Food Research International 74 (2015) 260–268

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Effect of carrier oils on the physicochemical properties of orange oil beverage emulsions

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ARTICLE INFO

Article history:
Received 16 November 2014
Received in revised form 22 April 2015
Accepted 2 May 2015
Available online 8 May 2015

Keywords:
Orange oil
Carrier oils
Beverage emulsions
Soybean soluble polysaccharides
Physicochemical property

ABSTRACT

In this study, the effect of carrier oils on the physicochemical properties of orange oil beverage emulsions was investigated. The beverage emulsions were prepared by soybean soluble polysaccharides (SSPS) using a two-stage processing of homogenization. Results showed that the presence of carrier oils could improve the physical properties of beverage emulsions, including droplet size, size distribution and turbidity, compared with only orange oil in oil phase of the beverage emulsion. And the effect of long chain triglycerides on the physical stabilities of beverage emulsions was significant ($p < 0.05$) than that with medium chain triglycerides (MCT). The oxidation rate of orange oil in the emulsion was faster compared to that of the orange oil/carrier oils in emulsions. However, the rheological properties of beverage emulsions were hardly dependent on the carrier oils. In addition, all the emulsions exhibited near-Newtonian fluid behavior. These findings revealed that the physicochemical properties of the beverage emulsions could be effectively improved by the presence of carrier oils.

1. Introduction

The term 'beverage emulsion' was used to describe the unique class of oil-in-water (O/W) emulsions providing only cloudiness and/or desirable aroma, cloudiness, and color in the finished emulsion-based product, including fruit drinks, punches and sodas (Tan, 1997). Beverage emulsion was firstly prepared as an emulsion concentrate, following by further dilution when it was consumed in soft drinks (Rezvani, Schleining, & Taherian, 2012). As it was defined, beverage emulsion was a kind of unstable system, dispersing one immiscible liquid in another in the presence of stabilizers or emulsifiers.

Generally, one of the two immiscible liquids is water phase with emulsifiers, such as hydrocolloid and protein. Hydrocolloid embraces all polysaccharides that are extracted from plants, seaweeds and microbial sources, as well as gums derived from plant exudates, and modified biopolymers made by the chemical or enzymatic treatment of starch or cellulose (Dickinson, 1994). And in contrast to protein, polysaccharides provide better stability to environmental stresses, like pH, salt, heating and freezing (Guzey, Kim, & McClements, 2004; Ogawa, Decker, & McClements, 2003; Yin, Chu, Kobayashi, & Nakajima, 2009). For instance, soybean soluble polysaccharides (SSPS) are acidic polysaccharides containing galacturonic acid, composed of a main rhamnogalacturonan backbone branched by β-1,4-galactan and α-1,3- or α-1,5-arabinan chains. SSPS are preferred as a potential stabilizer because their emulsifying property is not affected by pH or ionic strength and lower level of SSPS is required to stabilize acidic emulsions compared to those reported with gum Arabic and modified starches (Nakamura, Maeda, & Corredig, 2007; Nakamura, Yoshida, Maeda, Furuta, & Corredig, 2004).

As an important component of beverage emulsion, orange oil contains volatile constituents and a delightful color, which could provide aroma, cloudiness, and color in beverage emulsion. Moreover, it is also widely utilized in food industry as flavoring agent, such as beverage products, baked food, confectionery, dessert and ice cream (Mirhosseini, Tan, Hamid, & Yusof, 2008; Mei et al., 2009). On the other hand, orange oil is a functional essential oil, and has health-promoting potentials, such as anti-carcinogenic and anti-inflammatory activities (Qian, Decker, Xiao, & McClements, 2011).

In the previous studies, the oil phase of beverage emulsion was only one single type of oil. If necessary, a weighting agent could be added to adjust the density of the two phases (Kim & Morr, 1996; Mirhosseini, Tan, Hamid, Yusof, & Chern, 2009). Different types of emulsifiers were tried to embed the oil phase to make the system more stable for the physicochemical properties, such as smaller droplet size, higher turbidity, better stability (Harnsilawat, Pongsawatmanit, & McClements, 2006; Mirhosseini, Tan, Aghlara, et al., 2008; Taherian, Fustier, & Ramaswamy, 2006). However, the properties of beverage emulsions

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http://dx.doi.org/10.1016/j.foodres.2015.05.002
0963-9969/

were influenced by the nature of the oil phase, such as, the different lemon oil compositions (Rao & McClements, 2012), or different oil types (Klein, Aserin, Svitov, & Garti, 2010).

In this study, orange peel oil was preferred as the main composition of oil phase, considering its good organoleptic properties and wide applications, such as adding the orange aroma to food products (Braun & Cohen, 2007). The purpose of current study was to gain a better understanding of the effect of carrier oils on the physicochemical and rheological properties of O/W beverage emulsion. Two types of long chain triglycerides (canola oil and corn oil), and one medium chain triglycerides (MCT) as carrier oils were chosen to mix with orange peel oil, respectively. Then the mixture was applied to prepare beverage emulsions with SSPS. The droplet size and distribution, ζ-potential, turbidity, physical stability, oxidative stability, rheological behavior and tolerance toward high temperature, high ionic strength and different pH values were determined to evaluate the physicochemical properties of the beverage emulsions.

