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A REVIEW ON OLEOGEL AS BIOACTIVE DELIVERY IN FOOD

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Abstract

Oleogels are gaining popularity due to their appealing benefits such as ease of manufacture, superior fatty acid composition, and safe application in food products to meet consumers' desires for healthy products. Edible oleogels can be used to substitute unhealthy trans and saturated fats. They are porous materials having a three-dimensional gel network that self-assembles. This gel structure may physically entrap and hold a large volume of a continuous edible liquid-oil phase.This review contains the most recent information on the various oleogel systems and discuss oleogels properties characteristics that might be useful for delivery. It is demonstrated that oleogel and oleogel-based systems can be used as bioactive delivery in food. Oleogels are introduced as a delivery method, and emphasis is placed on the utilisation of lipid-based delivery systems to improve the bio-accessibility of molecules that are weakly water-soluble.

Keywords: Oleogel, Hydrogels, Bigel

Introduction

Oleogels can be used in the food sector to manage phase separation, limit oil phase mobility and migration, provide solid-like qualities without utilising large quantities of saturated fatty acids, and function as a carrier of bioactive substances. The world's current concerns include improving the nutritional characteristics of meals and reducing components that may be linked to health concerns. More and more nations are enacting legislation to limit the content of trans fats and saturated fats in food goods.

Due to the high intake of trans and saturated fats, these have emerged as the main health concerns, including cardiovascular disease, colon cancer, diabetes, obesity, stroke, breast cancer, shortened pregnancy periods, preeclampsia risks, disorders of the infant nervous system and vision, and allergies. Trans-fatty acids (TFAs) have been associated with adverse metabolic consequences, and there is significant evidence linking higher consumption of TFAs and saturated fat with coronary heart disease (Mozaffarian et al. 2006, 2009; Nishida and Uauy 2009, Nettleton et al. 2017). The FDA removed trans fats off the GRAS (generally recognised as safe) list in 2015 and banned the use of partly hydrogenated oils in food beginning in January 2020(Adili et al. 2020). The World Health Organization (WHO) recommends limiting saturated fat consumption to less than 10% of total caloric intake. The WHO also suggests substituting liquid oils rich in polyunsaturated fatty acids for solid fats such as butter. The availability, cost, and ability to modify the physical properties while maintaining desirable functional characteristics like appearance and

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texture of the final food products are the major challenges for the food industry to find desirable oil structuring methods and decrease the trans and saturated fats in the food product.

2. Hydrogels, Oleogels, Bigels, and Emulgels

Gels represent a type of colloid that consists of a solid-like three-dimensional network, in which a liquid phase is entrapped. A gel can be defined as a coherent system of at least two components, which exhibits mechanical properties of a solid, where both the dispersed component and the dispersion medium extend themselves continuously throughout the whole system (Contreras-Ramírez et al. 2022). The first attempts for convenient applications of organogels in drug delivery started in the last years of the 20th century(Bhushette et al. 2022). There is current interest in their application in pharmaceutical, cosmetic, food and petrochemical industries. To distinguish the gels including vegetable oils from the traditional "organogels", applied in chemical engineering, these edibleoil gels have been named oleogels (O'Sullivan, Barbut, and Marangoni 2016). Several food grade materials can be used as oleogelators such as proteins, polysaccharide, fatty acids, phytosterols etc., depending upon desired physical characteristics and applications in particular food systems. Gelation mechanisms entrapping oil help in retaining chemical characteristics of oil unlike inter-esterification and hydrogenation (A. R. Patel et al., 2014). Most important oleogelators used in food sector include waxes, ethylcellulose, alcohols or esters of fatty acids, phospholipids and phytosterols etc. (J. Lim, Hwang & Lee, 2017).

Gel formulations can be divided into two major classes according to the solvent used for their production; hydrogels refer to the case where the liquid phase is water, and organogels (or oleogels) when the dispersed liquid is an organic solvent and is structured by an organogelator.

