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Fish as an Important Functional Food for Quality Life

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Abstract

If the principle of “enhanced function” and “reduced risk of disease” claim is valid regarding the definition of functional foods, then fish must be chosen as one of the most important functional foods. Functional foods are foods that have potentially positive effects on health beyond basic nutrition. Fish contains components that can improve physical and mental health, and even can reduce the risk of diseases such as heart disease, cancer, diabetics, dementia, osteoporosis, psoriasis, lupus, arthritis, retinopathy, and other chronic and inflammatory diseases. Fish and fish products are a rich source of important components such as proteins, lipids, vitamins, minerals, and antioxidants, which are of significant nutritional values. Example of functional food components are important n-3 fatty acids EPA and DHA which have anti-inflammatory property and many health related roles. So, fish in human nutrition is required for growth, development, maintenance, and optimum health. As consumers of the age become more health conscious, the demand and market values for health promoting functional foods are expected to grow. The present study is to review the efficiency of functional food components of fish and fish products including safety for promotion of quality of human life.

Keywords: fish, functional food, n-3 fatty acids, EPA, DHA, amino acids, minerals

1. Introduction

Interest in nutrition science and the relationship between diet and health have increased the demand for information about functional foods. Improper diet is believed to increase susceptibility to civilization-related diseases. The demands for foods with positive impact on human health and wellness have come globally over the past two decades. This growth is driven by socio-economics and scientific factors, including increases in population, disposable income, life expectancy, and healthcare costs. The markets will need more continuous supply promoted by our increased understanding of the functional foods and their effects on various aspects of human health at a system and molecular level.

The questions for clear ideas are – what is a functional food? Is fish really a functional food? Clear concept, which is free from blurriness, will be important in assessing health and market values of quality products of this resource and in sustainable management.

1.1 Fish in the boundary of functional foods

The terminology and concept of functional foods are reported to have originated in Japan in 1880's [1] and functional foods are termed as "Foods for specified health use (FOSHU)". In Japan, the FOSHU organization states that functional foods are "processed foods containing ingredients that aid specific body function in addition to being nutritious". The limitation to this definition is that all imposed and whole foods are excluded. The American Dietetic Association (ADA) states that functional foods include "whole foods and fortified, enriched, or enhanced foods have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective level" [2]. "The limitation to this definition is that for a food to be functional, it must be consumed as a part of a varied diet" [2]. However, a functional food retains its functionality as part of any diet. Thus, ideas of functional foods spread to Europe, America, and rest of the world. Numerous different definitions of functional food have been developed. Functional foods must not be taken only for fortified food nor any pill or tablet.

The most acceptable definition given by experts after reviewing different definitions of functional foods is: "The functional food is or appears similar to any conventional food. It is a part of standard diet and is consumed on a regular basis, in normal quantities. It has proven health benefits that reduce the risk of specific chronic diseases or beneficially affect target functions beyond its basic nutrition work" [3].

Now, it is clear that fish is also a functional food considering principle of reduced risk, enhanced function and basic nutrition, and its validity. Researchers say, "Eat fish, live longer". Fish is where there is water. Fish is a great food in quality and quantity. The quality of fish as a food can be known from the statement: "If we have to prepare a pill for complete health, we would have taken all the ingredients from salmons".

The vast aquatic areas of seas and oceans of more than 71% of this planet's surface abound in this resource of fish. Moreover, inland waters, lake, rivers, and streams in hills and mountains are good sources of this food, though they have quality with variation. Water gives so much resource to human beings as a good source of high-quality protein. Fish and fishery by-products can be used as functional ingredients so as to improve health status of consumers promoting performance ability and well being.

Before 2500 years ago, Hippocrates taught the mankind with the tenet – "Let your food be your medicine and your medicine be your food."

The movement of functional foods from 1980s renews the ideas of food and health. There has been more growing interest in the idea–"Functional food is food that provides health benefits beyond basic nutrition." With support from the scientific and governmental communities bringing functional foods to markets will help billions suffering from chronic illness and general health problems.

1.2 Health aspects of nutrition science

Better early development and growth, health maintenance, reduced risk of obesity, and reduced risk of chronic diet-related diseases are aspects of nutrition science. Fish is a source of many vital ingredients: protein, carbohydrate, minerals and vitamins, peptides and lipid, and essential fatty acids.

2. Fish as a good source of proteins and peptides

The importance of protein and peptides is central in cell biology. Protein is the major functional and structural component of all the cells of the body; for

example, all enzymes, membrane carriers, blood transport molecules, the intracellular matrices, hair, fingernails, serum albumin, keratin, and collagen are proteins, as are many hormones and a large part of membranes. Moreover, the constituent amino acids of protein act as precursors of many coenzymes, hormones, nucleic acids RNA, DNA, and other molecules essential for life. Thus, an adequate supply of dietary protein is essential to maintain cellular integrity and function, and for health and reproduction [4].

Unless amino acids are present in the diet in the right balance, protein utilization will be affected [5]. In the world as a whole, protein-energy malnutrition (PEM) is fairly common in both children and adults [6], and is associated with the deaths of about 6 million children each year [7]. Protein deficiency has been shown to have adverse effects on the immune system, resulting in a higher risk of infections [8]. Protein deficiency has also been shown to adversely affect kidney function, where it has adverse effects on both glomerular and tubular function [9]. Obviously, protein deficiency has adverse effects on all organs [10]. In infants and young children, it has been shown to have harmful effects on the brain and may have long-term effects on brain function [11].

The nutritional value or quality of structurally different proteins varies and is governed by amino acid composition, ratio of essential amino acid, susceptibility to hydrolysis during digestion, source, and the effects of processing [12]. Functional amino acids (AA) are those AA that participate in and regulate key metabolic pathways to improve health, survival, growth, development, lactation, and reproduction of the organisms. Functional AAs play great roles in prevention and treatment of metabolic diseases, maintaining health and performance ability.

Fish proteins are highly digestible compared to other terrestrial animal and plant proteins. The protein in oily and white fish breaks down on digestion into polypeptides, peptides, and amino acids. Many of these compounds have bioactive properties.

