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The Effects of Iranian Gum Tragacanth on the Foaming Properties of Egg White Proteins in Comparison with Guar and Xanthan Gums

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ABSTRACT: This paper presents the results of studies concerned with the preparation of fresh food foams based on egg white and various hydrocolloids including Iranian gum tragacanth, guar and xanthan gums at different concentrations (0.002-0.040% w/w). The basic physical parameters of the obtained foams such as overrun, stability and morphology of gas bubbles were measured. Viscosity measurements were also performed, and Power law model was applied to describe the flow behavior of gum solutions. The addition of hydrocolloids into the egg white solution had a deteriorative effect on the foam expansion but enhanced the foam stability. In addition, ANOVA showed that by increasing the concentration of the hydrocolloids in egg white solution significantly decreased the overrun and foam drainage ($p<0.05$). The stability of egg white foam in the presence of gum tragacanth was lower than xanthan gum and higher than guar counterpart. However, higher overrun was observed for tragacanth when compared to xanthan. Optical microscopy also showed smaller bubbles for foams which stabilized with tragacanth or xanthan in comparison with larger ones in the case of guar gum that stabilized the egg white foam. Rheological measurements also showed a pseudoplastic behavior for gum solutions at higher concentrations.

Keywords: *Egg White Foam, Foam Stability, Gum Tragacanth, Guar Gum, Xanthan Gum.*

Introduction

Food foams may be defined as the products containing a gaseous phase stabilized in a matrix of water and proteins. Ice cream, whipped cream, mousses and meringues or marshmallows are foams that present these (Miquelim & Da Silva Lannes, 2009). Egg white is a good foaming agent that is commonly used in food industry. Different proteins in egg white (globulins, ovoalbumin, ovotransferin, lysozyme, ovomucoid and ovomusin) are responsible for this ability (Sadahira *et al.,* 2014). Proteins stabilize the foams by the following mechanism: adsorption, partially denaturation, and exposition of hydrophobic parts, aggregation and formation of a network at the interface of the foam films (Sagis *et al.,* 2001). Each of egg white proteins, plays an important role in foaming properties, for instance, globulins are the most important protein in the foam formation because of their surface activity (Lomakina & Mikova, 2006). Lysozyme, on the other hand, increases the strength of formed film through interaction with other proteins. Despite good foaming-ability, foams prepared from egg white are unstable and the foam drainage and collapse are the results of this instability (Ptaszek *et al.,* 2014).

Foaming properties of egg white proteins and stability of resulted foam are greatly influenced by different factors such as the storage and beating time, blending, homogenization, centrifugation,

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temperature, pasteurization, pH, water, sugar, presence of egg yolk, stabilizers and surfactants and metallic cations (Lomakina & Mikova, 2006). Hence, many researchers applied various methods for improvement of egg white foaming properties including the addition of low and high molecular mass chemicals such as mono-, di- and polysaccharides, change of pH and ionic strength, high pressure treatment, addition of copper ions and sodium chloride (Ptaszek *et al.,* 2014).

Recently, there is an increasing interest in low calorie and healthier foods, therefore the addition of mono and disaccharides to formulation is not desirable for consumers (Ptaszek, 2014). Also, some of other methods for foam stabilization such as changing pH and ionic strength showed post-use effects on the sensory properties of the final products (Ptaszek *et al.,* 2014). Accordingly, these methods are not common in food industry. Nowadays, utilization of polysaccharides particularly gums and hydrocolloids, for improvement of foam stability is a common and usual method.

In recent years, many researches have conducted investigations concerned with the effect of different polysaccharides (alone or in combination with other) on foaming properties of egg white proteins. For example, Sadahira *et al.* (2014) studied the influence of protein-pectin electrostatic interaction on the foaming stability mechanism in egg white foam. Zmudzinski *et al.* (2014) also studied the mechanical properties of egg white proteins fresh foam in the presence of xanthan gum (XG) and carrageenan. Miquelim and Da Silva Lannes (2009) identified the effect of interaction between egg albumin, gelatin, and guar gum (GG) on the rheological properties of resulting foam system. In general most common polysaccharides that are used for stabilization of foams are pectin, xanthan, and guar gum (Ptaszek, 2014).

