

The Omega-3 Fatty Acid Composition and Cost Analysis of Fish Oil Supplements: Fishing for
the Best Deals

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ABSTRACT

Introduction: The omega-3 fatty acids, eicosapentaenoic (EPA) and docosahexaenoic acid (DHA), have many health benefits such as reducing risks of heart disease, cancer and depression. EPA and DHA are found in oily fish and are also available in dietary supplements. The 2010 Dietary Guidelines for Americans recommend 1,750 mg EPA and DHA/wk, or 250 mg/day, which can be reached by consuming 8 ounces of seafood/week. For many people, achieving this recommended amount of EPA and DHA through diet alone may be difficult unless supplements are also used. Though the health benefits of fish oil are relatively clear, the content, purity and price of EPA and DHA needed for the recommended dosage is highly confusing. Purpose: To compare the content and cost of omega-3 supplements in order to assist practitioners and consumers in making choices about purchasing an omega-3 supplement. Methods: Thirteen randomly sampled dietary omega-3 supplements available in retail stores were analyzed. Oils were extracted and prepared for analysis by gas chromatography. After quantifying the levels of numerous fatty acids including EPA and DHA, a cost analysis was performed for each supplement based on retailer's list prices per unit (e.g., gram of oil), recommended dosage and composition. Results: Fish oil pills available for consumers varied greatly in content and price. The amount of DHA + EPA ranged from 10 mg/g to 894 mg/g EPA and DHA. The prices also varied from \$0.03 per pill, to \$1.23 per pill. Summary: Results from these analyses should clarify confusion regarding content and price per recommended serving of fish oil supplements, while

also enhancing the health and quality of life for the millions of Americans suffering from diseases that may be prevented with adequate dietary intake of omega-3 fatty acids.

INTRODUCTION

Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are omega-3 polyunsaturated fatty acids (PUFAs) and are precursors of eicosanoids. EPA and DHA are marketed in fish oil supplements and can be found in oily fish such as salmon, tuna, and herring. Arachidonic acid and linoleic acid are omega-6 PUFAs and precursors of prostaglandins and eicosanoids. Refined vegetable oils such as safflower, sunflower, and corn oils contain α -linoleic acid (1). Both α -linolenic and linoleic acid cannot be made by the body and must be obtained through diet (2). Although EPA and DHA can be synthesized from their precursor, α -linoleic acid, studies show that this is not very efficient and that tissue growth depends significantly on consumption of EPA and DHA through dietary sources (3,4). While EPA and DHA lead to reduced inflammation, arachidonic acid increases the production of proinflammatory cytokines (1). Thus, the ratio of omega-6 to omega-3 fatty acids may be very important in disease prevention and control.

Evolutionally, the omega-6/omega-3 ratio in hunter-gatherer diets was approximately 2:1 (5). Western diets are high in omega-6 fatty acids, and deficient in omega-3 fatty acids, leading to a ratio of about 16:1. (1,5). This high omega-6 to omega-3 ratio in the diet has been shown to promote various diseases such as cancer, inflammatory and autoimmune diseases, and cardiovascular disease. By increasing levels of omega-3 PUFAs, Americans can lower their omega-6/omega-3 ratio and this optimal ratio can potentially reduce the risk of many chronic diseases (2).

Coronary Heart Disease

Consumption of EPA and DHA reduces the risk of coronary heart disease by lowering triglyceride levels and blood pressure (6). Studies have shown that those who incorporate fish into their diets had a lower risk of mortality from coronary heart disease (7-10).

Cancer

Fish oil supplementation has also been found to display potential anti-cancer effects (11). Studies have shown that more aggressive tumor characteristics and increased mammary tumor promotion are linked with high levels of linoleic acids in the diet (12, 13). Fish oil supplementation has also been shown to improve quality of life and reduce weight loss in patients with cancer-related cachexia. An EPA enriched diet may have the ability to decrease the production of tumor necrosis factor (TNF), a potential mediator of cachexia, while also displaying a direct effect on tumor growth kinetics (14). Nude mice with xenografts of human breast cancer fed EPA and DHA enriched diets displayed suppression of tumor growth and metastasis (15).

Depression

EPA and DHA consumption can also reduce depression and suicide (16). Depressive symptoms have also been linked to cardiovascular disease, which is the leading cause of death in the United States. Studies have shown that depressed patients tend to have lower levels of omega-3 PUFAs than nondepressed control patients (1, 17).

