OAT β-GLUCAN IN MILK PRODUCTS: IMPACT ON HUMAN HEALTH

Algirdas Liutkevičius[1], Vilma Speičienė[1], Gitana Alenčikienė[1], Aldona Mieželienė[1], Arvydas Kaminskas[2], Jonas Algis Abaravičius[2], Dalius Vitkus[2], Valerija Jablonskienė[2]

[1]Kaunas University of Technology, Food Institute, Taikos av. 92, Kaunas, LT-51180
[2]Vilnius University, Faculty of Medicine, Universiteto st. 3, Vilnius, LT-01513

Abstract

The aim of this study was to determine the impact of the bioactive ingredient – oat β-glucan – on the quality characteristics of the fermented milk products (kefir, yogurt and fermented milk beverages) made on buttermilk-skimmed milk mixture base and establish the influence of the consumption of one of them on the health characteristics of volunteers. The enrichment of fermented milk products with 0.6 % oat β-glucan had no impact on the fermentation time, enhanced the apparent viscosity and changed sensory properties. The experiments of medical nutrition of volunteers showed a significant decrease of total ($p<0.05$) and low density lipoprotein ($p<0.05$) cholesterol, increase in high density lipoprotein cholesterol ($p<0.01$) in their blood after a 21-day period of consumption of fermented product with β-glucan. According to these findings, consumption of fermented milk beverage prepared on the buttermilk-skimmed milk base and enriched with oat β-glucan had a beneficial effect on human health.

Key words: *oat β-glucan, fermented milk beverages, human health*

1. INTRODUCTION

The demand for functional food in the developed countries of the world is great, because it relates to the prevention of widespread diseases (cardiovascular, high blood pressure, diabetes, obesity, etc.). Therefore, the development, production and presentation of new products with biologically active substances for consumers' choice are especially important. In this context, a polysaccharide β-glucan is one of the most effective ingredients for foodstuffs which can be directly attributed to the cholesterol-lowering effect (Othman, Moghadasian & Jones 2011). β-glucans are non-digestible polysaccharides, which contain D-glucose monomers as structural components and are linked with β-glycosidic bonds (Havrlentova et al. 2011). In nature β-glucans naturally occurs as cellulose in plants, the bran of cereal grains (oats, barley), the cell wall of yeast, certain fungi, mushrooms and bacteria.

In 1997, the US Food and Drug Administration (US FDA) approved a health claim for the reduction of heart disease risk with a daily consumption of 3 g of β-glucan (a minimum of 0.75 g per serving) originating from oat-formulated products that include oat bran, rolled oats and whole oat flour.

In 2010, the European Food Safety Authority (EFSA) has also authorized health claims according to which oat β-glucan ingestion leads to reduction of blood plasma cholesterol concentrations, which is a major risk factor for the development of coronary heart disease and the recommended daily intake was 3 g oat β-glucan and the claim can be used for the food products (portion) containing at least 1 g.

In our study as a matrix for the preparation of functional fermented beverages the buttermilk from the production of butter and skimmed milk were chosen. The main reasons for this elaboration are the high popularity of milk products among customers in Europe and large parts of the world on the whole, a high biological and nutritional value of buttermilk because it contains practically equivalent amounts of proteins, carbohydrates, minerals and vitamins like natural milk, but less fat and more of biologically valuable surface active substances like phospholipids. The latter, especially lecithin, are the fundamental building blocks of cellular membranes and take active part in cholesterol metabolism in human (Pandey & Sparks 2008).

The aim of the study was to establish the effect of added functional food ingredient – β-glucan – on physicochemical and sensory characteristics of fermented milk products made from buttermilk and skimmed milk (kefir, yogurt and fermented milk beverages), and to evaluate the effect of one of them on human health data.

2. MATERIALS AND METHODS

2.1. Materials

Buttermilk (0.3 % fat) and skimmed milk (0.05 % fat) were purchased from local supermarket. Oat β-glucan was obtained from Tate & Lyle Oat Ingredients (Sweden), κ-carrageenan – from Nexira (Ftrance). Milk beverages were fermented with 0,025 % starter from Chr. Hansen (Denmark) starters: for yogurt beverage – DVS YC-180, for kefir beverage – eXact®KEFIR 2, and for fermented milk beverage – FD DVS Flora Danica Normal.

