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INFLUENCE OF FLAX SEEDS (LINUM USITATISSIMUM L.) ON THE DEVELOPMENT OF MICROFLORA DURING STORAGE OF PROBIOTIC SULUGUNI CHEESE

Annotation

The paper presents the results of a study of the effect of steamed flax seeds (Linum usitatissimum L.) on the quality and safety of probiotic Suluguni cheese during storage in vacuum packaging at a temperature of 3±1℃ and a relative humidity of 85±5%. It was found that adding 2% steamed flax seeds to probiotic Suluguni cheese increases the microbiological stability of the product, inhibits the development of undesirable microflora, in particular BGKP, and ensures compliance with safety standards for 90 days of storage. It has been proven that the inclusion of flax seeds in the composition of probiotic Suluguni cheese has a positive effect on maintaining the viability of lactobacteria (including the probiotic culture Lactobacillus acidophilus La-5) throughout the entire storage period. High probiotic properties of "Suluguni with flax seeds" cheese are noted for 75 days of storage, since the number of viable cells of S. thermophilus and L. helveticus + L. acidophilus La-5 during the specified period is $1.1\times10^7...9.0\times10^8$ and $8.0\times10^7...1.04\times10^9$ CFU/g, respectively. The recorded dynamics confirms the pronounced prebiotic effect of bioactive components of flax seeds, which contribute to the creation of optimal conditions for the long-term viability of lactobacteria, including probiotic cultures. Studies of organoleptic indicators have shown that the addition of flax seeds to probiotic Suluguni cheese contributes to the preservation of elasticity and layering of the cheese mass, creamy color and the formation of a characteristic soft nutty flavor, which increases the sensory appeal of the product. The presence of 2% steamed flax seeds in probiotic Suluguni cheese ensured the preservation of high organoleptic and standardized physicochemical indicators of the product during 75 days of storage. Therefore, it is recommended to set the shelf life of probiotic cheese «Suluguni with flax seeds» in vacuum packaging at a temperature of 3±1℃ and a relative humidity of 85±5% to no more than 75 days, which is 15 days longer than that for Suluguni cheese according to the current standard..

Key words: cheese; Suluguni; flax seeds; health product; probiotic; physicochemical, organoleptic, microbiological quality indicators; microbiological stability; safety; storage.

Introduction

In the modern world, the food industry is actively responding to the growing consumer demand for health-promoting products with increased biological value. Fermented dairy products enriched with probiotic microorganisms play a key role in ensuring a balanced and healthy diet, as they contain probiotic microorganisms that can positively affect the state of the human intestinal microbiota, improve the bioavailability of nutrients, strengthen the immune system, and improve overall well-being. A special place among such products is occupied by probiotic cheeses, which ensure the intake of viable cultures of beneficial microorganisms into the body.

One of the key tasks in the production of probiotic cheeses is to preserve the activity of probiotic cultures during storage, since factors such as increased acidity, high salt content, and low storage temperatures of cheeses negatively affect the survival of probiotic cells and can promote the development of foreign microflora. Traditional methods of extending shelf life (using preservatives, regulating salt content and/or acidity) are not always consistent with the concept of healthy eating and may reduce the probiotic properties of the product. In this context, natural plant ingredients are considered as promising stabilizers of microbiological quality and safety, as well as prebiotics. In particular, flax seeds (Linum usitatissimum L.) contain bioactive compounds - polyphenols, flavonoids, linolenic acid, mucilages and natural antioxidants, which can exert antimicrobial effects and contribute to the preservation of probiotic activity in food products, including cheeses.

