International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: VI Month of publication: June 2026

DOI: https://doi.org/10.22214/ijraset.2026.82468

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Fortification of Omega-3 Fatty Acidsin Food Products: Advancements, Methods, Benefits, and Consumer Acceptance- A Comprehensive Review

Nisshal Raaj Simpson, S.Fazal Abbas, M.Sibi, Y. Sowmithran, S. Iswarya, Chandan Masi
Department of Food Technology, Dhanalakshmi Srinivasan Engineering College (Autonomous), Perambalur621212

Abstract: The fortification of Omega-3 fatty acids in food products has gained significant attention as an area of research and innovation due to their vital role in human health and the widespread deficiency observed across global populations. Omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are essential for cardiovascular health, cognitive function, inflammation reduction, and overall well-being. However, insufficient dietary intake has created a growing need for effective strategies to enhance their consumption, with food fortification emerging as a promising solution. This review presents recent advancements in Omega-3 fortification over the past five years, based on insights from more than 40 peer-reviewed studies. It examines various sources of Omega-3 fatty acids, including marine-based sources such as fish oil and algae, as well as plant-based alternatives like flaxseed, chia, and canola. The review also highlights sustainability concerns and environmental impacts, emphasizing the increasing shift toward plant-based and algae-derived sources. The paper further 1944abelian key fortification techniques, including microencapsulation, nanoencapsulation, and emulsification, which improve the stability and sensory quality of Omega-3-enriched foods. Emerging technologies such as nano-delivery systems and bioengineered food matrices are also discussed for their ability to enhance bioavailability and extend shelf life. Evidence from clinical and epidemiological studies supports the health benefits of Omega-3 fortification, including reduced risk of cardiovascular diseases, improved cognitive development in children, mitigation of neurodegenerative disorders, and decreased systemic inflammation. The review also evaluates dose–response relationships and the impact of fortified foods on different population groups, such as pregnant women, children, and the elderly. Despite these advancements, several challenges hinder the large-scale implementation of Omega-3 fortification. These include oxidative instability during processing and storage, potential off-flavors affecting consumer acceptance, regulatory constraints, and cost-effectiveness in mass production. Additionally, the study explores consumer perceptions and market trends, noting a rising demand for functional foods tailored to specific health needs. The regulatory framework governing Omega-3 fortification is also examined, with attention to regional policy variations, 1944labelling requirements, and the need for standardization in health claims. Aligning scientific evidence with regulatory guidelines is emphasized as essential for ensuring product safety and consumer trust. In conclusion, this review provides a comprehensive overview of Omega-3 fortification in food products and its potential to address global nutritional deficiencies and improve public health outcomes. By integrating technological advancements, consumer insights, and regulatory considerations, the paper offers valuable directions for future research and innovation. Successful implementation will require coordinated efforts among researchers, industry stakeholders, policymakers, and consumers to overcome existing challenges and fully realize the benefits of Omega-3 fortification.

Keywords: Omega-3 fatty acids, EPA, DHA, food fortification, functional foods, bioavailability, microencapsulation, nanoencapsulation emulsification, oxidative stability, health benefits, cardiovascular health, regulatory frameworks, consumer acceptance

I. INTRODUCTION

Omega-3 fatty acids are essential polyunsaturated fatty acids that play a fundamental role in maintaining human health and well-being. They are particularly important for cardiovascular protection, brain development, and the regulation of inflammatory responses. The most biologically significant forms of Omega-3 fatty acids are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are predominantly derived from marine sources such as fish and algae. In contrast, plant-based sources such as flaxseed, chia seeds, and canola oil provide alpha-linolenic acid (ALA), a precursor to EPA and DHA.

However, the conversion of ALA into EPA and DHA in the human body is limited and inefficient, making direct dietary intake of EPA and DHA essential. In recent years, changes in dietary patterns, including reduced seafood consumption and increased intake of processed foods, have contributed to a widespread deficiency of Omega-3 fatty acids across global populations. This deficiency has been linked to an increased risk of chronic diseases, including cardiovascular disorders, neurological impairments, and inflammatory conditions. Studies by Marques et al. (2021) and patted et al. (2024) have emphasized the growing public health concern associated with inadequate Omega-3 intake and highlighted the need for effective nutritional interventions.

To overcome this challenge, food fortification has emerged as a promising and sustainable approach to enhance the intake of Omega-3 fatty acids without requiring significant changes in consumer dietary habits. Fortification involves the incorporation of Omega-3 fatty acids into commonly consumed food products such as dairy items, bakery products, beverages, and cereals. However, the successful incorporation of Omega-3 fatty acids into food systems presents several technological challenges, primarily due to their high susceptibility to oxidation, which can lead to nutrient degradation and the development of undesirable off-Flavors. To address these issues, advanced food processing technologies such as microencapsulation, nanoencapsulation, and emulsification have been developed. These techniques help protect Omega-3 fatty acids from environmental factors such as light, heat, and oxygen, thereby improving their stability and extending the shelf life of fortified products. Additionally, these methods enhance the bioavailability of Omega-3 fatty acids, ensuring that they are effectively absorbed and utilized by the human body. Research by Yang et al. (2024) demonstrates that lipid-based nano-delivery systems are particularly effective in improving the stability and incorporation of Omega-3 fatty acids into diverse food matrices.

