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Effective Factors on the Stability of Oil-in-Water Emulsion Based Beverage: A Review

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Abstract

Beverage emulsions are systems that are composed of two liquids including oil and water which are prepared by homogenizing oil phase in an acidic aqueous phase. They must be stable in both concentrated and diluted form for a period of 6-12 months upon standing at room temperature. Two immiscible phases contained systems are thermodynamically unstable. In other words, they are vulnerable to break down over time by different process such as flocculation, coalescence, gravitational separation, phase inversion and ostwald ripening. The rate of destabilization depends on physicochemical properties of two phases, interfacial layer characteristic and the components present in both continuous and dispersed phase. However, beverage emulsions are thermodynamically unstable; it is possible to make it kinetically stable using an appropriate emulsifier with respect to emulsion properties, change the dispersed phase characteristic in a way that retards its upward movement. In this article, the most common factors affected on beverage oil-in-water emulsion stability are reviewed. We will also introduce some solutions to improve beverage emulsion stability.

Introduction

Beverage emulsions are classified as oil-in-water (o/w) emulsions that are prepared in concentrated form, then it must be diluted in sugar solution to make final product for consumer's consumption. Beverage emulsions must be stable in both concentrated and diluted form for a period of 6–12 months upon standing at room temperature (Rezvani et al., 2012).

Oil-in-water emulsions are systems that are composed of two immiscible liquids including oil and water (Farzi et al., 2013). In other words they consist of small spherical oil droplets in another immiscible aqueous phase (McClements, 2000). Generally, emulsions are called thermodynamically unstable systems due to the increase in interfacial area following emulsification. Hence, after enough time they will collapse, as the two phases attempt to minimize the contact area (Klinkesorn et al., 2004).

Emulsion physical breakage is mainly due to creaming, flocculation, coalescence, gravitational separation, phase inversion and ostwald ripening. It should be noted that lipid oxidation will also enhance emulsion physical instability due to oil droplet aggregation through free radical mechanism (Mosca et al., 2013). However, emulsions are thermodynamically unstable, it is possible to form kinetically stable (metastable) one for a reasonable period of time, if their destabilization rate is adequately low in comparison with the expended lifespan (Mirhosseini et al., 2009), by adding substances known as emulsifiers and/or thickening agents prior to homogenization (McClements, 2000) in order to increase the activation energy of the system (Dombrowski et al., 2007). The term “emulsion stability” has been described as emulsion aptitude to resist changes in its properties over time, either chemically or physically. Since beverage emulsions physical stability affect its acceptance by the consumers and its long term

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stability depends on the rate and extent of changes occurs in its structure and properties, the aim of this review article is to determine internal factors which affect beverage emulsions stability. However, environmental conditions of an emulsion experienced during its shelf life are important, too.

Interfacial characteristic

Oil-in-water emulsions are generally stabilized by two main types of molecular emulsifying agents: small molecule surfactants and water-soluble polymers (Dickinson et al., 1993) which are called emulsifier and thickening agent, respectively (Farzi et al., 2013). Emulsifiers are compound absorbed to the surface of freshly formed droplets and form a protective membrane which prevents them from unification. In other words, an emulsifier containing emulsion can be considered as three distinct sections: the continuous phase, the interior of dispersed phase and the interfacial region. The narrow region interface surrounding each emulsion droplet is a mixture of oil, water and emulsifier molecules (Mollakhalili and Mohammadifar, 2014).

The characteristic of layer that is called "interfacial layer" controls the physicochemical and functional properties of emulsion (Dickinson, 2003; Jeon et al., 1999; Mosca et al., 2013; Xu et al., 2012). These characteristics such as thickness, charge, packing and polarity are determined by selecting an appropriate emulsifier with respect to emulsion condition (Palazolo et al., 2005). Hydrocolloids are mainly chosen on the basis of their applications in oil-in-water beverage emulsions. Generally, suitable hydrocolloids, are high–soluble in cold water, have low viscosity in solution, high emulsifying capacity and no thickening effect. Amphiphilic polysaccharides such as gum Arabic and modified starch are the most commonly used hydrocolloids in beverage emulsions (Klein et al., 2010). These hydrocolloids are surface active and absorb to interfaces between oil and water and facilitate the production of small droplets by lowering the interfacial tension during homogenization (Taherian et al., 2008).

