Journal of Food Biosciences and Technology,
Islamic Azad University, Science and Research Branch, Vol. 10, No. 2, 91-100, 2020

Effect of Flaxseed *(Linum usitatissimum*) Mucilage on Physicochemical and Sensorial Properties of Semi-Fat Set Yoghurt

S. Arabshahi- Delouee[a*], Sh. Rahati Ghochani[b], A. Mohammadi[c]

[a] Assistant Professor, Department of Food Science and Technology, Azadshahr Branch, Islamic Azad University, Azadshahr, Iran.
[b] M.Sc. Student of Food Science and Technology, Azadshahr Branch, Islamic Azad University, Azadshahr, Iran.
[c] PhD Student of Food Science and Technology, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran.

Received: 8 August 2018 Accepted: 16 July 2019

ABSTRACT: In the present study, the effect of addition of flaxseed mucilage on the physicochemical and sensorial properties of semi-fat (1.5% fat) set yoghurt was evaluated. Yoghurt samples were incorporated with flaxseed mucilage at the levels of 0.00, 0.10, 0.15, and 0.20% and analyzed periodically for pH value, titrable acidity, viscosity, consistency, water holding capacity, syneresis, colour parameters, and sensory attributes during storage at 5°C (1, 7, and 15 days). The addition of flaxseed mucilage in the formulation of semi-fat yoghurt significantly influenced on chemical, physical, and sensorial properties of semi-fat set yoghurt during storage period. The pH value of all the samples decreased and acid value increased during storage period. Viscosity, consistency, water-holding capacity of the yoghurt samples increased while the syneresis value decreased with increasing the amount of flaxseed mucilage and storage time. Flaxseed mucilage addition decreased *L** value while increased *a** and *b** values of the yoghurt. The sensory attributes of yoghurt samples were also affected by the level of flaxseed mucilage, so that the sample containing 0.15% flaxseed mucilage was preferred in terms of all the sensory attributes tested by the panelists.

Keywords: *Flaxseed, Linum usitatissimum, Mucilage, Synersis, Yoghurt.*

Introduction

Yoghurt is one of the most popular dairy products, that is well known for its health and nutritional benefits (low lactose and high concentrations of calcium) for centuries. The origin of yoghurt is dated back to the 6000 B.C. (Coisson *et al.*, 2005; Weerathilake *et al.*, 2014). Yoghurt contains a network of three-dimensional casein strands aggregated through iso-electric precipitation due to the action of lactic acid bacteria. The fat cells and denatured serum proteins which are placed in this network as filler affect the quality characteristics of yoghurt such as textural properties, viscosity, and syneresis. In fact, the composition and structure of milk play a significant role in the desirability of the yoghurt (Aguirre-Mandujano *et al.*, 2009; Purwandari *et al.*, 2007).

Recently, consumers' interest in non-fat or low-fat dairy products has increased due to their health benefits. However, reducing the amount of fat negatively affects the texture, rheological and sensory properties of these products. Hydrocolloids have many functional properties and can be used as fat replacer in low-fat food products. Thus,

[*] Corresponding Author: sarabshahi@iauaz.ac.ir; saeedeh_arabshahi@yahoo.com

hydrocolloids including polysaccharides or proteins have attracted attention of scientists for the production of new food formulations. They provide various functions in food products such as thickening, stabilizing, gelling, fat substituting, crystallization inhibiting, encapsulating, etc. (Burey *et al.*, 2008). Decourcelle *et al.* (2003) studied about different concentrations of thickeners such as starch, pectin, locust bean gum, and guar in yoghurt formulation and reported that using of these compounds improved the sensory properties of samples. Brennan & Tudorica (2007) observed that addition of barley beta-glucan, guar gum, and inulin as fat replacers in the formulation of low-fat yoghurt increased the firmness of the product, decreased syneresis, and improved acceptability in terms of sensory properties. Also, Bahrami *et al.* (2013) produced probiotic yoghurt using xanthan gum, barley β-glucan, and guar gum. Their results highlighted that xanthan gum and β-glucan are suitable fat replacers for production of low-fat yoghurt.

Flax or linseed (*Linum usitatissimum*) is a member of the genus *Linum* in the family *Linaceae*. Health benefits and functional properties of flaxseed are attributed to its components including proteins, lignans, polyunsaturated fatty acids like α-linolenic acid, and soluble flaxseed gum (mucilage) (Hall *et al.,* 2006; Wang *et al.,* 2008). Flaxseed mucilage contains L-galactose, L-rhamnose, D-xylose, L-arabinose, and D-galacturonic acid (Mazza & Biliaderis, 1989; Warrand *et al.,* 2005). Flaxseed mucilage exhibits various functional properties including rheological properties (eg., gel forming ability), water-holding capacity, water-binding ability, and potential physiological functions in the gastro-intestinal tract such as reducing serum cholesterol, decreasing glycemic and insulinemic response (Qian, 2014; Wang *et al.,* 2008). The main objective of this study is to the develope a new formulation of semi-fat (1.5% fat) yoghurt product using flaxseed mucilage. Accordingly, the effect of the addition of flaxseed mucilage at various levels on the chemical, physical, and sensorial properties of semi fat yoghurt has been investigated.

