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Polyunsaturated Fatty Acids in Diet and Health

Not all fats make you fat!

The general view is that fats are simply unhealthy, useful at best as a calorie store for hard times, with one purpose only, to keep the body supplied with fuel for energy. This view is not all that wrong since about 80% of ingested fat and the saturated and unsaturated fatty acids it contains are stored in special cells and burnt up as required. However, things are not that simple. There's more to fats than meets the eye, some fats are good for you.

The Fats of Life

Oils and fats are both classed as lipids, substances of vegetable and animal origin that are widely found in nature and form the third major group of macronutrients after proteins and carbohydrates (1,2,3). We ingest them in a wide range of natural and processed foods. The body processes them with the help of specific enzymes and then puts them to work to stimulate and maintain important functions. Basically, fats, fatty acids and their metabolic products have three roles to play. They function as efficient stores of energy, and as protection against cold and other environmental influences.They are important building blocks of the cell membrane, the elastic skin that surrounds and protects every cell. They perform important physiological tasks as precursors of the hormone-like compounds prostaglandins, thromboxanes and leukotrienes (4). These compounds have a number of essential functions in the body and are involved in many physiological processes such as the functioning of the central nervous system, regulation of blood

pressure, the action of other hormones, inflammatory reactions and the immune system's defence mechanisms. Fig 1.

This third group of tasks is performed primarily by polyunsaturated fatty acids, PUFA's. The carbon chains of these important components of oils and fats have, in contrast to saturated and monounsaturated fatty acids, at least two double bonds, a feature that crucially influences their structure and physical and chemical properties.

Two families called PUFA

PUFA's can be divided into two groups, omega-6 and omega-3, which have different physiological functions and effects. The main omega-6 PUFA's are linoleic acid and its metabolites gamma-linolenic (GLA) and arachidonic acid (ARA), occurring particularly in vegetable oils. The main omega-3 PUFA's are alpha-linolenic acid and its metabolites, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are found in green leafy vegetables and in the fat of oily fish such as mackerel, herring, sardines and tuna fish (2,3,5) Table 1.

Table 1. Dietary sources of various fatty acids

Polyunsaturated fatty acid

omega-6

Linoleic acid (18:2 n-6)
Safflower seed (55-81%)
Evening primrose (70-75%)
Sunflower seed (20-75%)
Grape seed (58-78%)
Soybean (44-62%)
Sesame seed (35-50%)
Corn (34-62%)
Cotton seed (33-59%)
Groundnut (13-45%)
Black walnut (~62%)
English walnut (*55%)
Pine nut (~44%)
Black currant (44%)
Borage (38%)
Peanut (29%)
Olive (11%)
Egg yolk (11%)

Gamma-linolenic acid(18:3 n-6)

Borage (~20%)
Black currant (~17-20%)
Evening primrose(~10%)

omega-3

Alpha-linolenic acid (18:3 n-3)
Freshwater fish (1-6%)
Marine fish (~1%)
Linseed (45-60%)
Green leaves (56%)
Rapeseed (10-11%)

Eicosapentaenoic acid(20:5 n-3)

Freshwater fish (5-13%)
Pacific anchovy (18%)
Capelin (codfish) (9%)
Mackerel (8%)
Herring (3-5%)
Sardine (3%)

Docosahexaenoic acid(22:6 n-3)
Sardine (9-13%)
Pacific anchovy (11%)
Mackerel (8%)
Capelin (codfish) (3%)
Herring (2-3%)
Freshwater fish (1-5%)

Note: Values in parentheses represent percent of total fatty acid, Lee (2).

Though the human body is able to produce saturated and monounsaturated fatty acids from food components, it cannot synthesise PUFA's. In other words, it has to be supplied with them externally from specific foodstuffs such as leafy vegetables and fish (6,25) This explains why they

are also called “essential fatty acids”. We cannot function properly without PUFA’s, and a deficiency leads to symptoms such as skin damage, excessive loss of water through the skin, and disturbances of growth and hormonal balance.

