http://foodbulletin.net

FOOD BULLETIN
e-ISSN: 2979-9848

https://prensip.gen.tr

REVIEW ARTICLE

The Lipid Quality of Commercial Fish Oil Supplements

Bahar Tokur✉

Ordu University, Faculty of Marine Science, Department of Fisheries Technology Engineering, Ordu/Türkiye

ARTICLE INFO

Article History
Received: 25.06.2023
Accepted: 30.06.2023
First Published: 30.06.2023

Keywords
Fish oil
Food supplements
Lipids
Quality

ABSTRACT

The amount of polyunsaturated fatty acids that are present in fish oil, particularly docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), as well as any changes to those levels, are among the most critical factors that impact a customer's decision. These fatty acids are very prone to oxidative damage because their structures include double bonds, which makes them susceptible to the process of oxidation. Over the past few years, nutritional supplements have become increasingly common not just in our nation but also in countries all over the world. Fish oils, which may be purchased in pharmacies, markets, shopping malls, and even online, particularly as dietary supplements, degrade oxidatively during their shelf life, resulting in losses in the fatty acid content of the oil. For this reason, it is essential to investigate how their contents have evolved throughout time. The purpose of this review was to investigate the efficacy of fish oils as dietary supplements, namely those that come in encapsulated gel and liquid forms, respectively.

Please cite this paper as follows:

Tokur, B. (2023). The lipid quality of commercial fish oil supplements. *Food Bulletin*, *2*(1), 1-7. https://doi.org/10.29329/foodb.2023.570.01

1. Introduction

Polyunsaturated fatty acids, of which there are two types, omega-3 and omega-6, are essential for human and animal health but must be consumed from food sources because they cannot be produced. This is why these fats are considered "essential" to human nutrition. Linoleic acid (LA) is an important fatty acid needed for the synthesis of omega-6s in the body, whereas alpha-linolenic acid (ALA) is needed for the synthesis of omega-3s.

Fish oils, which include polyunsaturated fatty acids, have been the subject of substantial research into their positive effects on human health (Bayraklı & Duyar, 2019). Studies have shown that the omega-3 fatty acids present in fish oil have several beneficial effects on human health. Fish oil, which is high in long-chain omega-3 fatty acids, has been shown to help protect against heart disease (Garcia-Rico et al., 2007), protect brain function as people age (Calder, 2006; Marangoni et al., 2010), raise blood pressure, and lower platelet and leukocyte reactivity and lymphocyte proliferation. Pregnant women who take this supplement have a lower risk of miscarriage and a more successful pregnancy (Jensen et al., 2000; Sarp, 2017), and it also increases insulin sensitivity (Ellulu et al., 2015).

Moreover, it is effective in treating depression, anxiety, and a wide range of other conditions, including type 2 diabetes, rheumatoid arthritis, irritable bowel syndrome, age-related macular degeneration, dry eye, and stomach ulcers. Fish oil, according to proponents, does not lead to weight gain and serves crucial roles in warding off obesity (Calder, 2006; Ho et al., 2008; Mol., 2008).

✉ Corresponding author
E-mail address: baharorhun@gmail.com

Vegetable oils, including corn, sunflower, soybean, and cotton oils, contain ω6 fatty acids, which have largely supplanted ω3 in modern diets. In other words, limiting your intake of omega-6 fatty acids while increasing your omega-3 intake is essential for illness prevention (Covaci et al., 2007).

The World Health Organization (WHO) suggests eating fish once or twice a week for optimal health (WHO, 2019). Fatty acids are essential to human health, but getting enough of them from food alone can be challenging. Experts recommend taking fish oil to enhance your diet.