Materials and Methods

Commercial freeze-dried starter culture (YO-MIX® Multi, a blend of *Streptococcus salivarius* subsp. *thermophilus* and *Lactobacillus delbrucckii* subsp. *bulgaricus*) was provided from Danisco Co. (Denmark). Flaxseed mucilage was purchased from Giahessence Phytopharm and Pharmaceutical Co. (Gorgan, IRAN). Skimmed milk powder was obtained from Pegah Co. (Gorgan, IRAN). Pasteurized and homogenized milk was supplied from Ilvar Co. (Gorgan, IRAN). All other chemicals, reagents, and solvents used were of analytical grade and were purchased from Merck chemical company (Darmstadt, Germany).

- *Preparation of yoghurt samples*

Semi fat (1.5% fat) homogenized milk was standardized to 12 kg of solid non-fat/100 kg milk using skim milk powder. The flaxseed mucilage was added to standardized milk in quantities of 0.00 (negative control), 0.10, 0.15 and 0.20 kg/100 kg milk. The standardized full fat (3% fat) milk was also used as positive control. The prepared samples were homogenized using homogenizer (FT 9-Armfield, UK) at pressure about 7 Mpa and then pasteurized at 90ºC for 10 minutes. The samples were rapidly cooled down to 42ºC and inoculated with yoghurt culture YO-MIX (Danisco Co. Denmark) in quantity 2 ml of batch starter/1000 ml milk. The thoroughly mixed samples were poured into appropriate containers and incubated at 42ºC to obtain a titrable acidity of 80 Dornic degrees. The samples were cooled down rapidly to stop fermentation and stored at

5ºC for 15 days. The samples were analyzed for chemical, rheological and sensorial characteristics on 1st, 7th and 15th days of storage (Domagala *et al.*, 2006).

- pH and titrable acidity measurement

pH values of samples were measured according to AOAC (2005) standard method using a pH meter (Model 211, USA) at 20°C. In order to measure the titrable acidity, approximately 9 grams of each sample was diluted with the same volume of distilled water and titrated with 0.1 N NaOH, using phenolphthalein solution as an indicator. Titrable acidity of the samples was expressed as Dornic degrees (°D).

- Viscosity

Viscosity measurement was performed using a Brookfield viscometer (Model RV-DVII, USA) with a No 6 spindle rotating at 70 rpm. The temperature of the sample was 5 °C (Vareltzis *et al.*, 2016).

- Bostwick consistency

Consistency was determined according to the method of Farahnaky *et al.* (2011). The distance (in cm) which the material flowed in a Bostwick consistometer was measured at 10°C for 30s.

- Syneresis and water holding capacity

The syneresis of yoghurt samples was determined according to the method of Garcia-Perez *et al.* (2005). 25 grams of each sample was transferred into a funnel fitted with a 41-mesh stainless steel screen. The volume of the whey collected over 2 h at 4°C was measured in 50-ml graduated cylinder and reported as synersis .

In order to evaluate the water holding capacity of yoghurt samples, 5 grams of each sample was centrifuged (Sigma, Germany) for 30 min at 4500 rpm at 10°C. The supernatant was removed and the sediment weighed. The water holding capacity (WHC) was calculated based on the following equation (Sahan *et al.*, 2008):

$$\text{WHC (\%)} = (1 - w_t / w_i) / \times 100, \quad (1)$$

where w_t is the weight (g) of the pellet and w_i is the initial weight (g) of the sample.

- Color measurement

The color characteristics of the samples were measured according to the method of Garcia-Perez *et al.* (2005) with some modifications. The system included a digital camera (Canon, Japan) an image-capturing box and image analysis software (Image j 1.47v, National Institutes of Health, USA). Samples were transferred into a glass tube, holder was placed at the bottom of the box, and the digital camera was fixed 20 cm far from the sample.

- Sensory evaluation

The sensory evaluation of yoghurt samples was carried out according to the method of Barrantes *et al.* (1994). The samples were evaluated on first, 7th, and 15th days of storage by 10 experienced panelists. The sensory parameters judged were color (desirability of visual), taste and odor intensity and consistency by spoon (by gentle mixing yoghurt with a spoon). The qualitative (nonparametric) data was converted to quantitative (parametric) data according to a 1–5 points scale from 1(very unfavorable) till 5(very favorable).

- Statistical analysis

Analysis of variance, means, and standard errors were determined by using SPSS software program and significant differences of means using Duncan test at 1%. All the tests were performed in triplicate.

Results and Discussion

- pH and titrable acidity

pH and titrable acidity values of yoghurt samples are presented in Table 1. Analysis of variance indicated that the level of flaxseed mucilage and duration of storage had significant (p<0.01) effects on the pH and titratable acidity of the yoghurt samples. pH values of yoghurt samples ranged from 4.25 to 4.40 and acidity values ranged from 89.33 to 111.00 (°D). pH of the yoghurt samples decreased and acidity values increased during the storage period (p<0.01) that is due to the activity of yoghurt bacteria and production of lactic acid. The maximum and minimum values of pH belonged to the positive control (full fat yoghurt) and semi-fat yoghurt containing 0.20 % flaxseed gum, respectively. These results were in agreement with the results of Sahan *et al.* (2008) who reported that titrable acidity of non-fat yoghurt supplemented with beta-glucan increased during storage period.

