A Cost Analysis of EPA and DHA in Fish, Supplements, and Foods

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Abstract

Long-chain omega-3 polyunsaturated fatty acids (n-3 LC-PUFAs) are important components in healthy diets. Adequate intake of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) maintains proper neurodevelopment and reduces the risk of heart disease. Long-chain omega-3 polyunsaturated fatty acids are found primarily in fish, seafood, eggs, supplements, and fortified foods. The cost of food is a major influence on food choices. This study sought to determine the cost of 500 mg of EPA + DHA (the recommended intake) in seafood, food, and supplements in order to identify the most economical sources. Stores from five retail grocery chains in Honolulu, Hawaii were visited in June and July 2010 to collect data on the price of foods and supplements containing significant amounts of EPA or DHA. The analysis used information from a nutrient database comprising fourteen food composition databases detailing the omega-3 content of a wide variety of fish and seafood products. While fish oil supplements provided 500 mg of EPA + DHA at the lowest cost, relatively low-cost sources of EPA and DHA were available in fish with a variety of consumption characteristics, such as salmon and pelagic marine fishes. The most expensive sources of 500 mg of EPA + DHA were demersal marine fishes, milk and soy milk, and seaweeds. Strategies to increase intake of EPA and DHA include educating consumers on health benefits and sources, encouraging the consumption of seafood, improving the fatty acid profile of farmed seafood, and increasing the number of foods with EPA and DHA fortification.

Keywords: Cost; Omega-3 fatty acids; Fish; Seafood

Introduction

The long-chain omega-3 fatty acids EPA and DHA, which are obtained in the human diet primarily from seafood, are important components of health. Intake of DHA is especially important in childhood because DHA is a major component of the brain, eyes, and neural tissues [1]. DHA intake is also associated with increase in gestation length and reduction in the incidence of preterm births [2]. Mozaffarian and Rimm [3] determined that consumption of 250 mg/d of EPA + DHA was associated with a 36% decreased risk of coronary heart disease (CHD) mortality compared to little or no intake. Studies of populations with high fish intake such as Greenland Eskimos [4] and the Japanese [5] suggest that long-term consumption may further reduce the risk of CHD. Intake of EPA and DHA may also inhibit carcinogenesis [6], reduce risk of type-2 diabetes [7], reduce risk of non-alcoholic fatty liver disease [8], and improve clinical outcomes in inflammatory diseases [9]. The Academy of Nutrition and Dietetics (formerly the American Dietetic Association) recommends consuming two 4-oz (113 g) servings of fatty fish each week, providing about 500 mg of EPA + DHA per day [10].

Seafood is not the only dietary source of EPA and DHA. Eggs average 58 mg of DHA per 100 g (3.53 oz) [11]. Hens have the ability to elongate shorter chain omega-3 fatty acids in order to enrich their eggs with DHA; feeding hens a 20% flaxseed diet can increase the DHA content by more than 70% [12]. Seaweeds are another dietary source of n-3 LC-PUFAs. Dawczynski et al. [13] tested the fatty acid composition of 34 varieties of brown and red macroalgae and found high concentrations of EPA, up to 42.4% of total fatty acids in the case of hijiki (Sargassum fusiforme), although the total fat concentration was low for all varieties. Fortified foods are an increasingly available source of long-chain omega-3s. Much of the DHA supplied for use in fortified food products is provided by algal oil derived from heterotrophically grown microalgae [14]. Advantages of algal-derived DHA include acceptability to vegetarians, improved palatability and smell, increased stability, and reduced risk of contamination [15].

Supplemental EPA and DHA are available as fish oil, cod liver oil, omega-3-6-9 oil (fish oil plus vegetable oils), and algal-oil. One of the rationales for the use of supplements is safety, since consumption of seafood is associated with concerns about methylmercury and organochlorine (PCBs and dioxins) contamination. Consumption of fish and sea mammals, especially those on the top of the food chain, is the only known route of human exposure to methylmercury [16]. PCBs and dioxins are synthetic carcinogenic compounds that also bioaccumulate in animals; human exposure is associated with dietary intake, although not exclusively from seafood [17].

