

Content and economic evaluation of omega-3 fatty acid nutritional supplements

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Summary

Marine-derived omega-3 fatty acids, namely eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are abundant in seafood and fish oils. They are recommended for their many health benefits. There has been a large and sustained growth in sales of nutritional supplements containing omega-3 fatty acids during the COVID-19 pandemic. In this study, a total of 54 omega-3 fatty acids supplement products of various brands available in Turkey was analysed for their fatty acids content using gas chromatography. In 59.3 % of the products examined, EPA plus DHA content was found to be less than what was stated on the label. It was observed that 25.9 % could meet the daily EPA+DHA need with a capsule or a measure of consumption. Overall, 35.2 % of products were found satisfactory in terms of providing 80 % or more of the daily EPA+DHA requirement with a capsule or a measure of consumption and advantageous in terms of contents and price. The remaining 64.8 % of products could not provide 80 % of the daily EPA+DHA requirement with a single capsule. This study provided information on the accuracy of the declared contents of omega-3 fatty acids supplements and evaluated the advantages for the consumers.

Keywords

nutritional supplement; eicosapentaenoic acid; docosahexaenoic acid; health benefit; mislabelling; consumption assessment

Marine oils as nutrients have many functions in the human body. Omega-3 (ω -3) fatty acids are essential for human metabolism and have positive health effects. These fatty acids can be synthesized from various fatty acids. Although the synthesis of fatty acids is possible in plants, animals and humans, this function may encounter limiting factors in humans. The relatively high levels of linoleic acid (LA; C18:2 ω -6) in an average Western diet (consumed in vegetable oils and related products) means that the precursors for the pathway leading to the synthesis of ω -6 polyunsaturated fatty acids are predominant. In particular, the synthesis of LA and α -linolenic acid (ALA; C18:3 ω -3) from oleic acid is only possible in plants. In this case, it is necessary for humans to consume these essential fatty acids (LA, ALA) from exogenous sources. ALA is the preferred substrate for the synthesis by a process that can reach up to eicosapentaenoic

(EPA; C20:5 ω -3) acid and docosahexaenoic (DHA; C22:6 ω -3) acid. LA and ALA are considered dietary essential fatty acids as these cannot be synthesized in the human body [1–3].

Nevertheless, estimates based on stable isotope tracer experiments showed that the overall conversion rate of ALA to DHA in males is very low, ranging between < 0.05 % to 4 %. This value is about 9 % in females of reproductive age. This has led some researchers to question whether the consumers' needs for DHA can be met from endogenous supply in terms of beneficial effects, particularly during brain development [2]. In addition, it has been stated that EPA and DHA have positive effects in the prevention and treatment of cardiovascular complications, prostate, breast, lung and bowel cancers, hypertension, rheumatoid arthritis, osteoporosis, diabetes and asthma [2, 3]. It is a general perception among consumers that

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consumption of EPA and DHA “strengthens the immune system”.

Evidence from epidemiological studies highlights the nutritional importance of diets rich in fish, especially oil-rich fish [4]. Thus, it is recommended to consume two servings of oily fish per week by the American Heart Association and the American Dietetic Association [5, 6]. The recommended daily intake value for EPA plus DHA by the American Heart Association is 400–500 mg·d⁻¹ [6, 7]. The European Food Safety Authority (EFSA) recommends 250 mg·d⁻¹ EPA plus DHA for children and 500 mg·d⁻¹ for adults [7]. For consumers who do not consume enough fatty fish, fish oil or nutritional supplements sold as ω -3 fatty acids are a good alternative source. EPA and DHA make up most of the content of these supplements. The products are produced from fatty fishes such as sardines, anchovies, mackerels, sharks or from cod liver [8].

The importance of these nutritional supplements has increased since the COVID-19 outbreak. The fact that COVID-19 causes more severe complications and higher mortality among individuals previously diagnosed with cancer, cardiovascular diseases, diabetes or hypertension highlights the great importance of the immune system in this epidemic [9]. The immune system is a very complex system that allows humans to survive in the environment full of potentially pathogenic microorganisms. Many factors such as adequate and health-promoting nutrition, psychological state or genetic factors affect the functionality of the immune system [10]. Nutritional components of ω -3 fatty acids that are abundant in seafood, can increase immunity against hepatitis C, SARS, MERS and SARS-CoV-2 virus [4, 11]. Studies showed that the nutritional status of individuals infected with SARS-CoV-2 is of great importance for the prognosis and clinical severity of the disease [12]. Nutritional supplements of vitamins (vitamins A, B, C and D), minerals (iron, zinc, selenium) and ω -3 fatty acids have been suggested by ZHANG and LIU for the prevention of COVID-19 [13]. The benefits of fish and fish oils have led to massive and sustained growth in sales of nutritional supplements containing ω -3 fatty acids since the COVID-19 pandemic [13–15].