Literary review

Scientists [1] summarize the current state of research on the use of cheeses as an effective matrix for delivering probiotic and prebiotic components to the human body. The authors emphasize that cheese has unique physicochemical properties — high buffering capacity, high protein and fat content — that increase the ability of probiotics to survive transportation through the gastrointestinal tract. Studies confirm that both fresh (e.g., minas frescal, cream cheese, cottage) and mature cheeses (such as gouda, cheddar, canestrato pugliese) can maintain high concentrations of live cultures (>10^7 CFU/g) without changing the sensory characteristics of the product. Research [2] confirms the feasibility of using probiotic bacteria as an effective means of increasing the microbiological safety of cheeses such as Pasta Filata, including cheeses made from raw milk. The authors investigated the effect of different strains, including *Lactobacillus acidophilus, Lactobacillus rhamnosus GG*, and commercial starters Fresco and Culture A on the growth of pathogenic microorganisms (*E. coli* and *Staphylococcus aureus*), showing that probiotic bacteria significantly inhibit their development during fermentation, and also reduce their number after heat treatment and during storage. In addition, cheeses enriched with probiotics retained high organoleptic characteristics, including taste, texture and aroma for 28 days, which indicates their potential as a functional ingredient for the production of safe and sensory-appealing cheeses. An important example of the effective introduction of probiotic cultures into cheese is the study [3], which developed a functional panela cheese - a soft fresh cheese of Mexican origin using three strains: *Bifidobacterium animalis subsp. lactis, Lactobacillus delbrueckii subsp. bulgaricus* and *Lactobacillus rhamnosus GG*. The combination of these cultures with 4% inulin provided high viability of probiotic microorganisms for 22 days and improved sensory characteristics. This indicates the potential of synbiotic solutions for the creation of cheeses with functional properties. Recent studies directly indicate that flax mucilage can act as a prebiotic, improve survival and even regulate the expression of certain genes in *L. acidophilus* in cheeses [4].

Formulation of the problem

The aim of the study is to determine the effect of treated flax seeds on the development of microflora and the preservation of the activity of probiotic cultures in Suluguni cheese during storage.

To achieve this goal, the following tasks were defined and solved:

— to determine the dynamics of the development of lactobacteria (including probiotics) and foreign microflora during storage of control and experimental samples of Suluguni cheeses for 90 days at a temperature of 3±1ºC;

— to assess the effect of flax seeds on the viability of lactobacteria (including *Lactobacillus acidophilus La-5*) and indicators of microbiological stability of cheeses;

— to analyze changes in organoleptic and physicochemical indicators in control and experimental samples of Suluguni cheeses during storage and to determine the feasibility of using flax seeds as a physiologically functional ingredient in the technology of probiotic Suluguni cheese;

— determine the maximum shelf life of probiotic cheese «Suluguni with flax seeds» at a temperature of 3±1ºC.

Materials and methods

Raw materials for cheese production: cheese-based milk - raw cow's milk of not lower than grade I according to DSTU 3662:2018 "Raw cow's milk. Technical conditions"; direct-introduction starter cultures FD DVS TCC-20 (composition – Lactobacillus helveticus + Streptococcus thermophilus) and FD DVS La-5 (probiotic culture Lactobacillus acidophilus La-5®) produced by the company «Chr. Hansen» (Denmark); calcium chloride produced by the company Nedmag B.V. (Netherlands); liquid rennet ROSSO 80/20 produced by ALCE INTERNATIONAL S.R.L (Italy); flax seeds according to DSTU 4967:2008 "Oil flax seeds for processing. Technical conditions" produced by PE Agrofirma "LUGOVE" (Ukraine); rock salt for cooking not lower than the second grade according to DSTU 3585:2015 "Cooking salt. Technical conditions".

A batch of experimental samples of probiotic Suluguni cheese was produced using the technology developed by the authors [5] in the laboratory of the Department of Milk Technology, Oil and Fat Products and Beauty Industry of ONTU. Two samples of Suluguni cheese were produced: control – Suluguni cheese without the addition of flax (sample A), experimental – Suluguni cheese with the addition of 2% of processed flax seeds (sample B). To process flax seeds before adding them to the cheese mass, they were kept over steam at a temperature of 102±2ºC for 10 minutes. Such seed treatment ensures the inactivation of anti-nutrients, increases the bioavailability of bioactive components of the seeds, effectively destroys potentially pathogenic microorganisms and reduces the total number of mesophilic and thermophilic microflora. Both samples of probiotic Suluguni cheese after molding were packed in shrink film and stored at a temperature of 3±1ºC and a relative humidity of 85±5%, which corresponds to the recommended storage conditions for processed cheeses and allows observing the dynamics of the development of lactobacteria (including probiotic microflora) and changes in organoleptic and physicochemical indicators in real storage conditions. To assess changes in quality indicators and microbiological stability of cheeses during storage, samples were taken on the 1st, 5th, 15th, 30th, 45th, 60th, 75th and 90th day. At the same time, the most probable number (MPN) of lactobacteria (including L. acidophilus La-5), microbiological and physicochemical quality indicators, and an assessment of organoleptic indicators were performed.

