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Microemulsions as Nano-Carriers for Nutraceuticals: Current Trends and the Future Outlook

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Abstract

Present short paper is written so that a newcomer to the field can rapidly come up to speed on the topic and grasp the key points pertaining to microemulsion, as a nutraceutical nano-carrier, and its applications in the field of extraction, solubilisation, delivery, controlled release systems and so on. Though microemulsion system has various applications in different fields, here its food and nutritional applications are highlighted.

Keywords: *Microemulsions; Nano-Carriers; Nutraceuticals*

Current applications

Microemulsions are nano-sized (5 - 100 nm) spontaneously formed liquid mixtures of oil or hydrophobic compounds, water and relatively large amount of surfactants usually in combination with co-surfactants or co-solvents. Simplicity, low energy requirements and thermodynamic stability of such systems are key scale-up criteria which make its construction industrially feasible. They have different application areas as nanoencapsulation of bioactive compounds, drugs and food additives delivery systems, microreactors for enzymatic and organic reactions, as well as in oil recovery, biomolecules separation from liquid solution and nanoparticle synthesis via the reverse microemulsion method [1].

Nanoencapsulation and delivery systems

Formulation scientists have extensively studied microemulsion systems as a novel vehicle to enhance the drug and nutraceuticals delivery because almost half of the approved drugs and nutraceuticals are poorly water-soluble and have low uptake/permeation rates when administered orally [2].

Microemulsion technique can be applied in nanoencapsulation of any drug or food bioactive ingredient of different solubilities by entrapping the compound of interest within a protective matrix. Microemulsion-based formulations have brought out very promising outcomes regarding solubility, bioavailability and protection of drugs and bioactive molecules leading to their improved efficacy. These nanosystems enable improved delivery vehicles to be developed for antioxidant, essential oil, vitamin, as well as antidiabetic, anti-allergic, antiviral and antimicrobial agents in comparison to formulation developed conventionally [3].

Microemulsion system has been already successfully applied for encapsulation of orange peel oil where the mean droplet diameter of orange peel oils was assessed to be less than 20 nm [4].

Encapsulation of vitamin C, vitamin E, lycopene and lutein into microemulsion has been investigated [5-7]. Microemulsion was found as the best protective media for both vitamins and carotenoids where improved their stability during long-term storage even under direct UV radiation [7-9].

However, dissolution capacity and functionality of microemulsion depend on its molecular structures and internal phase existed in nano-sized droplets [9]. For example, oil-in-water (O/W) type of microemulsion is the most applicable and effective type in drug delivery [3]. On that account, microemulsion structural dynamics need to be investigated thoroughly in order to meet enhanced performances [1].

Microemulsion molecular structures have been recently investigated applying ultrasonic resonator technology [1], self-diffusion NMR [10], viscosity and electrical conductivity measurements along the selected dilution lines [4,8,9,11].

Microreactors of reactions

Application of microemulsions as useful microreactors for enzymatic and organic reactions is another area of considerable current interest which enables to overcome the solubility limitations of hydrophobic or poorly soluble compounds. Bearing in mind that organic and enzymatic synthesis is mainly performed in a homogenous liquid reaction medium, microemulsion systems can be an effective tool for bringing together reactants of extensively different polarities. The products and rates of these reactions can be engineered by the type and hydrophilic-lipophilic properties (HLB) of the reagents, HLB value of the surfactant used, molar ratios and concentration of reagents, rigidity of curvature and bending elasticity of interfacial films [12].

U-type microemulsions using varying amounts of non-ionic surfactants and propylene glycol (PG) have been served as microreactors for the Maillard reaction between glucose and leucine. The reaction produced unique new aroma products and reaction rate was controlled by the water activity of system [13].

Enzymatic reaction in a food-grade microemulsion composed of olive oil, lecithin, 1-propanol and water has been thoroughly studied by Papadimitriou, Sotiroudis and Xenakis [14]. Tyrosinase, a key oxidizing enzyme in melanin and other pigments synthesis, has been dissolved in the water core of the formulated microemulsions and the oxidation reaction of oleuropein, phenolic bitter compound found in green olives, was successfully conducted.

Oil Recovery

The exciting solvent extraction method of oil from oil seeds has many drawbacks, the most critical of which are expensive equipment to ensure safety measures in handling flammable solvents as well as consumption of significant quantities of toxic air pollutant solvents. Approximately 0.7 kg of hexane, the most commonly employed solvent in the vegetable oil extraction, per ton of seed is emitted into the atmosphere [15].

