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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
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Казакский национальный исследовательский
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NEWS

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OF THE REPUBLIC OF KAZAKHSTAN
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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**PRINCIPLES OF DEVELOPMENT OF OSMOTICALLY
AND BIOLOGICALLY ACTIVE COMPOSITIONS
FOR TECHNOLOGIES OF FERMENTED MILK DRINKS**

Abstract. Currently, yogurt is considered to be the most popular dairy product in the world. The high content of skim milk, Bulgarian sticks and thermophilic *Streptococcus*, the content of which in the finished product at the end of the term is not less than 10^7 CFU in 1g of the product, create a unique recognizable profile of the product. Taking into account the specifics of Kazakhstan, in particular, geographical, socio-cultural factors, as well as the centuries-old history of camel milk consumption, the problem of scientific justification and development of industrial technologies of yogurt on its basis is actualized. The research presents the results of the development of osmotically active sweetening composition with pronounced probiotic properties. With its use, the technology of the creation of yogurt from camel milk, including low-lactose one, has been developed. It was found that the optimum level of syrup is about 5% by weight of the product. The analysis of the produced yogurt and low-lactose yogurt showed their high organoleptic characteristics. The developed technology suggests the possibility of its implementation in the dairy industry, producing dairy products.

Key words: camel milk, fermented milk drink, ferment, prebiotic, fructose, isomaltulose, lactulose.

Among the many problems associated with the development of society, the most global is the task of improving the structure of nutrition of the population, ensuring the availability of food products, as well as the creation of enriched foods with desired properties that contribute to the adaptation of the organism in a super-dynamic environment [1-5, 24].

The practical achievement of the goals declared by the state policy in the field of production and consumption of food products is directly related to the technologies of milk processing, as an important component in human nutrition throughout his life [1, 6, 23].

One of the most popular dairy products today is yogurt, which is included in many diets, and is also used in cosmetology. Yogurt is a fermented milk product with a high content of skimmed milk solids, produced using a mixture of Bulgarian sticks and thermophilic *Streptococcus* [7].

Lactobacillus bulgaricus is a probiotic bacterium. The energy of exothermic process ($\Delta H < 0$) is obtained by microorganisms as a result of homofermentative lactic fermentation. In this case, the Bulgarian stick synthesizes peptidoglycanhydrolase - specific enzyme responsible for the hydrolysis of peptidoglycan required for the microbiological process. It is known to be an important component of the cell wall of bacteria, and also produces extracellular polysaccharides that improve structure, increase stability and prevent yogurt syneresis. The second necessary microbiological component is thermophilic *Streptococcus*, which is a plant probiotic. Under the action of enzymes secreted by *Streptococcus*, lactose fermentation occurs with the formation of lactic acid. Lactic acid destroys the putrid bacteria that cause food to rot in the colon [8].

Taking into account the specifics of Kazakhstan, in particular, geographical, socio-cultural factors, as well as the centuries-old history of camel milk consumption, the problem of scientific justification and development of industrial technologies of yogurt on its basis is actualized. At the same time, it is advisable to enrich the probiotic product with prebiotics, increasing the effectiveness of preventive action [9, 10].

One of the aspects of this problem is the development of a prebiotic composition with pronounced sweetening properties. It should be borne in mind that an unbalanced high-calorie diet with high consumption of fast-digested simple sugars in daily diets can provoke the risk of obesity, type 2 diabetes, etc. [8].

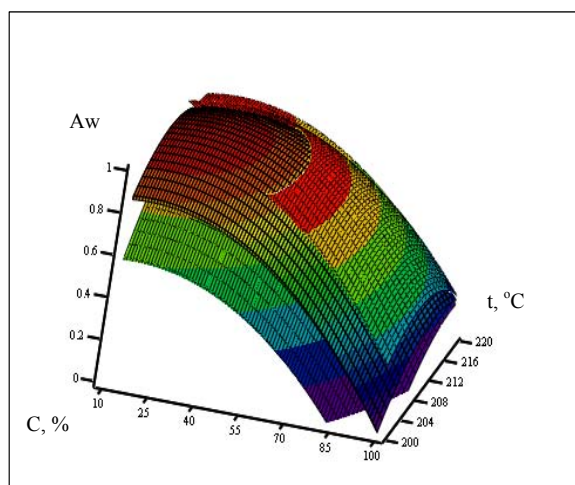
The aim of the work was to develop and study a sweetening osmotically active composition with prebiotic properties from the position of identifying the laws of formation of its thermodynamic characteristics depending on the concentration and species characteristics of solutions.