It should not be forgotten that protection and improvement of health are only possible by protecting one's health and improving health awareness. There are many brands and ingredients of ω -3 fatty acid supplements on the market. These fish oils come from various sources (such as fish liver oil, krill oil, algae oil or fish oil derived from fish meat). The prices of these products in the

market vary considerably [16]. Only information on ω -3 fatty acids is given on the label of some products but some products provide satisfactory information for the consumer on their label (total ω -3 fatty acid content, how much is produced from which seafood, EPA and DHA content separately, recommended daily dose). Although there are differences in the recommended daily dose and how much of the nutritional supplement is sufficient to meet the need, the price-performance ratio of these products varies widely. The origin of products under the name of ω -3 nutritional supplements sold in Turkey is stated as USA, Norway and Germany. The products sold are fish oil, fish liver oil, algae oil and krill oil, usually in the form of capsules or a liquid. Some of the products were ready for sale as imported and some of them were imported as ω -3 fatty acid-rich oil raw materials, and then the encapsulation or bottling process was conducted in Turkey.

The present study aimed to provide information on the accuracy of the declared contents of ω -3 fatty acids supplements on the market in Turkey and evaluated the advantages for the consumers.

MATERIAL AND METHODS

Samples

A total of 54 branded products sold as a source of ω -3 fatty acids and marine oil were investigated. These products were obtained from pharmacies, online drugstores and healthcare retailers in Turkey. Their shelf life reached the end of 2020 or 2021 and were still commercially available in 2021. Among these products, imported ones were 1 algae oil, 2 out of 6 products sold as krill oil, 3 out of 5 liquids and 4 fish liver oil products. Four out of 5 products with information on fish type on their labels and 13 out of 33 products without such information were imported products. All samples except imported products were fish oil produced abroad and products packaged in Turkey. Three packages of each product were examined. The contents of each package (consisting of several lots) were mixed and analysed in triplicate. While the data on EPA and DHA were given as grams per kilogram oil, general saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, ω -6 and ω -3 values were presented in percent. Prices of the products for 2021 were given in US dollars.

Fatty acids analysis

The fatty acid composition of the ω -3 prepara-

tions as nutritional supplements was determined as methyl esters of fatty acids (FAME) using gas chromatography (GC) by the modified method of ICHIHARA et al. [17]. A Clarus 500 gas chromatograph (Perkin Elmer, Waltham, Massachusetts, USA) equipped with an integrated autosampler and flame ionization detector (FID; Perkin Elmer) was used. A 60 m SGE BPX70 capillary column with an inner diameter of 0.25 mm and a film thickness of 0.25 μm (SGE Analytical Science, Melbourne, Australia) was used. The sample injection volume was 0.5 μl . Nitrogen was used as carrier gas at a flow rate of 1 $\text{ml}\cdot\text{min}^{-1}$. The injection port and FID temperatures were set to 220 $^{\circ}\text{C}$ and 240 $^{\circ}\text{C}$, respectively. Gas flows through FID were programmed to be air 450 $\text{ml}\cdot\text{min}^{-1}$ and hydrogen 45 $\text{ml}\cdot\text{min}^{-1}$. The oven temperature was maintained at 120 $^{\circ}\text{C}$ for 5 min, then raised to 240 $^{\circ}\text{C}$ at a rate of 5 $^{\circ}\text{C}\cdot\text{min}^{-1}$ and maintained constant at 240 $^{\circ}\text{C}$ for 15 min. FAME were identified by comparing retention times with a known reference material Menhaden Fish Oil (Supelco, St. Louis, Missouri, USA) and Supelco 37 Ingredient FAME Blend standards (Supelco). Fatty acids were relatively quantified in percent. EPA and DHA percent results in this study were calculated (semi-quantitative) using fixed coefficients from the quantitative assessment as well as EPA and DHA results presented in the GOED report [18]. The calculation was made according to the formula given in Eq. 1.

$$FA = [P \times FC \times 10] - [P \times FC \times C \times 0.1] \quad (1)$$

where FA is fatty acid content (in grams per kilogram), P is fatty acid percentage, FC is the weight of oil samples (expressed in grams), C is the conversion factor (for DHA, $C = 10.22$ and for EPA, $C = 6.55$).

RESULTS AND DISCUSSION

The label information of the contents given on the box by the seller companies generally consisted of the following; manufacturer or importer information, ingredient origin, capsule content, daily recommended capsule consumption, capsule or liquid amount, price, EPA and DHA amount information. This information is given comparatively in Tab. 1–Tab. 10 for 54 samples, together with the determined ω -3 fatty acid levels, EPA and DHA amounts together with the ratios of recommended daily dose. As seen in the tables, the information given in the column is the first ingredient on the product packaging (such as 500 mg krill oil, 1000 mg krill and fish oil, 1200 mg fish

oil) (Tab. 1, Tab. 3, Tab. 5, Tab. 7, Tab. 9). This content refers to the total amount of lipids in a serving. However, this content did not regard all of the ω -3 fatty acids or sum of EPA plus DHA.

