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Characterization of Iranian Doogh Enriched with Gum Tragacanth and Fennel Extract (*Foeniculum Vulgare* L.)

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ABSTRACT

The effect of gum tragacanth (0, and 0.15%) and Fennel (*Foeniculum vulgare*) (0, 2.5, and 5%) on the chemical and rheological properties, phase separation, *Lactic Acid Bacteria (*LAB*)* viability, and sensory characteristics of an Iranian dairy drink "Doogh" was investigated during 20 days of storage. Results cleared the stability of Dooghs prepared with Gum Tragacanth Dispersions (GTD) was significantly higher than samples without this hydrocolloid ($P< 0.05$). Doogh samples' viscosity in the presence of Fennel Extract Powder (FEP) was increased significantly ($P< 0.05$). Power-law and Herschel-Bulkley rheological models were appropriate models for describing the flow behavior of control and treated Doogh samples, respectively. The results showed that by increasing the amounts of FEP, LAB viability increased while the fungi population decreased significantly ($P< 0.05$). Therefore, this herbal powder could stimulate *LAB* growth and control the fungi population in treated samples. Finally, adding GTD to the Doogh sample was proper for improving stability, and enrichment with Fennel was suitable for increasing *LAB* viability and microbial spoilage control.

Keywords: Herschel-Bulkley rheological model, Microbial spoilage control, Lactic acid bacteria, Power-law model.

INTRODUCTION

Nowadays, Doogh is produced as a fermented dairy product in Iran, both traditionally and industrially, as a standard product (Zarei *et al*., 2015). This fermented product is produced and consumed worldwide, such as yogurt drink in Europe, Kefir and Kumis in the Middle East, Ayran in Turkey, Lassi in India and Doogh in Iran (Karim *et al*., 2017). Doogh is usually consumed because of desirable sensory properties, high digestibility, microbiological and nutritional quality. Additionally, consumers are willing to consume Doogh as a functional product to improve health and reduce disease risk. Industrial production of Doogh is usually done by diluting milk with water and adding edible sodium salt, and starter bacteria such as *Streptococcus thermophilus* and *Lactobacillus delbrueckii*, followed by fermentation to create the desired flavor (Ardalanian and Fadaei, 2018).

Since pH decreases during the Doogh production, especially fermented types, phase separation occurs at low pH and leads to undesirable appearance and tissue defects. Generally, in milk at natural pH (nearly 6.6), due to the presence of k- casein on the surface of casein micelles and creating electrostatic repulsive forces, aggregation is prevented and the caseins form stable micelles. However, when fermentation occurs and pH falls below the isoelectric pH, it leads to charge imbalances and electrostatic repulsion elimination. This leads to the accumulation of casein micelles and Doogh phase separation during storage (Khanniri *et al*., 2019).

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Many hydrocolloids such as guar gum and High Methoxyl Pectin (HMP) have been used to stabilize Doogh by creating a robust three-dimensional network for trapping water and caseins (Gorji *et al*., 2011; Hashemi *et al*., 2015). Tragacanth gum consists of two parts, soluble and insoluble in water. Bassorin is the water-insoluble part and tragacanth is the water-soluble part. In the study of electrostatic interaction between tragacanth gum and milk proteins, it was found that β-lactoglobulin reacts electrostatically with the soluble portion of tragacanth to stabilize Doogh (Gorji *et al*., 2011).

In the production of Doogh, raw material, starter cultures and secondary contamination such as fungal and bacteria through equipment, air, ventilation system, and packaging materials affect the quality of product and the shelf life. Fungal and bacterial contamination in Doogh can lead to bitterness, bloating, shelf life reduction, and diminished acceptability of the product. (Sayevand *et al*., 2018). Therefore, the use of herbal compounds with antimicrobial properties will effectively increase the microbial quality of Doogh.

Fennel (*Foeniculum vulgare*) is a perennial and aromatic plant usually used as a spice because of its pleasant smell, especially in India and Iran. Fennel contains essential oil, fatty acids, phenyl propane, monoterpenes, sesquiterpenes, coumarins, triterpenes, tannins, flavonoids, cardiac glycosides, saponins, etc. The presence of these compounds in the Fennel causes its antimicrobial properties (Ilić *et al*., 2019).

Therefore, the purpose of the current study was, to improve the stability and microbial properties of Doogh using the tragacanth and Fennel (*Foeniculum vulgare*) to enhance its acceptability for the consumers in Iran.