Using the criteria assessment for a number of factors: safety/availability/efficiency/manufacturability, etc. were originally selected osmotically active substances such as fructose, isomaltulose, inulin, lactulose, oligofructose.

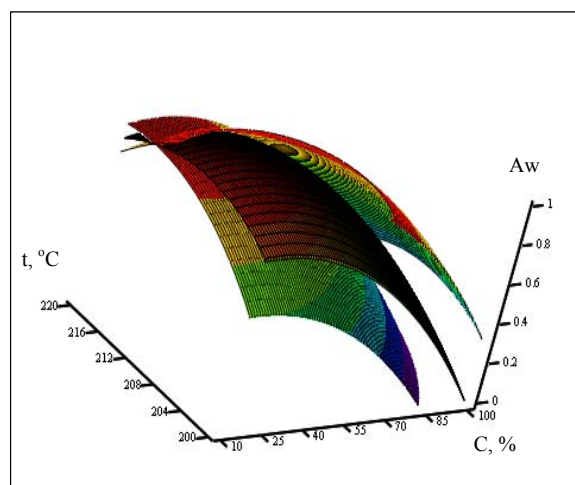
A complete factorial experiment for two factors – temperature and concentration for the above substances-was carried out. The response was the water activity index (A_w) in the solution. Statistical processing and visualization of experimental data was carried out using the methods of matrix algebra with the help of the programs "Microsoft Exel", "CurveExpert" and "MatLab».

Regression equations were found for all solutions of carbohydrates, as well as graphical data on the interpretation of numerical data on the dependence of osmotic pressure and water activity on the concentration of solutions of carbohydrates.

On figures 1 and 2 respectively, a graphical interpretation of the dependence of water activity (A_w) and osmotic pressure on the concentration ($C, \%$) of aqueous solutions of fructose is presented.



M,K,L



M,K,L

Figure 1 – The response surface of the regression equation, the lower and upper confidence intervals

Figure 1 shows that the surfaces of the upper and lower confidence limits have specific breaks. In fact, in these areas, the values of A_w should be taken as one or zero, respectively.

By analogy with the scheme of fructose research, the results were experimentally obtained, but the regression equations for solutions of inulin, lactulose, oligofructose and isomaltulose were obtained (table 1).

The analysis of all the above data shows that the results are similar to fructose studies: the regression equations describe the dependence under study with a certain error, which is determined by the temperature setting error ($(\pm 0,5)^\circ\text{C}$). In other words, the attempt to process the results as the data of a complete factorial experiment for two factors was somewhat incorrect.

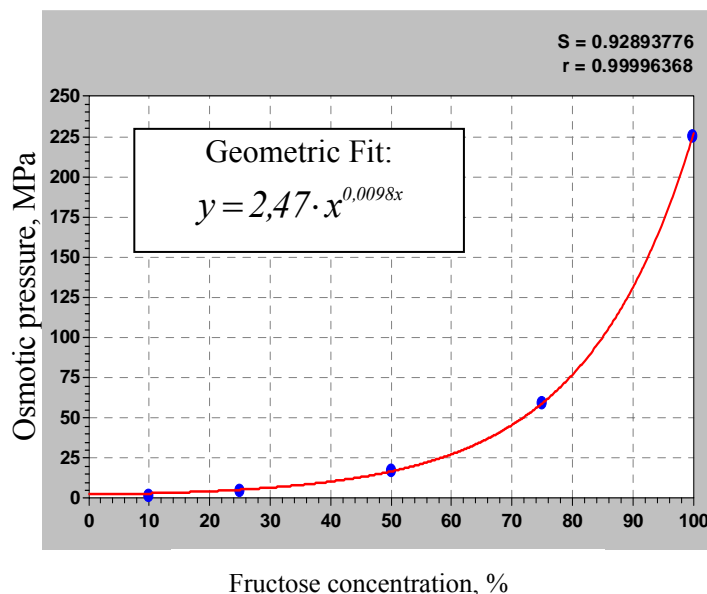


Figure 2 – Dependence of osmotic pressure on the concentration of fructose solutions

