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REVIEW

Nanotechnology in Food Systems with Applications in Oils and Fats

Rania I.M. Almoselhy [1*]

[1] Oils and Fats Research Department, Food Technology Research Institute, Agricultural Research Center, Egypt.

*Corresponding author: rania_almoselhy@outlook.com

[1] Dr. Rania I.M. Almoselhy- Associate Professor of Food Science and Technology.

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Abstract

The current review sought to highlight the significance of nanotechnology in food systems with the most recent developments in nanotechnology applications in the oil and fat industries. The definition and classification of nanotechnology (using bottom-up and top-down approaches) are covered first, followed by its importance to the food industry and food safety. The authentication and detection of adulteration are a few applications of nanotechnology that have been addressed in the oils and fats industry. The presence of dangerous chemicals and food packaging byproducts, including, plasticizers, was identified. Some applications of nanotechnology in lipids systems were mentioned.

Keywords: Nanotechnology, Food systems, Oils, and Fats

1. Definition of Nanotechnology

The National Nanotechnology Initiative defines nanotechnology as all structures roughly between 1 and 100 nanometers in size in at least one dimension. Even with this restriction, nanotechnology is typically used to describe structures that are up to a hundred nanometers in size and are made using either top-down or bottom-up techniques. The development of sophisticated products such as innovative medicines, unique diagnostic methods, and various nanotechnologies for enhanced theranostics is accomplished by integrating numerous scientific fields through nanotechnology (Khurana et al., 2023).

2. Nanotechnology Classifications Bottom-up and Top-down Methods

Nanotools, Nanodevices, and nanostructured materials are the three main divisions of nanotechnology. A synthetic approach, analytical tools, computer modeling, surface science, supramolecular chemistry, and nanolithography are some examples of nanotools. Contrarily, nanodevices include nanoelectronic, spintronic, nanosensor, drug delivery, and nano-optoelectronic components. Nanostructured materials include nanoparticles, nanowires, carbon nanotubes, nanocomposites, nanopatterned surfaces, thin solid films, supramolecular systems, etc. Bottom-up and top-down methods for nanotechnology are the two primary groupings into which they fall. In bottom-up synthesis, many methods, such as sol-gel, molecular condensation, vapor deposition, electrochemical synthesis, and chemical synthesis, are used to create the nanoparticles. Whereas the top-down processes include sputtering, mechanical processes, optical processes, and chemical etching. By removing metal and using a template, top-down methods are used to create nanoscale structures from the tiniest structures. Nanomaterials with at least one nanoscale dimension are referred to as nano-layered. Examples include thin films and surface coatings. Two-dimensional nanomaterials known as nanotubes or nanowires, such as carbon nanotubes and nanofibers, are found at the nanoscale. Nanoparticles are described as having all three dimensions at the nanoscale. Nanomaterials can therefore be used to create pharmacological objects that target human body cells like cancer cells (Kumar et al., 2023).

3. Nanotechnology in Food Industry

The food business uses nanotechnology in various ways, greatly facilitating the characterization, creation, and manipulation of nanostructures. The nanostructures boost the bioavailability and controlled release of food ingredients at the target site, as well as the solubility of food ingredients in vivo. These nanostructures are also used as anti-caking agents, nano-additives, nutraceutical delivery systems, etc. (Sahani & Sharma, 2021).

4. Nanotechnology for Food Safety

In the last ten years, the use of nanotechnology for applications related to food safety has grown quickly. The use of nanomaterials or nanostructures in analytical platforms for the identification of chemical, biological, and physical pollutants significantly improves analytical performance. Different nanomaterials and nanotechnology have been shown to have enhanced antimicrobial activity. However, the discovery of nanoscale contaminants in food has simultaneously prompted potential public health worries (He, 2023).

Considering the rapid development in nano-agrochemicals research, nanoparticles (NPs) could provide environmentally friendly agents for grain protection. An enormous number of researchers have investigated the toxicity of various nanomaterials (natural or synthesized) against the stored product insects. The nano-emulsions of essential oils (EO) such as mint, fennel, chamomile, sweet orange, and cumin as well as solid lipid NPs loaded by EO showed a toxicity against *Tribolium castaneum* and *Rhyzopertha dominica*. In addition, silica, alumina, zinc oxides, green synthesized silver, and lead NPs expressed high insecticidal activity against *Sitophilus oryzae*. Furthermore, nanoformulations act as repellents and antifeedants. Also, these nanoformulations reduced progeny production (Shalaby et al., 2022).

5. Nano emulsions in Food Technology

Food science and technology demonstrated the potential importance of nanotechnology (Almoselhy, 2022). One of the significant benefits of nanotechnology is increased surface area. Nanotechnology can provide solutions to a wide range of technical issues since the characteristics of nanomaterials can differ significantly from those of their macro- and micro-counterparts. Nanomaterials come in various forms, such as nanoparticles, nanofibers, and nanoemulsions (NEs). NEs are systems made up of emulsifiers, hydrophilic and lipophilic phases, and have particle sizes between 20 and 500 nm. NEs have applications in the cosmetic, pharmaceutical, and food industries. Due to their nano-size, transparency, or slightly cloudy appearance, they have many benefits, including the protection of active ingredients from external factors like heat, light, oxidation, and increasing bioavailability in the formula of beverages like sauces and syrups. NEs have a wide surface area and allow water-insoluble components to be dispersed in aqueous systems. A tiny quantity of nanoscale materials can be used to do tasks that can be accomplished with macro- and micro-scale materials. It was proven that coating fish fillets with nano mats containing only 15-20 mg of nano-size nisin could extend their shelf life to 12 days when used on 40-g fish fillets. Similar to this, authors enhanced the oxidative stability of mackerel fillets using nanoscale wheat germ. For 150 g of fillets, they utilized 3.6 mL of the wheat germ oil-containing nanoemulsion. 180 mg of wheat germ oil was included in the nanoemulsion (Ekin et al., 2021).