To the best of our knowledge, there are not reports on the effect of Iranian gum tragacanth (GT) on the foaming properties of egg white. This gum is a dried exudation of shrubs of the Asiatic *Astragalus* species that is mainly located in Iran and Turkey (Balaghi *et al.,* 2010). It has been reported that Iran supplies the best quality of this gum and Turkish tragacanth has lower quality (Koshani *et al.,* 2015). Gum tragacanth is a branched, heterogeneous, and anionic polysaccharide which has a wide application in food industry, for example in salad dressings, bakery emulsions, confectionary, soft drinks, and many other products as a stabilizer, thickener, emulsifier, and suspending agent (Balaghi *et al.,* 2010). GT was accepted as a GRAS since 1961 with an allowed level of 0.2-1.3% by weight of product and also has E-number of E413 in Europe. Tragacanthin (water-soluble) and bassorin (acidic water-swellable) are two main components of gum tragacanth. This gum consists of L-arabinose, D-galactose, D-glucose, D-xylose, L-fucose, L-rhamnose and D-galacturonic acid upon acid hydrolysis (Koshani *et al.,* 2015).

The current study was undertaken to elucidate the effect of Iranian gum tragacanth on the foaming properties of egg white according to its high viscosity and surface activity, and to compare it with xanthan and guar gums which are two conventional gums for the stabilization of egg white foam.

Materials and Methods

- *Materials*

Whole eggs were supplied by Telavang Company and stored at refrigerator until use. Citric acid, xanthan and guar gums were obtained from Merck Chemical company, (Darmstadt, Germany). The Iranian gum tragacanth was purchased from the medical plant market in Tehran, Iran and stored at room temperature. The raw GT was powdered in a high-speed mechanical blender and sieved to obtain uniform samples with a mesh size between 200 and 500 mm.

- Preparation of gum solutions

Stock Solutions of xanthan, guar and tragacanth gums, were prepared by dissolving and stirring an appropriate amount of the gums powder in distilled water. After obtaining a uniform solution, the samples were stored at 4°C for full hydration. The final concentration of gums in the foam pre-solutions was considered between 0.002-0.040 % w/w.

- Preparation of egg white foams

Egg white was separated carefully from the yolk, because it has been established that the presence of small amounts of egg yolk has a negative effect on the foaming properties of egg white. Thereafter, 170 g egg white was mixed with 30 mL of gum solution with desired concentration for obtaining a 15% w/w water in the final solution. Water addition was followed by pH adjustment. pH was adjusted to 7.2-7.5 (natural pH of egg white) with 1.0 M citric acid. Citric acid was added while solution was stirring for preventing of protein clotting. Finally, the mixed solution of egg white, gum and water was whipped for 3 min by a bakery mixer (model I/BSP-BM5, Berjaya Steel Product Sdn Bhd, Malaysia) equipped with a stationary bowl by 5.0 L capacity and a netted shaped mixing agitator. The speed of the mixer was set at maximum rate that is common for mixing of egg white and thin materials (speed grade of 8, equal to 852 rpm).

-Overrun

Overrun was measured according to the method proposed by Yang *et al.* (2009). Immediately after whipping, 100 mL of foam was gently transferred to a standard graduated beaker, leveled using a rubber spatula and weighted. This process was repeated for 3 times per foam. Finally, overrun was determined using the following equation:

$$\text{Overrun (\%)} = \frac{A-B}{B} \times 100$$

where A and B are the mass of 100 mL of the initial solution (before whipping) and resulting foam, respectively.

