ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 319-325
www.agriculturaljournals.com
Received: 02-09-2025
Accepted: 05-10-2025

Kadape BB
PhD Scholar, Department of AHDS, PGI, MPKV Rahuri, Maharashtra, India

Patange DD
Professor (CAS), Division of AHDS, RCSM College of Agriculture, Kolhapur, Maharashtra, India

AT Lokhande
Assistant Professor, Department of AHDS, PGI, MPKV Rahuri, Maharashtra, India

Kamble DK
Head of Department, Department of AHDS, PGI, MPKV Rahuri, Maharashtra, India

Waychal SN
PhD Scholar, Department of AHDS, PGI, MPKV Rahuri, Maharashtra, India

Corresponding Author:
Kadape BB
PhD Scholar, Department of AHDS, PGI, MPKV Rahuri, Maharashtra, India

Fortification of omega 3 fatty acid in dairy products

Kadape BB, Patange DD, AT Lokhande, Kamble DK and Waychal SN

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11e.973

Abstract
Omega-3 fatty acids (ω-3 FAs), including alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), are essential polyunsaturated fats with documented benefits for cardiovascular, cognitive, and inflammatory health. However, dietary intake remains below recommended levels in many populations. Fortifying commonly consumed foods like dairy products presents an effective approach to enhance omega-3 intake. This review explores the significance of omega-3 fatty acids, strategies for their incorporation into dairy matrices, stability challenges during processing and storage, and the health implications of fortified dairy consumption. Topics pertaining to functional foods, omega-3 fatty acids, their suppliers, and varieties of dairy products supplemented with these fatty acids were all critically reviewed. Products enhanced with unique components that provide positive and healthful benefits are known as functional foods. Modern diseases including atherosclerosis, Alzheimer's, type 2 diabetes, cardiovascular disease, and autoimmune diseases are all strongly linked to inadequate consumption of functional foods. Two types of polyunsaturated fatty acids are omega-3 and omega-6. For the human body, they play a crucial biochemical purpose. Numerous cardiovascular, cancerous, inflammatory, and autoimmune disorders are caused by high omega-6/omega-3 ratios and high omega-6 levels, whereas high omega-3 levels prevent the onset of these conditions. Omega-3 fatty acids can be found in algae, fish, and plants. By altering the diet of the animal or by directly adding vegetable or fish oils, dairy products can be enhanced with omega-3 fatty acids. The literature include both fresh and mature dairy products enhanced with omega-3 fatty acids from plant and animal sources. According to the literature review, there aren't enough studies on the topic of adding omega-3 fatty acids to Bulgarian dairy products.

Keywords: Yoghurt, cheese, monounsaturated fatty acids, polyunsaturated fatty acids, fish oil, vegetable oils

Introduction
Omega-3 fatty acids are vital nutrients that cannot be synthesized de novo in humans and must be obtained from the diet. The major dietary forms include ALA (18:3n-3), found in flaxseed and chia, and the long-chain fatty acids EPA (20:5n-3) and DHA (22:6n-3), primarily sourced from fish and marine oils (Adkins & Kelley, 2010) [1]. Due to evolving dietary patterns, many populations fall short of the recommended intake of 250-500 mg/day of EPA+DHA (EFSA, 2012).

Dairy products, including milk, cheese, yogurt, and butter, are excellent vehicles for functional food delivery owing to their widespread consumption and compatibility with lipid-based fortification. Incorporating omega-3s into these products can promote health benefits while aligning with consumer preferences for natural, nutritious foods. The concept of "functional foods" originated in Japan in 1984, referring to food products enhanced with bioactive ingredients that provide specific health benefits. These foods are designed not only to improve nutrition but also to support physiological functions while maintaining eating enjoyment (Hardy, 2000; Kwak & Jukes, 2001). [27, 42] Fortified foods, a subset of functional foods, are products supplemented with one or more essential nutrients at higher concentrations than those found in conventional counterparts. Their primary purpose is to address nutrient deficiencies in targeted population groups or society at large (Bonner *et al*., 1999) [6].

Functional foods can be categorized in several ways based on their intended health benefits and the components they contain. According to Makinen-Aakula (2006), functional foods may be classified into three main types. First, there are functional foods that enhance quality

of life, which include products containing probiotics and prebiotics known to support gut health and immune function. Second, some functional foods are designed to mitigate health risks, targeting conditions such as high cholesterol or hypertension through ingredients that help regulate blood lipids or blood pressure. Third, there are functional foods that aid digestion, such as lactose-free or gluten-free products, which are formulated to support individuals with specific intolerances or sensitivities.

Alternatively, Kotilainen *et al*. (2006) [40], Sloan (2000) [62], and Spence (2006) [63] propose a different classification system based on the nature of fortification and modifications in foods. This system includes foods fortified with additional nutrients—for example, fruit juices enriched with vitamin C, vitamin E, folic acid, zinc, or calcium. Another category includes foods supplemented with non-native bioactive components such as probiotics and prebiotics, enhancing their health-promoting properties. Additionally, some functional foods are developed by reducing, removing, or substituting certain ingredients to improve their health profile, such as low-sugar or fat-free variants. Finally, the classification includes foods enhanced with natural additives, such as dairy products fortified with omega-3 fatty acids, aimed at delivering specific nutritional benefits. Omega-3 fatty acids. From a chemical point of view, fatty acids are saturated and unsaturated. The classification of fatty acids is presented in Fig. 1.

