Development of an efficient stabiliser mixture for physical stability of nonfat unfizzy doogh

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The effects of locust bean, carboxymethyl cellulose, a mixture of locust bean and carboxymethyl cellulose and Persian gum on different properties of nonfat doogh were studied over a period of 28 days. The results showed that samples containing a mixture of locust bean and carboxymethyl cellulose had the highest stability. Furthermore, the rheological behaviour of the doogh changed from Newtonian to pseudoplastic. Better sensory acceptability was shown for the treatments containing a mixture of locust bean gum and carboxymethyl cellulose. In general, it was shown that a mixture of locust bean and carboxymethyl cellulose could be of practical use in the industrial production of nonfat doogh.

Keywords Carboxymethyl cellulose, Doogh, Hydrocolloid, Locust bean, Persian gum, Stability.

INTRODUCTION

There are many types of fermented milk drinks, which are known by different names in different regions of the world, for example sauermilch in Germany, lassi in India, kefir and kumiss in the Middle East, yoghurt drinks in Europe, ayran in Turkey, laban drink in most Arab countries and doogh in Iran (Kiani et al. 2008; Gorji et al. 2011). These drinking-type fermented milk products principally vary in terms of pH and titratable acidity, and amounts of nonfat solid, salt, fat and added water as well as taste and rheological properties (Kiani et al. 2008). Doogh, the typical Iranian fermented milk drink, is generally made by adding drinking water, salt and some aqueous herbal extracts and essential oils as flavouring agents into stirred yoghurt. This product has a pH lower than 4.5, nonfat solid content of more than 3.0% (w/w) and a salt content less than 1% (w/w) (Joudaki et al. 2013b; Shirkhani et al. 2015). This drink is very popular in Iran and is considered to be the national drink. Furthermore, doogh is exported to neighbouring countries such as Afghanistan, Iraq, Armenia and Azerbaijan, leading to an increase in industrial production (Gorji et al. 2011; Joudaki et al. 2013a).

As the pH of doogh and similar fermented milk drinks is low (≤4.5), phase separation, which is inevitable at this pH, results in an undesirable appearance during storage that is considered as a textural defect. Generally, in milk at natural pH (nearly 6.6), due to the presence of κ-casein on the surface of casein micelles and creating electrostatic repulsive forces, aggregation is prevented and the caseins form stable micelles (Kiani et al. 2010; Joudaki et al. 2013a; Azary and Nasirpour 2016). However, fermentation and acidification to pH values lower than the isoelectric point of casein result in charge imbalance and elimination of electrostatic repulsive forces. This results in the aggregation and precipitation of casein micelles and creating new electrostatic repulsive forces, aggregation is prevented and the caseins form stable micelles (Kiani et al. 2010; Joudaki et al. 2013a; Azary and Nasirpour 2016). However, fermentation and acidification to pH values lower than the isoelectric point of casein result in charge imbalance and elimination of electrostatic repulsive forces. This results in the aggregation and precipitation of casein micelles and phase separation during storage (Shirkhani et al. 2015; Khanniri et al. 2017). Fat plays an important role in the physicochemical and sensory properties of dairy products, and its reduction remarkably increases physical instability in fermented dairy beverages.
(Kiani et al. 2010; Gorji et al. 2011; Shirkhani et al. 2015). However, consumers’ awareness of the relationship between fat in the diet and cardiovascular diseases has resulted in an increasing demand for low-fat food products. Thus, fat reduction without significant changes in the physical and chemical stability, taste and texture behaviour is one of the most important challenges in the dairy industry for the production of low-fat products (Gorji et al. 2011). Overall, fat reduction intensifies physical instability and phase separation in doogh and fermented milks. Thus, different stabilisers are utilised to prevent phase separation in such fermented milks. Hydrocolloids are the most common stabilisers, which can noticeably hinder serum separation in acidified milk beverages by changing milk protein function, electrostatic and/or steric repulsion and enhancing viscosity (Koksoy and Kilic 2004; Shirkhani et al. 2015). Different kinds of hydrocolloids have been used to stabilise acidified milks, and the results have shown that this is affected by pH, ionic power and protein–polysaccharide ratio (Gorji et al. 2011).