2.1 Health benefits of important essential amino acids

Histidine, in addition to protein building is a precursor to histamine. It has anti-inflammatory role to help ease joint pain and stiffness, and antifungal functions [13]. Leucine helps increase muscle mass and helps muscle recover after exercise, regulates blood sugar, and supply the body with energy. Leucine is used clinically to help the body heal, and it also affects brain functions [14]. Isoleucine is found in lots of fish proteins. It is particularly recommended to professional athletics, body builders, as the primary function of isoleucine in the body is to boost up the energy levels and to assist the body in recovering from strenuous physical activity. It is important in hemoglobin synthesis [15]. Methionine is also used for increasing the acidity of urine, treating liver disorders, improving wound healing, treating depression, alcoholism, allergies, asthma, copper poisoning, radiation side effects, schizophrenia, drug withdrawal, and Parkinson's disease [16]. Threonine aids in the synthesis of glycine and serine that help in the production of collagen, elastin, and muscle tissue. Threonine supports cardiovascular, liver, central nervous, immune system functions and the growth of thymus, and helps in maintaining strong bone and tooth. It also speeds up wound healing and reduces accumulation of fat in the liver. Threonine is useful in treating Lou Gehrig's disease. Research shows that symptoms of multiple sclerosis (MS), another disease that affects nerve and muscle, are alleviated with threonine treatment [17]. Tyrosine is used for the treatment of a genetic disorder known as phenylketonuria. Tyrosine supplements can also help suppress appetite, promote weight loss, increase mental alertness, improve memory, and enhance athletic performance [18]. Phenylalanine promotes balanced neural and

cognitive function, and also plays a role in regulating your mood. It may help reduce mild pain symptoms, joint discomfort, and even out skin tone [19]. Tryptophan has gained recognition as an important remedy in orthomolecular medicine and is an important natural mood lifting substance and gets converted into serotonin, the “happy hormone.” Targeted supplements containing this essential amino acid can also encourage weight loss and help overcome sleep disorders [20]. Valine is associated with muscle metabolism, tissue repair, mental vigor, muscle co-ordination, and calm emotion [21]. Lysine is used to make medicine for preventing and treating cold sores. Lysine is also taken by mouth to improve athletic performance [22].

2.2 Health benefits of important non-essential amino acids

Aspartic acid is important in the development of nervous system. It has also been implicated in a variety of other outcomes, including: enhancing secondary calcium-dependent neurotransmission signaling, decreasing risks factors for developing cardiovascular disorders; increasing testosterone levels; helping to gain lean muscle mass and decrease fat stores; stimulating increase in muscle power; promoting hormone synthesis; increasing fertility; and enhancing spermatogenesis [23]. Glutamic acid, in addition to protein synthesis, has several key functions within the body and is critical for healthy brain development and function [24]. Glycine helps to form new muscle and also aids in muscle recovery. It is referred to as the anti-aging amino acid. It also helps to prevent cartilage loss, which especially is an issue in aging population [25]. Alanine plays a key role in maintaining glucose and nitrogen levels and thus energy is supplied in the body. Alanine has been shown to help protect cells from being damaged during intense aerobic activity, when the body cannibalizes muscle protein to help produce energy [26]. Arginine is anti-inflammatory, fight migraines, help phosphorus and calcium build bones and teeth. It is essential for spermatogenesis, embryonic growth, fetal and neo fetal growth, immune and tissue integrity [27, 28]. Proline is a vital element in the formation of the connective tissue structure, collagen. An additional benefit of stronger collagen is healthier, age-defying skin. Skin contains collagen, which helps to give it its’ elastic properties [29]. Serine provides crucial health benefits. It plays roles in protein, fatty acid, genetic code carriers (DNA and RNA) synthesis, and muscle build-up. Serine is a constituent in the brain and is a protective cover of nerves. Therefore, serine is an important amino acid for the proper functioning of the brain and nervous system. Furthermore, serine boosts healthy immune system by aiding the production of antibodies [30]. Cysteine is a protogenic amino acid having positive roles in immune system, skin and hair, male fertility, inflammation, osteoporosis, anti-aging, and general well-being of body [31]. Taurine is one of the most essential substances in the body. It increases the action of insulin, improves glucose tolerance, and acts as an antioxidant. It is vital for the proper functioning of the minerals, potassium, calcium, magnesium, and sodium. Taurine is found in large amount in the brain, retina, heart, and blood cells, and platelets. The best food source is fish and meats. Taurine is more than a performance boosting. Taurine benefits many common mental and physical conditions, such as anxiety, depression, insomnia, and diabetes, as well as athletic performance. Researchers in Europe have shown that taurine is beneficial for cardiovascular health. Taurine is very essential for the health of heads, hearts, muscles, ears, and eyes [32, 33]. Ornithine is important for detoxification and indirectly supports muscle growth. This amino acid can also help with wound healing and combat stress and fatigue, promoting better sleep [34]. Carnitine can help those with heart conditions by increasing glucose metabolism, increasing blood flow, correcting abnormal heart rhythms, and reducing toxicity [35].

2.3 Health benefits of fish collagen peptides

Fish collagen peptides are known to have the best absorption and bioavailability due to their similar smaller particle size compound to other animal collagens. It is a type-I collagen, which is the most abundant collagen in human body. Fish collagen is a complex structural protein with a high concentration of glycine, hydroxyproline, and proline. It has maintained the strength and flexibility of skin, ligaments, joints, bone muscles, tendons, blood vessels, gums, eyes, nails, and hairs. Type I is best known for providing the foundation for beautiful skin, strong connective tissues, and sturdy bones. So, fish collagen has very important roles in (1) anti-aging, (2) bone healing and regeneration, and (3) wound healing [36].

3. Carbohydrates

Though the fish is a protein food, carbohydrate is present in good amounts. So, it gives energy and structural components with mono, di, and poly carbohydrates.

4. Vitamins

Consumption of fish has many benefits of different vitamins—A, E, B, etc., promoting healthy vision and skin and immune system, and is important in the reproductive process, and enables heart, kidneys, lungs, and other organs to work properly [37, 38]. Vitamin D helps absorb calcium and keeps the bone strong and healthy, and is important in the immune system, brain, and nervous system, regulates insulin levels and aids diabetes management, supports lung function and cardiovascular health, influences the expression of genes involved in cancer development [39]. Vitamin E is a potential anti-oxidant with anti-inflammatory properties, fights free radicals and prevents disease [40]. Vitamin B complex, the eight B vitamins, play an important role in keeping our bodies running like well-oiled machines. These essential nutrients help convert our food into fuel, allowing us to stay energized throughout the day [38]. While many of the vitamins work in tandem, each has its own specific benefits — from promoting healthy skin and hair to preventing memory loss or migraines.

5. Benefits of fish as a dietary source of mineral elements

Fish is an important source of mineral elements. Their consumption contributes to the mineral deficiency of women and infants. Presence of minerals in addition to protein, lipid with essential fatty acids and vitamins makes it an important diet for human beings [41]. Different factors influence the contents of minerals. Fish contains a wide spectrum of macro and micro elements.

