Application of Microencapsulation in Lipids: Technological and Scientific Prospection

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The food industry has been actively developing solutions to address healthy eating challenges in today's fast-paced world. One such solution is using microencapsulation techniques for bioactive compounds, particularly lipids. This study aims to investigate the potential of microencapsulation technology in enhancing the stability of lipids against oxidation in the body, which can compromise their nutritional efficacy. A bibliometric mapping was conducted using *The Lens* database, applying a combination of keywords and filters to identify relevant patents and publications. The goal was to analyze the scientific and technological activity surrounding the topic. The results reveal a significant increase in research and patent activity over the past decade, primarily focusing on microencapsulation methods and their applications in food supplements. Furthermore, a growing trend toward using this technology to develop new functional foods with potential socioeconomic benefits was observed.
Keywords: Microparticles. Spray Drying. Stability. Oxidation.

The increasing health concern is the primary driver of research in human nutrition. In parallel, the hectic pace of modern life influences both the quantity and quality of meals, impacting the population's overall health. To address these issues, the food industry has focused on developing functional foods [1] designed not only to provide essential nutritional functions but also to offer metabolic and/or physiological benefits to human health, as defined by ANVISA (National Health Surveillance Agency). For functional foods to be effective, they must be safe for consumption without medical supervision and backed by scientific evidence [2].

However, many bioactive substances—particularly fatty acids (lipids)—present challenges in functional foods due to their susceptibility to oxidation. Oxidation, a natural catalytic process in the body, can degrade these compounds, preventing the release of their nutritional content and even leading to rancidity [3]. Another challenge is the sensory properties of some functional foods, mainly taste and aroma, which can affect consumer acceptance [4].

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Microencapsulation technology offers a promising solution to these challenges. The process involves encapsulating a bioactive compound (the core) in a protective coating made from a wall material, forming microcapsules. This encapsulation shields the bioactive substance from oxidation, thus preserving its stability. Once encapsulated, the core can be released within the body at controlled times and locations, optimizing nutritional benefits. Additionally, microencapsulation can mask undesirable flavors, aromas, and colors, making functional foods more palatable and accessible. Among the various microencapsulation methods, spray drying is the most commonly used in the food sector due to its ease of operation, cost-effectiveness, and high production rates [5].

This study aims to investigate the potential of lipid microencapsulation, particularly via spray drying, to enhance resistance to oxidation. Through bibliometric mapping, it seeks to assess the technology's impact on lipid stability and controlled release and explore future directions for its application in functional food development.

Materials and Methods

A bibliometric study analyzed the scientific and technological production related to lipid microencapsulation. This was achieved through a quantitative survey of available literature using *The Lens*, a free online database. Patents and publications on the topic were identified and analyzed to understand global research trends. Table 1 presents the filters applied on the research.

The search results were then analyzed to evaluate the global dissemination of research and patents, focusing on studies most closely related to the project's objectives.

Results and Discussion

The bibliometric search results revealed that lipid microencapsulation, regardless of the method used, is a widely explored technology, particularly within the pharmaceutical and food industries. The database contained 6,711 patents, of which 3,140 were active and 2,292 were pending. When grouped into a "simple family" (i.e., counting only the initial document without its derivations), the total dropped to 2,349 patents. When restricting the search to the title field, only 35 records were identified, reflecting the specific focus on lipid microencapsulation in food and medical applications.

These findings indicate that the technology is widely employed to improve the stability and functionality of bioactive compounds, such as omega-3 fatty acids, by protecting them from oxidative degradation. For example, patents such as *2017/197453* [6] and *2018/0280333* [7] describe methods for microencapsulating omega-3 fatty acids to enhance their stability in food products and their potential use in treating neurological conditions and chronic diseases. Patent *10898442* [8] presents a method for microencapsulating lipids to address taste, odor, and oxidative instability issues.