Microbiological studies were performed according to standard methods, which included the selection and preparation of samples for microbiological studies, tenfold dilutions and seeding on selective and accumulation media. Escherichia coli (coliform bacteria) were determined according to DSTU 7357:2013, Salmonella and Listeria monocytogenes spp. were determined according to DSTU EN 12824:2004 and DSTU ISO 11290-1:2003, respectively, Staphyloccos aures were determined according to GOST 10444.2-94. The viability of lactobacteria (including probiotic cultures L. acidophilus La-5) was assessed by determining the microflora of lactobacteria according to DSTU 7999:2015 with incubation of samples at a temperature of 37±1ºC for 3 days and subsequent preparation of smears from each fermented sample to determine the microflora of S. thermophilus and L. helveticus+L. acidophilus La-5. The use of two Lactobacillus cultures in the fermentation composition does not allow the microflora of L. acidophilus La-5 to be determined separately, therefore, during the research, it was decided to determine the total number of two Lactobacillus cultures.

The organoleptic indicators of the control and experimental samples of probiotic Suluguni cheeses were determined by the organoleptic method. The organoleptic indicators of the control sample of probiotic Suluguni cheese were compared with the indicators specified in DSTU 8160:2015 «Raw cheeses. General technical conditions». The organoleptic indicators of the experimental sample of probiotic Suluguni cheese were compared with the indicators recommended by the authors and developed during the scientific study.

The physicochemical indicators of probiotic Suluguni cheeses were determined according to standardized methods: the mass fraction of moisture - according to DSTU 8552:2015 Milk and dairy products. Methods for determining moisture and dry matter; the mass fraction of fat in the dry matter of cheese – according to DSTU ISO 2446:2019 (ISO 2446:2008, IDT) Milk. Determination of fat content; the mass fraction of table salt – according to DSTU ISO 5943 Cheese and processed cheeses. Determination of chloride content; active acidity – according to DSTU 8550:2015 Milk and dairy products. Measurement of pH by potentiometric method. Physico-chemical parameters of probiotic cheese «Suluguni with flax seeds» were determined in the cheese mass after the seeds were separated from it.

Results of the study and their discussion

Suluguni cheese is a unique food product that belongs to the category of seasoned brine cheeses, the distinctive feature of which is its layered structure, which distinguishes it from other cheeses of this type. To establish the shelf life of the developed probiotic cheese «Suluguni with flax seeds», two samples of probiotic Suluguni cheeses were produced in the laboratory of the Department of Milk Technology, Oil and Fat Products and Beauty Industry of ONTU (Fig. 1): control – Suluguni cheese without the addition of flax (sample A), experimental – Suluguni cheese with the addition of 2% processed flax seeds (sample B) according to the developed technology [5].

In the produced cheese samples, during 90 days of storage at a temperature of 3±1ºC and a relative humidity of 85±5%, a set of studies was conducted to determine changes in quality indicators that characterize their con sumer properties: organoleptic (Table 1), physicochemical (Table 2) indicators, microbiological stability of cheeses (Table 3) and their probiotic properties (Fig. 2).

