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Biotechnological features of production and quality assessment of lactose-free yoghurt

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Abstract. The production of lactose-free yoghurts as a dietary product for people with milk sugar intolerance requires its extraction, which can affect the sensory and physicochemical properties of the finished product, thus, their evaluation to improve the technology is relevant. The purpose of the work was to explore yoghurts produced by conventional and lactose-free technologies. The object of the study was organic drinking yoghurt with "blueberry" filler (with probiotic) 2.5% and lactose-free organic yoghurt (with probiotic) 2.5%. The experimental samples were determined by a group of tasters organoleptic indicators, and titrated acidity and active acidity, conditional viscosity and structural and mechanical parameters of the product. According to the results of the research, organic drinking yoghurt with blueberry filler tasted sour-milk, without foreign flavours and odours, moderately sweet, with a pronounced taste of "blueberry" filler, consistency – homogeneous, tender, dense, without gas generation, with fresh blueberry particles distributed throughout the yoghurt, colour – with a shading characteristic of blueberries. Organic lactose-free yoghurt had a sour taste, fermented milk, without foreign flavours and odours, and colour – white. According to the results of physicochemical studies of the experimental samples of organic drinking yoghurt with "blueberry" filling and lactose-free organic yoghurt, it was established that the titrated acidity was 80 and 85°T, pH was 4.7 and 4.5, respectively. The mass fraction of carbohydrates in drinking yoghurt with the "blueberry" filling was 9.8 g/100g compared to 4.4 g/100g in lactose-free yoghurt, including sugar, respectively – 5.8 and 0 g/100 g. The energy value and caloric content were higher in the yoghurt sample with "blueberry" filling. The conditional viscosity of the test samples was respectively 1 min. 30 sec. and 59 sec. The degree of syneresis in the samples of organic drinking yoghurt with "blueberry"

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filling and lactose-free organic yoghurt was 55 and 45%, moisture content was 44.07 and 39.49%, respectively. The results obtained are relevant for understanding the changes in the properties of lactose-free yoghurts compared to the conventional type of this fermented milk product

Keywords: lactose, lactase, yoghurt, organoleptic evaluation, physicochemical parameters, viscosity, functional products

Relevance

Milk and dairy products play a significant role in human nutrition, as they are a source of highly valuable, easily accessible substances that are in balanced proportions and are characterised by high digestibility in the body (Slavov, 2018; Vlasenko, 2012; Kovalchuk, 2020). However, not all people can consume dairy products. A significant part of the world's population suffers from milk sugar intolerance (partial or complete lactose intolerance) and, as a result, cannot consume dairy products in their natural form (Khavkin, 2009; Ipatova, 2013). To provide dietary dairy products to people with such pathology of digestive organs in Ukraine and all over the world, the production of functional products, in particular lactose-free dairy products, has been launched. Thus, nowadays, it is relevant to explore the technological features of production and evaluation of nutritional properties of lactose-free fermented milk products.

Analysis of Recent Studies and Publications

The theoretical and practical foundations of the production of functional and tactless dairy products are presented in the works of many well-known foreign (Dekker, Koenders, 2019; Dekker, 2016; Kárnyáczki; Csanádi, 2017) and domestic scientists (Misnyk, 2007; Khavkin, 2009; Ipatova, 2013). In their works, the working hypothesis of the production of high-quality tactless dairy products is based on the assumption that the extraction of lactose from milk does not significantly affect the organoleptic and physicochemical parameters of fermented milk products. Currently, there is an entire range of technical and technological methods for reducing lactose in milk and dairy products: enzymatic hydrolysis, baromembrane treatment, obtaining products of an artificial combination of components, etc.

The conventional way to reduce the amount of lactose in dairy products is the fermentation process during the gelation and coagulation of casein (Vlasenko *et al.*, 2016). Thus, during the production of fermented milk products or cheese ripening, lactose is naturally degraded (Mashkin & Parish, 2006). When the starter is added, lactic acid bacteria ferment milk sugar and produce lactic acid, which is necessary to start the coagulation process of casein (Gvozdev *et al.*, 2013). Thus, in all fermented milk products, cheeses are low-lactose, because milk sugar is fermented by bacteria, and as a result – its amount in them is less than in ordinary milk.