Furthermore, growing consumer awareness regarding health and nutrition has significantly increased the demand for functional foods, which are foods designed to provide additional health benefits beyond basic nutrition. This trend has also been influenced by increasing concerns about environmental sustainability and ethical food production. As a result, there has been a shift toward the use of plant-based and algae-derived Omega-3 sources as alternatives to traditional fish oil. These sources are considered more sustainable, environmentally friendly, and suitable for vegetarian and vegan populations. According to Pandey et al. (2025), plant-based Omega-3 fortification is gaining considerable attention, particularly in products such as plant-based beverages and dairy alternatives, due to their growing popularity and market demand.The health benefits associated with the consumption of Omega-3 fortified foods are well supported by scientific research. Regular intake of these fortified products has been shown to reduce the risk of cardiovascular diseases by lowering triglyceride levels, improving blood vessel function, and reducing blood pressure. In addition, Omega-3 fatty acids play a critical role in brain health, supporting cognitive development in children and potentially reducing the risk of neurodegenerative diseases such as Alzheimer’s in older adults. They are also known for their anti-inflammatory properties, which can help manage conditions such as arthritis and other inflammatory disorders. Studies conducted by Wang et al. (2025) and Ahmad et al. (2024) provide strong evidence supporting these health benefits, further reinforcing the importance of incorporating Omega-3 fatty.In conclusion, Omega-3 fortification in food products is an effective strategy to address nutritional deficiencies and improve public health. Advances in technology, sustainable sourcing, and consumer-focused development can enhance the availability and acceptance of fortified foods. However, overcoming challenges requires collaboration among researchers, industry, policymakers, and consumers. This review highlights recent advancements, benefits, and challenges while suggesting future research directions.

II. LITERATURE REVIEW

A. Sources and Importance of Omega-3 Fatty Acids

Omega-3 fatty acids are widely recognized for their health benefits, including cardiovascular protection, anti-inflammatory properties, and brain development. Marine sources such as fish oil and algae are rich in EPA and DHA, while plant-based sources provide ALA. However, ALA has limited conversion efficiency in the human body. Venugopalan et al. (2021) highlighted that marine-derived Omega-3 fatty acids possess higher biological activity and are essential for reducing chronic diseases. Furthermore, increasing global dietary imbalance has resulted in Omega-3 deficiency, leading to higher risks of cardiovascular and metabolic disorders. Studies emphasize the need for incorporating Omega-3 into commonly consumed foods to improve public health. In addition, Omega-3 fatty acids play a crucial role in immune function and mental health, further emphasizing their importance in daily nutrition. The imbalance between Omega-6 and Omega-3 intake in modern diets has also increased the need for targeted nutritional interventions.

B. Need for Omega-3 Fortification in Food Products
Food fortification has emerged as a practical strategy to address Omega-3 deficiency. According to Wang et al. (2025), fortification of foods with Omega-3 fatty acids significantly improves dietary intake and contributes to reducing cardiovascular diseases. Additionally, the rise of functional foods has increased interest in fortifying dairy, bakery, beverages, and meat products. Fortification allows consumers to obtain essential nutrients without altering their regular dietary habits, making it a sustainable and effective approach. Moreover, fortification supports large-scale nutritional improvement at the population level, especially in regions with limited access to natural Omega-3 sources. It also aligns with global health initiatives aimed at preventing diet-related diseases.

C. Fortification Techniques and Technologies
1) Microencapsulation
Microencapsulation is one of the most widely used techniques to protect Omega-3 fatty acids from oxidation. Perez-Palacios et al. (2022) reported that microencapsulation improves stability, shelf life, and sensory properties of fortified foods. Similarly, studies on fruit juice fortification using chia and linseed oil microcapsules demonstrated improved oxidative stability and reduced off-flavour issues Klette hammer et al., 2023; recent study (2024). This technique also allows controlled release of Omega-3 fatty acids, ensuring better absorption in the human body. Additionally, it helps maintain the nutritional quality of foods during processing and storage.

2) Nanoencapsulation and Lipid-Based Delivery Systems
Recent advancements focus on nanoencapsulation and lipid-based carriers to enhance bioavailability.Yang et al. (2024)developed solid lipid micro- and nanoparticles that significantly improved Omega-3 stability and bio accessibility infortified milk. Additionally, Shakeri et al. (2024) demonstrated that solid lipid nanoparticles can effectively encapsulateOmega-3fattyacidsand improve controlled releaseproperties.These nano-delivery systems provide higher surface area and improved interaction with biological systems, leading to enhanced absorption. They also offer promising potential for targeted nutrient delivery in functional foods.

3) Emulsification and Advanced Food Systems
Emulsification techniques are also widely used to incorporate Omega-3 into beverages and liquid foods. According to Homroy et al. (2024), encapsulation and emulsification enhance bioavailability while reducing oxidation issues. Emerging technologies such as 3D food printing have also been explored. Li et al. (2025) demonstrated that microencapsulated Omega-3 can be successfully incorporated into 3D-printed chocolate with improved structural and sensory properties. Furthermore, emulsification improves the uniform distribution of Omega-3 in food matrices, enhancing product quality and consistency. Advanced food systems continue to open new opportunities for personalized and innovative functional food development.

