Seafood, nutrition and human health

A synopsis of the nutritional benefits of consuming seafood

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1.0 Abstract

Seafood as a whole food is highly nutritious. Benefits to human health associated with the consumption of seafood are noted for multiple bodily organs and physiological functions. Seafood compares favourably with other protein sources as it offers superior macronutrients in the ideal form of lean proteins combined with healthy omega-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs), and a wide array of highly bioavailable micronutrients.

This exposition investigates the role of key nutrients present in seafood on human health. Particular focus is placed on marine sourced omega 3 fatty acids, protein, vitamins A, B12, D and E, iodine, selenium, calcium, zinc and iron.

2.0 Introduction

In the 1950's it was noted that Eskimos native to Greenland had a low incidence of heart disease despite having a diet high in oil. Furthermore, observational studies of Alaskan and Greenland Eskimo and Japanese populations revealed lower incidence and morbidity associated with coronary heart disease (1). Consequently, there has been intense interest in the health benefits associated with marine sourced omega-3 long chain polyunsaturated fatty acids (n-3 LC-PUFAs). Mounting evidence has shown that the consumption of marine n-3 LC-PUFAs, fish, seafood or fish oils has been positively linked with cognitive development and a reduced risk of chronic conditions including coronary heart disease, some cancers, diabetes, rheumatoid arthritis, dementia and Alzheimer's Disease (2).

While the health benefits of n-3 LC-PUFAs are now widely accepted, the benefits of fish or seafood consumption have largely been obscured by the intense interest in n-3 LC-PUFA fortified foods and supplements. Food products fortified with n-3 LC-PUFAs abound in the market place and the growth in the popularity of fish oil supplements has been extraordinary. Fish or seafood as whole foods provide health benefits beyond those that can be attributed to n-3 LC-PUFAs alone. Furthermore, the superior bioavailability of nutrients in seafood leads to the conclusion that seafood as a whole food is among the best dietary source of many nutrients (3).

This resource summarises the range of macro and micronutrients in seafood with a view to promoting the consumption of fish and seafood as whole foods that are highly valuable to a balanced diet.

3.0 Nutrients found in seafood

3.1 Marine sourced omega 3 fatty acids

The there is mounting evidence of health benefits associated with ingestion of n-3 LC-PUFAs. These include brain and retinal fetal development, cognitive development, mental health improvements (depression, schitzophrenia, dementia and attention deficit hyperactivity disorder), lower risk of coronary heart disease and protection against heart arrhythmia, greater plaque stability and anti-thombosis properties (4). Additionally, there is evidence of the role of n-3 LC-PUFAs in maintaining immune function and reducing inflammation for the treatment of all forms of inflammatory arthritis (4). Marine sourced n-3 LC-PUFAs are found in all seafood with the richest source being oily fish.

Marine sourced n-3 LC-PUFAs, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are the important fatty acids for which substantial scientific support for health benefit exists. EPA and DHA may be converted at a very low rate from plant sources of a shorter chain omega-3 fatty acid, alpha-linoleic acid (ALA); recent reviews however conclude that supplementation with ALA is not effective in raising blood DHA levels (5). Conversion rates of ALA to EPA and DHA are typically low and are influenced by background dietary lipid profiles (6). Consumption of preformed EPA and DHA from marine food sources is the most efficacious method to increase physiological status of EPA and DHA for the purpose of achieving the documented health benefits associated with these n-3 LC-PUFAs.

Despite the commercial popularity of n-3 LC-PUFA fortified foods and supplements, recent research indicates bioavailability of supplements varies dramatically (7). The shelf life of omega 3 fortified foods and supplements has been questioned in light of their susceptibility to oxidation and further, the safety concerns about the peroxides and other products of oxidation (8) .

3.2 Protein

The importance of protein is now recognised as being more complex than long realised roles of maintenance of bodily structures including muscles, bones, fingernails and hair. Protein, peptides and amino acid derivatives are important components in bone health, regulation of body composition, glucose metabolism, satiety, cell signalling, gastrointestinal health and bacterial flora (9).

Quality of protein has traditionally been assessed through the amino acid content, ratio of amino acids, source, susceptibility hydrolysis during digestion and the influence of any processing carried out (10). Animal sourced dietary proteins tend to be complete sources of protein in that they contain the full complement of essential amino acids. Fish protein tends to be high in lysine, sulphur containing amino acids and threonine; these amino acids are limiting in cereal based diets and add significance to the quality of fish and seafood protein sources.

