CFW FEATURE

Omega-3 Health:

Significance of Cereal Food Products

- Omega-3 fatty acids are essential for normal and preventive health but have been increasingly recognized as nutrients capable of modifying disease morbidity and pathophysiology.
- Consumption of omega-3 fatty acids in Western cultures is limited because of an historical emphasis to consume polyunsaturated fatty acids that have focused on omega-6 fatty acids from corn.
- Several food products have been developed to meet recommendations to consume greater amounts of omega-3 fatty acids. Cereal and bread fortified with omega-3 fatty acids from ground stabilized flax seed and marine based omega-3 offer a unique opportunity to meet recommendations to consume greater amounts of omega-3 fatty acids and meet the growing consumer demand for omega-3 fortified products.

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The essential nature of fat was first described by George and Mildred Burr at the University of Minnesota in 1929 (1). The Burr's described a deficiency syndrome that inhibited growth and reproduction and resulted in scaly dermatitis. Since this time, considerable knowledge about the roles that omega-3 and omega-6 fatty acids play in physiology have been reported (13).

While the essentiality of omega-6 fatty acids was well in place, however, it wasn't until 1982 that the definitive essentiality of omega-3 was reported by Holman (8) from a young girl injured by a gunshot wound who was maintained on a parenteral emulsion enriched only in linoleic acid (LA), an omega-6 fatty acid. While on the omega-6 "diet", this girl developed episodic paralysis and visual and neurological impairments, all of which were resolved with the reintroduction to her diet of α-linolenic acid (ALA; a plant-based omega-3 fatty acid). This rather drastic example served to underscore the significance of omega-3 fatty acids in human health, especially for the tissues where omega-3 fatty acids are found in high concentration, such as the central nervous system.

Omega-3 Health Benefits

Omega-3 fatty acids have become one of the highest profile nutrients on the block these days and for good reason. During the past 30 years, thousands of studies have been published that document their unique nature and health benefits.

These essential fatty acids contribute to our normal health and well being through structural and functional roles in membranes, in the regulation of the inflammatory and immune response, through the formation of eicosanoids, and by their effects on gene expression.

The omega-3 family contains several fatty acids that vary in chain length and degree of unsaturation. ALA comprises the majority of omega-3 in our diet today, with only small amounts of long-chain omega-3, eicosapentaenoic (EPA) and docosahexaenoic acid (DHA), being consumed. Many of the reported health benefits of omega-3 are attributed to EPA and DHA since they are the functional omega-3 isomers in living systems. EPA has well-known anti-inflammatory properties via its competitive inhibition of arachidonic acid metabolism by COX-2 enzymes, thus reducing production of series two eicosanoids, which are proinflammatory. DHA, the most highly unsaturated fatty acid in our body, is an integral part of membrane structure and subsequent function.

Controversy exists over the relative role that short-chain versus long-chain omega-3 play in the diet and physiological needs. Dietary sources of ALA are sometimes criticized because they cannot adequately support deposition of EPA and DHA. In the case of an infant growing in utero this is largely true, but Holman's studies from the 1960s clearly demonstrate that ALA is metabolized into EPA and DHA (11). However, this pathway is largely affected by the relative amounts of LA (omega-6) in the diet. Thus, the ratio of LA to ALA becomes an important determinant in how much long-chain omega-3 we produce.

While mass balance studies have reported that ALA is metabolized into EPA and DHA at a 5–15% conversion rate, data from our laboratory demonstrates that vegetarians consuming little or no long-chain omega-3s have virtually identical total omega-3 levels as their omnivorous counterparts (Table I). This is not to say that EPA and DHA do not serve as very important contributors to omega-3 intake. On the contrary, however, their main source, cold-water fish, may or may not be amenable to every palate. Thus, ALA consumption is an important source of omega-3 in our daily diet. Conversion rates of 10% still provide 100–200 mg of long-chain omega-3 based on an ALA intake of 1 to 2 g per day.

Loss of Omega-3 from the Diet

The change in the fat and fatty acid content of our diet has occurred primarily with the advent of industrialization. From an evolutionary perspective, a significant change in the diet has occurred within a relatively short time. The diet of our ancestors in the Paleolithic period (40,000–45,000 years ago) was estimated to be balanced in omega-6 and omega-3 (a ratio of 1:1, or 10- to 20-fold lower than today's standard) (6). The Paleolithic diet was high in green leafy vegetables, fruits, roots, and fish, with wild animals consuming a similar diet. The presence of corn and soy with their high proportion of LA has drastically affected the food supply's essential fatty acid composition in favor of omega-6.

Population studies confirm the consequence of a Western-type diet high in LA and low in ALA and long-chain omega-3s on dietary omega-3 status (Table I). Compared with populations that regularly consume fish, Americans have a relatively low omega-3 status. Populations, such as in Nigeria, consume lower amounts of fish but have diets with lower ratios of LA to ALA and have a high omega-3 status.

