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A comparative study on the emulsifying properties of various species of gum tragacanth

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ABSTRACT

Emulsification activities of three different species of gum tragacanth containing *Astragalus gossypinus*, *A. compactus* and *A. rahensis* were investigated. Emulsion stability indexes, particle size distributions, steady and unsteady rheological properties and some other physicochemical attributes including the surface tensions and uronic acid contents were taken into consideration. It was revealed that *A. gossypinus* created the most stable emulsions although having lower viscosity than *A. compactus*. It is believed that higher insoluble fraction and higher uronic content made this species a good steric and electrostatic emulsifier.

1. Introduction

Gum tragacanth (GT), exuded from different species of *Astragalus*, is a heterogeneous branched anionic biopolymer [1] with a high molecular weight (about 8.4×10^5 Da) [2] which belongs to the adsorbing polysaccharide category [3]. GT has been in Generally Recognized as Safe (GRAS) list since 1961 and can be used at 0.2–1.3% level in food stuffs [4]. Due to the unique properties such as high acid resistance, stabilizing, emulsifying and gelling ability, GT has numerous applications in food, pharmaceutical and cosmetic industries [5,6].

It is well known that GT consists of two different fractions: tragacanthin (water-soluble) and bassorin (water-swellable) [7]. It is not well understood yet if the two fractions are in physical or chemical association, but the fact that they can be separated easily, favors the probability of a physical mixture [8]. Balaghi et al. [4] reported that the ratios of soluble to insoluble parts, physicochemical and rheological properties of various species are completely different. They also suggested that the sugar composition of GT is strongly species-dependent and the functional properties of the gums are greatly influenced by their sugar compositions [9]. Anderson et al. [10] reported that bassorin and tragacanthin of different species have different amount of uronic acid, methoxyl and neutral sugar contents. So regarding different characteristics of various species, different applications could be expected for each species [9,11].

Emulsions form an important component of many processed food formulations [12]. They consist of two immiscible liquids (usually oil and water), one dispersed in the other as small droplets. Emulsions are thermodynamically unstable but can be kinetically stabilized for a reasonable period of time by adding emulsifiers and/or thickening agents [13]. It should be noted that most low molecular weight emulsifiers do not have health clearance, are limited in their use levels or are restricted to certain foods [14], while biopolymers such as proteins and polysaccharides are completely accepted as food ingredients [15]. So food industry has presented an increasing interest in replacing these biopolymers instead of low molecular weight emulsifiers [16,17].

Most polysaccharides exhibit thickening rather than emulsifying properties; means they prevent phase separation through increasing the viscosity of the continuous phase [18]. Although, it is reported that some polysaccharides such as gum Arabic (GA), modified starches, sugar beet pectin, some galactomannans and soy soluble polysaccharide exhibit emulsifying properties [18–23]. These surface active polysaccharides adsorb to the oil/water interface and stabilize dispersed phase against coalescence through steric or electrostatic interactions. Most studies about surface active polysaccharides have been carried out on GA and it is reported that the emulsifying activity of this gum is attributed to the small amount of protein which is included in its structure as an arabinogalactan–protein complex (AGP) [23–25]. On the whole,

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the surface activities of polysaccharide emulsifiers are attributed to the presence of a protein moiety linked covalently or physically to the polysaccharide (in GA, pectin, etc.) or the non-polar chemical groups attached to the hydrophilic polysaccharide backbone (in some galactomannans and hydrophobically modified starch) [18,26].

Anderson and Bridgeman [10] reported that different species of GT contain small amounts of protein (<4%w/w). Also, Balaghi et al. [4] reported that GT has significant surface activity and can rapidly decrease surface tension of water at low concentration. Many previous studies have classified GT among polysaccharide emulsifiers but no one have worked on samples with known botanical sources and also the characteristics of emulsion systems containing GT are not studied [1,16]. So the aims of this work are comparing the emulsifying properties of three different species of GT and discussing the physicochemical attributes.

2. Materials and methods

2.1. Materials

Three species of Iranian GT exuded by *Astragalus compactus*, *A. gossypinus* and *A. rahensis* were collected from different provinces of Iran. The raw gum was ground and sieved. Powdered gum with a mesh size between 100 and 500 μm was used in this study. The galacturonic acid contents of these species were 30, 37 and 9 mg/g, respectively. Commercial sunflower oil from the same lot was prepared from the local market.