2. Materials and methods

2.1. Materials

Orange peel oil was obtained from Huiyuan Co. Ltd. (Beijing, China). Canola oil was purchased from Richardson Oilseed Ltd. (Winnipeg, Canada). Corn oil was purchased from COFCO Co. Ltd. (Beijing, China). The fatty acid profiles of canola oil and corn oil were shown in Table 1, and they are mainly composed of long chain triglycerides. MCT oil was obtained from Lonza Inc. (NJ, USA). SSPS were obtained from MSC. Co. Ltd. (Kyeongnam, Korea). All other chemicals used were of analytical grade, unless otherwise stated.

2.2. Preparation of orange oil beverage emulsions

All the beverage emulsions were composed of SSPS, citric acid, orange peel oil and sodium azide. SSPS (4%, w/w), citric acid (0.4%, w/w) were added into deionized water. The solutions were stirred overnight to ensure complete dispersion and dissolution. Sodium azide (0.02%, w/w) was added as an antimicrobial agent. Pure orange peel oil was mixed with different carrier oils (canola oil, corn oil or MCT) in the percentage of 50% (w/w), respectively. The emulsion without the carrier oil (with the same amount of orange oil as the content of combined oil) was used as the control sample.

At ambient temperature, the oil phase (10%, w/w) was gradually added into water phase (90%, w/w) at a speed of 10,000 rpm for 10 min with a blender to form coarse emulsions, which were further homogenized using a Niro-Soavi Panda two-stage valve homogenizer (Parma, Italy) for three cycles at 50 MPa and 25 °C.

Table 1
Fatty acid composition of canola oil and corn oil.

Fatty acid	Canola oil	Corn oil
16:0	4.27 ± 0.09	10.57 ± 0.03
18:0	2.04 ± 0.27	1.01 ± 0.27
20:0	0.53 ± 0.06	Trace
16:1 *n*7	0.27 ± 0.08	Trace
18:1 *n*9	62.30 ± 1.84	27.62 ± 0.25
20:1 *n*9	1.45 ± 0.05	Trace
18:2 *n*6	19.79 ± 0.19	60.23 ± 0.53
18:3 *n*3	9.7 ± 0.26	1.12 ± 0.05

Note: Values were mean ± SD and the percentages of total fatty acids. The triglyceride notation refers to the length saturation of carbons in the triglyceride acyl chain (for example, C16:1 refers to 16 carbon chain length with 1 unsaturated bond). Composition information was obtained from reference of Lichtenstein et al. (1993).

2.3. Determination of droplet size and size distribution

Particle size and size distribution of beverage emulsions were determined by dynamic light scattering using a Zetasizer Nano-ZS90 (Malvern Instruments, Worcestershire, UK) at a fixed angle of 90°. Beverage emulsions were diluted (1:500) with deionized water prior to analysis to minimize multiple scattering effects. Results were described as cumulants mean diameter (size, nm) for droplet size, polydispersity index (PdI) for size distribution. Both measurements were performed in triplicate for each sample (Liu, Hou, Lei, Chang, & Gao, 2012).

2.4. ζ-potential measurement

Beverage emulsions were diluted (1:500) with deionized water prior to analysis to avoid multiple scattering effects. Diluted emulsions were injected directly into the chamber of a particle electrophoresis instrument (Nano-ZS90, Malvern Instruments, Worcestershire, UK). The ζ-potential was determined by measuring the direction and velocity of droplet movement in a well-defined electric field. All measurements were performed in triplicate with freshly prepared samples and the ζ-potential measurement was reported as the average of three individual injections (Hou et al., 2010).

2.5. Measurements of turbidity and pH

Turbidity was determined by diluting the emulsions with deionized water (1:1000) in a Turbidimeter (2100 N, HACH. Co. Ltd., Colorado, USA), and the measurement was performed in triplicate for each sample.

The pH of each sample was measured by pH meter (Hanna 211, HANNA Instruments, Italy) at 25 °C.

2.6. Physical stability

2.6.1. At ambient temperature of 25 °C

The physical stability of the emulsions was examined with the multisample analytical centrifuge (LUMiSizer, LUM GmbH, Berlin, Germany), which allows the intensity of the transmitted NIR light to be measured as a function of time and position over the entire sample length simultaneously. The samples in the LUMiSizer were centrifuged at 4000 rpm and 25 °C (Lei, Liu, Yuan, & Gao, 2014).

2.6.2. At high temperature and ionic strength

The emulsions were incubated at boiling water for 5 min, and then cooled down. The droplet size distribution was measured to evaluate the physical stability of beverage emulsions.

NaCl was dissolved in citric acid solution (10 mM, pH 3.5) to prepare 0.4 mol/L NaCl solution. The emulsions were mixed with the same volume of NaCl solution. The mixtures were shaken fully and placed at 25 °C for 12 h. The droplet size and its distribution were determined. Each sample was tested in triplicate.

2.6.3. At different pH values

The pH value of the original emulsions was adjusted to 5.0 or 7.0 with 1 mol/L NaOH solution, respectively. The emulsions were placed into cylindrical glass tubes and submitted to Turbiscan Lab® Expert stability analysis (Formulaction Co. Ltd., France). Measurements were carried out using a pulsed near infrared LED at a wavelength of 880 nm for 2 h at 55 °C. Each sample was tested in triplicate.

2.7. Measurement of oxidant stability of oils in beverage emulsions

The beverage emulsions were stored at 55 °C and oxidant stability of oils in the emulsions was evaluated at an interval of 1 week. Lipid hydroperoxides were measured according to the method of Shantha and