As can be seen in Tab. 2, the ω -3 fatty acids level varied between 23.9 % and 70.2 % in algae, krill and krill plus fish oil capsule products. In these examples, except for one example (product with code 7), the others did not meet the daily EPA and DHA requirement for consumers. Tab. 3 and Tab. 4 contain data on the declared composition of liquid products sold as fish and fish liver oil and the determined contents of ingredients. The ω -3 fatty acids levels of liquid products ranged from 15.8 % to 34.1 %. The label data of these products and the analysis results were found to be compatible in terms of EPA plus DHA content, except for one product (product with code 12). All products given in Tab. 4 fully met the daily recommended needs of consumers in terms of EPA and DHA amounts.

The composition of capsule products sold as fish liver oil are given in Tab. 5 and Tab. 6. These products contained in general a lesser amount of ω -3 fatty acids compared to other types of products. The products containing cod liver and shark liver oil products, the data on which are presented in Tab. 5, are recommended to be taken in a dose of one capsule per day, as shown on their labels. However, one capsule does not meet the requirement of 500 mg EPA plus DHA intake for an adult. In terms of the quantity of capsules in the product, it can be observed that product with code 15 was a very cost-effective option.

Tab. 7, Tab. 8 and Tab. 9, Tab. 10 show the composition of capsules marketed as fish oil with a specific origin and unknown origin, respectively. It was determined that the amount of ω -3 fatty acids in fish oil with specific origin given in Tab. 8 ranged from 22.6 % to 65.4 %. Three of the five items from Tab. 8 were salmon-based and the rest were anchovy, sardine and mackerel oil blends. The daily-recommended number of capsules on the label of products 17, 18, and 21 of these products was more than sufficient to meet the daily EPA plus DHA needs. The products with codes 17 and 18 were more cost-effective than the others. The capsule amounts recommended on the labels of 20 of the 33 products presented in Tab. 9 and Tab. 10 met the daily EPA plus DHA requirement.

The ingredient label is important for products sold as ω -3 fatty acid or fish oil supplements. Since consumers are interested in how much ω -3 fatty acids they get, particularly EPA and DHA, the presentation of our study data was given within

Tab. 1. Information about capsule products sold as algae, krill and mixed fish oil from label.

Sample code	Type of product	Country of origin		Price per kilogram of oil [USD]	Number of capsules		Oil content per capsule [mg]	EPA + DHA [g·kg ⁻¹]
		Manufacturer	Main component		Per packaging	Recommended per day		
1	Algae oil	Turkey	ns	400	30	1	500	200
2	Krill oil	Turkey	ns	1000	30	2	500	187
3	Krill oil	United Kingdom	ns	1190	30	2	500	202
4	Krill oil	Turkey	Norway	880	30	1	500	187
5	Krill oil	United Kingdom	ns	620	30	2	500	333
6	Krill oil + fish oil	Turkey	ns	450	32	1	1000*	296
7	Fish oil + krill oil	Turkey	Norway	280	50	2	950**	575

USD – US dollar currency, EPA + DHA – sum of eicosapentaenoic and docosahexaenoic acid contents.

* – product contains 600 mg of krill oil and 400 mg of fish oil, ** – product contains 948 mg of fish oil and 2 mg of krill oil.

Tab. 2. Determined content of fatty acids in capsule products sold as algae, krill and mixed fish oil.

Sample code	Type of product	SFA [%]	MUFA [%]	PUFA [%]	ω-3 [%]	ω-6 [%]	EPA [g·kg ⁻¹]	DHA [g·kg ⁻¹]	EPA + DHA	
									Determined [g·kg ⁻¹]	In 1 capsule* [g·kg ⁻¹]
1	Algae oil	27.8 ± 0.2	15.0 ± 0.2	56.5 ± 0.3	54.6 ± 0.3	1.8 ± 0.1	10.28 ± 0.00	330.39 ± 1.80	340.67	170.34
2	Krill oil	32.7 ± 1.0	23.3 ± 0.2	32.3 ± 0.3	26.6 ± 0.2	2.5 ± 0.1	148.96 ± 1.41	70.03 ± 0.65	218.99	109.50
3	Krill oil	33.3 ± 0.1	25.1 ± 0.1	32.6 ± 1.8	26.1 ± 0.1	2.4 ± 0.1	148.59 ± 1.13	70.03 ± 0.07	218.62	109.31
4	Krill oil	31.7 ± 0.3	24.3 ± 0.3	34.7 ± 0.4	23.9 ± 0.3	4.4 ± 0.1	122.51 ± 1.30	65.36 ± 1.05	187.87	93.94
5	Krill oil	18.8 ± 0.6	17.4 ± 0.3	49.9 ± 0.3	39.2 ± 0.2	5.5 ± 0.1	201.95 ± 1.10	117.79 ± 0.55	319.29	159.65
6	Krill oil + fish oil	21.8 ± 0.4	15.7 ± 0.1	39.9 ± 0.1	28.4 ± 0.1	6.2 ± 0.1	140.64 ± 0.29	94.63 ± 0.07	235.27	235.27
7	Fish oil + krill oil	4.3 ± 0.1	7.1 ± 0.1	81.0 ± 0.3	70.2 ± 0.4	4.6 ± 0.0	342.68 ± 1.60	250.13 ± 1.45	592.81	563.17
										113.0

Values shown are mean ± standard deviation (*n* = 3).

