JRIFST

Original Paper

www.journals.rifst.ac.ir
Journal of Research and Innovation
in Food Science and Technology
9 (2021) 4, 363-374
DOI: 10.22101/JRIFST.2020.212592.1136

Research Institute of Food Science and Technology

Textural and Sensory Properties of Reduced-fat Mayonnaise Prepared with Pre-gelatinized Cornstarch and Farsi gum

Hamidreza Mousakhani-Ganjeh[1], Mohammad Goli[2,3]*

1- MSc. Graduate, Department of Food Science & Technology, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

2- Associate Professor, Department of Food Science & Technology, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

3- Associate Professor, Laser and Biophotonics in Biotechnologies Research center, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

* Corresponding author email (mgolifood@yahoo.com)

Abstract

For the first time, the effect of the combination of Farsi gum (FG) and pre-gelatinized (pre-gel) cornstarch, as a fat replacer and substitute for xanthan-guar gum, on textural, stability, sensory, average droplet size and rheological characteristics of low-calorie mayonnaise were investigated. FG and pre-gel corn starch combination in ratios of (1:1), (1:2), and (2:1) at three concentrations of 1.5, 2.0, and 2.5% were added to mayonnaise. A mayonnaise sample with guar and xanthan gum (0.5%) was selected as the blank. Results showed textural parameters, i.e., hardness, apparent viscosity, adhesive force, adhesiveness, and hardness work done, increased by increasing the amount of FG so that was lower than that of the blank. Analysis of the average droplet size showed that blank exhibited the highest average droplet size. Average droplet size decreased and the viscosity of all treatments increased by increasing the percentage of gum. Mayonnaise color parameters showed no significant difference between color parameters (P>0.05). Finally, treatments pre-gel cornstarch: Farsi gum (1:2) 2.5%, pre-gel cornstarch: Farsi gum (2:1) 2.5% and pre-gel cornstarch: Farsi gum (1:2) 2% obtained the highest sensory evaluation scores, respectively.

Received: 2019.12.20
Accepted: 2020.07.26

Keywords
Farsi gum
Pre-gelatinized cornstarch
Reduced-fat mayonnaise
Sensory evaluation
Textural properties

Introduction

Mayonnaise is a kind of semi-solid oil-in-water emulsion containing 70-80% fat. Mayonnaise is traditionally prepared by carefully mixing egg yolk, vinegar, oil, and spices, especially mustard (Depree & Savage, 2001; Nikzade, Tehrani, & Saadatmand-Tarzjan, 2012). The amount and type of consumed fat are known to be important to the etiology of several chronic diseases, such as obesity, cardiovascular diseases, and cancer (Liu, Xu, & Guo, 2007; Sahan, Yasar, & Hayaloglu, 2008; Zoulias, Oreopoulou, & Tzia, 2002). However, fat, as a food component, particularly influences food rheological properties and sensory characteristics, such as flavor, mouthfeel, and texture (Mun, Kim, Kang, Park, Shim, & Kim, 2009). Therefore, imitating traditional product quality meanwhile preparing low-fat food is difficult. Thus, to establish the formulation of low-fat products, different non-fat ingredients roles are necessary to supply quality characteristics that are lost when fat is removed (Shen, Luo, & Dong, 2011). Generally, fat replacers are categorized into two groups: fat substitutes (fat-based) and fat mimetics (Hydrocolloids-based or protein-based) (Rahmati, Tehrani, Daneshvar, & Koocheki, 2015). Hydrocolloids are massively used in the food industry, especially in recent years. Hydrocolloids are complex combinations that are used to improve texture; control crystallization; prevent water and oil syneresis; coat aromas; flavor materials; increase thermal and physical stability; form films and product gels; and increase the consistency of the liquid, semi-liquid, and semi-solid food products. Numerous hydrocolloids are not metabolized in the human body and present low energy (calorie formation) (Phillips & Williams, 2000). Gum and starch, carbohydrate-based fat mimetics with a structure different from fats, may be modified chemically, physically, or enzymatically to mimic fat characteristics (mouthfeel, appearance, and thickness). They are principally used due to their unique ability to absorb water and develop viscosity (Maghsoudi, 2004; McClements & Demetriades, 1998; Miraglio, 1995). Iran is one of the countries that produce natural gum, such as FG and Tragacanth. The use of these types of gum in food formulations and other industries is important. As these gums are natural and native, as well as possess an assured market supply, these can be used in the food industry. Ensuring appropriate performance could be an important step toward the use of gums in the food industry. (Golkar, Nasirpour, & Keramat, 2015a; Golkar, Nasirpour, Keramat, & Desobry, 2015b; Jafari, Beheshti, & Assadpoor, 2012; Jafari, Beheshti, & Assadpour, 2013). FG is a transparent secretory gum that is obtained from the *Amygdalus scoparia Spach* tree, which is largely collected in the southern and western areas of Iran. The FG, which is also, indicated by different names, such as Zedo gum, Shiraz gum, and Farsi gum, is an anionic, acidic hydrocolloid [pH (0.5% wt. FG dispersion): 5.60]. Several basic studies on the FG have been conducted, including investigations on the physicochemical properties, structure determination, functional properties, and improvement of its emulsifying properties (Fadavi, Mohammadifar, Zargarran, Mortazavian, & Komeili, 2014; Ghasempour, Alizadeh, & Bari, 2012; Golkar *et al.*, 2015a,b; Jafari *et al.*, 2012;2013). Studies conducted on the application of this gum in food products also include the production of probiotic yogurt and stabilization of milk-orange juice (Ghasempour *et al.*, 2012). The aim of this study, for the first time, was to survey the effect of the combination of FG and pre-gel cornstarch (in levels of 1.5, 2 and 2.5% of mayonnaise formula weight with the rate of FG to pre-gel cornstarch 0.5, 1 and 2), as a fat replacer and substitute for xanthan-guar gum (available in the blank sample in which 0.5% gum with the rate of xanthan to guar gum 3 was consumed), on textural, stability, sensory, average droplet size, and rheological characteristics of low-calorie mayonnaise.