- *Viscosity*

Figure 1 shows changes in the viscosity values of various yoghurt samples over 15 days of storage. Significant differences were noted between viscosity values of some samples (p<0.01) according to the analysis of variance. The yoghurt samples incorporated with flaxseed mucilage had higher viscosity than the positive and negative control samples. The viscosity values were generally proportional to the level of flaxseed mucilage in the samples. Increasing viscosity of semi-fat yoghurt with flaxseed mucilage can be attributed to the water absorption capacity of the mucilage. Sahan *et al.* (2008) reported that hydrocolloid compounds bind free water and trap it in casein network thus increase the viscosity of the samples. Moreover, viscosity values of all the samples increased throughout storage. The highest and lowest viscosity values belonged to the sample containing 0.20% flaxseed mucilage and negative control sample, respectively. Similar results were also observed for non-fat plain yoghurt (Isleten & Karagul-Yuceer, 2006) and non-fat yoghurt with added beta-glucan (Sahan *et al.*, 2008) throughout storage. They explained that increasing viscosity of non-fat yoghurt during storage could be due to the protein rearrangement and protein–protein contact.

Table 1. Changes in pH and titrable acidity values of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days)

Sample	Flaxseed mucilage (%)	Time (day)	pH	Titrable acidity (°D)
Positive control[1]	0.00	1	4.31 ± 0.01[fg]	93.66 ± 1.15[f]
		7	4.32 ± 0.00[fg]	97.00 ± 1.73[e]
		15	4.25 ± 0.00[i]	111.00 ±1.73[a]
Negative control[2]	0.00	1	4.33 ± 0.01[ef]	90.33 ± 1.52[gh]
		7	4.34 ± 0.01[ef]	93.66 ± 1.15[f]
		15	4.31 ± 0.00[g]	97.66 ± 0.57[e]
FM_1*	0.10	1	4.36 ± 0.01[cd]	91.00 ± 1.73[gh]
		7	4.35 ± 0.01[de]	93.66 ± 1.52[f]
		15	4.28 ± 0.00[h]	102.00 ± 1.73[d]
FM_2	0.15	1	4.39 ± 0.01[ab]	89.33 ± 0.57[h]
		7	4.38 ± 0.02[bc]	91.66 ± 1.15[fgh]
		15	4.26 ± 0.01[i]	105.33 ± 0.57[c]
FM_3	0.20	1	4.40 ± 0.01[a]	89.33 ± 1.15[h]
		7	4.34 ± 0.01[ef]	92.33 ± 0.57[fg]
		15	4.25 ± 0.00[i]	108.00 ± 2.00[b]

[1] Positive control: full-fat (3% fat) yoghurt sample
[2] Negative control: semi-fat (1.5% fat) yoghurt sample
*FM: flaxseed mucilage
Mean values with different letters within each column indicate significant differences (p<0.01).