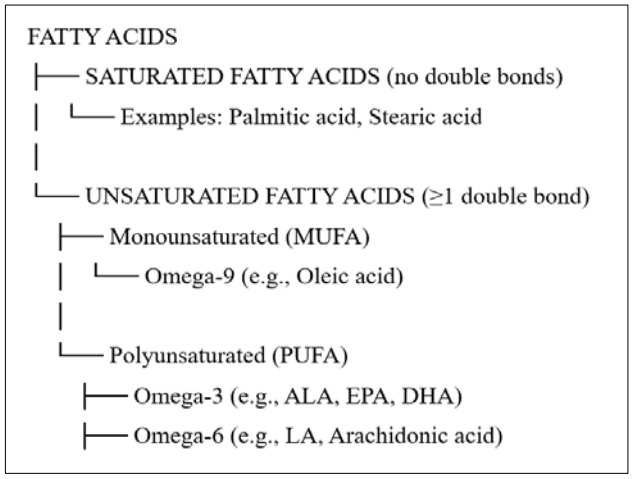

Fig 1: Classification of fatty acids

Saturated fatty acids don't contain a double bond in their hydrocarbon chain, for example (stearic acid C18:0). Unsaturated fatty acids are divided into ω-9 monounsaturated (with one double bond in the hydrocarbon chain) and polyunsaturated fatty acids (with more than one double bond in the hydrocarbon chain, ω-6, ω-3) (Fig. 2).

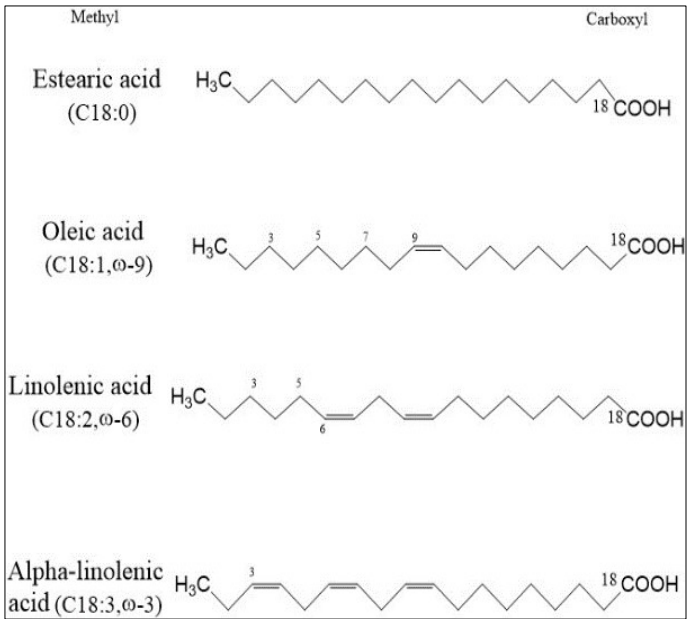

Fig 2: Chemical structures of saturated and unsaturated fatty acids

Monounsaturated fatty acids (ω-9) contain one double bond, and the 9 after ω indicates the position of the double bond in the hydrocarbon chain. Counting starts from the methylene end as shown in Fig. 2.

Classification and Health Implications of Polyunsaturated Fatty Acids (PUFAs)

Polyunsaturated fatty acids (PUFAs) are categorized into two primary groups: omega-6 (ω-6) and omega-3 (ω-3), distinguished by the position of their double bonds in the hydrocarbon chain. In ω-6 fatty acids, the double bond is located at the sixth carbon atom from the methyl end, whereas in ω-3 fatty acids, it is positioned at the third carbon atom (vide Fig. 2).

Dietary Sources and Structural Influence on Health

The ratio of saturated to unsaturated fatty acids varies across food sources. Saturated fats predominantly derive from animal-based products such as butter, cheese, and cream, while unsaturated fats are abundant in vegetable oils, fish oils, and algal oils. These structural differences significantly influence their physiological effects (Joordens *et al*., 2014) [33]. Unlike omega-3 and omega-6 fatty acids, the human body can synthesize monounsaturated (omega-9) fatty acids from saturated fats. Omega-9 fatty acids, found in almonds, walnuts, avocados, and olive oil (Peou *et al*., 2016; Wang *et al*., 2015) [53, 67], support vital physiological functions and help elevate HDL ("good") cholesterol levels (Gogus & Smith, 2010) [20].