Table 1 – Decoded Aw regression equations for inulin, lactulose, oligofructose and palatinose solutions

The name of carbohydrate	Regression equations	
Inulin	$f(x,y) := 0.89 - 0.4 \frac{x-55}{45} + 0.05 \frac{y-20.5}{1.5} + 0.01 \frac{x-55}{45} \frac{y-20.5}{1.5} - 0.24 \left(\frac{x-55}{45} \cdot \frac{x-55}{45} \right) - 0.08 \left(\frac{y-20.5}{1.5} \cdot \frac{y-20.5}{1.5} \right)$	(1)
Lactulose	$f(x,y) := 0.8994 - 0.35 \frac{x-55}{45} - 0.016 \frac{y-20}{1} + 0.012 \left(\frac{x-55}{45} \cdot \frac{y-20}{1} \right) - 0.2803 \left(\frac{x-55}{45} \cdot \frac{x-55}{45} \right) + 0.025 \frac{y-20}{1} \cdot \frac{y-20}{1}$	(2)
Oligofructose	$f(x,y) := 0.91 - 0.45 \frac{x-55}{45} - 0.36 \frac{x-55}{45} \cdot \frac{x-55}{45} - 0.01 \left(\frac{y-21}{1} \cdot \frac{y-21}{1} \right)$	(3)
Isomaltulose	$f(x,y) := 0.83 - 0.251 \frac{x-55}{45} + 0.24 \frac{y-20.5}{1.5} + 0.231 \frac{x-55}{45} \cdot \frac{y-20.5}{1.5} - 0.25 \left(\frac{x-55}{45} \cdot \frac{x-55}{45} \right)$	(4)

The results of further calculations showed that the coefficients in the regression equation of inulin and lactulose are significant. In the regression equation of (1) oligofructose coefficients are not significant at y and x·y, (2) isomaltulose – at y².

The type of aw response surfaces described by adjusted regression equations is shown in figure 3.

In this regard, the results of the experiment were processed as experimental data for one factor – the concentration of carbohydrates. Processing was carried out using the program "CurveExpert". The data are presented in figure 4.

Table 2 presents the corresponding regression equations for each of the described carbohydrates, taking into account the error values.

In accordance with the results of the experiment to identify Aw depending on the concentration of osmotically active agents, as well as taking into account the biological properties of carbohydrates, in particular, prebiotic, low glycemic index, etc., the research framework was narrowed to a specific model - fructose:isomaltulose:lactulose.

Based on these studies of organoleptic characteristics of model samples of syrup, taking into account the available data on the coefficients of sweetness, consumption rates, the following model of fructose syrup is proposed – fructose:isomaltulose:lactulose = 49,75:49,75:0,5.

