Omega-3s from Whole-Food Flaxseed

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Omega-3s are recognized to be widely deficient in the U.S. diet because of a number of macrosocietal trends that are unlikely to be reversed in the short term. Whether the problem is a shortage of dietary omega-3 or a surfeit of dietary omega-6 is beside the point. The fundamental problem is that the average U.S. diet is significantly deficient in omega-3s, and whole grains, such as flaxseed, should be a significant part of the solution.

While consumer and nutritional literature today is focused on the benefits of marine- and animal-derived long-chain omega-3s, eicosapentaenoic acid (EPA; 20:5ω3) and docosahexaenoic acid (DHA; 22:6ω3), the essential building block for these fatty acids is plant-derived α-linolenic acid (ALA; 18:3ω3). Animals metabolically convert ALA into EPA and DHA through a combination of desaturation, chain elongation, and chain-shortening reactions. Documentation of the nutritional, nutraceutical, and medical benefits provided by EPA and DHA is extensive and ongoing. Other research subjects include: 1) the nutritional benefits provided by ALA alone; 2) the degree of metabolic conversion of ALA into EPA and DHA in humans; and 3) the degree to which flaxseed's nutritional and nutraceutical benefits are attributable to its ALA content. This article will address each topic.

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ALA is the only omega-3 that is truly essential (i.e., cannot be manufactured in nutritionally significant quantities through human metabolism). On the other hand, EPA and DHA are converted from ALA by animals and algae. Typically, fish concentrate EPA and DHA obtained directly or indirectly from algae. For nonfish eating cultures, ALA is the only significant dietary source of omega-3.

Americans consume ALA in their diet from a variety of sources including nonhydrogenated canola and soybean oils, beans, fruits, leafy vegetables, baked goods, dairy products, margarines, and meats (6).

However, it is not enough. In part, this is because ALA-derived EPA and DHA act as precursors for metabolically active prostaglandins that behave agonistically to omega-6-derived prostaglandins. Currently, the average American diet skews heavily toward omega-6 (linoleic acid [LA]) consumption, ergo, toward omega-6 prostaglandin production at the expense of omega-3 prostaglandins. This has serious implications for a wide range of health disorders including cancer, coronary heart disease, immune system function, kidney health, and several neurological and psychological disorders. Although a 1:1 to 5:1 ratio of omega-6 to omega-3 in the diet is generally considered to be optimum, most literature cites actual dietary ratios of 10:1 or even 20:1 (2). The practical solution, therefore, is to drastically reduce omega-6 consumption, drastically increase omega-3 consumption, or both.

Thus, it is not just the omega-3 content but the ratio of dietary omega-6 to omega-3 that matters. Flaxseed is one of very few food sources that provide such a beneficial ratio, typically containing 20 to 25% of ALA omega-3 by weight to only 4–5% omega-6 LA.

ALA Omega-3 Requirements

Just how much ALA is converted into EPA and DHA by humans is a subject of controversy and a full review is beyond the scope of this article. What is known is that most ALA is rapidly absorbed from the blood stream, stored into adipose tissue, remains labile, the large majority is β-oxidized and metabolized into other, as-of-yet unknown lipid components, and an estimated 5 to 15% is converted into the long-chain omega-3s, EPA and DHA. The level of conversion depends on many factors, including the health of the subject, the subjects' DHA status, and the level of LA (omega-6) consumption. For example, one recent study documented a significant conversion of ALA to EPA and docosapentaenoic acid (DPA, a DHA precursor; 22:5ω3) but not to DHA in chronically ill subjects fed just 3 g per day of ALA in the form of flaxseed oil during a 26-week period. The subjects' EPA status increased by as much as 60% (8).

Another question is what health benefits can be attributed to ALA that are distinct from its EPA and DHA metabolites. Stephen C. Cunnane, a leading authority on essential fatty acids, catalogs a number of metabolic roles that may be attributable to ALA alone including: 1) providing protection against cardiac arrhythmia; 2) regulating LA (omega-6) homeostasis; 3) protecting against certain forms of cancer; and 4) providing precursors for other essential metabolites (6). One study documented that plant-derived ALA consumption significantly reduced risks of cardiac arrhythmia and sudden cardiac death (SCD) syndrome in women, irrespective of their consumption of long-chain fatty omega-3s (1), implying a unique role for ALA. Still largely unexplored is what role ALA may play in cell membrane function: its role in improving skin and hair quality in livestock and pets is well recognized by the pet food and animal feed industries, but mechanisms by which this may occur remain unclear.

In 2002, the National Academy of Sciences Institute of Medicine (NAS/IOM) factored conversion level considerations into its calculations of "adequate intake" (AI) values for ALA (2). The NAS/IOM report set AI for ALA at 1.1 g per day for women 19 years and older and 1.6 g per day for men 19 years and older, assuming a low (10%) rate of ALA conversion.