Over the past few years, the demand for fish oil has increased dramatically. The growth in aquaculture is the primary factor driving this market's predicted expansion from 2018's $3.28 billion to 2026's $5.42 billion. In 2016, 75% of the fish oil harvest went toward feeding fish in aquaculture. Fish oil is also utilized in animal feed, pet food, pharmaceuticals, dietary supplements, and functional meals (Giese & Fritsche, 2021). More and more people are turning to nutritional supplements as a non-pharmaceutical means of improving their health. Consumers' beliefs that these items are all-natural, risk-free, and effective are driving this expansion. In this regard, identifying the substances that are hazardous to human health and ensuring the quality of dietary supplements are both crucial (Dietz et al., 2007).

Food supplements are manufactured according to national or international standards that take contaminants, bioavailability, and maximum daily consumption into account when deciding on content. This is the case for both the FDA and the WHO. People of all ages, but notably kids, utilize these items to supplement their diets when they need a more well-rounded nutritional profile. Seafood is rich in nutrients, and nutritional supplements made from it include things like omega-3 fatty acids, proteins, enzymes, and carotenoids. The most prevalent types of seafood utilized in the production of nutritional supplements are seaweed, dried shellfish, and fish oil. Fish oil supplements can be bought in the form of liquid, capsules, or tablets (Dolan et al. 2003).

Fish oils sold as dietary supplements are highly vulnerable to oxidation because they include ω3 highly unsaturated fatty acids with many double bonds. While unoxidized fatty acids are depleted and replaced by a complex "soup" of lipid peroxides, aldehydes, and ketones are generated as secondary oxidation products throughout the oxidation process (Albert et al., 2015; Kazuo, 2019; Mason & Sherratt, 2017; Ozyurt et al., 2022). Because these nutritional supplements have a 2-year shelf life, monitoring any changes in their fatty acid composition or other chemical quality parameters is critical.

2. Lipid Quality of Fish Oil Supplements

The European Food Safety Authority (EFSA) made a declaration in 2010 regarding the scientific risk of rancidity and food hygiene associated with the consumption of fish oil for human health. The assessment encompasses various aspects of the fish, ranging from the fishing process to the final product, including considerations of hygienic conditions and the potential for rancidity. The significance of preserving fish as a final product outweighs the concerns of food safety, owing to the rigorous heating and refining techniques employed during the alkaline/acid processes and water phase removal in oil processing. It has been determined that the chemical degradation of oil is attributed to the presence of lipid oxidation products.

Changes in fish oils have been the subject of a significant amount of research during the process of fish preservation. Oils extracted from fish that have high autolytic activity and include polyunsaturated fatty acids are extremely vulnerable to lipolysis and oxidation. According to Soldo et al. (2019), as a consequence, they typically have a high amount of free fatty acids (FFA). The formation of free fatty acids during the hydrolysis of oil results in an alteration of the oil's organoleptic qualities (Ashton et al., 2002). The International Fish Meal and Oil Producers Association (IFOMA) has established that the acceptable range for the FFA value of crude fish oil is between 1% and 7% (often between 2% and 5%) of oleic acid (Bimbo, 1998). This is the maximum permitted amount of FFA value. However, the FFA values of edible oils should ideally be less than 3% (Ozyurt et al., 2013; Soldo et al., 2019).

Determining the peroxide (PO) value relies on the principle of titration with thiosulfate, which measures the amount of iodine that has been liberated as a result of the oxidation of iodide by epidioxide or hydroperoxide. The peroxide number can be stated as millimole O_2 in 1000 g of oil, or it can be expressed as milliequivalent grams/kg or micrograms/kg. It is recommended as a standard method in the industry (Shahidi & Zhong, 2005).

According to the Codex Alimentarius Commission's (CODEX, 1999), the maximum permissible PO value for edible oils is 10 meq/kg-$^{1.}$ In contrast, the European Food Safety Authority (EFSA, 2010) recommends that the PO value in refined fish oils used for food supplements not exceed 10 meg/kg. This recommendation is included in the European Pharmacopoeia, which contains listings of dosages, forms, and uses of medicinal medications. Moreover, fish oil should have a PO value of 5 meq. or less per kilogram, as indicated by the Global EPA and DHA Organization (GOED, 2008).