Lack of adequate information about the composition of varied food resources is a major drawback to their utilization rather than real shortages. The importance of mineral elements in human beings cannot be neglected. Their deficiencies cause a variety of diseases and failure in human health. Discussion of biochemical functions and the importance of the mineral elements in human health and disease will be helpful in determining in understanding the value and benefits of fish consumption. Significance of the elements included in the present study was reviewed.

5.1 Calcium (C)

Calcium is the most common mineral in human body. About 99% of the calcium in the body is found in bones and soft tissue. Calcium levels in the blood and fluids surrounding the cells must be maintained within a very narrow concentration range for normal physiological functioning. The physiological functions of calcium are so vital for survival that the body will demineralize bone to maintain normal blood calcium levels when calcium intake is inadequate [42]. Calcium plays a role in mediating the construction of relaxation of blood vessels, nerve impulse transmission, muscle contraction, and the secretion of hormones like insulin [43]. It is also required for membrane permeability, involved in blood clotting and enzyme activation.

Calcium deficiency causes rickets in children due to insufficient calcification by calcium phosphate of the bones in growing children. In adult, it causes osteomalacia. It may also contribute to osteoporosis [44]. Calcium deficiency also affects the dentition of both children and adult. Growing, pregnant, and lactating women require liberal amounts of calcium and phosphorus.

5.2 Phosphorus (P)

Phosphorus is an essential mineral that is required by every cell in the body for normal function. Approximately 85% of the body's phosphorus is found in the bone [43]. It functions as a constituent of bones, teeth, adenosine triphosphate (ATP), phosphorylated metabolic intermediates, and nucleic acids. It is practical that every form of energy exchange inside living cells involves the forming or breaking of high energy bonds that link oxides of phosphorus to carbon or carbon-nitrogen compounds [44–46]. A number of enzymes, hormones, and cell-signaling molecules depend on phosphorylation for their activation. Decrease in serum phosphorus is found in rickets, hyperparathyroidism and De Toni-Fanconi Syndrome. Deficiency in children causes rickets and in adult, osteomalacia. Increase in serum phosphorus is found in chronic nephritis and hyperparathyroidism.

5.3 Sulfur (S)

Sulfur is an essential component for all living cells. Sulfur is present in three amino acids, cystine, cysteine, and methionine. Inadequate sulfur intake reduces the feed intake, digestibility, rate of weight gain, and milk production [44]. Connective tissue, skin, hair, and nails are rich in sulfur. Also, thiamine and biotin (member of vitamin B-complex) and co-enzyme A contain sulfur in their molecule [45].

5.4 Potassium (K)

Potassium is an essential dietary mineral and electrolyte [47]. So, potassium is involved in maintenance of membrane potential and as co-factor for a number of enzymes [48]. Hypokalemia is most commonly a result of excessive loss of potassium, for example, from prolonged vomiting, the use of some diuretics, some forms of kidney disease or metabolic disturbance. Severe hypokalemia may result in muscular paralysis or abnormal heart rhythms (cardiac arrhythmias) that can be fatal [43, 48].

Hyperkalemia occurs in Addison's, advanced chronic renal failure, shocks and dehydration, and symptoms include dilation of heart, cardiac arrest, and small bowel ulcer [49].

5.5 Sodium (Na)

Sodium is the principal cation in extra-cellular fluids. It regulates plasma volume and acid–base balance, involved in the maintenance of osmotic pressure of body fluids, preserves normal irritability of muscles and cell permeability, activates nerve and muscle function and involved in Na^+/K^+ ATPase maintenance of membrane potentials, transmission of nerve impulse and the absorptive processes of monosaccharides, amino acids, pyrimidine and biles salts [44–46].

5.6 Magnesium (Mg)

Magnesium plays important roles in the structure and the function of the human body. Magnesium is involved in more than 300 essential metabolic reactions [50]. It is involved in (1) energy production, (2) synthesis of essential molecules, (3) structural roles, (4) ion transport across cell membranes, (5) cell signaling, (6) cell migration, etc. [51].

5.7 Iron (Fe)

Iron is a key element in the metabolism of almost all living organisms [52] and is required for a number of vital functions, including growth, healing, and immune function. Iron deficiency is associated with alterations in many metabolic processes like neurotransmitter metabolism, protein synthesis, organogenecy etc. and may impact brain functioning [53].

5.8 Copper (Cu)

Copper is a constituent of many enzymes and it plays a role in iron absorption [54]. Cu is an essential micro-nutrient necessary for the hematologic and neurologic systems [55]. It is necessary for the growth and formation of bone, formation of myelin sheaths in the nervous systems, helps in the incorporation of iron in hemoglobin and in the absorption of iron from the gastrointestinal tract (GIT), and in the transfer of iron from tissues to the plasma [45, 46].

5.9 Zinc (Zn)

Numerous aspects of cellular metabolism are zinc-dependent. Zinc plays important roles in growth and development, the immune response, neurological function, and reproduction. On the cellular level, the function of zinc can be divided into three categories: (1) catalytic, (2) structural, and (3) regulatory [56]. Nearly 100 different enzymes depend on zinc for their ability to catalyze vital chemical reactions [43]. The primary roles of zinc appear to be in cell replication and gene expression and in nucleic acid and amino acid metabolism. Vitamin A and E metabolism and bioavailability are dependent on zinc status [57]. It is required for tissue repair and wound healing, plays vital roles in protein synthesis and digestion, and is necessary for optimal insulin action as zinc is an integral constituent of insulin. It is an important constituent of plasma [45, 46].

5.10 Manganese (Mn)

Manganese plays important roles in a number of physiologic processes as a constituent of bone enzymes and an activator of other enzymes [58]. It is involved in (1) antioxidant function, (2) metabolism, and (3) bone development and wound

healing, etc. Manganese is a co-factor of hydrolase decarboxylase and transferase enzymes [46]. Consequently skeleton deformities, defects in shell quality occur when the manganese intake is inadequate [59].

5.11 Cobalt (Co)

Cobalt is required as a constituent of vitamin B12 and its metabolism is the same as for vitamin B12. In addition to its role in vitamin B12, cobalt is also a cofactor of enzymes involved in DNA biosynthesis and amino acid metabolism [60]. Vitamin B12 also plays a role in methylating choline and alanine. The latter is required for the synthesis of DNA, which regulates cell division and growth. Co is readily absorbed in the blood stream and excreted primarily in the urine. Deficiency disease is manifested in vitamin B12 deficiency [44].

