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Review

Nanoliposome technology for the food and nutraceutical industries

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ABSTRACT

Background: The word "nutraceutical" can be defined as a food substance or part of it, which provides the body with medical or health benefits, including disease prevention and therapy.

Scope and approach: Nutraceuticals are a natural way to achieve therapeutic outcome with minimal or no side effects. However, they are subject to degradation resulting from exposure to environmental factors such as humidity, oxygen, heat, light and extreme pH values. Nanoliposome, or nanometric bilayer phospholipid vesicle, is a very promising encapsulation technology for the nutraceutical industry. Protection of sensitive bioactive molecules, storage stability, high loading capacity, enhanced bioavailability, and sustained-release mechanism are among the advantages offered by nanoliposome technology. They can encapsulate lipophilic and hydrophilic material at the same time providing synergistic effect. This article reviews various aspects of nanoliposome technology including their main physicochemical properties, generally employed preparation methods, targeting strategies and their application in food and nutraceutical industries.

Key findings and conclusions: The great potential of nanoliposomes in food and nutraceutical industries is being rapidly established due to unique properties of these nanocarriers. Considering the global health problems, their utilization for effective disease prevention and health promotion is of vital importance.

1. Introduction

Nutrients and non-nutrient compounds in food that have health-promoting, disease-preventive, or medical properties are known as "nutraceuticals" (Camire, 2003). In other words, nutraceutical products are functional foods consumed for their distinguished health benefits. Most nutraceutical products are not pharmaceuticals and hence are being treated as food (Daud, Jalil, Azmi, & Ismail, 2017). They generally consist of food supplements, herbal products, prebiotics, probiotics and medical foods intended for prevention and treatment of disease (Shinde, Bangar, Deshmukh, & Kumbhar, 2014). Nutritional therapy is a healing mechanism employing dietary therapeutics or nutraceuticals as a complementary medicine. This therapy is based on the fact that foods are not only sources of nutrients and energy but can also provide medicinal effects (Chauhan Kumar, Kalam, & Ansari, 2013). Table 1 lists some of the nutraceutical molecules and compounds and their health benefits. The list of health benefits of nutraceuticals is immense, ranging from skin health and beauty to cardiovascular support and cancer prevention. In order to be acceptable for Human use, nutraceuticals, functional foods and dietary supplements must satisfy several requirements. They should maintain their activity even on long-term storage; they should be stable to heat processing; they should be easy to incorporate into food systems and be effective at low concentrations. Encapsulation technology can be employed to protect the chemical structure and function of food material and nutraceuticals and to increase the bioavailability and shelf life of the product. One of the most applied encapsulation and controlled release technologies is liposome, which is being used in the formulation of many pharmaceutical, cosmeceutical, cosmetic, nutraceutical and food products. Liposomes can be defined as closed, continuous, bilayered structures made mainly of lipid and/or phospholipid molecules (Mozafari & Mortazavi, 2005). On the other hand, nanoliposomes, or nanometric versions of liposomes, are colloidal structures formed by input of energy to a right combination of phospholipids and other ingredients in an aqueous solution (Danaei et al., 2018; Mozafari, Johnson, Hatziantoniou, & Demetzos, 2008). Nanoliposomes provide benefits and advantages of nanotechnology for the encapsulation, delivery and targeting of bioactive compounds (Chaudhry, Castle, & Watkins, 2017). They can also be employed to encapsulate and transport more than one bioactive agent, hence providing a synergistic effect (Choi, Thapa, Yong, & Kim, 2016; Gowda, Kardos, Sharma, Singh, & Robertson, 2017) as explained in the next sections. This paper will discuss nanoliposomal delivery technology together with methods of nanoliposome preparation, characterization, and its potential use as nutraceutical encapsulation

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Table 1
Classification of nutraceuticals based on their health benefits (Camire, 2003; Chauhan, Kumar, Kalam, & Ansari, 2013; Shinde et al., 2014).

Item	Nutraceutical health benefit	Examples of nutraceuticals
1	Antioxidant	Ascorbic acid, β-Carotene, Glutathione, Lutein, Polyphenolics, Tocopherols
2	Cardiovascular support	α-Glucan, Guar, Pectin, Saponins, Tannins
3	Anti-atherosclerotic	Calcium, Casein phosphopeptides, Daidzein, Genestein, Inulin, Soy protein
4	Antihyperlipidemic	β-sistosterol, Fibres from flax seed, Soybean
5	Anti-inflammatory	Capsaicin, Curcumin, Linolenic acid, Omega fatty acids, Quercetin
6	Antiarthritic	Chondroitin sulfate, Glucosamine, Omega fatty acids
7	Anti-obesity	Anthocyanins, Fisetin, Hydroxycitrate, Pterostilbene
8	Anti-diabetic	Boswellic acid, Ellagic acid, Fucoxanthin, Rutin
9	Anticarcinogenic	Ajoene, Capsaicin, Daidzein, Equol, Genestein, Limonene, Lutein, Sphingolipids
10	Hepatoprotective	Naringin, Naringenin, Piperine, Zingerone
11	Bone health or osteoporosis	Daidzein, Genistin, Inulin, Phytoestrogens

system. Nanoliposomes bring the benefits of nanotechnology to the field of encapsulation and controlled release of bioactive agents. Therefore, in the next section applications and advantages of nanotechnology in the area of food and nutraceuticals will be presented.