TBA analysis is the approach that is employed the most frequently for the detection of lipid oxidation (Shahidi and Wanasundara, 2002). According to Schormüller's report in 1969, a desirable quality material should possess a TBA value lower than 3 mg MA/kg.

Sprague et al. (2018) investigated the oxidation properties as well as the lipid and fatty acid levels of 23 different brands

of encapsulated fish oil products sold in the United Kingdom. The oil content was found to be between 91.4% and 118.9% of the manufacturer's claimed quantity, depending on the product. All items' peroxide (PO) and anisidine values were found to be lower than those set by pharmacopeias. The EPA+DHA level of twelve different products were also found to be lower than previously reported. The researchers, on the other hand, identified no link between oxidative measurements and unlabeled quantities of EPA and DHA in four of the items evaluated, and they additionally noticed that the PO value was substantially correlated with the expiration dates of the products.

Nevigato et al. (2021) conducted an investigation of three different fish oil supplements that are readily available in Italy. The results of the study indicated that the quantities of EPA and DHA present in two supplements were discovered to be below the stated levels on the product label (Table 1).

Table 1 Compliance with the label of dietary supplements analyzed (mg/100 mg oil) (Nevigato et al., 2021).

Supplement	EPA			DHA		
	Label	**Measured**	**%**	**Label**	**Measured**	**%**
Supplement no. 1	40	32.41	81	20	19.68	98
Supplement no. 2	33	25.76	78	22	20.06	91
Supplement no. 3	15	16.68	111	10	12.89	129

The compliance of the EPA+DHA label declaration and the oxidative quality of 48 widely used brands of omega-3 fatty acid dietary supplements in the United States were analyzed by Bannenberg et al. (2020). The research findings revealed that a significant proportion of the tested items, that is, 48 percent, exhibited lower levels of EPA+DHA than the values indicated on their respective labels, despite falling within the acceptable range of quantities. As per the authors of the study, it is crucial to assess and communicate the quality of end products in an optimal manner to ensure precise information dissemination regarding nutritional supplements to consumers. Furthermore, the study found no association between chemical quality values and the expiration date of the product.

In the study conducted by Karsli (2021), an analysis of the fatty acid content (FA) was performed, and various quality criteria were evaluated for 15 fish oil supplements that were commercially available in both syrup and capsule forms within the Turkish market. The results of the study indicated that the concentration of EPA in fish oil supplements varied between 3.51% and 20.51%, whereas the DHA level ranged from 3.28% to 52.42%. The researcher observed that the claims made by the Environmental Protection Agency (EPA) on the product labels were largely accurate for the samples that were examined. However, the quantities of docosahexaenoic acid (DHA) in particular supplements were significantly different from the claimed values. The study revealed that the EPA and DHA concentrations of fish oil capsules available in the retail market of Turkey were more consistent with the concentrations indicated on the label, in comparison to fish oil syrups.

The study conducted by Srigley and Rader (2014) involved an analysis of the fatty acid concentration and composition of 46 omega-3 fish oil supplements that were commercially available in the United States. As per the research findings, a majority of over 80% of the capsules containing fish oil were found to comprise EPA and DHA. Nevertheless, it was discovered that six of the aforementioned items were unable to fulfill the promises stated on their labels. Out of the 46 fish oils that underwent testing for EPA and DHA concentration, just 11 (24%) were found to have met the standards set by the FDA, thereby receiving official approval for human consumption.

In their study, Ako and Ogasawara (1994) conducted an analysis of the quantities of omega-3 fatty acids present in seven distinct brands of fish oil capsules that were commercially available in drugstores located in Hawaii. Research conducted on fish oil capsules that are available on the market has indicated a disparity between the stated and actual amounts of omega-3 fatty acids present in them.