Analysis of changes in physicochemical parameters (Table 2) shows that during storage of probiotic Suluguni cheeses, their proteins exhibit buffering properties, as evidenced by changes in active acidity. During the first 5 days, the most significant decrease in pH is noted in both cheese samples (but in the experimental sample, the decrease in pH is less than in the control sample); from the 5th to the 30th day, stabilization of the pH level is noted in both cheese samples, which is explained by the buffering properties of cheese proteins (cheese proteins bind H+ ions, which accumulate as a result of lactose fermentation in cheeses to organic acids (mainly lactic), due to which the level of active acidity in cheeses is stabilized). From the 30th to the 90th day, the level of active acidity in probiotic cheeses increases, which is probably explained by the hydrolysis of part of the proteins to peptides and amino acids (as evidenced by the appearance of a cheesy flavor in cheeses during this period - Table 1), as well as by further changes in organic acids (in particular, lactic acid). On the 90th day of storage, the acidity level in control sample A is 0.08...0.10 pH units lower than in freshly made cheese, while the acidity level in experimental sample B is only 0.03...0.05 pH units lower than in freshly made cheese, which can be explained by the influence of flax seeds on the development of microflora and directly on the acidity index.

The experimental sample of probiotic cheese «Suluguni with flax seeds» (Sample B) has a 10% higher moisture content compared to the control sample (Sample A) – Table 2, which is explained by the high moisture-retaining properties of flax seeds. During storage for 90 days, the moisture content in both cheese samples decreases: in the control sample – by 6.7…6.8%, in the experimental sample – by 3.7…3.8%. A decrease in the moisture content in cheeses contributes to a decrease in the fat content in the dry matter of cheeses: in the control sample of cheese (Sample A) during 60 days the fat content in the dry matter decreases from 46.5% to 44.9%, and on the 75th and 90th days it is 44.3% and 43.7%, respectively, which does not meet the requirements of regulatory documents; in the experimental cheese sample (sample B) over 75 days, the fat content in dry matter decreases from 46.5% to 45.0%, which meets the requirements of regulatory documents, and only on the 90th day of storage, the fat content in dry matter of sample B is less than the regulatory value – 44.6%.

а)

б)

Fig. 1 – Samples of probiotic Suluguni cheese:
a) – control (sample A); b) – experimental (sample B)

Table 1 – Changes in organoleptic parameters of Suluguni probiotic cheeses during storage (n = 3)

Shelf life (days)	Sample number	Appearance	Color	Consistency, structure of cheese dough	Aroma	Flavor
1	A	The surface is clean, without defects, has a slight shine	White, uniform throughout	Tender, elastic, slightly layered, without air bubbles with a small amount of whey when cut	Pure sour milk, fresh without foreign flavors	Soft sour milk taste, delicate; pleasant aftertaste
	B	The surface is clean, the seed distribution is uniform, and it has a slight sheen.	White with a slight cream tint	Tender, elastic, slightly layered consistency without air bubbles, when cut there are occasional inclusions of whole flax seeds, there is a small release of whey	Pure sour milk, fresh with a soft nutty note of flax	Soft sour milk with a subtle nutty accent
5	A	The appearance is stable; the surface is smooth with a slight sheen	White, uniform throughout	Tender, elastic, layering is preserved, there is a small release of whey	Pure sour milk, with light yogurt notes	More pronounced sourness, harmonious aftertaste without foreign shades
	B	Appearance is stable; surface is smooth with seed inclusions	White-cream, seed inclusions do not darken	Tender, elastic, slightly layered consistency without air bubbles, when cut there are occasional inclusions of whole flax seeds	Sour milk with a pronounced nutty note	Harmonious taste, sour milk with a soft nutty tone
15	A	The surface is slightly matte, without defects	White, with a slight cream tint	Moderately dense, elastic, uniform structure	Pure sour milk, with light creaminess	Rich, with pleasant creaminess and soft sourness
	B	The surface is slightly matte, with a shine near the seeds.	Creamy-white, seeds retain their natural color	Tender, elastic, slightly layered consistency without air bubbles, when cut there are occasional inclusions of whole flax seeds	Strong sour milk with a delicate flax aroma	Rich taste, structured with a nutty flavor
30	A	The surface is denser, matte without defects	Creamy-white, slightly shiny	Dense, elastic, layered medium	Pure sour milk, bright	Moderate sour milk, balanced
	B	The surface is stable, more matte, the shine around the seeds is preserved	Uniform creamy	Dense, elastic, elastic, layering high	Strong sour milk with a soft flax aroma	Rich taste, deep with a cheesy and pronounced nutty flavor
45	A	Matte surface with light compaction, no defects	Creamy-white, matte	Dense, elastic, layering decreases	Pure sour milk, bright, light cheese aroma	Sour milk with a slight cheesy flavor
	B	Matte surface, no drying	Creamy	Dense, elastic, elastic, high layering, moist	Strong sour milk with a bright flax seed aroma	Rich taste, deep with a cheesy and sweet nutty flavor
60	A	The surface is dry and even.	Creamy, uniform throughout	Dense, weakly elastic, homogeneous structure	Weak sour milk aroma, cheese notes are more noticeable	Moderately sour, cheesy aftertaste
	B	The surface is dry and even.	Rich creamy, darker around the seeds	Dense, homogeneous, elastic, elasticity does not decrease, layered	Moderate sour milk aroma with a grassy-nutty note	Rich taste, with a pronounced cheesy and light herbal-nutty flavor.
75	A	The surface is dried, without damage.	Creamy, darker towards the surface	Dense, brittle at the edges	Weak sour milk, cheese	The taste is sour, with a slight pungency
	B	The surface is evenly dried without compaction	Golden-cream	Dense, elastic, layered, not brittle at the break	Weak sour milk, cheese with a noticeable with a herbal-nutty note	Slightly sour with a pronounced cheesy and spicy herbal-nutty flavor
90	A	Visible drying of the surface, sealing of the edges	Creamy, darker towards the surface	Dense, moderately brittle, elasticity reduced	Very faint sour milk aroma	Sour taste, a noticeable pungency appears