Alzheimer's and Parkinson's disease

Fish oil supplementation can also positively impact the brain in relation to cognitive problems accompanied by Alzheimer's disease and Parkinson's (18). Lower intakes of EPA and DHA have been associated with increased risk of Alzheimer's disease. Omega-3 fatty acids are recommended in prevention of CVD and AD (19). Learning and cognitive development are also positively impacted by omega-3 fatty acids (20).

Dietary Guidelines

Because of the health benefits of EPA and DHA, in 2010, the Dietary Guidelines for Americans recommend 1,750 mg EPA and DHA per week, which translates to approximately 250 mg per day, and can be reached by consuming 8 ounces of seafood per week. For many people, achieving the recommended amount of EPA and DHA may best be achieved through supplements. Though the health benefits of fish oil are relatively clear, there are numerous brands available to the public, in various quantities and forms that are confusing in terms of 'consumer understanding' and also financially burdensome. Through analyzing the content and price of several fish oil supplements available on the market, my project seeks to provide clarity and guidance for consumers to make an informed and knowledgeable decision concerning their fish oil supplement brand.

METHODS

Thirteen randomly sampled dietary omega-3 supplements available in retail stores were analyzed. Oils were extracted from capsules and prepared for analysis by gas chromatography. After quantifying the levels of numerous fatty acids including EPA and DHA, a cost analysis

was performed for each supplement based on retailer's list prices per unit (e.g., gram of oil), recommended dosage and composition.

Fatty acid methyl esters were prepared from the oils using 5% hydrochloride acid in methanol at 76°C (5). Each capsule was analyzed in duplicates (when available) and C17:0 was used as the internal standard. A syringe was used to extract the oil from the fish oil supplement capsule and about 2-3 drops of the oil was placed into previously weighed glass test tube. The test tube was then reweighed after the addition of the oil in order to calculate the grams of oil used in analysis from each capsule. One ml of 5% Hydrochloric Acid in Methanol was added to the oil to methylate the fat. The internal standard was prepared in the 5% HCl in MeOH at a concentration of 100ug/ml. The samples were capped tightly, vortexed and heated in a bead bath at 76° C overnight.

After removing the samples from the bead bath the next day, 1 mL of hexane and 0.5ml of 0.88% KCl were added to each sample. The samples were capped tightly, vortexed, and placed in a centrifuge at 1000g for 10 minutes at 4°C. After removing the sample from the centrifuge, the top hexane phase was transferred to a new glass test tube with a glass pipette. One mL of hexane was added to the remaining bottom aqueous phase. After vortexing the samples and centrifuging again at 1000g for 10 minutes at 4°C, the top hexane phase was once again removed and combined with the top hexane phase from the prior transfer. The hexane was dried under a steady stream of nitrogen at room temperature until completely dry. The samples were weighed and 2 mL of hexane was added to each sample. The samples were vortexed and 300 ul was transferred to a GC vial. Samples were stored at -20 °C until GC analysis.

Analysis of fatty acid methyl esters was completed by gas chromatography (GC) using a 30-m Omegawax™320 fused silica capillary column (Supelco, Bellefonte, PA). Oven temperature started at 175°C and increased at a rate of 3° C/min until reaching 220°C. Flow rate of the carrier gas helium was 30 mL/min. Retention times of samples were compared to standards for fatty acid methyl esters (Matreya, LLC, Pleasant Gap, PA, Supelco, Bellefonte, PA and Nu-Check Prep Inc, Elysian, MN) Fatty acids are reported as percent of total identified fatty acids and EPA and DHA were also reported as mg/g of oil.

Prices of the various fish oil supplement brands were collected in March 2011 from respective stores or websites. To calculate price per pill of the different brands, the total price of the bottle was then divided by the quantity of pills in the bottle. The required dosage of the brands was then addressed and the price per recommended dosage was calculated by multiplying the price per pill by the amount of pills recommended to take each day. The manufacturer's recommended EPA and DHA dosage was then calculated for the total amount of EPA and DHA per day, and then correlated with the price per day.

RESULTS

Table 1 shows the brands of the 13 fish oil supplements and the EPA and DHA content, along with prices based on the label. Prices per pill ranged from \$0.03 to \$1.23 per pill, and price per day ranged from \$0.09 per day to \$1.23 per day. Manufacturer's stated EPA and DHA content per recommended dosage ranged from 200 mg EPA and DHA per day to 1440 mg EPA and DHA per day.

