13 Where Will Future LC-Omega-3 Come From? Towards Nutritional Sustainability

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Key Points

- Dietary recommendations for LC-omega-3 are highly variable.
- Estimates of current consumption are also variable, and uncertain.
- Intakes are always well below targets. Most should eat much more.
- Inadequate LC-omega-3 is today's greatest unrecognized deficiency disease.
- Shortages will become worse as global population grows.
- Challenge is to close the gap with nutrition policies.
- Concept of the Nutrition Policy Gap.
- Four principal sources of LC-omega-3: fish, plants, foods, supplements.
- Capture fish are already at limits. Some waste reduction is possible.
- Aquaculture is growing, but insufficiently to close gap.
- DHA from marine plants, algae, could expand greatly, but it is expensive.
- GM land plants also have large potential, but are controversial.
- Processed foods fortified with LC-omega-3 are common, but are niche products.
- LC-omega-3 supplements are popular, but are mainly private purchases.
- Potential distribution via public health systems for vulnerable.
- Combining all sources, adequate supplies are possible.
- Many technical, economic, and political issues lie ahead.
- Reduce omega-6 as well as increase LC-omega-3.
- Closing gap will be a long-term process. Rationing is inevitable.
- Sustainable political commitment as well as sustainable supplies.
- Pragmatic incrementalism is the likely outcome.

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INTRODUCTION

> We have had enough scientific conferences on LC-Omega-3.
> What we need is action.
>
> Michael Crawford
> 2011 Global Omega-3 Summit

Concepts of "sustainability" vary with context. For long chain (LC)-omega-3, "nutritional sustainability" is an appropriate goal: to attain and retain healthy nutrition status—for individuals, groups, nations, the world. Thus, one relevant definition of sustainability for these nutrients is as follows: Securing regular supplies of LC-omega-3 sufficient to meet the nutritional needs of the global population.

Seeing the problem in this way immediately raises two questions: (1) how much do we need? and (2) where will it come from?

The response here is to describe rather than prescribe. The purpose is not to advocate one approach to nutritional sustainability. Rather, this chapter identifies issues and sets out options for dealing with them, because hard choices lie ahead if we are to overcome the present widespread deficiency.

DIETARY RECOMMENDATIONS

A list of current recommendations for the daily intake of combined DHA/EPA appears in Table 13.1, an illustrative selection from large records maintained by the International Society for the Study of Fatty Acids and Lipids (ISSFAL) and the Global Organization for EPA and DHA (GOED), plus some recent additions. Clearly, views diverge on how much LC-omega-3 people should eat. That is the point of the table, to show the extreme variability in the targets, all set by scientific committees of various sorts. Recommendations differ by a factor of 5.5.

Several reasons lie behind the differences. Honest experts may honestly disagree. Some targets were set by specialists in lipids; others by generalist nutritionists. Some recommendations focus on physical health, usually cardiovascular, to the exclusion of mental health. Others derive the LC-omega-3 recommendation from a recommendation for fish, using a conversion factor based on a weighted calculation from the nutrient profiles of the species commonly consumed.

There are also differences in the "strategy of dietary recommendations": what the recommenders seek to achieve (1). Some forswear any attempt to set targets for what the human animal actually needs ("ideal" targets). They would be so distant from

Table 13.1
Selected daily dietary recommendations for EPA + DHA

Nation/organization	*Amounts (mg/day)*
Norway	1,100
Canada	1,100
NATO	800
Belgium	650
France	500
ISSFAL	500
Australia	500
UK	450
FAO	250
EFSA	250
Netherlands	200
USA	200
Average	*566*
Variation	*5.5×*

NATO North Atlantic Treaty Organization, *ISSFAL* International Society for the Study of Fatty Acids and Lipids, *UK* United Kingdom, *FAO* Food and Agriculture Organization of the United Nations, *EFSA* European Food Safety Authority, *USA* United States of America

present intakes that they would seem impossible for ordinary consumers to achieve. They would be so daunting, many would not even try. Ideal targets of fish consumption might seem like recommendations for another species—bears and ospreys might eat that much fish, but surely not us humans!

Instead, such nutrition experts set "feasible" targets, levels that they think might actually be eaten in the societies for which they are making recommendations. For example, the official UK advice for fish/LC-omega-3 acknowledged explicitly that "this recommendation represents a minimal and achievable average population goal and does not correspond to the level of fish consumption required for maximum nutritional benefit" (2).

Further, there are differences in the evidence on which recommendations are based. For most, randomized controlled trials are the only acceptable source. However, associations between food consumption and public health produce different targets. For example, Hibbeln uses epidemiological data to recommend at least 900 mg/day as an average population goal (3).

Despite their differences, all recommendations are high compared to present intakes. Most people in most countries consume too little. This gives "sustainability" in the case of LC-omega-3 an unusual meaning. In many contexts, sustainability means stopping the current situation from getting worse. With LC-omega-3, the need is for radical improvement. For these nutrients, sustainability is not about maintaining, but multiplying.

There is an important addition to the story that both complicates and assists in achieving desirable intakes. One of the recurrent agreements at the conference was that the effectiveness of LC-omega-3 is compromized by the presence of the omega-6 fat, linoleic acid (LA). The reason, in simplest form, is that in human metabolism they

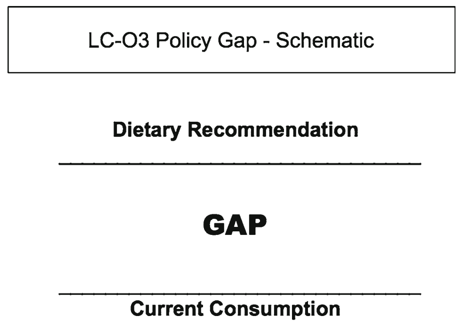

Fig. 13.1. The LC-omega-3 policy gap showing how dietary recommendations are higher than current consumption.

compete for the same enzymes, and LA wins. Hence, whatever amount of LC-omega-3 consumers eat, the benefits they receive are reduced. To overcome this, dietary recommendations for LC-omega-3 should take account of the background level of LA in a society. Dietary requirements for EPA and DHA could vary as much as 13-fold as a result, depending on the mix of fats commonly used (3).

