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Characterization of emulsion stabilization properties of quince seed extract as a new source of hydrocolloid

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ABSTRACT

The capability of seed extracts in stabilizing emulsions has particularly received interest in recent years. Upon soaking quince seeds into water, biopolymers inside the seeds are extracted to water, forming mucilage. This study investigates the physical stability, rheology and microstructure of oil (sunflower oil) in water emulsions, stabilized by 2% (w/v) whey protein isolate with varying concentrations of xanthan and quince seed gum. Quince seed gum resulted in emulsions with smaller low-shear viscosities and shear thinning capabilities compared to the same concentrations of xanthan. Quince seed gum emulsions with concentrations ≤ 0.1 (w/v), displayed rapid creaming due to bridging flocculation. Despite the difference in apparent viscosities, for gum concentrations < 0.2 (w/v), both gums demonstrated comparable stability with xanthan gum in general yielding marginally more stable emulsions. Gum concentrations > 0.3 (w/v) resulted in physically stable emulsions even after 5 months. Overall, quince seed gum displayed significant emulsification and stabilization properties.

1. Introduction

Preparation of a wide range of food products involves the dispersion of oil into water. The dispersion of oil in water increases the contact area, hence the interfacial tension between the two phases and carries the system to a higher overall free energy state. In agreement with the thermodynamic dictum that all systems prefer to be in their minimum energy state, the two phases have a tendency to separate and minimize interfacial area (Damodaran, 2005; McClements, 1999). These thermodynamically unstable systems can be kinetically stabilized by minimizing the rate of separation. Some favored methods of accomplishing this are, addition of amphiphilic molecules that adsorb on the interface and decrease interfacial tension, or addition of non-adsorbing thickening polysaccharides that reduce particle movements and collisions in emulsions by increasing the viscosity of the continuous phase (Bouyer, Mekhloufi, Rosilio, Grossiord, & Agnely, 2012).

Whey protein isolate (WPI) is a mixture α-lactalbumin and β-lactoglobulin and several other minor proteins (Sun, Gunasekaran, & Richards, 2007) and is widely used as a natural emulsifier in food products (Sun & Gunasekaran, 2009). When dissolved in emulsions, WPI tends to be rapidly adsorbed on the surface of oil droplets in the form of a stabilizing monolayer that prevent droplet agglomeration through a combination of electrostatic and steric interactions (Gwartney, Larick, & Foegeding, 2004).

In addition to surfactants, polysaccharides are often added in order to thicken emulsions, thereby decreasing the rate of common destabilization mechanisms such as flocculation, creaming, sedimentation or Ostwald ripening (Bouyer et al., 2012). Xanthan gum (XG) is one of the most preferred polysaccharides in this regard. XG is an anionic polysaccharide produced by the bacterium, *Xanthomonas campestris*. The structure consists of a β-(1–4)-D-glucose main chain and side chains of α-D-mannose, β-D-glucuronic acid and β-D-mannose as terminal residues (Bouyer et al., 2012). The polymer, when dissolved in water, exists as multiple forms of helices that are in interaction with one another, forming a complex yet loosely bound network (Jansson, Kenne, & Lindberg, 1975; Melton, Mindt, & Rees, 1976). This particular arrangement gives the gum its unique thickening and shear thinning properties (Benmouffok-Benbelkacem, Caton, Baravian, & Skali-Lami, 2010).

Quince is a fruit of the west Asian region, which is commonly cultivated in Caucasus regions, Syria, Afghanistan, Iran, Dagestan and Antalya (Trigueros, Pérez-Alvarez, Viuda-Martos, & Sendra, 2011). The scientific name of ordinary quince is *Cydonia oblonga* (Abbastabar, Azizi, Adnani, & Abbasi, 2015). A mature fruit contains roughly 10 seeds (Abbastabar et al., 2015). Seeds embody a mucinous material, which could be extracted upon mixing with water. Though the seeds have been used for years in Turkish culinary for gelling, they have recently attracted researchers' attention, which caused an increase in the amount of research on the subject. A number of researchers have demonstrated applications for this new source of hydrocolloid (Abbastabar et al., 2015; Hakala et al., 2014; Jouki et al., 2014a, b; Ritzoulis et al., 2014; Trigueros et al., 2011). Studies revealed that,

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mucilage extracted from quince seeds was composed of cellulose, water soluble polysaccharides and amino acids (with the most abundant ones being; glutamic acid, aspartic acid and asparagine) (Ritzoulis et al., 2014; Vignon & Gey, 1998). Water soluble polysaccharides were separated into glucans, galacto-glucans, manno-glucans or galacto-manno-glucans and acidic arabinoxylans (with the major component being partially O-acetylated (4-O-methyl-D-glucurono)-D-xylan that contains exceptionally high proportions of glucuronic acid residues) (Hakala et al., 2014; Ritzoulis et al., 2014). Water soluble hemicelluloses (uronic acids and glucuronoxylans) and celluloses consist approximately 46% of the total polysaccharides by weight of dry mucilage, with the rest yielding 45% glucose residues when analyzed after enzymatic hydrolysis (Hakala et al., 2014).

In a recent study, the mucilage was shown to possess great gelling capacity and introduced enhanced viscosity and shear thinning behavior to solutions (Abbastabar et al., 2015). Though the protein content of the seed extract had been known for years, recently the emulsifying properties of quince seed gum have been extensively studied and confirmed for a pH range of 6–8 (Ritzoulis et al., 2014).