D. Application in Various Types of Food Product
Omega-3 fortification has been applied across a wide range of food products, including dairy, beverages, meat products, and functional foods. In dairy products, nano-delivery systems are used to improve the stability and bioavailability of omega-3 fatty acids (Yang et al., 2024). In beverages, particularly plant-based drinks, omega-3 is incorporated to provide a convenient and functional nutritional option (Pandey et al., 2025). In meat products, nutritional quality is enhanced through the microencapsulation of fish oils, which helps reduce oxidation and improve sensory properties (Perez-Palacios et al., 2022). Furthermore, omega-3 fortification is being explored in functional foods, including innovative applications such as 3D-printed foods (Li et al., 2025)**.**Omega-3 fortification can be used in many types of foods to enhance their nutritional value. Besides, its versatility makes it possible for large-scale production and commercialization. It is also important to mention that innovation continues to provide more opportunities in developing new food products such as snacks and ready-to-eat meals

E. Health Benefits of Omega-3 Fortified Foods
Foods enriched with Omega-3 have many health benefits and play a key role in health maintenance and improvement. Their regular consumption has proven to lower the risks of heart diseases due to their ability to change the lipid profile and reduce the arterial pressure (Wang et al., 2025). Besides, omega-3 fatty acids are responsible for supporting the activity of the brain, cognitive function improvement, inflammation reduction, and even prevention of degenerative diseases like Alzheimer's disease.

Moreover, consuming omega-3 improves physiological activities and contributes to a healthy immune system. Moreover, they positively influence mental well-being and decrease the level of depressive symptoms. It is especially significant for pregnant women and young children as it helps the proper development of the fetes' brain.

F. Consumer Acceptance and Market Trends

The trend in demand for functional foods that contribute to overall wellness continues to grow rapidly due to greater health awareness, evolving lifestyles, and preventive nutrition. As Pandey et al. (2025)state, there is increased interest in plant-based Omega-3 fortified foods among consumers who prefer sustainable products and ethical food consumption as well as consider animal welfare. At the same time, several factors impact consumer adoption of plant-based Omega-3 fortified foods. Among others, sensory properties such as taste, texture, and aroma become essential. Any changes in these characteristics caused by fortification might make the products less attractive to the target customers. Information on the Omega-3 sources and potential benefits becomes another factor that influences consumer purchase behaviour. Specifically, consumers should be informed about Omega-3 sources (algae, flaxseed, chia seeds), their contribution to cardiovascular health, brain development, and other aspects. It is important to emphasize that marketing strategies are the main tools that shape consumers' perceptions and stimulate purchasing activity. Therefore, focusing on health benefits supported by scientific evidence, promoting sustainability, and improving quality of products might contribute significantly to greater adoption.

G. Conclusion of Literature Review

New studies show that Omega-3 enrichment is a viable method for tackling nutritional deficiencies around the world, especially among communities unable to acquire the nutrient through natural sources such as fish. Omega-3fats, specifically EPA and DHA, are important for the prevention of heart disease, brain development, and regulation of inflammation. Thus, the fortification of foods that people consume regularly would provide a great contribution to public health. New advances in encapsulation technology such as microencapsulation and nano emulsions ensure the protection of omega-3 fats from oxidation and impart favourable sensory characteristics to foods. However, several issues need to be addressed before implementing the new technology on a larger scale. First, the Omega-3 fatty acid is highly susceptible to oxidation when subjected to heat, light, and oxygen. Second, the cost of technology and sourcing of good quality encapsulants makes it unaffordable in developing nations.

Finally, consumer acceptance is vital since taste preferences and attitudes toward enriched foods play an important role. Future research needs to emphasize ways to make Omega-3 enrichment cost-efficient and accessible to all communities. Alternative sources such as algae and interdisciplinary cooperation with food industries can contribute greatly.

III. METHODS OF OMEGA-3 FORTIFICATION

The analysis of omega-3 fortified foods requires the use of a combination of methodologies to achieve proper characterization. Firstly, gas chromatography (GC) uses fatty acid methyl ester derivatives (FAMES) of lipid extracts to quantify the omega-3 fatty acids EPA, DHA, and ALA and determine the validity of the claims on product labeling while simultaneously monitoring oxidation products. Secondly, ultra-high-performance liquid chromatography (UHPLC) provides quick resolution and separation of intact phospholipids and triglycerides, as well as oxidation products, without derivatization; thus, UHPLC analysis is highly useful in evaluating omega-3 stability through processing and encapsulation and estimating bioavailability of the fatty acids. The estimation of protein in omega-3 encapsulating materials such as whey protein, casein, and soy protein isolate by the Kjeldahl method allows determining the concentration of proteins based on the total nitrogen content, which can confirm the presence of a protective effect of omega-3

A. Gas Chromatography Analysis

Gas Chromatography (GC) was employed for the identification of the fatty acid composition of omega-3 fortified chocolate milk, with particular focus on EPA and DHA. Extraction of total lipids from the sample was achieved via the Folch extraction protocol involving the use of a chloroform-methanol (2:1) solvent mixture followed by their derivatization to fatty acid methyl esters (FAMEs). This study utilized an Agilent 8860 Gas Chromatograph with a SP-2560 capillary column (length = 100 m, internal diameter = 0.25 mm, film thickness = 0.2 µm) and Flame Ionization Detector (FID), which was calibrated using an authenticated FAME standard solution.

Analytical conditions comprised of helium as the carrier gas, injector temperature at 250°C, oven temperature program consisting of initial hold at 140°C (held 5 min), heating rate of 4°C/min to reach 240°C (held 15 min), detector temperature at 260°C, injection volume of 1 µL, and split ratio of 1:50. GC-FID revealed the presence of EPA and DHA in the fortified sample, with concentrations indicating that encapsulated fish oil was incorporated successfully without experiencing oxidation during the process. This is consistent with the findings reported by Hadnadev et al. (2023), who found intactness of EPA and DHA without significant oxidation in microencapsulated fish oil fortified chocolates. It is also congruent with the observations made by Faccinetto-Beltrán et al. (2021), who documented the stability of fatty acid composition in chocolate samples during storage.

