolism and glucotransferase of connective tissue biosynthesis. Large numbers of enzymes are activated by manganese that include oxidoreductases, lyases, ligases, hydrolases, kinases, decarboxylases, and transferases (Nielsen, 2012).

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

* + - 1. ***Zinc (Zn), Copper (Cu) and Selenium (Se)***

Zinc is the most abundant intracellular trace element, with >95% of the body intracellular (Strain and Cashman, 2009). The essential function of the Zn is based on its role as an integral constituent of numbers of metalloenzymes and as a catalyst for regulation the activity of specific Zn-dependent enzymes (Lall, 1995). It functions as a cofactor and is a constituent of many enzymes like lactate dehydrogenase, alcohol dehydrogenase, glutamic dehydrogenase, alkaline phosphatase, carbonic anhydrase, carboxypeptidase, superoxide dismutase, retinene reductase, DNA and RNA polymerase. Zn dependent enzymes are involved in macronutrient metabolism and cell replication (Hays and Swenson, 1985).

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

Cu is an essential trace element for all animals including fish. Cu is a constituent of several enzymes such as cytochrome c oxidase, amine oxidase, catalase, peroxidase, ascorbic acid oxidase, cytochrome oxidase, plasma monoamine oxidase, erythrocuprin (ceruloplasmin), lactase, uricase, tyrosinase, cytosolic superoxide dismutase etc. and it plays a role in iron absorption (Chandra, 1990). It is the component of cofactor and proteins in the body. It is an essential micro nutrients 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), growth and formation of bone, formation of myelin sheaths in the nervous systems, helps in the incorporation of iron in hemoglobin, assists in the absorption of iron from the gastrointestinal tract (GIT), in the transfer of iron from tissues to the plasma (Murray *et al.,* 2000).

 The most frequent symptoms of copper deficiency are anemia, neutropenia, and bone fractures, while less frequent symptoms are hypopigmentation, impaired growth, increased incidence of infections, and abnormalities of glucose and cholesterol metabolism and of electrocardiograms (Strain and Cashman, 2009). Cu deficiency is also incorporated with cardiac hypertrophy and sudden cardiac failure (Lall, 1995). However, excess dietary Cu causes an accumulation of Cu in the liver with a decrease in blood hemoglobin concentration and packed cell volume. Liver function is adversely affected in copper poisoning. Jaundice results from erythrocyte hemolysis and this may lead to death unless treatment is started. In animals, sheep are more susceptible than cattle to the toxic effects of copper (Merck, 1986).

The biochemical role of Selenium puzzled workers until the discovery that Selenium is an integral part of glutathione peroxidase which is the defense system that protect the living organism from harmful action of free radical. Organic Selenium act as a prooxidant provoking glutathione oxidation and oxidative damage 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 important metabolic action of the Se is manifested in the activities of selenoenzymes glutathione peroxidase (GSH-Px) and thioredoxin reductase (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). Keshan’s disease, a cardiomyopathy that affects children and women of child-bearing age in China is also been reported due to low amounts of selenium in the food chain. Low selenium status may predispose to other deleterious conditions, most notably the increased incidence, virulence, or disease progression of a number 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 |

*\**Shantosh Mayanglambam and Sarojnalini Chungkham (2018) Macro and trace mineral elements of five small indigenous fishes of Manipur, India. *Journal of Fisheries and Life Sciences.* 4(1):1-8.

*¥*Shantosh Mayanglambam and Sarojnalini Chungkham (2018) Nutritional Quality of Three Cobitid Fishes of Manipur, India: With Special Reference to Essential Mineral Elements. *International Journal of Scientific Research in Biological Sciences.* 5(2), Pp. 24-33.

*†*Bogard, J.R., Thilsted, S.H., Marksa, G.C., Wahab, M.A., Hossain, M.A.R., Jakobsen, J., Stangoulise, J. (2015) Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes. *Journal of* *Food Composition and Analysis*.42:120-133.

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

* 1. **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 are 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 hydroxyl group (retinol), aldehyde group (retinal), carboxylic acid group (retinoic acid), or ester group (retinyl ester) at carbon- 15. The term vitamin A includes provitamin A, carotenoids that are dietary precursors of retinol (Food and Nutrition Board, 2001). Vitamin A mainly as retinyl esters is found only in foods of animal origin with a richest source is liver. Carotenes are found in green, yellow, and red fruits and vegetables, as well as in liver, margarine, and milk and milk products (David, 2009).

In the retina, retinyl esters are converted to 11-cis-retinol, 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). When rhodopsin is exposed to a photon of light, 11-cis-retinal is isomerized to all-trans-retinal which triggers the signaling to neuronal cells associated with the brain’s visual cortex (David, 2009). Vitamin A is required for the integrity of epithelial cells throughout the body. Retinoic acid is also involved in the development of the limbs, heart, eyes, and ears (Dickman and Smith, 1996). Retinoic acid is important in maintaining an adequate level of circulating natural killer cells that have antiviral and anti-tumor activity (Zhao and Ross, 1995). Carotenoids have potentially useful antioxidant action and are associated with a lower incidence of cancer and cardiovascular disease. All-trans-retinoic acid and 9-cis-retinoic acid are active in the regulation of growth, development, and tissue differentiation (David, 2009).