Evidence suggests a link between high levels of red and processed meat consumption and bowel cancer (11). In contrast, there is mounting evidence that consumption of seafood can be protective against some cancers (2). Further, consumption of seafood protein has been associated with increased insulin sensitivity in diabetics (12-13), reduced inflammation (14) and animal studies are consistently revealing that seafood protein results in lower blood pressure (15-18). Most commonly consumed items of seafood are rich in complete protein.

3.3 Vitamin D

Vitamin D can be obtained from sunlight or dietary sources. Vitamin D is important in regulating calcium and phosphorous in bone mineralization. Vitamin D also features in thyroid function, rennin and insulin production, immunity, skin condition, muscle strength and has been linked to the prevention of some cancers (19-20). The roles of vitamin D in regulating bone mineralization and adsorption of calcium inherently makes vitamin D important in the prevention of osteoporosis. As seafood is a good source of calcium and vitamin D, research has found that increasing consumption of seafood in the diet significantly improves bone mineral density in women(19).

Widespread awareness of the link between sun exposure and skin cancer in Australia and New Zealand has diminished vitamin D obtained from the sun. Sunscreen and clothing act as a barrier preventing not only sun damage but also the synthesis of vitamin D (20). Vitamin D deficiency and rickets (osteomalacia) are a current concern in paediatric health in Australia and New Zealand (21). Additionally, at risk populations including dark-skinned individuals, the elderly, the infirm who have limited mobility, and those who cover themselves due to adherence to religious beliefs, are especially susceptible to vitamin D deficiency and may need an alternative source of this essential vitamin.

The food chain of marine animals concentrates vitamin D and makes seafood the best dietary source of vitamin D (22). Although, seafood consumption can be beneficial in raising vitamin D levels, diet in isolation is unlikely to supply the recommended daily requirement for vitamin D (23); some sunlight exposure is recommended. Standard 2.4.2 of the Australian and New Zealand Food Standards Code specifies a minimal level of vitamin D to be contained in edible oils and spreads in an effort to boost dietary vitamin D in the general populace (24). Prevention of vitamin D deficiency can be achieved with a diet high in oily fish (20).

3.4 Iodine

Iodine deficiency disorders are diverse and include metal and physical disorders that can be debilitating (25). Iodine is vital for the effective functioning of the thyroid gland and thyroid hormone production thereby having profound influence on facilitating normal growth, metabolism, cell oxygen consumption and the development of the central nervous system.

Historically, iodine deficiency occurred in areas where the soil was low in iodine content and endemic goitre would be noted in local populations. Until recently, the trade in fresh produce in modern times had overcome geographic soil limitations. In contrast to the early 1990s where the iodine status of Australians was satisfactory, the iodine intake of the Australian population was recently considered inadequate, prompting calls for iodine fortification of all edible salts (25). The primary reason behind the decrease in iodine status over the last two decades has been the growth in popularity of chlorine based cleaning products in dairies and their preferential use over iodine based products (25). October 2009 heralded a change to the Australian and New Zealand Food Standards Code; Standard 2.1.1 now mandates that all salt used in bread making must be iodized. Recent mandatory fortification of The NHMRC has recommended that 'women who are pregnant, breastfeeding or considering pregnancy take an iodine supplement of 150μg each day (26).

Iodine is found in most seafood, with shellfish containing the most abundant quantities. Further, fish and seafood have the highest concentration of iodine relative to other foods commonly consumed in most diets (27). Seafood as a part of a healthy diet will improve iodine status.

3.0 Nutrients found in seafood (contd.)

3.5 Selenium

Selenium plays an important role in the body. Selenium prevents cellular damage and is protective against oxidative stress (28). Selenium also assists in regulating the function of the thyroid and supports healthy immune function. Selenium deficiency is more likely to occur in areas such as New Zealand due to reduced selenium levels in the soil. Low soil levels of selenium results in reduced selenium throughout the agricultural food chain.

Selenium is present in most finfish. Selenium in fish is highly bioavailable suggesting that fish is a superior source of dietary selenium relative to other sources including yeast (29). Recent research comparing a diet that includes salmon and one that includes salmon oil capsules, revealed that consumption of fish oil supplements deprived subjects of the dietary benefit of selenium (30).

Further to the nutritional benefit of selenium consumption, there is a growing foundation of research suggesting that selenium acts as a counteractive agent to mercury (28, 31-33). Studies have shown that when test organisms are exposed to toxic levels of mercury, an equal dose of selenium can substantially reduce the detrimental effects. It is possible that concerns of methylmercury accumulation in some fish populations may be moderated by selenium.