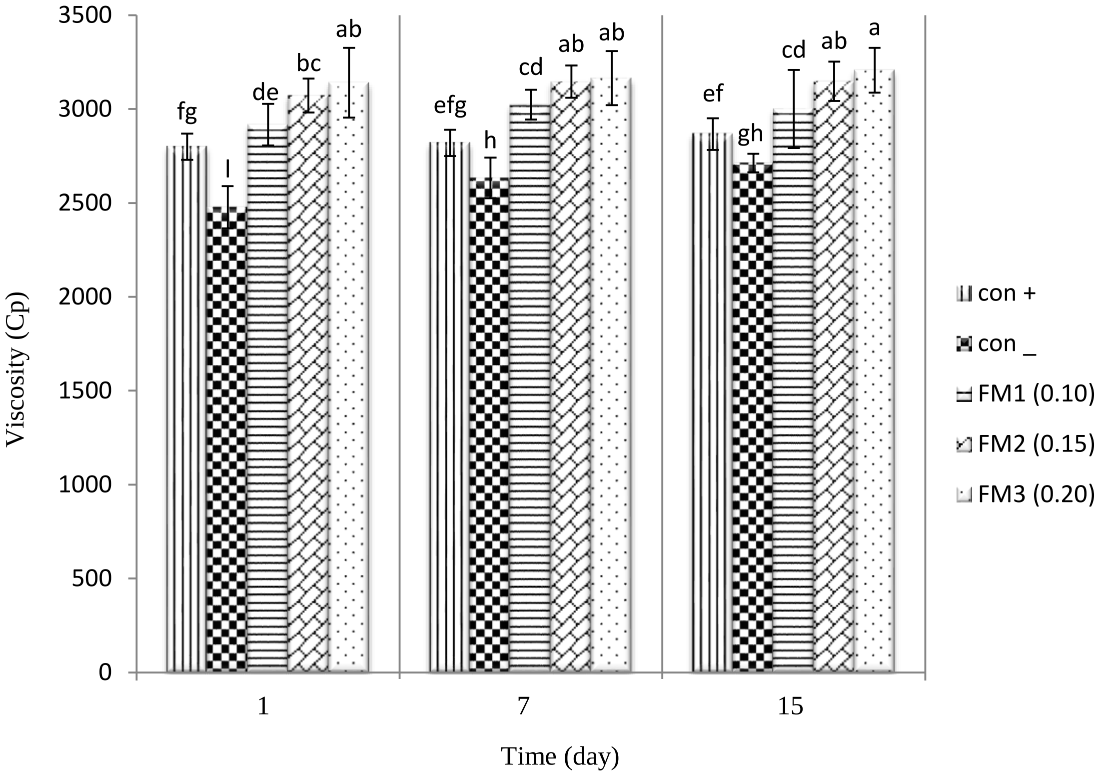

Fig. 1. Changes in viscosity (Cp) values of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days).
Positive control: full-fat (3% fat) yoghurt sample, Negative control: semi-fat (1.5% fat) yoghurt sample, FM: flaxseed mucilage. Mean values with different letters within each column indicate significant differences ($p<0.01$).

- *Consistency*

The changes in the consistency values of various yoghurt samples over 15 days of storage are shown in Figure 2. According to analysis of variance, significant differences were noted between the consistency of some samples ($p<0.01$). The consistency of samples increased with increasing the amount of flaxseed mucilage in the yoghurt. Moreover, consistency of all the samples increased throughout storage and were generally proportional to the level of flaxseed mucilage. The highest and lowest consistency belonged to the sample containing 0.20% flaxseed mucilage and negative control sample, respectively. Indeed, higher level of flaxseed mucilage increased the water absorption capacity resulting in the formation of a more robust gel network structure (Gonzalez-Martýnez *et al.*, 2002). Lucey (2002) found that using stabilizers such as polysaccharides and proteins in yoghurt formulation can improve the consistency via increasing viscosity and reducing syneresis. Pang *et al.* (2017) reported that using bovine gelatin and fish gelatin increase the consistency of yoghurt.

- *Syneresis and water holding capacity*

Whey separation is an important defect in yoghurt which is defined as the appearance of whey (serum) on the gel surface of set-type yoghurts. Syneresis is the shrinkage of the gel, which leads to whey separation (Lucey, 2004). The results of syneresis and water holding capacity (WHC) of yoghurt samples during storage are shown in Table 2. According to the results, addition of flaxseed mucilage to the yoghurt decreased the syneresis of the samples ($p<0.01$) which may be attributed to the interaction between flaxseed mucilage and the surface of casein micelles to strengthen the casein network and reduce syneresis (Hematyar *et al.*, 2012). The addition of stabilizers such as xanthan gum and carrageenan decreased syneresis of yoghurt samples (El-Sayed *et al.*, 2002). The syneresis of all the yoghurt samples decreased during the whole period of storage. The negative control sample and the sample containing 0.20% flaxseed mucilage had maximum and minimum syneresis throughout storage, respectively. These results are in agreement with the reports of Guzel-Seydim *et al.* (2005), Guven *et al.* (2005), and Isleten & Karagul-Yuceer (2006).

WHC is determined as drainage occurs during utilization of stress and detects protein network resistance against shear stress (Ebdali *et al.*, 2013). The results of WHC analysis are shown in Table 2. The addition of flaxseed mucilage to the yoghurt significantly ($p<0.01$) increased the WHC of the samples as the maximum and minimum WHC related to the sample containing 0.20% flaxseed mucilage and the negative control sample, respectively. This may be due to the association of flaxseed mucilage with casein network thus increasing the WHC. WHC of each sample did not change significantly ($p<0.01$) throughout storage period. Proteins and fat globules also play a key role in WHC of yoghurt. Wu *et al.* (2001) reported that the water-holding capacity related to the ability of the proteins to maintain water within the yoghurt structure. These researchers suggested that the fat globules in the milk might also play an important role in sustaining water.

