 https://doi.org/10.1051/e3sconf/202339201029

Potential use of flaxseed mucilage in dairy product technology

A Sungatullina[1], *T* Petrova[1], and *E* Nikitina[1*]

[1]Institute of Food Technology and Biotechnology, Kazan National Research Technological University, 68, K. Marks Str., Kazan, 420015, Russian Federation

Abstract. The use of flaxseed mucilage as a natural stabilizer in fermented milk was studied by varying the species of lactic acid bacteria used. It was found that flaxseed mucilage was effective in improving texture characteristics, reducing hardness and increasing elasticity. The increase in acid-forming activity of lactic-acid bacteria in the presence of flaxseed mucilage is possibly due to increased levels of starter microorganisms. Flaxseed mucilage in the dairy product did not significantly affect the total amount of proteins, however, there was a tendency to a slight decrease in the amount of proteins in variants FM with strains L.fermentum AG8 and L.plantarum AG9. Flaxseed mucilage has good potential for use as an effective stabilizer in dairy beverages.

1 Introduction

Flax (Linum usitatissimum L.) is widely used in the food industry for oil, dietary fiber, and for direct food consumption. Flax seeds contain a significant amount of water-soluble polysaccharides (mucilage), which is a mixture of neutral arabinoxylans and acidic rhamnose-containing polysaccharides [1].

It can be used in food systems as a hydrocolloid, thickener [2] and gelling agent [3]. In addition, the use of flaxseed mucilage (FM) in dietary can an effect on lowering blood glucose and cholesterol levels in people [4].

Yogurt is one of the most popular foods. Its consumption is increasing due to its good dietary, nutritional and taste properties. Texture and consistency are important components affecting the quality of yogurts. Increasing total solids, adding stabilizers (such as polysaccharides), manipulating variable processing parameters and starter culture characteristics can be used to improve texture.

The purpose of this work is to evaluate the use of mucilage from brown flax (FM) as a stabilizer in thermostatic fermented non-fat milk when varying the species of lactic acid bacteria and study physicochemical and textural characteristics.

[*] Corresponding author: ev-nikitina@inbox.ru

2 Materials and methods

2.1 Preparation of fermented milk

The UHT milk (Valio®, Russia) was used in this experiment (fat – 0.05 %). Fermented milks were prepared using starter culture consisted of *Limosilactobacillus fermentum* AG8 and *Lactiplantibacillus plantarum* AG9, described earlier [5] and Lactobacillus delbrueckii subs. bulgaricus ("Lactosynthesis", Moscow, Russia) served as a reference strain. The lactic acid bacteria (LAB) were stored in de Man, Rogosa, and Sharpe (MRS) broth (Himedia, India) with 50% glycerol at −80°C. For culture activation, a 100-μL aliquot of each culture was individually transferred into MRS broth and incubated at 37°C for 24 h. This culture was used for inoc-ulation into skimmed milk for pre-cultures.

Flaxseed mucilage (FM) of brown flax was used for fermented milk. FM was added to skimmed milk at a concentration of 0.2 % and subjected to heating, in a boiling water bath followed by heating at 100°C for 30 min; the mixture was stirred for uniform distribution of FM.

The pre-cultures of LAB were prepared by incubation at 40 ºC for 16 h in skimmed UHT milk. Obtained pre-cultures were inoculated (5 % v/v milk) into the skimmed and incubated at 40 °C for 8 h with following refrigeration at 6 ºC for 16 h. The physicochemical, textural properties of fermented milk were evaluated after 24 h.

2.2 Physicochemical analyses

Analysis of total titratable acidity (TTA), protein, protein in whey, lactose, glucose, dry matter, salts have been described by us earlier [6].

2.3 Apparent Viscosity and Textural Studies

The apparent viscosity of fermented milk samples was measured using a viscometer (RV-DVIII, Brookfield programming Rheometry, Inc., China). The spindle #3 and rate 30 min-1 was selected in configuration providing the torque in the range of 10 % to 90 % during measurements, as suggested by the manufacturer. The temperature of the samples was maintained at 6 °C ± 1 °C throughout the test. Measurements were carried out in 3 replicates for each treatment and results were expressed in mPa.s.

The texture profile analysis test was carried out using ST-2 texture analyzer (Quality Laboratory JSC, Moscow, Russia) with a cylindrical probe of 36 mm in diameter and 35 mm in height, which penetrated the undisturbed samples of fermented milk. Two cycles were applied to a depth of 10 mm at the rate of 0.5 mm s^{-1}, touch force 7 g. Fermented milk was tested in a chemical beaker with a diameter of 50 mm, the height of the sample was 25 mm. As a result, a plot of force versus time was obtained for each sample using the software ST-2 for Windows (Quality Laboratory JSC, Moscow, Russia). The following factors were determined: Firmness (g), Fracturability, Adhesion force (g), Adhesiveness, Cohesiveness, Gumminess, Springiness, Chewiness [6].:

3 Results

It was found that adding of FM low amounts to skim milk has a positive effect on the acid-forming ability of lactic acid bacteria when fermenting milk (Figure 1). The greatest stimulation of lactic acid synthesis was detected in the case of Bulgarian bacillus. In the future development of technological solutions, this means reducing the time of fermentation of dairy products, respectively, leads to a reduction in energy costs.