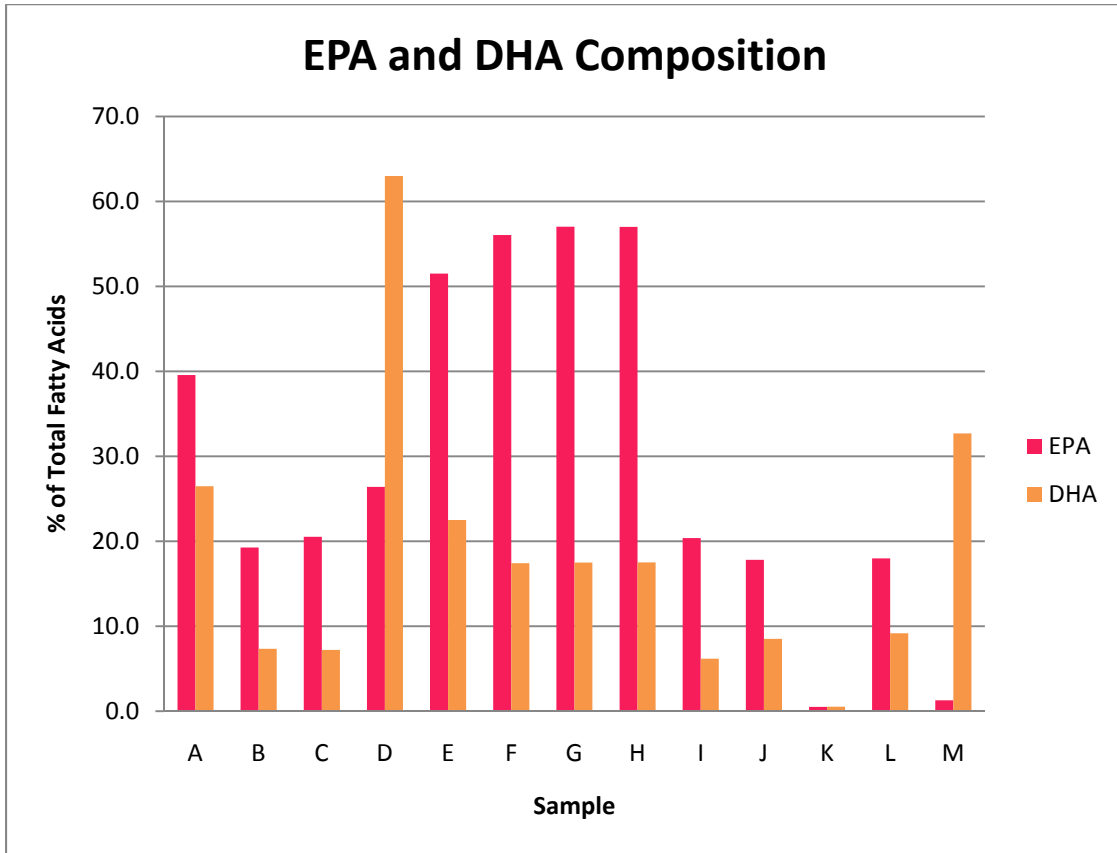
Table 1: Brands and prices of thirteen fish oil supplements

Sample	Brand	Amount Per Pill	Price per bottle	Price per pill	Price per day	Dose	EPA+DHA Dose per day
A	Nature Made Liquid Softgel Double Strength	1200 mg	\$17.47	\$0.19	\$0.39	2 softgels 1 time daily	1224 mg
B	Nature Made	1200 mg	\$16.99	\$0.17	\$0.68	2 softgels 2 times daily	1440 mg*
C	Origin Purified to eliminate mercury	1200 mg	\$5.00	\$0.05	\$0.20	2 softgels 2 times daily	1440*
D	Vital Oils 1000	1000 mg	\$36.95	\$1.23	\$1.23	1 softgel daily	1000 mg
E	Origin Triple Strength	1360 mg	\$8.99	\$0.30	\$0.30	1 softgel daily	950 mg*
F	Member's Mark Triple Strength	1400 mg	\$29.95	\$0.20	\$0.20	1 softgel daily	900 mg
G	Finest Natural	1400 mg	\$11.99	\$0.20	\$0.20	1 softgel daily	900 mg
H	Spring Valley	1400 mg	\$14.97	\$0.25	\$0.25	1 softgel daily	900 mg
I	Origin Odorless, Purified to eliminate mercury	1200 mg	\$19.07	\$0.07	\$0.21	1 softgel 3 times daily	1080 mg*
J	Kirkland Signature	1000 mg	\$8.99	\$0.03	\$0.09	1 softgel 3 times daily	900 mg*
K	Animal Hospital	ND	ND	ND	ND	ND	ND
L	Nordic Naturals Purified Fish Oil with Vitamin D	1000mg	\$28.95	\$0.48	\$0.97	2 softgels daily	1100 mg
M	Expecta	200 mg	\$24.19	\$0.81	\$0.81	1 softgel daily	200 mg