2.2. Preparation of beverages

Buttermilk-skimmed milk mix in proportion 60:40 is heated up to 60±2°C, κ-carrageenan (0.04 %), which was used as system stabilizer, that prevented phase separation in the final product, is dissolved, then mixture cooled to 30±2 °C and mixed with oat β-glucan in an electric stirrer. The amount of added β-glucan preparation (0.6%) is calculated so that 500 g of the beverage contains 3 g of pure β-glucan. The mixture is pasteurized (90±2°C), homogenized (120 bar), cooled down up to incubation temperature (for yogurt beverage – up to 43±2°C, for kefir and fermented milk beverages – up to 26±2°C), incubated up pH 4.6–4.7, distributed into plastic bottles (500 ml) and stored at 4±2°C. The same conditions were applied to control samples of beverages without be β-glucan and κ-carrageenan additives.

2.3. Active acidity measurements

Active acidity was determined by a WTW GmbH microprocessor meter pH 538, using electrode with a Sen Tix 97 T integrated temperature sensor.

2.4. Apparent viscosity measurements

Apparent viscosity was measured by a rotational viscometer “Rheotest-2” (Germany), equipped with the double concentric cylinder measuring system S/S_2. Measurements were performed at the temperature of 12º C by increasing the shear rate from 1.0 to 437.4 s^{-1}.

2.5. Sensory analysis

A quantitative descriptive analysis (QDA) was carried out for the assessment of the sensory properties and creation of sensory profiles for each prepared beverage. A total group of 7 trained assessors (female, aged 20–60) having work experience in the evaluation of various food products not less than 20 hours was used. The beverages were kept in closed bottles in a refrigerator (4±2 °C) before testing. The samples for sensory analysis (approximately 20 mL, 21±2 °C) were provided to the panel in 30 mL plastic cups, coded with three digital numbers. A 9 point structured scale (1 – low intensity/absent, 9 – highest intensity) was used to evaluate each sensory attribute. A preliminary acceptability (n=12) was evaluated by asking which sensory properties could negatively affect acceptability.

2.6. Study design of the biomedical nutrition test

Twenty five volunteers were selected for study from larger Vilnius University student population (23.5±5.5 years of age). All subjects modified their diet by 500 ml of functional beverage consumed daily over a period of 21 day. At the same time volunteers were encouraged not to change their dietary habits.

As mentioned earlier the beverage was made by using buttermilk-skimmed milk base enriched with 0.6 % β-glucan. The daily dose of β-glucan was about 3 g (by consumption 500 ml of the beverage). Three parties of beverages were produced and submitted for medical nutrition experiment every 7 days. The nutrient composition of functional drink is shown in Table 1.

Table 1. Nutrition declaration of 100 g of fermented milk beverage with oat β-glucan

Energy value	33.5/8.0, kJ/kcal
Fat	0.3 g
of which saturates	0.18
Carbohydrates	4.4 g
of which sugars	4.4 g
Protein	3.0 g
Calcium	118 mg
Phosphorus	90 mg
Fiber (β-glucan)	0.60 g
Salt	0.0

The volunteers were invited to arrive at the hospital between 7:30 a.m. and 9:00 a.m. after having fasted for 12 hours. Blood pressure was measured twice by automatic blood pressure monitor "Omron", anthropometric data and pulse rate was measured once after resting supine for 5 minutes, all measurements and blood samples were taken twice – on the first visit before the dose of functional beverage has been consumed and on the second visit after the last dose of functional beverage has been consumed (on the 21 day). The study was approved by the Lithuanian Bioethics Committee (2012-11-29; order No. 158200-12-227-158).

2.7. Biochemical analyses

Cholesterol and triglyceride concentrations in serum were analyzed by enzymatic colorimetric methods (Architect ci8200, Abbott, USA). LDL-cholesterol concentration was calculated using *Friedewald* formula. HDL-cholesterol was analyzed by accelerator selective detergent method (Architect ci8200, Abbott, USA). Plasma glucose concentration was analyzed by hexokinase enzymatic method (Architect ci8200, Abbott, USA). The serum insulin was measured by chemiluminescent microparticle immunoassay (Architect ci8200, Abbott, USA).Fibrinogen concentration in blood plasma was analyzed by Clauss coagulometric method (STA-Compact, Diagnostica Stago, France). C-reactive protein was analyzed by latex enhanced immunoturbidimetric assay (Architect ci8200, Abbott, USA).

2.8. Statistical analysis

Statistical analysis was performed using SPSS (Statistics Base 19.0). Dependent *t-test* for paired samples was carried out to examine the differences between the baseline and 21-day follow-up results. The significance level of $P \leq 0.05$ was used for all the analyses.

