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Zodo gum exudates from *Rosaceae* as a fat replacer in reduced-fat salad dressing

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Abstract

As a commonly used salad dressing, mayonnaise is a semi-solid, oil-in-water emulsion, which is prepared through the mixture of egg yolk, vinegar, oil, and mustard. Selecting new sources of hydrocolloids as stabilisers in the production of salad dressings, however, demands a sufficient understanding of potential hydrocolloids' functional properties such as rheological and physicochemical features. To shed light on this problem, the present work investigated the native Zodo gum (ZG) in concentrations of 3% and 4% which replaced 25% and 50% of oil in the formulation of reduced-fat salad dressings. All samples, including ZG1, ZG2, ZG3, ZG4, control, and commercial sample, showed pseudoplastic fluid behaviour (flow index < 1), while the viscosity of ZG1 was not found to be significantly different from commercial salad dressings which is widely available in the market ($p > 0.05$). Reduced-fat salad dressing samples with added ZG showed significantly higher stability than the control sample, while no significant difference was observed between ZG1, ZG2, and the commercial sample ($p > 0.05$). The minimum amount of calories was shown in ZG3 which had the lowest fat content (37.5%). The highest overall acceptance scores (4.21) were given to ZG1 and commercial sample in which the apparent viscosity was between 100 - 110 pa·s. Findings of the present work suggest that ZG is one of the most appropriate options as a fat replacer in reduced-fat salad dressings because of its affordable price, availability, and security of supply.

Introduction

Oil-in-water emulsions are of different types, normally ranging from those with a translucent appearance to the so-called coarse emulsions. Salad dressings as a kind of oil-in-water emulsion are divided into three types, as far as their fat content is concerned: full fat (normal traditional fat level), reduced fat (minimum 25% fat), and light (less than 1/3 fat or half fat) (Downing, 1996). In food industries, hydrocolloids are widely used to stabilise oil-in-water emulsions and to control the rheological properties. These compounds are odourless, colourless and digestible with no specific taste (Erçelebi and Ibanoğlu, 2010). They also have a low calorie value, which is an especially important property for the production of dietary foods. Hydrocolloids may chemically take the form of polysaccharides (e.g., Arabic gum, guar gum, carboxymethyl cellulose, carrageenan, starch, pectin) or protein (gelatine) (Koocheki *et al*., 2009). These polysaccharides can lead to macromolecular barriers by their increased water-phase viscosity (Papalamprou *et al*., 2005). Hydrocolloids are selected according to their functional properties. Two important issues, of course, are their price and security of supply. Considering these issues, starch is commonly used as a thickening agent (Medina-Torres *et al*., 2000).

Zodo gum (ZG) exudates are taken from Rosaceae (Mohammadi *et al*., 2011), and also known as Zed gum and Gommenotras in English and French, respectively. Like other gums in water, ZG produces a thick and viscose solution with multiple pharmaceutical, industrial and nutritional applications (Abbasi and Rahimi, 2008). White, yellow and red ZGs are cultivated in South and West

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regions of Iran. This gum is an anionic and acidic hydrocolloid (pH of 0.5 wt. % ZG dispersion is 5.60 ± 0.05), and consists of soluble and insoluble parts in water. It also includes another part with a molecular weight higher than 1,180 KDa, and is composed of galactose:arabinose (1:2) backbone (Golkar *et al*., 2015).

Given the importance of producing low-fat foodstuffs, as well as the economic aspect of cost reduction, the formulation of mayonnaise sauce with gums remains an underdeveloped topic in need of more research. Considering the properties of ZG as briefly reviewed above, the effective production of large quantities of ZG in Iran (Mohammadi *et al*., 2011), its cost-effectiveness, and its potential applications in the industry, the present work was aimed to investigate ZG as one of the native Iranian hydrocolloids to formulate and stabilise salad dressings comparable to full-fat samples.