Intake of EPA and DHA in the US in 1999-2000 was about 100 mg/day [18] or about one fifth of recommended intakes [19]. Strategies are needed to increase intake. In addition to the need for consumer education regarding the health benefits of long-chain omega-3s, consumers need information on the price of EPA and DHA found in...
commonly available foods. The objective of this study was to determine the cost of 500 mg of EPA + DHA in various seafood, food and supplement sources in order to identify the most economical sources of EPA and DHA in commonly available foods.

Methods

Branches of five large chain supermarkets (Costco, Foodland, Safeway, Times, and Walmart) in the Honolulu metropolitan area were visited in June and July 2010 to record prices of raw, prepared, frozen, and canned seafood, as well as fortified food products and supplements containing EPA and DHA. The method of processing of fish and seafood, the source (country of origin) and whether the item was wild-caught or farm-raised were also recorded. The price survey covered common food products for which EPA and DHA content is available.

When similar products were found at the same store location, we selected the product with the lowest price for evaluation. This treatment is consistent with the study’s focus on identifying the most economical sources of EPA and DHA in commonly available foods.

Analysis considered a total of fifteen categories: nine types of fish and seafood, the source (country of origin) and whether the item was wild-caught or farm-raised or to identify the species. In some cases, the most commonly available species/source based on the price survey covered.

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Table 1: Mean cost of 500 mg of EPA + DHA by category of supplements and foods

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Mean Cost/500 mg of EPA + DHA ± SD</th>
<th>Minimum</th>
<th>Minimum Item</th>
<th>Maximum</th>
<th>Maximum Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish /Cod Liver Oil Supplements</td>
<td>11</td>
<td>$0.19 ± 0.10</td>
<td>$0.03</td>
<td>fish oil</td>
<td>$0.20</td>
<td>cod liver oil</td>
</tr>
<tr>
<td>Omega 3-6-9 Supplement</td>
<td>2</td>
<td>$0.44 ± 0.08</td>
<td>$0.39</td>
<td>fish, plant oils</td>
<td>$0.50</td>
<td>fish, plant oils</td>
</tr>
<tr>
<td>Prenatal DHA Supplement</td>
<td>3</td>
<td>$0.97 ± 0.13</td>
<td>$0.87</td>
<td>prenatal vitamin</td>
<td>$1.11</td>
<td>prenatal vitamin</td>
</tr>
<tr>
<td>Salmon</td>
<td>25</td>
<td>$1.17 ± 1.27</td>
<td>$0.23</td>
<td>pink, C</td>
<td>$4.91</td>
<td>Atlantic, D/S</td>
</tr>
<tr>
<td>Pelagic Marine Fishes</td>
<td>30</td>
<td>$1.35 ± 1.24</td>
<td>$0.09</td>
<td>sardines, Fo</td>
<td>$4.72</td>
<td>mahimahi, Fo</td>
</tr>
<tr>
<td>Other Marine Fishes</td>
<td>9</td>
<td>$2.15 ± 1.48</td>
<td>$0.19</td>
<td>scad, Fe</td>
<td>$3.89</td>
<td>opakapaka, Fo</td>
</tr>
<tr>
<td>Eggs (Enriched)</td>
<td>2</td>
<td>$3.15 ± 0.53</td>
<td>$2.77</td>
<td>eggs, 12ct</td>
<td>$3.52</td>
<td>eggs, 12 ct</td>
</tr>
<tr>
<td>Eggs (Non-Enriched)</td>
<td>4</td>
<td>$3.64 ± 1.67</td>
<td>$2.11</td>
<td>eggs, xl, 18 ct</td>
<td>$5.74</td>
<td>eggs, 18 ct</td>
</tr>
<tr>
<td>Cephalopods</td>
<td>11</td>
<td>$4.43 ± 5.55</td>
<td>$0.49</td>
<td>squid, PF</td>
<td>$17.56</td>
<td>octopus, D/S</td>
</tr>
<tr>
<td>Mollusks</td>
<td>44</td>
<td>$4.88 ± 4.58</td>
<td>$0.53</td>
<td>mussels, Fo</td>
<td>$26.39</td>
<td>abalone, C</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>33</td>
<td>$5.46 ± 3.69</td>
<td>$1.34</td>
<td>shrimp, Fo</td>
<td>$14.54</td>
<td>shrimp, D/S</td>
</tr>
<tr>
<td>Fresh Water Fishes</td>
<td>11</td>
<td>$6.97 ± 5.62</td>
<td>$0.45</td>
<td>trout, Fe</td>
<td>$16.38</td>
<td>catfish, Fe</td>
</tr>
<tr>
<td>Milk and Soy Milk</td>
<td>3</td>
<td>$10.40 ± 1.77</td>
<td>$8.38</td>
<td>fortified milk</td>
<td>$11.70</td>
<td>fortified milk</td>
</tr>
<tr>
<td>Demersal Marine Fishes</td>
<td>6</td>
<td>$10.68 ± 16.49</td>
<td>$1.80</td>
<td>flatfish, Fo</td>
<td>$44.07</td>
<td>orange roughy, Fo</td>
</tr>
<tr>
<td>Seaweeds (dried)</td>
<td>13</td>
<td>$11.40 ± 8.86</td>
<td>$2.25</td>
<td>wakame</td>
<td>$28.72</td>
<td>nori</td>
</tr>
</tbody>
</table>