3.6 Calcium

Calcium is important for developing and maintaining bones and teeth as well as supporting the healthy functioning of muscles, nerves and the heart. Skeletal calcium serves as a reservoir for the supply of calcium for other body functions such as intracellular messaging(34) and as such after a long latency period, calcium deficiency results in osteoporosis (35). Adequate dietary calcium is required throughout life to prevent low bone mineral density, increased risk of fragility fractures and osteoporosis at a mature age (34).

Bony fish such as sardines and tinned salmon are very rich in calcium. Intakes of seafood greater than 250g per week, have been associated with greater bone mineral density (19). Of note however, is that calcium adsorption is dependent on adequate vitamin D and can be reduced by dietary interactions including dietary fibre and alcohol (34). It can be construed from evidence that seafood can promote bone density when consumed within an otherwise healthy diet due to the susceptibility of calcium to macro and micro nutrient interactions.

3.7 Vitamin B_{12}

Vitamin B_{12} is important to DNA synthesis, red blood cell and neurological function. Deficiency of vitamin B_{12} can be associated with megoblastic anaemia, neurological disorders, myelopathy, memory impairment, dementia, depression and cerebrovascular disorders (36).

Most fish and shellfish contain vitamin B_{12}. Clams, octopus, oysters, fish and fish roe are excellent sources of vitamin B_{12} (37). Dietary intake of fish has been linked to significant improvements in plasma B_{12} status (36). Researchers have identified that dietary vitamin B_{12} sourced from fish and a dairy product is more bioavailable than that from meat and eggs (36).

3.8 Vitamin A

Vitamin A plays an important role in supporting normal vision, reproduction, bone growth, immune functions and healthful maintenance of the eye, respiratory and urinary tract linings, the skin and mucous membranes (38). Deficiency in vitamin A is associated with increased infections from diarrhoea to respiratory infections. In developing countries supplementation can prevent approximately a quarter of childhood deaths (38).

Most fish and shellfish contain Vitamin A though the best marine sources are oily fish. Animal sourced vitamin A is in the fat soluble retinol that is converted to an active form such as retinal or retinoic acid; these are efficiently adsorbed and used by the body (38). Plant sources of vitamin A are the water soluble pigment group of carotenoids. Carotenoids are less efficiently adsorbed than preformed retinol (38)and are subject to a conversion factor when calculating retinol equivalents.

3.0 Nutrients found in seafood (contd.)

3.9 Vitamin E

Vitamin E is a highly efficacious antioxidant that is important to the skin, nervous system, heart and circulatory system. Although deficiency in vitamin E is uncommon, the various forms of vitamin E are protective of vitamins A and C by preventing their oxidation (38). Vitamin E is found in oils, nuts and green leafy vegetables (38); the highest marine source of vitamin E is oily fish.

3.10 Zinc

While only small amounts of this essential trace element are required, zinc acts as a catalyst for over 100 specific enzymes necessary for human metabolism (38). Zinc plays a role in optimal growth and development and functioning of the immune system. Zinc deficiency may result in stunted growth, vulnerability to infection and pregnancy outcomes (38).

Widespread zinc deficiency is an issue affecting Australian arable land (39), and thus crops raised in Australia may not continue to contribute significantly to human zinc requirements. Consequently, alternative sources such as zinc rich food should be consumed so that optimal zinc levels are met and maintained. As zinc binds to protein, foods such as seafood, which are sources of both zinc and protein, optimise bioavailability of dietary zinc (39). Oysters are known to be one of the richest natural sources of zinc.

3.11 Iron

Iron plays a vital role in facilitating the transportation of oxygen throughout the body within the haemoglobin complex and is associated with growth, healing and immune function. It is also critical for energy production within cells and DNA synthesis.

Research suggests that Australian women in particular may not be consuming adequate iron, and increasing the consumption of iron rich seafood within a balanced diet can play an important role in addressing this imbalance (40). Heam iron, found in seafood and animal sources is more readily bioavailable than non- heam sourced from plants.

4.0 Summary

The value of seafood within a healthy diet is clear from this overview of nutritional composition. Evidence on the health benefit of marine sourced omega 3 fatty acids is mounting with the strongest evidence associated with DHA. Conversion of plant sourced omega 3 PUFAs is less effective in producing the health benefits. It is unlikely that the average consumer is aware of the differentiation in function and education of the general public is required.