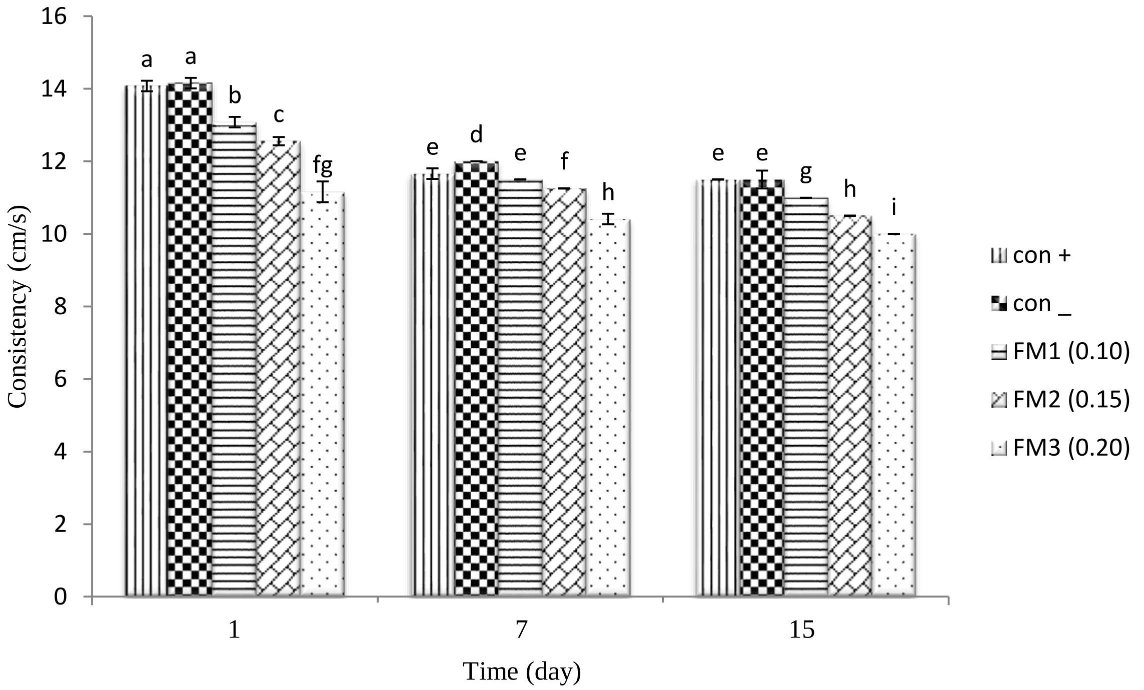

Fig. 2. Changes in consistency (cm/s) of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days).
Positive control: full-fat (3% fat) yoghurt sample, Negative control: semi-fat (1.5% fat) yoghurt sample, FM: flaxseed mucilage. Mean values with different letters within each column indicate significant differences ($p<0.01$).

Table 2. Changes in syneresis (g/25g) and water holding capacity (%) of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days)

Sample	Flaxseed mucilage (%)	Time (day)	Syneresis (g/25g)	WHC (%)
		1	13.91 ± 0.01[b]	63.33 ± 1.52[fg]
Positive control[1]	0.00	7	13.52 ± 0.02[e]	64.66 ± 0.57[efg]
		15	11.85 ± 0.02[e]	66.00 ± 0.00[def]
		1	14.32 ± 0.02[a]	59.33 ± 2.30[h]
Negative control[2]	0.00	7	13.79 ± 0.02[c]	60.66 ± 1.15[h]
		15	12.34 ± 0.02[h]	58.66 ± 1.15[h]
		1	13.85 ± 0.01[bc]	66.66 ± 1.15[de]
FM_1*	0.10	7	12.81 ± 0.21[f]	66.00 ± 0.00[def]
		15	11.71 ± 0.03[j]	68.00 ± 0.00[d]
		1	13.62 ± 0.02[d]	78.00 ± 2.00[abc]
FM_2	0.15	7	12.55 ± 0.03[g]	75.33 ± 3.05[c]
		15	11.54 ± 0.02[k]	76.00 ± 2.00[bc]
		1	13.45 ± 0.02[e]	80.66 ± 1.15[a]
FM_3	0.20	7	12.52 ± 0.02[g]	78.66 ± 1.15[ab]
		15	11.36 ± 0.01[l]	80.00 ± 2.00[a]

[1] Positive control: full-fat (3% fat) yoghurt sample
[2] Negative control: semi-fat (1.5% fat) yoghurt sample
*FM: flaxseed mucilage
Mean values with different letters within each column indicate significant differences (p<0.01).

- *Color characteristics*

Color characteristics as *L**, *a** and *b** values of various yoghurt samples are shown in Table 3. *L** value is an assessment of food whiteness (Owens *et al.*, 2001). Whiteness in dairy products is related to colloidal particles such as casein micelles and milk fat globules that are able to scatter light in the visible spectrum (Garcıa-Perez *et al.*, 2005). The *L** value of the semi-fat yoghurt decreased with increasing the amount of flaxseed mucilage (p<0.01) indicating that flaxseed mucilage donated a darkening effect, probably due to the absorption of water by flaxseed mucilage. *a** and *b** values of the yoghurt increased (p<0.01) with increasing the amount of flaxseed mucilage as the sample containing 0.20% flaxseed mucilage had the maximum *a** and *b**value among the samples. Pasteurization may have favored the release of some pigments from flaxseed mucilage that made the product more yellow. Moreover, pasteurization can induce destabilization of the casein micelles which increases *a** and *b** values. The addition of fiber to the yoghurt decreased *L** value and increased *b** value of the yoghurt during fermentation and cold storage process (Garcıa-Perez *et al.*, 2005).