Materials and methods

Raw material characterization

FG was collected from almond trees (*Angum scoparia Spach*) in Yazd province in May 2015. After collection, lighter-colored samples were selected for use in mayonnaise formulation. The spice powder, which includes mustard powder, from Isfahan Chika Co. was prepared. Sunflower oil, Salt, sugar, and vinegar (5% acetic acid) were purchased from local supermarkets.

FG powder preparation

The procedure does not include a drying process due to the prepared FG samples were dry. After separating clear and pure gum samples, those were separately powdered by a kitchen mill so that at least 75% of the particles pass through a sieve of 125 μm (mesh number 120). The obtained gum powders were used in mayonnaise formulation.

Mayonnaise preparation

Reduced-fat mayonnaise was prepared according to the method of Karshenas, Goli, & Zamindar (2018;2019). The composition of each formulation was prepared according to Table (1). Hydrocolloids were also used according to Table (2).

Table 1. Formulation of mayonnaise samples containing pre-gelatinized cornstarch and Farsi gum

Ingredients	Percentage
Vegetable oil	48
Egg yolk	12
Water (according to stabilizer or gum content)	15.90-17.90
Sugar	7
Vinegar (5% acetic acid)	12
Salt	2
Mustard powder	0.40
Preservatives	0.20
Stabilizer or gum	according to Table 2

Table 2. Amount of stabilizers used in mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F)

Formula	Stabilizer type	Concentration (%)
S1F1 (1.5)	Starch (pre-gel) : Farsi gum (1:1)	1.5
S1F1 (2)	Starch (pre-gel) : Farsi gum (1:1)	2
S1F1 (2.5)	Starch (pre-gel) : Farsi gum (1:1)	2.5
S2F1 (1.5)	Starch (pre-gel) : Farsi gum (2:1)	1.5
S2F1 (2)	Starch (pre-gel) : Farsi gum (2:1)	2
S2F1 (2.5)	Starch (pre-gel) : Farsi gum (2:1)	2.5
S1F2 (1.5)	Starch (pre-gel) : Farsi gum (1:2)	1.5
S1F2 (2)	Starch (pre-gel) : Farsi gum (1:2)	2
S1F2 (2.5)	Starch (pre-gel) : Farsi gum (1:2)	2.5
Blank	xanthan gum : guar gum (3:1)	0.5

Back extrusion test

The textural properties of mayonnaise samples were examined with the back extrusion test (LFRA 4500; Brookfield, USA) the day after production. This test involves a cylindrical probe with specified geometry inside the standard dish. Parameters such as hardness, adhesiveness, and adhesive force were determined with this test. The hardness (g) is the highest point of the test diagram. The adhesive force (g) is the necessary force to separate the probe from the sample (minimum point of the test diagram). The adhesiveness (g. s), is the negative area of the diagram and is a symbol of the product texture cohesion. To do this test, a probe with a diameter of 38 mm, penetration amount of 20 mm, and penetration speed of 1 mm/s was applied. A metal cylinder with an internal diameter of 45 mm and a height of 95 mm was selected for this test. About 45 g of refrigerated sample, due to being mayonnaise as cold food, was immediately weighed and poured within the cylinder. The measurements were done in three replications 24 h after the production of samples (Karshenas *et al.*, 2018;2019; Liu *et al.*, 2007; Worrasinchai, Suphantharika, Pinjai, & Jamnong, 2006).

