

Investigation on the emulsifying properties of Persian gum as a novel food emulsifier

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Abstract—*Persian gum (PG), an exudate of wild almond tree *Amygdalus scoparia* Spach, is one of the natural hydrocolloids which are mostly produced in Iran. In the present study, the emulsifying properties of its soluble fraction (SFPG): oil at various ratios [0.25:1 (E1); 0.5:1 (E2); 1:1 (E3); 2:1 (E4); 1:2 (E5)] in comparison to Arabic gum (AG) as control [1:1 (CTL)] have been studied. The results have indicated that heat treatment has no effects on the stability of the of SFPG emulsions against AG emulsion. Among all of the emulsions, E4 has the highest emulsion stability index over 5 weeks (ca. 99% at fifth week and room temperature); moreover the measurement of optical density justifies the good emulsifying properties of E4 (0.8752 in 500 nm at fifth week) which is significantly more than CTL (0.3648 in 500 nm at fifth week). Particle size distribution of the samples immediately after preparation, illustrates that E4 and CTL has a similar sharp curves with fine average droplet diameter (D [4,3] 0.8 μm); nevertheless at day 0, the emulsifying properties of E4 and CTL are similar, but during the storage for 5 weeks, E4 shows a higher stability than CTL.*

Keywords- *Persian gum, *Amygdalus scoparia* Spach, Emulsification; Stability.*

I. INTRODUCTION

From the Physicochemical point of view, emulsions are unstable systems which separate into two immiscible phases over a period of time but they can be stabilized by improvement of their kinetics stability [1]. A very important problem in emulsion technology is controlling the physical stability (against creaming, flocculation, and coalescence), rheological properties and chemical stability of the food emulsions [2] using appropriate emulsifiers and thickening agents. The ability of emulsifiers to produce a stable emulsion is due to their interfacial properties at oil–water and air–water interfaces [3]. Hydrocolloids or gums are water soluble/dispersible polysaccharides which are well-known as viscosity builders and/or gelling agents in aqueous systems. Some hydrocolloids can reduce the surface and interfacial tensions which are termed as emulsifiers, whereas the other kind has the power of stabilization that seems to be caused by the steric (or by a film–forming mechanical barrier) or the weak absorption of the hydrocolloids onto the oil droplets [2].

Wild almond tree (*Amygdalus scoparia* Spach, Rosaceae family), mostly grows in Irani–Tourani regions, it exudates Persian gum (PG) which its combination with Arabic gum or tragacanth can be used as a suspending or emulsifying

agent [4]. With the best of our knowledge, there is no report regarding the emulsifying properties of PG. Although, Arabic gum (AG) is already considered as the proper hydrocolloid for being used in dilute oil–in–water emulsions [5]. In addition, Qian, Cui, Wang, Wang & Zhou (2011) showed that the fractions of peach gum (from Rosaceae family) could stabilize emulsions (maximum emulsion stability was ca. 95%) much better than AG (ca. 65%). They believed that the polysaccharide fractions of peach gum, despite having no protein, showed emulsifying and stabilizing properties which was due to the high molecular weight and highly branched structures [6].

Therefore in this study, we aim to investigate the emulsifying properties of PG as well as its soluble fraction in comparison with AG.

II. EXPERIMENTAL

a) Materials

PG has been collected manually from the barks of mountain almond trees in Fars province (Iran). Except sunflower oil which was purchased from local supermarkets, all the chemicals with analytical grade have been obtained from Merck chemicals Company (Darmshtat, Germany).

b) Emulsifying ability

At first, for determination of the emulsifying ability of whole PG, its soluble (SFPG) and insoluble (IFPG) fractions, some emulsions containing various concentrations (0.25, 0.5, 1 and 2% w/v) of each above mentioned fractions against constant concentration of oil (5% w/v) at imidazole buffer (pH 7) are prepared. For this purpose, stock dispersion of PG (4% w/v) is prepared at imidazole buffer and after complete hydration for one night at room temperature, it is centrifuged (Sigma, 30-30k, Germany) at 14000 rpm for 15 min to separate the soluble (SFPG) from the insoluble fractions (IFPG). Afterwards, the SFPG is concentrated using a rotary evaporator (Heidolph, Laborota 4000 efficient, Germany) at low temperatures (<40 °C). The resulting SFPG is weighed (on the basis of its dry matter Table I) and used for the preparation of emulsions (150 ml). The sunflower oil (oil phase at various ratios) is added drop wise to the above aqueous phase while stirring (Janke & Kunkel, RW 20, Germany). The mixture pre-homogenized (21500 rpm for 1 min) by a disperser (UltraTurrax, IKA, Germany) to produce a pre-emulsion, then the homogenization is applied (APV, 200, Denmark) at different pressure levels (150, 200 and 250 bars).