To meet with such challenges, alternative extraction techniques are needed to eliminate the use of hazardous solvents like hexane. Microemulsion technique using different surfactants and co-surfactants, is an environmentally friendly approach in oil seeds extraction due to its ultra-high solubilisation capacity and ultra-low interfacial tension properties [16].

Abbasi and Radi ([11, 17] reported a high extraction efficiency (>80%) by microemulsion technique, using lecithin as surfactant and 1-propanol as co-surfactant, in canola oil extraction and arrived at the conclusion that triglycerides solubilisation capacity of the microemulsion system even increased at higher temperatures.

Microemulsion-based extraction technique has been successfully also applied for soybean oil extraction using a non-ionic surfactant and palm kernel oil from palm kernel seeds using mixed surfactant [15].

Green separation and solubilization

Microemulsion is of increasing significance in the food industry as vehicles for green separation and improved solubilisation of nutraceuticals and dietary supplements having multiple health benefits.

The possibility of using the microemulsion-based process for separation of lycopene, an active natural lipophilic antioxidant, from tomato industrial waste was investigated. Sonication followed by enzymatic pretreatments and then microemulsion-based extraction using natural surfactants led to nearly 39% extraction efficiency of lycopene [6,18]. The lycopene microemulsion showed satisfactory stability over heat treatments and exposure to UV where its monodispersity and nano-size could be of potential advantage to the food and related industries [19].

In a complementary study using olive oil microemulsion and natural surfactant lecithin it was showed that the procedure is potentially capable to increase the extraction efficiency up to 88% [unpublished data].

Over the past few decades, neutraceuticals, in general, and carotenoids, in particular, have taken great attention both by scientists and industries. Lutein, as an oxycarotenoid, is one of these ingredients which potentially reduces the risks of age-related macular degeneration (AMD) and cataracts by protecting the macula from damage of blue-wavelength photons, improves visual acuity and scavenges harmful reactive oxygen species formed in the photoreceptors, as well as other benefits such as antioxidant activity. The conventional process for lutein recovery from its resources is organic solvent extraction which has several disadvantages such as; toxicity, health and environmental hazards, time consuming and relatively expensive equipments. Moreover, the extracted lutein is insoluble in water and alternative methods are highly demanded. Therefore, the scientists attempted to evaluate the capability of microemulsion technique as a green and environmentally friendly technology in synchronic extraction and solubilization of lutein from spinach leaves and marigold petals [7].

Nanoparticle synthesis

Considerable interest in using microemulsion technique for nanoparticles synthesis arises predominantly from its ability to enhanced control of the primary particle properties such as shape, agglomeration, size distribution, uniformity and surface area of produced particles [20]. Moreover, simplicity and low energy requirements of procedure and mild reaction conditions makes this technique a very promising one to be applied for nanoparticle synthesis purposes [1,18].

To name an example, starch nanoparticles, having mean particles sizes of 83 nm, successfully synthesized by precipitation technique from a microemulsion. Nanoparticle of starch is found to have various applications as eco-friendly packaging products and delivery systems for food ingredients and nutraceuticals [21].

Future Trends

Future development may consider microemulsions as novel solution to conquer the issue of poor water solubility of highly hydrophobic compounds (food colorants, food additives, bioactive molecules, vitamins, etc.), enzymatic and chemical reaction nanoreactors, enhanced petroleum recovery process, drug and nutraceutical delivery system, catalysis, recovering and recycling nanoparticles and environmentally friendly decontamination of soils and solid surfaces in industrial scale.

Likewise, future orientations may include microemulsion application as targeted drug delivery carrier in cancer chemotherapy as unfortunately, chemotherapy does not differentiate cancer cells from normal cells through their active growing phases and in the meantime, side effects (low blood counts, hair loss, mouth sores, problems with breathing or even death) can be very burdensome [22].

Other possible areas of application may be oil extraction from commercialized oil-bearing plants using microemulsion technique as a clean technology for biofuel production. Global vegetable oil market is substantially dominated by palm oil and hence it has good potential to be used globally for industrial purposes [15,23].

However, microemulsion system, as an emerging technology in food industry and other fields of study, is in its infancy and we will very likely see fast progress over time before it will be applied in industrial manufacturing processes.

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