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Food Enrichment with Long Chain N-3 Poly Unsaturated Fatty Acids (LC PUFA)

Introduction

Incorporation of long chain fatty acids into the diet, continues as a topic of interest for both food manufacturers and nutrition specialists. From the discovery and early studies on long chain PUFA in 1929 by Burr and Burr the evidence of the health benefits continues to accumulate (1). The scientists discovered that the "syndrome" was due to a deficiency in a specific polyunsaturated fatty acid. This concept that specific components of fat are necessary for the proper growth and development led researchers to investigate the nature of PUFAs and their importance in biological processes. The body is not able to produce linoleic acid and alpha linolenic acid, the "mother" substances of the two PUFA families. As a result, linoleic acid (N-6 PUFA) and alpha-linolenic (N-3 PUFA) acid are essential fatty acids.

The scientific literature for PUFAs continues to expand with the thought that PUFAs are a large relatively unexplored nutrition frontier.

Background on PUFAS

Fats, which contain many different kinds of fatty acids, have three major roles to play in the body. First, they function as efficient energy stores. They are also important building blocks of the cell membrane. Thirdly they are critically important as precursors of the hormone-like compounds such as prostaglandins, thromboxanes and leucotrienes which are involved in a variety of critical biochemical functions.

PUFAs have at least two double bonds, a feature that crucially influences their structure, as well as their physical and chemical properties. PUFAs can be divided into two families -- N-6 and N-3 -- which have different physiological functions and act in concert with one another to regulate biological processes. The N-6 PUFA, linoleic acid, is converted into long-chain PUFAs, such as gamma-linolenic (GLA) acid and arachidonic acid (AA) through a process of desaturation and elongation. N-6 PUFA , but not AA, are found primarily in plants. The N-3 fatty acid, alpha-linolenic acid, is converted the same way to the long-chain PUFAs eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and found mainly in green leafy vegetables, the later , in the fat of oily fish (Chart 1).

Maternal/Infant Nutrition.

Throughout pregnancy, long-chain PUFAs are required for normal development of the placenta and fetus. Since these nutrients cannot be produced by the human body, the fetus and placenta are fully dependent on the mother's intake and stores of essential fatty acids (2,3).

Recent studies suggest that a relative deficiency of long-chain N-3 PUFAs develops during pregnancy and lactation (4). Some investigations have shown a progressive deterioration of the mother's DHA status during pregnancy, possibly indicating that the mother's capacity to meet the high fetal requirement for DHA is working at its limit and may even be inadequate (5). As a result, researchers suggest a possible need for increased N-3 PUFAs and specifically DHA supplementation during pregnancy.

Clinical data on the nutritional importance of PUFAs in babies suggest that they play a critical role in brain and eye development, particularly DHA. The naturally high concentrations of DHA in the retina and cerebral cortex of the fetus and infant suggest its integral involvement in neural and visual function (6).

The main concern regarding fatty acid nutrition in infancy is with preterm infants. This is because the rate of brain growth is known to the greatest in the last three months of pregnancy, a critical growth period that is shortened for preterms an dbecause preterms are born with low fat stores. Several studies have tested the effect of adding long-chain PUFAs to the diet of preterm infants(7). There is solid evidence that supplementation with DHA from marine oil improves the development of visual acuity, response to light and cognitive ability to integrate information soon after birth (8,9,10).

Research has established that the blood DHA levels of full-term infants fed formula is lower than that of breast-fed infants. This suggests that present infant formulas provide insufficient alpha-linolenic acids or that the enzymes needed to produce long-chain PUFAs are not sufficiently active during early life to support DHA production. Term infants therefore may also be dependent on a dietary source of DHA for optimal functional maturation of the eye (11,12) and cognitive development (13).

The scientific data regarding the critical need during pregnancy and for premature and term infants is so compelling that probably all infant formula's will be enriched with N-3 PUFA in the foreseeable future. The need for DHA and arachidonic acid (AA), in proper balance has lead the WHO/FAO and many other organizations to recommend that infant formulas contain these long chain polyunsaturated acids at levels similar to breast milk (14,15). Since infant formulas in North America do not as yet include DHA, newborns, particularly preemies are at risk.