Mayonnaise stability assessment

For mayonnaise physical stability assessment, a 50 g portion of the sample was weighed, placed into the centrifuge tubes, and then centrifuged at 5000 rpm and room temperature (20 °C) for 30 min. The layer of oil was removed and the weight of the sediment was measured. Mayonnaise stability was calculated by using the following Eq. (1) (Karshenas *et al.*, 2018). For mayonnaise thermal stability assessment, a 50 g portion of the sample was weighed, transferred into the centrifuge tubes, placed in an 80 °C water bath for 30 min and cooled, and then centrifuged at 5000 rpm and room temperature (20 °C) for 30 min. The layer of oil was removed and the weight of the sediment was measured. Mayonnaise thermal stability was calculated by using the following Eq. (1) (Karshenas *et al.*, 2018).

$$\text{Thermal stability (\%)} = \frac{\text{Remainder emulsion weight}}{\text{Initial emulsion weight}} \times 100 \quad (1)$$

Droplets size measurement

The droplet size average analysis of mayonnaise was performed by using a laser diffractometer Mastersizer 2000 with the Hydrosizer 2000S module (Malvern Instruments, UK) using static scattering laser beam set with a 5 mV helium/neon (635 nm). The droplet size measurement was reported as the Saunter mean diameter by Eq. (2) at room temperature (20±1 °C). A 0.04 g sample portion was diluted with 150 mL of 0.1% sodium dodecyl sulfate to prevent flocculation of the droplets and was injected into the set after homogenization. The prepared sample was injected into the set until the amount of light passing through the solution was 60-80%. All measurements were performed at 1, 30, and 60 days after sample preparation (Roland, Piel, Delattre, & Evrard, 2003).

$$d_{32} = \frac{\sum_{i=1}^{N} n_i {d_i}^3}{\sum_{i=1}^{N} n_i {d_i}^2} \quad (2)$$

Where d_{32} is by definition the ratio of the third to the second moment of the probability density function. The n_i and d_i are, respectively, the number and diameter of particulate matter in a particulate size fraction.

Viscosity measurement

As mayonnaise is a non-Newtonian fluid, displays a pseudo-plastic behavior. Therefore, apparent viscosity was used instead of viscosity. The evaluation of mayonnaise viscosity was conducted using a HAAKE Viscometer (model 7L, Thermo Fisher Scientific, Germany) in the shear rate 10 (S-1). All tests were fulfilled by L4 spindle at a controlled temperature of 25±2 °C and a speed of 12 rpm after sample homogenization and the spindle was allowed to circulate for five times in each sample. Sample viscosity was reported based on centipoise (Bourne, 2002).

Color measurement

Mayonnaise samples were photographed inside special boxes. The color parameters L*, a*, and b* of the photos were analyzed in Photoshop and standardized by standard RAL cards. Image taking of mayonnaise samples and standard RAL cards were conducted under highly controlled light conditions. L* indicates lightness and is variable from zero to 100, whereas a* indicates redness (+: Redness and -: greenness). Parameter b* is the yellowness index (+: yellowness and -: blue) that ranges from -120 to +120. The test was performed 24 h after sample preparation (Shen *et al.*, 2011).

Sensory analysis

Sensory evaluation of the mayonnaise samples was conducted using the 5-point hedonic test and various indices, such as appearance, color (mayonnaise usual color desirability and being creamy), smell, taste, texture (uniformity and rigidity), and total acceptance were considered. The sensory evaluation was graded using a scoring scale of 1 to 5 (higher number indicates product desirability) for each index by 20 trained panels after 1-day storage at room temperature (Worrasinchai *et al.*, 2006).

Statistical analysis

All tests were conducted in a completely randomized design with three replications using the SAS 9.0 software (Inst. Inc., Cary, NC, USA). All statistical comparisons were performed using Duncan's test at the level of 5%.

Results and discussion

Textural properties

Textural parameters of the mayonnaise samples are shown in Table (3). The comparison of the mayonnaise sample hardness and the other corresponding factor, i.e., hardness work done, showed that adding FG and pre-gel cornstarch resulted in increased hardness. The blank sample showed the highest hardness, which was significant in comparison with other samples (P<0.05). Samples S1F2 (2.5), S2F1 (2.5), and S1F1 (2.5) presented the highest amount of hardness. The differences were not significant compared with each other but were significant in comparison with samples containing a lower percentage of SF (*P*<0.05). S2F1 (1.5) and S1F1 (1.5) presented the lowest hardness of the total samples. Apparent viscosity comparison of mayonnaise samples showed that in a similar trend as hardness, S1F2 (2.5), S2F1 (2.5), and S1F2 (2) samples presented the highest apparent viscosity, whereas S1F1 (1.5) and S2F1 (1.5) showed the lowest apparent viscosity, and the differences were significant (*P*<0.05). The sample blank also showed the highest apparent viscosity, which had a significant difference in comparison with other samples. The comparison of the adhesive force parameter showed that the amount of this parameter increased with increasing FG and pre-gel cornstarch concentration. Meanwhile, samples containing higher hydrocolloid percentage show higher adhesive force, so that S1F2 (2.5) exhibited the highest adhesion force. Finally, samples with the lowest concentration (1.5%), exhibited the lowest adhesive force. The adhesiveness parameter showed similar trends of adhesive force. Adhesiveness increased in samples containing higher FG content, but the difference was not significant. Notably, all samples had a significant difference from the blank sample. The comparison of the "hardness work done" of mayonnaise samples also indicated that increasing hydrocolloid concentration significantly affected this feature. Samples S1F2 (2.5), S2F1 (2.5), and S1F1 (2.5) presented the highest value, whereas S2F1 (1.5) and S1F1 (1.5) showed the lowest value, and have not the significant difference with together (*P*>0.05). S2F1 (1.5) presented the lowest value of hardness work done. The blank sample had significantly higher hardness work done than the other samples (*P*<0.05). The textural integrity (hardness, adhesive force and adhesiveness) of the mayonnaise varied with type and the amount of thickening agents. Adhesiveness and adhesive force are the factors necessary to overcome the attractive forces between the product and the teeth. The addition of pre-gel cornstarch/Farsi gum combinations contributed to maintaining the mayonnaise in a homogeneous and viscous state. Meanwhile, mayonnaise thickened by xanthan-guar gum was more stable than those by pre-gel cornstarch/Farsi gum combinations (Table 3). Stability enabled by pre-gel cornstarch/Farsi gum combinations was attributed to the delayed course of retrogradation of cornstarch and a better acid resistant capability out of pre-gel cornstarch/Farsi gum strong internal electrostatic repulsion (Cai, Du, Zhu, Cai, & Cao, 2020). The formation of high molecular weight accumulations through hydrogen bonding has increased the viscosity of xanthan-guar samples (blank) and samples with higher FG compared to the other examples.