The type of oleogelator used and type of method followed for oleogelation (direct or indirect) has a direct impact on the properties of oleogels formed. Some important criteria which make the oleogel suitable for use in food industry include: (i) possession of lipophilic and interactive entities, (ii) surface activity, (iii) thermoreversible characteristics, (iv) natural origin, and (v) GRAS status (Pérez-Monterroza, Márquez-Cardozo & CiroVelásquez, 2014).

One of the main advantages of oleogels is the possibility of carrying lipophilic bioactive compounds, which is of great utility in both pharmaceutical and food applications [11]. The combined action between structure and health benefits supports the important role that oleogels can have in novel food products, as they can be tailored to meet the ideal properties for a food product, acting as a healthy substitute for solid fats. Great attention from the scientific and industrial communities towards oleogels has risen since they were first suggested as a possible substitute for fats.

Oleogelator plays an important role to produce oleogel. To create an oleogel, small quantities of certain structuring agent are added to edible oils. These structuring agent are known as organogelators (Botega et al., 2013), impart specific qualities to the oil and they generally form a network that provides structure to the gel. Some organogelators have already been approved for

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use in foods in specific applications or concentrations, while others await GRAS status. For the organogelators that currently have GRAS status, the small concentrations should be within the guidelines that would be allowed for those products. Research into the actual health effects of oleogels is in progress. Waxes have been the most effecticient of the crystalline oleogelators out of the studied crystalline oleogelators so far, because they may develop a well-formed network with significant oil-binding characteristics even at low concentrations (as low as 0.5 percent) (Doan et al., 2017; Patel et al., 2013). Many researches have been done on wax based oleogel systems such as "candelilla wax in safflower oil (Toro-Vazquez et al., 2007), sunflower wax in milk fat (Kanya et al., 2007), rice bran wax in olive oil (Dassanayake et al., 2009), beeswax and sunflower wax in olive oil (Yilmaz & Öğütcü, 2014), plant and animal based waxes in soybean oil (Mukti et al., 2013), and beeswax in hazelnut oil (Yilmaz & Öǂütcü, 2014)".

According to (Dassanayake et al., 2011), "oleogelators are categorized into selfassembly system and crystal particles system". Examples of oleogelators for selfassembly, network forming and wax based are shown in Table 2. Self-assembly system happens when oleogelators produced by molecular-self organization in liquid phase whereas crystal particles system happen when crystal particles formed by nucleation and continous increase in size of crystals in the liquid phase.

Oleogel as delivery vehicle

To overcome the challenges of delivery of lipid soluble molecules, various structured systems have been designed. These have been reviewed extensively in other publications. These systems can be classified as lipid-based, surfactant-based, or biopolymer-based, where all three address the effective delivery of hydrophobic molecules using differing strategies (O'Sullivan, Barbut, and Marangoni 2016). Since they function as fat replacements and have a considerably richer composition than standard solid fats, the structuring of liquid oils rich in PUFAs can have a substantial positive impact on human health. Moreover, the design of oleogels makes them effective delivery vehicles for bioactive molecules since it allows for both release control and preservation of bioactive compounds' functioning against oxidation (Pinto et al. 2021). However, this field is currently understudied, with most studies relying on the incorporation of liposoluble molecules rather than hydrosoluble compounds in the oleogel structure. Because of the lipophilic nature of oleogels, this appears to be the easiest way (Okuro et al. 2020).

(Yu et al. 2012) oleogel-based nanoemulsion is an excellent choice for encapsulating lipophilic bioactive chemicals and is relatively new in the realm of oral nutraceuticals delivery. In a related study, oleogel-based nanoemulsion was created to improve BC's solubility, loading capacity, and bioavailability. The findings supported earlier work by (Lu et al. 2016) and showed that the bioaccessibility of nutrient (BC) increased when loaded in oleogels and further enhanced following manufacture of oleogel-based nanoemulsion.

These formulations all significantly increase the loading content, bioavailability, and biological activity of wrapped nutraceuticals, proving the effectiveness of oleogel-based emulsions for delivering hydrophobic and indigestible bioactives (Zhao, Wei, and Xue 2022).