In 2004, the Washington firm of Olsson, Frank, and Weeda, P.C. petitioned the Food and Drug Administration (FDA) on behalf of three seafood companies to permit nutrient content claims for omega-3s based on the conclusions of the 2002 NAS/IOM "dietary reference intakes" report (11). Daily reference intakes were proposed at 1.3 g per day for ALA and 130 mg per day for DHA and EPA. The petition furthermore proposed that a "high in, rich, or excellent" source of ALA omega-3 claim could be made for products contributing 260 mg or more of ALA omega-3 per reference amount customarily consumed (RACC). This represents 20% of the AI for ALA omega-3 and is 10 times the amount required to make a similar claim for DHA/EPA omega-3. The FDA declined to contest the petition and so it entered into the Code of Federal Regulations.

What does this mean? Whole flaxseed contains, on average, approximately 20% ALA by weight. Thus, assuming an ALA content of 20%, only 6.5 g of flaxseed per day (slightly less than a tablespoon) has been determined by the NAS/IOM and codified by the FDA to meet the AI for ALA-omega-3, and by conversion, for EPA and DHA in adults. Just 1.3 g of flaxseed per RACC (RACCs are defined in Title 21, Section 101.12 of the Code of Federal Regulations) is adequate to label a food as a "high in, rich or excellent" source of ALA omega-3. For perspective, a reference serving for bread, tortilla, or pizza crust is 55 g (Table I). One-half of that level of flaxseed addition earns a "good source of ALA omega-3" designation.

Flaxseed, therefore, offers a practical and economical "whole food" solution to omega-3 deficiency, especially in cereal-based foods.

Flaxseed–A Whole-Food Source of Omega-3

As referenced previously, the list of physical and metabolic disorders attributable to omega-3 deficiency is quite extensive.

Since flaxseed represents one of the richest natural sources of ALA, many animal and human studies have used flaxseed as their dietary source of ALA. This can be confounding because flaxseed contains other significant components that contribute many of the same nutritional and nutraceutical benefits as ALA omega-3s. Consequently, unbundling the benefits specifically attributable to ALA from those contributed by flaxseed's other nutraceutical components such as gum mucilage, lignans, and polyphenolic antioxidants can be problematic. Two examples are: 1) cardiovascular disease; and 2) inflammation, immune activity, and cancer

Cardiovascular Disease. Whereas a considerable body of animal and human clinical data links flaxseed's ALA omega-3 content to the reduction of coronary vascular disease risks and symptoms, another body of evidence suggests a similar protective role exhibited by lignans, complex polyphenolic antioxidants with phytoestrogenic properties, that animal studies suggest may significantly reduce atherosclerosis, possibly via the reduction of oxidative stress (12). Whole-grain flaxseed contains approximately 1.0% lignans by weight so it can be difficult to compare the relative contributions of lignans and ALA to flaxseed's documented cardiovascular benefits. In addition, flaxseed contains at least 6–8% soluble and highly viscous mucilage gums, a combination of neutral arabinoxylans and galactoxylans and acidic rhamnosyluronic and galactopyranosyluronic polymers (7). Soluble, viscous hydrocolloids also benefit cardiovascular health by mechanisms such as cholesterol removal in the gastrointestinal tract and lower-bowel fermentation to short-chain fatty acids that suppress cholesterol production. Flaxseed contains 25–30% total dietary fiber.

Inflammation, Immune Activity, and Cancer. Omega-3s have been widely associated with the reduction of a variety of cancer risks in animals and humans (3). However, so have flaxseed lignans, particularly with regard to hormonally influenced cancers such as breast, colon, and prostate cancer. Lignans are fermented by intestinal bacteria into enterolignans that exhibit phytoestrogenic activity with documented anticarcinogenic benefits. Closely related physiological processes are immune function and inflammation. Anti-inflammatory activity has been documented for omega-3s, which produce prostaglandins that block proinflammatory (omega-6-derived) eicosanoids (5). Chronic obstructive pulmonary disease (COPD), characterized by chronic inflammation of the lungs, is reported to be the fifth leading cause of mortality worldwide. Administration of ALA to COPD patients resulted in significant reductions of inflammatory markers and improvement in their ability to absorb oxygen (10). ALA has also been shown to reduce production of proinflammatory cytokines and platelet aggregating factor. Flaxseed is not only rich in antioxidants (which have anti-inflammatory effects) and lignans (which may be limited to antioxidant activity within the gastrointestinal tract) but also rich in tocopherols, tocotrienols, and an estimated 1.0% (by weight) of phenolic compounds including coumaric, trans-ferulic, and trans-caffeic acids (7). Phenolic antioxidants appear to play an important role in protein-fiber cross-linkages within the seed matrix (13). Many of these compounds are anti-inflammatory and anticarcinogenic in their own right and may act synergistically.