Table 3. Textural parameters in mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F)

Formula	Hardness (g)	Apparent viscosity (g/cm×sec)	Adhesive force (g)	Adhesiveness (g×sec)	Hardness work done (g×sec)
S1F1(1.5)	239.00±20.51^{gf}	17.68±0.33^{c}	187.50±16.26^{ab}	1418.01±24.12^{a}	3566.06±164.06^{d}
S1F1(2)	274.75±1.06^{ef}	22.49±1.41^{bc}	222.25±1.77^{abc}	1696.09±174.69^{a}	4222.92±127.42^{cd}
S1F1(2.5)	231.75±30.76^{cd}	23.76±2.87^{bc}	270.50±31.82^{ced}	1853.92±14.63^{a}	4850.26±478.17^{bc}
S1F2(1.5)	269.75±13.08^{efg}	22.60±2.69^{bc}	221.25±15.20^{abc}	1844.41±314.59^{a}	4199.83±301.52^{cd}
S1F2(2)	312.75±0.35^{cde}	25.80±1.78^{b}	263.75±3.18^{cd}	1957.36±391.22^{a}	4872.12±99.96^{bc}
S1F2(2.5)	370.25±17.32^{b}	26.91±1.42^{cb}	317.25±14.50^{e}	1915.78±155.99^{a}	5624.43±261.545^{b}
S2F1(1.5)	228.75±22.27^{g}	18.55±5.00^{bc}	181.50±24.75^{a}	1359.83±476.53^{a}	3558.10±504.96^{d}
S2F1(2)	283.50±21.21^{ed}	21.65±1.19^{b}	236.75±20.85^{bcd}	1484.82±396.30^{a}	4020.57±98.37^{d}
S2F1(2.5)	334.75±9.55^{bc}	26.84±4.71^{b}	282.00±8.49^{de}	1958.38±575.32^{a}	5167.73±312.88^{b}
Blank	640.75±25.81^{a}	46.97±8.83^{a}	551.50±47.38^{f}	3583.58±1666.05^{b}	9584.56±648.15^{a}

Dissimilar lower cases in each column indicate a significant difference (*P*<0.05).

Thermal stability of emulsion

The stability of an emulsion refers to how long the internal phase will stay dispersed under normal conditions of shipping and storage. As the droplets of the dispersed phase coalesce and the phases separate, the emulsion is referred to as “broken”. The rate at which coalescence occurs depends on the type and concentration of the emulsifier, the size of the dispersed droplets, the charge on the particles, the emulsion viscosity, and the transportation and storage conditions. In low-fat content products, adding components, such as gum or a protein to the aqueous phase usually prevents or slows down the merging of droplets, and then emulsion breaking was delayed (Mun *et al.*, 2009). The results of Fig. (1) showed good stability, and oil and water phases separating was not observed in the samples. The blank presented the highest stability value (above 99%) that relative to guar and xanthan gum characteristics. In addition, the lowest thermal stability value (81.16%) belonged to S1F1 (1.5), which contained a 1.5% combination of FG and pre-gel cornstarch at a 1:1 ratio. Also, the highest thermal stability of the treatment (94.26%) was observed in sample S1F2 (2.5). Thermal stability decreased in all treatments over time, and differences between all treatments on the 1st and 30th day after production were not significant, except for blank. The difference between samples on the 1st and 60th day storage time in all treatments was not significant (P<0.05) except for blank, S2F1 (1.5), and S2F1 (2). The greatest significant difference in thermal stability between the 1st and 30th days after production was observed in the blank, and this difference in the other treatments was not significant over time (P>0.05). The reason for this may be the increased viscosity of the continuous phase due to the addition of xanthan-guar gum in blank and treatments including the higher amount of FG, i.e., S1F2. The gums by reducing the movement of the disperse phase, oil droplets, due to an increase in viscosity in the continuous phase, water, prevent the breaking and instability of the emulsion (Sathivel, Bechtel, Babbitt, Prinyawiwatkul, & Patterson, 2005). In pre-gelatinization, rapid drying prevents amylose and amylopectin crystallization, resulting in a glassy structure with high and rapid hydration capacity. As this kind of starch absorbs both warm and cold water rapidly, with no additional heating to develop viscosity, it is so-called instant starch (Rahmati *et al.*, 2015).

