Misconceptions About Nutritional Properties of Fish Oils

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INTRODUCTION

This chapter is presented as an introduction to this section of the book and with the aim to dispel certain possible misconceptions concerning fish oil nutritional properties. Fish oils contain a far wider spectrum of fatty acids than do other natural lipid sources (see Chapter 1). Just as ingested proteins require for maximum nutritional value a good balance of essential amino acids, in an analogous way lipids should contain a good balance of fatty acids which serve some useful function. Unfortunately our present stage of knowledge is incomplete with respect to which of the many fatty acids do perform useful functions under various states of normal and pathological conditions.

There are, however, indications that some fatty acids, not necessarily restricted to classical essential fatty acids (linoleic acid family), may perform such useful functions. For example, members of the linolenic acid family of fatty acids which occur in considerable proportions in fish oils both support growth and markedly lower serum cholesterol levels. On the other hand, presence of highly polyunsaturated fatty acids in fish oils has raised questions as to whether potentially undesirable effects may occur which stem from autoxidation leading both to the presence during oxidation of free radicals and to formation of certain oxidative intermediate and end-products. Some of these ideas will be examined briefly in this chapter.

HISTORICAL NOMENCLATURE DEVELOPMENT

Early research on essential fatty acids (EFA) overemphasized the curing of dermal symptoms even though recognizing that fatty acids of what are today described as of both the linoleic and of the linolenic acid families support growth. Knowledge of effects such as that on permeable membranes and cholesterol transport were completely lacking when EFA activity was first investigated. Since curing of dermal symptoms provided a specific assay procedure, the term EFA became linked more specifically to that aspect than to other effects of perhaps greater significance. Thus fatty acids of the linoleic acid family are now the only ones generally classified as having true EFA properties. If other effects, e.g., cholesterol depressant properties, had been discovered before dermal symptom curing properties, it is likely that we might today have a somewhat different concept of what constitutes an EFA. Certainly from a practical nutritional standpoint, support of growth and even probably cholesterol depressant effects have greater practical importance than do the curing of dermal symptoms. These facts are often overlooked and it is not uncommon to find statements expressing surprise that fish oils, low in classical EFA content, are useful in stimulating growth or in depressing serum cholesterol levels.

Another way in which the historical development of nomenclature has reflected adversely on ideas concerning nutritive value of fish oils relates to the use of the term "polyunsaturates." This term, classifying all fatty acids with two or more double bonds per molecule together has tended to mask the fact that there is a marked difference in degree and type of polyunsaturation. Most vegetable oils contain a high percentage of dienes (primarily linoleic acid) sometimes exceeding 50%. Particularly with respect to effects on serum cholesterol levels, the widespread usage of the term polyunsaturates without consideration of degree or type of polyunsaturation tends to oversimplify the situation and thereby confuses the issue. Furthermore as has been pointed out by Bloch (1964), it is the fatty acids with three or more double bonds which possess multifunctional properties and hence are of greatest biochemical interest.

Development of these commonly used terms occurred when lipid research was restricted quite largely to the less complex animal and vegetable fats and oils. In such context, terms like EFA and polyunsaturates used in their limited sense resulted only to a minor extent in erroneous interpretation of their significance to nutritional applications. Now that research on the much more complex fish oils is getting under way and some small attention focused upon them, we find that these limited and imperfectly understood terms sometimes lead to misconceptions. Considering only the classical EFA content, limited to fatty acids of the linoleic acid family, one might predict fish oils to possess far less growth-promoting fatty acid content than tallow. An actual comparison of total growth-promoting fatty acid content (linolenic plus linoleic acid family fatty acids), however, shows fish oil to contain far more of these growth stimulants (see Chapter 24). Likewise, comparison of vegetable and fish oil polyunsaturate content would, if used as sole criteria, indicate the former to possess far greater cholesterol depressant activity when actually fish oils possess such activity to a greater extent.

OXIDATIVE PROPERTIES OF FISH OIL POLYUNSATURATES

Because of the high degree of polyunsaturation of fish oil fatty acids, there is a potential for several adverse nutritional effects to develop. Accumulation of peroxides in large quantities *per se* may result in toxicity

(Andrews *et al.* 1960), presence of free radicals may cause alteration in protein quality (Roubal 1966), presence of high quantities of polyunsaturates in the diet under certain conditions cause undesirable effects such as growth retardation (Oldfield *et al.* 1963), and assimulation of polyunsaturates into the flesh of poultry which may cause development of undesirable flavors in the meat (Hardin *et al.* 1964). All of these effects may also be caused by consumption of unsaturated vegetable oils—e.g., the production of fishy flavor in the meat of poultry (Klose *et al.* 1951). With the greater quantity of natural antioxidants present in vegetable oils these effects are often less pronounced. The point has sometimes also been raised as to whether due to oxidative deterioration, an appreciable portion of the polyunsaturates may be altered or destroyed so as definitely to diminish their potential desirable nutritive properties.

These are all only potential effects. Whether or not they develop depends to a very large extent upon circumstances and the purpose for which this section is intended is to explore these circumstances.

The most important factor influencing the degree to which these potential alterations may develop is the degree and extent to which the polyunsaturates oxidize. This in turn is largely controlled by the use to which the oil is put.