Opposing Roles of Omega-6 and Omega-3 in Inflammation and Disease

Omega-6 and omega-3 fatty acids play crucial yet contrasting roles in biological processes, including inflammation and blood clotting. Research indicates that omega-6 fatty acids promote inflammation, whereas omega-3 fatty acids exert anti-inflammatory effects (Calder, 2006) [9]. Modern Western diets, characterized by high omega-6 and low omega-3 intake, have been linked to increased risks of chronic diseases, including:

- Cardiovascular disorders (Simopoulos, 2008) [60],
- Cancer (Wang *et al*., 2017) [68],
- Autoimmune and inflammatory conditions (Simopoulos, 2016; Kaliannan *et al*., 2019) [61, 35].

Conversely, higher omega-3 intake may mitigate these risks.

Optimal Omega-6 to Omega-3 Ratios for Health

The recommended dietary ratio of omega-6 to omega-3 ranges between 1:1 and 4:1, as this balance is associated with reduced chronic disease risk (Simopoulos, 2016; Kaliannan *et al*., 2019) [61, 35]. Kolanowski & Laufenberg (2006) suggest a maximum ratio of 4:1, while specific health conditions may require further adjustments:

- A 4:1 ratio was linked to a 70% reduction in mortality among coronary heart disease patients (de Lorgeril *et al*., 1994) [14].
- A 2:1-3:1 ratio alleviates inflammation in rheumatoid arthritis (James & Cleland, 1997) [32].
- A 5:1 ratio may improve asthma symptoms, whereas a 10:1 ratio is considered detrimental (Broughton *et al*., 1997) [8].

Essentiality of Omega-3 Fatty Acids

Omega-3 fatty acids are essential nutrients because humans lack the desaturase enzyme required to synthesize them (West *et al*., 2003) [71]. Three key omega-3 fatty acids (see Fig. 3) play critical roles in human biochemistry.

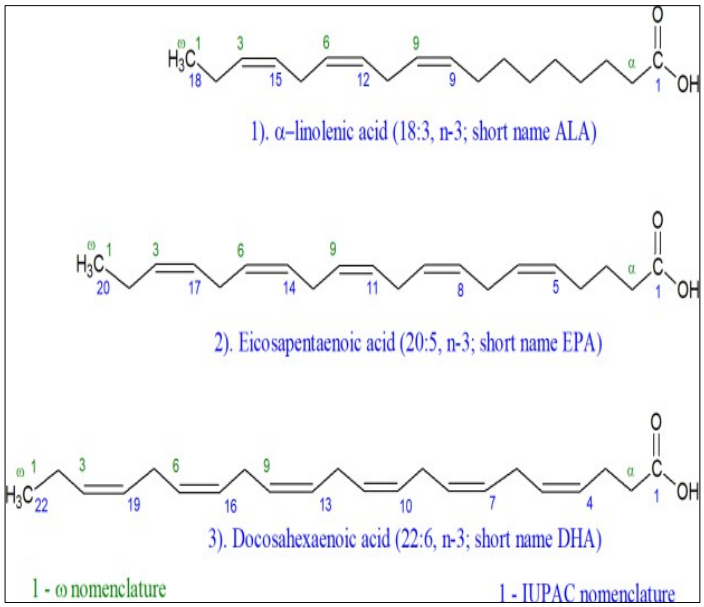

Fig 3: Chemical structures of α-linolenic acid, eicosapentaenoic acid, decoxaheptaenoic acid

The three-primary omega-3 fatty acids are α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). ALA, the shortest-chain omega-3 fatty acid, is predominantly found in plant sources such as vegetable oils and nuts, while EPA and DHA are primarily obtained from marine sources including fish and microalgae (Chew *et al*., 2008; Kalogeropoulos *et al*., 2010; Guedes *et al*., 2011; Ward & Singh, 2005) [11, 36, 23, 70]. Although the human body can convert ALA to EPA and DHA, this metabolic process is highly inefficient (Kalogeropoulos *et al*., 2010) [36], necessitating direct dietary intake of these essential fatty acids through supplements or omega-3-rich foods. Regular consumption of EPA and DHA has been associated with reduced risk of various chronic conditions including cardiovascular disease, type 2 diabetes, neurodegenerative disorders like Alzheimer's disease, and mental health conditions such as bipolar disorder and schizophrenia (Patel *et al*., 2021) [52]. Maintaining optimal health requires consistent dietary intake of these essential fatty acids. Global omega-3 consumption remains inadequate (Sioen *et al*., 2009). Bulgarian nutritional guidelines establish specific daily recommendations:

- ALA intake should constitute 0.5% of total energy intake across all age groups
- Combined EPA and DHA intake should be at least 250 mg/day for individuals over 2 years old
- Pregnant and lactating women require an additional 100-200 mg/day of DHA

The EFSA Panel (2012) [15] concluded that increased intake of these fatty acids poses no safety concerns, leading to unrestricted omega-3 consumption guidelines under Regulation 1925/2006.