The two essential fatty acids linoleic acid (omega-6) and alpha-linolenic acid (omega-3), both of which our bodies obtain from food, are transformed into longer-chain PUFA’s and their derivatives by enzymes (desaturases and elongases). The same enzymes are responsible for metabolising both omega-6 and omega-3 fatty acids. If too much of one PUFA family is taken into the body in the food, metabolism of the other family may be impaired. This can lead to an imbalance in the production of prostaglandins, leukotrienes and thromboxanes, important hormone-like substances which regulate numerous biological processes (2,4,7,8)Fig 1. These substances play a key role in preventing certain diseases and keeping us generally healthy. According to our present state of knowledge, GLA, ARA, EPA and DHA are particularly important physiologically. It is no coincidence that all four of these valuable fats are present in the mother’s milk.

Disease conditions thought linked to omega-3 PUFA are: coronary heart disease, blood lipid disorders, hypertension, atherosclerosis, thrombosis, vasospasm,arthritis, cancer, asthma, autoimmune diseases, inflammatory diseases, peroxisomal diseases and psoriasis.

Omega-6 PUFA’s tend to predominate in our modern diet, leading to an overproduction of metabolites. The situation can be redressed by reducing the amount of calories derived from fat, using vegetable oils and eating more fish. Taking fish-oil capsules containing omega-3 or foods enriched with polyunsaturated fatty acids from the omega-3 family also helps.

Good for the Heart and Circulation

The essential nature of the polyunsaturated fatty acids and their importance in keeping biological processes working was discovered in the late 1920's when Burr and Burr found that linoleic acid counteracted the skin damage caused in rats subjected to a fat-free diet (9). These early observations have been confirmed and expanded in a number of new studies showing that the omega-6 and omega-3 polyunsaturated fatty acids have a variety of beneficial activities in the human body in connection with a wide range of diseases (10).

Bang, Dyerberg and Hjorne, produced epidemiological studies of Eskimos living in Greenland which showed that this population group had an eight times lower chance of dying from cardiovascular disease than Eskimos who emigrate to Denmark. Since all Eskimos belong to a uniform, genetically similar population, this striking difference in the mortality rate is thought to be due to the traditional diet eaten by Eskimos in Greenland which is rich in two omega-3 polyunsaturated fatty acids: EPA and DHA. These PUFA's are found in fish and in the fat of whales and seals.

The presence of DHA and EPA in the diet seems to promote anti-thrombotic processes in the body. The healthy body maintains a fine balance between the tendency of blood to clot and other actions to maintain a health heart and circulation. Studies have suggested that an increased and dangerous prothrombotic tendency can be corrected on an ongoing basis by regularly eating EPA and DHA (11). Furthermore there are reliable indications that the development of cardiac arrhythmias, a complication of heart attacks which are often fatal, are less common in persons with good levels of EPA and DHA than in those with poor levels of these fatty acids (12,13). In

other words, people well supplied with these long chain (LC) PUFA's have a greater chance of surviving and likely preventing a heart attack. Arrthymias are a prime cause of death and new exciting research shows that LC omega-3 fatty acids help maintain a regular heartbeat and may reduce fatal heart attacks (14). There is further new research in the the cardiovascular area suggesting that omega-3 PUFA may have a role in reducing blood pressure (15,16), hypertension (17), lowering triglycerides (18) and may prevent restenosis following angioplasty (19).

Why DHA is so Important for Babies

The positive clinical data on the nutritional importance of polyunsaturated fatty acids in babies continues to build and points up the critical importance of LC PUFA for optimal development (20). The unborn child needs an adequate supply of DHA if the grey matter in its brain and the tissue and cell membranes of the retina are to develop fully and properly (21,22). For this reason, the necessary amount of DHA is provided through the mother's placenta during pregnancy particularly in the third trimester where it accumulates in the brain and retina of the fetus. Premature babies are affected particularly badly by DHA deficiency because they miss the vital phase before birth when DHA is supplied and when infant enzyme systems are not able to synthesise enough of this PUFA to ensure the normal development of the brain and retina (23-27). However, DHA (like all the other PUFA's in the omega-3 and omega-6 families) is also present in the mother's milk and provided by nature since the development of the brain and eye are not completed until many weeks after birth (27,28). It has been shown that sight develops normally, as in breast-fed babies if premature babies, are given an infant formula enriched with DHA. The addition of arachidonic acid (ARA) an omega-6 fatty acid and DHA to formulas is now widely recommended by world authorities and formula manufacturers are including these PUFA's in

products (29,30). The exception is the United States and Canada where the addition of these essential nutrients does not occur, but is currently under review.