-Foam stability

The stability of foam is usually determined by calculating the required time for collapsing a determined volume of foam. But this method is difficult and unreliable, because the collapse of foam is not always uniform. Therefore, in the present study, the foam stability was evaluated by monitoring the drainage. This was determined according to the procedure described by Sadahira *et al.* (2014) with some modification. In the modified method, volume of drained liquid from the foam after 30 min, was recorded and reported as mL/100 g foam.

-Micro-morphology analysis

The microscopic morphology of the selected foams with maximum stability was studied by a light microscope (BX51, OLYMPUS, Japan) equipped with a camera (SSC-DC338, SONY, Japan) at 25°C. For this purpose, immediately after whipping, small amounts of foams were placed onto a microscope slide and their morphology were viewed.

-Flow behavior of gum solutions

The flow behavior and apparent viscosity of gum solutions were measured with the help of a Brookfield viscometer (LVDV-II Pro, Brookfield Engineering Inc., USA) by using a ULA model of LV spindle at 20°C. For viscosity measurements, two concentrations of each gum with min and max of drainage were selected. Before viscosity measurements, these selected concentrations of gums were prepared separately by dissolving, stirring and complete hydration of an appropriate amount of gums in distilled water. About 25 mL of each sample was loaded into the cylinder of viscometer and sheared from 10 to170 s^{-1} within 5 s intervals. The obtained data was fitted to Power law model:

$\sigma = k\,(\gamma^{n})$

where σ, k, γ and n are shear stress, consistency coefficient, shear rate and flow behavior index, respectively.

- *Statistical analysis*

Data were analyzed by one-way ANOVA with SPSS software version 16 (IBM software, NY, USA) by using Duncan's test at 0.05 level of p for examination of differences among mean values.

Results and Discussion

- *Overrun*

The overrun indicates the gas hold-up in the egg white proteins foam. Foams are two-phase systems consisting of a dispersed phase (usually air) and a continuous phase (Talansier *et al.,* 2009). Foam overrun depends on the ratio of the dispersed to the continuous phases, reflecting the amount of air incorporated in the foam during whipping and formation. For example, high foam overrun indicates that more air was trapped, giving higher foam expansion (Pasban *et al.,* 2014a). As shown in Figure 1 overrun of egg white (1318 ± 25.5 %) was decreased in the presence of all three gums. Also, ANOVA showed that increasing the concentration of the hydrocolloids in egg white solution significantly decreased the overrun (p < 0.05). Therefore, gum concentration had an adverse effect on foam expansion. The results of Pasban *et al.* (2014a) also were also in accordance with our findings. They reported a higher foam density (lower foam expansion) for white button mushroom puree in the presence of endemic seed hydrocolloids (qodume shahri, basil, balangu and cress) and xanthan gum. According to the results of our experiments, it was found that the adverse effect of guar gum on the overrun was lower than the two other gums. Overrun of egg white solution with gum tragacanth also was higher in comparison with xanthan counterpart. These adverse effects partly might be due to the increasing of solution viscosity by means of gums. Thus, increasing the viscosity leads to a decrease in the incorporation of air, which