One implication is that dietary recommendations for LC-omega-3 should be made on a national basis, rather than on a one-size-fits-all approach grounded in human biology. It also has important implications for policy, opening up a two-pronged approach: reducing omega-6 consumption as well as increasing LC-omega-3.

LC-omega-3 is thus a complex example of the basic nutrition policy problem, represented schematically in Fig. 13.1.

Between present intakes and desirable consumption there is a gap. The size of the gap varies between countries. For Japan, one of the largest consumers of fish, it is relatively small. In most other societies, the shortfall is much greater. The larger the gap, the more demanding is the challenge to close it, the more vigorous are the policy initiatives required.[1]

That is the theory of it. In practice, the scale of change required also depends on the level of current consumption, which again varies greatly and uncertainly between countries.

CURRENT CONSUMPTION

Discovering how much LC-omega-3 people eat is difficult. In the dietary surveys of many countries, reported fat intakes are not subdivided into the constituent fatty acids. So, consumption estimates are sometimes derived by calculating the LC-omega-3 contained in foods, especially in the densest source, fish. But that does not help a great deal.

[1] This version of the Nutrition Policy Gap diagram presents it in a way relevant to LC-omega-3. That is, current consumption is below recommended levels, indicating that intakes need to be raised. This is also appropriate for representing micronutrient deficiencies in developing countries. But in the developed world most people suffer nutritional problems of excess rather than shortage. In particular, they consume too much fat, sugar, and salt. For that context, the diagram would be reversed, that is, to show that current consumption is above recommended levels, indicating that intakes need to be reduced. There is still a gap, but the desirable change is in the opposite direction.

The state government of California recently found 29 estimates of national and regional fish consumption in circulation, based on four methods, producing very different results (4). The two most common approaches—dietary surveys and supplies available for consumption—both have serious problems.

Dietary Surveys

There are many complex issues with survey techniques, but the most important is that all current methods rely on subjects telling the researchers honestly what they eat. That is, they all depend on self-report data.

But when you ask people what they eat, what you get back is lies. Most people claim to eat a healthier diet than they actually do, less in volume and a more nutritious mix. In nutritional jargon, this long-standing and universal problem is known as "under-reporting." In plain English, it is hypocrisy, false claims to virtue. These are not malicious deceits, they are the common lies that most people tell on most days: We put our best foot forward or show ourselves in the best possible light. Nonetheless, they are large lies. From double-labeled water analysis (DLW), we can assess the scale of misreporting. Adults in the UK, on average, claim to eat 25% fewer calories than they really consume (5), adolescents 34% less (6). But DLW cannot determine which foods are not being reported accurately; so post hoc correction is not possible, for fish or any other items.

These inaccuracies have a particular irony for fish. What is conventionally described as "under-reporting" is more correctly called "misreporting" or "net under-reporting." Some foods, perceived to be "healthy," like fruit and vegetables, are actually over-reported. People claim to eat more than they really do. Given its positive reputation, fish may be one of these. So, dietary survey data on fish consumption may *over-estimate* actual intakes. If so, and how much, are at present impossible to know.

However, research is actively underway to develop biomarkers that accurately measure how much people eat of both LC-omega-3 and oily fish ("intake biomarkers").[2] Results are promising. But it will still be some time before these can be converted into practical tools, inexpensive enough to be used in large-scale surveys that would provide good estimates of national consumption levels.

Supplies Available for Consumption

These figures are calculated by adding domestic fish production and imports, then deducting exports, and adjusting for any changes in stocks. In a bit of technical jargon that confuses more than it illuminates, such estimates are sometimes known as "disappearance data." Whatever they are called, they are not a direct measure of consumption, but of how much fish is on the market—what the population could eat, not what it actually eats. This is why some estimates of this sort refer to "apparent" fish consumption.

They contain inaccuracies in both directions. Some production and imports are left out because they are landed illegally. Further, the output of many small and inland

[2] For a systematic assessment of several options for biomarkers, of both LC-Omega-3 and oily fish, see The FISH Study, a joint research project by MRC Human Nutrition Research in Cambridge and the University of Southampton. Final report in preparation.

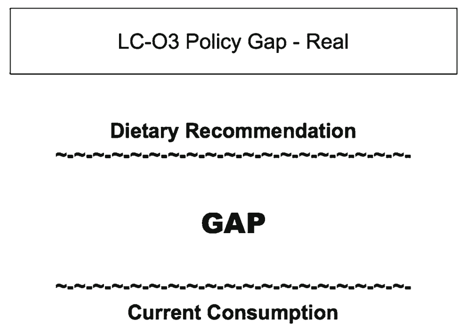

Fig. 13.2. A more realistic representation of the LC-omega-3 policy gap, with the *wavy lines* depicting variability in dietary recommendations vs. actual consumption.

fisheries is simply overlooked. So too, some “sport” fishing. In the opposite direction, some parts of fish are inedible—roughly half of all finfish, for example. Furthermore, the figures do not account for wastage along the food chain en route to consumers’ stomachs. In the UK, supplies available for consumption are estimated at 150 g/person/week; actual intakes at 50 g/person/week. That is, two-thirds of fish apparently disappears, if you believe official figures. In fact, both numbers mislead.