Materials and methods

Materials

Oil (Nazgul sunflower oil, Shiraz, Iran), eggs (Morvarid Co., Kazeroon, Iran), vinegar (distilled vinegar [acidity 5%], Saba Co., Kazeroon, Iran), salt (Bloor, Shiraz, Iran), sugar (Minoo, Shiraz, Iran), and mustard powder (Behrooz Co., Tehran, Iran) were purchased from the local market. All chemicals used in the present work were of analytical grade, and purchased from Merck (Germany).

Production of salad dressing

To produce mayonnaise using the Chen method (Chen, 2005), powder materials (except for gum) were first mixed. Then 1/3 vinegar was added and the mixture was stirred for 10 min by a hand blender (Philips, HR1361, China). After adding yolk, the mixture was then stirred for another 10 min. Next, ZG and water were added and again the mixture was stirred for another 10 min. After adding about 1/3 oil and further stirring, first the rest of the vinegar and then oil were added. Finally, the mixture was stirred for another 10 min. Based on the salad dressing classifications and 75% fat in commercial mayonnaise, in the present work, 56.25% fat was considered to be “reduced-fat”, whereas 37.5% fat was classified as “light”.

Composition analysis

Moisture, fat and ash were measured by AOAC Official Method 920.116, 938.06 and 920.117 (AOAC, 2000), respectively. Protein was measured by the Kjeldahl method. The amount of carbohydrate was obtained by deducting the percentage of ash, moisture, protein and fat. The amount of calories was calculated using Equation 1 (Liu *et al*., 2007). The pH was measured using a pH meter (Merohm 691, Switzerland).

$$\text{Calorie} = (\text{carbohydrate} \times 4) + (\text{fat} \times 9) + (\text{protein} \times 4) \qquad \text{(Equation 1)}$$

Sample stability

After keeping the samples in a laboratory tube at 50°C for 48 h, centrifugation was performed (10 min at 3,000 rpm). The stability of samples was calculated using Equation 2 (Mun *et al*., 2009):

$$\text{Stability (\%)} = (F_1/F_0) \times 100 \qquad \text{(Equation 2)}$$

where F_0 = sample weight, and F_1 = precipitated fraction weight after centrifugation.

Rheological properties of samples

Rheological behaviour was measured at 4°C Rheometer and 0.02 - 2.2 s^{-1} shear rate, by programmable viscometer of Brookfield Model LVDV-III (Brookfield Engineering Laboratories. Inc. USA) equipped with spindle 64. According to the Non-Newtonian and pseudoplastic nature of salad dressings, we also obtained consistency coefficient (K) and flow behaviour index (n), using Power Law Model and Curve Expert V1/4 (Worrasinchai *et al*., 2006; Kayacier and Dogan, 2006).

$$\tau = k(\dot{\gamma})^n \qquad \text{(Equation 3)}$$

where K = consistency coefficient (pa.s^n), t = shear stress (Dynes/cm^2), n = flow index, and $\dot{\gamma}$ = shear rate (s^{-1}).

Texture analysis

In order to measure the salad dressings’ texture, Texture Analyser (Brookfield model CT3, USA) was employed using a 4,500 g load cell. Probe penetration speed (23 mm diameter) was set to 1 mm/s in the transparent plastic cylinder (25 mm internal diameter and 30 mm height). The probe penetrated 28 mm into cylinder (maximum load) and returned to the initial position. Adhesive force, adhesiveness and firmness were obtained from the load-time graph. Firmness was the maximum of penetration force into cylinder in a cycle, and adhesiveness was under negative force peak in order to disconnect the probe from the sample. Maximum negative force showed adhesive force (Worrasinchai *et al*., 2006; Liu *et al*., 2007). Figure 2 shows the ZG1 extrusion plot.