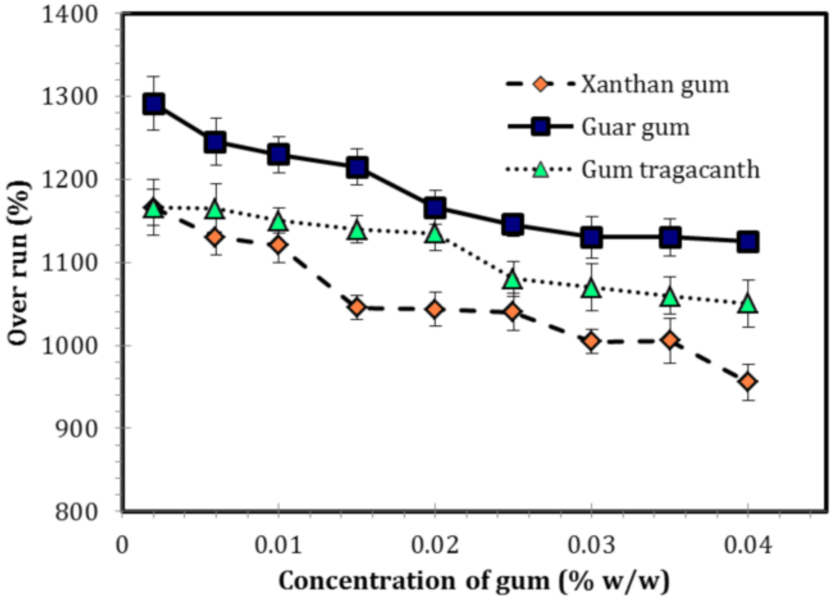

Fig. 1. The effect of different gums on foaming ability of egg white

results in the reduction of the foam expansion and an increase in the foam density. According to Azizpour *et al.* (2014), a high-viscosity liquid would prevent the trapping of air during whipping or mechanical mixing. Ibanoglu and Ercelebi (2007) also observed a lower foaming capacity for mixture of egg white and hydrocolloids including guar gum and pectin. However, they reported that the presence of these polysaccharides during heat treatment before whipping process does not affect the foaming properties of egg white.

In addition to the viscosity, the surface activity of gums can affect the overrun. It was reported that, the most obvious outcome of protein adsorption at air/aqueous interface (central importance to their foaming performance) is a reduction in interfacial (surface) tension (Foegeding *et al*., 2006). Therefore surface active hydrocolloids can help proteins to reduce the surface tension. Chemically-modified celluloses, modified-starch, gum arabic, some kinds of pectin and some galacomannans (e.g. guar and fenugreek gum) are of the most common examples of polysaccharides that exhibit good surface activity. It has been reported that highly surface-active polysaccharides may be enriched in deoxysugars (fucose and rhamnose) and contain auxiliary hydrophobic groups (methyl, acetyl and …) or some proteinaceous moieties which are attached covalently or physically to their backbone (Karimi & Mohammadifar, 2014). Efficiency of the surface-active molecules is generally evaluated by its ability in the reduction of surface tension of a solution. Therefore in the case of tragacanth, Karimi and Mohammadifar (2014) observed a reduction in the surface tension of water from 72.03 mN/m to 51.88 mN/m at room temperature. Reducing the surface and interfacial tensions by means of tragacanth was attributed to the presence of galactose units and protein in its chemical composition.

- *Foam stability*

Drainage volume is an important parameter to evaluate the stability of the foaming systems. This parameter is the flow of liquid through foam driven by capillary or external forces such as gravity which results in thinning of lamella (the thin wall of foam bubbles), followed by film rupture and foam destruction (Pasban *et al.,* 2014b). The effects of different gums including guar, xanthan and tragacanth on the drainage of foams are shown in Figure 2. As expected, lower drainage volumes resulted in more stable foam systems. ANOVA showed that the hydrocolloids which were tested as foam stabilizers in this study had a significant effect on the stability of egg white foam ($p<0.05$); lower drainage volume was observed for solution in the presence of gums in comparison with foam which prepared only from egg white (28 ± 1.25 mL/100 g foam). As shown in Figure 2, foam drainage decreased by increasing the concentration of the hydrocolloids including guar, xanthan and tragacanth. These positive effects of gums on egg white stability are mainly due to the increasing interfacial viscoelasticity of foam lamella (Ptaszek *et al.,* 2014). In agreement with our results, Zmudzinski *et al.* (2014) also reported a higher stability for freshly prepared foams based on egg white proteins and hydrocolloids (xanthan and carrageenan). Similar results were observed by Ptaszek (2014) for egg white foams with apple pectin and xanthan gum. In fact, the hydrophobic nature of hydrocolloids prevents them from being absorbed at plateau borders, thereby strengthening foam bubble and finally improving the stability of system (Pasban *et al.,* 2014a). As can be seen in Figure 2, xanthan gum had the greatest effect on foam stability. Drainage