Albert et al. (2015) studied the fatty acid content, peroxide (PO), and anisidine (AV) values, and estimated the total oxidation (Totox) values of fish oil supplements that were encapsulated and sold in New Zealand. The study revealed that a mere 3 out of 32 fish oil supplements contained EPA and DHA in quantities that were equivalent to or greater than the labeled content. Furthermore, the majority of supplements had 83% PO concerning recommended oxidation limit levels, with 25% surpassing AV limits and 50% in excess of Totox levels.

Jackowski et al. (2015) performed an analysis of the oxidation state and product composition of 171 ω3 PUFA dietary supplements that were commercially available in Canada. The research revealed that half of the examined items exhibited signs of oxidation, whereas an additional 18% approached the threshold of exhibiting such signs within the range of 1 to 3 years prior to their established expiration date. The study revealed that the levels of secondary oxidation

products and TOTOX were significantly reduced in unflavored, encapsulated dietary supplements as compared to their flavored counterparts. The levels of main, secondary, and TOTOX in fish oil supplements targeted toward children were significantly greater than those found in other demographic groups. In addition, scholarly investigations have determined that individuals who consume 3 polyunsaturated fatty acid (PUFA) products as dietary supplements may be susceptible to elevated levels of oxidative products. This has led to an indication for new legal mandates to ensure that all such products are subject to testing for oxidative safety and appropriateness.

Forty-seven fish oil supplements sold in New Zealand were analyzed by Bannenberg et al., (2017) for the content of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), as well as the oxidative status of the products. Among the products that underwent testing, it was found that 72%, 86%, and 77% of them adhered to the maximum limits established by the industry for Peroxide Value (PV), para-Anisidine Value (p-AV), and TOTOX, respectively (Table 2).

Table 2. The amount of EPA and DHA in fish oil capsules (in milligrams per serving). *Denotes a product for which the average of all laboratories' results fell short of label claims by more than 10% in Australia (Bannenberg et al., 2017).

Parameters	Percentage of tested products that complied with the GOED quality criterion for oxidative status (PV max. 5meq O2/kg; p-AV max. 20; TOTOX max. 26), and that adhered to labeled content of EPA plus DHA (*only for unflavored fish oils).	
	Bannenberg et al. (2017)	Albert et al. (2015)
PV	72%	17%
p-AV	86%*	75%
TOTOX	77%*	50%
EPA+DHA content compliance to label claim	91%	9%

Ozyurt et al. (2022) examined the fatty acid content and oxidative characteristics of the most widely used fish oil supplements in Turkey. The investigation concluded that the EPA and DHA concentrations of the capsule samples were often higher than those of the syrup samples. Free fatty acid (FFA) values were found to be above the 3% oleic acid limit recommended for high-quality oils in 4 groups, and thiobarbituric acid reactive substance (TBARs) values were found to be below 1 mg MA/kg in all groups of fish oil capsules and syrups (Figures 1, 2, 3).

