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

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**Abstract**

This chapter highlights the various importances 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. 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. Most small fishes are generally being less preferred than larger fish species however due to consumption of small fishes as a whole rich amount of micronutrients such as iron, zinc 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.

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 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. 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.

Small Indigenous Fish have shirt life cycle, highly prolific breeder and 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. 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 polyculture stocking with *Puntius sps.* It is also revealed that the small and shallow water bodies may generously be used for SIFFs culture and feasibility for 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.

Aquatic animal foods have a higher protein content than the terrestrial meat and in in addition aquatic protein in higher digestible and rich in several peptides and essential amino acids that are limited in terrestrial meat product (Sarvenaz and Sabine, 2018). Despite fish as a good sources of protein , fish are also 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).

In addition to protein and fatty acid, fish is known to be one of the major sources of oil soluble vitamins in human diet. They 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 around the eyes and viscera 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. Moreover, (Roos *et al.,* 2007). In bangladesh these small fishes which are highly accumulated with Vit. A, Ca, Fe and Zn are commonly consumed and play a pivotal role as a rich sources of Vit. A and to combat Vit. A deficiency among children. 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.

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).

 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). Calcium, sodium, phosphorus and chloride are included in macro minerals while potassium, iron, manganese, cobalt, magnesium, fluoride, copper, iodine, molybdenum, zinc, chromium, selenium and sulphur are included in micro minerals (Eruvbetine, 2003). The ultra-trace elements which are found in animal and are essential for animals include arsenic, boron, nickel, and silicon.

 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 detection of trace elements as essential nutrients and significance of mineral elements for human nutrition 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 work capacity, cognitive performance, lowered immunity to infections, pregnancy complications such as babies with low birth weight, reduced psychomotor skills and poor learning capacity (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, stage of development, environment, physiological status and species (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.

 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).

1. **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 is the scale of the fish and the exchange rate of Ca is three times higher in fish scale than in bone (Berg, 1968). The Ca absorbed is mostly deposited in bone and skin of the fish. The deposition pattern, retention by the skeleton and rate of uptake are independent of bone types and appear to be similar in freshwater and marine species (Lall, 1995).

Calcium is required for normal growth and development of the skeleton. During the skeleton growth and maturation until early twenties in human the average Ca accumulation is 150 mg/day. The Ca equilibrium become imbalance and loss of Ca from skeleton after 50 years in men and the menopause in women, this loss is associated with rise in fracture. Thus, to achieve optimal peak 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, cell membrane integrity, nerve transmission and activation of several important enzymes such as adenosine succinic dehydrogenase, triphosphatase (ATPase), lipase etc. are also mentained by Ca other than bone formation and maintenance of skeletal tissue (Lall, 1995). It is also required for membrane permeability, involved in muscle contraction, normal transmission of nerve impulses and in neuromuscular excitability.

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 symptom (Soetan *et al.,* 2010). Excess intake of 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 cardiac muscle contraction (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).

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

Phosphorus is an essential constituent of all known protoplasm which is uniform across animal tissues and is vitally involved in 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-). In human body phosphorus is the sixth most abundant element, comprising about 1.0 – 1.4% of fat - free mass or ∼ 12 g (0.4 mol) per kilogram in adults. 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 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 the adverse effect of excess phosphorus are owing to elevation of serum inorganic phosphate in the extracellular fluid (Strain and Cashman, 2009).

* + - 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. 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 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 CO2 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 functional and structural abnormalities including muscular weakness, impaired neuromuscular function of skeleton, smooth and cardiac muscle, mental confusion and paralysis (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\* |

*\**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.

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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),

* + 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. Mg ion in freshwater fishes are derived either by active uptake from the environment or from dietary sources (Lall, 1995). Mg is the essential cofactor in many enzymatic reactions 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 enhance 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, also 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).

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

Iron is an essential nutrient for humans and participates as a cofactor in many metabolic processes essential for sustaining life including electron transport, deoxyribonucleic acid (DNA) synthesis and oxygen 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 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).