*fish, flax, borage oils
*Cann, Fe=fresh, Fo=frozen, PF=previously frozen, D/S=dried/smoked

Table 1: Mean cost of 500 mg of EPA + DHA by category of supplements and foods

Results

Supplements, in particular fish oil supplements, are the most economical source of long-chain omega-3s, with the lowest cost of 500 mg of EPA + DHA (Table 1). Salmon, pelagic marine fishes, and other marine fishes are the three food categories providing 500 mg of EPA + DHA at the lowest cost. Within the salmon and pelagic marine fishes categories, there was a wide range of EPA + DHA costs, with 500 mg costing less than $0.25 for canned pink salmon and frozen sardines, and nearly $5.00 for smoked Atlantic salmon and fresh mahi-mahi. Eggs and omega-3 enriched eggs offer a lower cost of 500 mg EPA + DHA than fish oil supplements.
DHA than any of the remaining fish, seafood and food categories. Due to variability in egg size, number of eggs per carton, and production method (conventional versus free-range and/or organic), EPA + DHA prices overlapped between egg categories, with the lowest cost item in the non-enriched category costing less per 500 mg of EPA + DHA than the highest cost item in the enriched category.

After eggs, the next most economical categories for EPA + DHA were cephalopods, mollusks, and crustaceans (Table 1). Each of these categories offers economical sources of EPA + DHA as well as expensive sources. Items within a given category that were dried or smoked were invariably more expensive sources of EPA + DHA than fresh, frozen or canned, as would be expected given the additional processing and greater density of the foods after reduction in water content. The cost of EPA + DHA in the two remaining fish categories, fresh-water fishes and demersal marine fishes, was generally high. However, within both categories, there were several inexpensive sources of EPA + DHA. For example, fresh-water trout was one of the least expensive fresh or frozen fish sources of EPA + DHA in our survey, whereas catfish was one of the most expensive.

Among demersal marine fishes, orange roughy was the most expensive fish source of EPA + DHA, and its inclusion raised the average cost of EPA + DHA in the category substantially. Fortified milk/soy milk products were relatively expensive sources of EPA + DHA compared to most of the seafood and fish categories. Two of the three products sampled were fortified with algal oil DHA, while one (the least expensive) was fortified with fish oil. Although seaweeds, as a category, were the most expensive source of omega-3 fatty acids surveyed, dried wakame and hijiki averaged $3.32 and $3.70 per 500 mg of EPA + DHA respectively, or about the same cost as the omega-3s in eggs. However, the standard serving size for dried seaweeds is only 8 g, since it must be reconstituted before being eaten, and more than 10 servings (84 g) of wakame or hijiki would need to be eaten to consume 500 mg of EPA + DHA.

There are numerous individual items from many categories of fish and seafood that were inexpensive sources of 500 mg of EPA + DHA—costing $0.70 or less (Table 2). Besides fish oil and Omega-3-6-9 supplements containing fish oil, all of the items on Table 2 are fish and seafood. Among categories of seafood, only crustaceans lacked a product providing 500 mg of DHA + EPA at $0.70 or less. None of the food products fortified with algal oil (e.g. milk, soymilk, prenatal supplements) made the list of most economical sources of EPA + DHA. This likely reflects the relatively high cost of algal oil as a source of DHA and the fact that these are specialty products for niche markets.