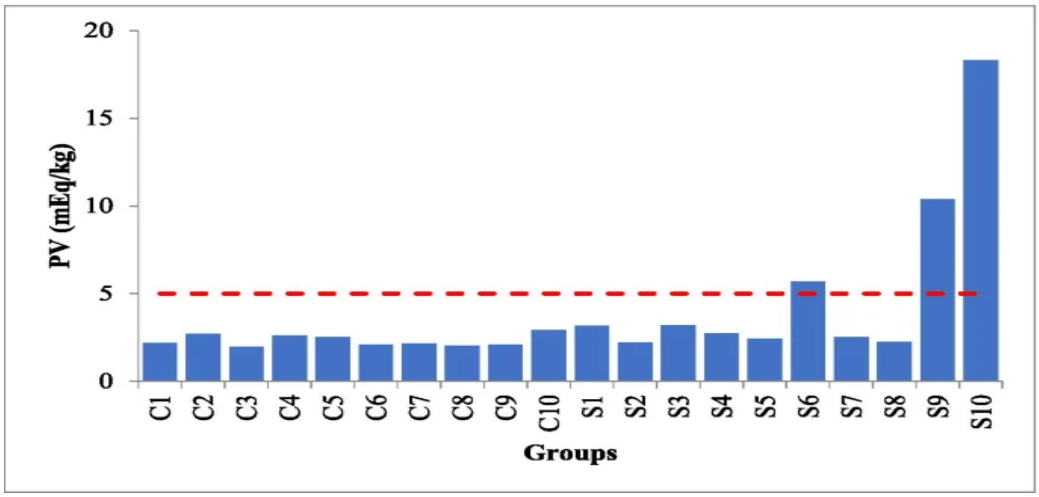

Figure 1. Peroxide values of suggested syrups and fish oil capsules (dashed line =3) (Ozyurt et al., 2022).

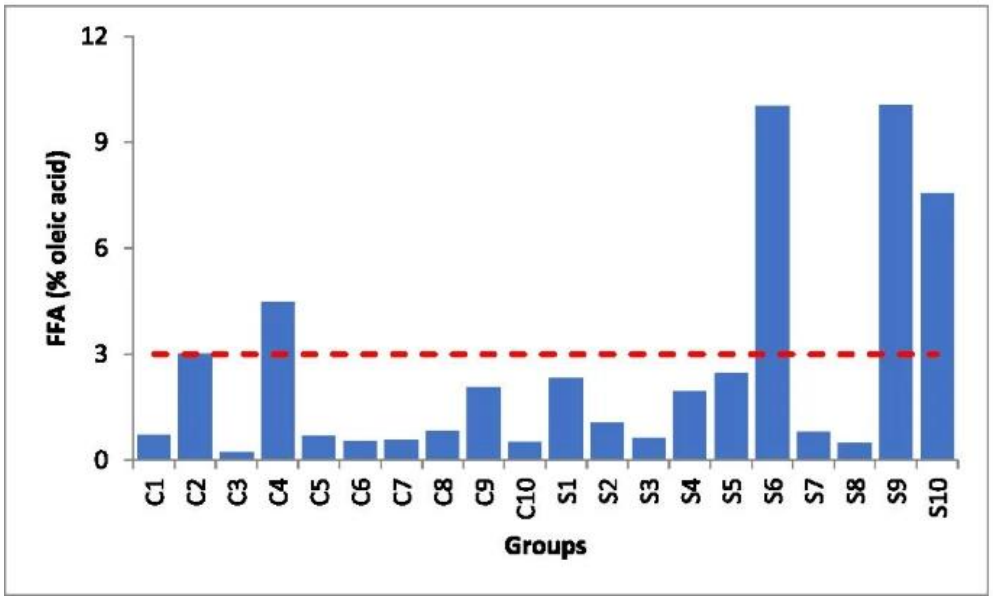

Figure 2. Values of free fatty acids (FFA) in fish oil capsules and syrups compared to the DV (dotted line =3) (Ozyurt et al., 2022).