 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 act as a cofactor for number of enzymes involved in synthesis of neurotransmitter and also required for proper myelination of spinal cord and white matter of cerebellar folds in brain and (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 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, organogenesis and protein synthesis (Beard,1999). However, hemosiderosis accompanied by bronze pigmentation in the skin is caused due to excessive accumulation of iron in pancreas, liver, lungs, heart and others tissue causes (Soetan *et al.,* 2010).

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

Mn is widely distributed in tissue of fish and animal, of which the higher concentration is found in bone, but significant amount is also present in muscle, gonadal tissues 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. Large numbers of enzymes are activated by manganese that include lyases, oxidoreductases, hydrolases, ligases, kinases, 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).

* + - 1. ***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 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). In macronutrient metabolism and cell replication, Zn dependent enzymes are involved. It also functions as a cofactor and is a constituent of many enzymes like glutamic dehydrogenase, lactate dehydrogenase, alkaline phosphatase, alcohol dehydrogenase, carbonic anhydrase, carboxypeptidase, DNA and RNA polymerase, retinene reductase and superoxide dismutase (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 malabsorption syndromes and chronic alcoholism (Tuerk and Fazel, 2009).The clinical manifestations of severe zinc deficiency in humans includes dermatitis, alopecia, sexual and skeletal immaturity, growth retardation, loss of appetite, neuropsychiatric disturbances, diarrhea and increased susceptibility to infections (Strain and Cashman, 2009).

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

 The deficiency of Cu cause more frequent symptoms such as neutropenia, anemia and bone fractures, while less frequent symptoms are impaired growth, hypopigmentation, 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, higher accumulation of Cu in the liver with a decrease in blood haemoglobin concentration and packed cell volume is due to excess dietary of Cu. 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 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 Se 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). It is also been reported that due to low amounts of selenium in the food chain, the Keshan’s disease, a cardiomyopathyis developed that affects children and women of child-bearing age in China. Low selenium may influence to other deleterious conditions, most notably the increased incidence of virulence or many disease progression 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.

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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)

* 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 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), aldehyde group (retinal), hydroxyl group (retinol) at carbon- 15. The term vitamin A includes carotenoids, provitamin A that are dietary precursors of retinol (Food and Nutrition Board, 2001). Retinyl esters as a form of Vit. A is only found in foods of animal origin with a richest source in liver. Carotenes are found in yellow, red fruits, green, 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). 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). 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 regulate by all-trans-retinoic acid and 9-cis-retinoic acid are active in (David, 2009).

Deficiency of vitamin A is lead to poor growth and vision, hemorrhage in anterior chamber of eye, night blindness, keratinization of epithelial tissue, , 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 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).

* + 1. **Vitamin D**

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

Maintaining of the plasma concentration of calcium, calcitriol (David, 2009), 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 (especially abdominal) obesity, 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 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).

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, with the development of central nervous system necrosis 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).

* + 1. **Vitamin K**

The word vitamin K was derived from Danish word coagulation (koagulation) by Dam, in 1935. Vitamin Phylloquinone (K1) in plant source and menaquinones (K2) 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 (K1), menaquinones (K2) and menadiol are the three compounds of vitamin K which have biological activity (David, 2009). The excellent sources 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 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 many forms of cancer in children (Ferland, 2009).

**Reference**

Anderson, G.J., Darshan, D., Wilkins, S.J., and Frazer, D.M. (2007) Regulation of systemic iron homeostasis: how the body responds to changes in iron demand. *BioMetals.* 20:665-674.

Andrew A.E. Fish processing technology. *University of Horin Press*, Nigeria. 2001. pp 7–8

Anthony W.N. and Helen L.H. (2009) Vitamin D. M.J. Gibney, S.A. Lanham, A. Cassidy, H. H. Vorster. *Introduction to Human Nutrition*. 2nd edition. John Wiley & Sons, Ltd., Publication. Pp.199-213.