New Areas of Exploration

The positive evidence for contribution of PUFA's towards preventing eczema, rheumatoid arthritis, restenosis and diabetes justifies further studies. Eczema and rheumatoid arthritis, for instance, each have an inflammatory component, a feature that might explain the positive effects. PUFA's are precursors of the prostaglandins, leukotrienes and thromboxanes, which play an important role in inflammatory processes. A possible exception is atomic dermatitis. This eczematous skin disease is known to be triggered by a complete or partial lack of desaturase enzyme, which leads to deficiency of gamma-linolenic acid. Selective administration of gamma linolenic acid (GLA) rich oils obtained from evening primrose or borage oil can relieve the symptoms. Research results presented at a recent International Conference on Highly Unsaturated PUFA in Barcelona showed positive results in treating severe diaper rash with topical applications of GLA type creams containing 40% borage oil.

Neurological and Peroxisomal Disorders are also thought to have a link to PUFA's. A recent hypothesis argues that depression may be caused by deficiencies of omega-3 fatty acids (31,32). Further, the development of aggressive behaviours appears linked to low dietary intake of PUFA (33). Finally certain peroxisomal diseases such as Zellweger Syndrome and ALD can be ameliorated through the use of various fatty acids (34). This emerging area of research holds promise in treating these conditions and results with disabled infants are encouraging.

Arthritis Sufferers May Now Have a New Weapon

Rheumatoid arthritis is a widespread disease particularly affecting old people with stiffness and painful tender joints as the primary symptoms. Since omega-3 fatty acids affects the immune

system, treatments with fish oils containing EPA and DHA have been reported in the literature. A recent meta analysis of 10 trials showed that fish oil supplementation for three months significantly reduced tender joints and morning stiffness as compared to controls (35). Modest clinical improvement is seen in 12 weeks. The benefits are that fish oils have few if any side effects. They are non steroidal and unlike, aspirin which is commonly used, do not cause gastro-intestinal upset or bleeding. Further studies are needed to fully establish a place in treatments but a reduction in current medication or as a combined treatment with anti-inflammatory drugs seems possible (12).

Eating for Health

Eating wisely and for health is still difficult in our prosperous, late-twentieth-century society. Over the last decades, our lifestyle and dietary habits have changed considerably. We eat too much saturated (bad) fat and too little unsaturated (good) fat. Our diet, which used to contain the right proportions of various fats and fatty acids such as omega-3 and omega-6 PUFA's, has become unbalanced (36,37). Our bodies have not been able to keep up with the rapid change in diet and the associated dramatic shift in the balance of fats. We basically still have the organism and metabolism of stone-age man.

In prehistoric times early man had a diet of roughly equal portions of omega-3 and omega-6 fatty acids (38). Most experts agree we should consume a ratio of between 5:1-10:1 of omega-6 to omega-3 in our diet (4,39). This balance is recommended by nutrition authorities to be more ideal . It may also explain why the modern diseases such as cardiovascular disease, arthritis, skin disorders, asthma and possibly cancers have increased in the last two centuries (35) Chart 1. Our genetic make-up simply cannot respond fast enough to this about-turn in diet. In the past, for example, we used to eat considerably more fruit and fresh leafy vegetables. Our diet has gradually

come to include more meat and more calories. Moreover, the meat and fat from artificially fattened animals has a completely different composition of fatty acids than meat from animals in the wild. The high-energy protein feed given to commercially farmed animals contains a higher proportion of linoleic acid which leads to a shift in the fatty acid profile of farmed animals' meat and fat (12,40). This, coupled with the widespread use of vegetable oils rich in linoleic acid, such as sunflower, corn and safflower oil, have resulted in a modern diet containing a large excess of omega-6 fatty acids. PUFA's from the omega-3 family, on the other hand, are often under-represented in the modern western diet (4).