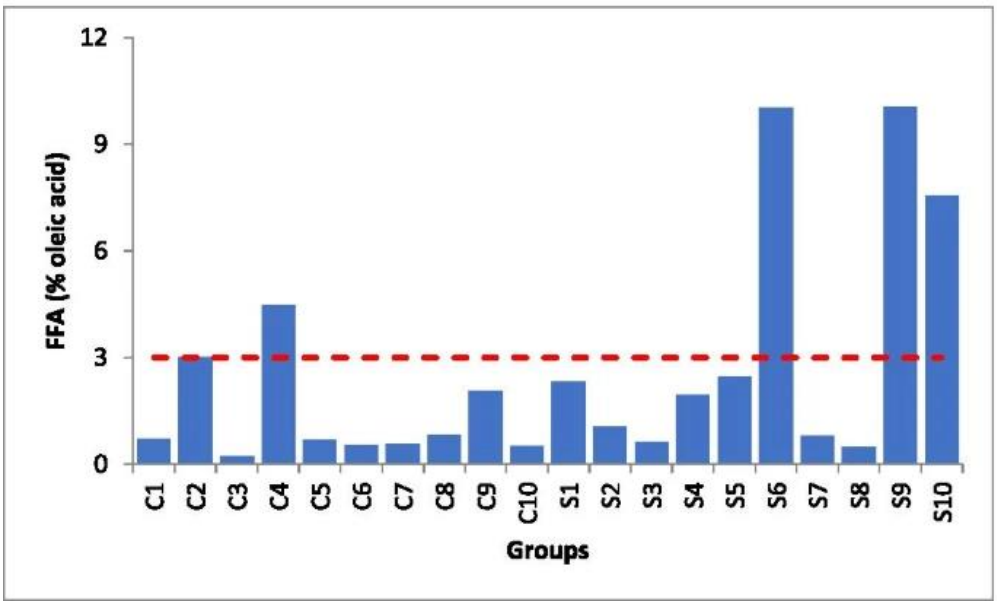

Figure 3. Standard value (dashed line =3) for recommended syrups compared to TBARs values of fish oil capsules (Ozyurt et al., 2022).

3. Conclusion

The popularity of fish oil supplements has been on the rise, and their significance in promoting good health is noteworthy. However, it is worth noting that the production and distribution of these supplements are not subject to any regulatory framework. Unfortunately, there is a lack of legal regulation to guarantee the satisfactory quality or precise labeling of fish oil supplements retailed in stores. A consensus at a global level is deemed necessary by researchers throughout various disciplines. The quality of lipids with a 2-year shelf life can no longer be guaranteed due to the impact of environmental factors.

Conflict of Interest

The author has no conflict of interest to declare.

References

Ako, H., & Ogasawara, E. O. (1994). ω-3 fatty acids in Hawaiian seafood. *Hawai'i Medical Journal*, *53*(5), 142-145.

Albert, B. B., José, G. B., Derraik, D., Cameron-Smith, P. L., Hofman, S., Tumanov, S. G., Villas-Boas, M. L., Garg, W., & Cutfield, S. (2015). Fish oil supplements in New Zealand are highly oxidized and do not meet the label content of n-3 PUFA. *National Library of Medicine*, *21*(5), 7928. https://doi.org/10.1038/srep07928

Ashton, I. P., Unilever, R., & Sharnbrook, D. (2002). *Safety and quality issues in fish processing*. Woodhead Publishing Limited.

Bannenberg, G., Mallon, C., Edwards, H., Yeadon, D., Yan, K., Johnson, H., & İsmail, A. (2017). ω3 long-chain polyunsaturated fatty acid content and oxidation state of fish oil supplements in New Zealand. *Scientific Reports*, *7*(1), 1-13. https://doi.org/10.1038/s41598-017-01470-4

Bannenberg, G., Rice, H. B., Bernasconi, A., Ferrari, A., Mallon, C., Navarrete, L., Hughes, R., Igarashi, J., Persons, K., Latynski, L., Phung, A., Wang, S., & İsmail, A. (2020). Ingredient label claim compliance and oxidative quality of EPA/DHA omega-3 retail products in the U.S. *Journal of Food Composition and Analysis*, *88*, 103435. https://doi.org/10.1016/j.jfca.2020.103435

Bayraklı, B., & Duyar, H. A. (2019). The effect of raw material freshness on fish oil quality produced in fish meal & oil plant. *Journal of Anatolian Environmental and Animal Sciences*, *4*(3), 473-479. https://doi.org/10.35229/jaes.636002

Bimbo, A. P. (1998). Guidelines for characterizing food-grade fish oil. *International Fishmeal and Oil Manufacturers Association, 9*(5), 473-483.

Calder, P. C. (2006). n-3 Polyunsaturated fatty acids, inflammation, and inflammatory diseases. *American Journal of Clinical Nutrition*, *83*, 505-519. https://doi.org/10.1093/ajcn/83.6.1505S

Chee, K. M., Gong, J. X., Good Rees, D. M., Meydani, M., Ausman, L., Johnson, J., & Schaefer, E. J. (1990). The fatty acid content of marine oil capsules. *Lipids*, *25*(9), 523-528. https://doi.org/10.1007/bf02537158

Codex Alimentarius Commission. (1999). *Procedural manual (11th ed.)*. FAO.