TABLE I. The formulation of the examined emulsions

Emulsion code ^a	Gum content (% w/v) ^b	Oil content (% w/v)
E1	0.25 (SFPG)	1
E2	0.5 (SFPG)	1
E3	1 (SFPG)	1
E4	2 (SFPG)	1
E5	1 (SFPG)	2
CTL	1 (AG)	1

^{a,b} E, CTL, SFPG and AG are the summary symbol of the Emulsion ,Control, Soluble fraction of Persian gum and Arabic gum, respectively.

c) Particle size distribution

Immediately after the emulsification, the particle size distribution and D [4,3] of the specimens are determined by Malvern Mastersizer (2000, UK) [7].

d) Microstructure

The microscopic images (magnitude $\times 40$ and $\times 100$) are taken from the emulsions immediately after preparation as well as after storage (5 weeks at room temperature) by an optical microscope (Olympus, AX70, Japan) which has been equipped with a digital camera (Olympus, DP12, Japan).

e) Optical Density (OD) measurement

The optical density (OD) of the diluted emulsions (dilution rate to 10 times) is measured immediately after preparation and also after storage (5 weeks at room temperature) by a spectrophotometer (Sinco, UVS-2100, Seoul, South Korea) at 500 nm. OD is in proportion to the number (per unit volume) and radius of the droplets which its changes against storage time reflects the emulsion stability to coalescence [8].

f) Emulsifying stability

For determination of the emulsion stability vs. heating (ESH), immediately after emulsification, 15 mL of each emulsion is heated at 80 °C for 30 min. Then it is centrifuged at 1600 rpm for 10 min and ESH is calculated by the ratio of the height of emulsified layer to the total height [9]. For monitoring of the creaming from preparation up to 5 weeks, a constant volume of emulsions are sealed in test tubes and stored at: refrigerator (4 °C), room (ca. 25 °C) and oven (50 °C) (Memert, Germany) temperatures. Regarding the coalescence and/or flocculation, the emulsion would separate to two or three phases which presents the creaming phenomenon and is illustrative of the emulsion stability index (ESI). ESI is a scale of rate which an emulsion creams flocculates or coalesces [10] ESI is calculated by the equation below:

$$ESI = [(HE - (HC + HS)) / HE] \times 100 \quad (1)$$

Where, HE, HC and HS are the height of the initial emulsion, cream layer and sediment phase, respectively [1].

III. RESULT AND DISCAUION

The initial results show that PG and specially SFPG, could emulsify the ratio of 10 times of oil against gum (0.5% w/v of SFPG and 5% w/v of oil) or less; though this emulsion became unstable after a day at refrigerator temperature, but it can be assigned to the ability of PG for emulsification.

It is acceptable that some characteristics such as hydrophilic/hydrophobic character, the acid/base character and the presence of specific groups, altogether can have an impact on the absorption of the hydrocolloids [11].

A monomodal distribution of droplet size with a small average diameter commonly signifies a stable system [7]. As it is shown in Fig. I all of the curves are monomodal but unfavorably, E5 has an extent distribution of particle size from 0.25 to 2.5 μm and D[4,3] 1.13 μm which demonstrates that low amount of gum against oil in the emulsion can strongly affect the droplet size distribution due to the fact that some oil droplets will remain uncoated in the emulsion because of gum shortage, which finally causes decreasing the stabilization of the matrix. Both E4 and CTL, have similar curves with D[4,3] 0.8 μm at a limited range of size distribution (0.3 to 2 μm) which refers to the emulsifying/stabilizing ability of SFPG in comparison to AG as a commercial emulsifier.

Our results is comparable to the results of Huang, Kakuda & Cui (2001) which showed that the fenugreek gum emulsion had a very small average droplet diameter, under 0.75 μm , as compared with methylcellulose, xanthan, pectin and AG with the average droplet diameter over 20 μm . Also it was demonstrated that the addition of more fenugreek gum was able to coat a greater surface area and induce the formation of greater number of smaller particles [10]. Also Garti, Slavin & Aserin, (1999) illustrated that at higher gum concentrations (>0.7 wt %), size reduction of oil droplets is difficult, whereas it was revealed that the emulsions with low gum concentration had a powerful tendency to flocculate, while those with high gum concentrations were without flocculation [8]. Furthermore the theory of depletion flocculation predicts that the increasing in the concentration of non-adsorbing biopolymers causes the increase of the interdroplet attractions [12].