Lactose-free dairy products are obtained after membrane filtration of milk and the addition of lactase enzyme to it. Having lost lactose in this way, milk does not change its taste, colour and fully preserves mineral compounds and vitamins. According to the authors (Slavov, 2019; Vlasenko, 2015), lactose-free products

differ from conventional products only in the absence or low content of lactose and have advantages in terms of dietary and functional nutrition. Therewith, it becomes less caloric due to a decrease in carbohydrate concentration by 35-45%, which is lower than in conventional milk (Dekker, Koenders, 2019). And this, in turn, can have an adverse effect on the consumer properties of some types of lactic acid products.

Therefore, a comparative assessment of the organoleptic and physicochemical characteristics of yoghurts produced by conventional and lactose-free technologies is quite relevant and is of both practical and scientific interest.

The purpose of the research – explore in a comparative aspect the biotechnological features of yoghurts produced by conventional and lactose-free technologies and evaluate their organoleptic and physicochemical properties.

Material and Methods of Research

The research was conducted in the laboratory of the Department of Processing Technologies and Quality of Livestock Products of Polissya National University, Zhytomyr.

The objects of the study were samples of yoghurts purchased in the branded outlets of LLC "Organic Milk", Zhytomyr, namely: organic drinking yoghurt with "blueberry" filler (with probiotic), mass fraction of fat 2.5% and lactose-free organic yoghurt (with probiotic) fat content 2.5% (Fig. 1).

Figure 1. *Research samples*

During sampling, the yoghurts corresponded to the three-day use-by date. After sampling, the samples were stored in a refrigerator at 6°C.

Organoleptic parameters (appearance, structure and consistency, taste and smell, colour) of yoghurt were evaluated according to DSTU 4343:2004 "Yogurts. General technical conditions" and were conducted by a group of five tasters. At the time of the study, all samples had a valid date of use and were coded with a three-digit code. In the experimental samples of yoghurt, physicochemical parameters were determined: titrated acidity (titrometric method), and active acidity (potentiometric method using an ionometer). The mass fraction of fat was determined according to GOST 5867-90 by the Gerber acid method. The mass fraction of protein was determined by the formal method.

The conditional viscosity was determined on an Oswald viscometer, and the duration (in seconds) of a continuous flow of the product was measured, which was 1 min. 30 sec. and 59 sec. respectively (Fig. 2).

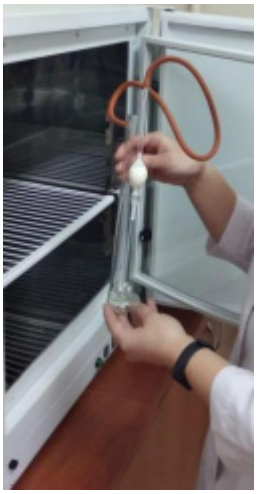

Figure 2. *Measurement of conditional viscosity on the Oswald viscometer*

To evaluate the structural and mechanical properties of the prototypes, the conditional viscosity was determined by the time of outflow of the product with a capacity of 10 cm^3 with an outlet of 5 mm and the degree of syneresis – by the amount of serum produced per 1 hour of free filtration. The moisture content in the experimental samples was determined on a moisture meter. The conditional viscosity was determined on an Oswald viscometer, and the duration (in seconds) of a continuous flow of the product was measured.

All analyses were performed in triplicate. The obtained results were processed biometrically using the built-in statistical functions package of MS Excel.

Research Results and their Discussion

In the conditions of LLC "Organic Milk" organic drinking yoghurt with "blueberry" filling is produced according to the conventional scheme by thermostatic method (Fig. 3).