Salmon and pelagic marine fishes were among the least expensive sources of EPA and DHA because both categories of fish contain numerous species with very high EPA and DHA contents. Many species in both groups provide more than 1000 mg of EPA + DHA per 100 g (3.53 oz) serving, with canned mackerel (not shown) and sardines exceeding 2000 mg of EPA + DHA per 100 g (Figure 1). Outside of these two categories only two items surveyed had greater than 1000 mg of EPA + DHA per 100 g - scad (other marine fishes) and trout (fresh-water fish). Non-fish seafood categories (mollusks, crustaceans and cephalopods) had moderate but consistent levels of EPA + DHA, typically in the 200 to 400 mg range per 100 g, although Pacific oysters are a particular good source of long-chain omega-3s, with over 600 mg per 100-g serving. A serving of two eggs (100 g), whether enriched or not, contains insufficient EPA + DHA to achieve recommended levels, but does contribute a significant amount towards a day’s recommended intake if combined with another source of EPA and/or DHA. For

### Table 2: Products with the lowest cost per 500 mg of EPA + DHA.

<table>
<thead>
<tr>
<th>Producta</th>
<th>Category</th>
<th>Cost / 500 mg EPA +DHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish oil supplement</td>
<td>Fish Oil Supplementsb</td>
<td>$0.03</td>
</tr>
<tr>
<td>Sardines, Foc</td>
<td>Pelagic Marine Fishes</td>
<td>$0.16</td>
</tr>
<tr>
<td>Scad, Fe</td>
<td>Demersal Marine Fishes</td>
<td>$0.19</td>
</tr>
<tr>
<td>Wild pink salmon, C</td>
<td>Salmon</td>
<td>$0.23</td>
</tr>
<tr>
<td>Farmed Atlantic salmon, Fe</td>
<td>Salmon</td>
<td>$0.26</td>
</tr>
<tr>
<td>Albacore tuna, C</td>
<td>Pelagic Marine Fishes</td>
<td>$0.38</td>
</tr>
<tr>
<td>Fish, flax, borage oil supplement</td>
<td>Omega-3-6-9 Supplements</td>
<td>$0.39</td>
</tr>
<tr>
<td>Farmed trout, Fe</td>
<td>Fresh-Water Fishes</td>
<td>$0.45</td>
</tr>
<tr>
<td>Mullet, Fo</td>
<td>Other Marine Fishes</td>
<td>$0.47</td>
</tr>
<tr>
<td>Squid, PF</td>
<td>Cephalopods</td>
<td>$0.49</td>
</tr>
<tr>
<td>Wild sockeye salmon, Fo</td>
<td>Salmon</td>
<td>$0.51</td>
</tr>
<tr>
<td>Mussels, PF</td>
<td>Molluscs</td>
<td>$0.53</td>
</tr>
<tr>
<td>Anchovies, C</td>
<td>Pelagic Marine Fishes</td>
<td>$0.55</td>
</tr>
<tr>
<td>Bigeye tuna, Fe</td>
<td>Pelagic Marine Fishes</td>
<td>$0.70</td>
</tr>
</tbody>
</table>

a Only the lowest cost data point is listed for each product.
b Includes cod liver oil supplements.
c Frozen, Canned, F= fresh, PF= previously frozen.

Figure 1: EPA and DHA content in selected foods, supplements and seafood items available in supermarkets in Honolulu, Hawaii. The EPA and DHA content for “Foods and Supplements” is in mg/serving, with the serving size listed for each item. All other items are listed on mg/100g (3.53 oz) basis. EPA and DHA data was compiled from the Composite Seafood Database [20] with the following exceptions: values for frozen and previously frozen shrimp items are based on data from Krzywienek and Panunzio [22]; values for farmed and wild tilapia are based on data from Karapanagiotidis et al. [23]; values for trout and Atlantic salmon are based on data from Blanchet et al. [24]. The processing method is specified only for items where different values were available based on the method of processing.
example, two omega-3 enriched eggs (providing 166 mg EPA + DHA) consumed the same day as a 100 g serving of either squid (400 mg), canned crab (363 mg), lobster (373 mg), or mussels (353 mg) provides more than 500 mg of EPA + DHA, although none of the items do so individually.

