

The Study of Synbiotic Dairy Products Rheological Properties during Shelf-Life

Ilze Beitane, Inga Ciprovica

Abstract—The influence of lactulose and inulin on rheological properties of fermented milk during storage was studied. Pasteurized milk, freeze-dried starter culture Bb-12 (*Bifidobacterium lactis*, Chr. Hansen, Denmark), inulin – RAFTILINE® HP (ORAFI, Belgium) and syrup of lactulose (Duphalac®, the Netherlands) were used for experiments. The fermentation process was realized at 37 °C for 16 hours and the storage of products was provided at 4 °C for 7 days. Measurements were carried out by BROOKFIELD standard methods and the flow curves were described by Herschel-Bulkley model.

The results of dispersion analysis have shown that both the concentration of prebiotics ($p=0.04<0.05$) and shelf life ($p=0.003<0.05$) have a significant influence on the apparent viscosity of the product.

Keywords—Apparent viscosity, *B.lactis*, consistency coefficient, flow behavior index, prebiotics.

I. INTRODUCTION

FUNCTIONAL fermented dairy products have long been known for their value in managing intestinal disorders [1]-[3]. The different approaches are applied including the fermentation of milk with probiotics, the addition of prebiotics, and the use of synbiotics [4], [5]. The application of each treatment influences rheology and texture properties of fermented products. In addition, the interactions between probiotic strains and prebiotics are another aspect that must be considered to achieve a high viable colony forming units of bacteria and to promote the acceptable sensory properties as well viscosity at the end of the self-life of the product.

Yoghurt is rheologically unstable fluid, shear thinning, which structural properties affect composition and quality of milk, way and methods of dry matter enrichment, production technology, and storage conditions [6], [7]. It is important to provide nutritional benefits, as well stability of synbiotic fermented dairy products during shelf-life.

Therefore the aim of the present study was to investigate the influence of lactulose and inulin on the rheological properties of fermented milk during shelf-life.

I. Beitane is with Faculty of Food Technology, Latvia University of Agriculture, Jelgava, LV-3001 Latvia (phone: 00371 63005647; fax: 00371 63005729; e-mail: Ilze.Beitane@llu.lv).

I. Ciprovica is with Faculty of Food Technology, Latvia University of Agriculture, Jelgava, LV-3001 Latvia (e-mail: Inga.Ciprovica@llu.lv).

II. MATERIALS AND METHODS

Pasteurized milk with fat content 2.5% and the strain of *Bifidobacterium lactis* (Bb-12, Chr.Hansen, Denmark) were used for experiments. During the experiments, the culture was maintained at -18 °C. As prebiotics were used RAFTILINE® HP inulin (ORAFI, Belgium) with polymerization degree ≥ 5 and degree of purity 99.5% and syrup of lactulose (Duphalac®, the Netherlands) with following composition (%): lactulose – no less than 67, lactose – less than 6, galactose – less than 10.

Different lactulose and inulin concentrations (1; 2; 3; 4 and 5%) were added individually to 100 g of milk. *Bifidobacterium lactis* was inoculated with 2 ml of milk suspension (10^6 cfu ml⁻¹) and cultured at 37 °C for 16 hours. The control sample was prepared without prebiotics for comparing the obtained results.

The samples of synbiotic fermented dairy products were stored at +4 °C for 7 days.

The rheological properties were determined with the DV-III Ultra Rheometer BROOKFIELD rheometer equipped with thermostatically controlled water bath TC-102 at 20.0±0.3 °C. All measurements were carried out by BROOKFIELD standard methods in three independent repeats on 1st and 7th day of synbiotic fermented dairy products shelf-life with controlled shear rate using a spindle SC4-16. The apparent viscosity was calculated at shear rate 7 s⁻¹. The flow curves were described by Herschel-Bulkley model.

III. RESULTS AND DISCUSSION

The apparent viscosity is relevant to content of total solids of yoghurt, i.e., with an increase of total solids in yoghurt increase the apparent viscosity [8]. The effect of lactulose on the apparent viscosity of analysed fermented milk samples is shown in Fig. 1.

The obtained results have shown that the different lactulose concentrations influence the apparent viscosity of product during its shelf-life. In fermented milk samples with lactulose were observed increasing of the apparent viscosity. The apparent viscosity is lower in analysed fermented milk samples with/without lactulose than in other fermented dairy products mentioned in literature. Kulikauskiene [9] had indicated that lactulose syrup added in 2.5% concentration did not influence significantly the yoghurt apparent viscosity during shelf-life. The differences between the obtained results and those in literature given might be explained with the fact that in the present research *B.lactis* was used as the starter culture.

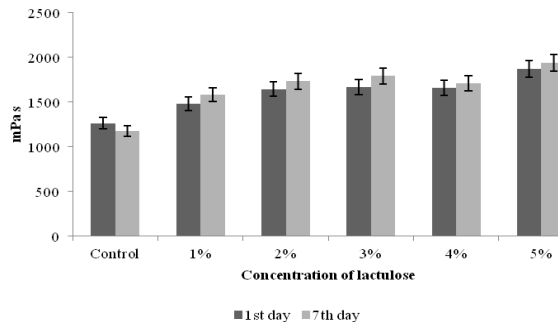


Fig. 1 The apparent viscosity of fermented milk samples with lactulose at 1st and 7th storage day, $\gamma=7.01 \text{ s}^{-1}$

The changes of the apparent viscosity in fermented milk samples with inulin were analysed during storage (Fig. 2).