Barua A, Stacewicz-Sapuntzakis M., and Furr H. (2011) Vitamin A - retinol. In: Herrmann W, Obeid R, editors. *Vitamins in the Prevention of Human* *Diseases*. Berlin; New York: Walter de Gruyter. p. 7-39.

Batra, J., and Seth, P.K., (2002). Effect of iron deficiency on developing rat brain. *Indian Journal of Clinical Biochemistry*. 17(2):108-114.

Beard, J.L. (1999) Iron deficiency and neural development: an update. *Archivos Latinoamericanos de Nutrición*. 49(3 Suppl. 2): 34-39.

Berg, A., (1968) Mem. 1st Ital. Idrobiol. Dott. *Maoco Marchi*. 23:161.

Bhouri, A.M., Bouhlel, I., Chouba, L., Hammami, M., El Cafsi, M., and Chaouch, A. (2010) Total lipid content, fatty acid and mineral compositions of muscles and liver in wild and farmed sea bass (*Dicentrarchus labrax*). *African Journal of Food Science.* 4(8):522-530.

Chandra, R.K. (1990) Micro-nutrients and immune functions: An overview. *Annals of the New York Academy of Sciences.* 587:9-16.

David A.B. (2009) The Vitamin. M.J. Gibney, S.A. Lanham, A. Cassidy, H. H. Vorster. In: *Introduction to Human Nutrition*. 2nd edition. John Wiley & Sons, Ltd., Publication.

De Clercq, A. (1932) Chemical composition of fish. *Natuurw. Tijdschr. (Ghent).* 14:63-64.

Dickman, E.D. and Smith, S.M. (1996) Selective regulation of cardiomyocyte gene expression and cardiac morphogenesis by retinoic acid. *Developmental Dynamics*. 206:39-48.

Eruvbetine, D. (2003) *Canine Nutrition and Health*. A paper presented at the seminar organized by Kensington Pharmaceuticals Nig. Ltd., Lagos on August 21.

Felts, R.A., Rajts, F., and Akhteruzzaman, M. (1996) *Small indigenous culture in Bangladesh*. IFADEP Sub-project-2. Development of Inland Fisheries. pp 4.

Ferland G. (2009) Vitamin K. M.J. Gibney, S.A. Lanham, A. Cassidy, H. H. Vorster. In: *Introduction to Human Nutrition*. 2nd edition. John Wiley & Sons, Ltd., Publication. Pp. 230-247.

Food and Nutrition Board (2000) Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids.

Hays, V.W., and Swenson, M.J., (1985) Minerals and Bones. In: *Dukes’ Physiology of Domestic Animals*. Tenth Edition pp. 449-466.

Heaney, R.P., (2012) Phosphorus. Erdman Jr., J.W., Macdonald, I.A., and Zeisel, S.H. In: *Present Knowledge in Nutrition*. 10th edition. John Wiley & Sons, Ltd., Publication. Pp. 447-458.

Hegsted, D.M., Chichester, C.O., Darby, W.J., McNutt, K.W., Stalvey, R.M., and Stotz, E.H. (1976) In: *Present Knowledge in Nutrition* (Nutrition Reviews), Fourth Edition. The Nutrition Foundation, Inc. New York, Washington.

Hei, A. and Sarojnalini, C. (2012) Proximate composition, Macro and Micro mineral elements of some smoke-dried hill stream fishes from Manipur, India. *Nature and Science*.10(1):59-65.

John E.H. (2013) *Fish Nutrition*. 3rd edition, Academic Press, Elsevier. Pp-116.

Kent, G. 1997 Fisheries Food security and the poor. *Food policy*. 22(5):393-404.

Kohinoor, M., Hasan, M.A., Thilsted, S.H., and Wahab, M.A. (2005) Culture of small indigenous fish species (SIS) with Indian major carps under semi-intensive culture system. *Biology*.