The importance of seafood as a whole food, in addition to n-3 LC-PUFA, cannot be underestimated. Seafood offers a range of nutrients that are frequently under-represented in habitual diets, including iodine, calcium, vitamin D, zinc and iron.

References

1. He K, Song Y, Daviglus ML, Liu K, Van Horn L, Dyer AR, et al. Accumulated Evidence on Fish Consumption and Coronary Heart Disease Mortality. Circulation. 2004;109:2705-11.
2. McManus A, Howieson J, Nicholson C. Review of literature and resources relating to the health benefit fo regular consumption of seafood as a part of a healthy diet: Centre of Excellence for Science, Seafood and Health, Curtin University2009.
3. Bourre J, Paquotte P. Seafood (Wild and Farmed) for the Elderly: Contribution to the Dietary Intakes of Iodine, Selenium, DHA and Vitamins B12 and D. The Journal of Nutrition, Health and Aging. 2008;12(3):186-92.
4. Ruxton CHS, Calder PC, Reed SC, Simpson MJA. The impact of long-chain n-3 polyunsaturated fatty acids on human health. Nutrition Research Reviews. 2005;18:113-29.
5. Brenna JT, Salem Jr N, Sinclair AJ, Cunnane SC. a-Linoleic acid supplementation and conversion to n-3 long-chain polyinsaturated fatty acids in humans. Prostaglandins, Leukotrienes and Essential Fatty Acids. 2009;80:85-91.
6. Goyens PLL, Spilker ME, Zock PL, Katan MB, Mensink RP. Conversion of a-linoleic acid in huamns is influenced by the absolute amounts of a-linoleic acid and linoleic acid in the diet and not by their ratio. American Journal of Clinical Nutrition. 2006;84:44-53.
7. Dyerberg J, Madsen P, Moller JM, Aardestrup I, Schmidt EB. Bioavailability of marine n-3 fattty acids formulations. Prostaglandins, Leukotrienes and Essential Fatty Acids. 2010;In Press.
8. Kolanowski W. Bioavailability of omega-3 PUFA from foods enrished with fish oil - A mini review. Polish Journal of Food and Nutrition Sciences. 2005;14/55(4):335-40.
9. Millward DJ, Layman DK, Tome D, Schaafsma G. Protein quality assessment: impact of expanding understanding of protein and amino acid needs for optimal health. American Journal of Clinical Nutrition. 2008 May 1, 2008;87(5):1576S-81.
10. Friedman M. Nutritional Value of Proteins from Different Food Sources. A Review. Journal of Agricultural and Food Chemistry. 1996 01/18;44(1):6-29.
11. World Cancer Research Fund International. Expert Report Recommendations2007.
12. Ouellet V, Marois J, Weisnagel SJ, Jacques H. Dietary Cod Protein Improves Insulin Sensitivity in Insulin-Resistant Men and Women. A randomized controlled trial. Diabetes Care. 2007;30(11):2816-21.
13. von Post-Skagegrd M, SVessby B, Karlstrom B. Glucose and insulin responses in healthy women after intake of composite meals containing cod, milk, and soy protein. European Journal of Nutrition. 2006;60:949-54.
14. Rudkowska I, Marcotte B, Pilon G, Lavigne C, Marette A, Vohl M. Fish nutrients depress levels of tumour necrosis factor a in cultured human macrophages. Physiological Genomics. 2010;40:189-94.
15. Demonty I, Deshaies Y, Lamarche B, Jacques H. Cod Protein Lowers the hepatic Triclyceride Secretion Rate in Rats. Journal of Nutrition. 2003;133(5):1398-402.
16. Ait-Yahia D, Madani S, Prost E, Prost J, Bouchenak M, Belleville J. Tissue Antoxidant Status Differs in Spontaneously Hypertensive Rats Fed Fish Protein or Casein Protein.The American Society for Nutritional Sciences Journal of Nutrition. 2003;133:479-82.
17. Ait-Yahia D, Madani S, Prost J, Bouchenak M, Belleville J. Fish protein improves blood pressure but alters HDL and LDL composition and tissue lipoprotein lipase activities in spontaeously hpertensive rats. European Journal of Nutrition. 2005;44:10-7.
18. Ait-Yahia D, Madani S, Savelli JL, Prost J, Bouchenak M, Belleville J. Dietary fish protein lowers blood pressure and alters tissue polyunsaturated fatty acid composition in spontaneously hypertensive rats. Nutrition. 2003;19:342-6.
19. Zalloua PA, Hsu Y-H, Terwedow H, Zang T, Wu D, Tang G, et al. Impact of seafood and fruit consumption on bone mineral density. Maturatis. 2007;56:1-11.
20. Holick MF. Vitamin D Deficiency. New England Journal of Medicine. 2007;357(3):266-81.
21. Munns C, Zacharin MR, Rodda CP, Batch JA, Morley R, Cranswick NE, et al. Prevention and treatment of infant and childhood vitamin D deficiency in Australia and New Zealand: a consensus statement. Medical Journal of Australia. 2006;185:268-72.
22. Lamberg-Allardt C. Vitamin D in foods and as supplements. Progress in Biophysics and Molecular Biology. 2006;92(1):33-8.
23. Osteoporosis Australia. Calcium, Vitamin D and Osteoporosis2009.