Cardiovascular Disease

Cardiovascular disease is the leading cause of death in industrialized countries (Chart 2) The initial studies by Dyerberg and Bang have lead to additional significant research producing sound evidence on the relationship between N-3 PUFA and CVD (16). Data on the benefits of incorporating long chain polyunsaturated fatty acids (LC PUFA) into the diet have been reported for many years (17,18,19,20).

Reviews by the U.S. Department of Health & Nutrition Services, National Institutes of Health (21), The Life Sciences Research Office of the Federation of Societies for Experimental Biology (FASEB) ,and The Council for Responsible Nutrition (CRN) (22), indicate that there is general consensus and that benefits would accrue to the population should dietary intake increased to around 1-2 gram long chain N-3 PUFA per day.

Control of the epidemic of coronary artery disease (CAD), the main cause of death in industrialized countries is feasible by appropriate lifestyle and nutrition activities. A population strategy to lower CAD is within reach and with the increasing costs and aging population there are very strong incentives for national strategies. Dietary fat and the mix of fatty acids appears to be the cornerstone of a nutritional policy to met these objectives(23).

World Recommendations

As a consequence of the research data, scientists and government bodies are not only promoting the benefit of fat reduction in general, but in many countries specific recommendations are now appearing that advise increasing dietary long chain N-3 PUFA intake. Typical of such recommendations are those in Canada from Health and Welfare Canada (HWC) and the British Nutrition Foundation (BNF) (19) (Charts 3,4).

The Food Industry and how to put fish into bread?

The fats and oils industry continues to feel the pressure from consumers to reduce fat intake in general. Changes in intakes of visible oils/fats such as margarine, spreads and salad dressings on a per capita basis continue in the U.S.A (Chart 5), and in Canada (Chart 6). Also industry is reducing or eliminating fat where feasible from products. However another possibility is to add "good" oils such as those rich in N-3 PUFA to high fat products. This may have the benefit of allowing health messages to appear on foods that formerly were regarded as “bad” by the consumer. Significant consumer education will need to be undertaken, but the desire from consumers to take nutrition matters into their own hands and have a greater understanding appears to be growing. Such awareness of dietary factors and the perceived benefits, particularly for prevention of cardiovascular disease, are drivers of consumer food trends.

“Nutraceuticals” or “pharmafoods” are new developments and the possibility of health claims for “Foods for The Prevention of Disease”, a new regulatory category may be feasible for N-3 PUFA (24). The evidence is strong and there may be sufficient “significant scientific agreement” as proposed by the FDA. At least foods designed for pregnant and lactating mothers, infant “follow-on” foods and “heart healthy” products for all ages can now be considered.

An interesting new development for the fats and oils industry is the use of “novel” refining techniques that are able to produce marine oils which can be added to a range of foods without affecting the flavor profile of the product. Previously, fish oils have been used only in a “hardened” or hydrogenated form to prevent the occurrence of fishy off-tastes and smells. Now, fish oils and dry powders, with microencapsulated oils are available for food fortification use. Only oils that have been specifically refined, protected and packed are suitable such as those offered from Hoffmann La Roche under the “ROPUFA” label.

Today a wide range of PUFA products in oil and powder form are available for various applications. The oily forms are easily added to the lipid phase with care being taken to protect the readily oxidizable PUFA. The powdered forms are used mainly in dry goods such as bakery products and milk powders. Microencapsulated powders are produced using special processes. They are dispersible in cold water and exceptionally stable. These properties together with neutral taste make them ideal for enriching foods such as reduced fat products, milk drinks, salad dressings, orange juice drinks and bread. Despite these protective measures when they are used on a commercial scale it should not be overlooked that in the oil each double bond is a potential oxidation site and oxidation can lead to the development of off-flavors.