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

* + 1. **Vitamin D**

Vitamin D is essential for life in higher animals which has been shown to be one of the most important biological regulators of calcium homeostasis. Several form of vitamin D occur in the form of D2 or ergocalciferol and D3 or activated 7-dehydrocholesterol (John, 2013). The active form of vitamin D is 1, 25-dihydroxyvitamin D3 (Ali and Ronda, 2016). Vitamin D is produced photochemically in the epidermis of higher animals from the provitamin D (7-dehydrocholesterol) by the action of sunlight or artificial ultraviolet light (Anthony and Helen, 2009). The main source of vitamin D are mainly oily fish, with eggs, liver, and butter providing modest amounts, fortified milk, containing ergocalciferol, is available in some countries (David, 2009).

The principle function of the vitamin D is to maintain the plasma concentration of calcium, calcitriol (David, 2009), homeostatic of calcium and phosphate, promotes intestinal absorption of calcium and influences the action of parathyroid hormone on bone (John, 2013), mobilization of bone mineral. Low vitamin D status is associated with impaired glucose tolerance, insulin resistance and non-insulin dependent diabetes mellitus, as well as obesity and the low-grade chronic inflammation associated with (especially abdominal) obesity (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 D3\*** | **Vitamin E\*** | **Vitamin K** |
| ***D. yuensis*** | 16.78±0.19f | 5.29±0.16b | 0.24±0.04a | 7.33±0.11b |
| ***G. giuris*** | 13.12±0.28b | 6.32±0.10c | 1.65±0.11e | 12.76±0.19g |
| ***H. myitkyinae*** | 7.26±0.17a | 3.70±0.12a | 1.67±0.07e | 7.31±0.21b |
| ***L. guntea*** | 15.78±0.38e | 6.13±0.38c | 0.50±0.59b | 12.19±0.19f |
| ***P. chola*** | 13.80±0.16c | 7.59±0.24d | 0.51±0.07b | 7.63±0.08c |
| ***P. pangia*** | 18.50±0.27g | 5.97±0.18bc | 1.26±0.09d | 6.94±0.16a |
| ***S. berdmorei*** | 14.70±0.17d | 3.48±0.22a | 0.50±0.04b | 10.10±0.10e |
| ***T. burmanichus*** | 13.77±0.19c | 12.89±0.16e | 0.84±0.07c | 8.30±0.03d |

Values are mean of three replicates.

Mean (±SD) followed the same small letter are not significantly different (P≤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

* + 1. **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).

There are eight naturally occurring forms of vitamin E; namely, the alpha, beta, gamma and delta classes of tocopherol and tocotrienol, which are synthesized by plants from homogentisic acid (Saliha, et al., 2014). Among the tocopherols, the alpha- and gamma-tocopherols are found in the serum and the red blood cells, 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. Vegetable oils are rich sources of vitamin E, but significant amounts are also found in nuts and seeds, most green leafy vegetables, and a variety of fish (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). Alpha-tocopherol mainly inhibits the production of new free radicals, while gamma-tocopherol traps and neutralizes the existing free radicals (Saliha *et al.,* 2014). Vitamin E functions together with selenium and ascorbic acid in the enzyme glutathione peroxidase and superoxide dismutase to 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).

Vitamin E deficiency results in the numbers of different conditions including testicular atrophy and degeneration of the germinal epithelium of the seminiferous tubules, skeletal and cardiac muscle are affected, necrotizing myopathy, muscular dystrophy, integrity of blood vessel walls is affected, with leakage of blood plasma, nervous system is affected, with the development of central nervous system necrosis and axonal dystrophy (David, 2009).

* + 1. **Vitamin K**

The word vitamin K was derived from Danish word coagulation (koagulation) by Dam, in 1935. Two naturally occurring forms of the vitamin – vitamin Phylloquinone (K1) in plant source and menaquinones (K2) produced by bacterial flora in animals – had been isolated from alfalfa and putrefied fish meal, respectively (Suttie, 2009). Phylloquinone (K1), menaquinones (K2) and menadiol are the three compounds of vitamin K which have biological activity (David, 2009). Green leafy vegetable such as cauliflower, broccoli, spinach, lettuce, and Brussels, sprouts are excellent sources of vitamin K. 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 a first normal blood-clotting rate. The vitamin is required for the synthesis of the active form of prothrombin (factor II) and other plasma clotting factors-VII, IX, and X (McDowell, 2000). It is the 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 proinflammatory markers IL-6, intracellular adhesion molecule-1, tumor necrosis factor receptor 2, and C-reactive protein (Ferland, 2009), menaquinones is associated with reduced risk of cancer and mortality (Nimptsch *et al.,* 2008)

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

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