*includes other Omega-3 fatty acids

ND=No Data Available

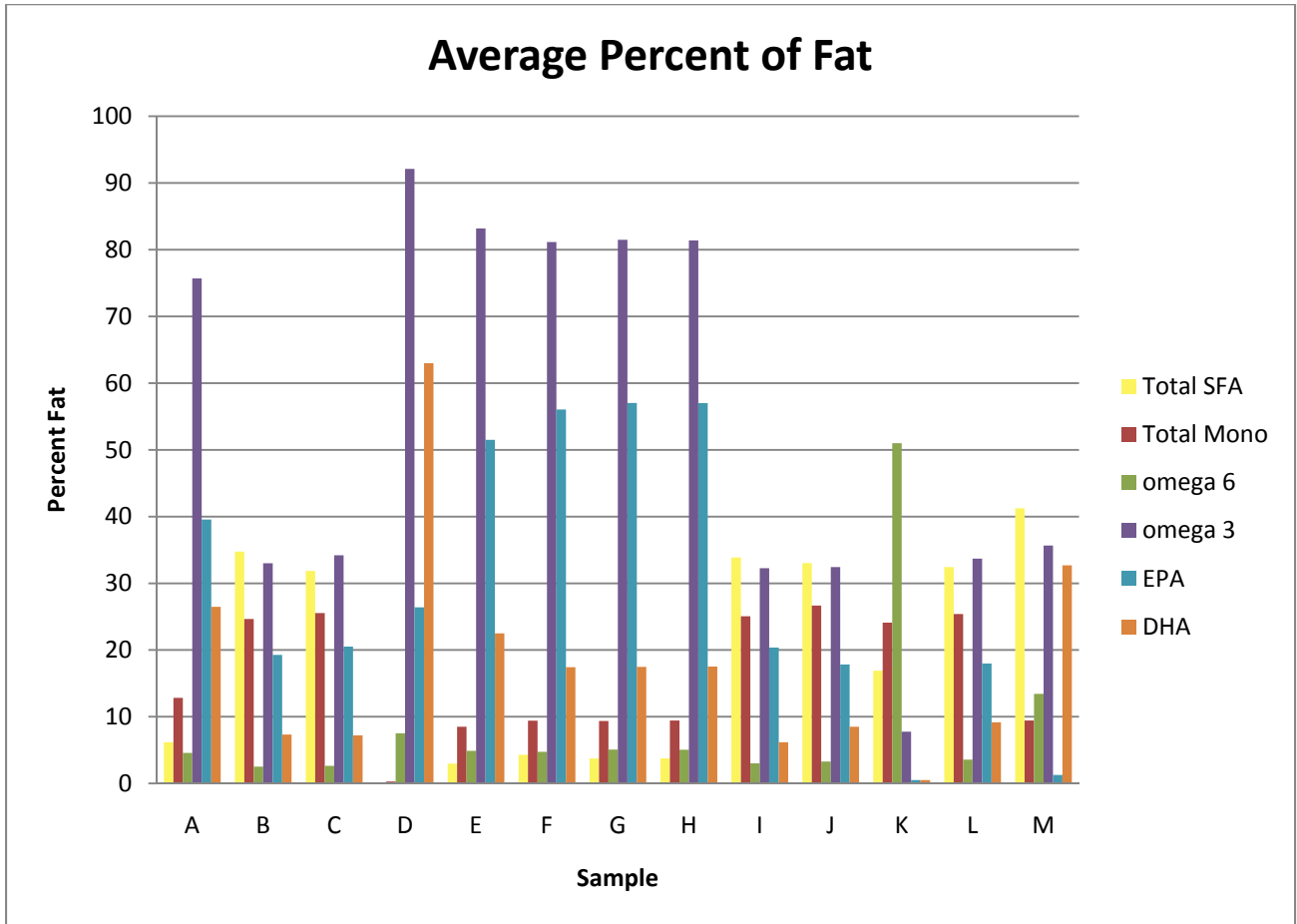
Figure 1: EPA and DHA Composition



Values are expressed as average percent of total identified fatty acids. Samples A-M were averaged between two pills and the results of the averages were used to represent EPA and DHA content per pill. EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

The thirteen different fish oil supplements vary in their amounts of EPA and DHA. The highest amount of EPA and DHA from the selected supplement brands was 894.0 mg/g and the lowest amount of EPA and DHA was 10.2 mg/g, which was a difference of 883.8 mg/g EPA and DHA.

Figure 2: Average Percent of Fat



Values are expressed as average percent of total identified fatty acids. Total SFA, total saturated fatty acids; Total Mono, total monounsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