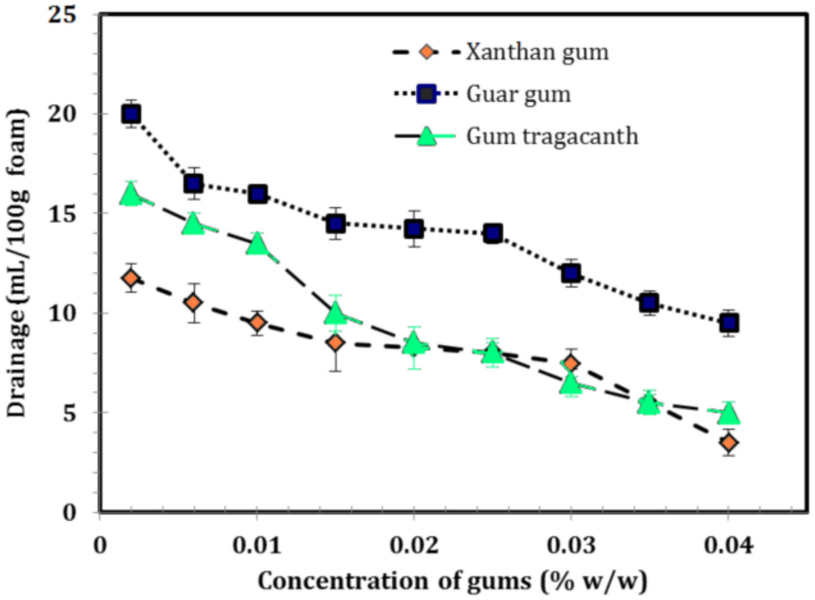

Fig. 2. The effect of different gums concentrations on drainage volume

volume of foams with tragacanth was also lower than guar gum. These observations might be due to the increase in aqueous phase viscosity by means of gums. Pasban *et al.* (2014b) suggested that foam is more stable at high viscosity and this would protect the interfacial wall from breaking easily. The positive effect of tragacanth gum on the foam stability in comparison with guar gum might be the result of higher viscosity as well as the surface activity. These results were supported by viscosity measurements which will be discussed later. Koshani *et al.* (2015) reported a higher stability for chicken egg white lysozyme foam that was conjugated with tragacanthin (water-soluble part of gum tragacanth) and this phenomenon was attributed to the thickening effect of tragacanthin.

- *Microscopic analysis*

Foam is a large volume of gas mixed with a much smaller amount of a fluid, but in time these two components tend to separate, the fluid drains and the foam becomes dryer and the bubbles compress together (Oboroceanu *et al.,* 2014). Micrographs for foam bubble size are shown in Figure 3. As mentioned earlier, in the case of gum tragacanth and xanthan gum, due to the higher viscosity of solution, the incorporation of air into foam was lower than those prepared by guar gum. Therefore the foam density increased and bubbles with smaller size were observed in the presence of these gums in comparison with the large ones in the case of egg white foam with or without guar gum. Furthermore, foams prepared in the presence of tragacanth and xanthan had a large number of more closely packed small bubbles as compared to either egg white or egg white-guar gum foams.