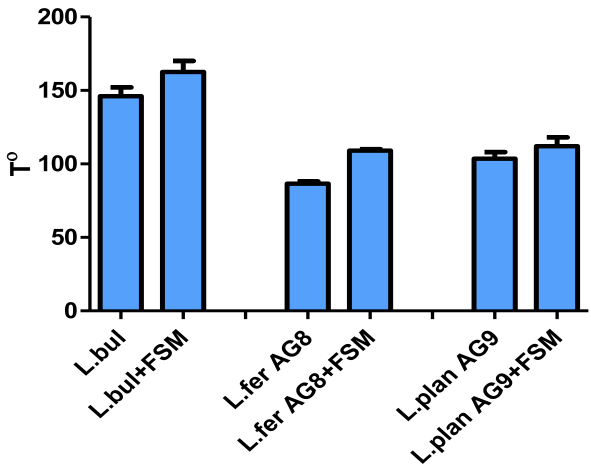

Fig. 1. Effect of FM on the acid formation of different LAB under conditions of skim milk fermentation.

0.2 % FM in the dairy product did not significantly affect the total amount of proteins, however, there was a tendency to a slight decrease in the amount of proteins in variants FM with strains L.fermentum AG8 and L.plantarum AG9 (Table 1). The fermented milk with FM had an increased level of proteins in the whey, indicating a redistribution of protein fractions between insoluble casein milk proteins and albumin whey proteins. These changes may be due to the surface-active and emulsifying properties of linseed mucus, manifested by increased solubility and availability of some caseins.

Table 1. Effect of FM on the protein components of fermented skim milk with varying LAB.

Strains	Proteins, %	Protein in whey, %	Ratio of protein in whey to total protein, %
Lb	4.11±0.21	2.93±0.12	71.26
Lb+FM	4.26±0.14	3.40±0.11	79.87
AG8	4.18±0.11	2.87±0.09	68.69
AG8+FM	4.12±0.09	3.01±0.04	73.02
AG9	4.18±0.13	2.91±0.03	69.67
AG9+FM	4.13±0.08	2.95±0.08	71.36

The stimulating effect of FM on lactic acid bacteria is confirmed by the decrease in the levels of lactose and glucose in the +FM variants (Table 2). The decrease in the level of carbohydrate components indicates their active inclusion in the metabolic processes of lactic acid fermentation. L.bulgaricus more actively digests lactose and glucose, as evidenced by their lower concentration compared with L.fermentum AG8 and L.plantarum AG9.

The increase in total dry matter at the expense of mucilage was reflected in an increase in the density of the fermented milk.

The increase in the amount of salts by 0.2 % in the variants with FM is the result of additionally introduced inorganic components with mucilage.

The texture characteristic of a fermented milk drink is an important characteristic that contributes greatly to the formation of the organoleptic characteristics of the product.

Table 2. Effect of FM on the chemical composition of fermented skim milk with varying LAB.

Strains	**Lactosa, %**	**Glucosa, mmol/L**	**Salts, %**	**Dry matter, %**	**Density, kg/m^3**
L.bulgaricus	4.32±0.11	1.4±0.1	0.68±0.01	9.66±0.22	1032.78±1.02
L.bulgaricus+FM	4.12±0.13	1.3±0.1	0.70±0.02	9.87±0.25	1033.52±0.98
AG8	4.24±0.04	8.5±0.2	0.67±0.02	9.71±0.26	1032.12±0.85
AG8+FM	4.45±0.09	5.7±0.1	0.70±0.01	9.86±0.20	1032.76±1.08
AG9	4.29±0.18	7.7±0.1	0.68±0.01	9.79±0.29	1032.03±0.56
AG9+FM	4.35±0.12	6.4±0.2	0.69±0.01	9.76±0.23	1033.06±0.98

Table 3 illustrates the changes of structural and mechanical properties of fermented skimmed milk. It was revealed that introduction of 0.2 % FM into the product composition increases dynamic viscosity and shear stress by 50 % compared to the variant without FM using strains L.bulgaricus and L.fermentum AG8. These parameters decreased in the presence of FM in the variant with L.plantarum AG9. In technological aspect, the index of syneresis and water-holding capacity of the milk gel of dairy product is important. It has been revealed that introduction of FM increases syneresis by 1-2 %, this is negative moment and requires application of corrective actions at further stages of practical application. However, positive is the fact that as a result of the introduction of the FM, lactic acid gel with a higher level of WHC is formed during fermentation (by 2-3 % than in variants without FM).

Table 3. Effect of FM on the structural-mechanical properties of fermented skim milk with varying LAB.