Marine sources, particularly fish, represent the richest sources of EPA and DHA. The fatty acid composition of fish varies significantly based on species, environment, and diet. Research indicates barbel contains the highest monounsaturated fatty acid content (18.51%), while river mullet provides the highest polyunsaturated fatty acid levels (1.87%), including omega-3 (Gaffari & Khoshnood, 2021) [17]. Species-specific analyses reveal salmon contains 0.8% EPA and 1.6% DHA, while Russian sturgeon provides

11.3% EPA and 0.7% DHA (Kyosev & Dragoev, 2008) [41]. These findings confirm freshwater fish as valuable dietary sources of essential omega-3 fatty acids (Gaffari & Khoshnood, 2021) [17].

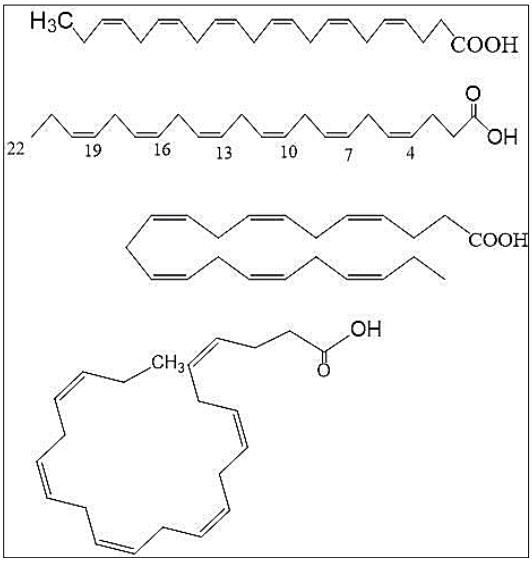

Fig 4.: Various images of the structure of DHA

Marine fish, including salmon and Russian sturgeon, remain among the most accessible and rich sources of omega-3 fatty acids. Fish oils, primarily derived from these species, are particularly valued for their high concentrations of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)—two polyunsaturated fatty acids with well-documented health benefits. Research indicates that EPA and DHA contribute to cardiovascular protection, reduced risk of certain cancers, and modulation of inflammatory immune responses (Gowda *et al*., 2018; Munoz-Tebar *et al*., 2019; Goksen *et al*., 2020) [22, 49, 21]. DHA is especially crucial for brain and eye development, making it essential during pregnancy and early childhood (Calder, 2016) [10]. Meanwhile, EPA exerts unique biological effects by competing with arachidonic acid (AA, an omega-6 fatty acid) in cell membranes, thereby influencing membrane properties. Unlike AA, which promotes inflammation and thrombosis, EPA exhibits anti-inflammatory and antithrombotic effects (Adkins & Kelley, 2010; Jump *et al*., 2012; Larsson *et al*., 2004) [1, 34, 44]. As shown in Table 1, tuna oil and 60% tuna oil concentrate contain the highest levels of EPA and DHA among omega-3 sources. Enriching foods with fish oil presents a viable strategy to boost omega-3 intake. However, a major technological challenge is the susceptibility of these oils to oxidation, which leads to undesirable fishy flavors and lipid degradation (Feizollahi *et al*., 2018; Gumus & Gharibzahedi, 2021) [16, 25].

Table 1: EPA and DHA composition of various omega-3 rich oils (Calder, 2016) [10]

Type of Oil	EPA (g/100g)	DHA (g/100g)	Total EPA+DHA (g/100g)
Cod liver oil	11	9.0	20
Krill oil	14	6.5	20
Tuna oil	11	35	46
Algae oil (infant formula)	0	>40	>40
60% fish oil concentrate	36	24	60

Omega-3 rich fish oils impart distinct sensory characteristics to fortified products, limiting their broader application in food formulations (Piombo *et al*., 2006; Botelho *et al*., 2013; Waraich *et al*., 2013; Ganesan *et al*., 2014) [54, 7, 69, 18]. To address these challenges, food manufacturers are exploring two primary solutions: (1) using highly refined, deodorized fish oils, and (2) employing encapsulation technologies to mask undesirable flavors and protect the oil during processing (Iafelice *et al*., 2008) [29]. The sensory impact of fish oil fortification depends on both the quantity added and the fish species used as the oil source (Gibney, 1997; Kolanowski *et al*., 1999; Roche & Gibney, 1994) [19, 38, 57].

The high oxidative susceptibility of fish oils necessitates strict control of manufacturing, packaging, and storage conditions to prevent degradation from oxygen exposure, UV light, elevated temperatures, humidity, and metal ion contamination (Jacobsen, 1999) [30]. Encapsulation technology has emerged as an effective strategy to mitigate oxidation while minimizing sensory impacts. Complementary approaches include incorporating natural antioxidants such as rosemary extract (Siejak, 2021) [58], chamomile compounds (Avula *et al*., 2014; Guimarães *et al*., 2013) [4, 24], or beetroot and ginger extracts (Srivastava *et al*., 2015) [65].

Plant-derived omega-3 sources offer distinct advantages, particularly for dairy fortification, as they avoid the strong flavors associated with fish oils. Dal Bello *et al*. (2015) successfully enriched yogurt using various plant oils with differing α-linolenic acid (ALA) content: flaxseed (71%), camelina (36%), raspberry (29%), Echium plantagineum (33%), and blackcurrant (14%) oils. These plant-based omega-3 precursors (ALA and linoleic acid) serve as metabolic precursors for EPA and DHA (Jakobsson *et al*., 2006; Sprecher *et al*., 1995) [31, 64], while also providing anti-inflammatory and immunomodulatory benefits (Czarnowicki *et al*., 2017; Harbige, 2003) [12, -26].