MATERIALS AND METHODS

Fennel was purchased from a local market in Tehran, Iran. Astragalus gossypinus gum was collected from plants grown in the Isfahan region. Sodium hydroxide was supplied by Sigma-Aldrich Chemie GmbH, from Munich, Germany. Starter culture containing *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* was provided from Danisco (Copenhagen, Denmark). MRS Agar (Man, Rogosa and Sharpe Agar), MRS Broth (Man, Rogosa and Sharpe Broth), Lactose Broth and Sabouraud Dextrose Agar (SDA) were provided by Merck, from Darmstadt, Germany.

Preparation of Tragacanth and Fennel Extract

The Astragalus gossypinus gum was grounded and powdered gum was sieved with a mesh size of 500 µ. Gum Tragacanth Dispersions (GTD) (0, and 0.15% w⁄v) were prepared by adding the powder to distilled water under gentle stirring at 30ºC. The dispersions were left at 3±1ºC for 24 hours to ensure complete hydration of powdered gum (Gorji *et al*., 2011). Following Dubrovskii *et al*. (2019), Fennel seeds were dried and washed with tap water to remove possible potential dust. Afterward, it was dried at room temperature for 48 hours, grounded by an analytical mill, and sieved. Powdered gum was added (100 g) to 1 L of distilled water. The mixture was boiled for 4 min, left to stand for 15 min, and then the extracts were filtered by Whatman No. 1 filter paper. The Fennel extracts were concentrated in a rotary evaporator (Heidolph, Germany) until 14% total solids, kept at 4°C and used at different concentrations (0, 2.5% , and 5% w/v).

Preparation of Doogh Samples

Fennel Extract Powder (FEP) and Gum Tragacanth Dispersions (GTD) were used at different concentrations [Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP), and T_5 (0.15%

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GTD, 5% FEP)]. FEP, GTD and 0.7% salt were dissolving into DI water (80°C for 10 minutes). At the next step, around 40% of the Doogh formulation (set yoghurt with 2.5% fat and acidity of 134 °D) was intermixed with the dilution mixture of the stabilizer and salt (0.7%). The aim was to make 1 liter of Doogh by blending 600 mL water and 400 mL yogurt. The prepared Doogh was homogenized with the homogenizer (T18 IKA, Germany) at 11,000 rpm for 30 seconds at 60°C. Then, the PET (Polyethylene Terephthalate) bottles were filled and the samples were pasteurized at 80°C for 15 minutes. After cooling to proper temperature (37±1°C), Doogh samples were fermented for 8 hours, and stored at 4°C for 20 days. For each treatment, one sample was prepared and the tests were performed in triplicate (Khodashenas and Jouki, 2020).

Physico-Chemical Analysis

The pH of the samples was measured using a digital pH meter (Taiwan, AZ 86502). Titratable acidity was measured by titrating samples with 0.1N NaOH (Gorji *et al*., 2011). The viscosity of the Doogh samples was assessed using the MCR301 rheometer (Anton, Paar, Austria) with the CC27 spindle. Doogh samples were poured into the machine reservoir and the CC27 spindle, at the shear rate of 1.0 to 500 (1 sesond), at 20°C. Doogh samples were equally poured into test tubes (similar in shape and size) for phase separation measurements and stored in a refrigerator (5ºC) for 20 days. The amount of the separated serum (transparent phase) on the surface of the samples was calculated in terms of percentage (Haji Ghafarloo *et al*., 2019). Doogh samples were tested on the 10^{th} and 20^{th} days of storage.

Microbial Analysis

For the microbiological analyses, 10 g of the sample was homogenized with 90 mL of the sterilized saline solution to obtain the initial dilution (10^{-1}). By applying this dilution, several of decimal dilutions were prepared using the same diluent. For the enumeration of the bacteria, the dilutions were plated in-depth in the MRS agar using the Pour Plate Technique (Merck, Germany). The plates were placed in a CO_2 incubator for 72 hours at 37°C. To enumerate mold and yeast, diluted samples were poured on Sabouraud Dextrose Agar plates (Quelab Company, Canada) and inoculated at 25°C for 3 to 5 days. The results were expressed as colony-forming units per gram of product (log CFU g^{-1}) (Haji Ghafarloo *et al*., 2019; Jafari *et al*., 2021). Coliform counts were evaluated in lactose broth (Merck Darmstadt, Germany) at 30ºC for 24 hours (Sayevand *et al*., 2018). Doogh samples were assessed on the 10^{th} and 20^{th} days of storage.