In publications, 120 articles were found, with most focusing on optimizing microencapsulation techniques and assessing their effects on the gastro-resistance and stability of bioactive compounds. For example, the article "Effect of incorporating fish oil encapsulates on the physical-chemical and sensory properties of biscuits" [9] used microencapsulated fish oil (rich in omega-3) in biscuit formulations.

This study demonstrated a significant reduction in lipid oxidation and good sensory acceptance of the product. Another study, "*In vitro* bioaccessibility of spray-dried refined kenaf seed oil applied to coffee drinks," found that microencapsulated kenaf seed oil exhibited better oxidative stability than unprocessed oil, successfully incorporated into coffee drinks [10].

A more recent study, "Influence of wall materials and homogenization pressure on microencapsulation of rice bran oil," [11] explored the effectiveness of spray drying in microencapsulating γ-oryzanol (a bioactive compound from rice bran oil) for nutraceutical, pharmaceutical, and cosmeceutical applications.

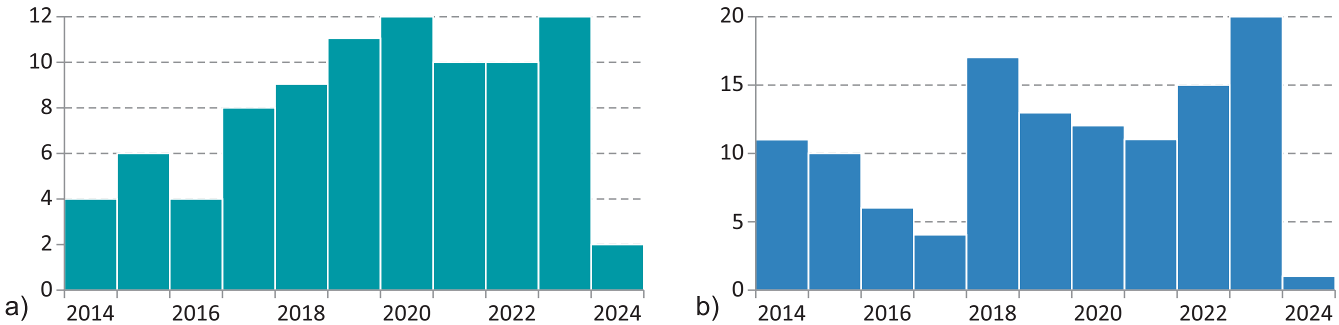
The results also show a resurgence of interest in lipid microencapsulation technology starting around 2018, with a slight dip during the COVID-19 pandemic (2020–2022) and a notable rebound in 2023–2024 (Figure 1) [12]. This trend suggests that microencapsulation technology continues to evolve and gain importance in the food and health sectors.

The geographical distribution of patents and publications reveals that countries with advanced research and development infrastructure, such as the United States, Europe, and China, lead in technological innovations in lipid

Table 1. Search filters applied in bibliometric study.

Type	Keywords	Field	Grouping	Period
Patent	“foods AND supplemented AND by AND microencapsulated AND lipids”	All fields	Simple family	2014-2024
	"lipids"	Titles	Simple family	2014-2024
Publications	“foods AND supplemented AND by AND microencapsulated AND lipids”, “microencap*”	All fields	-	2014-2024

Figure 1. Number of patents (a) and publications (b) filed during the period under analysis.



Source: The Lens (2024) [12].

microencapsulation. This underscores the importance of fostering research and development efforts to enhance national production and promote innovation in the food industry, ultimately improving public health and quality of life.

Conclusion

The bibliometric study has proven invaluable for analyzing the scientific and technological activity surrounding lipid microencapsulation. The results highlight this technique's growing interest and potential in improving lipids' stability, particularly in the context of functional foods. Microencapsulation enhances the nutritional value of foods and increases consumer acceptance by masking undesirable sensory characteristics. Given the potential benefits, it is clear that microencapsulation is an emerging trend that should continue to be explored. Its application can lead to the development of innovative functional foods that offer enhanced nutritional benefits, thus contributing to better public health and offering significant socioeconomic advantages.

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