



Influence of surfactant type and thermal cycling on formation and stability of flavor oil emulsions fabricated by spontaneous emulsification



Amir Hossein Saberi^a, Yuan Fang^b, David Julian McClements^{a,*}

^a Biopolymers and Colloids Laboratory, Department of Food Science, University of Massachusetts Amherst, Amherst, MA 01003, USA

^b PepsiCo Global R&D, 100 Stevens Ave, Valhalla, NY 1059, USA

ARTICLE INFO

Article history:

Received 1 June 2016

Received in revised form 11 August 2016

Accepted 13 August 2016

Available online 15 August 2016

ABSTRACT

Food-grade emulsions can be fabricated using simple and inexpensive low-energy homogenization methods. In this study, we examined the influence of surfactant type (Tween 40, 60, and 80), oil phase composition (limonene-to-medium chain triglyceride ratio), and temperature (25 to 95 °C) on the formation and stability of flavor oil-in-water emulsions (10 wt% oil, 15 wt% surfactant, pH 3) fabricated using spontaneous emulsification. Transparent emulsion-based delivery systems containing ultrafine droplets ($d < 40$ nm) could be formed at room temperature at certain limonene contents for all three surfactants. When these emulsions were heated and then cooled, appreciable droplet growth occurred at lower limonene levels (<60% limonene) leading to cloudiness, but ultrafine droplets were still present at higher limonene concentrations (80% limonene) leading to optical clarity. These results were attributed to the influence of oil phase composition and surfactant type on the phase inversion behavior of the surfactant-oil-water systems.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Emulsion-based delivery systems are widely used in the food industry to encapsulate lipophilic ingredients, such as ω -3 rich oils, oil-soluble vitamins, nutraceuticals, flavor oils, and essential oils (Cerqueira et al., 2014; Ezhilarasi, Karthik, Chhanwal, & Anandharamakrishnan, 2013; Silva, Cerqueira, & Vicente, 2012). Oil-in-water emulsions are thermodynamically unstable systems that contain emulsifier-coated lipid droplets dispersed within an aqueous medium (McClements, 2010). The physicochemical, sensory, and functional properties of oil-in-water emulsions can be tailored by controlling the dimensions and surface characteristics of the lipid droplets they contain. In certain food and beverage applications there are advantages to using emulsions containing ultrafine lipid droplets (diameter < 50 nm) since they tend to be optically transparent, have good stability to aggregation and gravitational separation, and may enhance the activity of encapsulated ingredients (McClements, 2013; McClements & Rao, 2011). Ultrafine emulsions can be produced using high-energy methods such as high-pressure valve homogenizers, microfluidizers, or sonicators, provided that system composition and homogenization conditions are optimized. The main drawback of these methods is that specially designed mechanical devices are required (“homogenizers”) that may be expensive to purchase and operate. Ultrafine emulsions can also be fabricated using low-energy methods that do not require any sophisticated equipment, such as spontaneous

emulsification (SE), emulsion inversion point (EIP), and phase inversion temperature (PIT) methods (Perazzo, Preziosi, & Guido, 2015; Solans & Solé, 2012). These methods rely on the spontaneous formation of ultrafine oil droplets in certain surfactant-oil-water mixtures when system composition and/or environmental conditions are altered in a specific manner. The major advantages of these low-energy methods over the more commonly used high-energy methods are: (i) they do not require any specially designed homogenizers; (ii) they are simple and inexpensive to implement; (iii) they can often produce smaller oil droplets; and (iv) they are more energy efficient (Anton & Vandamme, 2011; McClements & Rao, 2011). Conversely, the major disadvantages of low-energy methods are: (i) they typically require high amounts of surfactant; (ii) they are limited in the range of oil and surfactant types that can be used; and, (iii) the droplets produced are often unstable to coalescence at elevated temperatures.