The thirteen different fish oil supplements also varied in average percent fat. The composition of fats and which specific fat each supplement contains is important information for consumers to be aware of because this may affect their daily total consumption of certain fats, like saturated fat. Sample B has slightly higher amounts of saturated fatty acids than other brands, so if a consumer already is near the upper limit of dietary saturated fat intake, they might want to choose a supplement with a lower saturated fatty acid content.

Table 2: Average Percent of Fat

%Fat	A		B		C		D		E	
Total SFA	6.2	± 0.0	34.8	± 0.1	31.9	± 0.0	0.1	± 0.0	3.0	± 0.0
Total Mono	12.8	± 0.0	24.7	± 0.0	25.5	± 0.0	0.3	± 0.0	8.5	± 0.0
omega 6	4.6	± 0.0	2.5	± 0.0	2.6	± 0.0	7.5	± 0.0	4.9	± 0.0
omega 3	75.7	± 0.0	33.0	± 0.1	34.2	± 0.1	92.1	± 0.0	83.2	± 0.0
omega 6:omega 3	0.1	± 0.0	0.1	± 0.0	0.1	± 0.0	0.1	± 0.0	0.1	± 0.0
EPA	39.6	± 0.0	19.3	± 0.1	20.5	± 0.1	26.4	± 0.0	51.5	± 0.0
DHA	26.5	± 0.0	7.3	± 0.1	7.2	± 0.0	63.0	± 0.0	22.5	± 0.0
EPA:DHA	1.5	± 0.0	2.6	± 0.0	2.9	± 0.0	0.4	± 0.0	2.3	± 0.0
EPA+DHA	66.1	± 0.0	26.6	± 0.1	27.7	± 0.1	89.4	± 0.0	74.0	± 0.0