The dairy industry has increasingly focused on omega-3 fortification, employing two primary strategies: (1) modifying animal feed to enhance natural omega-3 content in milk, and (2) direct product fortification. While feed modifications using flaxseed, lupine, or rapeseed can triple milk's omega-3 content (Tzora *et al*., 2022) [66], direct fortification allows for more precise dosage control and higher omega-3 levels in final products.

Sensory studies reveal that plant-based omega-3 fortification generally achieves better consumer acceptance than fish oil-enriched products (Dal Bello *et al*., 2015; Bermúdez-Aguirre & Barbosa-Cánovas, 2011) [13, 5]. Optimal fortification levels vary by product type: yogurt and cream tolerate 1-5 g/kg fish oil, while spreadable cheeses and butter can incorporate 20-60 g/kg without compromising sensory qualities (Kolanowski & Weibbrodt, 2007) [39]. A single serving (30g) of fortified cheese can provide 180-360 mg of omega-3s, significantly boosting dietary intake, particularly for individuals with low fish consumption (Kolanowski & Weibrodt, 2007) [39]

Omega-3 Fortification in Dairy Products: Current Approaches and Outcomes

Current studies demonstrate varying strategies for omega-3 fortification across dairy products, with significant differences in optimal incorporation levels between product categories. Kolanowski & Weißbrodt (2007) [39] established

that liquid dairy products (yogurts and creams) tolerate 0.1-0.5 g/100 g fish oil, while semi-solid products (processed cheeses, spreads, butter, and soft cheeses) accommodate higher concentrations of 2-6 g/100 g. Comparative studies reveal important source-dependent differences: plant-based fortification with flaxseed oil (0.3 g/100g) in yogurt yielded 0.7 g omega-3/100g final product (Dal Bello *et al*., 2015) [13], while other plant oils showed varying efficiency (camelina 0.5→0.2 g, raspberry 0.7→0.2 g, black currant 1.4→0.4 g, Echium 0.6→0.6 g). Cheese studies by Bermúdez-Aguirre & Barbosa-Cánovas (2011) [5] revealed striking contrasts between sources - fish oil (1 g added) delivered higher final omega-3 levels than flaxseed oil in queso fresco (0.8 vs 0.2 g/100 g), cheddar (0.9 vs 0.5 g), and mozzarella (0.3 vs 0.08 g). These findings collectively suggest that: (1) product matrix significantly affects optimal fortification levels, (2) marine sources generally provide greater omega-3 bioavailability, but (3) plant sources may offer sensory advantages, particularly in delicate products like yogurts where Almasi *et al*. (2021) [2] successfully incorporated 0.2 g/100g flaxseed oil. The data underscores the need for product-specific formulation approaches to balance nutritional enhancement with sensory quality.

Conclusion

Recent research on dairy product fortification with omega-3 fatty acids reveals several key findings. While feed modification strategies for dairy animals show promising results in enhancing milk's natural omega-3 content, this approach presents limitations. First, it exclusively relies on plant-derived omega-3 sources (primarily ALA), and second, it yields variable omega-3 concentrations in the final product. In contrast, direct fortification enables more precise dosage control and consistent omega-3 levels across production batches.

The current market shows a clear preference for dairy products fortified with plant-based omega-3 sources over those using marine-derived (fish or algal) oils. This trend likely stems from the sensory challenges associated with fish oils, particularly their distinct flavor profile that can affect product acceptability. Modern encapsulation technologies offer effective solutions to these challenges by masking undesirable flavors while protecting the sensitive fatty acids from oxidation. Complementary approaches include incorporating natural antioxidants to further stabilize the oils and maintain product quality.