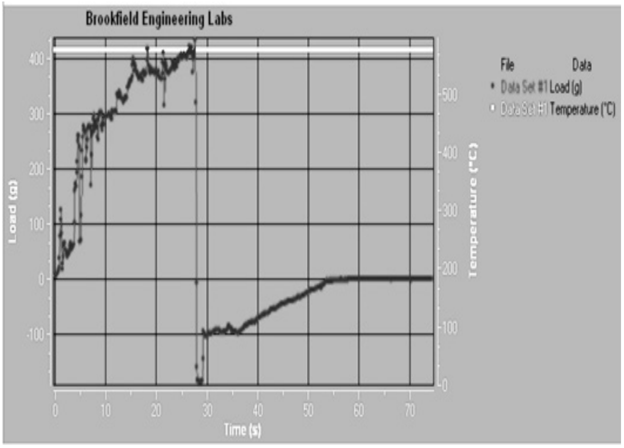

Figure 2. The extrusion plot for ZG1.

Sensory evaluation

A total of 20 panellists were trained in 120 min session prior to the evaluation so as to be familiar with attributes and scaling procedures of mayonnaise samples under study. The sensory evaluation was performed by the trained panellists using 5-points hedonic method for aroma, colour, consistency and overall acceptance aspects. Score (5) was considered the best, and score (1) the worst. All mayonnaise samples were coded with three-digit random numbers and presented to the panellists on a tray in individual booths. The orders of serving were completely randomised. Water was provided to cleanse the palate between two samples.

Statistical analysis

Five treatments were performed in a completely randomised design with three replications (n = 3). Analysis of Variance (ANOVA) was used to statistically analyse the results. The Duncan's test was conducted to compare the means using SPSS version 21.

Results and discussion

Chemical analysis and calorie value

As Table 2 shows, the moisture of samples increased as the amount of fat decreased. The calorie values of the reduced-fat salad dressing significantly decreased with increasing ZG ($p < 0.05$) with ZG3 (which had the lowest fat) yielded the lowest calorie. In this regard, Mun *et al*. (2009) observed a noticeable decline in energy level as modified starch was added as a substitute for fat in mayonnaise. They reported that this decline of energy was associated with the increased level of moisture and indigestive nature of modified starch.

No significant difference was found ($p > 0.05$) in pH in the case of reduced-fat salad dressing samples (3.80 - 3.85) even though the pH of the full-fat sample was found to be significantly lower than that of the other formulas ($p < 0.05$). The reason for this was that the level of water significantly increased ($p < 0.05$), along with an increase in the percentage of ZG and fat replacement, leading to a rise in pH due to the dilution of acetic acid in the continuous phase (Hathcox *et al*., 1995). Concerning microbiological health issues, vinegar can be used to lower pH in salad dressings down to 4.1 or less in order to enhance durability by reducing the risk of microorganisms.

Rheological behaviour

Rheological behaviour, based on which the quality index is assessed, is important in some products such as salad dressings. In addition, selecting new sources of hydrocolloids demands a good understanding of their functional properties, such as rheological and physicochemical features (García-Cruz *et al*., 2013). Table 3 shows the apparent viscosity of salad dressing samples at 0.43 s^{-1} shear rate. It is apparent that salad dressing viscosity increased as the percentage of ZG increased within the oil percentage under study, which ranged from 37.5% to 56.25%. The maximum viscosity was found to be 4% for ZG2. The reason for this was the fact that at higher hydrocolloid concentrations, oil-in-water emulsion

Table 1. The compounds in the formulation of mayonnaise (w/w).

Ingredients	Control	ZG1	ZG2	ZG3	ZG4
Oil	75	56.25	56.25	37.5	37.5
Egg yolk	7.27	7.27	7.27	7.27	7.27
Zodo gum	-	3	4	3	4
Vinegar	12	12	12	12	12
Salt	1	1	1	1	1
Sugar	2.5	2.5	2.5	2.5	2.5
Mustard powder	1	1	1	1	1
Water	remaining	remaining	remaining	remaining	remaining

Table 2. pH, proximate compositions, and calories of mayonnaise samples.