5.12 Chromium (Cr)

It plays a role in maintaining the configuration of the RNA molecule because Cr has been shown to be particularly effective as a cross-linking agents for collagen [61]. Cr has also been identified as the active ingredient of the glucose tolerant factor [62]. Cr affects the action of insulin in protein metabolism [63]. Cr deficiencies may exist particularly in children suffering from protein-caloric malnutrition [64].

5.13 Selenium (Se)

Selenium increases immunity, takes part in antioxidant activity that defends against free radical damage and inflammation, and plays a key role in maintaining a healthy body. Selenium is essential for successful male and female fertility and reproduction, and also reduces the risk of cancer, autoimmune, and thyroid diseases [65, 66].

5.14 Nickel (Ni)

It is found in small amounts in the human body and is believed to play a part in our overall health and bodily processes. Nickel may help as a critical cofactor to enzymes to speed up the normal chemical reactions in the body. It is found in our RNA and DNA, where it interacts with these nucleic acids. Too much nickel is toxic, and can have severe side effects [67].

6. Benefits of fish as dietary sources of lipids and essential fatty acids

Omega-3 (n-3) fatty acids such as docosahexaenoic acids (DHA) and eicosapentaenoic acid (EPA) are essential elements in human nutrition. The primary source of DHA and EPA are fatty fish and oils from the tissues of such fishes. DHA is a vital component of the phospholipids in the cell membranes throughout the body but particularly abundant in the brain, retina, and sperms. The fluidity of cell membrane is associated with DHA and aids in facilitating cell functions. Omega-3 fatty acids, in particular, DHA and EPA from fish and fish oil are essential for human development and in the prevention and amelioration of many common human disorders [68].

6.1 Cardiovascular diseases

Early studies starting from the Eskimos, to Japanese, Dutch, USA, still more researches show that regular consumption of fish reduces the risk of heart diseases

[68–71]. Fish consumption has a significant association with a low mortality in population groups with a high risk for coronary heart disease (CHD), whereas in low risk populations, this association is less impressive [70]. Dietary n-fatty acids aid to prevent heart disease through a variety of mechanisms [68].

Research at the University of Washington found that men and women, who consumed fatty fish just once in a week, reduced their risk of cardiac arrest by 50%. The American Heart Association published guidelines for patients with CHD recommending a consumption of fish and fish oil, totaling 1 g/day of EPA and DHA.

6.2 Role in the brain development and function

Ackman reports that the folklore about fish being a brain food is true [72]. DHA is essential for the proper development of the brain and retina in the fetus and infant [73]. Tropical fresh water fish is more similar to the composition of brain than any other food. Arachidonic and docosahexaenoic acids are important fatty acids in the brain. According to Dr. L Barbara, a key element in the nutrition for all ages, DHA is the building block of human brain tissues and the primary structural fatty acids in the gray matter of the brain and retina. Low level of DHA has been associated with depression, memory loss, dementia, and visual problem [74].

Although it is important for everyone to have an optimum level of DHA, it is especially important for the development of human brain, which grows at a rapid pace during the late stage of fetal development. The DHA contents of the fetal brain decrease three to five times during the final trimester of pregnancy and triple during the first 12 weeks of life. The brain's gray matter is composed of approximately 14 billion cells and adequate amount of DHA ensures optimal composition in the membranes of these nerve cells.

Dr. Levine Barbara believes that post-partum depression attention deficit hyperactivity disorder (ADHD) and low IQs are linked to brain serotonin levels, which are again connected to an increased tendency to depression, suicide, and violence [74].

Beneficial health outcomes are more likely to result from supplementation with docosahexaenoic acids itself than its precursor alpha-linolenic acid. The significant positive association between maternal docosahexaenoic acid intake during pregnancy and the children's mental processing at 4 years suggest that optimization of the docosahexaenoic acid status of the expectant women may offer long term developmental benefits to their children [75]. The EFAs – n-3 and n-6 fatty acids are increasing to be of value in limiting the cognitive decline during aging. A combined preparation of essential fatty acids helps improve the quality of Alzheimer patients.

6.3 Lupus

Fish oil consumption benefits patient with lupus. Systematic lupus erythematosus is a chronic inflammatory disease, which manifests symptoms like photosensitive facial rash, fatigue, anorexia, weight loss, and sweat and can progress to life threatening involvement of the heart, lungs, kidney, or central nervous system [76].

6.4 Rheumatoid arthritis

Omega-3 fatty acids help to ameliorate the symptomatic condition of rheumatoid arthritis and dietary fish oil supplement should now be regarded as a part of the standard therapy for the rheumatoid arthritis [77, 78], fish oil could potentially replace drug treatment for many RA patients. Fish oil is a cheaper, safer treatment option and could also serve as a preventative measure against RA. Eicosapentaenoic

acid (EPA), the main component of the fish oil, is known to inhibit the formation of these inflammatory agents [79].

6.5 Psoriasis

Some studies have shown that oral supplement with fish oils benefits psoriasis patients, which is fairly a common disease characterized by a red inflamed border [80]. Abnormal levels of leukotriene (metabolites of arachidonic acid) are believed to be involved in the development and progression of the disorder. Eicosapentaenoic acid (EPA), a major component of fish oils, is known to dampen the adverse effects of leukotriene and has been proven to have significant anti-inflammatory effects. Fish oil supplementation is useful in the treatment of psoriasis particularly when itching is a major problem [81].

6.6 Crohn's disease

Fish consumption helps patients with Crohn's disease, an inflammatory disease involving intestinal pains, diarrhea, and malabsorption of the nutrients. Elemental diet therapy is the preferred treatment in Japan [82].

6.7 Ulcerative colitis

Research at the Boston Medical Center reports that patients with chronic gastro intestinal disorder have abnormal essential profiles. Research at the Mount Sinai School of Medicine reports oil supplementation is highly effective in alleviating ulcerative colitis [83].

6.8 Asthma

Low level of omega-3 fatty acids in the blood is associated with the autoimmune disorders. Omega-3 fatty acid is proved to be helpful in lung and respiratory disorders like asthma. Inflammation of the airways is an important factor in asthma. Japanese researchers now report that supplementation with fish oil does indeed reduce asthma symptoms in children with long-term bronchial asthma [84].