Discussion

Our results show that fish oil supplements offer the lowest cost of EPA and DHA, which is unsurprising since they are produced and marketed solely as a source of long-chain omega-3s. Considering consumption of fish, seafood, eggs, and milk from a hedonic perspective, as well as a broader nutritional perspective, these products offer attributes in addition to their EPA and DHA content that lead individuals to consume them. Fish is an excellent source of high-quality protein, minerals including calcium, iron, selenium, and zinc, water-soluble vitamins B3, B6, and B12, as well as fat-soluble vitamins A, E, and D [25,26]. Eggs are an excellent source of high quality protein, are rich in vitamin D, riboflavin, vitamin B12, biotin and iodine, and also contain significant levels of vitamins A, folate, choline, phosphorus, and selenium [27]. Milk (and fortified soy milk) is a good source of protein and also one of the best bio-available sources of calcium [28]. Seaweeds are high in soluble fiber and are excellent sources of calcium, potassium, iron, copper and iodine [29]. Wakame also has been shown to have antihypertensive properties [30] and may have antihyperlipidemic effects, especially in combination with fish oil [31]. Consumption of fish, eggs, milk, and seaweed would have value as part of a healthy diet even if these foods lacked long-chain omega-3s, which needs to be considered in assessing the value-for-money of alternative sources of long-chain omega-3s.

In the case of omega-3-enriched eggs, milk, and soy milk, an important question is whether the added DHA is worth the added cost. Omega-3 enriched eggs contain more than twice the DHA content of non-enriched eggs (Figure 1) but were priced at about twice the cost per egg while providing just 74 mg additional EPA + DHA in a serving of 2 eggs (100 g). Fortified milk and soy milk products provide only 32 mg of DHA per 8-ounce serving, a content that would require a weekly consumption of 456 ounces (over 3.5 gallons) to obtain 500 mg of EPA + DHA per day at a cost of over $11.00 per gallon. However, the added expense of obtaining n-3 LC-PUFAs in these fortified products may be justified for individuals unwilling or unlikely to consume fish, seafood, or supplements on a regular basis.

Concerns associated with fish consumption include the potential for health problems associated with contaminants such as methylmercury, polychlorinated biphenyls (PCB), and organochlorines. Testing of five over-the-counter brands of fish oil supplements revealed negligible (12 µg/L or less) levels of methylmercury [32], and undetectable levels of polychlorinated biphenyls (PCBs) and organochlorines [33]. Cod liver oil supplements were also found to contain levels of PCBs and organochlorines below WHO daily intake limits [34]. These findings may suggest an advantage of obtaining long-chain omega-3s from supplements rather than fish and seafood. However, numerous authors have compared the benefits associated with fish intake against the risks from co-ingested contaminants and have concluded that the benefits outweigh the risks under typical circumstances [3,16,26,35]. Due to concerns about gestational and early childhood mercury exposure, the FDA currently provides fish consumption recommendations for women who may become pregnant, pregnant women, nursing mothers, and young children, with guidelines intended to reduce methyl mercury intake while continuing fish consumption [3,36].

Conclusion

This study has produced detailed information on the relative cost of long-chain omega-3 fatty acids available from common fish, seafoods, supplements, and fortified foods. Results reveal the value-for-money of alternative sources of long-chain omega-3s, and show relatively low-cost sources of EPA and DHA available in fish with a variety of consumption characteristics. Modifying the diets of farmed fish to improve their fatty acid profiles and incorporating algal oils into foods are two strategies that may improve the affordability and availability of long-chain omega-3s in the long-term. Providing information to consumers on the cost of long-chain omega-3s is one strategy to increase consumption given current market conditions.

Acknowledgements

Thanks to Skylar Fritz and Sheng-Ti Hung, research assistants at University of Hawaii, who participated in collection of price data, and to Dr. Isabelle Bionen, Ghent University, Ghent, Belgium, for sharing the composite seafood database.

References