The spontaneous emulsification and phase inversion temperature methods are two of the most popular low-energy approaches for producing ultrafine emulsions (Anton, Benoit, & Saulnier, 2008; Anton & Vandamme, 2009). The SE method involves titrating a mixture of oil and surfactant into water, while the PIT method involves heating a mixture of surfactant, oil, and water above the phase inversion temperature and then cooling rapidly. Despite these differences in implementation, it has been proposed that these two methods generate ultrafine oil droplets through a similar physicochemical mechanism based on movement of surfactant molecules from the oil phase to the water phase (Anton & Vandamme, 2009). The SE approach has been used to encapsulate various kinds of lipophilic active agents within ultrafine lipid droplets,

* Corresponding author.

E-mail address: mccllements@foodsci.umass.edu (D.J. McClements).

including antimicrobial essential oils (Chang, McLandsborough, & McClements, 2013), capsaicin (Choi, Kim, Cho, Hwang, & Kim, 2009), flavor oils (Chang & McClements, 2014), resveratrol (Davidov-Pardo & McClements, 2015), vitamin D (Guttoff, Saberi, & McClements, 2015), vitamin E (Saberi, Fang, & McClements, 2013b, 2013c), and ω -3 oils (Gulotta, Saberi, Nicoli, & McClements, 2014; Walker, Decker, & McClements, 2015). As mentioned earlier, one of the major potential limitations of emulsions produced by this method is the tendency for droplet coalescence to occur when they are heated above a certain temperature (Saberi, Fang, & McClements, 2013a). The origin of this effect is associated with changes in the molecular characteristics of non-ionic surfactant molecules with temperature (Anton & Vandamme, 2009; Israelachvili, 2011). At relatively low temperatures, the head groups of these molecules are highly hydrated, which makes them predominantly water-soluble and favors the formation of oil-in-water emulsions. Conversely, at relatively high temperatures, the head groups are less hydrated, which makes them more oil-soluble and favors the formation of water-in-oil emulsions. At the PIT, the surfactants are approximately equally soluble in both oil and water phases, and do not stabilize oil-in-water or water-in-oil emulsions very well. Consequently, oil-in-water emulsions are highly prone to droplet coalescence when their temperature is raised to a region just below the PIT (the so-called “droplet coalescence zone” or DCZ) (Kabalnov & Wennerstrom, 1996). The increase in droplet size that occurs when emulsions are exposed to these temperatures may be undesirable since it leads to changes in their optical properties or stability, e.g., cloudiness, creaming, or oiling off.

An understanding of the thermal stability of emulsions is important for many of their practical applications because commercial products are often exposed to different temperatures during their production, storage, or utilization. Previous studies have shown that the droplet size in emulsions produced by the SE method may increase, decrease or remain the same when exposed to a heating-cooling cycle (Anton & Vandamme, 2009; Saberi, Fang, & McClements, 2015b, 2013a). The behavior of a given system depends on its composition, the temperatures employed (compared to the PIT), and the cooling rate used (Anton & Vandamme, 2009; Izquierdo et al., 2002; Izquierdo et al., 2004; Kunieda, Fukui, Uchiyama, & Solans, 1996; Solans, Izquierdo, Nolla, Azemar, & Garcia-Celma, 2005). A number of recent studies have examined the impact of temperature on the properties of emulsions containing Tween-coated oil droplets prepared using low-energy methods (Hategekimana, Chamba, Shoemaker, Majeed, & Zhong, 2015; Mashhadi, Javadian, Tyagi, Agarwal, & Gupta, 2016; Prasert & Gohtani, 2016; Saberi, Fang, & McClements, 2015a, 2015b, 2013a). These studies show that the formation and stability of these emulsions depends on surfactant type, aqueous phase composition, and oil phase composition.

The main objective of the current study was therefore to examine the influence of system composition on the thermal stability of emulsions formed using a commonly used flavor oil (limonene). In particular, we examined the influence of surfactant type (Tween 40, 60, 80) and oil phase composition (limonene-to-MCT ratio) on the thermal stability of the emulsions. Here MCT refers to medium chain triglycerides, which are commonly used in the development of food-grade delivery systems. This information will be useful for identifying suitable conditions for forming flavor oil emulsions that are stable when exposed to temperature abuse during storage.