6.9 Kidney disorders

Donadio et al. report that low dose fish oil therapy is effective in IGA nephropathy, which is a common kidney disorder caused by an inflammation (Glomerulo nephropathy) in the network of blood capillaries involved in the filtration of waste products from the blood. Arachidonic acid is metabolized to eicosanoids that engender inflammation, while fish oils result in the production of the eicosanoids that combat inflammation. The 'good' eicosanoids likely slow renal disease progression by reducing glomerular and interstitial inflammation, mesangial cell contractility, platelet aggregate and vasoconstriction in response to renal injury [85]. The treatment of IgA nephropathy should include a balanced and enhanced intake of essential fatty acids [86].

6.10 Cancers

Long chain fatty acids Omega-3 fatty acids (PUFA) eicosapentaenoic acid (EPA) and docosahexaenoic acids (DHA) from the fish oil help inhibit the promotion and progression of the cancers while omega-6 PUFAs, notably arachidonic acid and its

derivatives, help promote the growth of cancer. They believe the n-3 PUFAs exert their beneficial effects in several different ways. They suppress the synthesis of pro-inflammatory eicosanoids from arachidonic acid and thus produce an overall anti-inflammatory effect. They positively affect gene expression, or the activities of signal transduction molecules involved in the control of cell growth, differentiation apoptosis, angiogenesis, and metastasis. They suppress excessive production of nitrogen oxide (NO) during chronic inflammation and thereby help prevent DNA damage and impaired DNA repair. They decrease estrogen production and thus reduce the estrogen-stimulated growth of hormone-dependent cancer cells. Fish oils improve insulin sensitivity and cell membrane fluidity and may help prevent metastasis through these effects [87].

6.11 Women health, pregnancy, and infants

DHA contents of women are higher than men. Adequate amount of n-3 fats is particularly important for women of child bearing age. Since significant brain and eye development occurs in uterus and continues during the first year of life after birth, optimal levels of DHA are crucial for pregnant and lactating women. DHA is the most abundant omega-3 fatty acids in the breast milk. It is also helpful in increasing female breast size. Omega-3 fatty acid from fish oil helps prevent muscular cramp–(dysmenorrhea, menstrual cramp)–the common gynecologic complaint and the leading cause of short term absenteeism among school girls. This is the compelling evidence that menstrual pain is caused by the action of the inflammatory prostaglandin and leukotrienes upon the uterus. The inflammatory compounds are derived from the omega-6 fatty acid–arachidonic acid. The researchers conclude that fish oil supplement has a beautiful effect on dysmenorrhea symptoms in adolescents. The polyunsaturated fatty acid status (PUFA) of the developing fetus depends on that of its mother as confirmed by the positive relation between maternal PUFA consumption and neonatal PUFA status. Pregnancy is associated with a decrease in the biochemical PUFA status, and normalization after delivery is slow. This is particularly true for docosahexaenoic acid DHA because, on the basis of the current habitual diet, birth spacing appeared to be insufficient for the maternal DHA status to normalize completely. Lower neonatal PUFA status correlated positively with birth weight, birth length, and head circumference.

Recent studies have shown that an adequate maternal intake of seafood, especially oily fish, or fish oil supplements improves verbal communication skills at 6 and 18 months of age, reduces the risk of pre-term birth (low birth weight), improves an infant's problem-solving capacity and eye and hand coordination, and results in a higher intelligence quotient (IQ) in children at 4 years of age [88]. The researchers conclude that fish oil supplementation in women with PPD is well tolerated and effective in reducing symptoms of depression [89]. Dr. Joseph Hibbeln of the US National Institutes of Health reports that the incidence of post-partum depression (PPD) is clearly linked to DHA status and seafood consumption [90]. The milk of 29 lactating women living in Doromoni near lake Kitangiri (Tanzania) had high contents of AA, DHA, and EPA, and low AA/DHA ratio. These could be traced to lifelong consumption of DHA and AA-rich fish from the nearby fresh water lake, Kitangiri [91].

6.12 Role in bone health

n-3 Fatty acids, especially DHA, are positively associated with bone mineral accrual and thus, with peak bone in young men [92]. The attainment of peak bone mass in adolescence and the prevention of age-related osteoporosis are also

potential effects of n-3 fatty acids [92]. Earlier studies have shown that a diet with a low n-3/n-6 ratio may have beneficial effects on bone mineral density.

6.13 Diabetes

The strongest kind of correlation exists between accumulation of body fat and diabetes [93]. Insulin resistance most probably results from increased accumulation of lipids in the peripheral tissues (lip toxicity) due to enhanced release of fatty acids from hypertrophic fat cells [94, 95]. Increased physical activity and dietary manipulation in patients with impaired glucose tolerance has been shown to lower the incidence of Type 2 diabetes by 60% [96, 97]. The researchers note that fish oil supplementation does not impair glycemic control and suggest that regular fish consumption should be considered as an integral part of a healthy diet for the management of diabetes [98].

6.14 Eye health

DHA is abundant in the retina and important for visual acuity. It may be helpful in preventing macular degeneration. Dietary DHA would be the appropriate n-3 fatty acids to use in studies to influence the development of visual impairment and even improve visual function in elderly people [99]. The man who ate fish more than once a week had a 50% lower incidence of late-stage macular degeneration than did the man who ate fish less than once per month [100].

6.15 Beautiful skin, hair, and nail

Omega-3 fish oil is also important functional ingredient for beautiful, healthy and shiny skin, hair, and nail [101].

6.16 Drug modulation/adjuvant

Simopoulos in a review shows that n-3 fatty acids in combination with drugs for the treatment of diseases is an area of immense interest [102]. Studies suggest that the concurrent ingestion or administration of n-3 fatty acids with drugs lead to potentiation of drugs effects, as with propranolol, which may lead to a decrease both in the dose of n-3 fatty acids and in the drug dose, or as with cyclosporin, to a decrease in toxicity of the drugs [102].

7. Conclusion

Fish as a source providing construction materials for RNA, DNA, numerous other biomolecules, cells, muscle tissues, bones, and organs that perform numerous different structural and functional roles with prevention and reduction of diseases is a super food on this planet. It is an excellent food providing all the essential amino acids, essential n-3 fatty acids, vitamins, and minerals. Fish protein is highly digestible and of high biological value. Fish contains biomolecules that enhance performance ability physically and mentally. Fish is a good food for early development. The review shows that fish contains many biomolecules that prevent and reduce the risks of many diseases. Fish is great as a food in quality and quantity comparing with other foods.