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Clinical Aspects of Omega-3

The use of supplemental and dietary omega-3 fatty acids is now reported to prevent and treat a multitude of diseases. Perhaps the most significant area for this research has been for cardiovascular disease (CVD). Since the discovery by Dyerberg and coworkers in 1975 that a high-fat, high-omega-3 diet actually protected individuals from atherosclerosis, several epidemiological studies have identified that diets enriched in ALA and fish promote cardiovascular health (5). The Chicago Western Electric study found that fish consumption as low as 35 g per day, or about one serving per week, significantly reduced the risk of myocardial infarction (3). Starting in 1958, this study followed more than 1,800 men aged 40–55 and free of known cardiovascular disease for a period of 30 years.

In addition to protecting against the development of CVD, secondary prevention studies have reported that supplementation with omega-3 reduces the risk of death and additional heart attacks.

The GISSI prevention study examined the effects of fish oil therapy in 11,324 patients with existing CVD (10). After 3.5 years of follow-up, patients given 850 mg of EPA and DHA experienced a 20% reduction in deaths from all causes and a 45% reduction in sudden death compared with those not given EPA/DHA. Benefits were reported to emerge as soon as 3 months after the initiation of fish oil therapy. Similar results were found in the DART trial that found a 29% reduction in all causes of death in men who consumed 200 to 400 g of fatty fish per week, providing an average of 500–800 mg of EPA and DHA per day (2). Whereas many studies have examined the role that fish oils play in down-regulating CVD risk, many studies have also found positive effects for reducing risk in patients consuming increased amounts of ALA. Djousse reported that dietary ALA was inversely correlated with development of calcified plaque in coronary arteries (4).

In 2002, the American Heart Association (AHA), citing the heart healthy benefits of omega-3 fatty acids, published a scientific statement recommending that persons consume at least two fatty fish meals per week and include food sources rich in plant-based omega-3 to prevent heart disease (9). In addition, for people suffering from known CVD, the AHA recommended that these individuals consume 1 g per day of EPA and DHA, combined either from oily fish or from fish oil supplements. Interestingly, the General Accounting Office of the federal government also recently recommended consumption of omega-3 fatty acids to support cardiovascular health.

The investigation of the treatment of psychiatric disorders with omega-3 fatty acids is a relatively new but potentially promising field of research (7). Major depression has been characterized by deficits of plasma and red blood cell omega-3 fatty acids, including EPA and DHA (12).

Fish consumption has also been noted to be predictive of major depression and suicide. Hibbeln (7) reported that persons consuming relatively greater amounts of fish were less likely to suffer from major and postpartum depression and less likely to commit suicide.

Limited intervention data are available for the treatment of depression with omega-3 fatty acids (15). In a pilot study, supplementation of EPA and DHA was reported to improve the outcome in bipolar disorders. Stoll (15), in a placebo-controlled, double-blinded study in 30 patients with bipolar depression, reported that 9.6 g per day of omega-3 as EPA (6.2 g) and DHA (3.4 g) resulted in significant improvements in remission and outcome as compared with placebo treatments (olive oil). The reductions in depressive- and mania-related events in the omega-3 treatment group were so significant that the study was stopped after 4 months.

Omega-3 Fortification of the American Diet

A group of leading U.S. physicians, biochemists, and nutritionists released guidelines for adequate intake of omega-3 fatty acids (Table II; 14). Proposed adequate intakes for EPA and DHA are 650 mg per day (combined) with an ALA intake of 2.2 g per day. This represents a significant increase from our present daily intake of EPA and DHA, approximately 50–100 mg per day, and ALA of 1 gram per day. It has also been recommended that the intake of LA be limited to 6.7 g per day from the present average intake of 10–20 g per day. This recommendation, in effect, serves to reduce the average dietary LA to ALA ratio from the present 10:1 to 2.3:1, which supports greater conversion of ALA into long-chain omega-3. Table III lists the essential fatty acid content in various grains and food.

To meet recommendations for higher omega-3 intake, several food manufacturers have begun enriching foods and food products with sources of omega-3, (e.g., stabilized ground flax and microencapsulated fish oil). Designer food products like omega-3 eggs, milk, and pork have also emerged as meaningful sources of dietary omega-3.

Stability has been one of the main challenges of fortifying foods with omega-3 fatty acids. The same physical characteristics that provide omega-3 with their health benefits (i.e., their degree of unsaturation) also increase the likelihood that they will oxidize, promoting off-flavors and compromising shelf life. Fish-oil-derived fatty acids have proven difficult to work with because of their marked instability, characteristic to produce off-flavors in foods produced with heat and oxygen exposure, or the ability to compromise extended shelf life. Microencapsulation of EPA and DHA has been promoted to solve this problem.

Ground, stabilized flax seed has been used successfully in the cereal and foods world to produce omega-3 fortified products. With only three carbon-carbon double bonds, ALA, is considerably more stable than EPA and DHA and with 22% (by weight) omega-3, flax seed has proven itself an efficient way of making healthy breads and cereals healthier.