Recognizing the variability and uncertainties involved with both dietary recommendations and consumption estimates, it becomes clear that the schematic diagram in Fig. 13.1 is too tidy to represent the real world. The fuzziness of the figures is better depicted in an amended version (Fig. 13.2).

The irregular lines indicate that we are not able, for the present, to agree on numbers for either recommended or actual intakes. The direction of desirable change is clear, but we cannot measure the gap with precision. The best we can conclude is that we are now eating much too little and that we ought to eat much more. Compared with the conclusions of other chapters in this book, such a statement may seem skimpy, not to say unscientific. In fact, it is a rigorous conclusion—as rigorous as a strict examination of the currently available data allows.

Saying that people are eating much too little of a nutrient is, in the formal language of nutrition, saying that people are malnourished. And malnutrition is a subject of serious international policy attention, particularly in nutrition initiatives for developing countries. But that attention concentrates on the so-called “big four” deficiencies: iron, iodine, vitamin A, and zinc.

Outside scientific conferences, the widespread inadequate intakes of LC-omega-3 are not commonly recognized. Non-specialists, even those in seemingly relevant organizations, often have an incomplete understanding of the nutritional complexity of fish, particularly of its unique cluster of brain-specific nutrients, including trace elements as well as LC-omega 3. They see fish simply as a source of protein.

Several anecdotes were reported at the 2011 Global Omega-3 Summit conference expressing this narrow view by officials of well-known organizations with responsibilities for food. One extremist said he was not concerned about declining fish stocks, because there were many other sources of protein. As a result of such disregard, inadequate intake of LC-omega-3 is the greatest unrecognized deficiency disease in the world today.

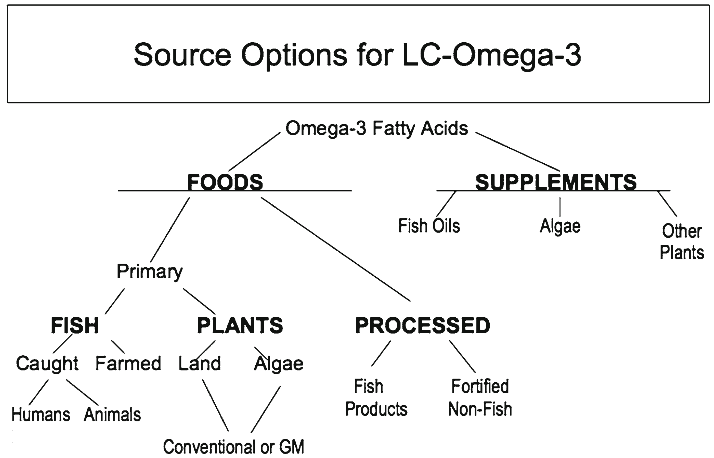

Fig. 13.3. Sources of LC-omega-3s divided into food sources (fish, plant and processed foods) and nutritional supplements.

Intellectual neglect has practical consequences. Policy makers must first be persuaded there is a problem with LC-omega-3. Only then will possible solutions get a hearing.

POLICY OPTIONS FOR PROVISION

The principal options for providing the global population with the multiplied levels of LC-omega-3 they need, on a sustainable basis, are set out in Fig. 13.3.

They are grouped under four headings: fish, plants, processed foods, and supplements. The following sections work through them systematically, from left to right, starting with the consensus-preferred option.

Fish: Finfish and Shellfish

Virtually all specialists agree that the best source of LC-omega-3 is fish, especially oily fish that contain the highest concentrations of DHA, and especially wild caught fish. But are there enough fish in the sea to provide the amounts we need? No.

They are not adequate now and unlikely to become so. Thurstan and Roberts summarize the recent history. "On a global scale, availability of wild fish per capita has been in decline since 1970. Per capita availability today is 20% less than recommended consumption levels."[3]

For the future, the Food and Agriculture Organization (FAO) has summarized the prospects candidly. "Levels of captures of fish in the wild have remained roughly stable since the mid-1980s…There is little chance of any significant increases in catches beyond these levels…This leveling off, coupled with a growing world population and increasing per capita demand for fish, spells trouble" (7).

[3] Personal communication from Thurstan R, Roberts C, based on, Health recommendations and global fish availability: are there enough fish to go around? University of York. Final report in preparation.

"Trouble" means that the total global catch will remain insufficient to provide all people in the world with the average amount of fish consumption recommended by those national authorities that have set targets, about 260 g/person/week. Attempting to increase it would be counterproductive. Raising takes would reduce stocks, plundering the future to provide for the present—unsustainability incarnate.

One reaction to this fact is nutritional capitulation—adjust dietary recommendations to available supplies, rather than the other way around. Gripped by the chronic local melancholia, a UK Parliamentary committee concluded, "…the state of many fish stocks is a serious cause for concern. DEFRA, the Department of Health and the Food Standards Agency, should consider the wisdom of continuing to advise consumers to eat at least two portions of fish a week at a time when the ability of the marine environment to meet this demand is questionable" (8). Eat less fish!

More positive responses are possible. First, the *net* supply of capture fish available for consumption could increase substantially if present high levels of wastage were reduced. There are many reasons why edible fish are not eaten. In Tunisia, the lack of cold storage leads to high levels of spoilage. In Oman, the problem is the lack of a wholesale market to aggregate, store, and redistribute supplies. As a result, these countries, both with long coastlines, catch less than half what they easily could. Their citizens eat an even smaller portion.