Fish is a food for brain and health that can also be proved from the present review. Human mind is the medium through which the civilization was developed. It is the medium through which any goal and success can be achieved. Human brain

can be compared to hardware in a computer while mind is compared to software. Healthy long life, enhanced physical and mental performance ability, well-being are all factors for quality life. So, it is rightly concluded that “fish is an important functional food for quality life” considering the principle of definition of functional food and its validity.

In addition to fish being highly delicious and tasty to sensory organ, the present facts and ideas will motivate more humans to choose fish as one of best functional foods for efficient and quality life.

There are variations in quality of fishes depending on species, habitat, temperature, season, feeding, etc. Special care for safety aspects should be taken in processing, harvesting, and storing effects and about fishes from toxic polluted areas.

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References

- [1] Arai S. Global view on functional foods: Asian perspective. *British Journal of Nutrition*. 2002;**88**(Suppl. 2): S139-S143
- [2] Hasler C. The changing face of functional foods. *Journal of the American College of Nutrition*. 2000;**19**:499s-506s
- [3] Doyon M, Labrecque J. Functional foods: A conceptual definition. *British Food Journal*. 2008;**110**(11):1133-1149. DOI: 10.1108/00070700810918036
- [4] Food and Nutrition Board. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids (Macronutrients). Washington, D. C.: National Academies Press; 2005
- [5] Duffy B, Gunn T, Collinge J. Pencharz PB. The effects of varying protein quality and energy intake on the nitrogen metabolism of parenterally fed very low birth weight (<1600g) infants. *Pediatric Research*. 1981;**15**:1040-1044
- [6] Stephenson LS, Lathan MC, Ottesen EA. Global malnutrition. *Parasitology*. 2000;**121**:S5-S22
- [7] FAO (Food and Agriculture Organization). The State of Food and Agriculture 2000. Rome: Food and Agriculture Organization; 2000
- [8] Bistrian BR. Recent advances in parental and enteral nutrition: A personal perspective. *Journal of Parenteral and Enteral Nutrition*. 1990;**14**:329-334
- [9] Benabe JE, Martinez-Maldonado M. The impact of malnutrition on kidney function. *Mineral and Electrolyte Metabolism*. 1998;**24**:20-26
- [10] Corish CA, Kennedy N. Protein-energy under nutrition in hospital in-patients. *British Journal of Nutrition*. 2000;**83**:575-591
- [11] Pollitt E. Developmental sequel from early nutritional deficiencies: Conclusive and probability judgements. *Journal of Nutrition*. 2002;**130**:350S-353S
- [12] Friedman M. Nutritional value of proteins from different food sources. A review. *Journal of Agriculture and Food Chemistry*. 1996;**44**:6-29
- [13] Benefits of L-Histidine–Pure Formulas [Internet]. 2018. Available from: <https://www.pureformulas.com/benefits/benefits-of-histidine> [Accessed: September 6, 2018]
- [14] What Are the Functions of Leucine? Food and Drink [Internet]. 2017. [livestrong.com](https://www.livestrong.com). <https://www.livestrong.com> [Accessed: May 6, 2018]
- [15] Isoleucine [Internet]. 2018. Available from: <https://aminoacidstudies.org/isoleucine> [Accessed: May 16, 2018]
- [16] Methionine: Uses, Side Effects, Interactions, Dosage, and Warning [Internet]. 2018. Available from: <https://www.webmd.com/vitamins/ai/ingredientmono-42/methionine> [Accessed: June 7, 2018]
- [17] L-threonine [Internet]. 2018. Available from: <https://aminoacidstudies.org/l-threonine/> [Accessed: May 12, 2018]
- [18] Tyrosine [Internet]. 2018. Available from: <https://aminoacidstudies.org/tyrosine/> [Accessed: May 6, 2018]
- [19] Phenylalanine [Internet]. 2018. Available from: <https://aminoacidstudies.org/phenylalanine/> [Accessed: May 6, 2018]

- [20] Tryptophan [Internet]. 2018. Available from: <https://draxe.com/Tryptophan/> [Accessed: May 15, 2018]
- [21] Valine–Uses, Benefits, Sources and Dosage–Planet Ayurveda [Internet]. Available from: www.planetayurveda.com/library/valine [Accessed: May 25, 2018]
- [22] 5 Surprising Health Benefits of L-Lysine–AminoGenesis [Internet]. 2018. Available from: www.aminogenesis.com/5-Surprising-Health-Benefits-of-L-Lysine_b_188.htm
- [23] D-Aspartic Acid Benefits for Muscle Building and Sexual Health [Internet]. 2013-2018. Available from: <https://nootriment.com/d-aspartic-acid-benefits/> [Accessed: June 1, 2018]
- [24] Glutamic Acid [Internet]. 2018. Available from: [https://aminoacidstudies.org/glutamic acids/](https://aminoacidstudies.org/glutamic-acids/) [Accessed: May 14, 2018]
- [25] Glycine: The Amino Acid [Internet]. 2018. Available from: <https://draxe.com> [Accessed: June 18, 2018]
- [26] L-alanine [Internet]. 2018. Available from: <https://aminoacidstudies.org/l-alanine/>
- [27] Arginine (L-arginine): Heart Benefits and Side Effects–WebMD [Internet]. 2018. Available from: <https://www.webmd.com/heart/arginine-heart-benefits-and-side-effects> [Accessed: May 6, 2018]
- [28] Wu G, Bazer F, et al. Arginine metabolism and nutrition in growth, health and disease. NIH Public Access. Amino Acids. 2009;37:153-168. DOI: 10.1007/S00726-008-0210-y
- [29] Health Benefits of L-Proline Powder–Hellenia [Internet]. 2018. Available from: <https://www.hellenia.co.uk/blog/post/health-benefits-l-proline-powder/> [Accessed: May 20, 2018]
- [30] Serine [Internet]. 2018. Available from: <https://draxe.com/ornithine> [Accessed: May 14, 2018]
- [31] Cysteine [Internet]. 2018. <https://aminoacidstudies.org/l-cysteine/> [Accessed: May 6, 2018]
- [32] Warskulat U, Flögel U, Jacoby C, Hartwig HG, Thewissen M, Merx MW, et al. Taurine transporter knockout depletes muscle taurine levels and results in severe skeletal muscle impairment but leaves cardiac function uncompromised. The FASEB Journal. 2004;18(3):577-579. DOI: 10.1096/fj.03-0496fje. PMID 14734644
- [33] Huxtable RJ. Physiological actions of taurine. Physiological Reviews. 1992;72(1):101-163. PMID 1731369
- [34] Ornithine [Internet]. 2018. Available from: <https://draxe.com/ornithine> [Accessed: May 14, 2018]
- [35] L-Carnitine—A Review of Benefits, Side Effects and Dosage–Healthline [Internet]. Available from: <https://www.healthline.com/nutrition/l-carnitine> [Accessed: June 5, 2018]
- [36] Axe. Fish Collagen: The Anti-Aging Protein with the Best Bioavailability [Internet]. 2018. Available from: <https://draxe.com/fish-collagen/> [Accessed: June 2, 2018]
- [37] Vitamin A: Sources and Benefits–Live Science [Internet]. <https://www.livescience.com/51975-vitamin-a.html> [Accessed: June 14, 2018]
- [38] Vitamin B Complex: Benefits, Side Effects, Dosage, Foods, and More [Internet]. Available from: <https://www.healthline.com/health/food-nutrition/vitamin-b-complex>
- [39] Singh U, Devaraj S, Jialal I. Vitamin E, oxidative stress, and inflammation. Annual Review of Nutrition. 2005;25:151-174