In agreement with our observations, Lomakina and Mikova (2006) reported that the formation of small bubbles leads to a slow drainage of liquid from the foam. Moreover, it was suggested that hydrocolloids in the foams provide a yield value in the liquid phase that retains the bubbles in place (Pasban *et al.,* 2014a). The higher the stability of bubbles with smaller initial size can be explained based on bubble destabilization mechanisms. Creaming occurs in foam due to the density difference

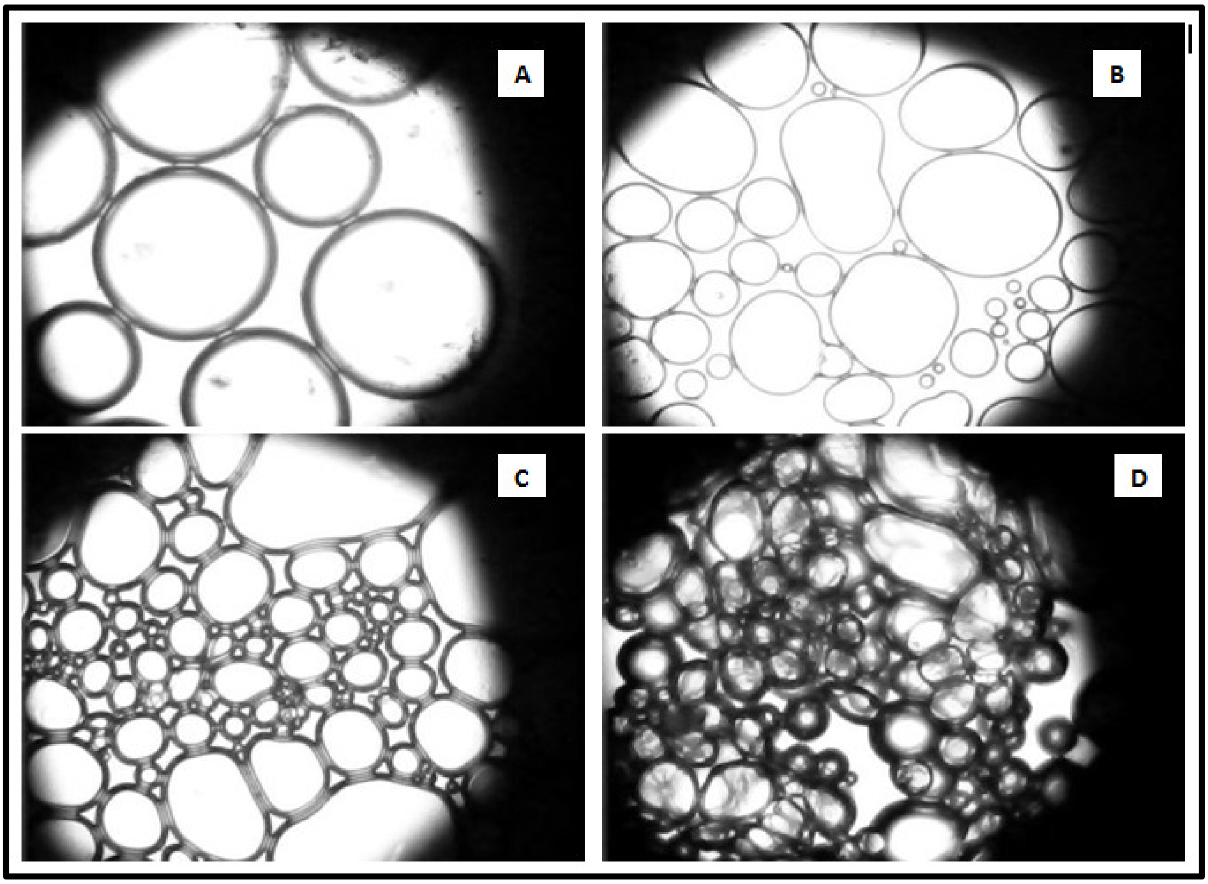

Fig. 3. Typical photomicrographs of foams with highest stability (i.e. minimum drainage) which prepared from (A) egg white without gums, (B) egg white + guar gum, (C) egg white + gum tragacanth, and (D) egg white + xanthan gum.

between gas and the continuous phase. A larger bubble size leads to greater buoyancy force and a faster creaming rate according to Stokes law (Walstra, 2003). Disproportionation occurs when gas diffuses from small bubbles through the aqueous phase into larger bubbles, resulting in small bubbles shrinking and large bubbles growing. The driving force of this process is the Laplace pressure difference between bubbles, which depends on the bubble size distribution. Large bubbles in the foam get larger due to disproportionation, and move faster to the top due to the creaming phenomenon. The gathering of large bubbles promotes coalescence, which is the rupturing of the film between two bubbles producing one larger bubble. These destabilizations result in an increase in bubble size and a decrease in bubble count (Yang *et al.,* 2009).