Covaci, A., Voorspoels, S., Vetter, W., Gelbin, A., Jorens, P., Blust, R., & Neels, H. (2007). Anthropogenic and naturally occurring organobrominated compounds in fish oil dietary supplements. *Environmental Science Technology*, *41*(15), 5237-5244. https://doi.org/10.1021/es070239g

Dietz, B., & Bolton, J. L. (2007). Botanical dietary supplements gone bad. *Chemical Research in Toxicology*, *20*(4), 586-590. https://doi.org/10.1021%2Ftx7000527

Dolan, P., Nortrup, D. A., Bolger, M., & Capar, S. G. (2003). Analysis of dietary supplements for arsenic, cadmium, mercury, and lead using inductively coupled plasma mass spectrometry. *Journal of Agricultural and Food Chemistry*, *51*(5), 1307-1312. https://doi.org/10.1021/jf026055x

Ellulu, M. S., Khaza'ai, H., Abed, Y., Rahmat, A., Ismail, P., & Ranneh, Y. (2015). Role of fish oil in human health and possible mechanism to reduce the inflammation. *Inflammopharmacology*, *23*(2), 79-89. https://doi.org/10.1007/s10787-015-0228-1

EFSA. (2010). Scientific opinion on fish oil for human consumption. Food hygiene, including rancidity. *EFSA Journal*, *8*(10), 1-48. https://doi.org/10.2903/j.efsa.2010.1874

Garcia-Rico, L., Leyva-Perez, J., & Jara-Marini, M. E. (2007). Content and daily intake of copper, zinc, lead, cadmium, and mercury from dietary supplements in Mexico. *Food and Chemical Toxicology*, *45*, 1599-1605. https://doi.org/10.1016/j.fct.2007.02.027

Giese, E., & Fritsche, J. (2021). New approaches to detect compositional shifts in fish oils. In T. Lafarga, G. Bobo & I. Aguiló-Aguayo (Eds.), *Oil and oilseed processing: Opportunities and challenges* (pp. 81-101). Wiley Blackwell. https://doi.org/10.1002/9781119575313.ch5

GOED. (2008). *Webinar for "The global organization for EPA & DHA omega-3s".* GOED.

Ho, C. T., Simon, J. E., Shahidi, F., & Shao, Y. (2008). *Dietary supplements: An overview*. ACS Symposium Series. Washington.

Jackowski, S. A., Alvi, A. Z., Mirajkar, A., Imani, Z., Gamalevych, Y., Shaikh, N. A., & Jackowski, G. (2015). Oxidation levels of North American over-the-counter ω3 (ω3) supplements and the influence of supplement formulation and delivery form on evaluating oxidative safety. *Journal of nutritional science*, *4*(4). https://doi.org/10.1017/jns.2015.21

Jensen, C. L., Maude, M., Anderson, R. E., & Heird, W. C. (2000). Effect of docosahexaenoic acid supplementation of lactating women on the fatty acid composition of breast milk 66 Lipids and maternal and infant plasma phospholipids. *The American Journal of Clinical Nutrition*, *71*(1), 292-299. https://doi.org/10.1093/ajcn/71.1.292s

Karsli, B. (2021). Comparative analysis of the fatty acid composition of commercially available fish oil supplements in Turkey: Public health risks and benefits. *Journal of Food Composition and Analysis*, *103*, 104105. https://doi.org/10.1016/j.jfca.2021.104105

Kazuo, M. (2019). Prevention of fish oil oxidation. *Journal of Oleo Science*, *68*(1), 1-11. https://doi.org/10.5650/jos.ess18144