Samples	pH	Fat	Water	Protein	Carbohydrate	Ash	Calorie (kcal/100 g)
ZG1	3.80 ± 0.08^{b}	58.30 ± 0.08^{c}	32.00 ± 0.19^{c}	1.19 ± 0.03^{a}	7.12 ± 0.28^{b}	1.39 ± 0.09^{b}	557.94 ± 1.25^{c}
ZG3	3.85 ± 0.08^{b}	39.15 ± 0.13^{a}	50.78 ± 0.13^{e}	1.19 ± 0.02^{a}	7.53 ± 0.38^{b}	1.35 ± 0.10^{b}	387.23 ± 0.30^{a}
ZG4	3.83 ± 0.08^{b}	39.30 ± 0.13^{a}	49.75 ± 0.11^{d}	1.20 ± 0.05^{a}	8.37 ± 0.34^{c}	1.38 ± 0.08^{b}	391.98 ± 0.29^{b}
ZG2	3.82 ± 0.08^{b}	57.92 ± 0.12^{b}	31.25 ± 0.10^{b}	1.21 ± 0.2^{a}	8.44 ± 0.26^{c}	1.18 ± 0.04^{a}	559.88 ± 0.14^{d}
Control	3.63 ± 0.11^{a}	67.17 ± 0.1^{d}	26.18 ± 0.08^{a}	1.20 ± 0.05^{a}	4.02 ± 0.28^{a}	1.43 ± 0.05^{b}	625.41 ± 0.14^{e}

Values are mean of triplicate (n = 3) ± standard deviation. Different letters within similar column indicate significant difference ($p < 0.05$).

Table 3. The results of apparent viscosity test, consistency coefficient, flow index, firmness, and stability of mayonnaise samples.

Samples	Apparent viscosity (mpa s)	Consistency coefficient (mpa s^{n})	Flow index	Firmness (g)	Adhesiveness (mj)	Adhesive force(g)	Stability(%)
ZG1	110,025 ± 1,000^{c}	627.79 ± 9.43^{d}	0.330 ± 0.002^{c}	445.50 ± 30.11^{cd}	14.95 ± 1.98^{c}	178.83 ± 3.32^{bc}	95.00 ± 0.30^{d}
ZG3	14,897 ± 754^{a}	90.48 ± 3.97^{a}	0.386 ± 0.008^{d}	304.50 ± 52.22^{a}	9.37 ± 0.37^{a}	123.50 ± 12.81^{a}	93.00 ± 0.15^{b}
ZG4	26,694 ± 300^{b}	164.12 ± 2.91^{b}	0.404 ± 0.004^{d}	384.83 ± 29.80^{b}	9.82 ± 0.73^{a}	156.66 ± 29.02^{b}	94.00 ± 0.180^{c}
ZG2	185,052 ± 10,618^{d}	980.79 ± 59.17^{e}	0.253 ± 0.027^{b}	556.83 ± 12.35^{e}	17.58 ± 0.41^{d}	185.33 ± 1.15^{c}	95.35 ± 0.10^{d}
Control	32,793 ± 3,018^{b}	184.83 ± 9.48^{b}	0.310 ± 0.025^{c}	464.33 ± 5.48^{d}	16.41 ± 0.28^{cd}	179.50 ± 10.14^{bc}	87.40 ± 0.60^{a}
Commercial	109,000 ± 5,567^{c}	568.29 ± 26.73^{c}	0.206 ± 0.008^{a}	405.33 ± 4.50^{bc}	11.80 ± 0.30^{b}	164.86 ± 3.06^{bc}	95.06 ± 0.20^{d}

Values are mean of triplicate (n = 3) ± standard deviation. Different letters within similar column indicate significant difference ($p < 0.05$).