Sensory Analysis

A consumer panel of 9 trained panelists (5 women and 4 men, ages 20-30) performed the sensory analysis using a 5-point hedonic scale ranging from 1 (dislike extremely) to 5 (like extremely). The sensory parameters included color, taste, flavor, texture, and general acceptability. These parameters were analyzed on the 30^{th} day of storage. The Doogh samples were prepared in numbered containers released to panelists at 4±1ºC. (Shariati *et al*., 2019).

Statistical Analysis

Experiments were performed in triplicate, and the significant differences between means were analyzed using one-way ANOVA and LSD post hoc tests (SPSS, version 22, 2016). The nonparametric data were analyzed by applying the Kruskal-Wallis tests.

RESULTS AND DISCUSSION

Changes in pH and Acidity

The pH values and acidity of different Doogh samples during cold storage can be

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seen in Table 1. As shown, the addition of the GTD powder decreased the pH values of the experimental Doogh samples significantly (*p<0.05*). The highest pH value was detected for the T_5 sample on the 10th day, while the T_1 samples displayed the least pH values on the 20th day. The pH values of all samples were decreased during 20 days of refrigerated storage (P< *0.05*). The acidity of Doogh samples was increased during the 20th day of cold storage (Table 1) significantly (P< 0.05). On the 10th day, minor acidity was detected for the T_4 sample with 5% FEP, while the T_1 samples containing 0.15% of GTD showed the highest acidity on the 20th day. The results revealed that the acidity values of T_1 samples containing 0.15% GTD increased significantly on the 20th day (P< 0.05) as compared to the control samples.

The pH value and acidity of Doogh are important factors for quality determination. Codex (2018) determined the maximum pH of 4.5 and the minimum acidity of 0.3 for Doogh. In this study, the resulting data of Doogh pH value and acidity corresponded to the Codex recommended limits and were in the range of 3.28-3.71 and 1.03-2.9%, respectively. Similarly, Sari *et al.* (2018) reported a range of 3.03-4.27 for pH values and 0.4-1.67% for the acidity of Iranian Doogh. The presence of GTD and FEP in most samples did not affect the pH value and acidity significantly (P> 0.05). Also, the pH value of samples on 20th day decreased significantly compared to the 10th day (P< 0.05). It seems, therefore, that the GTD and FEP provide a valuable source of nutrients for LAB, since these compounds contain significant concentrations of carbohydrate compounds, which is a well-known promoter for *LAB* during storage. In line with our research, Ziaolhagh and Jalali (2017) reported that the acidity of bio-Doogh containing the wild thyme essence and xanthan gum increased during fermentation. Contrary to our studies, Ardalanian and Fadaei (2018) reported adding Ginseng extract did not affect the pH of synbiotic Doogh samples.

Phase Separation

The serum separation of Doogh samples was increased significantly (P< 0.05) over the 20 days of cold storage (Table 1). On the 10th day, the minor phase separation percentage was detected for the T_1 samples containing 0.15% of GTD. On the 20th day, the T_5 sample with 0.15% GTD and 5% FEP exhibited the highest phase separation percentage. The rate of phase separation in T_1 samples significantly decreased compared to the control sample and other treatments on the 10th and 20th days.

Gum tragacanth is an anionic polysaccharide carrying a negative charge due to ionized carboxyl groups of galacturonic acid. In an acidic medium, most

Table 1. Physicochemical characteristics of Doogh samples with different concentrations of Gum Tragacanth Dispersions (GTD) and Fennel Extract Powder (FEP) on 10th and 20th days.[a]

Physico-chemical characteristics							
		pH		Acidity		Phase separation (%)	
Treatments		10th day	20th day	10th day	20th day	10th day	20th day
Samples	Control	3.56 ± 0.08 ^{Aa}	3.46 ± 0.01 ^{Bab}	١.٠٩ ± ٠.٠٢ ^{Cb}	٢.٢٠±٠.٠9 ^{Bab}	24.00± 0.30 ^{Bb}	34.40 ±0.40 ^{Aa}
	T_1	3.46± ٠.٠٥ ^{Bab}	3.28 ± 0.$^{0.7}$	١.٧٦± ٠.٠٥ ^{BCb}	٢.٩٢ ±٠.٠٧ ^{Aa}	19.36± 0.50 ^{Cb}	23.76 ±0.57 ^{Bb}
	T_2	3.6 ± ٠.٠٦ ^{Aa}	3.47 ± ٠.٠٦ ^{Bab}	١.٠٨± ٠.٠٧ ^{Cb}	٢.١٥±٠.٠٧ ^{Bab}	24.83± 0.1٥ ^{Bb}	35.40 ±0.20 ^{Aa}
	T_3	3.61 ± ٠.٠٤ ^{Aa}	3.48 ± ٠.٠٤ ^{Bab}	١.٠٨± ٠.١١ ^{Cb}	٢.١٣±٠.٠٩ ^{Bab}	25.46± 0.60 ^{Bb}	37.03 ±0.35 ^{Aa}
	T_4	3.69 ± ٠.٠٣ ^{Aa}	3.5 ± ٠.٠٤ ^{Bab}	١.٠٣±٠.٠٥ ^{Cba}	١.٨٢±٠.٠٧ ^{Bab}	26.00± 0.30 ^{Bb}	38.80 ±0.70 ^{Aa}
	T_5	3.71 ± ٠.٠4 ^{Aa}	3.52 ± ٠.٠6 ^{Bab}	١.٠٤± ٠.١٥ ^{Cb}	١.٨٠±٠.٠٩ ^{Bab}	25.2± 0.4٥ ^{Bb}	39.46 ±0.47 ^{Aa}