2.2. Preparation of gum dispersions

GT dispersions (0.5% w/w) were prepared by adding 0.5 g of gum powder (100–500 μm) to 99.5 g of distilled water that had been heated up to 35 °C. This mixture was then stirred for 10 min at 800 rpm. Sodium azide (100 mg L^{-1}) was added to prevent microbial growth. The solution was stored at 4 °C overnight to ensure that the hydration of the gum was complete. Other concentrations include 0.1, 0.2, 0.3, and 0.4% (w/w) were obtained by diluting these dispersions. These concentrations were chosen based on previous studies (data not shown).

2.3. Production of O/W emulsions

For the preparation of O/W emulsions, 10% (w/w) sunflower oil was added gradually to the gum dispersions and homogenized for 15 min at 13,500 rpm (based on previous studies) by Ultraturax (IKA T25, Deutschland, Germany). Emulsions were ice-coated in order to prevent temperature fluctuations.

2.4. Emulsion physical stability

Emulsion stability was evaluated by measuring the extent of gravitational phase separation. For the measurement of physical stability, freshly prepared emulsions (15 ml) were transferred into cylindrical glass tubes (internal diameter 10 mm, height 120 mm), capped and stored for 270 days at room temperature. The emulsion stability index (ESI) was calculated as follows (Eq. (1)):

$$\mathrm{ESI}(\%) = \frac{\mathrm{HE} - (\mathrm{HC} + \mathrm{HS})}{\mathrm{HE}} \times 100 \quad (1)$$

where HE is the initial emulsion height, HC is the height of the cream layer and HS is the height of the sedimentation phase. Monitoring tests were performed in triplicate and the mean of the three individual trials was taken for data analysis.

2.5. Particle size analysis

The particle size distributions of dispersions and emulsions were determined at room temperature with a laser diffraction particle size analyzer (Cilas 1090, Orleans, France) equipped with a 5 mW He/Ne (635 nm) laser beam. The concentrated emulsions were diluted with deionized water (1:100) to avoid multiple scattering effects. Size measurements are reported as the volume weighted mean diameter and diameter in number (Eqs. (2) and (3)):

$$D_{4,3} = \frac{\sum n_i d_i^4}{\sum n_i d_i^3} \quad (2)$$

$$D_n = \frac{\sum n_i d_i}{\sum n_i} \quad (3)$$

where n_i is the number of particles of class "i", and d_i is the diameter of class "i".

Also, the distribution width of droplet size, known as the polydispersity index (span), was determined from Eq. (4):

$$\mathrm{span} = \frac{d_{0.9} - d_{0.1}}{d_{0.5}} \quad (4)$$

where $d_{0.1}$, $d_{0.5}$ and $d_{0.9}$ are diameters at 10%, 50%, and 90% cumulative volume, respectively.

2.6. Rheological properties

Steady shear viscosity, strain and frequency sweep oscillatory shear tests were performed with a Physica MCR 301 rheometer (Anton Paar GmbH, Graz, Austria) equipped with a concentric cylinder measurement system with a radius ratio of 1.0846. The temperature was adjusted to 25 °C with a peltier system equipped with fluid circulator with an accuracy of 10^{-2}. Rheological data were collected using Rheoplus software version 3.21 (Anton-Paar). Flow curves were obtained at shear rates of 0.1–300 s^{-1} (and at 1–300 s^{-1}, when the behavior of the system approached Newtonian). A power law model was used to describe the rheological properties of emulsions. The flow behavior index (n) and consistency coefficient (m) values were obtained by fitting the shear rate versus apparent viscosity to the power law model (Eq. (5)):

$$\eta_a = m\gamma^{n-1} \quad (5)$$

where η_a is the apparent viscosity (Pa s), m is the consistency coefficient (Pa s^n), γ is the shear rate (s^{-1}) and n is the flow behavior index (dimensionless).

Strain sweep tests were performed at strain of 0.05–300% and fixed frequency of 1 Hz to determine the linear region of viscoelasticity. Frequency sweep tests were carried out at frequency of 0.01–15 Hz and constant strain of 1% to evaluate the dynamic rheological properties such as G' and G''.

2.7. Optical microscopy

Oil in water emulsions were gently agitated in a glass test tube to ensure homogeneity prior to analysis. A drop of emulsion sample was placed on a microscope slide, covered with a cover slip. Microstructure was visualized by light microscopy (CETI microscopes, Magnum Compound, Belgium) at 40× magnifications. Images were made immediately after preparation of emulsion.

2.8. Statistical analysis

All treatments were performed three times and the data were analyzed by variance (ANOVA). Significant differences between