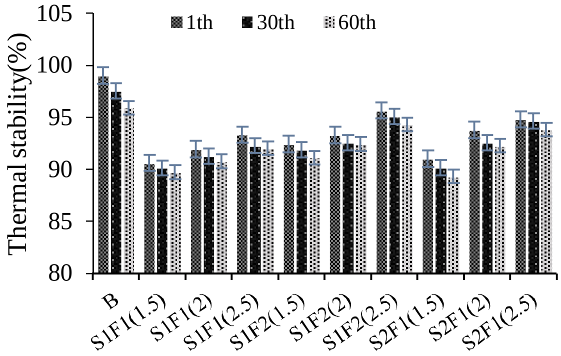

Fig. 1. Thermal stability experimental results for mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F)

Average droplet size

The average droplet size of mayonnaise samples showed that treatment S1F2 (2.5) possessed the lowest droplet size on the 1st day of production, and droplet size average decreased with the increase in the percentage of gum (Table 4). Therefore, the average droplet size was orderly decreased in all treatment with an increasing amount of FG and pre-gel cornstarch. Comparison of the average droplet size of samples showed that S1F2 (2.5), which possessed an average droplet size of 0.71 μm, presented the lowest droplet size, which was significantly different from those of other treatments except from samples S1F1 (2.5) and S2F1 (2.5), with an averages droplet size of 0.97 and 0.88 μm, respectively. The blank showed the highest average droplet size, 1.19 μm among the treatments after the treatments S1F1 (1.5) and S1F2 (2) with an averages droplet size of respectively, 1.62 and 1.32 μm, and the differences were significant in comparison to other samples. Samples containing a lower percentage of gum had a larger droplet size average, which indicated that droplet size became smaller with the increase in the number of gums used in mayonnaise. Increasing the amount of FG and pre-gel cornstarch altered average droplet size. Using higher amounts of hydrocolloids, regardless of origin, resulting in a smaller average droplet size of the mayonnaise after emulsion preparation, thus preventing coalescence of oil droplets and maintaining product stability. The droplet size of samples did not change within 60-day storage time for S1F2 (2.5) and 30-day storage time for blank, but the other samples had significantly changed. Increasing the average droplet size was correlated to the amount and type of applicable gum used in mayonnaise formula so that stabilizers, which have high molecular weight, directly altered rheological properties and continuously increased the viscosity in the continuous phase. This increase in viscosity reduced the movement of oil droplets toward each other and prevented them from bonding to each other to form larger droplets (Golkar *et al.*, 2015a,b; Puligundla, Cho, & Lee, 2015). As well as, the higher contents of hydrocolloids due to the role of their physical barriers, prevented droplet flocculation and coalescence after emulsion preparation that consequently resulted in smaller particle size and narrower distribution curve for mayonnaise samples (Rahmati *et al.*, 2015).

Table 4. The average droplet size (μm) of the different mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F) during storage time

Formula	Time (day)		
	1	30	60
S1F1(1.5)	1.06±0.01^{bC}	1.42±0.02^{aBC}	1.62±0.01^{aA}
S1F1(2)	0.83±0.09^{dC}	0.98±0.03^{eBC}	1.07±0.09^{dA}
S1F1(2.5)	0.73±0.02^{fC}	0.83±0.01^{fBC}	0.97±0.04^{eA}
S1F2(1.5)	0.94±0.02^{cB}	1.06±0.01^{dAB}	1.11±0.01^{dA}
S1F2(2)	0.86±0.01^{dC}	1.15±0.05^{cB}	1.32±0.02^{bA}
S1F2(2.5)	0.76±0.00^{efA}	0.74±0.01^{gA}	0.71±0.01^{fA}
S2F1(1.5)	1.01±0.01^{bC}	1.17±0.02^{cB}	1.31±0.01^{cA}
S2F1(2)	0.87±0.02^{dC}	1.03±0.01^{dcB}	1.22±0.01^{dA}
S2F1(2.5)	0.77±0.01^{eB}	0.84±0.01^{fAB}	0.88±0.01^{eA}
Blank	1.28±0.02^{aB}	1.24±0.06^{bAB}	1.19±0.02^{cA}

Dissimilar lower cases in each column indicate a significant difference (P<0.05), and dissimilar upper cases in each row indicate a significant difference (P<0.05)