[a] Samples included Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP). Means within each column followed by different letters (A–B) show significant different (P<0.05) between treatments at the same time. Means within each row followed by different letters (a–b) show significant different (P< 0.05) at a treatment during storage period

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of the $–COO^-$ groups are converted into -COOH groups, consequently, a notable increase could be seen in the hydrogen bonding interactions between hydrophilic groups and the additional physical degree of crosslinking. Also, Ca^+ ions in the Doogh medium could form covalent cross-links between the free carboxyl and amino groups along neighboring polymer chains; so, they can reduce the negative charge. Therefore, the interaction between Ca^+ ions and negative charge components could lead to a stronger network (Azarikia and Abbasi, 2010; Gorji *et al*., 2011). The capacity of the hydrocolloids to prevent the phase separation of Doogh samples during storage has also been reported by Haji Ghafarloo *et al*. (2019), showing that phase separation in Doogh enriched by gum arabic was slower compared to control sample during storage. According to previous studies, Doogh samples containing a mixture of locust bean and CMC became more stable (Khanniri *et al*., 2019).

As it is clear, adding FEP to treated samples had no positive effect on Doogh stability. Although pectin is a hydrocolloid present in the Fennel extract, applying a low concentration of pectin alone increases the instability of Doogh samples compare to control (Giosafatto *et al*., 2007; Hashemi *et al*., 2015). Also Joudaki *et al*. (2013) reported that a high concentration of pectin is essential to form a weak gel network for the stability of Doogh in the long term.

Viscosity and Rheological Properties

Figure 1 represents the apparent viscosity of different Doogh samples during cold storage. As shown, the apparent viscosity of the treated samples decreased during cold storage and in some Doogh samples this decrease was significant ($P< 0.05$). Moreover, compared to the control, T_4 sample with 5% FEP displayed a significant increase in the apparent viscosity during cold storage ($P< 0.05$). T_5 sample on the 20th day had the least apparent viscosity, while T_4 sample on the 10th day showed the highest apparent viscosity. It was demonstrated that higher viscosity in the samples containing higher amounts of FEP was due to high molecular weight of FEP and the presence of galacturonic acid residues linked by bonds α (1→4) that partially acetylated or esterified by methyl groups (Arioui *et al*., 2017). Similarly, the higher apparent viscosity in milk–sour was obtained using inulins and hydrocolloids (Teimouri *et al*., 2017). Although adding FEP increased Doogh samples viscosity, the presence of FEP had no positive effect on Doogh samples stability. This increase in viscosity appears to create some interactions

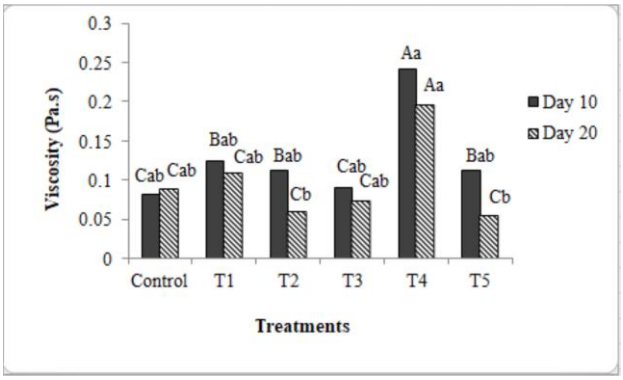

Figure 1. Viscosity of Doogh samples containing different concentrations of Gum tragacanth dispersions (GTD) and Fennel extract powder (FEP) during storage [(Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP)]. Means within each column followed by different letters (A–B) show significant difference ($P< 0.05$) between treatments at the same time. Means within each row, followed by different letters (a–b) show significant difference ($P< 0.05$) at a treatment during storage period.