Carboxymethyl cellulose (CMC), which is an anionic hydrocolloid, can interact with casein micelles through electrostatic interaction and stabilise the system. On the other hand, neutral hydrocolloids such as locust bean gum (LBG) decrease phase separation by increasing the viscosity of the continuous phase (Koksoy and Kilic 2004; Everett and Mcleod 2005). It was reported that LBG in combination with other hydrocolloids showed a synergistic effect in enhancing viscosity and system stabilisation (Keogh and O’kennedy 1998). Locust bean gum has been used to improve the serum separation in Ayran, and the results showed that phase separation was prevented by LBG at a level of 0.10% without any adverse effect on the sensory properties (Koksoy and Kilic 2004). Zedo gum or Persian gum (PG), a natural hydrocolloid, is transparent and, due to variable chemical compounds, it appears as yellow, orange and red colours. Persian gum is a nonstarch hydrocolloid and, similar to other gums, it increases viscosity of water solutions (Ghasempour et al. 2012). Although PG is used in the pharmaceutical industry as an emulsifier agent, there is only little commercial use of this gum in food production. Therefore, in this study, two commercial hydrocolloids (CMC and LBG) and Persian gum, alone and in combination, were used to design an efficient mixture in order to increase the physical stability of nonfat doogh.

Preparation of Doogh
Doogh samples were prepared by reconstitution of skim milk powder with 3.5% of milk solid nonfat, heated (90°C for 15 min) and cooled down to 42°C (fermentation temperature). The starter culture was added to the pasteurised skim milk, and this was then incubated at 45°C until the pH reached near 4.4. After fermentation, the doogh samples were cooled to 5°C. The appropriate concentration of hydrocolloids used in the doogh formulation was selected based on preliminary experiments. Thus, locust bean (0.15% w/w), carboxymethyl cellulose (0.6% w/w), locust bean in combination with carboxymethyl cellulose (0.1: 0.2% w/w) and locust bean in combination with Persian gum (0.1: 0.1% w/w) were used. Hydrocolloid–salt solutions were prepared by dissolving hydrocolloids and NaCl (0.5% w/w) in deionised water at room temperature, followed by a heating step to 80°C, at which the solutions were stirred for 15 min and kept overnight at 5°C to complete the hydration of hydrocolloids. Finally, the hydrocolloid–salt dispersion was added to the doogh prepared as described above and this was stored at 5°C for 28 days.

Physical stability evaluation
Doogh samples were filled into glass tubes to measure serum separation and stored for 28 days at 5°C. The height of the serum phase was measured and divided by the total height of sample in a tube and multiplied by 100. The results were expressed as the serum separation in percentage (Heydari et al. 2018).

Rheological measurements
Rheological experiments were performed using a Physica MCR301 rheometer (Anton Paar, Graz, Austria) equipped with concentric cylinder geometry (radius ratio of 1.0846). The temperature was controlled with a Peltier system equipped with a fluid circulator (Gorji et al. 2011; Shirkhani et al. 2015; Khanniri et al. 2017). Before measurement, samples were shaken carefully to achieve a homogenous solution. Rheological characteristics of the samples were determined after sample preparation and during 28 days of storage. Flow behaviour curves were obtained at shear rates from 0.1 to 1000/s.

Analysis of particle size
The particle size distribution of the samples was determined by dynamic light scattering using a Cilas particle analyzer 1090. Analyses were performed after sample preparation and during 28 days of storage. Size distribution was characterised by $d$ (0.1), $d$ (0.5) and $d$ (0.9), which are the size of particles below which 10%, 50% and 90% of the samples lies, respectively, volume mean diameter ($D$ [4, 3]), surface mean diameter ($D$ [2, 1]) and span that are based on the following equation (where $n_i$ is the number of particles with diameter $d_i$ (Hashemi et al. 2015; Joudaki et al. 2013b)):
D[4, 3] = \frac{\sum n_id_i^4}{\sum n_id_i^3} \quad (1)

D[2, 1] = \frac{\sum n_id_i^2}{\sum n_id_i} \quad (2)

\text{Span} = \frac{d_{90} - d_{10}}{d_{50}} \quad (3)

**Sensory evaluation**

A panel of 30 assessors evaluated the sensory properties according to their previous experience in dairy product evaluation. The sensory characteristics included flavour, mouthfeel and overall acceptability. Each of these parameters was scored on a five-point scale: 0 = not consumable; 1 = unacceptable; 2 = acceptable; 3 = satisfactory; and 4 = excellent. Doogh samples were presented to the panellists at 5°C in three-digit coded containers, and mineral water was served for rinsing between treatments. Sensory analysis was performed after sample preparation and on day 28. (Heydari et al., 2011)

**Microscopic experiment**

At first, doogh samples (0.15 mL) were diluted with deionised water (20 mL) and then were dyed with 0.5 mL of rhodamine B solution (0.01% w/w) to stain the casein particles. Then the samples were diluted with 20 mL of distilled water. Microscopic images were taken by means of light microscopy (E1000 model; Nikon, Tokyo, Japan) at 100× magnification.