Europe has a different problem—discards at sea to keep within quotas. The official estimate is that 23% of all fish caught by European Union (EU) countries, and half of all whitefish, is dumped dead back into the water (9). The reform of the Common Fisheries Policy, initiated in 2011, proposes a total ban on discards.

Second, we could "catch more by fishing less." That is, if we took less fish for a while, fish stocks would grow back to sustainable levels, then catches could actually increase. This option is vividly illustrated by balancing UK fish landings against the national recommendation for fish consumption—takes vs. targets (Fig. 13.4).[4]

The British recommendation of 280 g/week is middling by international standards. Yet only twice in the twentieth century has total fish availability been sufficient to meet even this modest aspiration. Both periods occurred immediately after World Wars, during which normal fishing had been suspended, allowing stocks to recover. Globally, Roberts estimates that "taking a sustainable proportion of fish through improved ocean management would lead to a 30–40% increase in fish supplies" (10).

In summary, considerable expansion in the availability of caught fish to consumers is possible. But eliminating waste and restoring stocks are major policy challenges, and our track record provides no grounds for optimism. Even if we succeed, the increase in accessible supplies would not be on a scale sufficient to meet nutritional needs. Other sources of fish will be needed.

At present, some 20% of the total global catch is used to produce fishmeal and fish oil. This is largely from the fish caught off the west coast of South America, the pelagic species that live near the ocean surface. They are small and bony, not universally popular with humans, so they were long used to feed North American pigs. Currently, much goes into feed pellets and flakes for farmed fish, mainly salmon (11).

[4]Personal communication from Thurstan R, Roberts C, based on, Health recommendations and global fish availability: are there enough fish to go around? Figure 2a. University of York. Final report in preparation.

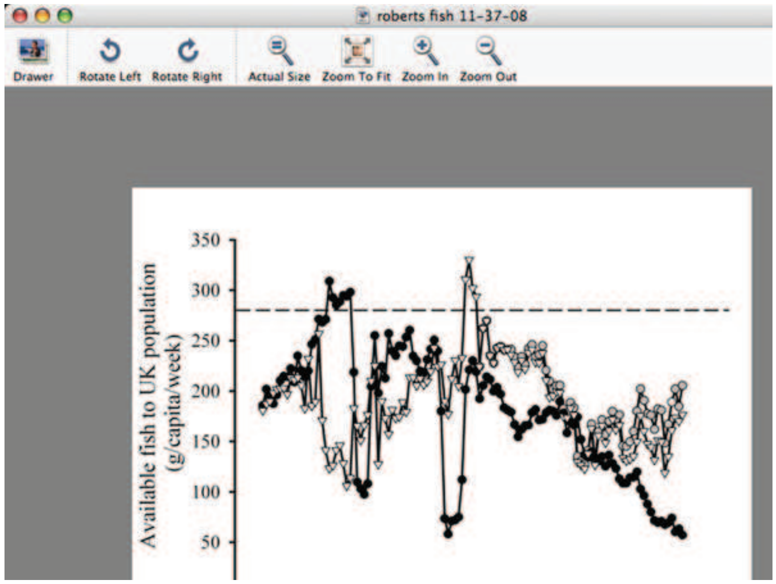

Fig. 13.4. Fish available (g/capita/week) on an annual basis in the UK. *Closed circles* show fish available from capture fisheries after processing. *Open triangles* show fish available when imports minus exports are included, *open circles* when aquaculture is added to the latter. The *dashed line* shows the amount of fish consumption recommended by the Food Standards Agency. Figure courtesy of Thurstan R and Roberts C, University of York.

Much of this could be diverted to direct human consumption in the forms of fish oil as a food additive and as nutrition supplements. Increasing amounts already are. But there are swings-and-roundabouts to such a change. It would curtail the supply of LC-omega-3 to farmed salmon that, in turn, pass it on as a popular source of LC-omega-3 for humans.

The limits on growth from capture fish indicate that any large expansion in fish supply will have to come from aquaculture. Fish farming is overwhelmingly concentrated in Asia, especially strong in shellfish and herbivorous finfish. Europe and North America are minor players in the global industry, but are important for the carnivorous oily fish that are good sources of LC-omega-3: salmon and trout, sea bass, and bream.

But salmon farming is already pressing against the bounds of sustainability. As traditionally practiced, it effectively depended on feeding fish to fish, the caught pelagics to the caged salmon. However, the catch of pelagics is already at its maximum and is unlikely to rise. A shortage of fish oils is probable (12), so any substantial expansion of oily fish aquaculture is constrained by the feed supply. Hence, the search is on for alternative routes to growth.

One alternative came to public attention in 2011, with the proposed approval in the USA of a genetically modified (GM) salmon that grows more rapidly and hence consumes less feed. Predictably, the decision was controversial. Equally predictably, salmon farmers in Europe will seek approval to raise this fish. Despite strong and divergent views about all forms of GM foods, this is a policy choice that will certainly have to be made, one way or the other, sometime in the present decade.

A different approach, already underway, is the substitution of fish oil in salmon feed with vegetable oils, mainly rapeseed. This is already common practice in Norway and likely to increase. It has also recently been proposed for Scotland, explicitly in the name of sustainability, by a coalition of environmentalists, academics, feed manufacturers and retailers, organized by the Marine Conservation Society (MCS) (13).