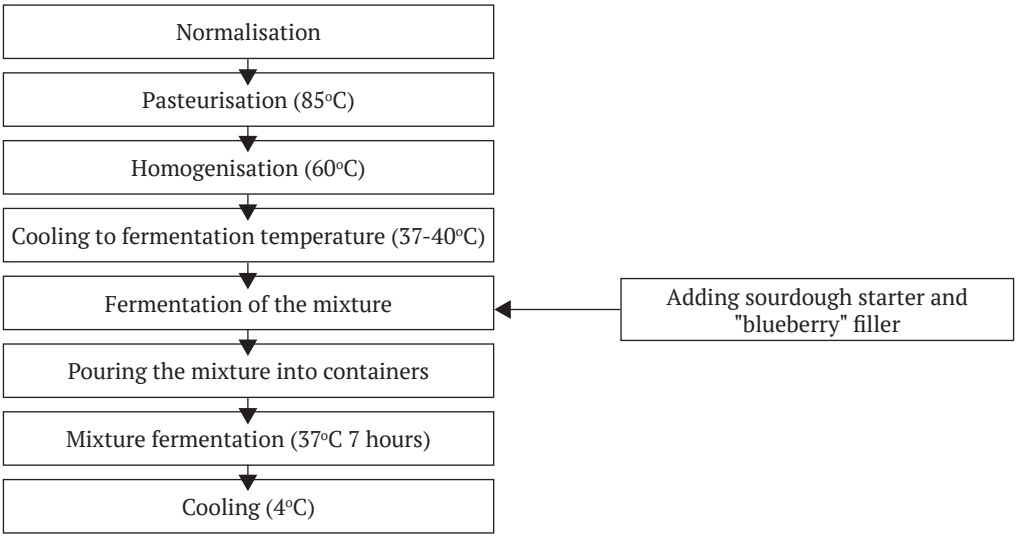

Figure 3. *Scheme of technological process of organic drinking yoghurt production with "blueberry" filling*

The most common way in the world to reduce the lactose content in milk is to add the enzyme lactase to the product (Slavov *et al.*, 2019; Vlasenko *et al.*, 2018; Skorchenko & Greek, 2012). The enzyme splits up to 98% of the lactose in milk. In the conditions of LLC "Organic Milk", this scheme of lactose-free yoghurt production is used (Fig. 2).

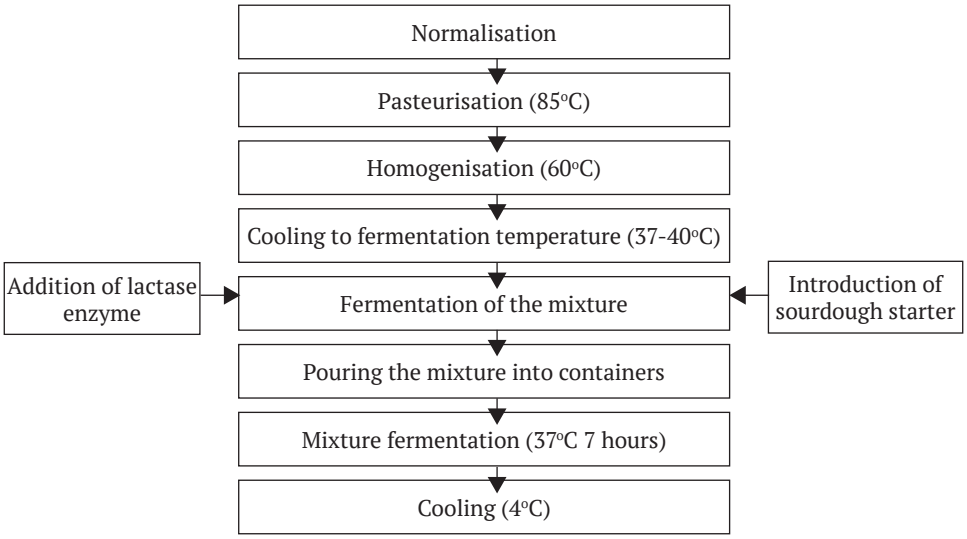

Figure 4. *Scheme of the technological process of lactose-free yoghurt production in the conditions of LLC "Organic Milk"*

The difference in technological schemes is that lactose-free yoghurt contains the enzyme lactase. Due to the addition of this component to milk, people with lactose intolerance can enjoy dairy products and not feel any discomfort. Considering that lactose intolerance is the absence (lack) of the enzyme lactase, it is simply added to the products. Thus, milk sugar is already split in this product.

The results of the organoleptic evaluation of lactose-free yoghurt are presented in Table 1. According to the main organoleptic indicators, lactose-free yoghurt with 2.5% fat content practically did not vary from organic drinking yoghurt with "blueberry" fillers of similar fat content. Some differences were observed only in the sweet and sour taste. The lactose-free version of fermented organic milk with probiotics had a less pronounced sweet taste than organic drinking yoghurt and was sourer. It is explained by the fact that products with lactose hydrolysis have a more sour taste due to the lower content of milk sugar (Dekker, 2016). Organic lactose-free yoghurt (with probiotic) with 2.5% fat content had a sour taste, fermented milk, without foreign tastes and odours, and white colour. The consistency of lactose-free yoghurt was homogeneous, tender, and dense, without gas production, and practically did not vary from organic drinking yoghurt.