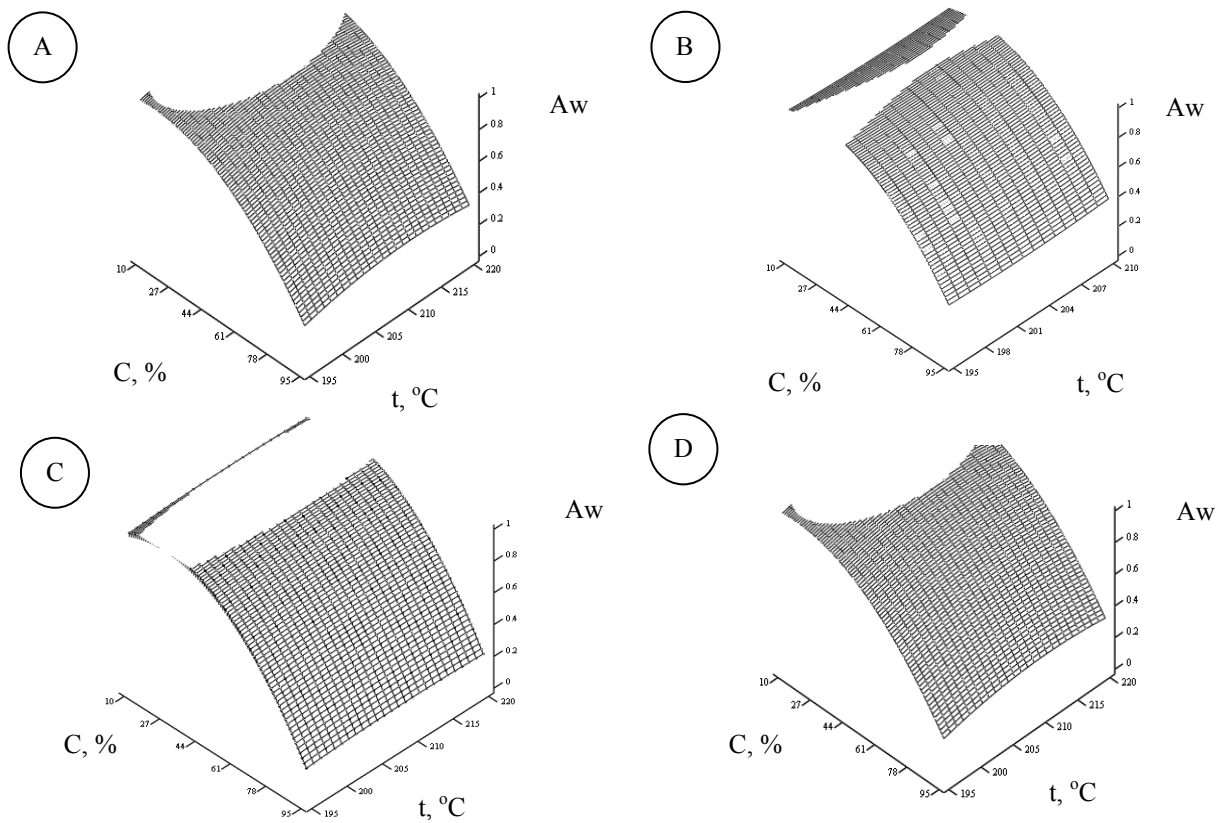


Figure 3 – Surface response regression equations of carbohydrates (A - inulin, B - lactulose, C - oligofructose, D - isomaltulose)