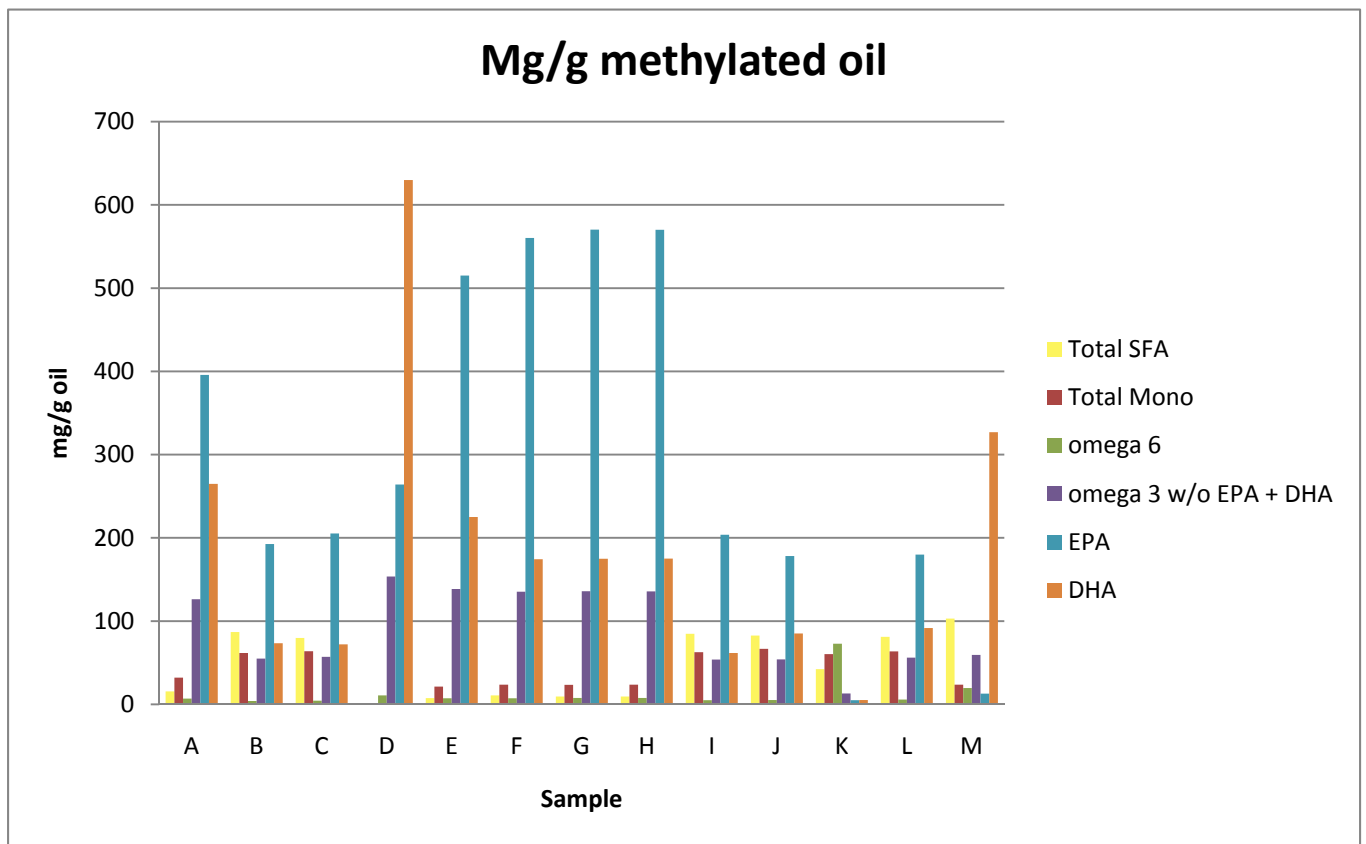
%Fat	F		G		H		I		J	
Total SFA	4.291	± 0	3.749	± 0	3.766	± 0	33.87	± 0.1	33.04	± 0
Total Mono	9.411	± 0	9.352	± 0	9.423	± 0	25.07	± 0	26.66	± 0.1
omega 6	4.752	± 0	5.078	± 0	5.049	± 0	3.022	± 0	3.279	± 0
omega 3	81.16	± 0	81.49	± 0	81.4	± 0	32.25	± 0	32.43	± 0.1
omega 6:omega 3	0.059	± 0	0.062	± 0	0.062	± 0	0.094	± 0	0.101	± 0
EPA	56.04	± 0	57.02	± 0	57.01	± 0	20.38	± 0	17.82	± 0.1
DHA	17.42	± 0	17.49	± 0	17.51	± 0	6.169	± 0	8.505	± 0.1
EPA:DHA	3.216	± 0	3.261	± 0	3.256	± 0	3.304	± 0	2.1	± 0
EPA+DHA	73.46	± 0	74.51	± 0	74.52	± 0	26.55	± 0.1	26.33	± 0.1

%Fat	K		L		M	
Total SFA	16.9	± 0	32.43	± 0	41.22	± 0.1
Total Mono	24.11	± 0	25.4	± 0	9.431	± 0
omega 6	51	± 0	3.564	± 0	13.42	± 0
omega 3	7.765	± 0	33.7	± 0	35.65	± 0
omega 6:omega 3	6.568	± 0	0.106	± 0	0.377	± 0
EPA	0.501	± 0	17.98	± 0	1.283	± 0
DHA	0.52	± 0	9.166	± 0	32.69	± 0
EPA:DHA	0.963	± 0	1.962	± 0	0.039	± 0
EPA+DHA	1.021	± 0	27.14	± 0	33.97	± 0.1

Values are expressed as percent of total identified fatty acids ± standard deviation. Total SFA, total saturated fatty acids; Total Mono, total monounsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Table 2 expresses the total saturated fatty acids, total monounsaturated fatty acids, total omega-6 fatty acids, total omega-3 fatty acids, the omega-6 to omega-3 ratio, EPA content, DHA content, the ratio of EPA to DHA, along with the amount of EPA and DHA averaged across each pill. A ratio of EPA: DHA is important in seeking to maintain an optimal EPA: DHA ratio in the diet.