Table 1. *Organoleptic evaluation of research samples*

Indicator	Characteristic	
	organic drinking yoghurt with "blueberry" filling (with probiotic) 2.5 %	organic lactose-free yoghurt (with probiotic) 2.5 %
Taste and odour	Sour milk, without foreign tastes and odours, moderately sweet, with a pronounced taste of "blueberry" filler	Sour milk, without foreign flavours and odours, sour taste
Consistency	Homogeneous, tender, dense, without gas production, with fresh blueberry particles distributed throughout the yoghurt mass	Homogeneous, delicate, moderately dense, without gas production
Colour	With a shade that is typical for blueberries	White

One of the most significant factors that allow using fermented milk for human consumption is its acidity. In addition, viable bacterial cultures are the foundation for the production of fermented milk, and their activity causes changes in the finished fermented milk beverages (Dekker & Koenders, 2019). In these studies, the effect of lactose hydrolysis on the acidity of fermented milk was hardly noticeable (Table 2). In the samples of this drink, the titrated acidity was slightly higher (85°T) compared to drinking yoghurt (80°T). A similar picture was observed for active acidity, which was 4.5 in lactose-free yoghurt against 4.7 in drinking yoghurt. Similar conclusions were reached by (Csanádi, 2017), who noted that lactose-free yoghurts had a lower pH and a higher concentration of lactic acid than the control yoghurts using classical technology. The authors explain their findings by the fact that the splitting of lactose into monosaccharides facilitates

the metabolism of bacteria and enhances the fermentation process.

Regarding the indicators of total nutrition, a significant difference between the samples was observed only in the concentration of carbohydrates. Thus, the mass fraction of carbohydrates in drinking yoghurt with "blueberry" filling was 9.8 g/100 g for 4.4 g/100 g in lactose-free yoghurt, including sugar 5.8 and 0 g/100 g, respectively (Table 2).

Table 2. *Physicochemical parameters of the research samples*

Indicator	Organic drinking classic yoghurt (with probiotic) 2.5%	Organic lactose-free yoghurt (with probiotic) 2.5%
Titrated acidity, °T	80	85
Active acidity	4.7	4.5
Mass fraction of fat, g/100g	2.5	2.5
Mass fraction of protein, g/100g	2.5	2.9
Mass fraction of carbohydrates	9.8	4.4
Including sugar, g/100g	5.8	0
Energy value, kJ/100 g	327	216
Calorie content, kcal/100g	78	55

Energy value and caloric content were slightly higher in the sample of yoghurt with "blueberry" filling.

Evidently, this is connected with the higher mass fraction of carbohydrates and sugar in the composition of this yoghurt.

As for the ingredient composition of the yoghurt samples, the only difference between them was that the first sample contained "Blueberry" filler, and the second – Lactase enzyme. The starter and probiotic consisted of the same lactic acid bacteria (Table 3).

Table 3. *Composition of yoghurt of research samples*

Organic drinking yoghurt with "blueberry" filler (with probiotic) 2.5%	Organic lactose-free yoghurt (with probiotic) 2.5%
Organic cow's milk normalised	
«Blueberry» filler 8% (organic frozen blueberries, organic sugar, citric acid - acidity regulator, pectin - thickener)	-
organic sugar	-
yoghurt sourdough starter (streptococcuc termophilus, lactobacilius delbrueckii subsp bulgaricus)	
probiotic: lactobacillus rhamnosus	
-	lactase enzyme

One of the significant indicators of nutritional evaluation of fermented milk drinks is syneresis – the separation of the liquid phase from the gel. This process can be spontaneous or occur only when the gel is mechanically destroyed by cutting, shaking or freezing. This visible defect can occur during the storage of fermented milk drinks and can affect the consumer properties of the final product (Dekker & Koenders, 2019). This indicator is primarily influenced by the total solids concentration and protein content in fermented milk, which increases the hardness of the gel and the retention capacity of whey in yoghurt. In addition, the type of milk and the type of starter used can affect the syneresis of fermented beverages (Kárnyáczki & Csanádi, 2017). In these studies (Table 4), it was established that lactose-free yoghurt had a lower syneresis (45%), while the samples of drinking yoghurt with "blueberry" filling (55%). Similar data were observed (Dekker, 2016). The authors attributed this phenomenon to a lower amount of synthesised exopolysaccharides in lactose-free yoghurt at a higher enzyme concentration.