6. Nanotechnology in Oil and Fat Industries

6.1. Detection and Quantification of Adulterant Residues in Edible Oil

Quality and authenticity of edible oils are considered very important criteria as they affects the humans' health (Hashem et al., 2020). In the lab, fiber optic sensors for the detection and quantification of adulterant residues in edible oil were developed. The underlying tenet of detection is the sensitive reliance on the wavelength shift caused by the variations in the refractive indices of the multimode fiber cladding's surrounding medium. The development of this low-cost multimode fiber optic sensor is useful for identifying and assessing oil adulteration. A fiber optic sensor combined with gold nanoparticles exhibits an improvement in the developed sensor's sensitivity in identifying the level of adulteration in coconut oil (Jadhav et al., 2017).

6.2. Detection and Quantification of Hazardous Plasticizers in Edible Oil

Phthalate ester (PAE) plasticizers, a frequently used industrial addition of plastic products, can easily contaminate food and endanger human health. Raman spectroscopy (SERS)-based approach has been applied for the quick, accurate, and reliable detection of PAE plasticizers in edible oils. As a substrate for SERS, a two-dimensional (2D) silver plate was created that worked in tandem with a nanosilver sol to detect potassium hydrogen phthalate (PHP), a hydrolysate of a PAE plasticizer. Five samples of edible oil were used for detection accuracy. As a result, it is anticipated that using SERS technology to detect PHP will open up a pathway for the detection of PAE plasticizers in oils and fats, and it has exciting potential applications in the field of food safety (Wang et al., 2023).

6.3. Vegetable Oils in Lipid Nanoparticle Preparation

A promising area for treating various illnesses is the creation of lipid nanoparticles using vegetable oils. Advanced knowledge of formulation design, preparation methods, product stability, and proof of concept using performance tests is necessary for developing these particles. The most recent research on using vegetable oils to create lipid-based nanocarriers is well-documented. Vegetable oil-based lipid-based nanocarriers have demonstrated higher efficacy in trials compared to commercial therapies, highlighting their potential for usage in nanotechnology-based medicinal and aesthetic goods. For the preparation of based-lipid nanocarriers including vegetable oils, nanoemulsion and nanostructured lipid carriers (NLCs) were the recommended carriers' formulation strategies. By increasing the therapeutic efficacy of natural chemicals, these carriers provide a cutting-edge approach to pharmaceutical use. The medication release profile was examined using mathematical models in order to assess the formulation's effectiveness. The systematic selection of the components also made it possible to incorporate hydrophilic and hydrophobic chemicals, improve medication stability and carrier capacity, and achieve superior performance in comparison to the traditional drug product. To create lipid nanoparticles using vegetable oil, one obstacle to be addressed is lipid oxidation to be stabilized (Masiero et al., 2021).

One of the most promising encapsulation techniques in the realm of nanotechnology is lipid-based nanoparticles. The use of edible and/or commercially accessible oils and fats in the food sector stands out as one of the primary trends in the development of these structures, replacing synthetic lipid matrices, which are not as practical for food applications in terms of cost, availability, or regulatory considerations. Fully hydrogenated soybean oil (FHSO) and high oleic sunflower oil (HOSO) were used as the lipid matrices to create nanostructured lipid carriers (NLC). Different lipid systems, including 80:20, 60:40, 40:60, and 20:80 FHSO:HOSO (w/w), were used to create NLC, with emulsifiers such as soy lecithin (SL), Tween 80, or whey protein isolate (WPI). The 80:20, 60:40, and 40:60 FHSO:HOSO (w/w) systems resulted in stable particles with acceptable crystallinity features to obtain NLC (Lüdtke et al., 2022).

6.4. Utilization of Nano-sized Bleaching Earth Powder for Bleaching Edible Oils

A recent work of high novelty has been carried out to get benefits of nanotechnology in bleaching some edible oils by using nano-sized bleaching earth powder produced by the mechanical milling of the bleaching powder in a planetary ball mill of 12 mm diameter balls for 10 h., then performing the bleaching process which resulted in the production of high quality bleached oils with superior quality parameters (Almoselhy et al., 2020).

6.5. Nanostructured lipid carriers (NLCs) loaded with free phytosterols (FPs)

High-pressure homogenization (HPH) of lipid matrices (LMs) made with fully hydrogenated canola (CA), crambe (CR), and high oleic sunflower oils (HOSOs) offered significant opportunities for the creation of nanostructured lipid carriers (NLCs) containing free phytosterols (FPs) for the inclusion of bioactive chemicals. High concentrations of FPs were successfully incorporated into the lipid nanoparticles. The heat resistance of NLCs was greater than that of LMs. The inclusion of FPs was favored by the separation of CA and CR in NLC formulations. The created NLCs can enrich foods like spreads, margarine, and beverage. Subsequent studies are recommended to increase the usage of additional vegetable fats and oils to create nanostructured systems with various crystalline properties and thermal stability for various food products (Almoselhy, 2020; Santos et al., 2019).

Conclusion

By highlighting the definition, classification, characterization, and importance of contemporary fast-growing nanotechnology and its significance in food systems with applications in oils and fats research, the current review effectively achieved its goal.

Conflict of Interest

The author declares no conflict of interest.

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