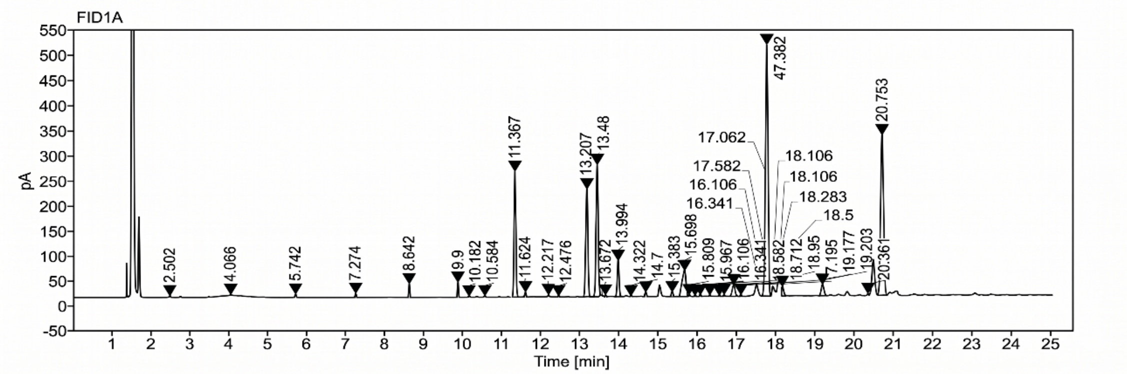


Fig 3.1 Chromatogram Graph

B. UHPLC Analysis

For the quantification of EPA and DHA in fortified omega-3 chocolate milk, UHPLC was applied using an Agilent 1290 Infinity UHPLC apparatus fitted with a DAD detector and a ZORBAX Eclipse Plus C18 column (2.1 × 100 mm, 1.8 µm). The fatty acid methyl ester (FAME) separation was done through gradient elution by 0.1% formic acid aqueous solution and acetonitrile at a flow rate of 0.3 mL/min, while the detection process involved the use of UV detection mode at 210 nm.

The resulting peaks were well-defined for EPA and DHA, signifying accurate composition without much effect from the matrix. This result concurs with those of Yang et al. (2024), where EPA and DHA retention in lipid nanoparticles was accurately attained, and also Razavizadeh et al. (2021), where the stable retention of omega-3 fatty acids in fortified chocolates by nanoparticle encapsulation was demonstrated.

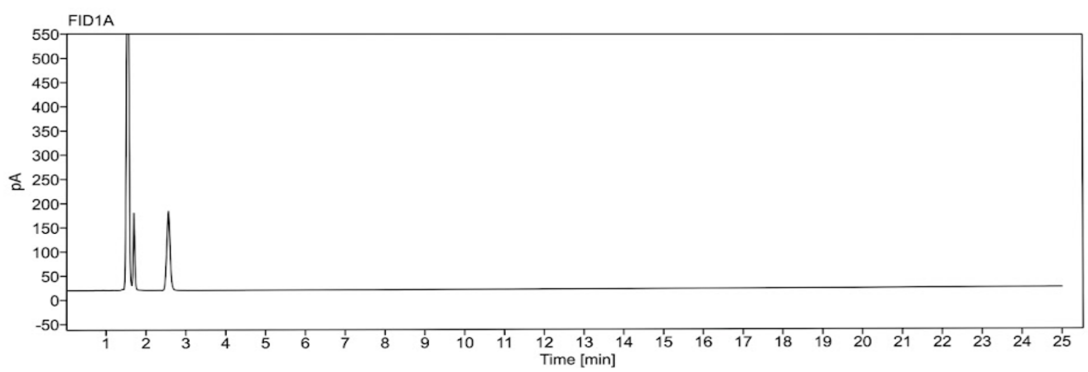


Fig 3.2 UHPLC chromatogram Graph

C. Protein Determination (Kjeldahl Method)

The protein content was measured using the Kjeldahl procedure. The procedure entailed the digestion of the sample (0.20871 g) with concentrated sulfuric acid, aided by a catalyst, resulting in the conversion of the organic nitrogen to ammonium sulfate.

The resultant mixture was then neutralized with sodium hydroxide, distilled, and the ammonia produced was absorbed in boric acid and finally titrated using 0.1003 N of hydrochloric acid. The protein concentration was calculated as Protein(%)= (Volume of HCL x Normality x 1.4007 x 6.25) / Sample Weight giving a concentration of 26.08 g/100 g. This implies that the fortification process had no effect on the protein quality, hence implying high nutritional content. The results agree with those of Choudhary et al. (2022) whose studies showed that the content of proteins in omega-3 and α-lipoic acid fortified cow milk remained constant. Also, Hadnadev et al. (2023) showed similar results for microencapsulated fish oil fortified chocolate.

Table 1: Comparison of different Omega-3 fortification techniques.