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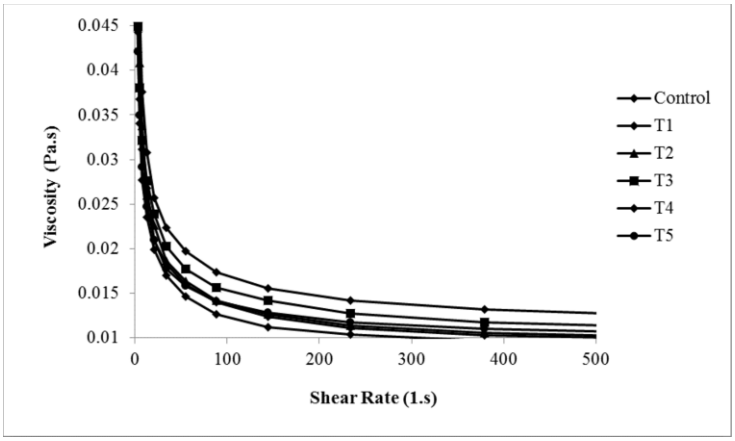
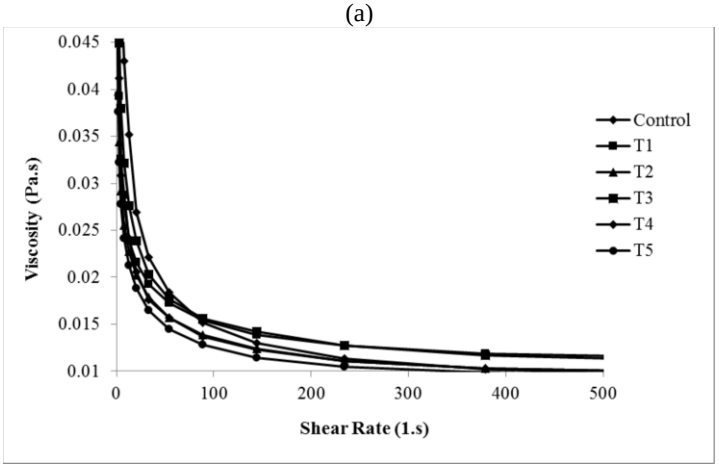
other than FEP interaction with milk proteins (Hashemi *et al*., 2015; Joudaki *et al*., 2013). It should be noted that samples having higher GTD concentrations revealed higher viscosity and stability. This is possibly due to the GDT's ability to induce formation of a network structure in Doogh samples. Tragacanth polysaccharides can cover the Casein micelles particles and interact with water and β-lactoglobulin, increasing viscosity and stability (Ghaderi-Ghahfarokhi *et al*., 2020). A similar trend has been reported by Ghorbani Gorji *et al*. (2011) for the effect of gum tragacanth on viscosity and stability Doogh. Moreover, the results showed that some treated Doogh samples' viscosity decreased significantly during storage ($P< 0.05$). This decrease may be related to the microbial enzyme that hydrolyzes casein micelle polymer during the storage period. However, the growth of microorganisms during storage, production of organic acids, and reduction of pH can effectively reduce the viscosity of Doogh samples. Consistent with our results, Haji Ghafarloo *et al*. (2019) reported decrease in viscosity of some enriched Doogh samples by gum arabic during storage.

Figure 2 (a-b) represent the flow curves of the relationship between shear rate values and apparent viscosity in the samples on 10^{th} and 20^{th} days. As shown in these Figures, with increasing the shear rate, the apparent viscosity of Doogh samples decreased;



(a)



(b)

Figure 2. Flow curves of Doogh samples containing different concentrations of Gum Tragacanth Dispersions (GTD) and Fennel Extract Powder (FEP) during storage [(Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP)] on 10^{th} (a) and 20^{th} (b) days.

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therefore, Doogh is considered as a shear-thinning fluid. The relationship between shear rate and apparent viscosity is nonlinear, so, Doogh is a non-Newtonian fluid. It seems that pseudo-plastic behavior of control and treated samples in the presence of hydrocolloids could be due to the high amount of dry matter and the increased internal interaction between the particles in Doogh (Karim *et al.*, 2017). The results related to the rheological behavior were similar to other studies when hydrocolloids were used in acidic milk beverages (Khanniri *et al*., 2019).