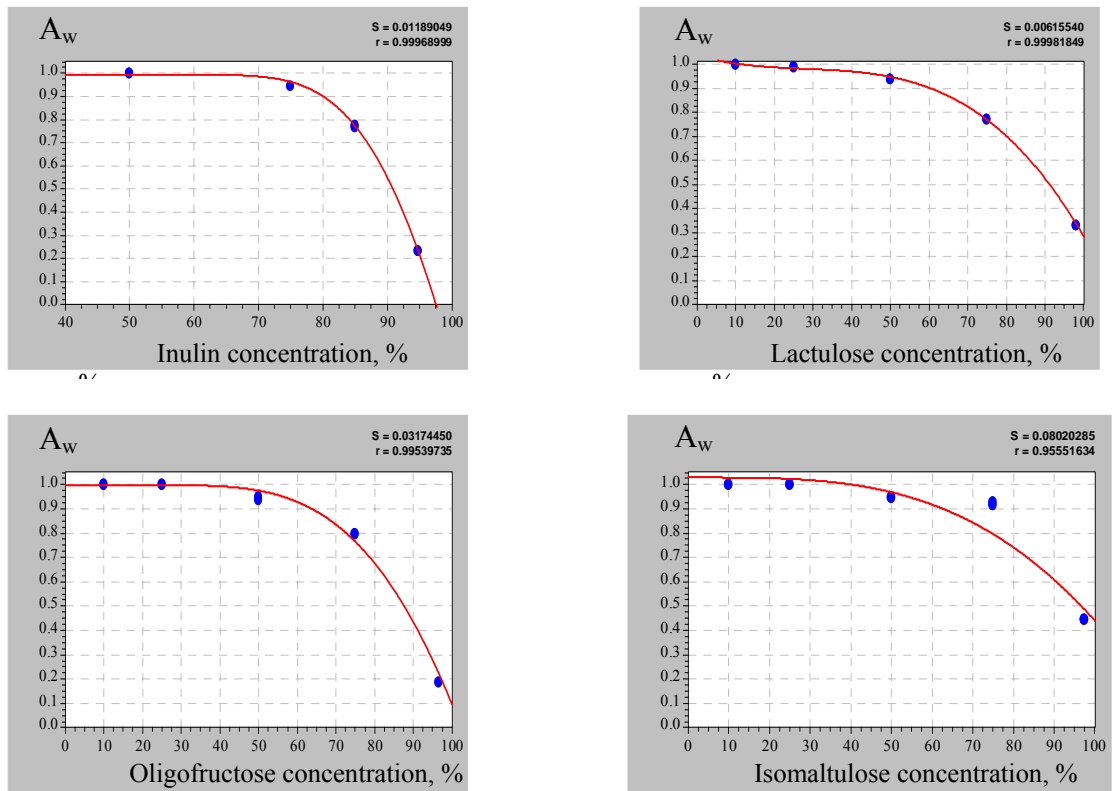


Figure 4 – Graphical interpretation of the dependence of A_w on the concentration of carbohydrates

Table 2 – Aw regression Equations for solutions of inulin, lactulose, oligofructose and isomaltulose

The name of carbohydrate	Regression equations	
Fructose	$Y = 9,960 \cdot 10^{-1} \pm 1,160 \cdot 10^{-1} - (1,140 \cdot 10^{-3} \pm 3,100 \cdot 10^{-4}) \cdot x + (2,0357 \cdot 10^{-5} \pm 6,620 \cdot 10^{-6}) \cdot x^2 - (9,0024 \cdot 10^{-7} \pm 3,950 \cdot 10^{-7}) \cdot x^3$	(5)
Inulin	$y = (0,994 \pm 5,02 \cdot 10^{-3}) - (23,267 \pm 9,73 \cdot 10^{-6}) e^{(1,295 \cdot 10^6 \pm 2,48 \cdot 10^{-7}) \cdot x} - (2,822 \pm 6,45 \cdot 10^{-4})$	(6)
Lactulose	$y = 1,036 \pm 7,04 \cdot 10^{-3} - (4,64 \cdot 10^{-3} \cdot x \pm 8,44 \cdot 10^{-5}) + (1,43 \cdot 10^{-4} \cdot x^2 \pm 1,22 \cdot 10^{-5}) - (1,724 \cdot 10^{-6} \cdot x^3 \pm 2,46 \cdot 10^{-7})$	(7)
Oligofructose	$y = 1,0929 \pm 4,01 \cdot 10^{-2} - (1,14 \cdot 10^{-2} \cdot x \pm 3,46 \cdot 10^{-3}) + (3,513 \cdot 10^{-4} \cdot x^2 \pm 7,61 \cdot 10^{-5}) - (3,4 \cdot 10^{-6} \cdot x^3 \pm 4,776 \cdot 10^{-7})$	(8)
Isomaltulose	$y = \frac{(1,029 \pm 9,72 \cdot 10^{-2}) \cdot (8,1879972 \cdot 10^7 \pm 8,28 \cdot 10^{-3}) - (9,368 \cdot x^{3,346} \pm 1,788 \cdot 10^{-4})}{(8,19 \cdot 10^7 + x^{3,346} \pm 1,091 \cdot 10^{-6})}$	(9)

Monosaccharide fructose, which is part of the developed osmotically active composition, is not absorbed by insulin-dependent tissues, this process takes a relatively long time, which causes particularly useful properties of fructose [11-13]. Metabolism is fast and occurs mainly in the liver, but also in the intestinal walls and kidneys.