Technically, biologically, a substantial reduction in fish oils is possible (11). It lowers the density of DHA/EPA in the fish, but the absolute amounts remain high, because farmed fish is fattier. One issue is perceptual: Will the public reputation of salmon as "healthy" be compromized by the substitution, to the point that it is seen merely as a "floating vegetable"? (14)

Also coming is a potential corrective to that problem, which raises other issues—a DHA-rich oil for use in fish feed, derived from GM rapeseed/canola. This plant was developed under the EU's "Lipgene" research initiative, intentionally to create a sustainable, land-based source of DHA. It is being commercialized by the industrial partner BASF, which has applied for regulatory approval in the USA and Europe (15). The first intended market is fish farmers. Further ahead, it may have direct consumer applications, discussed later. Thus, GM plant sources of DHA are also a policy option that will come to a decision point sometime during this decade.

In the longer term, a new form of aquaculture is emerging—"marine agriculture," creating hospitable inshore environments, to raise and harvest fish sustainably, without containment or artificial feeding, as already practiced at Okayama in Japan (16).

By one route or another, substantial expansion in global supplies of fish is possible. But two major problems lie ahead. On the demand side, the prices of fish in all its forms (caught, farmed, fish oil, fishmeal, and traded products) are likely to rise steeply in the medium-term ahead (17). This will constrain purchases by consumers and food/supplement manufacturers alike. On the supply side, the global growth rate of aquacultural production is already slowing significantly. It is too early to predict future supplies, but even under optimistic scenarios, fish are unlikely to provide all of the large increase in LC-omega-3 that would be desirable. Other supply options need to be considered.

Plants: Conventional and GM

LC-omega-3 from *marine* plants, algae, are already widely consumed, produced by a fermentation process. The problem is that they are more expensive than fish oils, and hence are currently confined to high-value products, like infant formulas and nutrition supplements. Plans are underway to raise production and reduce costs. Expanding this technology towards producing national level volumes is an option. Cost is the constraint, more than capacity.

Many others have recognized algae's potential as a source of LC-omega-3. Experimental projects are in various stages of development to produce larger volumes at lower cost—in the overflow ponds of power stations, in large farms using solar power, in contained systems, in new forms of marine agriculture.

These ventures have expanded recently, attracted by the demand for biofuels, to convert algal oils into ethanol, with and without genetically modifying the algae. If successful, they might produce low-cost raw material for food uses as well. Some argue that basic algal biology will doom these experiments to failure. Others are investing billions in the hope they will succeed.[5] The issue is whether algae can become an economical and sustainable source for both food and fuel, as sugar has in Brazil. Trials are in development. Time will tell.

Efforts to produce LC-omega-3 from genetically modified versions of *land* plants have been underway for some years. Monsanto and DuPont, for example, have been working on soybeans. The Lipgene project began with linseed, then shifted to rapeseed/canola. It is the most advanced GM plant source at present, now being brought to market by BASF. Also working on GM canola is a new joint project by Martek and Dow in the USA. If all succeed, they have the potential for a major increase in supplies of LC-omega-3.

But the issues ahead are not just technical. They include consumer and political acceptability in multiple markets, regulatory approval in diverse jurisdictions, incentivizing farmers to grow new varieties in large volumes, engaging processors of ingredients and manufacturers of final products, plus, of course, the cost compared with alternative oils, over the medium and long terms, in increasingly volatile commodity markets.

Processed Foods: Fortifying What with What?

Scientists convinced of the nutritional virtues of LC-omega-3 have to face an unpleasant fact: many people do not like fish. Worse, in some societies, fish is not part of popular food culture, so the majority eat miniscule amounts. Strategies to increase LC-omega-3 intake, whether for individuals or nations, must therefore include alternative, albeit inferior, sources.

Conveniently, manufactured foods fortified with omega-3s have proliferated in recent years, especially in developed societies, where processed products form a large part of the diet, with more than 2,500 launched commercially so far.[6] Successful "carrier foods" vary between countries—breads in Australia, milk in Japan, fat spreads in many countries, even non-fat-bearing products like orange juice. Others, with an ironic twist, are "fortified fish." Adding omega-3s to frozen, semi-processed, and recipe fish dishes increases sales.[7]

Strategies include not just fortification-in-the-factory, but on-the-farm as well. Omega-3 eggs are established in several countries. Whole chickens with modified fat profiles are also under development (18). Both are produced by indirect fortification, that is, adding fatty acids to hens' diets—enriched chicken feed, if that is not an oxymoron.

More recently, fortification-in-the-home has been employed too. A successful model for micronutrient fortification of the diets of malnourished children is being extended. Specialty products have been designed for domestic use—powder in sachets and a "sauce" emulsion that can be added to any food, containing up to 720 mg of EPA/DHA in 15 mL—with applications in both developing and developed countries.

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[5] For example, see $600-million program, "Synthetic Genomics Inc. and ExxonMobil Research and Engineering Company Sign Exclusive, Multi-Year Agreement to Develop Next Generation Biofuels Using Photosynthetic Algae," SGI announcement, 14 July 2009.

[6] The Global Organization for EPA and DHA (GOED) maintains a proprietary database of all foods fortified with LC-Omega-3. For details contact GOED at: http://www.goedomega3.com/contact-us.html

[7] Personal communication from the British Frozen Food Federation.

Omega-3 fortified foods have been commercially successful in another sense important for public health: they have remained on the market for longer than most new products created by the food industry, where the attrition rate is notoriously high. Longer too than some other nutritionally fortified products, like foods with the ACE package of added antioxidants. Some bizarre examples of first-wave omega-3 products (ice cream, pancakes, and blueberry muffins) have disappeared, but according to records maintained by GOED, others have lasted a decade.