Thickness

Immediately after emulsion formation, its stability is determined by the strength/range of the repulsive interactions between pairs of closely approaching droplet surfaces (Dickinson, 2009; Dickinson et al., 1993). Except at very low ionic strength that long ranged electrostatic repulsion is important, the physical space occupied by the interfacial layer determines the minimum inter droplet separation. The thickness of absorbed monolayer also influences on the oxidative stability of an emulsion (Decker et al., 2010; Dickinson, 2009). Lipid oxidation leads to the development of surface-active reaction products which may be competent to emulsifier displacing from the droplet surface with promoting emulsion instability. This membrane acts as a barrier to the penetration and diffusion of molecular species that initiate lipid oxidation into the droplets. The relative thickness of films between pairs of droplets will be in the order of:

particles>hydrocolloids>proteins>surfactants

Droplet charge

Oil droplet aggregation will be prevented in electro statically stabilized emulsions, if the droplet surface charges are more negative than -30 mV or more positive than +30 mV (Surh et al., 2006). The droplet charge will also influences on the lipid oxidation. It has been shown that lipid oxidation rate is the highest one for negatively charged droplets both in metal catalyzed oxidation and in the absence of added metal (Yi et al., 2014). However, uncharged and positively charged are not such susceptible to lipid oxidation which may be due to the repulsive effect of positive charge and it may have different trends in a long time enough for a significant amount of oxidation have occurred (McClements and Decker, 2000; Osborn and Akoh, 2004).

Packing

Emulsifier packing density at the oil-water interface in oil-in-water emulsion is influenced by physical and chemical properties of surfactant. It can have an impact on the passing of oxygen, free radicals and pro oxidants through the interfacial layer (Waraho et al., 2011a; Waraho et al., 2011b). As a result, it will be an important parameter in determining the chemical and physical stability of oil-in-water emulsion. Increasing the packaging degree at the interface also decreases the surface energy. Therefore, it will improve the emulsion stability (Parker et al., 2003).

Dispersed phase characteristic

Droplet size

Droplet diameter is a key parameter in determining oil-in-water emulsion stability according to Stokes law. In fact, there is a direct correlation between oil droplet diameter and emulsion stability. In an emulsion, droplet size presented by volume and number mean diameters which are sensitive to volume and number of particles in system, respectively (Karimi and Mohammadifar, 2014). In addition to droplet diameter, particle size distribution is also important for beverage emulsions. Since beverage emulsions mainly contain flavor agents which have small chain fatty acids, dissolvable in

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continuous aqueous phase, it is possible to pass through continuous phase and merge in larger droplet. This will increase oil-in-water emulsion instability due to ostwald ripening. In order to evaluate the emulsion stability, one way is to measure particle size distribution changes during time (Dickinson et al., 1991; Drelich et al., 2010). Reducing droplets size will enhance the emulsion stability in a way that emulsions by droplet diameter below 100 nm are called micro emulsion and are thermodynamically stable (McClements, 2000). Higher stability of smaller dispersed phase diameter containing emulsion could be perceived for at least two reasons which the first one is destabilizing processes such as coalescence that cause an increase in droplet size, the second one is "ageing" that decreases the stability of some emulsions significantly (Maia Filho et al., 2012).

It should be noted that lipid oxidation is accelerated by reaction that take place at the surface of emulsion droplets. So, smaller droplet size will increase its tendency to lipid oxidation because of their larger surface areas per unit volume (Osborn and Akoh, 2004). It is worthy to note that particle size distribution mainly determined by homogenizing process and is out of our control.