3. RESULTS

3.1. Fermented milk products measurements

The indices of the active acidity of fermented milk products are given in Table 1. Yoghurt beverages samples were incubated for 3 h (43±2°C), kefir and fermented milk beverages samples – for 16 h (26±2°C)

Table 2. Impact of oat β-glucan on active acidity of fermented milk products

Fermented milk products	**pH**
Yoghurt beverage without β-glucan	4.66±0.05
Yoghurt beverage with β-glucan	4.60±0.04
Fermented milk beverage without β-glucan	4.71±0.04
Fermented milk beverage with glucan	4.66±0.06
Kefir beverage without β-glucan	4.72±0.05
Kefir beverage with β-glucan	4.65±0.07

The active acidity of kefir, fermented milk and yogurt beverages made on buttermilk-skimmed milk base without β-glucan is quite similar. The addition of β-glucan to buttermilk-skimmed milk media had no effect on the duration of fermentation as only slightly lowered the active acidity of all the beverages. This data conforms to the results of other researchers (Bekers et al. 2001).

The dependence of the viscosity of the fermented milk products on the shear rate without and with addition of β-glucan is given in Figure 1. All products demonstrated non-Newtonian behaviour: apparent viscosity decreased with the shear rate increase.

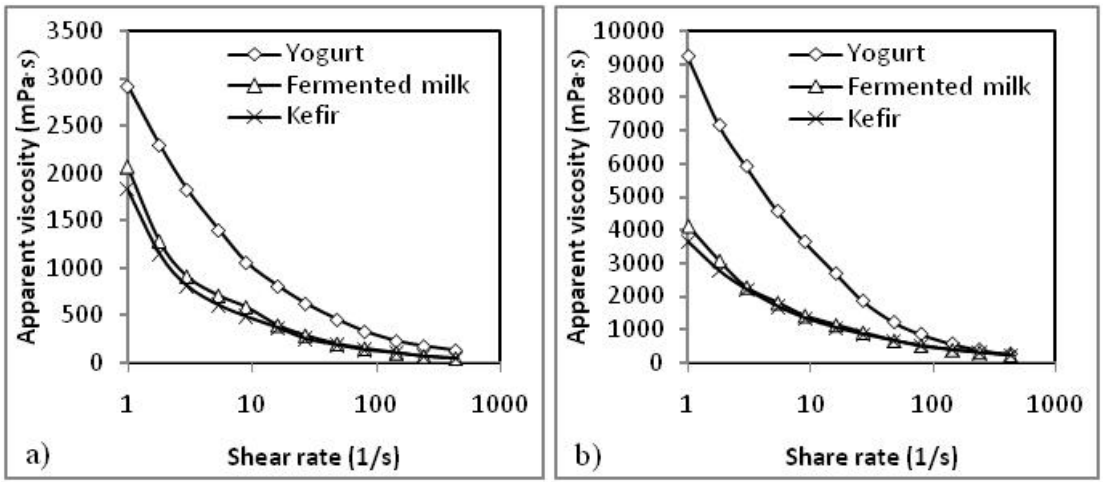


Fig. 1. The dependence of viscosity on the shear rate of the fermented milk beverages: a) control (without oat β-glucan), b) with oat β-glucan

Yogurt beverages samples, both with and without β-glucan, showed the highest apparent viscosity. The apparent viscosity of kefir and fermented milk beverages, both with and without β-glucan, was significantly lower. Having inserted β-glucan into the composition of these products the apparent

viscosity increases approximately twice in the case of kefir and fermented milk beverages and more than three times in the case of yogurt beverage. The β-glucan contribution to the increased viscosity of fermented milk products was demonstrated and by the other authors (Vasiljevic, Kealy &Mishra 2007).

The results of the sensory evaluation (Fig. 2) showed that the tested beverages samples with β-glucan, fermented with different starters, differed with regard to the properties of odour, taste and texture.