They have endured despite pockets of resistance. Some oppose the idea of fortification in principle (like Germany's Federal Institute for Risk Assessment),[8] and others reject the use of DHA in particular products (breastfeeding organizations against infant formulas (19)). Among consumers, however, omega-3s have come to be seen in a generalized, if imprecise, way as "good for you." Food manufacturers recognize and appeal to this public perception, so the number of new fortified products continues to grow.

Nonetheless, major problems remain before fortified foods can provide enough people with enough LC-omega-3 to improve the nutritional status of nations. They concern the scale of sales and what is actually added to products—the "forticant."

To have an impact on public health, fortified foods must be widely and frequently consumed. The traditional policy has been to enhance *staple* foods (like flour and salt), eaten by most people on most days. Japan took a different route to the same end. To combat widespread calcium deficiency in the 1980s, companies fortified *popular* foods—soft drinks and confectionery. Nutritionists may demur, but such convention-busting carriers have proven effective mechanisms for delivering deficient nutrients to deca-millions. Breakfast cereals are a Western example of the populist approach, with multi-nutrient fortification now long established and uncontroversial, indeed routine. They have become significant sources of micronutrients in several countries.

No omega-3 fortified products have achieved such widespread consumption. None have become mass-market foods; they remain "niche" items. Sales are limited, not only because many are specialty foods, but also because they also carry higher prices. To achieve the nutritionally desirable volumes, manufacturers will have to either broaden the appeal of existing products or develop new ones.

Two main factors underlie the inhibiting higher prices. First, the cost of the omega-3 oils added to products is no longer trivial and continues to rise. New sources of supply, for example, algal oils or GM plants, may reduce costs. More mutable are the higher margins that many companies add on to products perceived as "healthy," because they attract more nutritionally aware consumers who are willing to pay more for foods they think will do them good. They carry a "health premium."

Future growth of omega-3 fortified foods, on the scale required, will depend on closing, then reversing, the price differential, converting the "health premium" into a "health

[8] Communication of 12 August 2009 from the Government of the Federal Republic of Germany to the Commission of the European Communities. This includes an assessment by the Bundesanstalt fur Risikobewertung (BfR) suggesting that there is "need to place certain conditions and restrictions on the addition of (LC-Omega-3) fatty acids to foods, so as to avoid excessive intakes and its possible undesirable consequences for health." An English language summary is available in BfR Opinion No. 030/2009, 26 May 2009. More details were provided by BfR, in response to questions from the Commission, in a second letter of 12 August 2010.

incentive," to extend WHO's principle: Make the healthy choice not just the easy choice, but also the cheaper choice.

In itself, this would help convert some omega-3 products from niche to mainstream items. But other approaches are possible—either the traditional route of putting omega-3s into staples or the development of new, more populist fortified products.

One option has an impressive precedent. In the late 1930s, the Boyd-Orr survey made Britain aware of its nutritional deficiencies, especially among the young. The government then commissioned Unilever to develop a new fish product that children would eat. The result was the fish finger (or fish stick), now popular in many countries. It simplified fish selection and cooking, regularized the size and shape of the food, and ameliorated any "fishy" taste with a crumb coating. New popular processed products using oily fish are one route forward.

Another very twenty-first century product, with mass market potential, lies just over the horizon. One part of the plan to commercialize GM canola is to produce a salad oil for direct sale to consumers. It would be formulated to provide a recommended daily intake of DHA in a tablespoonful. Many practical problems lie ahead, not least the acceptability of GM foods in diverse markets.

A second serious problem is that not all "omega-3s" used to fortify foods are LC-omega-3. Several different oils are employed, including plant oils containing only the shorter chain omega-3s, notably alpha-linolenic acid (ALA). The practical problem is that humans convert ALA into DHA very poorly. People need to consume DHA directly from their diet, "pre-formed DHA." The consequence of fortification with ALA is that consumers will not derive the health benefits uniquely provided by DHA.

The inferiority of some "omega-3" fortified foods is invisible to the public because of a convention on labeling and claims that has developed in many countries. In an attempt at consumer-friendliness, marketers have stripped out the complicating technical acronyms ("LC*n*-3PUFA" and its cousins). De facto, commercial promotion and consumer recognition have settled, for the most part, on "omega-3" as a descriptor, an apparent simplification that disguises a pernicious ambiguity.

This umbrella phrase covers both the long-chain and the shorter chain omega-3s, both DHA and ALA, both expensive marine oils and cheap land-plant oils, both oils that produce proven benefits to mental and physical heath and those that, whatever their other merits, do not.

This convention has been legally formalized in the European Union recently, through approval of a regulation (20) governing nutrition claims about omega-3s in processed foods. It allows "omega-3" claims on products fortified with *either ALA or DHA*. The effects are illustrated in Table 13.2, analyzing margarine, one of the most popular "omega-3" fortified foods in Europe.

The EU dietary recommendation for ALA is 2,000 mg/person/day. Under EU labeling rules, a product may claim to be "High" in a nutrient if, in 100 g of the food, it provides 30% of this target, that is, 600 mg of ALA. But margarine is seldom eaten in 100-g lumps. The daily portion most commonly recommended by manufacturers is 20 g/day. This delivers 120 mg/day of ALA. But poor conversion in humans means that very little becomes DHA inside consumers. A position paper by ISSFAL (21) summarizes many studies by concluding that "the conversion of ALA to DHA is of the order

Table 13.2
European Union regulation for omega-3 nutrition claims using margarine as an example (20)

What it takes to be "high" in LC-omega-3		
Diet recommendation	ALA	2,000 mg
"High" claim	=30% (per 100 g)	600 mg
Margarine	Portion 20 g/day	120 mg
Conversion	ALA-to-DHA <1%	<1 mg

of 1% in infants, and considerably lower in adults." As a result, a product delivering less that 1 mg/day of DHA can claim to be "high" in "omega-3s."