A number of special forms are available for specific fields such as pediatric nutrition . These products are rich in DHA essential for optimum development in children.

A Very Special Kind of Oil Refining.

The specific refining process for fish oils suitable for food applications requires, neutralizing to remove free fatty acids, bleaching with diatomaceous earth to remove pigments. This also removes some of the peroxides, heavy metals and possible pesticide residues. Special deodorizing and absorption techniques remove peroxides, aldehydes and ketones which play an important role in the development of off-flavors. Finally, stabilization with an antioxidant mixture of tocopherols, ascorbyl palmitate and lecithin protects the product from future degradation and oxidation (Chart 7). Packaging under an inert gas further protects the product until use.

In any food manufacturing/process system there are a number of factors which need to be addressed when considering the addition of LC PUFA. Since added water is a common ingredient of many foods wherever possible this should be deionised and deaerated before coming in contact with PUFA. The addition of a metal chelator such as citric acid will help overcome the pro-oxidant effect of heavy metal ions such as iron and copper (Chart 8).

The removal of oxygen is particularly important in low fat products such as margarines and spreads containing emulsifiers, thickeners and flavoring agents. Whenever homogenization or emulsification is required it is recommended that the process is carried out either under vacuum or inert gas blanket to minimize exposure to oxygen. For products requiring pasteurization direct steam is preferred to plate heat exchangers. In all cases additional antioxidants will be required to protect the product and provide the desired shelf-life. Typically tocopherols, ascorbyl palmitate or sodium ascorbate are used. The exact nature and amounts required will depend upon the individual product concerned, the fat content and overall composition of the fat blend and the shelf life needed.

Global Food Developments

Food technology has now advanced to the point where we can in theory enrich any food with a N-3 polyunsaturated fatty acid. Some of these enriched products are already marketed in the UK, Korea, Taiwan and Scandinavian countries. Methods of incorporating PUFA into milk drinks, yogurt and ice cream are being developed. In other countries the time has yet to come for PUFA enriched foods. Resistance from producers and consumers still has to be overcome and technical problems need to be resolved. Nutritionists and food developers realize that these foods need not only to be healthy but must taste as good as similar products. Finally there is a degree of prejudice against fish and fish derivatives that is widespread. In Scandinavia, Mediterranean and Atlantic coastal regions, fish consumption enjoys a long tradition and triggers a "Healthy" association. A survey in the UK in 1993 revealed that while 70% of men and women questioned knew that consumption of oil-rich fish could guard against cardiovascular disease, only a few interviewees regularly ate such fish. Further the idea of yogurt or bread containing 1% fish oil is not particularly attractive. This negative attitude of the average consumer needs to be overcome and awareness of the benefits mobilized. Likewise food manufacturers need to have good nutritional rationale and guidance as to why they should look at the opportunity to gain marketshare or add value to products enriched with PUFA.

At the forefront of developments are infant and baby follow-on foods in Europe and the Far East, breads in Europe and UK, and margarines now entering the mainstream in the UK with the launch of "Live" brand from Golden Vale and "Life" with the TESCO supermarket chain. Additionally niche products such as soups, ice tea drinks, cakes, biscuits and the restoration of N-3 PUFA to canned seafood and tuna are being launched.

With due care and proper precautions being taken, it is possible to produce a wide variety of foodstuffs enriched with LC PUFA. However each product must be considered on a case by case basis with expert help to formulate new products. Despite the technical issues incorporating LC PUFA into foods there is no doubt that this concept offers food processors the opportunity to introduce a new range of foods associated with definite health benefits which will enjoy the support of the scientific community as helping in disease prevention.

PUFA: A Promising Future.

The future prospects for these beneficial fats seems promising. This is based on the existing findings and research results. Sooner or later LC PUFA will become an important ingredient of foods. They will eventually prove themselves as did the vitamins thirty years ago. The market potential is great, and as new products find their way to the market and consumer knowledge grows so will the acceptance. The possible development of RDA's in the future will bring these amazing substances into the mainstream of the food industry.

