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An Overview of Nano-Scale Food Emulsions: A Mini Review

Şelale YALÇINÖZ[1*], Emine ERÇELEBİ[1]

[1] The University of Gaziantep, Faculty of Engineering, Department of Food Engineering, Gaziantep/Turkey

*Corresponding Author: selalekara@gantep.edu.tr

Abstract

Emulsions with droplet size in the nanometric scale (typically in the range of 20-200 nm, or milky up to 500 nm) are often referred in the literature as miniemulsions, nano-emulsions, ultrafine emulsions, submicron emulsions, emulsoids, unstable microemulsions etc. Due to their characteristic size, nano-scale emulsions appear transparent or translucent to the naked eye. They possess the ability of incorporation into optically transparent products, which gives the great potential of increasing bioavailability of lipophilic functional substances, that is, nano-sized emulsions can be used in encapsulating of bioactive components, being as a carrier for bioactive components, and preventing their degradation. Recently, nano-scale emulsions are also attracting increasing attention due to their characteristic feature of kinetic stability. A kinetic stability that lasts for months, stability against dilution or even against temperature changes, totally unlike the (thermodinamically stable) microemulsions. These properties make nano-scale emulsions of great interest for fundamental studies of food, medical and pharmaceutical industries. The aim of this study is to present a mini-review on properties of nano-scale emulsions, and an overview of nano-scale food emulsion.

Keywords: Applications, Bioactive Components, Encapsulation, Food, Nano-Scale Emulsion

INTRODUCTION

Nano-scale emulsions

Nano-scale emulsions, also referred to in the literature as miniemulsions, ultrafine emulsions, emulsoids, unstable microemulsions, submicrometer emulsions, are a class of emulsions with very small and uniform droplet size, typically in the range of 50-200 nm, or milky up to 500 nm (Porras et al., 2008). Mainly two types of nano-scale emulsions present due the type of continuous phase, namely, oil-in-water (O/W) and water-in-oil (W/O) emulsions (Figure 1a). In oil in water emulsions, oil droplets dispersed in continuous phase of water. In water-in-oil emulsions, water is dispersed in continuous phase of oil.

Due to their smaller droplet size they may appear transparent or translucent (Figure 1 b,c) (Solans et al., 2005; Pey et al., 2006). Such emulsions are of interest primarily because of their droplet size, however their potential has also been investigated in such applications as functional ingredient encapsulation and nano-structured multiple emulsions. Applications studied for nano-scale emulsions include polymerization and other reaction processes, drug delivery, cosmetics, and novel foods (Henry et al., 2009).

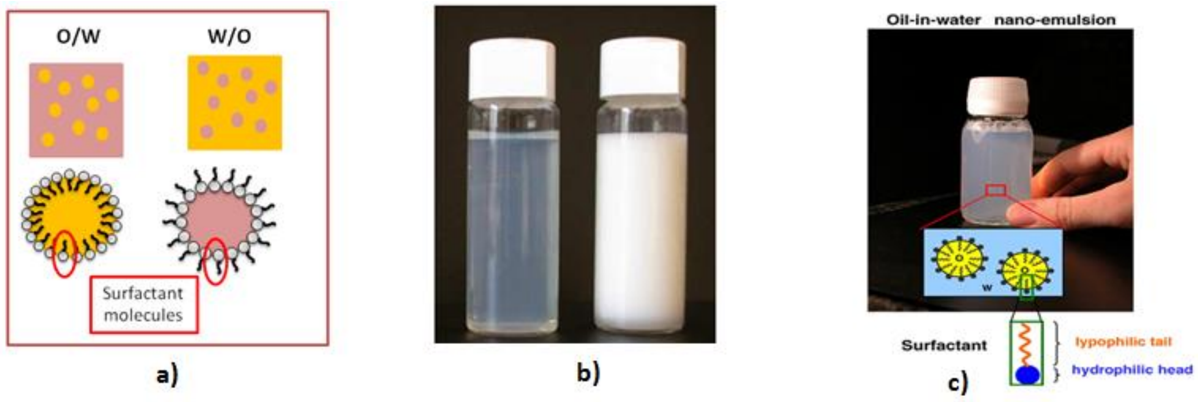

Figure 1.a) Schematic representation of O/W and W/O nano-scale emulsions. **b)** Picture of a nano-scale emulsion (left) and a macro-emulsion (right) with droplet diameters of 35 nm and 1 µm, respectively (Solans et al., 2005). **c)** Visual aspect of an O/W nano-scale emulsion and structural conformation of the droplet (Gutiérrez et al., 2008).