This is the legalized deception of consumers. For manufacturers, the regulation creates a powerful financial incentive to use cheap ALA plant oils instead of more expensive marine oils that contain LC-omega-3. Why not, when the product can carry the same nutrition claim? Such cost-cutting substitution means that the probable effect of the regulation will be to *decrease* the availability of fortified foods containing pre-formed DHA.

To conclude on foods, the critical decisions for fortification as a public health strategy are: what nutrients to add to what carrier foods? With LC-omega-3, so far, neither of these issues has been resolved sufficiently for fortified products to have a major impact on the nutritional status of nations.

Nonetheless, as public understanding of DHA and EPA grow, among policy makers as well as consumers, there is potential to expand fortified foods as sources of LC-omega-3, a form of provision that is both publicly acceptable and environmentally sustainable.

Supplements: A Supplementary Source

As with fortified foods, sales of omega-3 supplements have grown in recent years, also mainly in developed societies. But there are significant differences between the two sectors.

Crucially, many genuine LC-omega-3 supplements are available that provide pre-formed DHA, as part of a combination of fatty acids. Indeed, among supplements, assertions of distinctiveness and superiority are commonplace—not just generalized omega-3s, but also fish oils, cod liver oils, algal oils, krill oils, as well as explicit DHA/EPA capsules. In parallel with the range of recommendations, they offer a range of dosages, including "high," "optimal," "ideal," "triple," "strongest," and "super fish."

Further, within the supplement world, LC-omega-3 are not just niche products. By several measures, they are second only to multi-vitamins in popularity. And sales are still increasing, not just in absolute numbers but also as a proportion of the supplement market (22).

Indeed, the market has grown large enough to stimulate segmentation on several fronts. Cheaper own-label variants have been introduced by supermarket, pharmacy, and health food chains. Sub-brands are directed at sensitive consumer groups, notably pregnant women and children. Vegetarians are solicited by algal oils. Others are targeted at patient categories, suggesting advantages to heart, brain, or eyes, as in "mood, mind, and cardio" or "smartfish." All of which indicates a broad appreciation among the general public, at some level of sophistication, of the health benefits of LC-omega-3.

Nonetheless, looked at from a public health perspective, there are unresolved issues with supplements. They range from the technical to the existential.

At the simplest, even authentic LC-omega-3 supplements are inadequate replacements for the distinctive package of nutrients provided by fish. Some pills combine DHA/EPA with other nutrients, but none offer a complete replication, and are unlikely to do so in future. The practical limitations of supplements as substitutes are part of the justification for the consensus advice: first and foremost, eat fish.

At the other extreme, some critics invoke a different principle: that human nutrient needs are best met from a natural diet—from fresh, raw ingredients, without manufactured foods, and certainly without supplements. This is not just a specialist perspective of some nutritionists and doctors, but also common among environmentalists, health advocacy groups, food journalists and, most visibly, celebrity chefs.

For some, supplements will always be, at best, a second best. This is not a majority view in the population, or sales of supplements and convenience foods would not be so high. But it reflects a fundamental strategic divide on how to achieve nutritional change—between the principled (move quickly and directly to a healthy diet) and the pragmatic (gradually improve the popular products people eat now).

The natural food approach is particularly demanding for LC-omega-3, where the raw food to which people should revert is the not-universally popular fish. Further, as shown earlier, a sufficient supply for whole populations is unattainable. Even in Japan, a country with very high levels of fish consumption, average LC-omega-3 intake falls short of the national dietary recommendation.

Raising consumption of fish is made even more difficult by concerns about toxins. As a result, in some countries, recommended intakes are intentionally reduced below desirable levels, especially for pregnant women. Warnings about toxic risks frighten some people off fish altogether. This has the effect of stimulating supplement sales, as an apparently safer way to consume LC-omega-3. But a resolution may be in sight, in the form of a new approach to assessing toxicity, incorporating it within a single comprehensive risk-benefit analysis for fish, showing that nutritional gains greatly outweigh toxic dangers (23–25).

These issues are reflected in practical policy debates about the regulation of supplements. Some countries, like some nutritionists, are suspicious of supplementation. Concerns include the ingredients, safety, strength, availability, and promotion of supplements. In other countries, notably the USA, access to supplements is seen as a consumer right, and regulation as a restriction on freedom.

At a more earthly level, there is the issue of cost. By the standards of affluent countries, supplements are not absolutely expensive, but not trivial either, for routine use by families. They are discretionary, not essential, purchases. This is relevant because most are distributed through commercial channels rather than public health systems. In poor countries, in rural areas, where LC-omega-3 deficiency is high, that private sector distribution system does not exist, and most people would not have the money to use it, even if it did.

Some LC-omega-3 are dispensed on prescription, for therapeutic, prophylactic, and developmental purposes. That channel is likely to increase as new pharmaceuticals, now under development, are approved (22). For now, the majority of LC-omega-3 supplements are obtained through purchase by individuals, so prices limit intakes.

In summary, supplements will never, on their own, offer a solution to the large global shortage in LC-omega-3. But they could make important contributions through targeted public health programs for selected, vulnerable groups. At present, however, with rare exceptions, they do not.

Antenatal programs in many countries provide free foods to pregnant women, some including supplements. But not LC-omega-3. School feeding programs serve meals to hundreds of millions of children, sometimes with nutritional standards, sometimes including free items, like fruit (Europe) or fortified porridge (Malawi). But not LC-omega-3. Care homes for the elderly provide not just meals, but all manner of remedies. But not LC-omega-3.