References

1. Adkins Y, Kelley DS. Mechanisms underlying the cardioprotective effects of omega-3 polyunsaturated fatty acids. J Nutr Biochem. 2010;21(9):781-792. DOI:10.1016/j.jnutbio.2009.12.004
2. Almasi K, Esnaashari SS, Khosravani M, Adabi M. Yogurt fortified with omega-3 using nanoemulsion containing flaxseed oil: Investigation of physicochemical properties. Food Sci Nutr. 2021;9(11):5897-6444. DOI:10.1002/fsn3.2571
3. Arterburn LM, Oken HA, Hoffman JP, Bailey Hall E, Chung G, Rom D, *et al*. Bioequivalence of docosahexaenoic acid from different algal oils in capsules and in a DHA-fortified food. Lipids. 2007;42(11):1011-1024. DOI:10.1007/s11745-007-3098-5
4. Avula B, Wang YH, Wang M, Avonto C, Zhao J, Smillie TJ, *et al*. Quantitative determination of phenolic compounds… Chamomile/*Chrysanthemum* flower heads. J Pharm Biomed Anal. 2014;88:278-288. DOI:10.1016/j.jpba.2013.08.037
5. Bermúdez-Aguirre D, Barbosa-Cánovas GV. Quality of selected cheeses fortified with vegetable and animal sources of omega-3. LWT Food Sci Technol. 2011;44(7):1577-1584. DOI:10.1016/j.lwt.2011.01.023
6. Bonner G, Warwick H, Barnardo M, Lobstein T. The need for fortification. In: Fortification Examined: How Added Nutrients Can Undermine Good Nutrition. London: The Food Commission; 1999. p. 17-22.
7. Botelho PB, Mariano K, Rogero MM, Castro IA. Effect of *Echium* oil compared with marine oils on lipid profile… LDLr knockout mice. Lipids Health Dis. 2013;12:38. DOI:10.1186/1476-511x-12-38
8. Broughton KS, Johnson CS, Pace BK, Liebman M, Kleppinger KM. Reduced asthma symptoms with n-3 fatty acid ingestion… Am J Clin Nutr. 1997;65(4):1011-1017. DOI:10.1093/ajcn/65.4.1011
9. Calder PC. n-3 polyunsaturated fatty acids, inflammation, and inflammatory diseases. Am J Clin Nutr. 2006;83(6 Suppl):1505S-1519S. DOI:10.1093/ajcn/83.6.1505S
10. Calder PC. Docosahexaenoic acid. Ann Nutr Metab. 2016;69(Suppl 1):8-21. DOI:10.1159/000448262
11. Chew YL, Lim YY, Omar M, Khoo KS. Antioxidant activity of three edible seaweeds from South East Asia. LWT Food Sci Technol. 2008;41(6):1067-1072. DOI:10.1016/j.lwt.2007.06.013
12. Czarnowicki T, Krueger JG, Guttman-Yassky E. Novel concepts of prevention and treatment of atopic dermatitis… J Allergy Clin Immunol. 2017;139(6):1723-1734. DOI:10.1016/j.jaci.2017.04.004
13. Dal Bello B, Torri L, Piochi M, Zeppa G. Healthy yogurt fortified with n-3 fatty acids from vegetable source. J Dairy Sci. 2015;98(12):8375-8385. DOI:10.3168/jds.2015-9688
14. De Lorgeril M, Renaud S, Salen P, Monjaud I, Mamelle N, Martin JL, *et al*. Mediterranean *α-linolenic acid*-rich diet… Lancet. 1994;343(8911):1454-1459. DOI:10.1016/S0140-6736(94)92580-1
15. EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). Scientific opinion on tolerable upper intake level of EPA, DHA and DPA. EFSA J. 2012;10(7):2815. DOI:10.2903/j.efsa.2012.2815
16. Feizollahi E, Hadian Z, Honarvar Z. Food fortification with omega-3 fatty acids; microencapsulation… Curr Nutr Food Sci. 2018;14(2):90-103. DOI:10.2174/1573401313666170728151350
17. Gaffari SM, Khoshnood Z. Comparative study of fatty acid composition of five freshwater fish species… Food Sci Appl Biotechnol. 2021;4(1):57-62. DOI:10.30721/fsab2021.v4.i1.115
18. Ganesan B, Brothersen C, McMahon DJ. Fortification of foods with omega-3 PUFA. Crit Rev Food Sci Nutr. 2014;54(1):98-114. DOI:10.1080/10408398.2011.578221
19. Gibney MJ. Incorporation of n-3 polyunsaturated fatty acids into processed food. Br J Nutr. 1997;78(2):193-195. DOI:10.1079/BJN19970138