**Statistical analysis**

The measurements in all the tables are the means of triplicate observations. The results obtained were subjected to analysis of variance (ANOVA) using SPSS software (version 21.0), and if F-values were significant, the means were compared by Duncan’s multiple range tests. Significant differences between mean values were defined at P < 0.05. The Friedman and Wilcoxon tests were used for sensory evaluation test.

**RESULTS AND DISCUSSION**

**Physical stability**

The abilities of the hydrocolloids to prevent phase separation of the doogh samples during the refrigerated storage are presented in Table 1. The results showed that all samples containing hydrocolloid were stable up to 7 days of storage but after a week, the physical stability of the doogh samples decreased because of overacidification, large particle sedimentation and casein aggregation at the bottom during the storage period (Hashemi et al. 2015). There was a significant difference between control samples and samples containing hydrocolloids. The sample formulated with LBG in combination with Persian gum (0.1: 0.1% w/w) was more unstable than the other doogh samples containing hydrocolloids and had the highest instability rate at the end of storage time. There was no obvious difference between dooghs formulated with a mixture of LBG and Persian gum (0.1: 0.1% w/w) and those prepared with LBG alone on day 21. The highest stability was observed in samples containing a mixture of locust bean and CMC (0.1: 0.2% w/w); which had the lowest instability rate, and the control sample showed the highest phase separation throughout the storage time. Therefore, locust bean and carboxymethyl cellulose had a synergistic effect on decreasing serum separation in the samples. The increase in stability of doogh samples formulated with the combination of LBG and CMC was probably because of the ability of these polysaccharide molecules to induce the formation of a three-dimensional network in doogh. Locust bean gum and CMC can induce binding of polysaccharide molecules to each other or to proteins and thus create a stable product (Norton et al. 1999).

In a study by Koksoy and Kilic (2004), it was indicated that LBG at a concentration of 0.1% reduced the serum separation of ayran by 83% compared with control samples. The authors announced that the induced steric repulsions between LBG and casein micelles were the reason for stabilisation of ayran (Koksoy and Kilic 2004). Carboxymethylcellulose is an anionic polysaccharide that creates a negative charge due to the presence of carboxyl groups. The effective interaction occurs between CMC and casein at a pH below 5.2. Carboxy methylcellulose adsorbs onto the casein particles and makes bridges between the casein micelles that help them become stable (Du et al. 2007). In addition, steric repulsion generated by the adsorbed CMC layer and electrostatic repulsion produced between casein particles influences the stability of Doogh (Du et al. 2009). The present study indicated that CMC alone (0.6% w/w)

<table>
<thead>
<tr>
<th>Table 1 Serum separation (%) in different treatments during storage period*</th>
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<tr>
<td><strong>Storage time</strong></td>
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<tr>
<td>Treatments**</td>
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<td></td>
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<tr>
<td>L_{0.1} – C_{0.2} = 4.4</td>
</tr>
<tr>
<td>L_{0.1} – F_{0.1} = 4.4</td>
</tr>
<tr>
<td>L_{0.15} = 4.4</td>
</tr>
<tr>
<td>C_{0.6} = 4.4</td>
</tr>
<tr>
<td>B = 4.4</td>
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</tbody>
</table>

*Means shown with different small and capital letters represent significant differences (P < 0.05) in the same columns (among the treatments) and rows (between days in each treatment), respectively.