In developing countries, supplementation has been a mainstay of nutrition policy for decades, organized by governments and international agencies. Programs have focused on two of the largest international deficiencies, iron and vitamin A. But not LC-omega-3. More broadly, many poor countries offer food as an incentive to raise participation in social programs—visiting antenatal clinics, attending school, working on public infrastructure projects. Some of these programs include nutrition standards. But not LC-omega-3

These are all public programs reaching groups that are commonly deficient in LC-omega-3. The distribution channels already exist. There is no need to construct new institutions, just to include LC-omega-3 among the foods they dispense. Such programs could become cost-effective distribution systems for supplements.

While the retail price of LC-omega-3 supplements may be substantial, when bought in bulk for public health programs they can be inexpensive. For example, in a local trial in the UK, a daily dose of 500 mg of EPA/DHA was provided to all women attending antenatal clinics for 5 months. It reduced extreme premature births (before the 34th week) by 32%. The cost was less than 8p/9c/13¢ per person, per day.[9] Larger procurement for a national program would be substantially cheaper. But even at this price, every pregnant woman in the UK could be given LC-omega-3 supplements for a total annual cost of less than £11 million/€12.5 million/$18 million. The saving on birth complications alone would make this an extraordinarily cost-effective program, before even taking into account the multiple, life-long benefits for the child and the family.

This is a template of global public health significance. Provision of low-cost supplements to large numbers of malnourished people through already-existing public distribution channels could have a substantial impact, especially in developing countries. They would not meet total population needs. But in the current state of gross deficiency, they could become a transformative source of LC-omega-3 for selected, high priority groups.

CONCLUSION

This has been a systematic summary of the principal options for increasing the supply of LC-omega-3. Could they meet the definition of "sustainability" set out at the beginning—enough to fulfill the needs of the global population? Especially as, during

[9]Personal communication from Laurence Wood, project leader on a clinical improvement trial in Coventry and Warwickshire. Final report in preparation. For details contact him at email.lozza@gmail.com

the writing of this chapter, the goalposts moved, the task became more difficult, because the United Nations raised its estimate of the number of people on the planet in 2100 from nine billion to ten billion (26). Can increasing production catch up with the increasing population?

Probably yes. No single source will suffice, but some combinations might. Much will depend on new policies being implemented competently and on technical developments proving effective, economic, acceptable, and sustainable. Using all the options described here, supplies of LC-omega-3 could be expanded substantially—but not soon, not easily, not without controversies and compromises, not to universal approval. Pragmatic incrementalism is the realistic prospect.

The process would also involve many other considerations beyond the specific focus of this chapter, on the sources, the physical supplies, of LC-omega-3. For a full nutrition policy, this analysis needs to be supplemented with others, before, alongside, and after it.

Before policymakers act, an issue needs to get onto the political agenda. With LC-omega-3, this has not yet been achieved. Even those concerned with extreme malnutrition in developing countries usually do not recognize the deficiency. A symbol of that ignorance and/or indifference occurred at the 2011 Global Omega-3 Summit. The European Commission, whose headquarters is just down the road from where the summit was held in Bruges, and who are in the midst of designing a new Common Fisheries Policy, did not send a delegate to this meeting. The health benefits of fish are not yet on their agenda.

The task of improving LC-omega-3 status is made more demanding because, in many parts of the world, poor and rich alike, intakes of fats are dominated by omega-6s. They effectively reduce the benefits people receive from the LC-omega-3 they consume. Therefore, additional policies to reduce omega-6 intakes would be desirable, in parallel with whatever actions we take to increase supplies of LC-omega-3. And that is an even greater challenge, because so many economic interests are invested in their production and use. Full discussion of the options for reducing omega-6s would require a substantial paper in its own right, beyond the scope of this chapter. But they are essential if populations are to achieve the tissue targets for LC-omega-3 set out in other chapters in this book.

Even if we manage to raise LC-omega-3 supplies to sufficient levels, a major problem would remain: distribution. It is often observed that there is no gross shortage of food in the world, but more than a billion people still go hungry. Available supplies are very unevenly distributed. The future of LC-omega-3 will also raise issues of distributive justice.

In the real world, we will not achieve adequate amounts immediately. Even under optimistic scenarios, raising LC-omega-3 supplies will take a long time. So, choices will have to be made. As amounts gradually increase, who among the deficient should receive them first? Whom should we prioritize? Distribution according to need? Many of the most deficient are very hard to reach—poor people living in remote rural areas of land-locked countries. Should we try? Or quite the reverse: should we deal first with the easy-to-reach, bringing improvement to many quickly, a cost-benefit approach that is also one kind of public health strategy? Or should we establish a biological pecking order, giving precedence to pregnant women and their babies, wherever they live? In a world of scarcity, rationing is inevitable. But, at present, access to LC-omega-3 depends largely on geographical accident or economic resources. We can do better than that.

Recognizing the inevitable gradualness of any increase in LC-omega-3 supplies raises another, even messier, issue. Overcoming the currently large and widespread deficiencies in LC-omega-3 involves not just one-off policy decisions but also prolonged action to implement them. So obtaining sustainable supplies of LC-omega-3 will also require sustainable political commitment.

Nonetheless, there are grounds for optimism. Our understanding of the fundamental science has improved greatly over the roughly 50 years since the structure of DHA was first worked out, as these proceedings demonstrate. We do not know everything, but we know enough. We have sufficient knowledge to begin applying it, sufficient to reduce the immense injuries to mental and physical health caused by consuming too little LC-omega-3. As Michael Crawford said in his keynote lecture to the 2011 Global Omega-3 Summit, what we need now is action.

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