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Stability assessment of conjugated linoleic acid (CLA) oil-in-water beverage emulsion formulated with acacia and xanthan gums

Maryam Nikbakht Nasrabadi, Sayed Amir Hossein Goli *, Ali nasirpour

Department of Food Science and Technology, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran

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ABSTRACT

The development of a conjugated linoleic acid (CLA) oil-in-water beverage emulsion containing acacia gum (AG) and xanthan gum (XG) was investigated. D-optimal design and response surface method was used and 10% w/w AG, 3.5% w/w CLA and 0.3% w/w XG was introduced as the optimum formula. Afterward the effect of storage time on the physicochemical properties of selected formulation including specific gravity, turbidity, viscosity, average droplet size, span, size index, creaming index, oxidation measurements and stability in its diluted form, were determined. Findings revealed that the size of oil droplets increased after six weeks and resulted in instability of the emulsion concentrate. Peroxide value increased until 21 days and then decreased dramatically, whereas TBA and Totox values began to increase after this time. Turbidity loss rate was low demonstrating the good stability of the diluted emulsion. The results revealed that it is possible to produce a stable CLA oil-in-water emulsion for using in beverages.

1. Introduction

Beverage emulsions are a unique class of food emulsions, as they are first prepared as an emulsion concentrate and then usually diluted several hundred times, in a sugar solution, to produce the finished beverage (Shachman, 2005; Szterk, Roszko, & Górnicka, 2013). A finished beverage typically consists of a small percentage of emulsion dispersed in water, in companion with other ingredients, including sweetener, acidulent, preservative and dye (Reiner, Reineccius, & Peppard, 2010). The emulsions in both the concentrate and diluted forms must have a high degree of stability, and be stable, as required by the beverage industry (Szterk et al., 2013; Tan, 1997). Destabilizing mechanisms, such as flocculation, coalescence and Ostwald ripening, result in creaming in the emulsion and ring formation in the finished product (Piorkowski & McClements, 2013). Apart from physical changes, some chemical transformations, pertained to the emulsion components, also take place, which are mainly related to oxidation of the lipid phase and the lipid-soluble components. Lipid oxidation affects the quality of emulsion-based products, influencing their flavour, odour, and nutritive value. However, the emulsion structure could impact the oxidation rate (Szterk et al., 2013).

Acacia gum (AG) is a natural hydrocolloid which has been used as an emulsifier in beverage emulsions. AG is a complex mixture of glycoproteins and polysaccharides and its functionality as an emulsifier is generally ascribed to the small protein content (1–3%) (Dickinson, Galazka, & Anderson, 1991). Xanthan gum (XG) is a polysaccharide secreted by *Xanthomonas campestris*, commonly used as a food thickening agent and a stabilizer. One of the most remarkable properties of xanthan gum is its ability to produce a large increase in the viscosity of a liquid by adding a very small quantity which helps to prevent oil separation in emulsions (Papalamprou, Makri, Kiosseoglou, & Doxastakis, 2005).

In most of the beverage emulsions, the flavour oil, such as orange and lemon oil, is the major component of the oil phase (Rao & McClements, 2012; Rezvani, Schleining, & Taherian, 2012). However, vegetable oils, edible waxes and functional lipophilic compounds can also be used. Mohagheghi, Rezaei, Labbafi, and Ebrahimzadeh Mousavi (2011) used pomegranate seed oil as a functional component using oil-in-water emulsion stabilized by AG. Gharibzahedi, Mousavi, Hamedi, and Khodaiyan (2011) evaluated the application of both AG and XG for forming and stabilizing walnut oil-beverage emulsions. In addition, Taherian, Britten, Sabik, and Fustier (2011) examined the effect of pH on the lipid oxidation and the emulsifying performance of whey protein isolate (WPI) and/or fish gelatin in fish oil-in-water beverage emulsion. Liu, Hou, Yang, and Gao (2014) examined the potential of oil-in-water emulsions stabilized by acacia gum as a β-carotene delivery system and the influence of antioxidants on the chemical degradation of β-carotene was investigated. Szterk et al. (2013) examined the oxidation stability of beverage emulsions containing linseed

* Corresponding author.
E-mail address: amirgoli@cc.iut.ac.ir (S.A.H. Goli).

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oil, refined canola oil, and refined palm olein with, or without, the addition of β-carotene. The factors influencing the chemical stability of WPI-stabilized β-carotene emulsions during storage was also evaluated by Xu et al. (2013). Sun and Gunasekaran (2010) investigated the oxidative stability and rheology of Menhaden oil-in-water emulsions stabilized by WPI and XG as a function of heating temperature and time.

Conjugated linoleic acid (CLA) is a mixture of positional and geometric isomers of octadecadienoic acid commonly found in beef, lamb and dairy products. CLA has been reported to have several beneficial effects, such as antiadipogenic, anticarcinogenic, antiatherogenic, antidiabetogenic and antiinflammatory properties (Gnadig, Xue, Berdeaux, Cheardigni, & Sebe-dio, 2003; Yao et al., 2013). Therefore, it can be used as a bioactive lipophilic ingredient in oil phase of beverage emulsions (Nikbakht Nasrabadi, Goli, & Nasirpour, 2015).