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ω-3 – omega-3 fatty acids, ω-6 – omega-6 fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

* – sum of fatty acids in 1 capsule was calculated according to Eq. 1, ** – percentage of daily intake recommended by the European Food Safety Authority for adults (500 mg per day) [8].

Tab. 3. Information about liquid products sold as fish oil from label.

Sample code	Type of product	Country of origin		Price per litre of oil [USD]	Liquid volume [ml]		EPA + DHA [g·kg ⁻¹]
		Manufacturer	Main component		Per packaging	Recommended per day	
8	Fish oil	Norway	Norway	130	200	5	260
9	Fish oil	Norway	Norway	130	200	5	260
10	Fish oil	Turkey	ns	60	150	5	242
11	Fish oil	Turkey	ns	40	150	5	52
12	Cod liver oil	Norway	Norway	80	250	5	200

ns – not specified, USD – US dollar currency, EPA + DHA – sum of eicosapentaenoic and docosahexaenoic acid contents.

Tab. 4. Determined content of fatty acids in liquids sold as fish oil.

Sample code	Type of product	SFA [%]	MUFA [%]	PUFA [%]	ω-3 [%]	ω-6 [%]	EPA [g·kg ⁻¹]	DHA [g·kg ⁻¹]	EPA + DHA			
									Determined [g·kg ⁻¹]	In 5 ml liquid oil* [g·kg ⁻¹]	Daily intake for adults** [%]	Daily intake for children** [%]
8	Fish oil	28.9 ± 0.0	20.7 ± 0.5	40.1 ± 0.1	33.6 ± 0.1	3.0 ± 0.1	167.93 ± 0.10	111.15 ± 0.00	279.08	1 200.03	580.0	290.0
9	Fish oil	28.0 ± 0.0	21.0 ± 0.1	40.8 ± 0.1	34.1 ± 0.2	2.0 ± 0.0	166.62 ± 0.25	108.18 ± 0.10	274.81	1 181.67	473.0	237.0
10	Fish oil	28.2 ± 0.0	21.8 ± 0.1	40.3 ± 0.1	32.1 ± 0.1	3.0 ± 0.0	163.26 ± 0.20	102.98 ± 0.40	266.23	1 144.81	458.0	229.0
11	Fish oil	19.6 ± 0.1	29.7 ± 0.0	44.8 ± 0.1	15.8 ± 0.1	27.4 ± 0.0	55.60 ± 0.30	76.58 ± 0.20	132.19	568.42	227.0	114.0
12	Cod liver oil	15.6 ± 0.0	41.6 ± 0.2	29.6 ± 0.1	22.7 ± 0.3	3.0 ± 0.0	77.38 ± 0.05	105.94 ± 0.20	183.32	788.28	315.0	158.0

Values shown are mean ± standard deviation (*n* = 3).

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ω-3 – omega-3 fatty acids, ω-6 – omega-6 fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

* – sum of fatty acids in 5 ml (4.3 g) was calculated according to Eq. 1, ** – percentage of daily intake recommended by the European Food Safety Authority for adults (500 mg per day) and for children (250 mg per day) [8].

Tab. 5. Information about capsule products sold as fish liver oil from label.

Sample code	Type of product	Country of origin		Price per kilogram of oil [USD]	Number of capsules		Oil content per capsule [mg]	EPA + DHA [g·kg ⁻¹]
		Manufacturer	Main component		Per packaging	Recommended per day		
13	Cod liver oil	United Kingdom	ns	650	30	1	500	166
14	Cod liver oil	USA	ns	150	90	1	1 000	260
15	Cod liver oil	United Kingdom	ns	150	180	1	1 000	688
16	Shark liver oil	USA	ns	150	50	1	1 200	–

ns – not specified, USD – US dollar currency, EPA + DHA – sum of eicosapentaenoic and docosahexaenoic acid contents.

Tab. 6. Determined content of fatty acids in capsule products sold as fish liver oil.

Sample code	Type of product	SFA [%]	MUFA [%]	PUFA [%]	ω-3 [%]	ω-6 [%]	EPA [g·kg ⁻¹]	DHA [g·kg ⁻¹]	EPA + DHA	
									Determined [g·kg ⁻¹]	In 1 capsule* [g·kg ⁻¹]
13	Cod liver oil	20.1 ± 0.0	36.8 ± 0.1	20.3 ± 0.2	12.7 ± 0.1	3.3 ± 0.0	2.71 ± 0.03	81.83 ± 0.07	84.54	42.27
14	Cod liver oil	26.4 ± 0.1	21.6 ± 0.4	41.5 ± 0.0	33.2 ± 0.1	1.8 ± 0.1	161.95 ± 0.17	102.98 ± 0.05	264.93	264.93
15	Cod liver oil	22.0 ± 0.4	31.8 ± 0.1	35.8 ± 0.1	29.0 ± 0.1	2.0 ± 0.1	125.92 ± 0.35	103.34 ± 0.30	229.26	229.26
16	Shark liver oil	17.7 ± 0.1	24.5 ± 0.1	46.6 ± 0.1	28.6 ± 0.1	12.6 ± 0.2	132.56 ± 0.35	81.70 ± 0.17	214.26	257.11

Values shown are mean ± standard deviation ($n = 3$).