Apparent viscosity

The study of gum rheological characteristics is important for improving the textural and sensory characteristics of food. In addition, rheological characteristics perform a substantial function in the design, evaluation, and modeling of the food production process. The viscosity of mayonnaise treatments with different percentages of stabilizers was given in Fig. (2). The highest viscosity was related to the blank sample, and the difference with other produced samples was significant (P<0.05). The viscosity increased with an increasing stabilizer amount. Following the control sample, samples S1F2 (2.5) and S2F1 (2.5) exhibited the highest viscosity between the other treatments, and the difference between these two samples was not significant (P>0.05). The results showed that viscosity more considerably increased by increasing the percentage of gum, the components with high molecular weight, in all treatments, caused to increase the consistency. Stabilizers directly altered rheological properties and continuously increased the viscosity in the continuous phase. This increase in viscosity reduced the movement of oil droplets toward each other and prevented them from bonding to each other to form larger particles (Puligundla *et al.*, 2015). According to Fig. (2), the viscosity of mayonnaise samples decreased during storage time, which is related to the decrease in the pH of mayonnaise due to hydrolytic and lipolytic activities in the oil during 60-day storage time. As well as, the decrease of viscosity can be due to the growth of oil droplets size (Table 4) and more gradual acidic hydrolysis of pre-gel cornstarch than the other gums, which affect the structure of the pre-gel cornstarch molecular chain and destroy the functionality of the pre-gel cornstarch, thereby affecting the properties of the final product during 60-day storage time (Cai *et al.*, 2020; Rahbari, Aalami, & Maghsoudlou, 2013). According to the obtained results, changes during the first month were significant for all samples, except for sample S1F2 (2.5), which contain higher gum. In the research, excluding the blank, the highest and lowest viscosities were observed in treatments S1F2 (2.5) and S1F1 (1.5), respectively. Increasing the amount of FG to pre-gel cornstarch caused high levels of high molecular weight molecules in the liquid phase, which caused increased resistance to flow or consistency (Feizabadi, Karazhyan, & Mahdian, 2013). In mayonnaise, the high contact area resulted in friction between the fat droplets, which with applying shear stress opposes against free movement of the spindle of viscometer and therefore shows high viscosity. Decreasing the diameter of the fat particles in treatments containing high gum caused the contact surface area between the fat droplets increasing viscosity. Therefore, the viscosity of the samples can reflect and align with the textural properties especially average droplet size (Liu *et al.*, 2007).

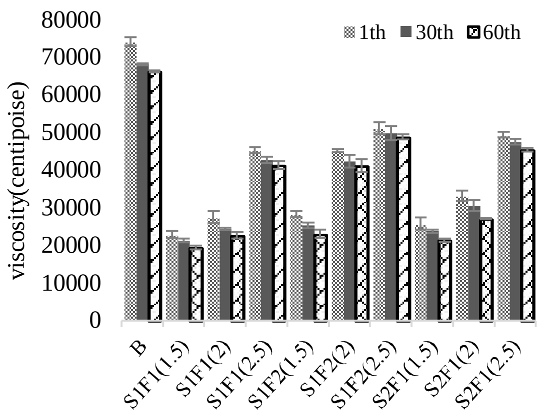

Fig. 2. Viscosity experimental results for mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F)

Color assessment

Color is one of the important factors in the choice of various products by consumers. The colorimetric results of the samples were reported in Table (5). Among color factors, mayonnaise sample lightness exerts a significant impact on consumer acceptance. According to Table (5), the comparison of the L* of samples on the first day of production showed no significant difference between treatments (P>0.05). However, this factor significantly increased during storage (P<0.05). Usually, as the size of the emulsion droplets decreases, the color becomes lighter, i.e. higher L*, which is due to the increase in light scattering. This statement is well observed in the case of covalence complexes of FG and pre-gel cornstarch (Golkar *et al.*, 2015a;b). No significant difference was observed between the blank sample and other samples in 60-day storage time. The comparison of the average a* of samples showed that sample S1F1 (2) presented the highest value, whereas S1F2 (2.5) and S2F1 (1.5) exhibit the lowest value, without having any significant difference with together (P>0.05). Also, a* and b* increased in each treatment over time, due to a significant reduction of average droplet size over time (Table 4). Nevertheless, in each time, the difference between treatments was not significant (P>0.05). In general, the addition of hydrocolloids used does not affect the colorimetric parameters of mayonnaise samples (Karshenas *et al.*, 2018;2019).