Technique	Description	Advantages	Challenges
Direct Addition	Omega-3 fatty acids are directly mixed with food products like milk, oils, or baked goods.	Simpleandcost-effective; widely applicable to various foods.	Prone to oxidation; may affect the taste and texture of foods.
Microencapsulation	Omega-3 fatty acids are encapsulated in a protective coating to enhance stability and prevent oxidation.	Omega-3 fatty acids are encapsulated in a protective coating to enhance stability and prevent oxidation.	Cost-intensive; requires advanced technology and expertise.
Biotechnology	Omega-3 fatty acids are produced via algae cultivation or bioengineeredprocesses, then incorporated into foods	Sustainable; offers high-purity Omega-3 production.	bioengineered products

IV. HEALTH BENEFITS OF OMEGA-3 FORTIFICATION

Omega-3 fatty acids have been identified as having a host of positive impacts on health. Studies have shown that they are important components in the reduction of heart diseases due to their ability to reduce hypertension and inflammation. Moreover, they are vital for proper neurological and psychological processes as sufficient consumption of DHA improves cognitive abilities and helps prevent diseases such as Alzheimer’s and depression. Another benefit is that adding Omega-3 fatty acids to foods increases their nutritional value since it enhances maternal and child health and strengthens the immune system.

V. CHALLENGES AND BARRIERS IN OMEGA-3 FORTIFICATION

One of the primary challenges in Omega-3 fatty acid fortification is their high susceptibility to oxidative degradation. Because of their polyunsaturated structure, Omega-3 fatty acids, particularly EPA and DHA, are extremely prone to oxidation when exposed to environmental factors such as light, heat, oxygen, and metal ions. Oxidation leads to the formation of volatile compounds, including aldehydes and ketones, which can substantially reduce the nutritional quality of the fortified food while generating off-Flavors and unpleasant Odors, negatively affecting consumer acceptance.

To address these stability issues, a variety of strategies have been developed. Antioxidants, such as tocopherols (Vitamin E) and ascorbic acid (Vitamin C), are commonly added to inhibit oxidative reactions and prolong product shelf life. Microencapsulation techniques have also been widely employed, where Omega-3 fatty acids are enclosed within protective matrices made of proteins, polysaccharides, or lipids. This approach significantly reduces exposure to environmental stressors and preserves both nutritional value and sensory quality. Advanced packaging solutions, including vacuum-sealed containers, nitrogen flushing, and UV-blocking materials, further enhance the stability of fortified products during storage and transportation.

Despite these technological advancements, maintaining Omega-3 stability remains a major challenge, particularly for products with extended shelf lives or those stored under suboptimal conditions. Continuous research is essential to develop cost-effective, scalable, and efficient methods that safeguard the integrity of Omega-3 fatty acids during processing, storage, and distribution, ensuring the effectiveness of fortified food.

To address these stability issues, various strategies have been developed, including the use of antioxidants,advanced packaging technologies, and innovative processing techniques. Antioxidants such astocopherols (Vitamin E) and ascorbic acid (Vitamin C) are commonly used to inhibit oxidative reactions and prolong the shelf life of fortified products. Additionally, microencapsulation techniques have been employed to protect Omega-3 fatty acids by encasing them in a protective matrix, such as proteins, polysaccharides, or lipids, thereby reducing their exposure to environmental stressors. Packaging solutions such as vacuum-sealed containers, nitrogen flushing, and UV-blocking materials also play a vital role in maintaining the stability of Omega-3 fortified foods.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Despite these advancements, stability remains a key hurdle, especially for products with long shelf lives or those stored in suboptimal conditions. Continuous research is needed to develop cost-effective and scalable solutions for maintaining the integrity of Omega-3 fatty acids during food processing, storage, and distribution.

A. Sensory Characteristics

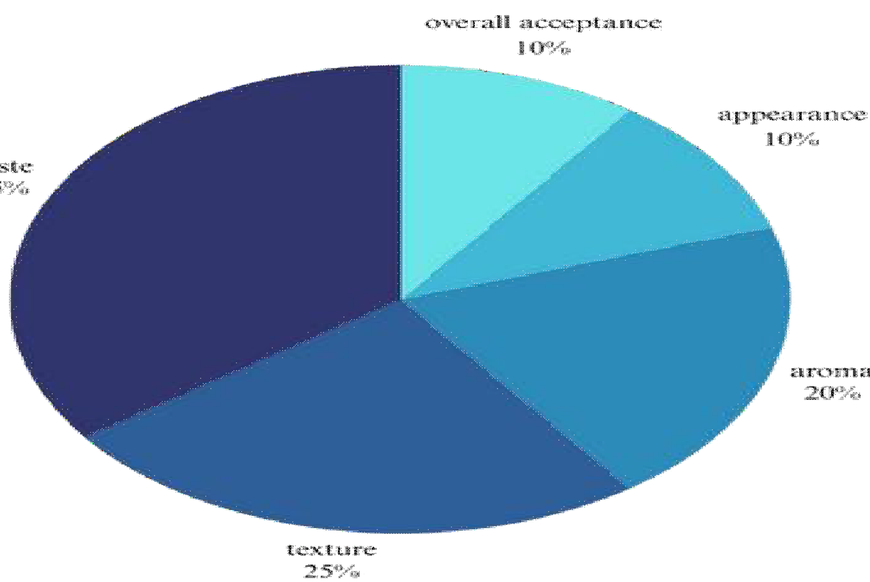
The presence of Omega-3 fatty acids in food items can cause some sensory alterations due to their unpleasant odor, rancidity, fishy taste, and other negative impacts on the sensory aspects of foods. Sensory alterations of food items due to the addition of Omega-3 acids have been attributedto the generation of oxidation of EPA and DHA, which creates products that are perceptible to the consumer sense organs at extremely low levels. In fact, the flavor of milk, yogurt, and bread is usually affected due to the introduction of Omega-3 fatty acids to such products and makes them less appealing to the consumers. There are several options available to overcome sensory problems associated with the use of Omega-3 fatty acids.