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ω-3 – omega-3 fatty acids, ω-6 – omega-6 fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

* – sum of fatty acids in 1 capsule was calculated according to Eq. 1, ** – percentage of daily intake recommended by the European Food Safety Authority for adults (500 mg per day) [8].

Tab. 7. Information about capsule products sold as fish oil with specific origin from label.

Sample code	Type of product	Country of origin		Price per kilogram of oil [USD]	Number of capsules		Oil content per capsule [mg]	EPA + DHA [g·kg ⁻¹]
		Manufacturer	Main component		Per packaging	Recommended per day		
17	Fish oil from salmon	Turkey	ns	50	60	3	1 200	300
18	Fish oil from wild salmon	USA	ns	90	50	2	1 000	400
19	Fish oil from salmon	USA	ns	80	200	2	1 000	300
20	Fish oil from anchovy sardine mackerel	USA	ns	320	60	2	500	260
21	Fish oil from anchovy sardine mackerel	USA	ns	390	60	2	1 000	600

ns – not specified, USD – US dollar currency, EPA + DHA – sum of eicosapentaenoic and docosahexaenoic acid contents.

Tab. 8. Determined content of fatty acids in capsule products sold as fish oil with specific origin.

Sample code	Type of product	SFA [%]	MUFA [%]	PUFA [%]	ω-3 [%]	ω-6 [%]	EPA [g·kg ⁻¹]	DHA [g·kg ⁻¹]	EPA + DHA	
									Determined [g·kg ⁻¹]	In 1 capsule* [g·kg ⁻¹]
17	Fish oil from salmon	27.1 ± 0.1	20.7 ± 0.1	40.4 ± 0.0	31.2 ± 0.0	3.2 ± 0.0	162.14 ± 0.14	99.21 ± 0.07	261.34	313.61
18	Fish oil from wild salmon	28.7 ± 0.0	23.5 ± 0.0	40.3 ± 0.0	32.6 ± 0.0	3.5 ± 0.0	134.47 ± 0.11	134.04 ± 0.22	268.52	268.52
19	Fish oil from salmon	13.0 ± 0.1	21.1 ± 0.1	37.6 ± 0.1	22.6 ± 0.1	17.3 ± 0.0	100.93 ± 0.85	64.78 ± 0.07	165.70	165.70
20	Fish oil from anchovy sardine mackerel	27.9 ± 0.0	20.1 ± 0.5	41.6 ± 0.1	33.4 ± 0.1	2.8 ± 0.0	168.49 ± 0.42	106.03 ± 0.21	274.52	137.26
21	Fish oil from anchovy sardine mackerel	8.0 ± 0.0	14.1 ± 0.1	70.6 ± 0.1	65.4 ± 0.1	2.5 ± 0.1	309.08 ± 0.85	213.41 ± 0.65	522.54	522.54

Values shown are mean ± standard deviation (n = 3).

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ω-3 – omega-3 fatty acids, ω-6 – omega-6 fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

* – sum of fatty acids in 1 capsule was calculated according to Eq. 1, ** – percentage of daily intake recommended by the European Food Safety Authority for adults (500 mg per day) [8].

Tab. 9. Information about capsule products sold as fish oil with unknown origin from label.

Sample code	Type of product	Country of origin		Price per kilogram of oil [USD]	Number of capsules		Oil content per capsule [mg]	EPA + DHA [g·kg ⁻¹]
		Manufacturer	Main component		Per packaging	Recommended per day		
22	Fish oil	Turkey	ns	440	32	1	1200	917
23	Fish oil	Switzerland	ns	410	30	1	670	549
24	Fish oil	Germany	ns	220	50	2	1200	530
25	Fish oil	Norway	Norway	290	50	3	1000	500
26	Fish oil	Turkey	Norway	230	60	2	1000	550
27	Fish oil	Turkey	ns	130	60	1	1000	500
28	Fish oil	Turkey	Norway	130	45	2	1000	500
29	Fish oil	Turkey	ns	110	150	4	500	300
30	Fish oil	France	ns	140	60	2	693	361
31	Fish oil	Turkey	ns	110	50	2	1300	300
32	Fish oil	Turkey	ns	260	30	2	750	300
33	Fish oil	Norway	Norway	190	180	2	1000	260
34	Fish flesh oil	USA	USA	130	100	2	1000	300
35	Fish oil	Turkey	ns	90	200	–	1000	320
36	Fish oil	Turkey	Spain	350	30	1	1250	500
37	Fish oil	Turkey	ns	120	80	2	1000	300
38	Fish oil	Turkey	ns	310	60	2	500	300
39	Fish oil	Turkey	ns	50	90	2	1000	320
40	Fish oil	USA	Norway	640	60	1	1000	525
41	Fish oil	Turkey	ns	120	100	4	500	200
42	Fish oil	Turkey	ns	110	60	2	1000	300
43	Fish oil	USA	ns	150	90	2	1000	300
44	Fish oil	USA	ns	310	60	2	1200	448
45	Fish oil	Turkey	ns	260	30	1	900	474
46	Fish oil	Australia	Norway	30	200	2	1000	300
47	Fish oil	Switzerland	ns	300	45	1	1200	550
48	Fish oil	Germany	ns	250	60	2	500	300
49	Caviar oil	Turkey	ns	1030	30	1	700	386
50	Fish oil	Turkey	Norway	750	30	1	900	588
51	Fish oil	USA	ns	470	50	1	950	588
52	Fish oil	Turkey	ns	150	45	1	1000	580
53	Fish oil	Switzerland	ns	490	45	1	1200	808
54	Fish oil	Turkey	ns	240	50	1	970	585