Lall, S.P. (1995) Macro and trace elements in fish and shellfish. In: *Fish and Fishery Products: Composition, Nutritive Properties and Stability*,Ruither, A., Ed., USA, CAB International, Pp. 187-214.

Larkin, E.C., and Rao, C.A. (1990). Importance of fetal and neonatal iron; adequacy for normal development of central nervous system, In: *Brain* *behavior and iron in the infant diet* (Dobbing, J. ed), London, UK pp. 43-63.

Lersen, T., S. H. Thilsted, K. Kongsbak, and M. Hansen, *“Whole small fish as a rich calcium source”,* British Journal of Nutrition, Vol. 83, Pp. 191-196, 2000.

Malhotra, V.K. (1998). *Biochemistry for Students*. Tenth Edition. Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India.

Malhotra, V.K. (1998). *Biochemistry for Students*. Tenth Edition. Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India.

McDowell, L. R. (2000) *Vitamins in animal and human nutrition*. Second edition. Iowa State University Press. Pp. 227-263.

Merck, V.M. (1986) *The Merck Veterinary Manual*. Sixth Edition. A handbook of diagnosis, therapy and disease prevention and control for the veterinarian. Published by Merck and Co., Inc., Rahway, New Jersey, USA.

Mill, C.F. 1980. The mineral nutrition of livestoke. E.J. Underwood (Ed.) Common wealth Agriculture Bureaux. Pp 8.

Mohan, K.M., Sugunan, V.V., Sen, D.P., Chandrika, S., Vishwanath, W. (2010) *Management of small fish resources-need for paradigm shift in attention* *to enhance production and multiple benefits to people.* Workshop on Small Indigenous freshwater species: Their role in poverty alleviation, food security and conservation of biodiversity, CIFRI (ICAR).

Murray, R.K., Granner, D.K., Mayes, P.A., and Rodwell, V.W. (2000) *Harper’s Biochemistry*, 25th Edition, McGraw-Hill, Health Profession Division,USA.

Nielsen F.H. (2012) *Manganese, Molybdenum, Boron, Chromium, and other Trace Elements*. Erdman Jr., J.W., Macdonald, I.A., and Zeisel, S.H.,Present knowledge in nutrition. 10th edition. John Wiley & Sons, Ltd.,Publication. Pp. 586-607.

Nimptsch, K., Rohrmann, S., and Linseisen, J. (2008) Dietary intake of vitamin K and risk of prostate cancer in the Heidelberg cohort of the European prospective investigation into cancer and nutrition (EPIC - Heidelberg). *American Journal of Clinical Nutrition.* 87:985 – 992.

Ozcan, M. (2003). Mineral Contents of some Plants used as condiments in Turkey. *Food Chemistr*y. 84:437-440.

Palani, K.M., Ruba, A.A., Jeya, S.R., and Shanmugam, S.A. (2014) Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the Thoothukudi coast of India. *Journal of Nutrition & Food* *Sciences*. 4(1):259.

Prashanth, L., Kattapagari, K.K., Chitturi, R.T., Baddam, V.R., and Prasad, L.K. (2015) A reviews on role of essential trace elements in health and disease. *Journal of Dr. NTR University of Health Science.* 4:75-85.

Roos, N., M.A. Wahab, C. Chamnan and, *“The role of fish in food based strategies to combat Vitamin A and mineral Deficiencies in Developing countries”,* Journal of Nutrition, Vol. 137, Pp. 1106–1109, 2007.

Roos, N., T. Leth, J. Jakobsen and S. H. Thilsted, *“High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for foodbased strategies to reduce vitamin A deficiency”,* International Journal of Food Sciences and Nutrition, Vol. 53, Pp. 425–437, 2002.

Roos, N., Wahab, M.A., Chamnan, C. and Thilsted, S.H. 2007. The role of fish in food based strategies to combat Vitamin A and mineral Deficiencies in Developing countries. *J. Nutr.*137: 1106–1109.