The aim of this work was to evaluate the performance and the stability of CLA oil-in-water beverage emulsions formulated by AG and XG during 49-day storage at room temperature. The effects of the storage time on specific gravity, turbidity, viscosity, average droplet size, span, size index, creaming index, oxidation measurements of CLA beverage emulsion and stability in its diluted form were investigated.

2. Materials and methods

2.1. Materials

Sodium benzoate and food grade citric acid were purchased from Merck (Darmstadt, Germany). AG was purchased from Daejung (Shiheung, South Korea). XG and potassium sorbate were provided by Behin azma Co. (Shiraz, Iran) and Zamzam Co. (Isfahan, Iran), respectively. CLA oil was kindly donated by Nutrition lipid Co. (Wormerveer, Netherlands).

2.2. Optimization of the formulation of CLA beverage emulsion

In order to optimize the formulation, three factors of AG content (5–10% w/w), XG (0.1–0.3% w/w) and CLA oil content (3.5–6.5% w/w) were evaluated by response surface methodology (RSM). Eighteen formulations of emulsion were prepared for the optimization procedure based on a D-optimal design and specific gravity, opacity, emulsion stability, viscosity and particle size were considered as responses. Finally, regarding to the high value of stability, opacity, specific gravity and viscosity and the least average droplet size (D_{43}) the optimum formulation was selected as 10% w/w AG, 3.5% w/w CLA and 0.3% w/w XG (Nikbakht Nasrabadi et al., 2015).

2.3. Beverage emulsion preparation and storage

The selected emulsion was prepared two separate times and the physicochemical properties were measured for each emulsion twice. For preparation of the water phase, citric acid (0.4% w/w) was added to deionized water (60 °C) to adjust pH. To avoid microbiological contamination potassium sorbate (0.1% w/w) and sodium benzoate (0.1%w/w) were then added. During mixing, AG was gradually dispersed in the water phase (60 °C) and mixed for 5 min using a mixer. The solution was kept at ambient temperature overnight for full hydration of AG. XG solution was prepared separately by dissolving XG in deionized water and then mixed with the AG solution. While mixing, CLA oil was slowly added to the water phase and mixed for 1 min to attain an initial coarse emulsion by mechanical stirring using an Ultra-Turrax homogenizer (IKA T25 digital, Staufen, Germany) at 10,000 rpm. The premix was then homogenized under vigorous stirring at 16,000 rpm for 2 min at room temperature (Gharibzahedi, Mousavi, Hamedi, & Khodaiyan, 2012; Mirhosseini & Tan, 2010). In order to asses the stability of beverage emulsion over storage, the optimized formulation of the CLA beverage emulsion was evaluated weekly during the 49-day storage at room temperature.

2.4. The physicochemical properties of beverage emulsion

2.4.1. Specific gravity

The specific gravity of the emulsion was measured in duplicate for each of the two prepared emulsions at room temperature by a 25-ml specific gravity bottle (Taherian, Fustier, & Ramaswamy, 2007; Taherian, Fustier, & Ramaswamy, 2008).

2.4.2. Turbidity

The turbidity of the emulsion determined in duplicate by diluting each emulsion in deionized water (1:1000) and measuring the absorbance at 660 nm against distilled water using a spectrophotometer (UV 2100, Unico, England) (Gharibzahedi, Mousavi, Khodaiyan, & Hamedi, 2012; Taherian, Fustier, & Ramaswamy, 2006).

2.4.3. Viscosity

Viscosity was evaluated by the means of Brookfield viscometer (Brookfield DV-I prime, USA) equipped with spindle No 18, immediately after homogenization. A fixed volume of 8 ml for each sample was used and readings were taken at 100 rpm (Gharibzahedi, Mousavi, Khodaiyan, et al., 2012; Mirhosseini, Tan, Hamid, Yusof, & Chern, 2009).

2.4.4. Droplet-size distribution

Droplet-size distribution of each prepared beverage emulsions were measured right after sample preparation using a laser light scattering particle analyzer (Horiba LA-930, Japan). To avoid multiple scattering effects, beverage emulsions were diluted to 1:100 in distilled water prior to analysis. Each sample was analyzed three times and data are presented as the average. For expressing particle size distribution, volumetric percentage by volume-weighted mean diameter (D_{43} (, based on the following Eq. (1), was applied;

$$D_{43} = \frac{\sum nidi^4}{\sum nidi^3} \quad (1)$$

where ni is the number of droplets of diameter di (Yao et al., 2013).

Span, also known as polydispersity index (PDI) was calculated by Eq. (2);

$$\text{Span} = \frac{[d(v,90) - d(v,10)]}{d(v,50)} \quad (2)$$

where $d(v,90) - d(v,10)$ is the range of the data and $d(v,50)$ is the median diameter Gharibzahedi, Razavi, & Mousavi, 2013).

2.4.5. Size index

Beverage emulsions were diluted with deionized water (1:100) and the spectral absorption of diluted emulsions was measured for two times at 800 nm and 400 nm against distilled water using a spectrophotometer (UV 2100, Unico, England). Then the ratio of the readings at 800 nm over 400 nm defined as size index (Harnsilawat, Pongsawatmanit, & McClements, 2006).

2.4.6. Creaming measurement

An emulsion sample (10 ml) was placed in plastic tubes in duplicate for each of the two prepared emulsions, capped and then stored at ambient temperature. Creaming was determined by observing the height of the meniscus between the opaque