2. Nanotechnology in food and nutraceutical industry

The term nanotechnology is originated from the Greek word “nanos” which means dwarf or small (Malik, Pirzadah, Kumar, & Rehman, 2017). It is an interdisciplinary scientific area, which involves the manipulation, preparation, processing and application of substances or devices that have at least one dimension in the nanometer size range (Mozafari, 2007). Nanotechnology aims to develop and generate new materials by precisely engineering atoms and molecules to yield new molecular assemblies at subcellular levels on the scale of individual organelles, or even smaller components. Nanoscale is the size scale at which the properties of material are generally different than they are for the bulk phase (or “macroscale”). For many materials and substances, this is approximately in the range of 1–300 nm (Chung, 2017; Neubauer, Winter, Caruthers, Lanza, & Wickline, 2008). In this size range, properties of material and devices change because as objects become very small, their surfaces decrease less than their volumes, causing nanoscale materials (or nanomaterials) to have significantly larger surface-to-volume ratios than larger objects. More surface area means that nanomaterials and nanosystems have higher reactivity; different elastic, tensile, and magnetic properties; increased conductivity; or increased tendency to reflect and refract light (McNeil, 2011). Vital components of prokaryotic and eukaryotic cells such as DNA, proteins, cell walls, cell membranes and ribosomes are in nanometer size range. These biological molecules and nanostructures display properties and behaviour different than macroscale material. For instance, the way in which proteins fold into globular structures is a process with no resemblance among larger objects.

Nanotechnology has already started to impact a number of industries and scientific fields, including aerospace, information technology, medicine, cosmetics, agriculture, food additives and nutraceuticals. In the area of food science and nutrition, nanotechnology is being used as a means to understand how physicochemical characteristics of nanoscale materials can change the structure, texture, nutritional value and quality of food components (Mozafari et al., 2008). Food and nutraceutical nanotechnology provide improved taste, flavor, smell, color, texture and consistency of foodstuffs as well as nutraceutical compounds. The other advantages of nanotechnology in the food and nutrition area are increased absorption and bioavailability of nutraceuticals and health supplements, development of food antimicrobials, new food packaging materials with improved mechanical, barrier and antimicrobial properties, nanosensors for traceability and monitoring the condition of food during transport and storage and encapsulation of food components or additives (Cerqueira et al., 2017; Chaudhry et al., 2008). An important aspect of food and nutraceutical nanotechnology is the encapsulation and controlled release of bioactive material, which will be presented in the next sections.

2.1. Nanoencapsulation in the area of food and nutraceuticals

In the food industry, encapsulation is used to stabilize and control the release of core material and to separate reactive or incompatible components of formulation. Nanocapsules and nanocarrier systems offer the food processor many advantages by means of protecting sensitive food components, ensuring against nutritional loss, incorporate pulsative or time-release mechanisms into the formulation, mask or preserve flavors and aromas, and transform liquids into easily handled solid ingredients (Cerqueira et al., 2017; Rossi et al., 2014; Yurdugul & Mozafari, 2004).

Protection of micronutrients and sensitive nutraceutical compounds from degradation and loss of activity has been extensively studied within the context of microencapsulation systems. However, to give targeted controlled release is a key functionality that can be achieved much more efficiently by employing nanoencapsulation technologies. As a consequence of improved stability and targeting, the amount of material or bioactive agents required to exert a specific effect when encapsulated is much less than the amount required when unencapsulated. This is particularly useful when dealing with expensive food and nutraceutical compounds. A timely and targeted release improves the effectiveness of bioactive material, broadens the application range of food ingredients and ensures optimal dosage, thereby improving cost-effectiveness of the product. Reactive or sensitive compounds such as antioxidants and omega-3 fatty acids can be turned into stable ingredients through encapsulation by nanocarrier systems (Mozafari et al., 2006; Rasti, Erfanian, & Selamat, 2017). The range of applications for nanoencapsulation in the food and nutraceutical industries has been increasing because of the many advantages and benefits that these technologies can offer to the encapsulated material. These include enhancing the stability of the encapsulated material by protecting them from environmental, enzymatic, and chemical changes, providing buffering against extreme pH, temperature, and ionic strength variations, and masking undesirable odors or tastes (Chaudhry, Castle, & Watkins, 2017; Yurdugul & Mozafari, 2004). Nanoencapsulation technology has recently been employed to increase the bioavailability of a lipophilic compound (curcumin) encapsulated inside nanoparticles (with diameters around 250–350 nm) composed of proso millet protein (Wang, Gulati, Santra, Rose, & Zhang, 2018).

Nanoparticles and nanocarrier systems are used as medical devices, as imaging agents and diagnostics, and as drug carriers for therapeutics for many different types of diseases. For this latter application, molecules such as chemotherapeutic agents can be selectively adsorbed or attached to the nanoparticle surface or interior. The drug is affixed to the nanoparticle by covalent conjugation or noncovalent attachment (i.e. encapsulation). Polymer coatings can also be bound to nanoparticle drug carriers in order to increase their solubility and biocompatibility (McNeil, 2011). There are various types of encapsulation technologies that can be employed in the food and nutraceutical sector. These