Power-Law and Herschel-Bulkley models, as rheological models, were used to determine the flow behavior of Doogh samples. The power-law and Herschel-Bulkley regression parameters are shown in Table 2. The correlation coefficient (R^2) clearly showed that the control and treated samples had the best fit with the Power-Law and the Herschel-Bulkley models, respectively. Electrostatic interactions between the positive charge of casein groups and anionic polysaccharides in FEP and GDT could cause higher strength against shear stress; hence, initial stress would be needed to cope with the new binding (Laurent and Boulenguer, 2003). Similary, Ghorbani Gorji *et al*. (2011) stated that the power-law model was suitable for controlling the Doogh sample, while the cross model gave a better fitting for samples with a higher amount of gum tragacanth. Similarly, Beitane and Ciprovica (2012) reported synbiotic fermented milk samples as non-Newtonian fluid and used the Herschel-Bulkley model to describe their rheological behavior.

Changes in the Healthful and Unhealthful Microorganism

Table 3 shows variation of the microbial data in Doogh samples during cold storage. The *LAB* cell count revealed a significant decrease during the cold storage period ($p<0.05$). The viability of *LAB* in the most treated samples was more than the control sample on the 10th and 20th days ($P< 0.05$). The highest number of LAB was observed for the T_3 sample on the 10th day (6.47 Log CFU mL^{-1}), and the least number was detected on the 20th day for the control sample (3.69 Log CFU mL^{-1}). Although none of the samples had Coliform contamination on the 10th and 20th days of storage, some samples had fungi contamination on these days.

Table 2. Parameters of Herschel Bulkley model and Power Law of Doogh samples with different concentrations of Gum Tragacanth Dispersions (GTD) and Fennel Extract Powder (FEP) on 10th and 20th days.[a]

Day 10							
	$t= k(\gamma)^n$ Power Law			$t= t_0+k(\gamma)^n$ Herschel–Bulkley model			
Treatments	$k(Pa\times s^n)$	n	R^2	t_0	n	$k(Pa\times s^n)$	R^2
Control	0.019	0.897	0.998 [b]	0.111	0.935	0.015	0.997
T_1	0.030	0.864	0.998	0.113	0.894	0.024	0.999
T_2	0.022	0.881	0.997	0.123	0.922	0.016	0.999
T_3	0.024	0.865	0.992	0.098	0.897	0.021	0.999
T_4	0.012	0.958	0.994	0.171	0.998	0.008	0.997
T_5	0.022	0.885	0.998	0.103	0.918	0.017	0.999
Day 20							
Treatments	$t= k(\gamma)^n$ Power Law			$t= t_0 + k(\gamma)^n$ Herschel–Bulkley model			
	$k(Pa\times s^n)$	n	R^2	t_0	n	$k(Pa\times s^n)$	R^2
Control	0.019	0.900	0.999	0.100	0.936	0.015	0.998
T_1	0.023	0.887	0.9992	0.083	0.911	0.020	0.9996
T_2	0.019	0.896	0.9983	0.081	0.923	0.016	0.9989
T_3	0.024	0.892	0.9993	0.078	0.914	0.020	0.9997
T_4	0.026	0.868	0.992	0.211	0.941	0.014	0.996
T_5	0.014	0.946	0.997	0.092	0.979	0.011	0.998

[a] Samples included Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP). The shadowed correlation coefficient (R_2) show the best fitted rheological models. [b] The shadowed correlation coefficient (R_2) show the best fitted rheological models.

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Table 3. Microbial test results of Doogh samples with different concentrations of Gum tragacanth dispersions (GTD) and Fennel extract powder (FEP) on 10th and 20th days.[a]

		Microorganism count (Log cfu g^{-1})					
Days		10th day	20th day	10th day	20th day	10th day	20th day
Type		*Lactic Acid*		*Fungi*		*Coliform*	
Samples	Control	5.31 ± 0.2^{ABa}	3.69 ± 0.19^{Bb}	1.47 ± 0.15^{Bb}	2.69 ± 0.19^{Aa}	ND	ND
	T_1	5.31 ± 0.18^{ABa}	4.17 ± 0.36^{Bab}	ND	1.31 ± 0.3^{Bb}	ND	ND
	T_2	6.39 ± 0.2^{Aa}	4.6 ± 0.3^{ABb}	ND	ND	ND	ND
	T_3	6.47 ± 0.5^{Aa}	5.54 ± 0.35^{ABab}	ND	ND	ND	ND
	T_4	6.30 ± 0.2^{Aa}	4.17 ± 0.4^{Bb}	ND	ND	ND	ND
	T_5	6.30 ± 0.24^{Aa}	4.30 ± 0.36^{Bb}	ND	ND	ND	ND

[a] Samples included Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP). Means within each column followed by different letters (A–B) show significant different ($P< 0.05$) between treatments at the same time. Means within each row followed by different letters (a–b) show significant different ($P< 0.05$) at a treatment during storage period