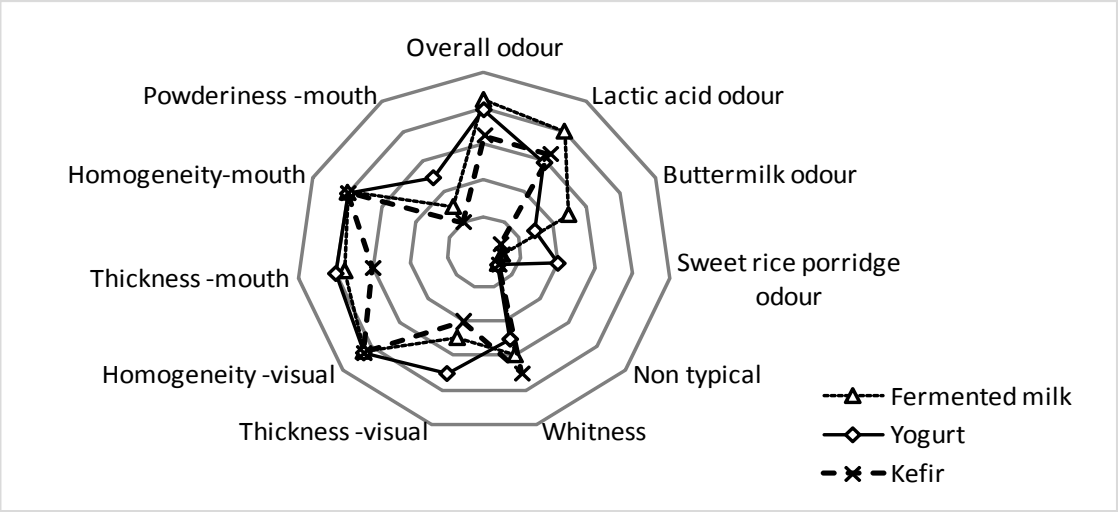


Fig. 2 Impact of oat β-glucan addition on the odour, colour and texture of fermented milk products

As stated by (Bekers et al. 2001), the starter cultures used in developing new beverages have a direct impact on the sensory characteristics of the final product. The oat β-glucan preparation, that were used for this purpose may have had impact in this respect (Lyly et. al 2003). Most intensive sweet buttermilk-like odour had fermented milk beverage, in yogurt beverage assessors were able only detect some notes of this odour, while in kefir there was no such odour at all, even all beverages were made on the buttermilk-skimmed milk base (Fig. 2). Yogurt beverage samples differed from fermented milk and kefir beverage samples by a weakly expressed taste resembling a sweet rice porridge porridge, which was not felt in other samples. Addition of β-glucan preparation significantly increased thickness of all samples, but only yogurt beverage had highest thickness and quite clearly expressed powderness and the least expressed lactic acid taste.

In assessing a preliminary acceptance of the samples, it became clear that the samples of fermented milk and kefir beverages were more acceptable than yogurt beverage samples (Fig. 3).

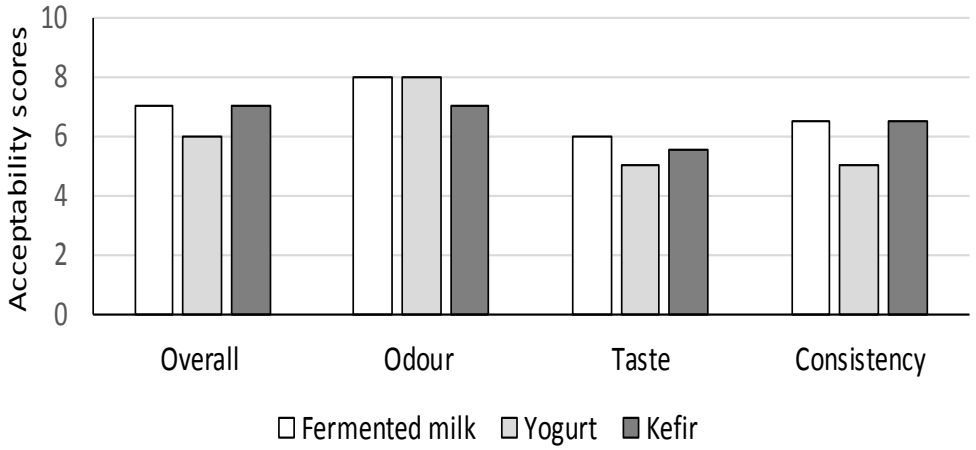


Fig. 3 Acceptability of overall (colour, taste and consistency) of kefir, yogurt and fermented milk products, containing oat β-glucan

The fermented milk beverage as the most acceptable for consumers was chosen for the medical nutrition experiments.

3.2. Medical nutrition experiment

The data of blood lipids, carbohydrates and other measurements of the group of volunteers before and after the diet supplementation by functional beverage are summarized in Table 3.

