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Influence of pure gum on the physicochemical properties of whey protein isolate stabilized oil-in-water emulsions

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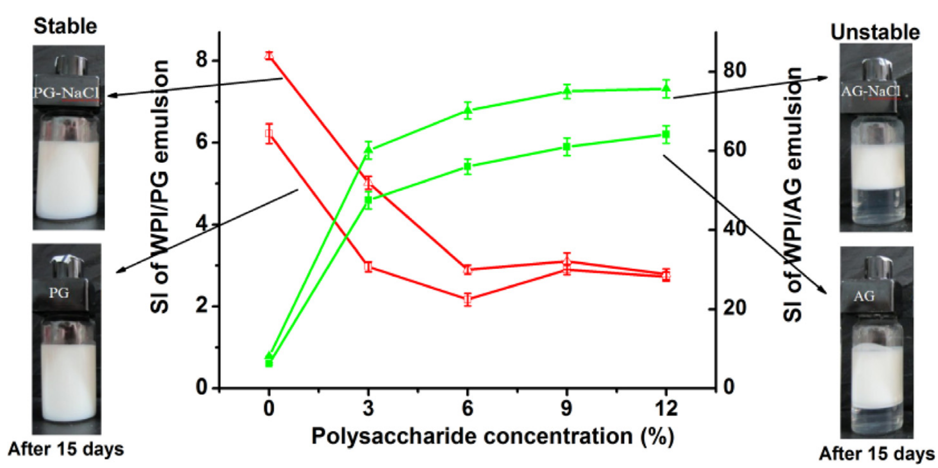
HIGHLIGHTS

- The addition of PG improved the stability of emulsion stabilized by WPI.
- Emulsion stability was mainly dominated by the steric and electrostatic repulsion.
- Emulsions prepared with WPI/PG exhibited good stability to storage time and NaCl.
- The apparent viscosity of WPI/PG emulsion increased with increasing PG.
- Emulsions showed better stability stabilized by WPI/PG than WPI/AG.

GRAPHICAL ABSTRACT



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ABSTRACT

The effect of pure gum (PG) on the properties of oil-in-water emulsions prepared with whey protein isolate (WPI) was studied at different pH (3–7). The mean particle diameters, turbidity, rheological properties and stability of the emulsions stabilized by the WPI/PG mixture were evaluated. The results showed that the emulsion prepared with WPI/PG had a small particle size and good stability, because the WPI/PG mixture created a relatively thick surface layer, reducing interactions between droplets through steric repulsion. All the emulsions exhibited shear-thinning behaviors at tested shear rates in the range 0.1–300 s^{-1}, the apparent viscosity of WPI/PG emulsions increased with increasing the PG concentration under different pH. A viscosity hysteresis phenomenon was observed in the process of heating up, which meant that the apparent viscosity was not a single-valued function of temperature. The emulsions prepared with WPI/PG (pH 3, 6% PG) were more resistant to environmental stress than those coated with WPI/arabic gum (AG). The experimental results have implications for the development of emulsion-based delivery systems for use in food and beverage products.

1. Introduction

Emulsions are defined as a dispersion of two or more immiscible liquids in which one of the liquids is dispersed in the other as

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small droplets (0.1–100 μm) [1]. In the food, pharmaceutical and cosmetic field, emulsions are widely used as drug delivery systems for parenteral, oral, and topical (skin and eye) routes [2]. They are consist of mixtures of at least one liquid dispersed in another one in the form of droplets, both liquids being immiscible, or poorly miscible one with the other [3]. The main challenge raised by the use of emulsions is their thermodynamic instability. Indeed, they are prone to destabilization and phase separation [4]. In accordance with the thermodynamic dictum that all systems evolve towards their global energy minimum state, the emulsions rapidly tend to phase separate in order to minimize the interfacial contact area and free energy. This instability manifests itself by various mechanisms: flocculation, coalescence, creaming, and ostwald ripening. Oil-in-water (O/W) emulsions, based on synthetic emulsifiers, are used in various food systems. Indeed, these synthetic emulsifiers may cause acute toxic symptoms in animals and humans and have an environmental impact [5]. Nowadays, the food industry has a growing interest in the replacement of synthetic emulsifiers by natural ones, such as polysaccharides and proteins. Natural biopolymer molecules (proteins and polysaccharides) can prevent droplet aggregation and stabilize emulsion by adsorbing on the oil-water surface, forming an interfacial film and reducing the interfacial tension. So they are extensively used as functional ingredients in food industry to stabilize emulsions and foams, control texture and structure of foods, protect and deliver bioactive ingredients to targeted sites [6]. Previous studies clearly demonstrated that a number of different biopolymers can be used to prepare multilayer emulsions using the layer-by-layer technique, consisting of oppositely charged biopolymers, adsorbed to each other at the oil-water interface, with improved stability against environmental stresses, or controlled release properties [7]. Meanwhile, the emulsions stabilization or destabilization by biopolymers depends on various parameters, such as biopolymer nature, biopolymer concentration, pH, ionic strength, etc. [7]. Nevertheless, there is still a relatively poor understanding of the influence of specific biopolymer characteristics on the formation, properties, and stability of multilayer systems, e.g., droplet charge, hydrophobicity, rigidity, thickness of the biopolymer layer at the oil-water interface, its permeability, and environmental responsiveness, which concomitantly would lead to changes in emulsion characteristics, such as stability and delivery [8].