-Viscosity measurements and flow behavior

As it can be seen (Table 1), the highest viscosity was observed for xanthan. Viscosity of gum tragacanth also was higher than guar at both concentrations (0.002 and 0.040 % w/w). These results support our observations about overrun and foam stability. At concentration of 0.002%, gum solutions showed a Newtonian ($n \approx 1$) flow behavior in comparison with shear-thinning ($n<1$) ones at 0.040 % counterparts (Table 2). In fact, as the concentration increases, the behavior changes from Newtonian to pseudoplastic in which viscosity decreases with the increase in the shear rate.

Table 1. Viscosity of different samples at 50 s^{-1}

Concentration (% w/w)	Gum	Viscosity (cp)
0.002	Xanthan	2.15 ± 0.015^a
	Tragacanth	1.73 ± 0.034^b
	Guar	1.34 ± 0.005^c
0.040	Xanthan	2.71 ± 0.035^a
	Tragacanth	2.00 ± 0.020^b
	Guar	1.63 ± 0.112^c

Means with different superscripts within a column differ significantly ($p< 0.05$).

Table 2. Parameters from power law model fitting for different gum solutions

Concentration (% w/w)	Gum	*n*	*K (Pa.s^n)*	R^2 (%)
0.002	XG	0.98 ± 0.01^a	0.024 ± 0.002^a	99.4 ± 0.6
	GT	0.98 ± 0.02^a	0.018 ± 0.004^b	99.5 ± 0.0
	GG	0.97 ± 0.03^a	0.012 ± 0.001^c	98.9 ± 0.5
0.040	XG	0.88 ± 0.04^a	0.068 ± 0.005^a	99.1 ± 0.4
	GT	0.87 ± 0.05^a	0.043 ± 0.008^b	99.0 ± 0.1
	GG	0.90 ± 0.02^a	0.028 ± 0.010^c	99.8 ± 0.2

Means with different superscripts within a column differ significantly ($p< 0.05$).

The molecular origin of pseudoplastic behavior has been attributed to the fact that the applied shear stresses can cause the disentanglement of biopolymers, alignment of biopolymers with the shear field, or the disruption of weak physical interactions holding biopolymers together. Each of these molecular events has a characteristic relaxation time associated with it. At relatively low shear rates, there is insufficient time for these molecular phenomena to occur during the duration of the applied shear stress, therefore the viscosity of the biopolymer solution is relatively high. As the shear rate is increased, these molecular relaxation phenomena occur on a similar timescale as the duration of the applied shear stresses, therefore the viscosity begins to decrease. At sufficiently high shear rates, these molecular relaxation phenomena are completed within the experimental timescale and the solution reaches a constant low viscosity (Hosseini *et al.,* 2015).

Conclusion

Gum tragacanth appropriately stabilized the egg white foam and decreased its drainage. Stability of foam in the presence of gum tragacanth was lower than xanthan gum. However, higher overrun was observed for tragacanth as compared to xanthan. Optical microscopy also showed smaller bubbles for foams which were stabilized with tragacanth or xanthan in comparison with larger ones in the case of guar gum that stabilized egg white foam. The higher stability of foams with xanthan and tragacanth was due to their higher viscosity. In general, it can be concluded that the

Iranian gum tragacanth can be considered as a suitable alternative for the traditional gums in the case of egg white foam stabilizing.

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