On the basis of these two examples, flaxseed is far more than just a source of ALA omega-3. It is also a significant source of dietary fiber, protein, antioxidants, and lignans, some of which offer synergistic health benefits. In this respect, flaxseed offers an apt model for all whole grains or seeds and underscores the groundswell recognition advanced to the nutritional value of "whole grains", "whole seeds" and "whole foods".

This view holds that foods represent complex nutrient systems that should be evaluated and consumed in their entirety,

Table I. Amount of ground flaxseed required to qualify products for a "high in, excellent, or rich source" of α-linolenic acid omega-3 nutrient content claim

	U.S. Reference Serving[a] (grams per serving)	Ground Flaxseed (% final formula weight)
Bread	55	2.4
Bread rolls	50	2.6
Cookies and crackers	30	4.3
Muffins and sweet goods	55	2.4
Nutrition bars	40	3.3
Pancakes (dry mix)	40	3.3
prepared, frozen	110	1.2
Waffles (prepared, frozen)	85	1.5
Pizza crust	55	2.4
Beverages	240	0.5
Breakfast cereals (cooked, flavored, sweetened)	55	2.4
Ready to eat high fiber	30	4.3
Granola	40	3.3
Dry instant	15	8.7
Pasta (dry weight)	55	2.4

[a] Title 21, section 101.12 of the Code of Federal Regulations.

not just on the basis of a few isolated components. This recognition has crystallized with a number of industry-backed whole-grain initiatives and spurred the creation of new organizations such as the Grain Foods Foundation (www.grainfoodsfoundation.org).

Incorporation of Flaxseed into Foods

Flaxseed is a pleasant tasting, slightly nutty, slightly sweet whole grain that, as a flour, incorporates readily into a wide variety of foods, especially cereal-based foods. As with any grain, such as oats or wheat, however, flaxseed carries its own particular handling considerations.

Whole-grain (or whole seed, depending on the expected FDA-approved terminology) flaxseed contains approximately 40% oil, 95% of which is unsaturated and one-half of which is polyunsaturated ALA. Unlike corn, wheat, soy, or other major seeds, the oil is not concentrated in a readily removable germ. Rather, the oil is distributed throughout the seed matrix, with approximately 75% found in the cotyledon, 22% in the seed coat, and 3% in the germ (7). As previously indicated, the seed matrix is especially rich in antioxidant value and exerts a protective effect for the naturally encapsulated flaxseed oil. Should flaxseed oil be separated from the grain matrix for use as a nutritional supplement or food ingredient, separate antioxidant mechanisms must be applied to protect the oil against oxidative degradation.

The challenge in milling or grinding flaxseed is to protect the highly unsaturated oil content within the naturally encapsulating grain matrix. If the oil is released, it readily oxidizes and generates the familiar pungent aroma of linseed oil (flaxseed's industrial moniker). Improperly milled flaxseed will, over time, develop rancidity. Consequently, as with oat flour for example, the milling of whole flaxseed into flour for which the shelf stability can be guaranteed is as much an art as it is a science.

Is milling necessary? For nutritional value, the answer is yes! Seeds are designed to pass through the intestinal tract intact. Milling the seeds into flour exposes their contents to digestion. This was documented rather dramatically in the case of flaxseed lignans, whereby researchers found that feeding ground or crushed flaxseed to human subjects increased the bioavailability of enterolignans (converted by intestinal bacteria from lignans) from 28% (in whole seeds) to 43% (9).

Once milled, flaxseed flour can readily be incorporated into a wide variety of products including baked goods, pastas, breakfast cereals, batters and breadings, tortillas, extruded pet foods, and even beverages. Whole-ground flaxseed's ALA content, encapsulated within its natural grain matrix, readily withstands even the most extreme baking conditions (4).

Flaxseed is hypoallergenic, and consequently, does not trigger special package labeling requirements. It is also characterized by an almost complete absence of digestible or glycemic carbohydrates. Finally, it requires very little flaxseed to fulfill a "high in, rich, or excellent" source of ALA nutrient content claim, confirming its importance as a practical, convenient, and economical whole-food solution to the omega-3 nutritional deficiency challenge confronting the American food supply.

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Sean Moriarty is president of ENRECO, Inc. (Newton, WI.) a flaxseed and specialty grains company that he purchased from the Natural Ovens of Manitowoc company in 2004. Moriarty and his spouse, Brenda, share a personal goal of promoting the improvement of human health and well being through nutrition. Prior to his purchase of ENRECO, the Moriartys created KEY Nutrients, LLC, an ingredient trading company specializing in flaxseed-based animal nutrition formulations, and OmegaFields, a company that develops and markets flaxseed-based supplements to the equestrian, pet food, and human nutrition marketplace. These experiences provided the genesis for Moriarty's commitment to purchase and develop ENRECO into a market leader in flaxseed and high-value, grain-based nutritional ingredients. Moriarty is a registered tribal member of the Oneida Nation Indians of Wisconsin.