Strains	**Viscosity, MPa/s**	**Shear stress, Pa**	**Syneresis, %**	**WHC, %**
L.bulgaricus	819.0	5263.5	11.6	50.6
L.bulgaricus+FM	1227.4	7879.5	12.7	53.9
AG8	2699.4	17330.0	11.3	49.4
AG8+FM	3545.0	22759.5	13.9	52.4
AG9	3638.7	23359.5	11.5	52.3
AG9+FM	3275.5	21028.5	13.3	54.5

The fermented milk had less hardness and chewiness when FM was used. Consistently, elasticity increased in the samples with FM. The Adhesiveness of the samples in the presence of FM depended on the LAB strain (Table 4). Adhesiveness in the *L. bulgaricus*+FM sample increased by 5 units compared to the control, whereas in the other variants there was no such increase.

Table 4. Effect of FM on textural parameters of fermented non-fat milk.

Strains	***L. fermentum AG8***		***L.plantarum AG9***		***L. bulgaricus***	
Parameter	-FM	+FM	-FM	+FM	-FM	+FM
Hardness, g	34.1	33.1	33.7	33.6	32.7	33.6
Elasticity	0.367	0.404	0.404	0.395	0.440	0.385
Adhesion force, g	-8.1	-8.0	-8.1	-8.000	-7.30	-8.00
Adhesiveness	40.903	39.566	34.185	35.122	32.005	37.633
Cohesiveness	0.237	0.233	0.253	0.254	0.292	0.262
Corrected cohesion	0.143	0.136	0.153	0.161	0.222	0.178
Gumminess	8.069	7.709	8.533	8.526	9.561	8.806
Springiness	10.69	10.7	11.39	11.22	11.91	11.5
Stringiness	9.11	8.83	8.2	8.2	8	8.71
Chewiness	86.263	82.490	97.188	95.665	113.868	101.269

Thus, the formation of the texture of fermented milk is influenced not only by the presence of a stabilizer in the form of FM, but also by the used strain of lactic acid bacteria.

4 Discussion

FM is a neutral polysaccharide consisting of rhamnogalacturonan I and arabinoxylan, the latter having a prebiotic effect [7]. Therefore, the increase in the level of acid formation in variants with FM may be due to an increase in the number of lactic acid bacteria. An increase in viscosity combined with an increase in the elasticity index indicates the formation of a gel-like structure between FM and milk protein aggregates. This structure filling all the space stabilizes the matrix of fermented milk. Similar data were obtained by a number of researchers [8-9].

5 Conclusion

The use of flaxseed mucilage as a natural stabilizer in fermented milk was studied by varying the type of LAB used. Flaxseed mucilage was effective in improving texture characteristics, reducing hardness and increasing elasticity. The increase in acid-forming activity of LAB in the presence of FM is possibly due to increased levels of starter microorganisms.

Considering the beneficial properties of flaxseed mucilage, FM can be recommended for use in yogurt, not only improving the physical and chemical properties of the product, but also increasing its health benefits. Flaxseed mucilage has good potential for use as an effective stabilizer in dairy beverages.

Acknowledgement

The study was supported by the Russian Science Foundation and Academy of Sciences of Republic of Tatarstan under Scientific Project No. 22-26-20022.

References

1. A. Ziolkovska, Laws of flaxseed mucilage extraction, Food Hydrocolloids, **26**,197–204 (2012)
2. M. Wu, D. Li, L. Wang, Y. Zhou, Z. Mao, Rheological property of extruded and enzyme treated flaxseed mucilage, Carbohydrate Polymers, **80,** 460–466 (2010)
3. H. Chen, S. Xu, Z. Wang, Gelation properties of flaxseed gum, Journal of Food Engineering, **77**, **2**, 295–303 (2006)
4. G. Thakur, A. Mitra, K. Pal, D. Rousseau, Effect of flaxseed gum on reduction of blood glucose and cholesterol in type 2 diabetic patients, International Journal of Food Sciences and Nutrition, **60**, 126–136 (2009)
5. E. Gavrilova, E. Anisimova; A. Gabdelkhadieva, E. Nikitina, A. Vafina, D. Yarullina, M. Bogachev, A. Kayumov, Newly isolated lactic acid bacteria from silage targeting biofilms of foodborne pathogens during milk fermentation, BMC Microbiology, **19**, **1**, 248 (2019)
6. E. Nikitina; T. Petrova, A. Vafina, A. Ezhkova, M. Nait Yahia, A. Kayumov, Textural and Functional Properties of Skimmed and Whole Milk Fermented by Novel

Lactiplantibacillus plantarum AG10 Strain Isolated from Silage, Fermentation, **8**, 290 (2022)

7. R. Naran, G. Chen, N.C. Carpita, Novel Rhamnogalacturonan I and Arabinoxylan polysaccharides of flax seed mucilage, Plant Physiology, **148**, **1,** 132–141 (2008)
8. M. Mousavi, A. Heshmati, A.D. Garmakhany, A. Vahidinia, M. Taheri, Optimization of the viability of Lactobacillus acidophilus and physicochemical, textural and sensorial characteristics of flaxseed-enriched stirred probiotic yogurt by using response surface methodology, LWT - Food Science and Technology, **102**, 80–88 (2019)
9. S. Basiri, N. Haidary, S.S. Shekarforoush, M. Niakousari, Flaxseed mucilage: A natural stabilizer in stirred yogurt, Carbohydrate Polymers**, 187**, 59–65 (2018)