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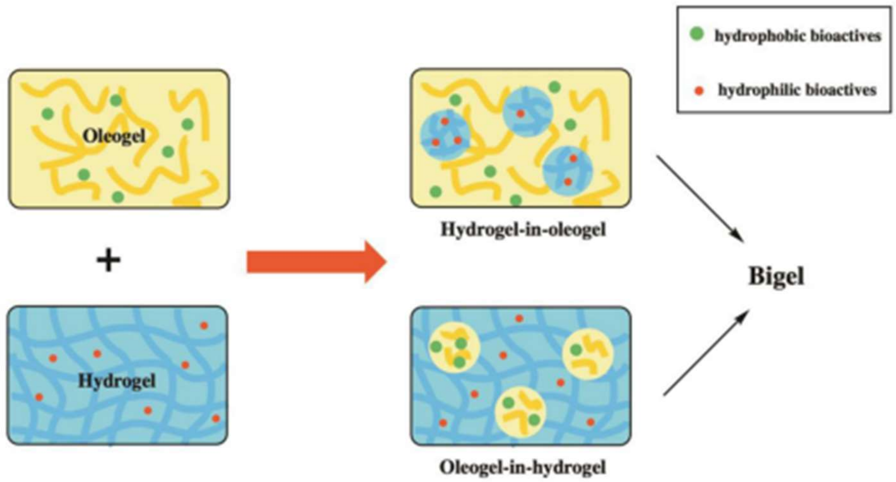

Fig.1. Schematic representation of bigel

The combination of oleogels with hydrogels produces hybridgels (or bigels), which have both hydrophilic and lipophilic properties (Figure 1). The properties of hybridgel are closely connected to the hydrogel and oleogel structures, as well as the hydrogel/oleogel ratios. Hybridgels have long been regarded as good drug transporters, whether hydrophilic or lipophilic (Zhao, Wei, and Xue 2022).

Further evidence that oleogel-based methods may be utilised to deliver poorly water-soluble nutraceuticals comes from the utilisation of these oleogels to create rapid-digestion emulsions (Yu et al. 2012). Since then, new formulations for the administration of curcuminoids have been created, with writers taking use of the variety of edible gelators suited for oil structuring. Li et al. 2019 created a new curcumin-loaded oleogel formulation by using sitosterol and lecithin's capacity to form self-assembled fibres, and they investigated its oxidative stability and release behaviour.

In a recent study, the efficacy of an oleogel emulsion based on soy lecithin to improve probiotic viability was examined. The results showed that in an oleogel emulsion based on soy lecithin, oxidation was obviously delayed. Instead of the oleogel emulsion's physical barrier, soy lecithin's presence boosted probiotic vitality (Zhuang et al. 2021). There have been no studies that directly demonstrate the beneficial effects of oleogels on probiotic protection and delivery . Although it appears promising in theory, additional study into probiotic delivery via oleogels is needed to confirm its practicality and benefits. Probiotic distribution via oleogels is theoretically promising, but further study is needed to confirm its viability and benefits (Zhao, Wei, and Xue 2022).

CONCLUSIONS

Oleogels for the delivery of bioactive compounds have been developed often throughout the past five years. The usage of oil-soluble chemicals was the main focus of the majority of the studies. However, there are examples of emulgels and bigels being used to transport water-soluble substances as well as to deliver oil- and water-soluble substances simultaneously in the same

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system. A few research assess their digestion-related degradation mechanisms in addition to the large number of studies on their creation, manufacture, and characterisation. This method enables the use of oleogel-based devices for the release of bioactive chemicals in the human stomach. The future will be to create tailor-made oleogel systems that allow us to manage oleogel structure breakdown, lipolysis rate control, and bioaccessibility of bioactive substances all at the same time. Co-delivery systems require more research, which should be done to show how effective they are in delivering both lipophilic and hydrophilic chemicals. More in vivo research is also required. It is crucial to fully comprehend how these bioactive molecules are absorbed, and this issue has to be dealt with in the next years.

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