Regarding the inadequate quality of some optical microscopic pictures, hence only two pictures of E1 are shown in Fig. II optical microscopy doesn't seem an excellent way for monitoring the growth of such small droplets in emulsions, but it can give a viewpoint about their

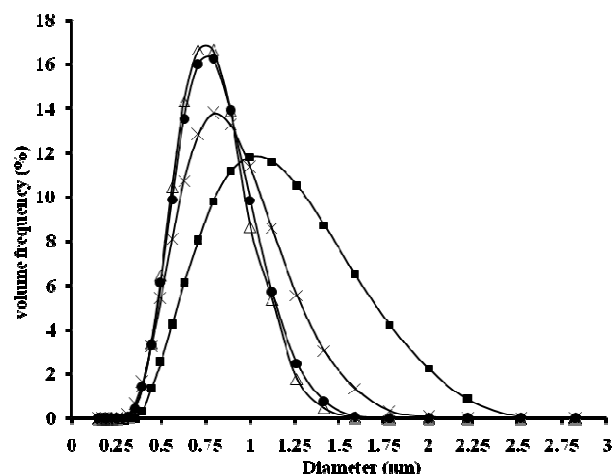


Figure. I. Particle size distribution of some emulsions (×, E1; Δ, E4; ■, E5; and ●, CTL) immediately after preparation

bulk appearance fast and well [7]. Apparently, it is demonstrated that the period of time could increase the size of droplets in emulsion that may be due to the various destabilizing phenomena like aggregation, coalescence and flocculation and so on; this result is also comparable to the ESI. The nature and power of the interactions at the surface of droplets affect the type and degree of flocculation which these attractions altogether lead to bridging flocculation and repulsion to depletion flocculation [2].

In accordance with Fig. III, OD is increased in all of the emulsions from week 0 to 5 as well as by rising up the concentration of SFPG against constant oil. E3 has similar OD vs. CTL (with the same formulation and meaningless difference) which demonstrates that SFPG has a very good emulsifying/stabilizing impact on the emulsion in comparison with AG. The monotonic increase at OD respect to gum concentration indicates an increase in the emulsifying activity index and total surface area of the droplets [8]. On the other hand, the OD of E4 and E5 are equal that it can be resulted from the more content of oil in E5 against E4.

After centrifugation, none of the heat treated emulsions separated and had a very homogenous texture; On the other hand, the ESH was 100% for SFPG; But the ESH of CTL was approximately 88%, that probably was due to the denaturation of the proteins that induced by heating. This confirms Williams, Phillips, Stephen & Churms (2006) and Garti, Slavin & Aserin, (1999) which reported that the emulsifying power of AG can be lost by heating and this causes some precipitation of correlation between nitrogen content of AG and its surface activity which showed that there is no simple correlation between nitrogen content and emulsifying properties [14].

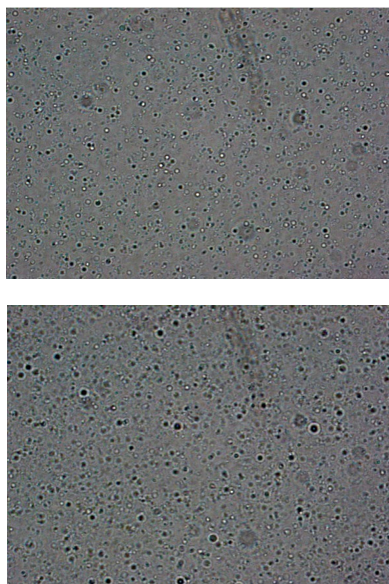


Figure. II. Optical microscopic pictures of E1: (Top) immediately after preparation, (Under) after 5 weeks storage at room temperature (25 °C) with magnitude $\times 40$

Garti, Slavin & Aserin, (1999) suggested that in most of the cases, the stability of the emulsions containing polysaccharides can be considered a non-absorbing 'depletion stabilization' [8]. These facts demonstrated that the probable reason of the high ESH of the SFPG couldn't be related to its protein contents ($0.146 \pm 0.013\%$), therefore it has a strong enhancing effect on the emulsion matrix viscosity. In theory, heat treatment of the gum solution can affect the gum as the following forms: (1) expose the hydrophobic segments of the gum to the oil phase (unfolding effect), e.g. heat treated solutions of guar gum form more stable emulsions; (2) lead to protein denaturation in the gum-protein complex; (3) decrease surface and emulsification properties of the gum, e.g. AG; (4) cleave intramolecular hydrogen bonds and change the hydrophobicity/ hydrophilicity balance of the gum [2]. Creaming is causal of the gravitation in which dispersed particles are less dense than the suspending fluid which finally tends to rising to the top, and forming a concentrated layer (the cream) and this is a sign of emulsion instability and subsequent breaking down [15]. Generally speaking and with respect to Fig. IV, the emulsions at room temperature were more stable than the others which it may be due to the fact that at low temperatures, the sedimentation is easier whereas at high temperatures, the oil phase can be separated from the matrix easily and both of them can ease the separation of the phases in the emulsion. All the emulsions had high ESI even after 5 weeks and the best of them was E4, which is comparable to the CTL.