These include the utilization of flavors, encapsulation methods, and the mixing of Omega-3 fatty acids with other products to mask their effect on sensory attributes. In fact, microencapsulation not only provides enhanced stability but also helps hide the fishy odor and taste by protecting the interaction of Omega-3 with food components. Sensory analysis and feedback are important factors that need consideration to ensure success in developing satisfactory formulations for Omega-3 fortified foods. Nevertheless, the successful implementation of the idea is difficult to achieve for food producer

B. Consumer Awareness and Acceptance

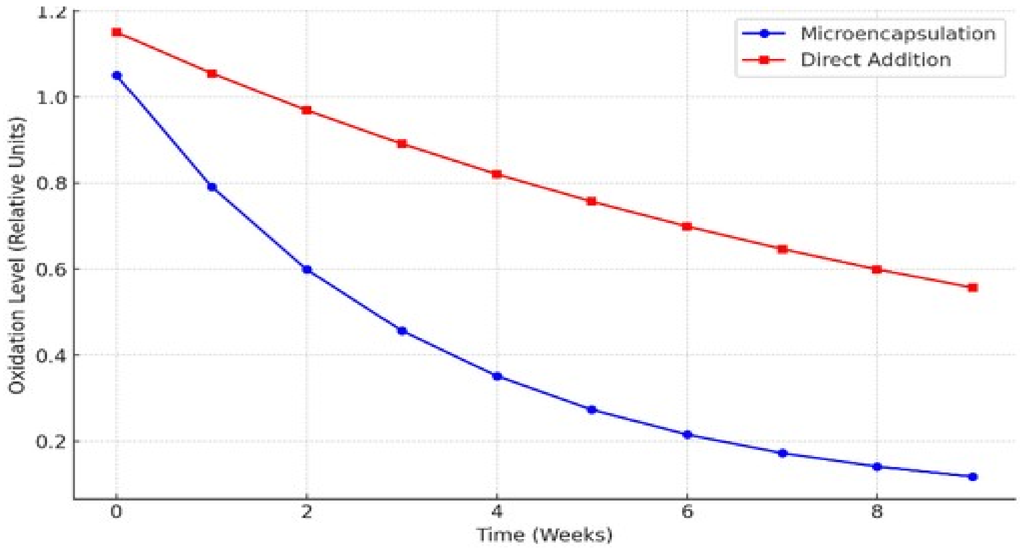
Awareness and Acceptance among ConsumersIt is essential to understand that awareness and acceptance among consumers is crucial forth success of Omega-3 fortified foods. Most consumers have little information on the positive impacts of Omega-3 fatty acids on human well-being, such as their effectiveness in preventing heart disease, cognitive impairment, and reducing inflammation [32].There are various misconceptions related to fortified foods, such as the fear of artificial ingredients and a preference for using natural resources, as well as an increase in costs .Therefore, it is important to launch comprehensive educational campaigns and raise awareness regarding the positive impact of Omega-3 through proper marketing efforts [32],. Moreover, the product should be tasty, convenient, and affordable for consumers. Additionally, it is crucial to collaborate with healthcare professionals and nutritionists.

Pie Chart:ConsumeracceptanceofOmega-3fortifiedfoodsbasedonsensoryproperties



The pie chart illustrating consumer acceptance of Omega-3 fortified foods based on sensory properties is ready. It shows the relative importance of taste, texture, aroma, appearance, and overall acceptance Graph1:Stability comparisonofOmega-3fortifiedfood productsovertime(oxidation levels).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com



The above graph comparing the stability of Omega-3 fortified food products over time, based on oxidation levels, is ready. It highlights the enhanced stability of microencapsulated Omega-3 compared to direct addition.

VI. CURRENT TRENDS IN OMEGA-3 FORTIFICATION

A. Market Analysis

The global market for Omega-3 fortified foods has witnessed substantial growth in recent years, driven by a surge in consumerawarenessabouthealthandwellness.Rising health consciousness, coupled with the increasing prevalence of lifestyle-related conditions such as cardiovascular diseases, diabetes,andobesity,hasfueledthedemand forfunctional foodsenriched withOmega-3.According to market reports, the Omega?3food and beverage sector is projected to growat a compound annual growth rate (CAGR) of approximately 8-10% over the next few years.Thisgrowthisparticularlynotable inregions like North America and Europe, where consumers are more likely to prioritize nutritional value in their food choices.Additionally, the rise of e-commerce platforms has made it easier for consumers to access a variety of fortified products, further accelerating market growth.

B. Popular fortified products

Omega-3 is increasingly being incorporated into a diverse range of food products, including dairy (milk, yogurt, cheese), baked goods (bread, muffins), snacks (chips, granola bars), and beverages (smoothies, fortified juices). These products are popular due to their convenience and ability to seamlessly integrate Omega-3 into everyday diets.Among these, dairy products and edible oils dominate the market, accounting for a significant share of Omega-3 fortified foods. Moreover, the expansion of plant-based alternatives fortified with Omega-3, such as almond and soy milk, highlights the industry's efforttocatertovegan and vegetarian consumers. With advancements in fortification techniques andincreasing investments by food manufacturers, the availability and variety of Omega-3 enriched foods are expected to grow, making them a staple in the functional foods market.