Recently, nano-scale emulsions are also attracting increasing attention due to their characteristic feature of kinetically stability. A kinetic stability that lasts for months, stability against dilution even against temperature changes, totally unlike the (thermodynamically stable) micro-emulsions (Tadros et al., 2004; Anton et al., 2008). Nano-scale emulsions have good stability against coagulation of droplets because the range of attractive forces acting between droplets decreases with increasing droplet size, while the range of steric repulsion less dependent on particle size (Hélder et al., 2012). Nano-scale emulsions highly stable to gravitational separation because the relatively small particle size means that Brownian motion effects dominate gravitational forces which means no creaming and sedimentation occurs on storage (Tadros et al., 2004). Nano-scale emulsions, in contrast to micro-emulsions, are not the thermodynamically stable, i.e. they are not equilibrium phases and their size of droplets tends to increase with time before phase separation (Porras et al., 2008).Nano-scale emulsions are prepared using low-energy, high-energy methods. The high-energy methods include high-shear stirring, ultrasonic emulsification, high-pressure homogenization, microfluidics and membrane emulsification. The most widely used low-energy methods include phase inversion (the phase inversion temperature (PIT), phase inversion composition (PIC)) and the spontaneous emulsification in nonequilibrium systems (Fryd & Mason, 2012; Koroleva & Yurtov, 2012).

Food grade nano-scale emulsions

Nanoemulsions of which all the building components of nanoemulsions are safe for human consumption or ‘‘generally recognized as safe’’ (GRAS) materials are considered as “Food Grade” (Abbas et al., 2013). To obtain food grade nano-scale emulsions, all the components mainly, oil, surfactant and aqueous phase should be food grade. Hélder et al. (2012) classify solvents that can be used in preparation of nano-scale food emulsions. In this context, organic solvents such as sunflower oil, corn oil, olive oil, soybean oil, medium chain triglyceride, sesame oil, paraffin oil, ethanol, octanoic acid and caprylic acid are used without any restriction, acetone, n-hexane, tetradecane and ethyl acetate can only be used up to 50 ppm, while solvents such as n-decane, hexadecane, isohexadecane, and chloroform cannot be used in food-grade nano-scale emulsions.

Emulsions breakdown is usually retarded by using emulsifiers, which are surface-active ingredients that adsorb to the surface of freshly formed oil droplets during homogenization. Once adsorbed, they facilitate further droplet disruption by lowering the interfacial tension, thereby reducing the size of the droplets produced during homogenization. Emulsifiers also reduce the tendency for droplets to aggregate by forming protective films and/or generating repulsive forces between the droplets. A good emulsifier should rapidly adsorb at the surface of oil droplets formed during homogenization, rapidly lower the interfacial tension by a significant amount and protect the droplets against aggregation during emulsions processing, storage, and utilization (Camino et al., 2011). Typical GRAS emulsifiers suitable for nano-scale food emulsions are surfactants (e.g. Tweens®, Spans®, Brijs®, pluronics, sugar esters, poloxamers), proteins (e.g. whey, casein, soy and gelatin), polysaccharides (e.g. gum arabic, modified starch, pectin) and phospholipids (e.g. lecithin and lyso-lecithin) (McClements,2013).

Many of the previous studies on food-grade nano-scale emulsions involve the preparation of nano-scale emulsion consisting of Food-Grade oil-surfactant-aqueous phase combination by using different emulsification methods (i.e., low-energy or high energy methods) and, are aimed to fabricate, characterize and determine their characteristic properties such as particle size, physical properties and stability. Most previous studies based on high-energy emulsification methods on model systems at ideal conditions by using low density essential oils as oil phase and buffer solutions with neutral pH as an aqueous phase (Rao &McClements, 2011a; Choi et al., 2011; Qian & McClements, 2011; Rao & McClements, 2012a, b; Yang et al., 2012; Kaltsa et al., 2013). The priorities were directed toward to explore applications of nano-scale food emulsions. Subsequent to the discovery of the basic characteristic features of nano-scale emulsion, the nano-scale emulsions studies have been directed toward to the use of these characteristic properties in a way to improve functional properties of foods and to increase their bioavailability. That is, nano-scale emulsions have been developed to encapsulate a number of different lipophilic components (such as β-carotene (Tan & Nakajima, 2005; Chu et al., 2007; Yuan et al., 2008; Mao et al., 2009; Hélder et al., 2011), citral (Choi et al., 2009; Mei et al., 2009), flavor oil (lemon oil) (Rao & McClements, 2011b), D-limonene (Li & Chiang, 2012), Vitamin E (Mayer et al., 2013), omega-3 oil (Chalothorn & Warisnoicharoen, 2012) and etc.) and essential oils such as basil oil (Ghosh et al., 2013); cinnamon (Ghosh et al., 2013); peppermint (Liang et al., 2012); thyme (Ziani et al., 2011), lemongrass (Salvia-Trujillo et al., 2014) and etc.

CONCLUSION

In this study, a mini-review on properties of nano-scale emulsions, and an overview of nano-scale food emulsion are presented. Emulsions with droplet size in the nanometric scale (typically in the range of 20-200 nm, or milky up to 500 nm) are often referred in the literature as miniemulsions, nano-emulsions, ultrafine emulsions, submicron emulsions, emulsoids, unstable microemulsions and etc. Nano-scale emulsions are kinetically stable but, they are thermodynamically unstable. Nano-emulsions are unique due to their long term physical stability with no apparent flocculation, coalescence, creaming or sedimentation. Due to their characteristic size, nano-scale emulsions appear transparent or translucent to the naked eye, which gives the ability of incorporation into optically transparent products, which gives the great potential of increasing bioavailability of lipophilic functional substances.

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