Isomaltulose during the digestion process is metabolized in the intestinal mucosa by the enzyme complex saharase - isomaltase [14]. The main difference between the metabolism of sucrose and isomaltulose is that the hydrolysis of isomaltulose is much slower than the hydrolysis of sucrose, which indicates the possibility of reducing the glycemic and insulin response in healthy people and patients with type II diabetes (insulin-dependent) in the use of this carbohydrate [11, 13, 15]. Glycemic index (GI) of isomaltulose - 37 (in comparison, fructose - 19). The glycemic index is used to assess the effects of food after consumption on blood sugar by comparing the body's response to the product with the body's response to pure glucose (glucose GI is 100). Isomaltulose, as well as fructose, has a hypoacidogenic effect in relation to dental plaque, i.e. it is non-cariogenic [11, 14, 16].

Lactulose is now recognized as a classical bifidus factor [17]. This prebiotic is not split in the upper part of the gastrointestinal tract and passes through the large intestine, where bifidobacteria are used as a source of energy and carbohydrate.

Taking lactulose does not cause an increase in blood glucose, so it can be used in the diet for diabetics [11, 17].

It is very important that lactulose, unlike many other prebiotics, is not an alien element for dairy products, and embodies the therapeutic and preventive value of the nature of dairy products. For lactulose is not difficult to overcome all the natural protective barriers of the body and as part of any product to reach the habitat of normoflora. It stimulates quantitative growth of own microflora, therefore, there is no problem of survival [18].

The most important property of lactulose is its functional stability, that is, its ability to maintain all its healing properties in the widest range of media and technological regimes. And it opens almost unlimited possibilities of lactulose use in the food industry in the production of functional foods [17]. The use of lactulose in the food industry is expanding, including in the production of confectionery, beverages, food for dietary and diabetic nutrition, dietary SUPPLEMENTS as a low-calorie sweetener with functional properties. However, the main application of lactulose as a food prebiotic component is the production of functional dairy products [19-22].

For further use of the obtained results in the development of the technology, the studies of the formation of the Aw index in full-scale models-analogues of yogurt from camel milk with a different mass fraction of the developed composition.

Dry whole camel milk was used for preparation of fermented milk beverage. The production process involved the restoration of milk powder, fat normalization, homogenization at (12±2) MPa, pasteurization

at $(85\pm 2)^{\circ}\text{C}$ for 5-10 minutes, cooling to the fermentation temperature $(40\pm 2)^{\circ}\text{C}$ and the introduction of a production symbiotic ferment VNIMI STBP (*Streptococcus salivarius* subsp. *termophilus* and *Lactobacillus delbrueckii* subsp. *Bulgaricus*) in an amount of 10% by weight of milk. The end of the fermentation process was determined by the formation of a clot characteristic consistency, as well as by the acidity, the value of which should be $\text{pH } 4.7\pm 0.05$. Then the finished product was poured and cooled in the refrigerator to $(4\pm 2)^{\circ}\text{C}$, where for 4-6 hours it was further maturation. The experimental data are presented in table 3.

Table 3 – Formation of a Aw in the models-analogues of the product

Variant \ Indicator	M. D. FR milk, %	M. D. fat, %	M. D. syrup, %	Aw
1	14,4	3,9	3,0	0,994
2			5,0	0,991
3			7,5	0,987
4			10,0	0,985
5			12,5	0,980

The organoleptic assessment of models-analogs of the product is carried out – table 4.

Table 4 – Organoleptic evaluation of analog models of concentrated product

The name of the indicator	A variant of the formulation				
	1	2	3	4	5
Taste and smell	Weakly sweet, without foreign tastes and smells	Weakly sweet, without foreign tastes and smells	Sweet, without foreign tastes and smells	Too sweet, without foreign tastes and smells	Too sweet, without foreign tastes and smells
Consistency	Homogeneous, viscous	Homogeneous, viscous	Homogeneous, viscous	Homogeneous, too viscous	Homogeneous, too viscous
Color	White with a faint cream tint	White with a faint cream tint	White with a faint cream tint	White with a cream tint	White with a strong cream tint
Points according to the method of VNIMI	8	9	10	8	7

In parallel, a similar scheme developed a technology of low-lactose beverage, which was characterized in that the pasteurized and chilled milk was introduced 0,02-0,03% β -galactosidase (activity 5200 u/g) to its mass, after which the mixture was kept for 2,5-3,0 hours for lactose hydrolysis. Other processes are similar to the basic technology. As studies have shown, the low-lactose drink was characterized by a relatively large decrease in Aw, slightly more pronounced sweetness and intensity of the cream shade.