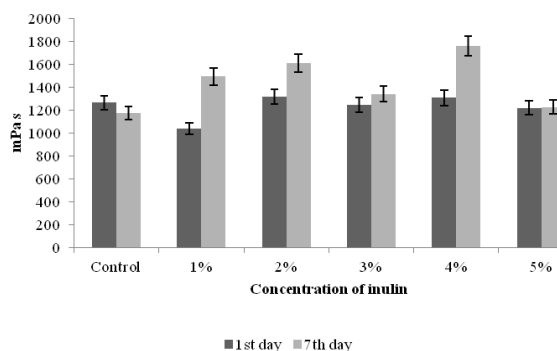


Fig. 2 The apparent viscosity of fermented milk samples with inulin at 1st and 7th storage day, $\gamma=7.01 \text{ s}^{-1}$

The obtained results have shown that the different inulin concentrations influence the apparent viscosity of fermented milk samples during shelf-life.

In fermented milk samples with 1%, 2%, and 4% of inulin, there was observed an increase of the apparent viscosity during shelf-life. The highest apparent viscosity was established in the sample with 4% of inulin. It corresponds to information given in literature: increasing the inulin concentration in yoghurt up to 4% its viscosity also increases [7]. Moreover, the parallel may be drawn with the results of investigations on the bifidogenic effect of inulin [10]–[12] which was established at 4% concentration in this study.

The results of dispersion analysis have shown that both the concentration of prebiotics ($p=0.04<0.05$) and shelf-life ($p=0.003<0.05$) have a significant influence on the apparent viscosity of the product. The lowest apparent viscosity of fermented milk samples with inulin was established on 1st day of shelf-life.

As to concentration, the fermented milk sample with 4% of inulin differed to pseudoplastic liquefactionable liquids of share force where deviation from the Newton's liquids depends on the concentration of prebiotics.

Herschel-Bulkley model was used for description of the rheological parameters of fermented milk samples and the results are presented in Table 1.

The value of the flow behaviour index is a measure of deviation from Newtonian flow. For shear thinning fluids $n<1$, whereas for Newtonian fluids $n=1$ [13]. It is obvious that fermented milk samples with prebiotics and control sample have shown the highest deviations from Newtonian flow. The pronounced deviations were determined in fermented milk samples with 1% of lactulose and 1% of inulin. It could be concluded that all fermented milk samples are non-Newtonian, which behaviour can be described as plastic, pseudoplastic, or dilatant [13]. Pseudoplastic flow means shear-thinning flow, therefore the fermented milk samples with prebiotics conform to the characteristic of yoghurt in literature [6], [7]. During shelf-life the flow behaviour index depending on added prebiotics concentration was decreased or increased, but changes were insignificant.

TABLE I
RHEOLOGICAL PARAMETERS OF FERMENTED MILK SAMPLES WITH LACTULOSE AND INULIN, CALCULATED BY HERSCHEL-BULKLEY MODEL

The type of prebiotics	Concentration, %	Consistency coefficient, mPa s		Flow behavior index (n)		Veracity, %	
		1st day	7th day	1st day	7th day	1st day	7th day
Lactulose	1	7139	4148	0.15	0.33	98.1	90.9
	2	2379	3546	0.46	0.36	85.2	88.8
	3	4516	3802	0.26	0.33	91.1	89.2
	4	3710	3473	0.34	0.38	86.1	84.4
	5	2836	4037	0.38	0.36	90.5	86.4
Inulin	1	5455	3362	0.20	0.40	97.9	86.2
	2	3104	6557	0.43	0.25	88.3	92.6
	3	5198	3302	0.28	0.38	96.2	83.9
	4	3161	2812	0.43	0.51	87.1	75.6
	5	4085	9160	0.34	0.10	96.0	94.5
Control		5062	3694	0.28	0.33	95.0	93.0

The obtained results have shown that there is coherence between consistency coefficient and flow behaviour index: the highest consistency coefficient and the lower flow behaviour index. The highest consistency coefficient was determined for fermented milk samples with 1% of lactulose (7139 maps s) and 1% of inulin (5455 mPa s). It could be explained with increased the shear stress ($D_o=3.51$ Pa and $D_o=2.23$ Pa) at the beginning point of the shear rate. It means that it is required the greater power for breaking the product structure. The others samples have shear stress at the beginning point of the shear rate between 0.24 and 1.25 Pa. In *Herschel-Bulkley* model the shear stress at the beginning point ($D_o=0$) is used. It explains the highest consistency coefficient of fermented samples with 1% of lactulose and inulin. The coherence between consistency coefficient and flow behaviour index was confirmed during shelf-life, too. If consistency coefficient of fermented milk samples is increased than flow behaviour index is decreased and the other way.

IV. CONCLUSION

The concentration of prebiotics ($p=0.04<0.05$) and shelf-life ($p=0.003<0.05$) have a significant influence on the apparent viscosity of the analysed products.

The analysed fermented milk samples with prebiotics are differed to pseudoplastic liquefactionable liquids of share force where deviation from the Newton's liquids depends on the concentration of prebiotics.

The coherence has been established between consistency coefficient and flow behaviour index during the study of synbiotic fermented milk samples rheological properties.

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Ilze Beitane, Dr.sc.ing., assistant professor at the Latvia University of Agriculture, Faculty of Food Technology, was born in Latvia, Jelgava in 1976. In 2008 she defended PhD thesis and obtained doctoral degree in food science. Main topics of research: functional dairy products. She has 14 scientific publications and participated in 4 different projects.

Inga Ciprovica, Dr.sc.ing., professor at the Latvia University of Agriculture, Faculty of Food Technology, was born in Latvia, Riga in 1969. Scientific interests – dairy science and technology. She has 101 scientific publications and participated in 20 different projects. At present I.Ciprovica is a dean of Faculty of Food Technology at the Latvia University of Agriculture.