ns – not specified, USD – US dollar currency, EPA + DHA – sum of eicosapentaenoic and docosahexaenoic acid contents.

Tab. 10. Determined content of fatty acids in capsule products sold as fish oil with unknown origin.

Sample code	Type of product	SFA [%]	MUFA [%]	PUFA [%]	ω -3 [%]	ω -6 [%]	EPA [g·kg ⁻¹]	DHA [g·kg ⁻¹]	EPA + DHA	
									Determined [g·kg ⁻¹]	In 1 capsule* [g·kg ⁻¹]
22	Fish oil	1.06 ± 0.1	1.7 ± 0.1	81.3 ± 0.2	66.7 ± 0.2	13.9 ± 0.0	309.60 ± 0.90	252.78 ± 0.85	562.38	674.85
23	Fish oil	5.9 ± 0.0	10.5 ± 0.1	73.6 ± 0.0	67.9 ± 0.0	4.3 ± 0.0	332.78 ± 0.58	227.14 ± 0.35	559.92	375.03
24	Fish oil	8.6 ± 0.1	11.8 ± 0.2	71.7 ± 1.3	67.6 ± 1.2	21.9 ± 0.1	334.74 ± 7.05	217.18 ± 5.05	551.92	662.30
25	Fish oil	5.2 ± 0.0	8.2 ± 0.1	59.6 ± 0.4	42.8 ± 0.4	15.1 ± 0.1	196.43 ± 0.31	164.03 ± 0.42	360.46	360.46
26	Fish oil	27.5 ± 0.1	20.7 ± 0.0	41.5 ± 0.2	32.5 ± 0.1	2.6 ± 0.0	164.66 ± 0.49	104.06 ± 0.14	268.71	268.71
27	Fish oil	20.3 ± 0.0	18.7 ± 0.0	52.1 ± 0.0	45.4 ± 0.0	3.2 ± 0.0	227.55 ± 0.14	145.17 ± 0.07	372.73	372.73
28	Fish oil	3.9 ± 0.1	9.0 ± 0.1	52.8 ± 0.4	32.9 ± 0.0	17.9 ± 0.1	178.30 ± 0.05	97.14 ± 0.52	275.44	275.44
29	Fish oil	26.5 ± 0.0	19.7 ± 0.6	42.9 ± 0.1	33.8 ± 0.0	3.1 ± 0.0	165.69 ± 0.28	111.87 ± 0.07	277.55	138.78
30	Fish oil	8.4 ± 0.0	14.7 ± 0.0	69.5 ± 0.1	61.6 ± 0.1	4.8 ± 0.1	304.09 ± 0.49	208.02 ± 0.28	512.11	354.89
31	Fish oil	25.2 ± 0.0	21.2 ± 0.0	44.8 ± 0.2	34.6 ± 0.2	5.0 ± 0.0	172.13 ± 0.50	109.71 ± 0.21	281.85	366.40
32	Fish oil	26.9 ± 0.0	23.1 ± 0.0	37.6 ± 0.0	30.8 ± 0.0	3.1 ± 0.1	151.67 ± 0.14	95.53 ± 0.00	247.20	185.40
33	Fish oil	27.0 ± 0.0	20.8 ± 0.0	42.2 ± 0.1	34.0 ± 0.1	1.8 ± 0.0	175.41 ± 0.37	100.19 ± 0.21	275.60	275.60
34	Fish flesh oil	13.0 ± 0.0	20.8 ± 0.1	27.7 ± 0.0	20.1 ± 0.3	9.5 ± 0.0	85.32 ± 0.07	59.88 ± 0.06	145.20	145.20
35	Fish oil	13.6 ± 0.0	19.6 ± 0.4	36.4 ± 0.4	22.7 ± 0.3	9.5 ± 0.0	106.72 ± 0.28	71.82 ± 0.20	178.54	178.54
36	Fish oil	3.1 ± 0.1	5.4 ± 0.0	80.4 ± 0.2	67.2 ± 0.2	9.0 ± 0.1	346.89 ± 1.27	194.01 ± 0.57	540.90	649.08
37	Fish oil	25.7 ± 0.0	20.5 ± 0.4	43.0 ± 0.1	35.0 ± 0.0	2.5 ± 0.0	169.24 ± 0.18	106.57 ± 0.08	275.81	275.81
38	Fish oil	26.5 ± 0.0	20.5 ± 0.0	43.3 ± 0.1	35.0 ± 0.0	2.2 ± 0.1	165.87 ± 0.30	113.75 ± 0.17	279.63	139.81
39	Fish oil	25.9 ± 0.0	21.1 ± 0.1	43.1 ± 0.0	34.8 ± 0.0	2.5 ± 0.0	164.66 ± 0.10	113.48 ± 0.15	278.14	278.14
40	Fish oil	9.3 ± 0.0	19.8 ± 0.1	64.2 ± 0.1	58.1 ± 0.0	3.0 ± 0.0	382.40 ± 0.15	85.02 ± 0.09	467.42	467.42