Thus, the osmotically active composition with pronounced probioticski properties. With its use, the technology of yogurt from camel milk, including low-lactose, has been developed. It was found that the optimal level of syrup is about 5-7,5% by weight of the product. The analysis of the produced yogurt and low-lactose yogurt showed their high organoleptic characteristics. The developed technology suggests the possibility of its implementation in the dairy industry, producing dairy products.

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СҮТҚЫШҚЫЛДЫ СУСЫНДАРДАР ТЕХНОЛОГИЯСЫ ҮШІН БИОЛОГИЯЛЫҚ БЕЛСЕНДІ КОМПОЗИЦИЯНЫҢ ОСМОСТЫҚ ҚЫЗМЕТІН ЕНГІЗУ ҚАҒИДАТТАРЫ

Аннотация. Қазіргі уақытта йогурт әлемдегі ең танымал сүтқышқылды өнім болып саналады. Сүттегі майсыздандырылған заттардың жоғары құрамы, болгар таяқшасы мен термофилді стрептококк дақылдары, дайын өнімде сақтау уақытының соңында дейін болатын сүтқышқылды бактериялардың 1 г өнімде 10⁷ кем емес КТБ құрауы өнімді бірегей танымал жасайды. Қазақстанның географиялық, әлеуметтік-мәдени факторларын, сондай-ақ түйе сүтін тұтынудың ғасырлық тарихын ескере отырып, түйе сүті негізінде алынатын йогурттың өнеркәсіптік технологияларын ғылыми дәлелдеу және дамыту мәселесі өзекті болып табылады. Жұмыста пребиотикалық қасиеттері бар тәттілендіргіш заттардың осмостық белсенді композицияның дамуының нәтижелері келтірілген. Оны қолдана отырып түйе сүтінен йогурт технологиясы, соның ішінде төменгі лактозалы йогурт әзірленді. Шырынның оңтайлы қосылатын мөлшері өнімнің салмағы бойынша шамамен 5% құрайтыны анықталды. Өндірілген йогуртке және төменгі лактозалы йогурттарға жүргізілген талдаулар олардың жоғары органолептикалық сипаттамаларын көрсетті. Жасалған технология оны сүтқышқылды өнімдер өндіретін сүт кәсіпорындарында іске асыру мүмкіндігін ұсынады.

Түйін сөздер: түйе сүті, сүтқышқылды сусын, ашытқы, пребиотик, фруктоза, изомальтулоза, лактулоза.

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ПРИНЦИПЫ РАЗРАБОТКИ ОСМОТИЧЕСКИ ДЕЯТЕЛЬНЫХ БИОЛОГИЧЕСКИ АКТИВНЫХ КОМПОЗИЦИЙ ДЛЯ ТЕХНОЛОГИЙ КИСЛОМОЛОЧНЫХ НАПИТКОВ

Аннотация. В настоящее время йогурт по праву считается самым популярным кисломолочным продуктом в мире. Высокое содержание обезжиренных веществ молока, культуры – болгарской палочки и термофильного стрептококка, содержание которых в готовом продукте на конец срока составляет не менее 10⁷ КОЕ в 1 г продукта, создают уникальный узнаваемый профиль продукта. Учитывая специфику Казахстана, в частности, географические, социально-культурные факторы, а также многовековую историю потребления верблюжьего молока, актуализируется проблема научного обоснования и разработки промышленных технологий йогурта на его основе. В работе представлены результаты разработки подслащивающей осмотически активной композиции с выраженными пребиотическими свойствами. С ее применением разработана технология йогурта из верблюжьего молока, в том числе низколактозного. Установлено, что оптимальный уровень внесения сиропа составляет порядка 5% к массе продукта. Анализ произведенного йогурта и низколактозного йогурта показал их высокие органолептические показатели. Разработанная технология предполагает возможность ее внедрения на предприятиях молочной отрасли, производящих кисломолочную продукцию.

Ключевые слова: верблюжье молоко, кисломолочный напиток, закваска, пребиотик, фруктоза, изомальтулоза, лактулоза.

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