- *Sensory evaluation*

The mean scores of sensory evaluation of the yoghurt samples are shown in Table 4. Analysis of variance of results indicated significant differences (p<0.01) between sensory scores of yoghurt samples. Among the attributes assessed, colour was highly influenced by addition of flaxseed mucilage in the yoghurt as the sample containing 0.20% mucilage received the least score by the panelists throughout storage period. In terms of taste and odor attributes, the sample containing 0.15% flaxseed mucilage received higher scores than other samples. Increasing the amount of flaxseed mucilage improved consistency; however, the sample containing 0.10% mucilage was scored

Table 3. Changes in *L**, *a**, and *b** values of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days)

Sample	Flaxseed mucilage (%)	Time (day)	L^*	a^*	b^*
Positive control[1]	0.00	1	89.1 ± 3.1 ᵃ	2.5 ± 0.1 ᵉ	3.0 ± 0.6ᶜ
		7	89.1 ± 3.5 ᵃ	2.4 ± 0.2 ᵉ	2.4 ± 0.4 ᵉ
		15	88.4 ±0.4 ᵃᵇ	2.2 ± 0.3 ᵉᶠ	2.7 ± 0.5 ᵈ
Negative control[2]	0.00	1	87.6 ± 1.8 ᵇ	2.1 ± 0.3 ᶠ	2.7 ± 0.2ᵈ
		7	88.0 ± 1.5 ᵃᵇ	2.0 ± 0.6 ᶠ	2.8 ± 0.1 ᵈ
		15	87.3 ±1.4 ᵇ	2.2 ± 0.2 ᵉᶠ	2.9 ± 0.2ᵈ
FM_1*	0.10	1	85.3 ± 5.1 ᶜ	2.9 ± 0.5 ᶜ	3.5 ± 0.2 ᵇᶜ
		7	85.6 ± 2.5 ᶜ	2.8 ± 0.1 ᶜ	3.4 ± 0.1 ᵇᶜ
		15	85.7 ± 2.4 ᶜ	2.7 ± 0.2 ᵈ	3.2 ± 0.2 ᶜ
FM_2	0.15	1	83.2 ± 3.0 ᵈ	3.1 ± 0.5 ᵇᶜ	3.8 ± 0.2 ᵃᵇ
		7	84.2 ± 3.1 ᵈᶜ	3.0 ± 0.2 ᶜ	3.8 ± 0.1 ᵃᵇ
		15	84.6 ±1.7 ᵈᶜ	3.0 ± 0.2 ᶜ	3.7 ± 0.2 ᵇ
FM_3	0.20	1	81.3 ± 2.1 ᵉ	3.5 ± 0.3 ᵃ	4.1 ± 0.2 ᵃ
		7	81.3 ±3.2 ᵉ	3.4 ± 0.1 ᵃᵇ	4.0 ± 0.1 ᵃ
		15	81.6 ± 4.4 ᵉ	3.2 ± 0.3 ᵇ	4.2 ± 0.3 ᵃ

[1] Positive control: full-fat (3% fat) yoghurt sample
[2] Negative control: semi-fat (1.5% fat) yoghurt sample
* FM: flaxseed mucilage
Mean values with different letters within each column indicate significant differences ($p<0.01$).

Table 4. Mean scores for sensory properties of yoghurt samples made with or without flaxseed mucilage during storage period (5°C, 15 days)

Sample	Flaxseed mucilage (%)	Time (day)	Consistency	Colour	Odor	Taste	Overall Acceptability
Positive control[1]	0.00	1	3.8±1.5 ᵇ	3.9±2.4 ᵃ	3.6±1.5 ᵈᵉ	3.4±2. 4 ᵈ	3.4±0.4 ᶠ
		7	3.8±0.2 ᵇ	3.9±3.5 ᵃ	3.7±0.2 ᵈᵉ	3.6±3.5 ᶜ	3.4±0.1 ᶠ
		15	3.7±3.1 ᵇ	3.8±0.8 ᵃ	3.5±3.1 ᵉ	3.1±0.8 ᵉ	3.5±0.2 ᵉᶠ
Negative control[2]	0.00	1	2.2±0.2 ᵉ	2.4±2.4 ᶜ	2.9±0.2 ᶠ	2.5±2.4 ᶠ	3.3±0.2 ᵍ
		7	2.7±3.1 ᵈ	2.2±0.8 ᶜ	2.8±3.1 ᶠ	2.1±0.8 ᶠᵍ	3.1±0.1 ⁱ
		15	3.0±1.5 ᶜ	2.3±3.5 ᶜ	2.5±1.5 ᵍ	2.0±3.5 ᵍ	3.0±0.2 ⁱ
FM_1*	0.10	1	3.8±3.1 ᵇ	3.9±0.8 ᵃ	3.8±3.1 ᵈ	3.9±0.8 ᵇᶜ	3.7±0.1 ᵉ
		7	3.9±1.5 ᵇ	3.8±3.5 ᵃ	3.9±1.5 ᵈ	3.8±3.5 ᵇᶜ	3.5±0.2 ᵉᶠ
		15	3.9±0.2 ᵇ	3.8±2.4 ᵃ	3.9±0.2 ᵈ	3.8±2.4 ᵇᶜ	3.2±0.2 ʰ
FM_2	0.15	1	4.3±1.5 ᵃᵇ	3.5±2.4 ᵃᵇ	4.5±1.5 ᵃᵇ	4.5±2.4 ᵃ	4.7±0.4 ᵃ
		7	4.2±0.2 ᵃᵇ	3.4±3.5 ᵃᵇ	4.6±0.2 ᵃ	4.4±3.5 ᵃ	4.7±0.1 ᵃ
		15	4.2±3.1 ᵃᵇ	3.2±0.8 ᵇ	4.4±3.1 ᵇ	4.1±0.8 ᵇ	4.5±0.2 ᵃᵇ
FM_3	0.20	1	4.5±1.5 ᵃ	3.2±0.8 ᵇ	4.1±1.5 ᶜᵈ	4.0±0.8 ᵇᶜ	4.5±0.2 ᵃᵇ
		7	4.5±3.1 ᵃ	3.2±3.8 ᵇ	4.2±3.1 ᶜ	4.1±3.5 ᵇ	4.4±0.1 ᵇ
		15	4.4±0.2 ᵃ	3.3±2.4 ᵇ	4.2±0.2 ᶜ	4.0±2.4 ᵇᶜ	4.2±0.2 ᶜ