2. Materials and methods

2.1. Materials

Medium chain triglyceride (MCT) oil (MIGLYOL® 812) was purchased from Warner Graham Company (Sasol Germany GmbH). Limonene, non-ionic surfactants (Tween 40, Tween 60, and Tween 80), citric acid, and sodium benzoate were purchased from Sigma-Aldrich Co. (St. Louis, MO). Double distilled water was used in the preparation

of all solutions and nanoemulsions. All concentrations are expressed as a mass percentage (wt/wt%).

2.2. Emulsion preparation

Emulsion formation was carried out using the spontaneous emulsification method explained in our previous study (Saberi, Fang, & McClements, 2013c). In brief, SE was performed by addition of an organic phase to an aqueous phase that was being continuously stirred using a magnetic stirrer. The composition of the buffer solution was designed to imitate the aqueous phase of many commercial beverage products (citric acid, pH 3.0). Unless otherwise stated, the experiments were carried out using standardized conditions: (i) *composition* - 10 wt% total oil, 15 wt% surfactant, and 75 wt% aqueous phase; (ii) *stirring* - magnetic stirrer speed of 600 rpm; (iii) *preparation temperature* - 45 °C. In these samples, the oil (10 g) and surfactant (15 g) were first mixed together and then the mixture was slowly poured into 75 g of aqueous phase over a 15 min period with continuous stirring.

2.3. Particle size measurements

Particle size distributions were measured using a dynamic light scattering instrument (Zetasizer Nano ZS, Malvern Instruments, Malvern, UK). This instrument determines the particle size from intensity-time fluctuations of a laser beam (633 nm) scattered from a dilute emulsion. Each individual measurement was an average of 13 runs. To avoid multiple scattering effects, samples were diluted before the particle size measurements using acidic buffer solution (pH 3.0). The mean particle diameter (*Z-average*) was calculated from the particle size distribution. All measurements were conducted at ambient temperature.

2.4. Turbidity measurements

The influence of thermal treatment on the turbidity (absorbance at 600 nm) of the samples was determined using a UV-visible spectrophotometer with temperature scanning capabilities (Evolution Array, Thermo Scientific). Temperature scanning measurements were carried out by measuring the turbidity (τ) of the emulsions as the temperature increased from 25 to 95 °C at 1 °C per minute, and then decreased back to 20 and/or 25 °C at different cooling rates.

2.5. Statistical analysis

All experiments were carried out at least twice using freshly prepared samples. Turbidity *versus* temperature profiles are only shown for one of the samples to enhance the clarity of presentation, but both samples behaved very similarly with less than $\pm 5\%$ standard deviation in the turbidity values. The results for the impact of limonene concentration and surfactant type are reported as the calculated mean and standard deviation.

3. Results and discussion

3.1. Influence of oil composition and surfactant type on formation

Initially, we examined the influence of oil phase composition and surfactant type on the formation of emulsions by spontaneous emulsification. Emulsions were prepared containing different limonene levels in the oil phase (50 to 80%) using three non-ionic surfactants (Tween 40, 60, and 80). These limonene levels were used because previous studies have reported that only large droplets can be produced (i) if the limonene content is lower due to inefficient emulsion formation or (ii) if the limonene content is higher due to droplet growth caused by Ostwald ripening (Li, Zhang, Yuan, Liang, & Vriesekoop, 2013; Rao & McClements, 2012a, 2012b). All three surfactants could produce emulsions containing ultrafine oil droplets ($d < 60$ nm) with the smallest

Download English Version:

<https://daneshyari.com/en/article/6394771>

Download Persian Version:

<https://daneshyari.com/article/6394771>

[Daneshyari.com](https://daneshyari.com)