Table 5. Color parameters of different mayonnaise formulation containing pre-gelatinized cornstarch (S) and Farsi gum (F) in the first and sixty days after production

Formula	L* (Brightness)		a* (Redness)		b* (Yellowness)	
	1	60	1	60	1	60
S1F1(1.5)	26.30±0.67[abcB]	38.25±2.83[abA]	-15.70±0.11[bB]	-5.25±1.36[abA]	58.00±2.67[aB]	87.82±3.85[abA]
S1F1(2)	25.60±0.11[abcdB]	42.93±2.46[abA]	-12.69±3.13[aB]	-6.80±2.00[abA]	57.00±1.60[aB]	87.16±0.82[abA]
S1F1(2.5)	25.70±0.16[abcdB]	43.50±4.92[abA]	-15.50±0.33[abB]	-6.43±0.72[abA]	58.80±1.60[aB]	88.02±3.36[abA]
S1F2(1.5)	22.90±1.41[dB]	46.99±3.68[aA]	-15.20±0.06[abB]	-8.54±1.24[bA]	56.10±2.20[aB]	88.75±4.76[abA]
S1F2(2)	24.50±0.02[cdB]	35.15±6.92[bA]	-15.20±0.88[abB]	-4.85±3.18[abA]	57.30±1.20[aB]	89.74±5.10[abA]
S1F2(2.5)	27.63±0.82[abB]	46.39±2.41[aA]	-16.00±0.10[bB]	-6.87±1.80[abA]	57.70±0.00[aB]	86.35±0.26[abA]
S2F1(1.5)	28.56±0.08[aB]	39.55±0.06[abA]	-16.00±0.62[bB]	-6.37±0.62[abA]	57.00±5.30[aB]	86.14±1.03[abA]
S2F1(2)	27.62±1.20[abcB]	41.03±2.48[abA]	-14.60±1.24[abB]	-4.76±0.96[aA]	57.40±4.00[aB]	86.07±1.34[abA]
S2F1(2.5)	27.28±1.25[abcB]	40.93±8.12[abA]	-15.50±0.64[abB]	-5.07±2.14[abA]	54.40±2.50[aB]	84.51±0.92[abA]
Blank	25.20±3.15[bcdB]	43.78±1.07[abA]	-15.45±1.70[abB]	-7.68±0.74[abA]	54.90±4.10[aB]	91.48±1.51[aA]

Dissimilar lower cases in each column indicate a significant difference (*P*<0.05), and dissimilar upper cases in each row indicate a significant difference (*P*<0.05)

Sensory evaluation

As shown in Table (6), the statistical analysis results of four evaluated characteristics, namely, appearance, color, smell, and taste, of all treatments have not significantly different (*P*<0.05). However, a comparison of the average of textural scores of treatments showed that the blank, S1F1 (2.5), S1F2 (2), S1F2 (2.5), and S2F1 (2.5) presented the highest score among all samples. One of the main features that were evaluated in the sensory evaluation of mayonnaise was the overall acceptance. In fact, the test panels provided the total score of each treatment based on previous characteristics (appearance, color, smell, taste, and texture) that show satisfaction with the treatments. According to the comparison of the average overall acceptance score of treatments, S2F1 (2.5) and S1F2 (2.5) presented the highest score, with scores of 4.6 and 4.5, respectively. S1F2 (2), S1F1 (2.5), and S2F1 (2) were placed in the following ranks, with scores of 4.3, 4.2, and 4.2, respectively, which were not statistically different from each other and finally, S1F2 (2.5) selected for statistical purposes. According to these scores in Table (6) may argue that used gums did not have any effect on appearance, color, odor, and taste of mayonnaise because the scoring average of characteristics has not significantly different. However, evaluation of the scoring average of texture and overall acceptability showed that the most important feature in scoring by test panels was the final product texture because mayonnaise with higher textural score showed higher overall acceptance. The overall acceptance was higher in the treatments containing more hydrocolloid as a result of the considerably higher viscosity compared with other samples (Karshenas *et al.*, 2018).

Table 6. Sensory evaluation of mayonnaise samples containing pre-gelatinized cornstarch (S) and Farsi gum (F)

Formula	Sensory analysis					
	Appearance	Texture	Taste	Smell	Color	Overall acceptance
S1F1(1.5)	3.90±0.70[a]	3.40±0.20[b]	3.70±0.70[a]	4.20±0.60[a]	3.70±0.70[a]	3.50±0.90[b]
S1F1(2)	3.70±0.50[a]	3.60±0.90[b]	3.90±0.60[a]	3.80±0.70[a]	3.90±0.70[a]	3.70±0.70[b]
S1F1(2.5)	3.80±0.50[a]	4.10±0.80[ab]	3.80±0.40[a]	3.90±0.80[a]	3.80±0.60[a]	4.20±0.40[ab]
S1F2(1.5)	3.70±0.70[a]	3.50±0.70[b]	3.90±0.70[a]	3.90±0.70[a]	3.90±0.80[a]	4.00±0.40[b]
S1F2(2)	3.70±0.60[a]	3.80±0.70[ab]	3.60±0.50[a]	4.20±0.80[a]	4.10±0.80[a]	4.30±0.70[ab]
S1F2(2.5)	4.00±0.50[a]	4.60±0.60[a]	3.80±0.30[a]	4.20±0.70[a]	4.30±0.80[a]	4.60±0.20[a]
S2F1(1.5)	3.80±0.70[a]	3.60±0.90[b]	3.90±0.40[a]	3.90±0.90[a]	3.80±0.90[a]	3.60±0.70[b]
S2F1(2)	4.00±0.70[a]	3.70±0.70[b]	3.90±0.40[a]	3.80±0.70[a]	4.00±0.80[a]	4.20±0.20[ab]
S2F1(2.5)	4.00±0.80[a]	4.50±0.60[a]	3.70±0.30[a]	4.10±0.60[a]	4.10±0.80[a]	4.40±0.30[ab]
Blank	3.90±0.60[a]	4.40±0.20[a]	3.80±0.60[a]	4.10±0.60[a]	3.70±0.60[a]	4.10±0.50[ab]

Dissimilar lower cases in each column indicate a significant difference (*P*<0.05).