Dickinson (2009) demonstrated that very low concentrations of hydrocolloid in emulsion has a destabilizing effect, since the depletion flocculation induced by the non-absorbing hydrocolloid leads to enhanced serum separation of the emulsion; however at higher concentrations of hydrocolloid, when the depletion interactions are stronger, due to the viscoelastic character of the interconnected regions of emulsion droplets that are flocculated in a gel-like network, creaming is inhibited [16].

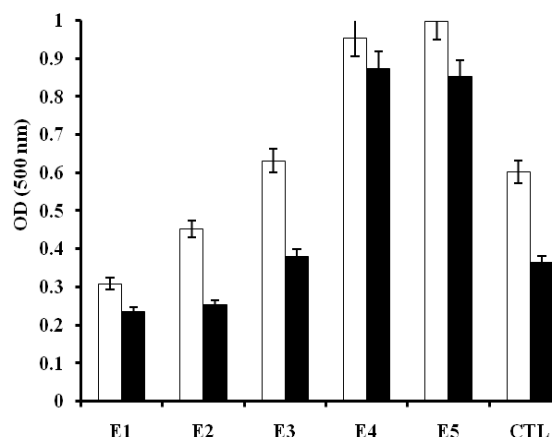


Figure. III. Effect of storage on the optical density of emulsions (E1-E5 and CTL) at: □, week 0 (immediately after preparation); and ■, week 5

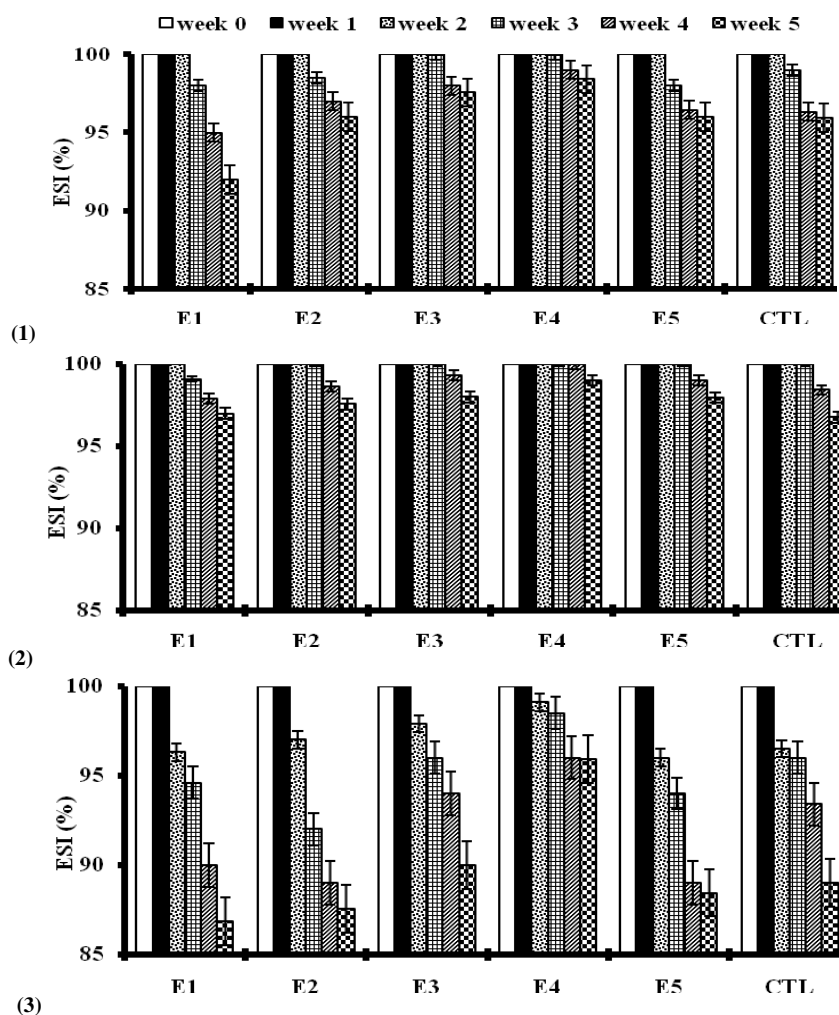


Figure IV. Emulsion stability index (ESI) of the emulsions (E1–E5 and CTL) at different temperatures: (1) 4°C, (2) 25°C and (3) 50°C from week 0–5.

Also, Semenova, Dickinson, Burlakova & Zaikov (2010) illustrated that at higher polysaccharide concentration in emulsion, the combination of depletion flocculation and local phase separation (at microscopic length scale) is the predominant stabilizing mechanism against the macroscopic creaming and serum separation [17].

IV. CONCLUSION

SFPG can act as a very effective emulsifier/stabilizer in emulsions which is comparable to the AG. Different formulations of the emulsions in this research demonstrate that 2% w/v of SFPG with 1% w/v of oil can produce an emulsion with high stability at least for 5 weeks.

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