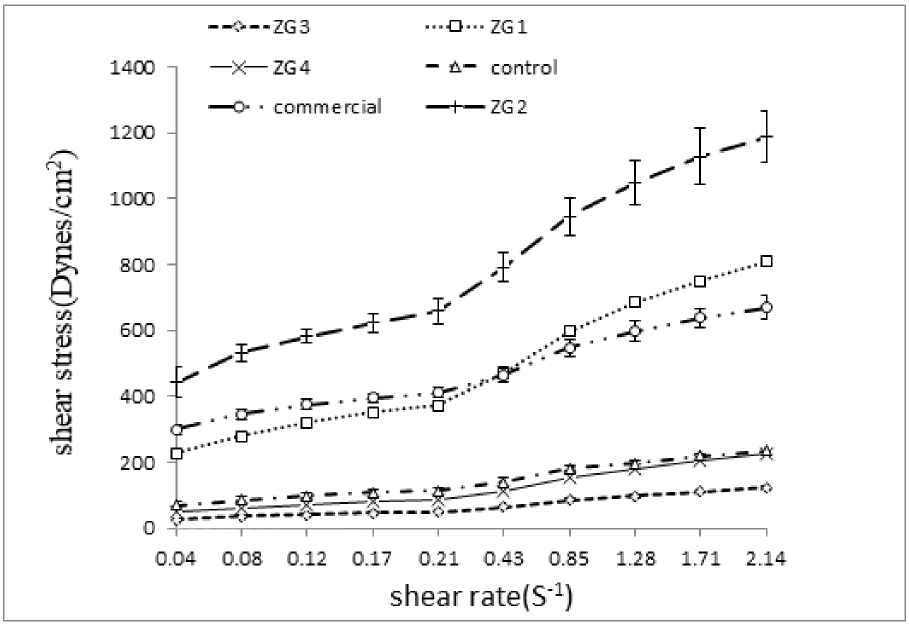

Figure 1. The flow curves of six mayonnaise samples.

led to droplet flocculation. Generally speaking, emulsions with flocculated oil droplets have higher viscosities than unflocculated emulsions (Kupongsak and Sathitvorapojjana, 2017). Erçelebi and Ibanoğlu (2010) observed an increase in viscosity in the presence of guar gum, reporting that the significant impact of the hydrocolloid was associated with the effect of the thickening polysaccharide in the continuous phase. Their findings, in fact, justify the results of the present work. On the other hand, no significant difference was found in ZG4 (Table 1) and control viscosity, although 50% of oil was replaced (*p*

> 0.05). More interestingly, no significant difference was found in the viscosity of ZG1 and that of the commercial sample, which is widely available in the market ($p > 0.05$). Since viscosity is considered to be one of the important quality features, any difference in terms of this quality is also important.

Rheological parameters (K and n) were fitted with high determination factor (R^2) (99%) (Table 3). Figure 1 shows the shear stress versus shear rate, while the flow index, which is less than 1 (0.206 - 0.404), indicates pseudoplastic behaviour of all samples. This behaviour is a suggestion of irreversible structural break and reduced viscosity due to molecular alignment (Marcotte *et al*., 2001). Consistent with these results, multiple studies reported pseudoplastic properties and shear thinning behaviour due to a flow index of less than 1 (Lorenzo *et al*., 2008; Thomareis and Chatziantoniou, 2011; Nikzade *et al*., 2012). On the other hand, when high viscosity and a good mouthfeel are desired, the gum needs to have a low flow index in the salad dressing (Marcotte *et al*., 2001). Consistency coefficients ranged from 90.48 to 980.79 mpa·s^n (Table 3). As Table 3 illustrates, based on power law parameters, the differences were significant among samples ($p < 0.05$). The maximum consistency and the minimum flow index were observed in ZG2, whereas the minimum consistency and the maximum flow index were observed in ZG3. Thus, it was concluded that an increased concentration of ZG led to increased consistency coefficient of the treatments. The reason for this might be attributed to ZG's dependency on increased water binding capacity. In other words, increased consistency coefficient is associated with the nature of viscosity in most emulsions (Soleimanpour *et al*., 2013).

Firmness

Firmness is one of the most important and effective factors in mayonnaise formulations. As can be seen in Table 3, an increase in ZG, which in turn resulted in increased viscosity of emulsion, led to higher firmness (Liu *et al*., 2007). Generally, firmness in ZG1 was not found to reveal a significant difference from the control and the commercial mayonnaise formulations ($p > 0.05$). The reason for this observation was that adding ZG increased the elasticity of emulsion by forming a strong gel structure in the continuous phase. During the emulsification, the added ZG formed a thicker and sticky structure, and it led to diameter reduction in oil droplets due to a decrease in coalescence (Raymundoa *et al*., 2002). Similar results were reported in the production of low-fat mayonnaise as in the case of using β-glucan (Worrasinchai *et al*., 2006), using Xanthan gum (Nikzade *et al*., 2012), optimising oil-in-water emulsion (stabilised by the white lupin proteins) (Raymundoa *et al*., 2002). In these studies increased firmness were also reported.