To the best of our knowledge, the current literature is still lacking in the number of comprehensive studies regarding the use of quince seed gum for stabilizing emulsions. In this study, the goal is to assess the emulsion stabilizing performance of quince seed gum with respect to a commonly used and studied emulsion stabilizer, xanthan gum. The objective of the study is to investigate the physical stability, rheology and microstructure of oil (sunflower oil) in water emulsions, stabilized by 2% w/v (g/mL) WPI and varying concentrations of xanthan and quince seed gums.

2. Materials & methods

2.1. Materials

Quinces were of variety *C. oblonga* cultivated in Antalya and were purchased from a local grocery store in Ankara, Turkey. Xanthan gum and sodium azide (≥99.99% trace metals basis) were purchased from Sigma Aldrich. Whey protein isolate having a protein content of 88% (WPI) (*Bipro*, *Hardline* Nutrition, Turkey) was used. Sunflower oil (*Yudum*, Balıkesir, Turkey) was purchased from a local grocery store in Ankara, Turkey. Distilled water was used to prepare all solutions.

2.2. Extraction of quince seed gum

For quince seed gum extraction, a modified version of the method by Abbastabar et al. (2015) was followed. Seeds were removed from the fruit flesh and freeze-dried. In order to maximize surface area for extraction, the seeds were ground prior to soaking into deionized water. Water–ground seed mixture (with a water/solid ratio of 50:1) was continuously agitated at 30 °C for 24 h. The resulting solution was centrifuged, filtered with a cheese cloth and freeze dried to obtain the crude gum extract. The method yielded approximately 8% extract based on dry weight of seeds.

2.3. Measurement of protein content

Total nitrogen content (N_2) was determined by the Kjeldahl method and protein content was estimated by multiplying the nitrogen value by 6.25 (Jouki et al., 2014a, b). Measurements were carried out in triplicates.

2.4. Emulsion preparation

Sun flower oil was added into 2.5% w/v (g/ml) WPI solution prepared with distilled water, to obtain dispersions with 2% (w/v) WPI and 20% (w/v) sun flower oil. An O/W emulsion was formed by homogenization at 7500 rpm for 2 min with a high-speed homogenizer (WiseTis HG-15D, Wertheim, Germany). Xanthan gum (XG) and quince seed gum (QG) with varying concentrations (0.05%, 0.1%, 0.2%, 0.3%, 0.5%, 0.75% w/v) were added to the emulsions and homogenized at 7500 rpm for 3 min. Sodium azide (0.02% w/v) was added into the final emulsions as an antimicrobial agent. The final compositions of the emulsions are given in Table 1. Day 0 measurements were carried out within 1–3 h of emulsion preparation. For time-dependent measurements, the emulsions were sealed and stored in refrigerator at 4 °C. With a simple chilling test, it was assured that oil did not freeze under refrigeration temperature. No pH adjustments were made to the final emulsions since both WPI concentration and oil-phase volume fraction had little effect on pH. The final pH of the emulsions ranged between 6.5–7.

2.5. Rheological characterization

Shear rate ramp and amplitude sweep tests were conducted using a cone-and-plate (40 mm diameter and 4° cone angle, 0.1425 mm gap) dynamic rheometer (Kinexus Dynamic Rheometer, Malvern, UK). For shear rate ramp, shear stress values were recorded for shear rates varying between 0.1 s^{-1}–100 s^{-1}, with a total ramp time of 2 min and 20 sample points. Amplitude tests were conducted to measure the linear viscoelastic region of the samples with varying strains of 0.1%–100% and at a fixed frequency of 1 Hz. Storage (G′) and loss (G″) moduli were recorded for increasing strains (at constant frequency).

The data were fit to power-law model;

$$\tau = K\dot{\gamma}^n$$

where τ is shear stress, K is the consistency index, $\dot{\gamma}$ is shear rate, n is flow behaviour index. All rheological measurements were performed at 25 ± 0.1 °C within 2 h of emulsion preparation.

2.6. Particle size measurements

A light diffraction based particle size analyzer (Mastersizer 3000, Malvern, UK) was used to analyze the volume–moment mean diameter (d_{43}), calculated as;

$$d_{43} = \frac{\sum n_i d_i^4}{\sum n_i d_i^3}$$

where n_i is the number of particles in emulsion with diameter d_i. Refractive indices of 1.46 and 1.33 were used for the fat droplet, and the aqueous phase, respectively. For fat droplets, an absorption of 0.01 was used (Ruttarattanamongkol, Afizah, & Rizvi, 2015). Emulsions were diluted to

Table 1
Composition of the O/W emulsions.

Sample description	Conc. Of WPI (% w/v)	Conc. of sun flower oil (% v/v)	Conc. of xanthan gum (% w/v)	Conc. of quince seed gum (% w/v)
NOX	2	20	0	0
0.05X	2	20	0.05	0
0.1X	2	20	0.1	0
0.2X	2	20	0.2	0
0.3X	2	20	0.3	0
0.5X	2	20	0.5	0
0.75X	2	20	0.75	0
0.05Q	2	20	0	0.05
0.1Q	2	20	0	0.1
0.2Q	2	20	0	0.2
0.3Q	2	20	0	0.3
0.5Q	2	20	0	0.5
0.75Q	2	20	0	0.75