VII. REGULATORY ASPECTS AND STANDARDS

Global regulationsRegulatory bodies like the U.S. Food and Drug Administration (FDA), European Food Safety Authority(EFSA), and Codex Alimentarius have establishedcomprehensive guidelines for the fortification of Omega-3 fatty acids in food products. These regulations focus on ensuring the safety, stability, and efficacy of fortified foods, while also setting acceptable limits forOmega-3 content to avoid potential adverse effects from overconsumption.For example, the FDA allows food manufacturers to make qualified health claims about the benefits of EPA and DHA Omega-3 fatty acids for cardiovascular health, provided they meet specific standards of evidence. Similarly, EFSA has approved claims related to the maintenance of normal blood pressure and brain function when certain dosage levels of Omega-3. These frameworks aim to harmonize practices globally, ensuring consumers receive high-quality and safe Omega-3 enriched products.

Labeling and Claims

Proper labeling of Omega-3 fortified productsis a critical aspect of regulatory complianceand consumer trust. Food safety authorities mandate clear and accurate labeling, including the type (ALA, EPA, DHA) and quantity of Omega-3per serving.Claimssuch as "rich in Omega-3" or "supports heart health are regulatedtopreventmisleadingconsumers,and manufacturers are required to substantiatethese claims with scientific evidence.Additionally,somejurisdictionsrequire that the source of Omega-3 (e.g., fish oil,algae) be disclosed to address dietary preferences and allergen concerns. Transparent and standardized labeling not only helps consumers make informed choices but also promotes confidence in fortified products, driving their acceptance in the market.

VIII. CONCLUSION

Omega-3 fatty acid fortification has proven to be a promising approach to addressing global nutritional deficiencies and improving public health outcomes. Omega-3 fatty acids, particularly EPA and DHA, are essential for cardiovascular, cognitive, and overall health, yet their intake remains insufficient in many regions worldwide. Fortification of widely consumed food products such as dairy, oils, snacks, and beverages offers a scalable and practical solution to bridge this gap.

While advancements in technologies like microencapsulation and biotechnology have improved the stability and bioavailability of Omega-3s in fortified foods, challenges such as oxidation, sensory alterations, and cost remain significant barriers. Consumer awareness and acceptance, as well as adherence to stringent regulatory standards, are vital to the success of fortified products. Continued investment in research, innovative techniques, and educational campaigns is necessary to overcome these challenges and expand the reach of Omega-3 fortified foods. By addressing these barriers collaboratively, the food industry, policymakers, and researchers can unlock the full potential of Omega-3 fortification to improve health outcomes on a global scale.

REFERENCES

[1] Calder, P. C. (2021). "Omega-3 fatty acids and inflammation: The essential fatty acids in the regulation of inflammatory diseases." Journal of Clinical Lipidology, 15(4), 531-542. DOI
[2] Zeng, C., et al. (2020). "Omega-3 polyunsaturated fatty acids and cardiovascular disease: The clinical evidence." Journal of Clinical Medicine, 9(3), 862. DOI
[3] Kondo, Y., et al. (2022). "Impact of Omega-3 fatty acids on health: Mechanisms and bioavailability." Food Science & Nutrition, 10(5), 1641-1653. DOI
[4] Graham, S. H., et al. (2021). "Marine and plant-based Omega-3 sources: Comparisons of bioavailability." Nutrients, 13(9),3225. DOI
[5] Lankinen, M., et al. (2020). "The role of plant-based Omega-3 fatty acids in human health." Nutrients, 12(1), 163. DOI
[6] Kralova, S., et al. (2019). "Omega-3enriched foods: Sources, benefits, and consumer trends." International Journal of Food Sciences and Nutrition, 70(2), 167-176. DOI
[7] Haug, W., et al. (2021). "Methods forOmega-3 fatty acid fortification in food systems: Challenges and opportunities." Critical Reviews in Food Science and Nutrition, 61(4), 560-573. DOI
[8] Kiefl, E., et al. (2022)."Microencapsulation techniques for the fortification of Omega-3 fatty acids in functional foods." Food Research International, 154, 110938. DOI
[9] Jin, H., et al. (2020). "Advances in biofortification of Omega-3 fatty acids using genetically modified organisms." Frontiers in Nutrition, 7, 114. DOI
[10] Gharachorloo, M., et al. (2021)."Techniques for stabilizing Omega-3 fatty acids in food products." Food Chemistry, 352, 129419. DOI
[11] Calder, P. C., et al. (2020). "Omega3 fatty acids and cardiovascular health: A review of evidence." Journal of Human Nutrition and Dietetics, 33(5), 599-610. DOI
[12] Yildirir, A., et al. (2020). "The role ofOmega-3 fatty acids in reducing inflammation and promoting metabolic health." Clinical Nutrition, 39(10), 3254-3261. DOI
[13] Sadeghi, N., et al. (2021). "The effect of Omega-3 supplementation on inflammatory markers:Asystematicreviewand metaanalysis." Journal of Lipid Research, 62(7), 100076.DOI
[14] Lee, Y., et al. (2020). "Omega-3 supplementation during pregnancy and early childhood: Effects on neurodevelopment." Nutrients, 12(6), 1782. DOI
[15] Sharma, R., et al. (2021). "Challenges in the fortification of foods with Omega-3 fatty acids: Stability, sensory quality, and regulatory issues." Food Control, 121, 107620. DOI
[16] Liu, S., et al. (2021). "Impact of storage conditions on Omega-3 stability in fortified foods." Journal of Food Science, 86(4), 1406- 1413. DOI
[17] Liew, L., et al. (2020). "Consumer acceptance of Omega-3 enriched foods: A systematic review." Food Quality and Preference, 83, 103918. DOI
[18] Gunawardena, N., et al. (2021). "Consumer awareness andattitudestowardsOmega-3 fortified foods: A global survey." Food Research International, 140,109890.DOI
[19] Martínez, J. A., et al. (2021). "Omega-3 fatty acids and their role in cognitive function and prevention of neurodegenerative diseases." Nutrients, 13(4), 1162. DOI
[20] Pan, S., et al. (2020). "Market potential of Omega-3 fortified functional foods: Consumer preferences and trends." Journal ofthe American Oil Chemists' Society, 97(4), 357-365. DOI
[21] Barendregt, A., et al. (2022). "A review on market trends and challenges in Omega-3 fortified food products." Food Technologyand Biotechnology, 60(1), 1-9. DOI
[22] Kross, B., et al. (2020). "Sustainability of Omega-3 fatty acid sources: Algae vs. fish oil." Sustainability, 12(3), 832. DOI