41	Fish oil	6.1 ± 0.0	13.5 ± 0.1	65.7 ± 1.8	55.2 ± 1.9	8.1 ± 0.0	257.64 ± 0.25	171.12 ± 0.11	428.76	214.38
42	Fish oil	24.9 ± 0.1	22.4 ± 0.3	43.7 ± 0.2	35.7 ± 0.2	2.0 ± 0.0	178.02 ± 0.92	106.21 ± 0.57	284.23	284.23
43	Fish oil	28.3 ± 0.1	21.4 ± 0.1	41.7 ± 0.0	34.9 ± 0.0	2.0 ± 0.0	164.19 ± 0.23	114.02 ± 0.29	278.21	278.21
44	Fish oil	8.8 ± 0.0	13.4 ± 0.0	58.1 ± 0.1	46.7 ± 0.1	8.6 ± 0.0	217.83 ± 0.33	157.83 ± 0.12	375.67	450.80
45	Fish oil	8.7 ± 0.1	15.0 ± 0.0	71.8 ± 0.0	67.2 ± 0.0	2.1 ± 0.0	315.86 ± 0.16	157.83 ± 0.21	478.69	459.70
46	Fish oil	16.3 ± 0.0	16.5 ± 2.8	40.6 ± 0.0	28.6 ± 0.0	6.8 ± 0.0	133.17 ± 0.11	88.70 ± 0.17	221.87	221.87
47	Fish oil	9.4 ± 0.0	12.7 ± 0.1	69.3 ± 0.1	62.9 ± 0.2	4.1 ± 0.2	313.24 ± 1.05	213.50 ± 0.95	526.74	632.09
48	Fish oil	27.8 ± 0.0	19.3 ± 0.1	40.1 ± 1.0	32.8 ± 0.1	2.8 ± 0.0	166.15 ± 0.50	102.62 ± 0.65	268.77	134.39
49	Caviar oil	14.0 ± 0.0	12.3 ± 0.2	64.2 ± 0.7	61.1 ± 0.6	2.0 ± 0.1	119.90 ± 1.10	379.50 ± 4.05	499.40	349.58
50	Fish oil	8.3 ± 0.0	7.9 ± 0.0	70.7 ± 0.2	68.6 ± 0.2	1.5 ± 0.0	323.06 ± 0.95	217.09 ± 0.90	540.14	486.13
51	Fish oil	3.5 ± 0.0	6.4 ± 0.0	76.7 ± 0.3	69.7 ± 0.3	6.2 ± 0.0	322.87 ± 1.15	233.97 ± 0.90	556.84	528.99
52	Fish oil	0.8 ± 0.0	11.5 ± 0.0	68.5 ± 0.2	55.8 ± 0.2	12.0 ± 0.0	319.04 ± 0.85	156.22 ± 0.70	475.26	475.26
53	Fish oil	0.7 ± 0.0	0.8 ± 0.1	98.0 ± 0.1	97.4 ± 0.1	0.6 ± 0.0	511.73 ± 1.40	319.35 ± 0.90	831.08	997.30
54	Fish oil	5.8 ± 0.1	10.9 ± 0.1	73.8 ± 0.0	70.6 ± 0.0	1.8 ± 0.1	320.16 ± 0.35	218.26 ± 0.10	538.41	522.26

Values shown are mean ± standard deviation ($n = 3$).SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ω -3 – omega-3 fatty acids, ω -6 – omega-6 fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

* – sum of fatty acids in 1 capsule was calculated according to Eq. 1, ** – percentage of daily intake recommended by the European Food Safety Authority for adults (500 mg per day) [8].

these criteria. Several studies reported that the EPA and DHA contents of nutritional fish oil supplements conformed to the ingredient label claim [19–23]. Yi et al. [16] examined commercial fish oil capsule samples sold in Hong Kong retail stores. A significant variation in the contents of the quantified components in all samples in terms of EPA and DHA was observed. These results are consistent with the findings of this study.