References

1. Burr, G.O. Burr, M.M., A new deficiency disease produced by rigid exclusion of fat from the diet. J. Biol. Chem. 82:345-367, 1929.

2. Clandinin, M.T., Chappell, J.E., et al. Intrauterine fatty acid accretion in brain: implications for fatty acid requirements. Earl. Hum. Dev. 4:121-130, 1980.

3. Simopoulos, A.P. Omega-3 fatty acid in health and disease and in growth and development. Am. J. Clin. Nutr. 54:438-63, 1991.

4. Al, M.D.M., Hornstra, G., et al. Biochemical EFA status of mothers and their neonates after normal pregnancy. Early Hum. Dev. 24:239-48, 1990.

5. Al, M.D.M., Houwelingen, A.C., et al. Essential fatty acids, pregnancy and pregnancy outcome. Presentation at the Second International Congress of the ISSFAL International Society for the Study of Fatty Acids (June 7-10, 1995), National Institutes of Health, Bethesda, Maryland,

6. Birch, D.G., Birch, E.E., et at. Dietary essential fatty acid supply and visual acuity development. Invest. Opthamol. And Vis. Sci. 32:3242-53, 1992.

7. Carlson, S.E., The Role of Pufa in Infant Nutrition. Inform 6:8, 940-946, 1995.

8. Crawford, M.A. Essential fatty acid requirements during early development. Presentation at the Second International Congress of the ISSFAL International Society for the Study of Fatty Acids (June 7-10, 1995), National Institutes of Health, Bethesda, Maryland.

9. Uauy, R., Birch, D.G., et at. Effect of dietary omega-3 fatty acids on retinal function of very low birth weight neonates. Pediatr. Res. 28:485-92, 1990.

10. Lucas, A.,Morley, R., Breast milk and subsequent intelligence quotient in children born preterm. Lancet. 339:261-64, 1992.

11. Makrides, M., Simmer,K., et al. Erythrocyte docosahexaenoic acid correlates with visual response of healthy term infants. Pediatr. Res. 33 (4 Pt 1):425-27, 1993.

12. Carlson,S.E., Werkman, S.H., et al. Visual acuity development in health preterm infants: effect of marine-oil supplementation. Am. J. Cl. Nutr. 58:(1):35-42, 1993.

13. Lanting, C.I., Fidler, V., et al. Neurological differences between 9-year-old children fed breast-milk or formula-milk as babies. Lancet 334:1319-22, 1994.

14. Lipids in early development in fats and oils in Human Nutrition, FAO/WHO #57, 1994: 49-55.

15. Unsaturated fatty acids: nutritional and physiological significance. The Report of the British Nutrition Foundation's Task Force, BNF, 1992.

16. Dyerberg, J., Bang, H.O., Hjorne, N., Fatty acid composition of the plasma lipids in Greenland Eskimos. American Journal Clinical Nutrition 28, 958, 1975.

17. Kromhout, D., Bosschieter, E.B., Coulander, C., The inverse relation between fish consumption and 20-year mortality from coronary heart disease. The New England Journal of Medicine 312, 1205-1209, 1985.

18. Leaf, A., Weber, P.C., Cardiovascular effects of n-3 fatty acids. The New England Journal of Medicine 318, 549-557, 1988.

19. Simopoulos, A., Omega-3 fatty acids in health and disease. Nutrition and Aging, 129-156, 1990.

20. Kinsella, J.E., Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanisms. American Journal Clinical Nutrition 52, 1-28, 1990.

21. Effects of fish oils and polyunsaturated omega-3 fatty acids in health and disease, U.S. Dept. Of Health and Human Services. Public Health Service, Nat. Inst.. of Health, 1993.

22. Omega-3 polyunsaturated fatty acids in health and disease and in growth and development. The Council for Responsible Nutrition, 1990.

23. Nestel, P.J.,Controlling coronary risk through nutrition. Can. J. Cardiology. 11 Supplement G, 9-14. 1995

24. Prepared Foods, Fast forward into functional foods, 38-48, June 1995