20. Gogus U, Smith C. n-3 Omega fatty acids: A review. Int J Food Sci Technol. 2010;45(3):417-436. DOI:10.1111/j.1365-2621.2009.02151.x
21. Goksen G, Fabra MJ, Ekiz HI, López-Rubio A. Phytochemical-loaded electrospun nanofibers… Food Control. 2020;112:107133. DOI:10.1016/j.foodcont.2020.107133
22. Gowda A, Sharma V, Goyal A, Singh A, Arora S. Process optimization and oxidative stability of omega-3 ice cream… J Food Sci Technol. 2018;55(5):1705-1715. DOI:10.1007/s13197-018-3083-4
23. Guedes AC, Amaro HM, Barbosa CR, Pereira RD, Malcata FX. Fatty acid composition of wild microalgae and cyanobacteria… Food Res Int. 2011;44(9):2721-2729. DOI:10.1016/j.foodres.2011.05.020
24. Guimarães R, Barros L, Dueñas M, Calhelha RC, Carvalho AM, Santos-Buelga C, *et al*. Infusion and decoction of wild German chamomile… Food Chem. 2013;136(2):947-954. DOI:10.1016/j.foodchem.2012.09.007
25. Gumus CE, Gharibzahedi SMT. Yogurts supplemented with lipid emulsions rich in omega-3… Trends Food Sci Technol. 2021;110:267-279. DOI:10.1016/j.tifs.2021.02.016
26. Harbige LS. Fatty acids, immune response, and autoimmunity. Lipids. 2003;38(4):323-341. DOI:10.1007/s11745-003-1067-z
27. Hardy G. Nutraceutical and functional foods: Introduction. Nutrition. 2000;16(7-8):688-689. DOI:10.1016/S0899-9007(00)00332-4
28. Harris WS, Miller M, Tighe AP, Davidson MH, Schaefer EJ. Omega-3 fatty acids and CHD risk. Atherosclerosis. 2008;197(1):12-24. DOI:10.1016/j.atherosclerosis.2007.11.008
29. Iafelice G, Caboni MF, Cubadda R, Di Criscio T, Trivisonno MC, Marconi E. Functional spaghetti enriched with long-chain omega-3 FA. Cereal Chem. 2008;85(2):146-151. DOI:10.1094/CCHEM-85-2-0146
30. Jacobsen C. Sensory impact of lipid oxidation. Fett/Lipid. 1999;101(12):484-492. DOI:10.1002/(SICI)1521-4133(199912)101:12<484::AID-LIPI484>3.0.CO;2-H
31. Jakobsson A, Westerberg R, Jacobsson A. Fatty acid elongases in mammals. Prog Lipid Res. 2006;45(3):237-249. DOI:10.1016/j.plipres.2006.01.004
32. James MJ, Cleland LG. Dietary n-3 fatty acids in rheumatoid arthritis therapy. Semin Arthritis Rheum. 1997;27(2):85-97. DOI:10.1016/S0049-0172(97)80009-1
33. Joordens JC, Kuipers RS, Wanink JH, Muskiet FA. A fish is not a fish: fatty acid patterns… J Hum Evol. 2014;77:107-116. DOI:10.1016/j.jhevol.2014.04.004
34. Jump DB, Depner CM, Tripathy S. Omega-3 supplementation and cardiovascular disease. J Lipid Res. 2012;53(12):2525-2545. DOI:10.1194/jlr.R027904
35. Kaliannan K, Li XY, Wang B. Multi-omic analysis implicates omega-6/omega-3 imbalance… Commun Biol. 2019;2:276. DOI:10.1038/s42003-019-0521-4
36. Kalogeropoulos N, Chiou A, Gavala E, Christea M, Andrikopoulos NK. Nutritional evaluation of chickens fed *DHA-rich microalgae*. Food Res Int. 2010;43(8):2006-2013. DOI:10.1016/j.foodres.2010.05.018
37. Kolanowski W, Laufenberg G. Enrichment of food with PUFA. Eur Food Res Technol. 2006;222(3-4):472-477. DOI:10.1007/s00217-005-0089-8
38. Kolanowski W, Swiderski F, Berger S. Fish oil application for food enrichment. Int J Food Sci Nutr. 1999;50(1):39-49. DOI:10.1080/096374899101409
39. Kolanowski W, Weißbrodt J. Sensory quality of dairy products with fish oil. Int Dairy J. 2007;17(10):1248-1253. DOI:10.1016/j.idairyj.2007.04.005
40. Kotilainen L, Rajalahti R, Ragasa C, Pehu E. Health-enhancing foods: Opportunities in developing countries. World Bank; 2006.
41. Kyosev D, Dragoev S. Technology of the Fish and Fish Products. 1st ed. HVP; 2009.
42. Kwak NS, Jukes DJ. Functional foods: regulatory concept. Food Control. 2001;12(2):99-107. DOI:10.1016/S0956-7135(00)00028-1
43. Lai G, Pes M, Addis M, Pirisi A. New functional dairy products from sheep and goat milk. Dairy. 2020;1(2):154-168. DOI:10.3390/dairy1020010
44. Larsson SC, Kumlin M, Ingelman-Sundberg M, Wolk A. Long-chain n-3 FA for cancer prevention. Am J Clin Nutr. 2004;79(6):935-945. DOI:10.1093/ajcn/79.6.935
45. Lin LZ, Harnly JM. Identification of phenolics in *Chamomile*, tarragon, *Mexican arnica*. Nat Prod Commun. 2012;7(6):749-752. DOI:10.1177/1934578X1200700615
46. Makinen-Aakula M. Trends in functional foods dairy market. In: Proceedings of the Third Functional Food Net Meeting; 2006.
47. Matić IZ, Juranic Z, Savikin K, Zdunić G, Nadvinski N, Godevac D. Chamomile and marigold tea anticancer activity. Phytother Res. 2013;27(6):852-858. DOI:10.1002/ptr.4807
48. Mulinacci N, Romani A, Pinelli P, Vincieri FF, Prucher D. Characterization of *Matricaria recutita* L. extracts. Chromatographia. 2000;51(5-6):301-307. DOI:10.1007/BF02490607
49. Muñoz-Tebar N, De la Vara J, de Elguea-Culebras GO, Cano E, Molina A, Carmona M, *et al*. Chia (*Salvia hispanica* L.) oil-enriched sheep cheese. LWT. 2019;108:407-415. DOI:10.1016/j.lwt.2019.03.092
50. Motulsky AG, Bierman EL, Goodman DS, *et al*. Fats and other lipids. In: Diet and Health. Washington: National Academies Press; 1989. p. 159-258.
51. Nováková L, Vildová A, Mateus JP, Gonçalves T, Solich P. Determination of phenolics in chamomile. Talanta. 2010;82(4):1271-1280. DOI:10.1016/j.talanta.2010.06.057
52. Patel A, Karageorgou D, Katapodis P, Sharma A, Rova U, Christakopoulos P, *et al*. Bioprospecting of thraustochytrids. Trends Food Sci Technol. 2021;115:433-444. DOI:10.1016/j.tifs.2021.06.044
53. Peou S, Milliard-Hasting B, Shah SA. Impact of avocado diets on lipoproteins. J Clin Lipidol. 2016;10(1):161-171. DOI:10.1016/j.jacl.2015.10.011
54. Piombo G, Barouh N, Barea B, Boulanger R, Brat P, Pina M, *et al*. Characterization of seed oils from *Actinidia chinensis*, *Passiflora edulis*, and *Psidium guajava*. OCL. 2006;13(2-3):195-199. DOI:10.1051/ocl.2006.0026
55. Raal A, Orav A, Püssa T, Valner C, Malmiste B, Arak E. Essential oils and polyphenols in chamomile teas. Food Chem. 2012;131(2):632-638.