Recent examples of dietary change exist as well. Japan is a particularly striking example of this fateful trend. While the Japanese were still eating their traditional diet low in both fat and meat, the population had very few problems with cardiovascular diseases. During the 1960s, however, the Japanese diet began to copy the western example. Nowadays, diseases such as high blood pressure, thrombosis, arteriosclerosis and heart attacks, all of which are due at least in part to an unhealthy diet, are at the top of the statistics as causes of mortality.

In short, we need to adjust our eating habits more to our real physiological needs. We need to go back to a diet in which fish, fresh fruit and vegetables play a greater role and animal fats play a minor role. We need to make a deliberate effort to eat omega-3 PUFA's rather than omega-6 PUFA's. If we ate enough fish, we would automatically get enough omega-3 PUFA's. Nutritionists recommend eating between 30 and 60 grams daily of the right kind of oily fish to supply our needs. This, of course, is easier said than done. Fish is expensive and not to everyone's taste.

However there is now a new way of supplying these polyunsaturated fatty acids - by adding them to everyday foods such as bread, margarine and milk drinks. Today fish oils can be incorporated into foods without giving them an unpleasant taste. This is an easy and effective way of making up for the deficiency of omega-3 PUFA's that has developed over the centuries. There is no need for people to change their eating habits or the types of fat they consume since the nutritional value of their food is improved.

So How Do We Put Fish Into Bread?

Food technology has now advanced to the point where, in theory, any product with an oily or fatty component can be enriched with omega-3 polyunsaturated fatty acids. These include spreads, margarine, butter, mayonnaise and salad sauces, and bread, biscuits and cakes. Some of these PUFA-enriched products are already marketed in the UK, Korea and the Far East and European countries. Methods of incorporating PUFA in products such as milk-drinks, yoghurt and ice cream are currently being developed and promising solutions appear to be in sight.

A survey conducted in Great Britain in 1993 even revealed that, while 70% of the men and women questioned knew that the consumption of oil-rich fish such as mackerel and herring helped guard against cardiovascular disease, few interviewees regularly ate fish. Also the idea of a yoghurt containing 1% fish oil is not particularly attractive. This negative attitude of the average consumer needs to be overcome and awareness raised about consuming polyunsaturated omega-3 fatty acids, as something positive for health. Food producers also require education and guidance. They want to hear rational science based arguments explaining why and how they could change their product formulations. Above all, they need to be made aware of the opportunity for developing "nutraceutical" type foods enriched with PUFA.

A Promising Future for Unsaturated Fatty Acids

Food, glorious food!

Today a wide range of PUFA products in oil and powder form are available for various applications under the tradenamed “Ropufa” from Hoffmann La Roche The powdered forms are used mainly in dry goods such as bakery products and milk powder. The micro-encapsulated powder is produced using a special process. They are dispersible in cold water and are exceptionally stable. These properties, together with a neutral taste and odour, make Ropufa '30' omega-3 EPA Oil and Ropufa '10' omega-3 EPA Powder, ideal for enriching foods such as margarine, reduced-fat products, milk drinks, yoghurts, salad dressings, mayonnaise, orange juice drinks and bread. A number of special products are available for specific fields such as paediatric nutrition; these products are rich in docosahexaenoic acid, the essential omega-3 fatty acid needed to ensure optimum development in children. Arachidonic oil and powder are also available.

Special Refining and Quality Assurance Means Bland Fish Oils

Product of these special types of products is not simple. The quality of the incoming raw oils, the individual manufacturing stages and the resulting refined products from the omega-3 and omega-6 families) are all part of the program to produce odor free oils and powders. The products are tested to evaluate the colour, appearance, organoleptic profiles and the elimination of any unwanted impurities.Finally the novel refined oil is protected with a powerful antioxidant system to prevent further oxidation to peroxides or aldehydes which may cause off-flavors. The shelf stability of the finished ingredients is good with 12-18 months stability in original unopened containers Chart 2.

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