- [40] The Role of Vitamin D [Internet]. 2018. Available from: <https://my-clevelandclive.org> [Accessed: June 1, 2018]
- [41] Eyo AA. Fish Processing Technology in the Tropics. New Bussa, Nigeria: National Institute for Freshwater Fisheries Research (NIFFR); 2001. pp. 10-170
- [42] Heaney RP. Calcium, dairy products and osteoporosis. *Journal of the American College of Nutrition*. 2000;19(2 Suppl):83S-99S. (PubMed)
- [43] Food and Nutrition Board, Institute of Medicine. Calcium. Dietary Reference Intakes: Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Washington, D.C.: National Academy Press; 1997. pp. 71-145
- [44] Hays VW, Swenson MJ. Minerals and Bones. In: Dukes' Physiology of Domestic Animals. 10th ed. London, UK: Cornel University Press; 1985. pp. 449-466
- [45] Malhotra VK. Biochemistry for Students. 10th ed. New Delhi, India: Jaypee Brothers Medical Publishers (P) Ltd; 1998
- [46] Murray RK, Granner DK, Mayes PA, Rodwell VW. Harper's Biochemistry. 25th ed. USA: McGraw-Hill, Health Profession Division; 2000
- [47] Peterson LN. Potassium in nutrition. In: O'Dell BL, Sunde RA, editors. Handbook of Nutritionally Essential Minerals. New York: Marcel Dekker, Inc; 1997. pp. 153-183
- [48] Sheng HW. Sodium, chloride and potassium. In: Stipanuk M, editor. Biochemical and Physiological Aspects of Human Nutrition. Philadelphia: W.B. Saunders Company; 2000. pp. 686-710
- [49] Soetan KO, Olaiya CO, Oyewole OE. The importance of mineral elements for humans, domestic animals and plants: A review. *African Journal of Food Science*. 2010;4(5):200-222
- [50] Spencer H, Norris C, Williams D. Inhibitory effects of zinc on magnesium balance and magnesium absorption in man. *Journal of the American College of Nutrition*. 1994;13(5):479-484
- [51] Rude RK, Shils ME. Magnesium. In: Shils ME, Shike M, Ross AC, Caballero B, Cousins RJ, editors. Modern Nutrition in Health and Disease. 10th ed. Baltimore: Lippincott Williams & Wilkins; 2006. pp. 223-247
- [52] Fairbanks VF. Iron in medicine and nutrition. In: Shils ME, Olson JA, Shike M, Ross AC, editors. Modern Nutrition in Health and Disease. 9th ed. Philadelphia: Lippincott Williams & Wilkins; 1999. pp. 193-221
- [53] Beard JL, Dawson HD. Iron. In: O'Dell BL, Sunde RA, editors. Handbook of Nutritionally Essential Minerals. New York: Marcel Dekker, Inc; 1997. pp. 275-334
- [54] Chandra RK. Micro-nutrients and immune functions: An overview. *Annals of the New York Academy of Sciences*. 1990;587:9-16
- [55] Tan JC, Burns DL, Jones HR. Severe ataxia, myelopathy and peripheral neuropathy due to acquired copper deficiency in a patient with history of gastrectomy. *Journal of Parenteral and Enteral Nutrition*. 2006;30:446-450
- [56] Cousins RJZ. In: Bowman BA, Russell RM, editors. Present Knowledge in Nutrition. 9th ed. Vol. 1. Washington, D.C.: ILSI Press; 2006. pp. 445-457
- [57] Szabo G, Chavan S, Mandrekar P, Catalano D. Acute alcoholic consumption attenuates IL-8 and MCP-1 induction in response to

ex vivo stimulation. *Journal of Clinical Immunology*. 1999;**19**:67-76

[58] Nielsen FH. Ultratrace minerals. In: Shils M, Olson JA, Shike M, Ross AC, editors. *Modern Nutrition in Health and Disease*. 9th ed. Baltimore: Williams & Wilkins; 1999. pp. 283-303

[59] Gordon RF. Poultry diseases. In: *The English Language Book Society*. London: Bailliere Tindall; 1977

[60] Arinola OG. Essential trace elements and metal binding proteins in Nigerian consumers of alcoholic beverages. *Pakistan Journal of Nutrition*. 2008;**7**(6):763-765

[61] Eastmond DA, Mac Gregor JT, Slesinki RS. Trivalent chromium: Assessing the genotoxic risk of the essential trace element and widely used human and animal nutritional supplement. *Critical Reviews in Toxicology*. 2008;**38**:173-190

[62] Brown M. Harnessing chromium in the fight against diabetes. *Drug Discovery Today*. 2003;**8**:962-963

[63] Roginski EE, Mertz W. Effects of chromium supplementation on glucose and amino acid metabolism in rats fed a low protein diet. *The Journal of Nutrition*. 1997;**97**: 525-530

[64] Mertz W. Chromium as a dietary essential for man. In: Hoekstra WG et al., editors. *Trace Element Metabolism in Animals*. 2nd ed. Baltimore: University Park Press; 1974

[65] Top 8 Selenium Benefits [Internet]. Available from: <https://draxe.com/selenium-benefits/> [Accessed: July 7, 2018]

[66] Selenium Benefits, Signs of efficiency & Foods [Internet]. Available from: <https://draxe.com/selenium-benefits/> [Accessed: May 30, 2018]

[67] Nutriherb. Nickel Health Benefits [Internet]. Available from: <http://www.nutriherb.net/nickel.html> [Accessed: November 1, 2012]

[68] Connor WE. Importance of n-3 fatty acids in health and disease. *The American Journal of Clinical Nutrition*. 2000;**71**(suppl):171S-175S