DOI:10.1016/j.foodchem.2011.09.042
56. Roby M, Sarhan M, Selim K, Khalel K. Antioxidant and antimicrobial activities of fennel and chamomile. Ind Crops Prod. 2013;44:437-445. DOI:10.1016/j.indcrop.2012.10.012
57. Roche H, Gibney MJ. Fish oil enriched spreads and platelet phospholipids. Int J Vitam Nutr Res. 1994;64(3):237-242.
58. Siejak P, Smułek W, Fathordobady F, Grygier A, Rudzińska M, Nowakowski PT, *et al*. "Five Thieves' Oil" characterization. Molecules. 2021;26(10):2931. DOI:10.3390/molecules26102931
59. Sioen I, De Henauw S, Van Camp J, Volatier JL, Leblanc JC. Nutritional-toxicological conflict in seafood consumption. Regul Toxicol Pharmacol. 2009;55(2):219-228. DOI:10.1016/j.yrtph.2009.07.003
60. Simopoulos AP. Omega-6/omega-3 ratio importance. Exp Biol Med. 2008;233(6):674-688. DOI:10.3181/0711-MR-311
61. Simopoulos AP. Omega-6/omega-3 ratio and obesity risk. Nutrients. 2016;8(3):128. DOI:10.3390/nu8030128
62. Sloan A. Top ten functional food trends. Food Technol. 2000;54(4):33-62.
63. Spence JT. Challenges in functional food composition. J Food Compos Anal. 2006;19(8):S4-S6. DOI:10.1016/j.jfca.2005.11.007
64. Sprecher H, Luthria DL, Mohammed BS, Baykousheva SP. PUFA biosynthesis pathways. J Lipid Res. 1995;36(12):2471-2477. DOI:10.1016/S0022-2275(20)41084-3
65. Srivastava P, Prasad SGM, Mohd NA, Prasad M. Antioxidant activity of herbal yogurt. Pharma Innov J. 2015;4(3):18-20.
66. Tzora A, Voidarou C, Giannenas I, Bonos E, Fotou K, Nelli A, *et al*. Effect of omega-3 enrichment on ovine milk. Foods. 2022;11(22):3736. DOI:10.3390/foods11223736
67. Wang L, Bordi PL, Fleming JA, Hill AM, Kris-Etherton PM. Moderate fat diet with/without avocado. J Am Heart Assoc. 2015;4(1):e001355. DOI:10.1161/JAHA.114.001355
68. Wang W, Yang J, Nimiya Y, Lee SK. ω-3 PUFA and CYP450 metabolites suppress colorectal tumors. J Nutr Biochem. 2017;48:29-35. DOI:10.1016/j.jnutbio.2017.06.006
69. Waraich EZ, Ahmed R, Ahmad MY, Ashraf SB, Saifullah MS, Naeem M, *et al*. *Camelina sativa* review. Aust J Crop Sci. 2013;7(10):1551-1559.
70. Ward OP, Singh A. Omega-3/6 FA alternative sources. Process Biochem. 2005;40(12):3627-3652. DOI:10.1016/j.procbio.2005.02.020
71. West DV, Maes M. PUFA in depression. Acta Neuropsychiatr. 2003;15(1):15-21. DOI:10.1034/j.1601-5215.2003.00004.x
72. Xie XY, Wang R, Shi YP. Flavonoids from *Matricaria chamomilla*. Chem Nat Compd. 2014;50(5):910-911. DOI:10.1007/s10600-014-1114-6
73. Zieliński AAF, Haminiuk CWI, Alberti A, Nogueira A, Demiate IM, Granato D. Phenolic compounds and antioxidant activity of Brazilian teas. Food Res Int. 2014;60:246-254. DOI:10.1016/j.foodres.2013.09.010