**L_{0.1} – C_{0.2} = 0.1% LBG – 0.2% CMC, L_{0.1} – F_{0.1} = 0.1% LBG – 0.1% Persian gum, L_{0.15} = 0.15% LBG, C_{0.6} = 0.6% CMC, B = without hydrocolloid in pH 4.4.
could not create an appropriate stability during the storage period. The result was in agreement with previous research by Ntazinda et al. (2014). They investigated the stabilising behaviour of soybean soluble polysaccharides (SSPS) and CMC in acidified skimmed milk drinks. They reported that SSPS (6 g/L) was more effective than CMC (6 g/L) when they were used individually. However, use of CMC alone did not prevent serum separation in acidified skimmed milk drinks (Ntazinda et al. 2014).

Previous studies showed that the interaction between casein micelles and charged hydrocolloids does not occur at milk pH (about 6.6), but with a decrease in pH and increase in positive-charge casein micelles, anionic polysaccharides adsorb onto the surface of casein micelles via electrostatic interactions and increase the stability (Tromp et al. 2004). Evaluation of the use of hydrocolloids alone showed that the level of locust bean had more effect on serum separation compared with the level of carboxymethyl cellulose in doogh. Noncharge polysaccharides such as LBG build a hydrocolloid network and entrap the water and casein micelles (Syrbe et al. 1998; De Kruif and Tuinier 2001). Although reducing fat enhances serum separation (Koksoy and Kilic 2004; Gorji et al. 2011), it is worth mentioning that the doogh samples in the present study were stabilised using hydrocolloids without the presence of fat.

Rheological properties

The apparent viscosity (η) versus shear rate of doogh treatments on days 0 and 28 is shown in Figure 1 (a,b), respectively. Results indicated that the presence of hydrocolloids showed shear-thinning (pseudoplastic) behaviour where the viscosity increased with the decrease in shear rate (Janhøj et al. 2008; Azarikia and Abbasi 2010) and control samples showed Newtonian flow behaviour where the viscosity was independent of the shear rate. Other researchers have also reported that fermented drinks such as doogh exhibit non-Newtonian flow behaviour (Kiani et al. 2010). The results clearly showed that the apparent viscosity of samples containing hydrocolloid was higher than doogh samples without stabiliser. Therefore, the hydrocolloids increased apparent viscosity (Janhøj et al. 2008; Azarikia and Abbasi 2010; Hashemi et al. 2015). Probably, the interactions between the chains were the cause of the increases in the apparent viscosity. The greatest apparent viscosity was observed in samples containing 0.6% w/w CMC, followed by treatments; LBG (0.1% w/w) in combination with CMC (0.2% w/w), LBG alone (0.15% w/w) and mixture of LBG (0.1% w/w) with Persian gum (0.1% w/w), respectively, and control samples showed the lowest level of viscosity on days 0 and 28. In a study by Ntazinda et al. (2014), it was observed that by increasing CMC level from 3 to 6 g/L, the viscosity of acidified skimmed milk drink (pH 4) was enhanced (Ntazinda et al. 2014). Probably, CMC adsorbs onto the casein micelles by electroerosption and generates a protein–polysaccharide complex and the viscosity of the serum is increased by nonadsorbed CMC that leads to stabilisation of acidified milk drinks (Du et al. 2009). Syrbe et al. (1998) mentioned that nonadsorption polysaccharides such as LBG are thickening agents that enhance the viscosity by the formation of a network and entrap the casein particles (Syrbe et al. 1998). Also, other studies have reported an increase in the viscosity through nonadsorption polysaccharides in acidified milk drinks (Koksoy and Kilic 2004). On the other hand, Camacho et al. (2005) investigated the effect of the mixture of LBG and λ-carrageenan on the rheological properties of dairy creams. Their study indicated that the functional role of LBG was related to an increase in the emulsion shear stability (Camacho et al. 2005).

Particle size measurement

Particle size distribution is extensively used to investigate the formation of protein–polysaccharide complexes. Table 2 shows particle size parameters in doogh samples. The lowest $D_{3,4}$ (13.59 μm) and $D_{2,1}$ (6.15 μm) were obtained for treatments containing LBG alone. The highest $D_{3,4}$ (23.11 μm) and $D_{2,1}$ (12.05 μm) values were obtained for samples prepared with the combination of LBG and CMC on day 0, and control treatment had the highest $D_{3,4}$ (33.55 μm) and $D_{2,1}$ (17.5 μm) on day 28. The mean diameter of D90 was about 63.17 μm in plain doogh without any hydrocolloid. It was observed that doogh samples containing hydrocolloids, except the samples containing a mixture of locust bean and Persian gum (0.1: 0.1% w/w), had smaller particles than the control samples on day 28. Therefore, the results obtained indicated that hydrocolloids prevented aggregation of casein micelles and increased the dispersion of particles by three mechanisms including steric inhibition, electrostatic repulsion and increasing in combination with the viscosity of the continuous phase (Du et al. 2007). The highest $d_{90}$ and span value were for samples formulated with a mixture of locust bean and Persian gum (0.1: 0.1% w/w). It is hypothesised that increase in the span and $d_{90}$ in samples containing Persian gum was due to its insoluble fraction. Abbasi and Mohammadi (2013) reported that Persian gum forms soluble and insoluble fractions (Abbasi and Mohammadi 2013).