[69] Bang HO, Dyerberg J, Sinclair HM. The composition of the Eskimo food in north western Greenland. *The American Journal of Clinical Nutrition*. 1980;**33**(12):2657-2661

[70] Nordoy A. Fish consumption and cardiovascular disease: A re-appraisal. *Nutrition, Metabolism & Cardiovascular Diseases*. 1996;**6**: 103-109

[71] Harper CR, Jacobson TA. Usefulness of omega-3 fatty acids and the prevention of coronary heart disease. *The American Journal of Cardiology*. 2005;**96**(11):1521-1529

[72] Ackman RG. Fresh water fish lipids-an over looked sources of beneficial long chain n-3 fatty acids. *European Journal of Lipid Science and Technology*. 2002;**104**(5):253-254

[73] Connor WE et al. Increased docosahexaenoic acid levels in human newborn infants by administration of sardines and fish oil during pregnancy. *Lipids*. 1996;**31**(suppl):S183-S187

[74] Levine BS. Most frequently asked question about DHA. *Nutrition Today*. 1997;**32**:48-49

[75] Decsi T, Koletzko B. N-3 fatty acids and pregnancy outcomes. *Current Opinion in Clinical Nutrition and Metabolic Care*. 2005;**8**(2):161-166

[76] Duffy EM, Meenagh KG, McMillan SA, Strain JJ, Hannigan MB, Bell AL. The clinical effect of dietary supplementation with omega-3

fish oils and/or copper in systemic lupus erythematosus. *The Journal of Rheumatology*. 2004;**31**(8):1551-1556

[77] Cleland LG, James MJ. Fish oil and rheumatoid arthritis: Anti-inflammatory and collateral health benefits. *Journal of Rheumatology*. 2000;**27**:2305-2306 (editorial)

[78] Darlington LG, Stone TW. Antioxidants and fatty acids in the amelioration of rheumatoid arthritis and related disorders. *British Journal of Nutrition*. 2001;**85**:251-269

[79] Kremer et al. Fish-oil fatty acid supplementation in active rheumatoid arthritis: A double-blinded, controlled, crossover study. *Annals of Internal Medicine*. 1987;**106**:497-503

[80] Mayser P, Mrowietz U, Arenberger P, Bartak P, Buchvald J, et al. Omega-3 fatty acid-based lipid infusion in patients with chronic plaque psoriasis: Results of a double-blind, randomized, placebo-controlled, multicenter trial. *Journal of the American Academy of Dermatology*. 1998;**38**:539-547

[81] Bittiner SB, Cartwright I, Tucker WFG, Bleehen SS. A double-blind, randomised, placebo-controlled trial of fish oil in psoriasis. *The Lancet*; **331**(8582):378-380

[82] Tsujikawa T, Satoh J, Uda K, Ihara T, Okamoto T, Araki Y, et al. Clinical importance of n-3 fatty acid-rich diet and nutritional education for the maintenance of remission in Crohn's disease. *Journal of Gastroenterology*. 2000;**35**:99-104

[83] Alex A, Triadafilopoulos G. Fish oil fatty acid supplementation in active ulcerative colitis: A double-blind, placebo-controlled, crossover study. *American Journal of Gastroenterology*. 1992;**(87)**:432-437

[84] Nagakura T, Matsuda S, Shichijyo K, Sugimoto H, Hata K. Dietary supplementation with fish oil rich in v-3 polyunsaturated fatty acids in children with bronchial asthma. *The European Respiratory Journal*. 2000;**16**:861-865

[85] Donadio JV et al. The long-term outcome of patients with IgA nephropathy treated with fish oil in a controlled trial. *Journal of the American Society of Nephrology*. 1999;**10**:1772-1777

[86] Holman RT, Johnson SB, Bibus D, Spencer DC, Donadio JV. Essential fatty acid deficiency profiles in idiopathic immunoglobulin A nephropathy. *American Journal of Kidney Diseases*. 1994;**23**(5):648-654

[87] Larsson SC, Kumlin M, Ingelman-Sundberg M, Wolk A. Dietary long-chain n-3 fatty acids for the prevention of cancer: A review of potential mechanisms. *The American Journal of Clinical Nutrition*. 2004;**79**(6):935-945

[88] Innis SM, Friesen RW. Essential n-3 fatty acids in pregnant women and early visual acuity maturation in term infants. *The American Journal of Clinical Nutrition*. 2008;**87**(3):548-557

[89] Freeman MP et al. Randomized dose-ranging pilot trial of omega-3 fatty acids for postpartum depression. *Acta Psychiatrica Scandinavica*. 2006;**113**:31-35

[90] Hibbeiln JR et al. Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAS study): An observational cohort study. *Lancet*. 2007;**369**:579-584

[91] Hornstra G. Essential fatty acids in mothers and their neonates. *American Journal of Clinical Nutrition*. 2000;**71**(5):1262S-1269s

[92] Hogstrom M, Nordstrom P, Nodrstrom A. N-3 fatty acids are

positively associated with peak bone mineral density and bone. The American Journal of Clinical Nutrition. 2007;**85**:803-807

[93] Flachs P, Rossmeisl M, Bryhn M, Kopecky J. Cellular and molecular effects of n-3 polyunsaturated fatty acids on adipose tissue biology and metabolism. Clinical Science. 2009;**116**:1-16

[94] Kopelman PG. Obesity as a medical problem. Nature. 2000;**404**:635-643

[95] Kahn SE, Hull RL, Utzschneider KM. Mechanisms linking obesity to insulin resistance and type 2 diabetes. Nature. 2006;**444**:840-846

[96] Tuomilehto J, Lindstrom J, Eriksson JG, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. 2001

[97] Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. The New England Journal of Medicine. 2002;**346**:393-403

[98] Hu FB, Willette WC. Optimal diet for the prevention of coronary heart disease. JAMA. 2002;**288**:2569-2579

[99] Simopoulos AP. Essential fatty acids in health and chronic disease. American Journal of Clinical Nutrition. 1999;**70**:560S-569S

[100] Wayne S et al. Dietary fat and fish intake and age-related maculopathy. Archives of Ophthalmology;**118**:401-404

[101] Omega 3 Fish Oil for Beautiful Skin, Hair and Nail [Internet]. 2015. Available from: www.bellapellelas.com [Accessed: February 6, 2018]

[102] Simopoulos AP. Omega-3 fatty acids in inflammation and autoimmune diseases. Journal of the American College of Nutrition. 2002;**21**(6):495-505