Conclusions

Farsi gum, as a fat replacer, can be used to producing low-fat mayonnaise. Texture parameters, i.e., hardness, apparent viscosity, adhesive force, and hardness work done, increase by increasing the amount of this gum, and the amount of these parameters were lower than that of the blank. The blank possessed the highest average droplet size, and the average droplet size decreased with an increasing percentage of FG. The average droplet size continuously decreased with increasing the amount of FG in all pre-gel corn starch: Farsi gum treatments. The rheological behavior of all treatments improved with increasing the amount of FG in all pre-gel cornstarch-Farsi gum treatments. Therefore, the treatments (2.5%) exhibited the highest viscosity, but the viscosity of all samples was significantly lower than that of the blank (P<0.05). No significant difference was shown between color parameters (L*, a*, and b*). Finally, samples S1F2 (2.5), S2F1 (2.5), and S1F2 (2) obtained the highest sensory evaluation scores, respectively.

Acknowledgments

The authors would like to thank Pouyan Company for his great assistance and cooperation during this study. Isfahan (Khorasgan) Branch, Islamic Azad University is also acknowledged for their financial support.

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خواص حسی و بافتی مایونز کم‌چرب تهیه‌شده با نشاستهٔ ذرت ژلاتینه‌شده و صمغ فارسی

حمیدرضا موسی‌خانی گنجه[1]، محمد گلی[2و3*]

1- دانش آموختهٔ کارشناسی ارشد، گروه علوم و صنایع غذایی، واحد اصفهان (خوراسگان)، دانشگاه آزاد اسلامی، اصفهان، ایران

2- دانشیار، گروه علوم و صنایع غذایی، واحد اصفهان (خوراسگان)، دانشگاه آزاد اسلامی، اصفهان، ایران

3- دانشیار، مرکز تحقیقات لیزر و بیوفوتونیک در فناوری‌های زیستی، واحد اصفهان (خوراسگان)، دانشگاه آزاد اسلامی، اصفهان، ایران

* نویسندهٔ مسئول (mgolifood@yahoo.com)

چکیده

در این تحقیق برای اولین‌بار، اثر ترکیبی صمغ فارسی و نشاسته از پیش ژلاتین‌شدهٔ ذرت را به‌عنوان جایگزین چربی و جایگزین صمغ گوار-زانتان روی بافت، پایداری، خواص حسی، متوسط اندازهٔ قطره‌ها و خواص رئولوژی مایونز کم‌کالری موردتحقیق قرار گرفت. ترکیب نشاستهٔ پیش‌ژلاتینه‌شده-صمغ فارسی در نسبت‌های 1:1، 1:2 و 2:1 در سه غلظت 1/5، 2 و 2/5 درصد به مایونز اضافه گردید و نمونهٔ مایونز با ترکیب صمغ گوار-زانتان با نسبت 1:1 به میزان 0/5 درصد به‌عنوان نمونهٔ شاهد انتخاب گردید. نتایج نشان داد که پارامترهای بافتی مانند سفتی، ویسکوزیتهٔ ظاهری، نیروی چسبندگی، چسبندگی و کار اندازه‌گیری‌شده برای اندازه‌گیری سفتی با افزایش مقدار صمغ فارسی افزایش یافتند و البته از نمونهٔ شاهد هم کمتر بود. نتایج به‌دست‌آمده از اندازه‌گیری اندازهٔ قطره‌ها نشان داد که بالاترین اندازهٔ قطره‌ها متعلق به نمونهٔ شاهد بوده است و با افزایش درصد صمغ کاهش یافته است. ویسکوزیتهٔ همهٔ تیمارها با افزایش درصد صمغ افزایش یافت. نتایج نشان داد که اختلاف معنی‌داری بین پارامترهای رنگی مشاهده نشده است. درنهایت تیمارهای به‌ترتیب تیمار نشاستهٔ پیش‌ژلاتینه‌شده-صمغ فارسی (به نسبت 1:2) 2/5 درصد، تیمار نشاستهٔ پیش‌ژلاتینه‌شده-صمغ فارسی (به نسبت 2:1) 2/5 درصد و تیمار نشاستهٔ پیش‌ژلاتینه‌شده-صمغ فارسی (به نسبت 1:2) 2 درصد بالاترین امتیازهای ارزیابی حسی را به خود اختصاص دادند.

واژه‌های کلیدی: ارزیابی حسی، خواص بافتی، صمغ فارسی، مایونز با چربی کاهش‌یافته، نشاستهٔ پیش‌ژلاتینه‌شدهٔ ذرت