References (contd.)

24. Food Standards Australia New Zealand. Food Standards Code. 2010.

25. Li M, Eastman CJ, Waite KV, Ma G, Zacharin MR, Topliss DJ, et al. Are Australian children iodine deficient? Results of the Australian National Iodine Nutrition Study. Medical Journal of Australia. 2006;184(4):165-9.

26. National Health and Medical Research Council. Iodine supplementation for pregnant and breastfeeding women. NHMRC Public Statement. January 20102010.

27. Gunnarsdottir I, Gunnarsdottir BE, Steingrimsdottir L, Maage A, Johannesson AJ, Thorsdottir I. Iodine status of adolescent girls in a population changing from high fish to lower fish consumption. European Journal of Clinical Nutrition [serial on the Internet]. 2010; Advance online publication.

28. Weber DN, Connaughton VP, Dellinger JA, Klemer D, Udvadia A, Carvan MJ. Selenomethionine reduce visual deficits due to developmental methylmercury exposures. Physiological Behaviour. 2008;93:250-60.

29. Fox TE, Van den Heuval EGHM, Atherton CA, Dainty JR, Lewis DJ, Langford NJ, et al. Bioavailability of selenium from fish, yeast and selenate: a comparative study in humans using stable isotopes. European Journal of Clinical Nutrition. 2004;58:343-9.

30. Pagua M. The effect of consuming farmed salmon compared to salmon oil capsules on long chain omega 3 fatty acid and selenium status in humans. Massey Research Online [serial on the Internet]. 2009: Available from: http://muir.massey.ac.nz/handle/10179/1230.

31. Ganther HE, Sunde ML. Factors in fish modifying methylmercury toxicity and metabolism. Biological Trace Element Research. 2007;119:221-3.

32. Peterson SA, Ralston NVC, Peck DV, Van Sickle J, Robertson JD, Spate VL, et al. How Might Selenium Moderate the Toxic Effects of Mercury in Stream Fish of the Western U.S.? Environmental Science Technology. 2009;43(10):3919-25.

33. Ralston NVC, Blackwell JL, Raymond LJ. Importance of molar ratios in selenium-dependent protection against methylmercury toxicity. Biological Trace Element Research. 2007;119(3):255-68.

34. Straub DA. Calcium Supplementation in Clinical Practice: A Review of Forms, Doses, and Indications. Nutrition in Clinical Practice. 2007 June 1, 2007;22(3):286-96.

35. Heaney RP. Long-latency deficiency disease: insights from calcium and vitamin D. Am J Clin Nutr. 2003 November 1, 2003;78(5):912-9.

36. Vogiatzoglou A, Smith AD, Nurk E, Berstad P, Drevon CA, Ueland PM, et al. Dietary sources of vitamin B-12 and their association with plasma vitamin B-12 concentrations in the general population: the Hordaland Homocysteine Study. Am J Clin Nutr. 2009 April 1, 2009;89(4):1078-87.

37. Stabler SP, Allen RH. Vitamin B12 Deficiency as a Worldwide Problem. Annual Review of Nutrition. 2004;24(1):299-326.

38. Ekweagwu E, Agwu AE, Madukwe E. The role of micronutrients in child health: A review of the literature. African Journal of Biotechnology. 2008;7(21):3804-

39. Alloway BJ. Soil factors associated with zinc deficiency in crops and humans. Environmental Geochemical Health. 2009;31:537-48.

40. Ahmed F, Coyne T, Dobson T, McClintock C. Iron status among Australian adults: findings of a population based study in Queensland, Australia. Asia Pacific Journal of Clinical Nutrition. 2008;17(1):40-7.

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