[1] Positive control: full-fat (3% fat) yoghurt sample
[2] Negative control: semi-fat (1.5% fat) yoghurt sample
* FM: flaxseed mucilage
Mean values with different letters within each column indicate significant differences ($p<0.01$).

similar to the positive control sample. Regarding the sensory evaluation it might be concluded that the sample containing 0.15% flaxseed mucilage was preferred by the panelists among the samples investigated. Increasing the level of beta-glucan composite in the non-fat yoghurt negatively influenced the sensory scores of the yoghurt

(Sahan *et al.,* 2008). Garcia-Perez *et al.* (2005) determined that there were significant differences in orange aroma and flavor between control and fiber orange yoghurts and the differences increased with the fiber concentration. Seçkin & Baladura (2011) found that fibrous strained yoghurts weren't preferred by panelists because of their ragged structure, dominant apple taste and strong odor.

Conclusion

The results of this study indicated that the addition of flaxseed mucilage at the levels of 0.10, 0.15 and 0.20 % in the formulation of semi-fat yoghurt significantly ($p<0.01$) influenced chemical, physical, and sensorial properties of semi-fat set yoghurt. The pH value of all the samples decreased and acidity value increased during storage period. Physical properties including viscosity, consistency, water holding capacity, a^* and b^* values of the yoghurt increased while syneresis and L^* value decreased with increasing the amount of flaxseed mucilage and storage time. The sensory attributes of yoghurt samples were affected by the level of flaxseed mucilage. Based on the results obtained, the application of flaxseed mucilage in yoghurt formulation as a suitable fat replacer is recommended due to its improving effects on physicochemical and sensorial properties of semi-fat yoghurt.

References

Aguirre-Mandujano, E., Lobato-Calleros, C., Beristain, C. I., Garcia, H. S. & Vernon-Carter, E. J. (2009). Microstructure and viscoelastic properties of low-fat yoghurt structured by monoglyceride gels. LWT - Food Science and Technology, 42 (5), 938–944.

AOAC. (2005). Official methods of analysis. 17th ed, Association of Official Analytical Chemists, Washington, DC, USA.

Bahrami, M., Ahmadi, D., Alizadeh, M. & Hosseini, F. (2013). Physicochemical and Sensorial Properties of Probiotic Yogurt as Affected by Additions of Different Types of Hydrocolloid. Korean Journal for Food Science of Animal Resources, 33(3), 363-368.

Barrantes, E., Tamime, A. Y. & Sword, A. M. (1994). Production of low calorie yogurt using skim milk powder and fat-substitute. 3. Microbiological and organoleptic qualities. Milchwissenschaft, 49, 205–208.

Brennan, C. S. & Tudorica, C. M. (2007). Carbohydrate-based fat replacers in the modification of the rheological, textural and sensory quality of yoghurt: comparative study of the utilization of barely beta-glucan, guar gum and inulin. International Journal of Food Science and Technology, 43(5), 824-833.

Burey, P., Bhandari, B. R., Howes, T. & Gidley, M. J. (2008). Hydrocolloid gel particles: formation, characterization, and application. Critical Reviews in Food Science and Nutrition, 48(5), 361-377.

Coisson, J.D., Travaglia, F., Piana, G., Capasso, M. & Arlorio, M. (2005). Euterpe oleracea juice as a functional pigment for yogurt. Food Research International, 38(8), 893–897.

Decourcelle, N., Lubbers, S., Vallet, N., Rondeau, P. & Guichard, E. (2003). Effect of thickeners and sweeteners on the release of blended aroma compounds in fat-free stirred yoghurt during shear conditions. International Dairy Journal, 14(9), 783-789.

Domagala, J., Sady, M., Grega, T. & Bonczar, G. (2006). Rheological properties and texture of yoghurts when oat-maltodextrin is used as a fat substitute. International Journal of Food Properties, 9(1), 1–11.

Ebdali, S., Motamedzadegan, A., Hosseini-parvar, S. H. & Shahidi, S. A. (2013). Comparative study on effect of pectin, gelatin and modified starch replacement with fish gelatin in textural properties and graininess of Non-fat yogurt, https://www.civilica.com/Paper-IECFP01-IECFP01_034.html

El-Sayed, E. M., Abd El-Gawad, I. A., Murad, H. A. & Salah, S. H. (2002). Utilization of laboratory-produced xanthan gum in the manufacture of yogurt and soy yogurt. European Food Research and Technology, 215(4), 298–304.