Sensory characteristics

The results of the sensory evaluation are shown in Table 3. It was found that the lowest taste, mouthfeel and overall acceptance scores belonged to plain doogh samples. Therefore, in this study, there was a difference between the treatments containing stabilisers and the control treatment in terms of taste, mouthfeel and total acceptance during the storage period. Doogh samples containing a mixture of LBG and CMC received higher taste, mouthfeel and total acceptance scores in comparison with other by doogh samples prepared on day 0 and day 28 ($P < 0.05$). In addition,
there was no significant difference between the samples containing a combination of LBG and Persian gum and the samples were stabilised with CMC and LBG alone regarding taste and mouthfeel at the end of storage period. Koksoy and Kilic (2004) mentioned that LBG does not have any bad effect on the flavour of ayran (Koksoy and Kilic 2004).

It seems a mixture of LBG and CMC had a positive effect on the sensory properties as well as the stability of doogh, as is shown in Table 1. The control sample had higher score regarding taste at the beginning of the storage than at the end of storage, because during storage time, the increasing acidity and pH reduction lead to a sour taste in the product.

### Microscopic observation

The microscopic images of the most stable doogh sample (containing a mixture of LBG and CMC) and control sample are indicated in Figure 2 (a,b), respectively. In the control sample, great clusters of casein micelles were visible and they were in an aggregated form. However, images of doogh stabilised with a mixture of LBG and CMC revealed that there was no aggregation and the casein particles were separated. It can be elucidated that large aggregates are converted to small pieces in the presence of hydrocolloids.

### Table 3 Sensory analysis of Dooghs at day 0 and 28*

<table>
<thead>
<tr>
<th>Treatments**</th>
<th>Taste</th>
<th>Mouthfeel</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>d0</td>
<td>d28</td>
<td>d0</td>
</tr>
<tr>
<td>L₀.₁–C₀.₂–4.₄₄</td>
<td>2.₉₉³⁺⁺⁺</td>
<td>3.₁²⁺⁺⁺</td>
<td>3.₁²⁺⁺⁺</td>
</tr>
<tr>
<td>L₀.₁–F₀.₁–4.₄₄</td>
<td>2.₁¹⁺⁺⁺</td>
<td>2.₂¹⁺⁺⁺</td>
<td>2.₈²⁺⁺⁺</td>
</tr>
<tr>
<td>L₀.₁₅–4.₄₄</td>
<td>2.₁¹⁺⁺⁺</td>
<td>2.₁¹⁺⁺⁺</td>
<td>1.₉¹⁺⁺⁺</td>
</tr>
<tr>
<td>C₀.₆–4.₄₄</td>
<td>1.₉¹⁺⁺⁺</td>
<td>2.₂²⁺⁺⁺</td>
<td>1.₉¹⁺⁺⁺</td>
</tr>
<tr>
<td>B–₄.₄</td>
<td>2.²⁺⁺⁺</td>
<td>1.₂⁺⁺⁺</td>
<td>2.₂²⁺⁺⁺</td>
</tr>
</tbody>
</table>

*Means shown with different small and capital letters represent significant differences (P < 0.05) in the same columns (among the treatments) and rows (between days in each treatment), respectively.

**L₀.₁–C₀.₂ = 0.₁% LBG–0.₂% CMC, L₀.₁–F₀.₁ = 0.₁% LBG–0.₁% Persian gum, L₀.₁₅ = 0.₁₅% LBG, C₀.₆ = 0.₆% CMC, B = without hydrocolloid in pH 4.₄.