Roos, N., Wahab, M.A., Chamnan, C., and Sakuntala, H.T. 2006. Understanding the links between agriculture and health. 2020 Vision for food, agriculture and the environment.

Saadettin, G., Barbaros, D., Nigar, A., Ahmet, C. and Mehmet, T. 1999. Proximate composition and selected mineral content of commercial fish species from the Black sea. *J. Sci. Food Agric*. 55: 110-116.

Sakuntala, T. 2010. Management of small fish resources-need for paradigm shift in attention to enhance production and multiple benefits to people. Workshop on Small Indigenous freshwater species: Their role in poverty alleviation, food security and conservation of biodiversity, CIFRI (ICAR).

Saliha R., Syed T. R., Faizal A., Absar A., Shania A., Farzana M. (2104) The role of Vitamin E in human health and some diseases. *Sultan Qaboos* *University Medical Journal*. 14(2):157-165.

Sarvenaz, K.T. and Sabine, S. (2018) Nutritional Value of Fish: Lipids, Proteins, Vitamins, and Minerals. *Reviews in Fisheries Science & Aquaculture.* 26(2):243–253

Satish, K. and Trivedi, A.V. (2016) A reviews on role of Nickel in the biological system. *International Journal of Current Microbiology and Applied* *Sciences*. 5(3):719-727.

Schimidt-Hebbel, H. (1950) Investigation bromatologicas en pescados chilean. *Anales bromatol (madrid)*. 2:5-10.

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.

Soetan, K.O., Olaiya, C.O., and Oyewole, O.E. (2010) The importance of mineral elements for humans, domestic animals and plants: A review. *African* *Journal of Food Science.* 4(5):200-222.

Steffen, S.W. (2006) Freshwater fish-wholesome foodstuff. *Bulgarian Journal of Agricultural Science.* 12:320-328.

Strain, J.J., and Cashman, K.D. (2009) Minerals and Trace Elements. In: Gibney, M.J., Lanham, S.A., Cassidy, A., and Vorster. H. H., *Introduction to* *Human Nutrition*. 2nd edition. John Wiley & Sons, Ltd., Publication.

Suttie J.W. (1995) The importance of menaquinones in human nutrition. *Annual Review of Nutrition*.15:399-417.

Szczeklik, A., Gryglewski, R.J., Domagala, B., Dworski, R. and Basista, M. (1985) Dietary supplementation with vitamin E in hyperlipoproteinemias: Effects on plasma lipid peroxides, antioxidant activity, prostacyclin generation and platelet aggregability. *Thrombosis and Haemostasis*. 54:425–30.

Tan, J.C., Burns, D.L., and Jones, H.R. (2006) Severe ataxia, myelopathy and peripheral neuropathy due to acquired copper deficiency in a patient with history of gastrectomy. *Journal of Parenteral and Enteral Nutrition*. 30: 446-450.

Thilsted, S.H., N. Roos, and H. Nazmul, *“The role of Small Indigenous Fish species in food and nutrition security in Bangladesh”,* World Fish Center, Naga, the ICARM Quarterly*,* July-December (Supplement), Pp. 82–84, 1997.

Tuerk, M.J. and Fazel, N. (2009) Zinc deficiency. *Current Opinion in Gastroenterology.* 25:136-143.

Uluozlu, O.D., Tuzena, M., Mendila, D., Soylak, M. (2007) Trace metal content in nine species of fish from the Black and Aegean Seas, Turkey. *Food* *Chemistry*. 104(2):835-840.

Window, H., Stein, D., Scheldon, R. and Smith, J. R. (1987) Comperation of trace metal concentration in muscle of a benthopelagic fish *Coryphaenoidae armatus* from Atlantic and Pacific Ocean. *Deep Sea* *Research.* 34**:**213-220.

Zhao, Z. and Ross, A.C. (1995) Retinoic acid repletion restores the number of leukocytes and their subsets and stimulates natural cytotoxicity in vitamin A-deficient rats. *Journal of Nutrition*. 125:2064–2073.