Improving the viability of the LAB in probiotic dairy products during storage has been one of the most critical challenges in recent years. In dairy products, bacteriostatic and/or bactericidal factors, such as low pH, organic acids, high redox potential, hydrogen peroxide, molecular oxygen, bacterial competition, and changing temperatures, during storage can decrease the viability of LAB (Ghaderi-Ghahfarokhi *et al*., 2021). The results showed that the presence of GDT was not useful to improve LAB viability. Probably, lack of growth stimulant agents in gum tragacanth caused the insignificant increase of LAB in T1 sample ($P> 0.05$). Similarly, Ghaderi-Ghahfarokhi *et al*. (2021) reported that gum tragacanth had a lower effect on probiotic survival than inulin due to its complex, branched structure. Although increasing FEP concentration up to 2.5% had a positive effect on the viability of LAB, increasing the FEP concentration up to 5% did not affect the survival of LAB. It seems that presence of growth stimulant agents in FEP is one of the possible reasons for the significant increase of LAB in treated samples. However, no study has been performed on the stimulant effect of Fennel extract on LAB in food systems. While Kocheki Shahmokhtar and Armand (2017) reported organic compounds such as hydrocarbons in FEP, these compounds may have a stimulant effect on lactic acid bacteria.

Sensory Properties

The data obtained from the panelists' evaluation of the 10th and 20th days of storage in terms of color, taste, odor, texture, and general acceptance using the Chi-square are shown in Figure 3 (a-b). The results revealed significant differences ($P< 0.05$) in color, flavor, texture and general acceptance of Doogh samples, except for smell on the 10th day. The highest color scores belonged to the control sample and T_1 treatment, and the least color scores belonged to the T_4 and T_5 samples. Regarding the smell parameter, all samples had the same acceptance, and no difference was observed in any of the samples on the 10th day, but T_4 and T_5 treatments received smaller score in smell evaluation on the 20th day. The flavor evaluation result showed that T_1, T_2, T_3 treatment, and the control sample had the highest acceptance, but T_4 and T_5 received the least acceptance. The best texture was observed in the samples treated with 0.15% GTD (T_1) on 10th and 20th days. Also, the worst texture was found in T_4 treatment on the 10th day and T_5 treatments on the 20th day.

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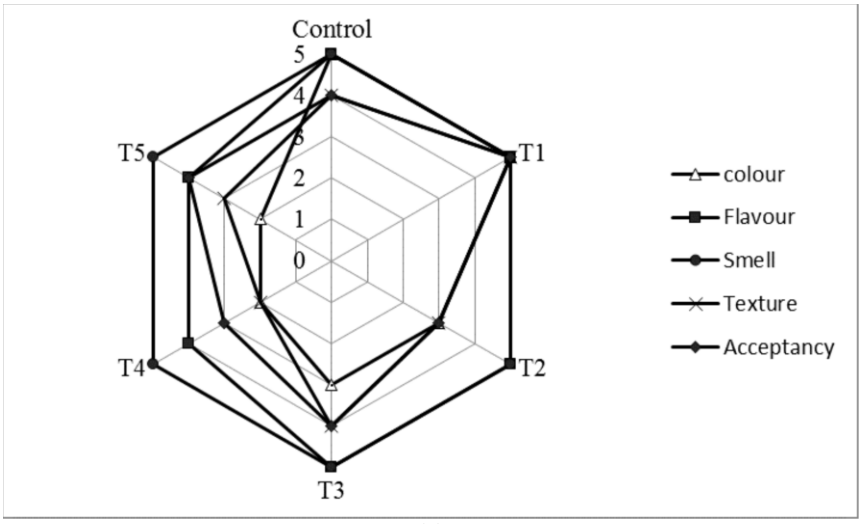
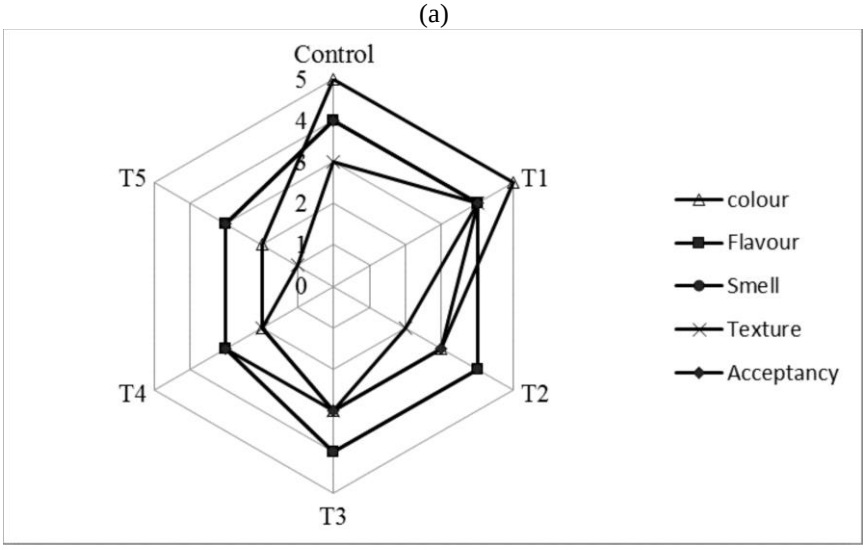