Marangoni, F., Agostoni, C., Borghi, C., Catapano, A. L., Cena, H., Ghiselli, A., & Riccardi, G. (2010). Dietary linoleic acid and human health: Focus on cardiovascular and cardiometabolic effects. *Atherosclerosis*, *292*(2020), 90-98. https://doi.org/10.1016/j.atherosclerosis.2019.11.018

Mason, R. P., & Sherratt, S. C. (2017). Omega-3 fatty acid fish oil dietary supplements contain saturated fats and oxidized lipids that may interfere with their intended biological benefits. *Biochemical and Biophysical Research Communications*, *483*(1), 425-429. https://doi.org/10.1016/j.bbrc.2016.12.127

Mol, S. (2008). Fish oil consumption and effects on human health. *Journal of Fisheries Sciences, 2*(4), 601-607. https://doi.org/10.3153/jfscom.2008023

Nevigato, T., Masci, M., & Caproni, R. (2021). Quality of fish-oil-based dietary supplements available on the Italian market: A preliminary study. *Molecules, 26*(16), 5015. https://doi.org/10.3390/molecules26165015

Opperman, M., Marais, D. I., & Spinnler Benade, A. J. (2011). Analysis of ω3 fatty acid content of South African fish oil supplements. *Cardiovascular Journal of Africa, 22*(6), 324-329. https://doi.org/10.5830/cvja-2010-080

Ozyurt, G., Şimşek, A., Etyemez, M., & Polat, A. (2013). Fatty acid composition and oxidative stability of fish oil products in Turkish retail market. *Journal of Aquatic Food Product Technology, 22*(3), 322-329. https://doi.org/10.1080/10498850.2011.644882

Ozyurt, G., Ekmen, D., Durmuş, M., & Ucar, Y. (2022). Assessment of the safety of dietary fish oil supplements in terms of content and quality. *Environmental Science and Pollution Research, 29*(17), 25006-25019. https://doi.org/10.1007/s11356-021-17581-5

Sarp, Y. (2017). *Son trimestrdaki gebelere yapılan omega 3 yağ asidi desteğinin gestasyon yaşı ve yenidoğan gelişimine etkisinin incelenmesi* (Master's thesis, İstanbul Medipol University). (In Turkish)

Shahidi, F., & Zhong, Y. (2005). Lipid oxidation: Measurement methods. In F. Shahidi (Ed.), *Bailey's industrial oil and fat products* (pp. 357-385). John Wiley & Sons.

Schormüller, J. (1969). *Handbuch der lebensmittel chemie, band ih/2 teil. Tierische lebensmittel eier, fleisch, buttermilch*. Springer-Verlag. (In German)

Shahidi, F., & Wanasundara, U. (2002). Methods for measuring oxidative rancidity in fats and oils. In C. C. Akoh & D. B. Min (Eds.), *Food lipids, chemistry, nutrition, and biotechnology* (pp. 465-505). Marcel Dekker. https://doi.org/10.1201/9780203908815.ch14

Soldo, B., Šimat, V., Vlahović, J., Skroza, D., Ljubenkov, I., & Generalić Mekinić, I. (2019). High quality oil extracted from sardine by-products as an alternative to whole sardines: Production and refining. *European Journal of Lipid Science and Technology, 121*(7), 1800513. https://doi.org/10.1002/ejlt.201800513

Sprague, M., Cooper, S., Tocher, D. R., & Betancor, M. B. (2018). Encapsulated fish oil products available in the UK meet regulatory guidelines concerning EPA+ DHA contents and oxidative status. *European Journal of Lipid Science and Technology, 120*(10), 1800105. https://doi.org/10.1002/ejlt.201800105

Srigley, C. T., & Rader, J. I. (2014). Content and composition of fatty acids in marine oil omega-3 supplements. *Journal of Agricultural and Food Chemistry, 62*(29), 7268-7278. https://doi.org/10.1021/jf5016973

WHO. (2019). *WHO global report on traditional and complementary medicine*. World Health Organization.