Stability test

Creaming is unusual in high-fat mayonnaise (almost 80%) because the droplets are so close together that they cannot move (Mun *et al*., 2009). In the present work, the reduced-fat salad dressings had significantly higher stability when compared with the control, as ZG was added to the former. No significant difference was found between ZG1 and ZG2 ($p > 0.05$) (Table 3). It has been observed that using Xanthan and guar gums as well as some other proteins could lead to increased stability, while preventing low-fat mayonnaise creaming due to increased viscosity of the continuous phase and the lowered movement of oil drops (Papalamprou *et al*., 2005; Nikzade *et al*., 2012). On the other hand, despite the negative impact of the flocculation of oil droplets through biopolymers on the quality of emulsions, this process is desired in salad dressing. Furthermore, besides increasing viscosity, the process also forms a 3D network of gel-like accumulated particles (Mun *et al*., 2009). Therefore, considering the significant relationship between increased gum and increased stability, we assume that the flocculation of droplets and increased viscosity of the continuous phase contribute to the stability of reduced-fat salad dressings with added ZG. Additionally, this phenomenon may be attributed to most biopolymers that help the stability of droplets as a result of the combination of physical and chemical

Table 4. Sensory analysis of mayonnaise samples.

Samples	Consistency	Aroma	Colour	Overall acceptance
ZG1	3.82 ± 0.10^c	3.54 ± 0.14^b	3.72 ± 0.10^c	4.21 ± 0.10^d
ZG3	3.12 ± 0.07^a	3.39 ± 0.12^b	3.08 ± 0.07^a	2.29 ± 0.06^a
ZG4	3.39 ± 0.10^b	3.43 ± 0.10^b	3.19 ± 0.04^{ab}	3.12 ± 0.07^b
ZG2	4.38 ± 0.07^e	3.46 ± 0.11^b	3.91 ± 0.05^d	3.40 ± 0.10^c
Control	3.50 ± 0.02^b	2.86 ± 0.09^a	4.12 ± 0.06^e	3.56 ± 0.14^c
Commercial	4.09 ± 0.11^d	3.59 ± 0.08^b	3.32 ± 0.03^b	4.21 ± 0.07^d

Values are mean of 20 panellists (n = 20) ± standard deviation. Different letters within similar column indicate significant difference ($p < 0.05$).

interactions, such as electrostatic interactions and hydrogen bonding (Phillips and Williams, 2009).

Sensory evaluation

The sensory evaluation scores of reduced-fat salad dressings are shown in Table 4. The highest overall acceptance scores (4.21) were given to ZG1 and commercial in which the apparent viscosity was between 100 - 110 pa·s. The lowest overall acceptance score was achieved when apparent viscosity was 14.897 pa·s. (ZG3). There was no significant difference in the acceptability and aroma scores between ZG1 and commercial. The consistency scores of reduced-fat salad dressing was significantly ($p < 0.05$) influenced with added ZG. This was mainly contributed by the viscosity of ZG. However, the score for consistency of ZG1 was significantly higher ($p < 0.05$) than the control, ZG3 and ZG4. The salad dressings showed significant influence in colour scores, which decreased with decreasing fat level. Furthermore, the content of ZG in the reduced-fat salad dressing also increased the colour scores of the samples.

Conclusion

Different studies have attempted to achieve stability in reduced-fat salad dressings, concentrating on the application of different emulsifiers and gums including Xanthan and guar. In the present work, despite reduced calorie and 25% of fat, the ZG1 sample, based on the proposed formula, was not found to be significantly different, in terms of viscosity, stability and firmness, from the commercial sample, which is widely available in the market. Therefore, ZG is introduced as a new source because of its affordable price, availability, and the security of supply.

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