(a)



(b)

Figure 3. Sensory evaluation of Doogh samples containing different concentrations of Gum Tragacanth Dispersions (GTD) and Fennel Extract Powder (FEP) during storage. [Control (0% GTD, 0% FEP), T_1 (0.15% GTD, 0% FEP), T_2 (0% GTD, 2.5% FEP), T_3 (0.15% GTD, 2.5% FEP), T_4 (0% GTD, 5% FEP) and T_5 (0.15% GTD, 5% FEP)] on 10^{th} (a) and 20^{th} (b) days.

After ten days of storage, T_1 treatment was chosen as the best, but on the 20^{th} day of storage, T_1 treatment and control sample were chosen as the best treatments in term of general acceptance. Similarly, Azarikia and Abbasi (2010) revealed that the presence of tragacanthin extracts significantly enhanced the taste score of Doogh. In line with our research, Ziaolhagh and Jalali (2017) reported that adding hydrocolloids such as xanthan gum positively affected the texture of bio-Doogh.

CONCLUSIONS

The present study indicated that by adding GTD to Doogh, the pH values decreased and acidity increased during the storage period. Presence of FEP had no significant effect on pH and acidity values. Although, using GTD led to a significant reduction in the rate of phase separation and an increase of the apparent viscosity, adding FEP had no

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positive effect on Doogh stability. The flow behavior index (n) was less than 1, thus indicating that Doogh could be regarded as a pseudo-plastic fluid. The Doogh sample containing FEP could maintain the acceptable LAB level on the 10^{th} day of storage. T_1 treatment, which contained 0.15% of GTD, had the best condition for phase separation reducing and organoleptic properties among consumers. However, since the survival of LAB increased in T_3 treatment, this treatment should also be considered on the 10^{th} day. Overall, further studies are required to formulate a functional Doogh with high overall acceptability and standard LAB viability for storage during 20 days.

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تأثیر صمغ کتیرا و عصاره رازیانه (*Foeniculum Vulgare* L.) بر خصوصیات دوغ ایرانی

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چکیده

تأثیر صمغ کتیرای (۰ ، ۰/۱۵٪) و عصاره رازیانه (۰%، ۲.۵%، ۵%) بر خصوصیات شیمیایی و رئولوژی، جدایی فاز ها، ، زنده مانی باکتری های اسید لاکتیک (LAB) و ویژگی های حسی نوشیدنی لبنی ایرانی "دوغ" در مدت ۲۰ روز ذخیره سازی مورد بررسی قرار گرفت. نتایج حاصل نشان داد پایداری دوغ های تهیه شده از عصاره کتیرا (GTD) از نمونه هایی که فاقد این هیدروکلوئید بود، به طور معنی داری بیشتر بود($P < 0.05$). با افزایش مقادیر پودر عصاره رازیانه (FEP)، ویسکوزیته بیشتر نمونه های دوغ به طور معنی داری افزایش یافت ($P < 0.05$). مدل هاي رئولوژیکی قانون توان و هرشل-بالکلی مدل هاي رئولوژیکي مناسب براي توصیف رفتار جرياني نمونه هاي دوغ شاهد و دوغ تیمارشده به ترتیب بودند. نتایج حاصل نشان داد با افزایش غلظت FEP در نمونه های دوغ، میزان زنده ماندنی LAB افزایش اما جمعیت قارچ ها به طور معنی داری کاهش یافت($P < 0.05$). بنابراین، این پودر گیاهی می تواند رشد LAB را تحریک کرده و جمعیت قارچ ها را در نمونه های تیمار شده کنترل کند. به طور کلی، افزودن GTD به نمونه های دوغ برای بهبود پایداری آن و غنی سازی با رازیانه برای افزایش زنده ماندن LAB و کنترل فساد میکروبی مناسب بود.

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