A similar picture was observed for the humidity content in the research samples. In addition, it was lower in lactose-free yoghurt and amounted to 39.49% against 44.07% in drinking yoghurt with "blueberry" filling (Fig. 5).

Table 4. *Structural and mechanical indicators of research samples*

Indicator	Organic drinking yoghurt with "blueberry" filling (with probiotic) 2.5%	Organic lactose-free yoghurt (with probiotic) 2.5%
Conditional viscosity	1 min. 30 sec.	59 sec
Degree of syneresis, %	55	45
Humidity content, %	44.07	39.49

Figure 5. *Determination of humidity content in research samples*

Conclusions and Perspectives

The conducted studies on biotechnological features and consumer qualities of yoghurts produced by conventional and lactose-free technologies provide grounds to state:

1) LLC "Organic Milk" organic drinking yoghurt with "blueberry" filling is produced from organic milk according to the conventional scheme by the thermostatic method. During the production of lactose-free yoghurt, the addition of lactase enzyme is provided in the technological line;

2) lactose-free version of fermented organic milk in its consumer qualities practically did not differ from the drink made by the classical method and had high consumer quality;

3) some differences in the organoleptic evaluation and physicochemical parameters were not significant and were caused by the technological feature of the preparation of the fermented milk product;

4) lactose-free yoghurt had a less distinct sweet taste than organic drinking yoghurt and was sourer;

5) the mass fraction of carbohydrates in drinking yoghurt was significantly higher than in lactose-free yoghurt, caused by the addition of "blueberry" filler. In addition, lactose-free yoghurt had no sugar in its composition;

6) in the future, it would be advisable to explore the effect of the lactase enzyme on the viability of fermented milk microflora, which is a source of probiotics in finished products for functional purposes.

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Біотехнологічні особливості виробництва та оцінка якості безлактозного йогурту

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Анотація. Виробництво безлактозних йогуртів, як дієтичного продукту для людей з непереносимістю молочного цукру потребує його вилучення, що може позначитись на сенсорних та фізико-хімічних властивостях готового продукту, тому їх оцінювання для удосконалення технології є актуальним. Метою роботи було дослідження йогуртів, виготовлених за традиційною та безлактозною технологіями. Об'єктом дослідження були йогурт органічний питний з наповнювачем «чорниця» (з пробіотиком) 2,5 % та йогурт безлактозний органічний (з пробіотиком) 2,5 %. У дослідних зразках визначали групою дегустаторів органолептичні показники, а також титровану кислотність і активну кислотність, умовну в'язкість та структурно-механічні показники продукту. За результатами досліджень, йогурт органічний питний з наповнювачем «чорниця» на смак був кисломолочний, без сторонніх присмаків і запахів, у міру солодкий, з вираженим присмаком наповнювача «чорниця», консистенція – однорідна, ніжна, щільна, без газоутворення, з частками чорниці свіжої, які розподілені за всією масою йогурту, колір – з відтінком, характерним для чорниці. Йогурт безлактозний органічний мав кислуватий смак, кисломолочний, без сторонніх присмаків і запахів, колір – білий. За результатами фізико-хімічних досліджень дослідних зразків йогурту органічного питного з наповнювачем «чорниця» та йогурту безлактозного органічного встановлено, що титрована кислотність становила 80 та 85 °Т, pH відповідно – 4,7 та 4,5. Масова частка вуглеводів у йогурті питному з наповнювачем «чорниця» становила 9,8 г/100 г за 4,4 г/100 г в йогурті безлактозному, у тому числі цукру відповідно – 5,8 та 0 г/100 г. Енергетична цінність та калорійність була вищою у зразку йогурту з наповнювачем «чорниця». Умовна в'язкість дослідних зразків становила відповідно 1 хв. 30 сек. та 59 сек. Ступінь синерезису у зразках йогурту органічного питного з наповнювачем «чорниця» та йогурту безлактозного органічного становив 55 та 45 %, вміст вологи відповідно – 44,07 та 39,49 %. Отримані результати мають значення для розуміння змін у властивостях безлактозних йогуртів у порівнянні з традиційним видом цього кисломолочного продукту.

Ключові слова: лактоза, лактаза, йогурт, органолептична оцінка, фізико-хімічні показники, в'язкість, функціональні продукти