Figure 3: Mg/g Methylated oil



Values are expressed as average percent of total identified fatty acids. Total SFA, total saturated fatty acids; Total Mono, total monounsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Figure 3 shows that the thirteen various fish oil supplements varied in contents of total saturated fatty acids, total monounsaturated fatty acids, omega-6, omega-3, EPA and DHA. Sample D (Vital Oils 1000) had the highest amount of DHA at 629.9 mg/g DHA, and 894.4 mg/g total EPA and DHA, but this is also the pill that would cost a consumer \$1.23 per day to consume. Comparable amounts of EPA and DHA can be achieved by choosing a supplement like E (Origin Triple Strength Fish Oil), at that would cost the consumer \$0.30 per day and provide 740 mg/g EPA and DHA.

Table 3: Mg/g Methylated oil

mg/g methylated oil	A		B		C		D		E	
Total SFA	15.4	± 1.8	86.9	± 12.8	79.6	± 11.6	0.2	± 0.0	7.4	± 1.1
Total Mono	32.1	± 5.2	61.7	± 8.3	63.8	± 8.3	0.8	± 0.1	21.3	± 2.3
omega 6	6.9	± 0.8	4.1	± 0.6	4.3	± 0.6	10.8	± 2.6	7.3	± 1.2
omega 3	126.2	± 15.1	55.0	± 3.8	57.0	± 3.7	153.5	± 38.7	138.6	± 12.9
omega 6:omega 3	0.1	± 0.1	0.1	± 0.2	0.1	± 0.2	0.1	± 0.1	0.1	± 0.1
EPA	395.7	± 0.2	192.6	± 0.6	205.2	± 0.6	264.1	± 0.1	515.0	± 0.2
DHA	264.8	± 0.1	73.4	± 0.8	72.1	± 0.5	629.9	± 0.3	225.0	± 0.1
EPA:DHA	1.5	± 1.5	2.6	± 0.8	2.8	± 1.2	0.4	± 0.4	2.3	± 1.2
EPA + DHA	660.5	± 0.4	266	± 1.4	277.3	± 1.1	894	± 0.4	740.1	± 0.3

mg/g methylated oil	F		G		H		I		J	
Total SFA	10.73	± 2	9.372	± 1.8	9.416	± 1.8	84.68	± 12	82.6	± 12
Total Mono	23.53	± 3.5	23.38	± 3.5	23.56	± 3.5	62.67	± 8.4	66.66	± 8.4
omega 6	7.158	± 1.2	7.65	± 1.3	7.615	± 1.3	4.879	± 0.7	5.209	± 0.9
omega 3	135.3	± 9.8	135.8	± 9.9	135.7	± 9.9	53.75	± 3.2	54.05	± 4.5
omega 6:omega 3	0.053	± 0.1	0.056	± 0.1	0.056	± 0.1	0.091	± 0.2	0.096	± 0.2
EPA	560.4	± 0.2	570.2	± 0.2	570.1	± 0.1	203.8	± 0.4	178.2	± 0.6
DHA	174.2	± 0.1	174.9	± 0.1	175.1	± 0	61.69	± 0.1	85.05	± 0.6
EPA:DHA	3.216	± 2.6	3.261	± 1.7	3.256	± 11	3.303	± 2.8	2.096	± 1
EPA + DHA	734.6	± 0.3	745.1	± 0.3	745.2	± 0.2	265.5	± 0.5	263.3	± 1.2

mg/g methylated oil	K		L		M	
Total SFA	42.25 ±	7.8	81.06 ±	12	103.1 ±	18
Total Mono	60.27 ±	17	63.49 ±	8.1	23.58 ±	6.8
omega 6	72.88 ±	27	5.695 ±	0.9	19.56 ±	6.2
omega 3	12.94 ±	3.8	56.16 ±	4.9	59.42 ±	20
omega 6:omega 3	5.631 ±	7	0.101 ±	0.2	0.329 ±	0.3
EPA	5.006 ±	0	179.8 ±	0.1	12.83 ±	0.3
DHA	5.2 ±	0	91.66 ±	0.1	326.9 ±	0.4
EPA:DHA	0.963 ±	0.6	1.961 ±	1.3	0.039 ±	0.6
EPA + DHA	10.21 ±	0	271.4 ±	0.2	339.7 ±	0.7