Whole-grain bread fortified with ground, stabilized flax seed can provide meaningful amounts of ALA per day, as much as 300–600 mg per serving, while maintaining a “low fat” designation. Alvarado Street Bakery (Rohnert Park, CA; www.alvaradostreetbakery.com) has developed a whole-grain flax-fortified bread providing 360 mg of ALA per 40 g serving. Aunt Millie’s Bakery (Fort Wayne IN; www.auntmillies.com) has also devel-

Table II. Adequate intakes of specific fatty acids for adults

Fatty Acid[a]	2,000 kcal diet (g/day)	Energy (%)
LA	4.44	2.0
(upper limit)	6.67	3.0
LNA	2.22	1.0
DHA + EPA	0.65	0.3
DHA minimum	0.22	0.1
EPA minimum	0.22	0.1
TRANS-FA (upper limit)	2.00	1.0
SAT (upper limit)	…	<8.0
MONOs	…	…

[a] LA = linoleic acid; LNA = α-linolenic acid; DHA= docosahexaenoic acid; EPA = eicosapentaenoic acid; TRANS-FA = trans-fatty acids; SAT = saturated fat; and MONO = monunsaturate fat.

Table I. Plasma omega-3 status of healthy populations

Population/Location	Total Omega-3[a]	Total Omega-6[a]	Ratio (ω6:ω3)[a]
Nigeria	13.4	30.3	2.26
Northern Sweden	13.1	35.8	2.73
Keralites (India)	10.4	29.2	2.80
Southern Sweden	8.68	37.4	4.31
Australia	7.35	39.9	5.43
Minnesota omnivores	5.53	42.6	7.70
Minnesota vegetarians	5.48	42.1	7.68
Bulgaria	5.26	41.0	7.79

[a] Percentage of plasma phospholipid.

oped a whole-grain flax-fortified bread containing 650 mg of ALA per serving.

Several omega-3 enriched breakfast cereal products have also emerged. Enjoy Life Food's (Chicago, IL; www.enjoylifefoods.com) nutty flax has approximately 400 mg of ALA per serving. Pinah's Company (Milwaukee, WI; www.pinahs.com) has developed heart snacks, providing 1,300 mg of ALA per serving.

Making simple food choices to increase intakes of ALA, EPA, and DHA, while limiting your intake of LA, will go a long way for improving omega-3 status and providing omega-3 health benefits. Consumption of plant- and animal-based omega-3 should be emphasized to achieve maximal benefit. Breads and cereals, serving as a food staple in the American diet, have a unique opportunity to provide daily omega-3 intake and meet the needs of a "deficient" society.

Table III. Essential fatty acid content in various grains and foods

Food	18:2ω6	18:3ω3	Ratio
Oils			
Almond	22.3	0.1	223
Brazil nut	29	46.6	0.6
Canola	24	10	2.4
Coconut	1.3	0	--
Corn	52	1	52
Flax	12.7	57	0.22
Hazelnut	15.0	0	--
Olive	7.3	0.6	12.1
Pistachio nut	17.8	0.3	59.3
Pumpkin Seed	42	0	--
Rice bran	33.4	1.6	20.9
Safflower	77	0.2	385
Sesame	45	0.6	75
Soybean	51.1	6.8	7.5
Soybean (hydrogenated)	19.4	1.5	12.9
Sunflower	69	0.1	690
Walnut	52.9	10.4	5.1
Walnut germ	54.8	6.9	7.9
Vegetables/Fruits			
Avocado	1.9	0.1	19
Bean, common	0.3	0.6	0.5
Bean, lima	0.5	0.2	2.5
Bean, navy	0.2	0.3	0.66
Bean, pinto	0.2	0.3	0.66
Broccoli	0.03	0.1	0.3
Cauliflower	0	0.01	0
Kale	0.1	0.2	0.5
Lettuce, Butterhead	0	0.1	--
Lettuce, Red Leaf	0	0.03	--
Mustard	0	0.04	--
Peas	0.2	0.2	1
Purslane	0.09	0.4	0.23
Raspberries	0.2	0.1	2
Strawberries	0.1	0.1	1
Soybean, green	0.6	3.2	0.19
Soybeans	0.4	2.1	0.19
Spinach	0.1	0.9	0.11
Strawberries	0.1	0.1	1
Cereal Grains			
Barley, bran	2.4	0.3	8
Corn, germ	17.7	0.3	59
Oats, germ	11.0	1.4	7.9
Rice, germ	6.4	0.2	32
Wheat, bran	2.2	0.2	11
Wheat, germ	5.9	0.7	8.4
Wheat, hard red	1.1	0.1	11
Nuts and Seeds			
Beechnuts	18.4	1.7	10.8
Butternut	34.0	8.7	3.9
Chia seeds	3.4	3.9	0.87
Hickory	20.9	1.0	20.9
Walnut, black	34.2	3.3	10.4
Walnut, English	32.3	6.8	4.8

[a] Fatty acid composition (gram of fatty acid per 100 g) for various plant oils, grains, vegetables, and fruits and nuts and the ratio of 18:2ω6 to 18:3ω3

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