[23] Li, Z., Kotoski, S. P., & Srigley, C. T. (2019). Matrix Extension Validation of AOCS Ce 2c-11 for Omega-3 Polyunsaturated Fatty Acids in Foods. Journal of the American Oil Chemists' Society.
[24] Aman Shamil et al. (2023). Microencapsulated bioactive compounds for fortification of dairy products
[25] 3.K. Novotny, K. Fritz, & M. Parmar. (2020). Omega-3 Fatty Acids.
[26] 4.John H. Lee, Amit Prasad, T. Jarreau, J. O'Keefe, R. Milani, & C. Lavie. (2013). Omega-3 Fatty Acids and Cardiovascular Disease. In Journal of Marine Science: Research & Development.
[27] Shahidi, F., & Ambigaipalan, P. (2018).Omega-3 Polyunsaturated Fatty Acids and Their Health Benefits. Annual Review of Food Science and Technology, 9, 345–381.
[28] Balk, E. M., & Lichtenstein, A. H. (2017).Omega-3 Fatty Acids and Cardiovascular Disease: Summary of the 2016 Agency of Healthcare Research and Quality Evidence Review. Nutrients, 9(8), 865.
[29] S. Vairagade. (n.d.). Probiotics and Its Innovative Technics of Fortification in Dairy Products:
[30] Aman Shamil, A. Nautiyal, & Ishita Omar. (2023). Microencapsulated bioactive compounds for fortification of dairy products: A review. In The Pharma Innovation.
[31] Acosta, N. B., et al. (2020).Milk fortified with calcium: Changes in the physicochemical and rheological characteristics. LWT - Food Science and Technology.
[32] Wallace, T. C., & Reider, C. (2021).Calcium-fortified foods in public health programs.
[33] Roman Karki, Pravin Ojha, D. Dongol, Sushma Maharjan, Utshah Manandhar, & Sophi Maharjan. (2024). Food Fortification: Global Experience, Importance, Challenges and Potential in Nepal. In Journal of Food Science and Technology Nepal.
[34] M. Smith (2024) – Functional Breads with Encapsulated Vitamin C and Fish Oil 13.A. Brown (2016) – Oxidative Stability of Granola Bars with Fish Oil Emulsion.
[35] V. Renuka, D. Ramasamy, & V. Dhineshkumar. (2016). fortification of omega-3 fatty acids in processed cheese spread.
[36] Vishal S. Pandule (2021) Omega-3 Fatty Acid-Fortified Butter: Preparation and Characterisation of Textural, Sensory, Thermal and Physico-Chemical Properties
[37] Samantha C. et al. (2023) Omega-3-Enriched and Oxidative Stable Mayonnaise Formulated with Spray-Dried Microcapsules of Chia and Fish Oil Blends
[38] E. Hernandez (2020) Development and Characterization of Stabilized Omega-3 Fatty Acid and Micronutrient Emulsion Formulation for Food Fortification
[39] T. Pérez-Palacios, J. Ruiz-Carrascal, Estefanía Jiménez-Martín, J. C. Solomando, & T. Antequera. (2018). Improving the lipid profile of ready-to-cook meat products by addition of omega-3 microcapsules: effect on oxidation and sensory analysis. In Journal of the science of food and agriculture.
[40] M. Murage, E. Muge, B. Mbatia, & M. Mwaniki. (2021). Development and Sensory Evaluation of Omega-3-Rich Nile Perch Fish Oil-Fortified Yogurt. In International Journal of Food Science.
[41] C. Jacobsen. (2010). Oxidation of fish oils and foods enriched with omega-3 polyunsaturated fatty acids.
[42] Jorge Carlos Ruiz Ruiz, Elizabeth Ortíz Vázquez, & M. R. Segura Campos. (2017). Encapsulation of vegetable oils as source of omega-3 fatty acids for enriched functional foods. In Critical Reviews in Food Science and Nutrition.
[43] Z. Hadian. (2016). A Review of Nanoliposomal Delivery System for Stabilization of Bioactive Omega-3 Fatty Acids. In Electronic Physician.
[44] S. Shariat, Vahid Hakimzadeh, & A. Pardakhty. (2020). The physicochemical and organoleptic evaluation of the nano/micro encapsulation of Omega-3 fatty acids in lipid vesicular systems. In Nanomedicine Journal.