Values are expressed as percent of total identified fatty acids ± standard deviation. Total SFA, total saturated fatty acids; Total Mono, total monounsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

Table 3 expresses the total saturated fatty acids, total monounsaturated fatty acids, total omega-6 fatty acids, total omega-3 fatty acids, the omega-6 to omega-3 ratio, EPA content, DHA content, the ratio of EPA to DHA, along with the amount of EPA and DHA averaged across each pill. EPA and DHA content range from 263 mg/g -894 mg/g EPA and DHA.

DISCUSSION

Much variance exists in composition and price of fish oil supplements. Results from these analyses should be useful for consumers regarding content and price per recommended serving of fish oil supplements. In reference to the analysis of these thirteen omega-3 supplements, the best value for the amount of EPA and DHA would be Kirkland Signature Natural Omega-3 Fish Oil at \$0.03 per pill and \$0.09 per day. This brand of fish oil supplement provides 900 mg EPA and DHA per day which exceeds the recommended dose of 250 mg per day, but provides an adequate dose in efforts to reduce triglycerides and provide beneficial effects.

Sample K was an animal hospital fish oil supplement that was not in capsule form. The low EPA and DHA values may be due to a higher required dosage, or a difference in dosage

recommendations for animals, but no data was available for analysis. In future directions, this should be replaced with a brand for which data is available.

Dosage must be taken into consideration when analyzing the total amount of EPA and DHA that would be consumed with supplementation of the various brands. For example, although sample B (Nature Made), C (Origin), I (Origin, Odorless), J (Kirkland Signature) and L (Nordic Naturals) have lower amounts of EPA and DHA, the dosage of the brands is 2-3 softgels per day. Whereas D (Vital Oils), E (Origin Triple Strength), F (Member's Mark Triple Strength), G (Finest Natural) and H(Spring Valley) have dosages of 1 softgel daily. The more concentrated fish oil supplements with a dosage of one softgel daily were found to be slightly more expensive than the brands that require 2-3 softgels daily to achieve the recommended dosage. Thus, if a consumer is more concerned with the issue of the cost of a supplement, they would be best advised to choose a brand such as Kirkland Signature Natural Omega-3 Fish Oil which would cost them \$0.09 per day to get 900 mg EPA and DHA. However, if a consumer is more concerned with not being able to remember to take a fish oil supplement three times per day, then they should choose a brand like Finest Natural that will cost them \$0.20 per day, but they will only have to take one softgel per day to get the 900 mg EPA and DHA.

Taking a fish oil supplement could enhance the health and quality of life for those suffering from diseases that may be prevented with adequate dietary intake of omega-3 fatty acids . Our findings suggest that there are a few supplements that are more affordable than others. Choosing an affordable supplement is possible but requires that consumers are aware of content of supplements as well as recommendations for health benefits. Fish oil supplementation has the potential to not only save lives, but also to save billions of dollars that are currently spent on preventable diseases.

LIMITATIONS AND FUTURE DIRECTIONS

Several issues to consider that may have influenced the results of my data were the storage of the pills, the amount of pills that were available for analysis, and the prices that were used for the cost analysis. Pills were kept at room temperature, but they were not all purchased at the same time, so ages of the supplements could have varied. Also, for certain brands, only one or two pills were available for analysis whereas other brands could each have samples taken from separate pills. In terms of pricing of the fish oil supplements, an average was taken of the varied prices for each brand, but this could vary by state, store, and sales and promotions.

In further work on this project, a more broad selection of brands would be beneficial to analyze. A pricing of brands across different stores would further help consumers to not only find out which supplement fits their needs best, but also where they can purchase this supplement at the most affordable price. Different forms of fish oil supplement besides the capsule form would also be interesting to analyze for compositional consistency. Another topic of interest would be the consistency of composition in pills within the same bottle. This might be difficult to design in that being sure to get all of the oil out of the pill would present a challenge.

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