Dispersed phase volume fraction

Dispersed phase volume fraction plays an important role in increasing emulsion viscosity and its stability toward creaming. Increasing the oil phase volume fraction in an oil-in-water emulsion promotes the emulsion stability due to enhanced packing fraction of oil droplets (Dickinson et al., 2003; Soleimanpour et al., 2013). The attractive forces between droplets drive the formation of flocs that can be inhibited using an appropriate emulsifier to enhance the steric and electrostatic repulsion (Intarasirisawat et al., 2014).

Study of the effect of oil phase volume fraction on lipid oxidation in an oil-in-water emulsion revealed that decreasing oil phase volume fraction enhanced lipid oxidation and emulsion instability. This fact may be due to an increased generated radicals per droplet (McClements and Decker, 2000). It should be noted that study of the effect of dispersed phase concentration on the auto oxidation and enzymatic oxidation indicated the same results (Roozen et al., 1994).

Dispersed phase physical state

The stability of emulsion is influenced by its dispersed phase physical state. Solid state dispersed phase is less stable toward oxidation, because during crystallization, components putted in dispersed phase migrate to the surface of droplets and make it less resistant to lipid oxidation (Cornacchia and Roos, 2011).

The dispersed phase physical state in an emulsion can influence on a number of its most important bulk physicochemical and organoleptic properties, including appearance, rheology, flavor and aroma in addition to its stability.

Density

The ingredients used to form the oil phase in beverage emulsions are mainly pure and deodorized oil (canola, coconut, and corn oils). These oils are very rich in low molecular weight fatty acids, so there is a difference between oil and aqueous phase density. According to Stokes law, the velocity at which a droplet moves is directly proportional to the density difference between oil and water phases. In order to prevent creaming and phase separation due to density difference between oil and water, weighting agents are added to oil phase (Mirhosseini et al., 2008; Paraskevopoulou et al., 2009).

Weighting agents (density-adjusting agents) are lipophilic compounds with specific gravity higher than that of water and have a restricted use because of the perceived health risk disadvantages, undesirable taste, and so oxidative instability (Cornacchia and Roos, 2011; Taherian et al., 2006).

However, restricted concentration of weighting agents may enhance the gravitational separation by changes in average droplet size induced via the aggregation of oil droplets and the changes in the refractive index of oil phase and aqueous phase. As a result, many authors attempt to stabilize beverage emulsions through modification of water phase.

Continuous phase characteristic

The stability of many food emulsions is usually determined by the rheological properties of the two phases. The creaming of oil droplets in beverage emulsions is also strongly dependent on the rheological properties of the continuous aqueous phase.

Viscosity enhancement using hydrocolloids modifies the texture and mouth feel of food products as well as reducing the rate at which particles cream or sediment. Hydrocolloids stabilize the emulsion through viscosity effect, steric hindrance, and electrostatic interactions. The concentration of hydrocolloid to enhance emulsion stability must be calculated carefully, since at a certain concentration it will enhance emulsion instability via depletion flocculation (McClements, 2000).

Addition of high molecular weight hydrocolloids capable of modifying the rheological properties of aqueous phase could improve the quality of beverage emulsions. For instance, the addition of 0.3% (w/w) xanthan gum to the emulsions, stabilized by modified starch, could reduce the

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overall average particle size and polydispersity (an index for the range of particle size distribution) and enhance the shelf stability of the beverage emulsions. This function is due to the formation of aggregates by xanthan gum and reversible shear thinning viscosity of the emulsions.

Conclusion

In this overview, the factors affecting the beverage emulsions stability were explained. The importance of particle size distribution and rheological properties of water phase and emulsions on stability of beverage emulsions were highlighted. It was revealed that the modification of rheological characteristic of continuous aqueous phase can play an important role in relation to the storage stability of beverage emulsions. When the steric stabilization mechanism is dominant, the type of hydrocolloid, its concentration, and combination are responsible for rheological properties of emulsions.

It is concluded that beverage emulsions stability depends on its composition and microstructure, as well as the environmental conditions experiences during its lifetime (e.g., temperature variations, mechanical agitation, and storage conditions). It should be noted that selecting an appropriate emulsifier with respect to emulsion properties is important to create a kinetically stable emulsion.

Conflicts of interest

None declared.

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