Instead of the content label showing the total amount of oil on the box, the EPA and DHA ratios corresponding to one serving should be checked on the label. Since there is no target intake of total ω -3 fatty acids in fish, fish liver oil or krill oil consumption, the expected benefit from these products is to meet the daily EPA and DHA needs. In ω -3 fatty acids products offered as food supplements, the contents of the box (EPA and DHA amounts) and daily consumption information are usually given on the label. According to the legislation [24, 25], the recommended amount of EPA and DHA for daily use of the product should be written on each fish oil label. If there is a total of 120 capsules in the box of a product and it is recommended to consume 3 capsules per day, the total servings equivalent of this product is 40 servings. As the higher price cannot guarantee higher EPA and DHA content [16], it is important to consider the balance between the price and content of these products. As seen in Tab. 2, it was observed that one capsule consumption in all krill oil products could meet the daily EPA plus DHA intake in the range of 19–113 %. Considering the 6th product in this table, which had the second-highest EPA plus DHA, this product contained 32 capsules, and it was recommended to take one capsule per day. With this single capsule intake, half of the daily EPA plus DHA need is met. According to the content, two capsules this product should be taken to meet the daily EPA and DHA needs. Then, this product is actually not for 32 days of daily intake but for 16 days and is worth approximately 450 USD per kilogram of oil. The cost of the product numbered 7 in Tab. 1 and Tab. 2 is 280 USD per kilogram of oil and the box content consists of 50 capsules. As a food supplement, this product can meet the daily EPA and DHA requirement of 113 % for 50 days. For this product, it is recommended by the box label information to consume 2 capsules per day and this consumption is not mandatory. It is important to evaluate the values and prices of products according to these parameters so that consumers can reach the right information without misleading. In a market research study, Yi et al. [16] stated that there is no linear relationship between the EPA and DHA

contents of fish oil supplements and their price.

The same was found to be true for fish oils sold as a liquid. The recommended consumption amount for ω -3 fatty acids oils in liquid form was given in the label information as 5 ml for children and adults. As presented in Tab. 3, the daily consumption of one measure in all products and the recommended 250–500 mg EPA plus DHA amount for a child and an adult person are quite high in products sold as liquid fish oils. As seen in Tab. 4, 500 mg EPA plus DHA recommended for an adult in all products is easily met with 1 spoonful of liquid fish oil per day. These products can be used for a minimum of 30 days and a maximum of 50 days. When we compare the sales price with other products, it is possible to say that these products are quite advantageous.

Essential nutritional components such as vitamins C, D, and E, zinc, selenium or ω -3 fatty acids are also important for the immune system [4, 13]. However, dietary habits and preferences vary among the human population and the prevailing belief is that the intake of these components from the diet is insufficient. Nowadays, the intake of these components through food supplements has increased. The demand for nutritional supplements has additionally increased during COVID-19 [13–15]. This situation has increased the importance of the composition and quality of the food supplements sold. As reported by DOAEI et al. [26], although ω -3 fatty acids supplementation appears to improve the levels of various parameters of respiratory and kidney function in critically ill patients with COVID-19, further clinical studies are required.

The composition of the ω -3 fatty acids-containing food supplements, the accuracy of the label information, the adequacy in meeting daily needs and the price/content advantage are important. BANNENBERG et al. [23] classified food supplements according to their compliance with the label claim. They found that 41 % of all products analysed had EPA plus DHA content between 80 % and 100 % of the content declared on the label, while the rest contained 100–139 % of it. According to FDA (21 C.F.R. §101.9) US Food Classification of EPA and DHA [25], the EPA and DHA level of adequacy of products is defined in two food classes in terms of nutritional labelling and suitability of foods containing nutritional supplements. Food supplements that equal ≥ 100 % of the claimed content are defined as Class I, while those that equal at least 80–99 % of the declared value are Class II products [23].

In 59.3 % (32 products) of the 54 products examined in this study, EPA plus DHA content was

found to be less than what was stated on the label. It was observed that 25.9 % (14 products) could meet the daily EPA plus DHA need with a capsule or a measure of consumption. In addition, when products were compared in terms of label information, 25.9 % of the 54 products examined in this study were found to be Class I and 9.3 % Class II products. At the same time, 19 products (35.2 %) that met the daily 80 % or more intake dose of EPA plus DHA with a capsule or a measure of consumption were found to be advantageous in terms of quantity and price. It was determined that the remaining 35 products (64.8 %) could not meet the daily EPA and DHA requirement of more than 80 % with a single capsule.

CONCLUSIONS

In the study, it was determined that products differed in composition, but the more expensive products did not contain more EPA plus DHA. It was determined that 35.2 % of the 54 products were economical and sufficient to meet the daily 80 % or more EPA plus DHA need. The fact that this was true not only for national brand products but also for internationally sold ones, suggests that a similar situation may exist in other countries. Compliance with the label information of these products, which are offered for sale at high prices with advertised positive health effects, should be monitored by state authorities with stricter controls to protect consumers from being misled.

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