Farahnaky, A., Safari, Z., Ahmadi Gorji, F. & Mesbahi, G.R. (2011). Use of gelatin as a fat replacer for low fat cream production. Iranian

Journal of Food Science and Technology, 31(8), 45-52.

Garcıa-Perez, F. J., Lario, Y., Fernandez-Lopez, J., Sayas, E., Perez-Alvarez, J. A. & Sendra, E. (2005). Effect of orange fiber addition on yogurt color during fermentation and cold storage. Colour Research and Application, 30(6), 457-463.

Gonzalez-Martınez, C., Becerra, M., Chafer, M., Albors, A., Carot, J. M. & Chiralt, A. (2002). Influence of substituting milk powder for whey powder on yoghurt quality. Trends in Food Science and Technology, 13(9), 334–340.

Guven, M., Yasar, K., Karaca, O. B. & Hayaloglu, A. A. (2005). The effect of inulin as a fat replacer on the quality of set-type low-fat yogurt manufacture. International Journal of Dairy Technology, 58(3),180–184.

Guzel-Seydim, Z. B., Sezgin, E. & Seydim, A. C. (2005). Influences of exopolysaccharide producing cultures on the quality of plain set type yogurt. Food Control, 16(3), 205–209.

Hall, C., Tulbek, M. C. & Xu, Y. (2006). Flaxseed, Advances in food and nutrition research 51:1-97. Editor: Fidel Toldrá. Elsevier Inc.

Hematyar, N., Mohagheghi Samarin, A., Poorazarang, H. & Elhamirad, A.H. (2012). Effect of Gums on Yogurt Characteristics. World Applied Sciences Journal, 20(5), 661-665.

Isleten, M. & Karagul-Yuceer, Y. (2006). Effects of dried dairy ingredients on physical and sensory properties of nonfat yogurt. Journal of Dairy Science, 89(8), 2865–2872.

Lucey, J. A. (2004). Cultured dairy products: An overview of their gelation and texture properties. International Journal of Dairy Technolog, 57(2), 77–84.

Lucey, J.A. (2002). Formation and physical properties of milk protein gels. Journal of Dairy Science, 85(2), 281-294.

Mazza, G. & Biliaderis, C.G. (1989). Functional properties of flaxseed mucilage. Journal of Food Science, 54(5), 1302–1305.

Owens, S.L., Brewer, J.L. & Rankin, S.A. (2001). Influence of bacterial cell population and pH on the color of nonfat milk. Lebensmittel-Wissenschaft Technol, 34(5), 329 –333.

Pang, Z., Deeth, H., Yang, H., Prakash, S. & Bansal, N. (2017). Evaluation of tilapia skin gelatin as a mammalian gelatin replacer in acid milk gels and low fat stirred yogurt. Journal of Dairy Science, 100(5), 2436-3447.

Purwandari, U., Shaha, N. P. & Vasiljevic, T. (2007). Effects of exopolysaccharide-producing strains of Streptococcus thermophilus on technological and rheological properties of set-type yoghurt. International Dairy Journal, 17(11), 1344–1352.

Qian, K. Y. (2014). Structure-Function Relationship of Flaxseed Gum from Flaxseed Hulls. A Thesis resented to The University of Guelph, Guelph, Ontario, Canada.

Sahan, N., Yasar, K. &Hayaloglu, A. A. (2008). Physical, chemical and flavour quality of non-fat yogurt as affected by a b-glucan hydrocolloidal composite during storage. Food Hydrocolloids, 22(7), 1291–1297.

Seçkin, A. K. & Baladura.E. (2011). Effect of using some dietary fibers on color, texture and sensory properties of strained yogurt. GIDA, 37, 63-69.

Vareltzis, P., Adamopoulos, K., Stavrakakis, E., Stefanakis, A. & Goula, A. M. (2016). Approaches to minimise yoghurt syneresis in simulated tzatziki sauce preparation. International Journal of Dairy Technology, 69(2), 191-199.

Wang, Y., Wang, L. J., Li, D., Ozkan, N., Chen, X. D. & Mao, Z. H. (2008). Effect of flaxseed gum addition on rheological properties of native maize starch. Journal of Food Engineering, 89(1), 87–92.

Warrand, J., Michaud, P., Picton, L., Muller, G., Courtois, B., Ralainirina, R. & Courtois, J. (2005). Structural investigations of the neutral polysaccharide of Linum usitatissimum L. seeds mucilage. International Journal of Biological Macromolecules, 35(3), 121–125.

Weerathilake, W. A. D. V., Rasika, D. M. D., Ruwanmali, J. K. U. & Munasinghe, M. A. D. D. (2014). The evalution,processing,varieties and health benefits of yogurt. International Journal of Scientific and Research Publications, 4(4),1-10.

Wu, H., Hulbert, G. J. & Mount, J. R. (2001). Effects of ultrasound on milk homogenization and fermentation with yogurt starter. Innovative Food Science and Emerging Technologies, 1(3), 211–218.