Oils in Food for Human Consumption

Fresh Fish.—In fresh, unfrozen fish, the oil ordinarily oxidizes not at all or at the most to a very slight extent up until the time it becomes inedible from spoilage or other causes. This stability of the oil is dependent partly upon the fact that fresh fish, being highly perishable, is held at temperatures close to 0°C. and even so the storage life is limited to a very short period of days. The effect of low temperature and short storage time in any case does not permit extensive oxidation to take place. Of greater importance, however, is the effect cited by Stansby (1963) wherein there seems to be a competition for oxygen between bacteria and lipids such that the rate of oxidation of lipids is greatly repressed whenever aerobic bacterial spoilage is taking place. This results in the ordinary situation in peroxide values being in the range of 0 to 2, never ordinarily above 5 or at the most 10, in the lipid of fish oils in such fish up to the time when flavor alteration makes the fish of unacceptable quality. At such low levels of oxidation the peroxides are ordinarily at less than one per cent of the levels where they will *per se* cause any problems and free radical formation is far too low to cause any measurable alteration in protein quality. Other undesirable effects are also imperceptible.

Preserved Fish.—In frozen fish, storage temperatures are much less than in unfrozen, refrigerated fish but this desirable factor is more than offset by the fact that bacterial action is arrested making fully available to the lipid any oxygen present. Usually the fish is stored in partially oxygen-impenetrable packaging, limiting access to air. Nevertheless, oxidation of oil in frozen fish after several months of storage generally somewhat exceeds that occurring in unfrozen fish. The levels of oxidation reached, however, are still very small with maximum peroxide numbers generally in the range of 5 to 10 with extreme values up to 25 occuring only with excessive storage periods well in excess of a year which rarely occur. Even these degrees of oxidation are far below levels required for any appreciable adverse nutritional effects.

Canned fish, being stored in a vacuum, does not permit oxidation of the lipid so that no adverse changes take place.

Fish preserved by curing processes such as salting, smoking, and pickling are held at room temperature sometimes with fairly free access to air. When any of these products are stored for extensive period of time, increasing degrees of oxidation occur. Although peroxide levels can become higher in the oil of these types of products than in the others considered above, a built-in safety factor limiting consumption of excessively oxidized products is the flavor. Flavor alteration starts at very low levels of oxidation such that even in fresh fish with peroxide numbers in the range of 0 to 2 (and resulting carbonyl content—actual cause of the flavors—at almost indeterminable levels) a pronounced, perhaps unpleasant, flavor may be apparent. Long before oxidation reaches levels where undesirable nutritional properties would occur, the flavor has become so objectionable at least to the average taste in Western countries that the fish would never be eaten.

The question of whether the mere presence of highly polyunsaturated fatty acids from fish in human diets may result in adverse effects, even though no oxidation has taken place, remains to be considered. These effects, e.g., depression in growth and such conditions as encephalomacia have been observed only in farm animals or poultry in which fish oils have been used for long periods of time as a significant part of the daily diet and usually then only in the absence of adequate amounts of tocopherol. Animals living in a captive state may, in such cases, utilize fish oil as a constant portion, sometimes at a relatively high level, of their diet which then may bring about these adverse effects. Failure to ever note such conditions in humans doubtlessly is due to the far lower content of the total diet which fish plays. Even in countries such as Japan where fish may be a major source of animal protein and where Imaichi *et al.* (1965) have shown that human depot fat may contain significant proportions of typical C_{22} polyunsaturated fish oil fatty acids, there have been no indications of adverse effects of inclusion of these high levels of fish in the diet.

Stability of Fish Oil Polyunsaturation in Human Food.—The common processing methods used in preserving fish do not cause breakdown in the polyunsaturates. Thus Roubal (1963) was unable to detect any change in fatty acid content of tuna between the raw and uncooked state or after canning. The degree of oxidation present in refrigerated or otherwise preserved fish is so low that there is ordinarily no measurable change in degree of unsaturation as estimated by iodine number and there is no evidence for alteration in fatty acid content.

Summary.—In summary, the oil in the flesh of fish used for human consumption does not cause adverse nutritional problems. This is true whether the fish is freshly caught, or has been preserved. The lack of such changes is due, on the one hand, to the very slight degree of oxidation which occurs before flavor alteration renders the fish unfit for consumption, and, on the other hand, to the relatively low levels at which fish are used in human diets as compared to higher levels sometimes used with farm animals.

OILS IN FEED OF ANIMALS

Since the topic of nutritional effects of fish oils in the diet of animals is treated extensively in Chapter 24, it will be touched upon only briefly here.

Fish oil is fed to animals largely in the form of oil present in fish meal with the practice of adding fish oil as a feed supplement currently much less common than when fish-liver oils were the principal sources of vitamins A and D. During and immediately after the manufacture of fish meal, rapid, active oxidation of fish oil left in the meal takes place. This oxidation, probably by action of free radicals produced, causes some reduction in protein quality (Roubal 1966), but the loss cannot be severe as shown by the considerable literature on the superior protein quality of fish meal as well as the extensive commercial use of fish meal as a supplement to vegetable proteins.

The use of fish oils in the diets of animals and poultry is accompanied by several problems. Only as a result of relatively recent research are we reaching a point where these problems can be intelligently met. Fishy flavor may be imparted to the meat of animals fed excessive quantities of fish oil, but our present knowledge of limiting quantities to safe levels now permits control of this problem. Knowledge of the importance of the use of adequate antioxidants in farm animal diets (Oldfield *et al.* 1963) is beginning to solve problems formerly critical with respect to adverse effects caused by the polyunsaturates *per se*. The fact that fish oils while containing only small quantities of classical essential fatty acids are very high in growth-promoting fatty acids of the linolenic acid family is only recently being appreciated. Greater detail on these and other matters related to utilization of fish oils by animals, and in metabolism, will be found in Chapters 21 to 24.

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