The natural biopolymers used in this work are whey protein isolate and pure gum. Whey protein isolate has been widely used in the formation and stabilization of food emulsions due to its excellent functional and nutritional properties. Klein et al. developed an emulsion which was prepared under pH 7 by 10% of whey protein isolate and arabic gum 3:1 mixing solution with 10% oil phase; this emulsion can remain stable at 25 °C more than one month without significant changes [9]. Taherian et al. found that the emulsion prepared with the compounding use of WPI and fish gelatin has high stability under acidic conditions, which was better than the emulsion prepared by WPI [10]. As a new emulsifier, pure gum (PG), also called starch sodium octenyl succinate (SSOS), a starch derivative produced by esterification of native starch, has been approved for the use in foods by the United Nations food and agriculture organization and the world health organization(FAO/WHO) because of its nontoxicity and degradability [11]. PG is not affected by pH and ionic strength significantly and has good emulsifying ability, it can make emulsion reach a stable state through steric stabilization mechanism [12]. In recent years, the research scholars has carried out a lot of researches on preparation methods, physical and chemical properties and application characteristics of PG [13,14]. PG was also used in the beverage, enema, noodles, cake and other food industry due to the expansion of application range. However, the details about the interaction between polysaccharide and WPI membrane at the oil-water interface were less reported.

The objective of this paper was to investigate the influence of polysaccharide on the properties and stability of the emulsions stabilized by WPI. The major factors (PG concentration, pH, and ionic strength) that influenced the adsorption of the PG molecules onto the WPI-coated droplets were determined. Moreover, the underlying mechanism of the emulsion stability was investigated against changes induced by storage time, pH and salt. Additionally, the rheological properties and the stability of the emulsions during conventional storage, pH, and ionic strength were assessed.

2. Materials and methods

2.1. Materials

Whey Protein Isolate was obtained from Yinhe weiye import and export Co., Ltd., Tianjin, China. Pure Gum and Arabic Gum were purchased from Shanghai Seebio Biotech, Inc., Shanghai, China. Palm Oil was purchased from a local supermarket in Zhejiang (China). All other chemicals used were of analytical or better grade.

2.2. Emulsion preparation

Various concentrations of PG and AG mixtures were obtained by dissolving each powder in pH 7.0 phosphate buffer to prepare 6%, 9%, 12% and 24% dilutions. 0.2% potassium sorbate was added to inhibit the growth of microorganisms. WPI solutions were obtained by dissolving each powder in 5 mM pH 7.0 phosphate buffer under gentle stirring at room temperature for 24 h and then overnight at 4 °C to ensure biopolymer dissolution. The WPI solution was prepared using a high-speed stirrer (IKA T25 Basic, Staufen, Germany) at 10,000 rpm for 1 min. The emulsions were prepared by dispersing palm oil in WPI solution using a high-speed stirrer (IKA T25 Basic, Staufen, Germany) at 10,000 rpm for 1 min.

Primary emulsions with 0.2% WPI, 20% palm oil and 0.1 potassium sorbate were prepared by homogenization twice with a high-pressure homogenizer at 25 MPa through the homogenizer (APV1000, APV Co., Crawley, U.K.). Finally, this dilute emulsion was diluted with different ratios of polysaccharide stock solutions (PG, or AG) and phosphate buffer solution under magnetic stirring for 30 min to yield secondary emulsion with the following compositions: 10% palm oil, 0.1% WPI, 1.5% with potassium sorbate, 3–12% PG, or 3–12% AG. The effects of the NaCl concentration, the storage time and the polysaccharide concentration on the stability of emulsions were researched.

2.3. Turbidity measurements

An indication of droplet aggregation in the emulsions was obtained from measurements of the turbidity versus wavelength because the turbidity spectrum of a colloidal dispersion depended on the size of the particles [15]. To some extent, the stability of emulsion could be reflected by absorbance value. Emulsion samples were diluted 1:1000 using sodium phosphate buffer of the appropriate pH as that of the testing sample. The turbidity of emulsion was determined using an UV–vis spectrophotometer (UV-2101PC, Shimadzu Corp., Tokyo, Japan) at 800 and 400 nm. The stability of emulsion could be characterized by absorbance ratio $SRI = \lambda_{800}/\lambda_{400}$, and the emulsion became stable when $SRI < 0.3$ [16]. All measurements were made in triplicate.

2.4. Particle size determination

Emulsion samples were diluted 1:1000 using sodium phosphate buffer of the appropriate pH as that of the testing sample. The mean particle size and particle size distribution of the emulsions were determined using a Zetasizer Nano ZS particle size analyzer