Table 3. Serum levels of lipids, carbohydrates and other biochemical characteristics of the volunteers before and after diet supplementation by functional beverage (n=25)

Blood characteristics	**Before**	**After**	***p***
	Mean±SD	**Mean±SD**	
Total cholesterol (mmol/L)	**4.67±0.86**	**4.53±0.93***	**0.048**
HDL-cholesterol (mmol/L)	**1.52±0.27**	**1.62±0.25****	**0.003**
LDL-cholesterol (mmol/L)	**2.80±0.73**	**2.53±0.85****	**0.008**
Triglycerides (mmol/L)	0.77±0.38	0.82±0.39	0.423
Insulin (pmol/L)	53.85±22.51	62.42±26.72	0.113
Fasting glucose (mmol/L)	**4.85±0.44**	**5.12±0.47****	0.008
Fibrinogen (g/L)	3.06±0.61	2.92±0.41	0.306
CRP (mg/L)	0.93±1.65	0.68±0.65	0.474

HDL – high density lipoprotein; LDL – low density lipoprotein; CRP – *C*-reactive protein**.**

Data are given as mean and standard deviation (SD);* $p<0.05$; ** $p<0.01$

After the consumption of functional beverage enriched with β-glucan, the total cholesterol and LDL-cholesterol concentrations in plasma of blood of the volunteers decreased by 3% ($p<0.05$) and 9.6% ($p<0.01$), respectively, while HDL-cholesterol level increased by 6.5% ($p<0.01$). These results may be explained by β-glucan as a fiber impact on the lipid digestion. Several different mechanisms take place in the achievement of hypocholesteremic effect by oat β-glucan consumption. One of them is the

property of β-glucan to entrap bile acids in the intestine and thus increase bile acid exclusion in the feces (Ellegard & Andersson 2007). Concentrated oat β-glucan also may undergo a fermentation process to produce short-chain fatty acids (SCFAs), including propionate, acetate, and butyrate (Queenan et al. 2007). These compounds can inhibit the rate-limiting enzyme of cholesterol β-hydroxy-β-methylglutaryl coenzyme A reductase to inhibit cholesterol synthesis.

LDL-cholesterol is believed to increase atherosclerosis through high serum LDL level inducing LDL particles to migrate into the walls of blood vessels. The HDL-cholesterol is the "good" cholesterol which helps to reduce the "bad" cholesterol level in the blood. It brings cholesterol into the liver and further will be removed with the bile into the intestine. These observations have shown a positive effect of the beverage on blood cholesterol level and therefore had a beneficial impact on the health and reduced the risk of atherosclerosis.

We found that after the diet supplementation, the concentration of glucose in plasma of blood of volunteers increased by 5.2%, from 4.85 mmol/L to 5.12 mmol/L ($p < 0.01$), but did not exceed the permitted limit of normal range (normal glucose level ranges from 4.2 to 6.1 mmol/L) and thus could not have a negative impact on the health of volunteers.

The findings on anthropometric data, body composition, blood pressure and pulse evaluation findings presented in Table 4.

Table 4. Anthropometric, body composition measurements, blood pressure and pulse data in the group of volunteers before and after diet supplementation (n=25)

Measurements	**Before**	**After**	
	Mean±SD	**Mean±SD**	***p***
Weight (kg)	66.95±8.83	68.38±7.81	0.532
Height (cm)	171.00±7.97	171.90±8.21	0.556
BMI (kg/m^2)	22.86±2.17	23.16±1.91	0.463
Body fat (%)	27.70±9.18	28.69±9.05	0.665
Skeletal muscle (%)	31.32±7.85	30.61±7.62	0.479
Visceral fat (%)	3.87±1.21	4.19±1.03	0.296
Systolic blood pressure (mmHg)	130.08±14.54	128.19±12.68	0.519
Diastolic blood pressure (mmHg)	75.08±7.53	71.95±8.03	0.155
Pulse (rate/min)	78.12±13.70	81.28±12.22	0.102

BMI – body mass index.

Data are given as mean and standard deviation (SD)

The results showed that all the parameters did not differ significantly between baseline (before) and after 21 day diet supplementation.

4. CONCLUSIONS

The use of oat β-glucan had no impact on the fermentation time of fermented products (yogurt, kefir and fermented milk beverages), and significantly increased the viscosity of the products. Evaluation of the preliminary sensory acceptance of the samples revealed that cultured milk beverages with oat β-glucan is rated as the products of the highest acceptance, while yoghurt beverage – of the lowest one. Fermented milk beverage was chosen for medical nutrition experiments.

Medical nutrition experiment showed that the administration of fermented milk beverage with oat β-glucan for 21 day resulted in a statistically significant change in total cholesterol, LDL-cholesterol and HDL-cholesterol. Therefore, the developed functional beverage could be recommended for persons with an increased blood lipid level.

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