### Table 2 Particle size parameters of doogh samples*

<table>
<thead>
<tr>
<th>Particle size parameters</th>
<th>D₁₀ (µm)</th>
<th>D₅₀ (µm)</th>
<th>D₉₀ (µm)</th>
<th>D₃,₄ (µm)</th>
<th>D₂,₁ (µm)</th>
<th>Span (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments**</td>
<td>d₀</td>
<td>d₂₈</td>
<td>d₀</td>
<td>d₂₈</td>
<td>d₀</td>
<td>d₂₈</td>
</tr>
<tr>
<td>L₀.₁–C₀.₂–4.₄₄</td>
<td>6.₂₄²⁺⁺⁺</td>
<td>7.₀₃²⁺⁺⁺</td>
<td>1₉.₉₄²⁺⁺⁺</td>
<td>2.₁₃²⁺⁺⁺</td>
<td>4₄.₃²⁺⁺⁺</td>
<td>4₇.₄²⁺⁺⁺</td>
</tr>
<tr>
<td>L₀.₁–F₀.₁–4.₄₄</td>
<td>2.₉₉²⁺⁺⁺</td>
<td>3.₄₁²⁺⁺⁺</td>
<td>1₉.₂₅²⁺⁺⁺</td>
<td>1₂.₆₈²⁺⁺⁺</td>
<td>5₂.₈²⁺⁺⁺</td>
<td>₈₅.₄²⁺⁺⁺</td>
</tr>
<tr>
<td>L₀.₁₅–4.₄₄</td>
<td>0.₀₈²⁺⁺⁺</td>
<td>2.₈₄²⁺⁺⁺</td>
<td>3.₇₁²⁺⁺⁺</td>
<td>1₀.₄₉²⁺⁺⁺</td>
<td>1₃.₂₅²⁺⁺⁺</td>
<td>₂₉.₀₆²⁺⁺⁺</td>
</tr>
<tr>
<td>C₀.₆–4.₄₄</td>
<td>3.₈₄²⁺⁺⁺</td>
<td>₄.₂₂²⁺⁺⁺</td>
<td>₁₄.₉₅²⁺⁺⁺</td>
<td>₁₅.₄₁²⁺⁺⁺</td>
<td>₂₉.₈₅²⁺⁺⁺</td>
<td>₃₁.₈₉²⁺⁺⁺</td>
</tr>
<tr>
<td>B–₄.₄</td>
<td>4.₃₇²⁺⁺⁺</td>
<td>₉.₇₅²⁺⁺⁺</td>
<td>₁₄.₇₉²⁺⁺⁺</td>
<td>₂₉.₈₂²⁺⁺⁺</td>
<td>₃₄.₃₆²⁺⁺⁺</td>
<td>₆₃.₁₇²⁺⁺⁺</td>
</tr>
</tbody>
</table>

*Means shown with different small and capital letters represent significant differences (P < 0.05) in the same columns (among the treatments) and rows (between days in each treatment), respectively.

**L₀.₁–C₀.₂ = 0.₁% LBG–0.₂% CMC, L₀.₁–F₀.₁ = 0.₁% LBG–0.₁% Persian gum, L₀.₁₅ = 0.₁₅% LBG, C₀.₆ = 0.₆% CMC, B = without hydrocolloid in pH 4.₄.
CONCLUSIONS

The present study revealed that stability of nonfat doogh could be significantly affected by the combination of absorbent (carboxymethyl cellulose or Persian gum) and nonabsorbent (locust bean) hydrocolloids. The results showed that the mixture of hydrocolloids had a synergistic effect and increased the stability of nonfat doogh through three mechanisms, including spatial inhibition, electrostatic repulsion and increasing viscosity of the continuous phase. The samples containing LBG alone and a mixture of LBG and CMC were the most stable at the end of the storage period. However, in respect of sensory evaluation, the highest scores were related to the treatment containing LBG and CMC. Moreover, it was demonstrated that the addition of hydrocolloids resulted in smaller particle size. In general, the doogh sample containing a mixture of LBG: CMC with the ratio of 1:2 was shown to be the best treatment with desirable characteristics for the production of nonfat unfizzy doogh.

ACKNOWLEDGEMENT

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES


Heydari S, Mortazavian AM, Ehsani MR, Mohammadiifar MA and Ezzatpanah H (2011) Biochemical, microbiological and sensory
characteristics of probiotic yogurt containing various prebiotic compounds. *Italian Journal of Food Science* **23** 153–164.