Table 2 – Changes in the physicochemical parameters of Suluguni probiotic cheeses during storage (n = 3, p ≥ 95)

Shelf life (days)	Sample number	Mass fraction of fat in dry matter of cheese, %	Mass fraction of moisture, %	Mass fraction of table salt, %	Active acidity, pH units
1	A	46,5 ± 0,5	48,8 ± 0,1	1,70 ± 0,05	5,15 ± 0,01
	Б	46,5 ± 0,5	53,7 ± 0,1	1,70 ± 0,04	5,15 ± 0,01
5	A	46,4 ± 0,5	48,7 ± 0,1	1,70 ± 0,07	4,96 ± 0,01
	Б	46,4 ± 0,5	53,6 ± 0,1	1,70 ± 0,06	5,07 ± 0,01
15	A	46,1 ± 0,5	48,4 ± 0,1	1,70 ± 0,08	4,95 ± 0,01
	Б	46,2 ± 0,5	53,4 ± 0,1	1,70 ± 0,08	5,05 ± 0,01
30	A	45,8 ± 0,5	48,0 ± 0,1	1,80 ± 0,01	4,96 ± 0,01
	Б	46,0 ± 0,5	53,2 ± 0,1	1,70 ± 0,09	5,05 ± 0,01
45	A	45,3 ± 0,5	47,5 ± 0,1	1,80 ± 0,02	4,98 ± 0,01
	Б	45,7 ± 0,5	52,9 ± 0,1	1,80 ± 0,01	5,07 ± 0,01
60	A	44,9 ± 0,5	47,0 ± 0,1	1,80 ± 0,03	5,01 ± 0,01
	Б	45,4 ± 0,5	52,6 ± 0,1	1,80 ± 0,01	5,09 ± 0,01
75	A	44,3 ± 0,5	46,3 ± 0,1	1,80 ± 0,04	5,04 ± 0,01
	Б	45,0 ± 0,5	52,2 ± 0,1	1,80 ± 0,02	5,10 ± 0,01
90	A	43,7 ± 0,5	45,5 ± 0,1	1,80 ± 0,05	5,06 ± 0,01
	Б	44,6 ± 0,5	51,7 ± 0,1	1,80 ± 0,03	5,11 ± 0,01

The mass fraction of table salt in both samples of Suluguni probiotic cheeses varies within 1.7…1.8% (Table 2), which meets the requirements of regulatory documents. The increase in the table salt content from 1.7% to 1.8% is explained by the decrease in the moisture content in the cheeses.

The microbiological stability of cheeses is mainly determined by the dynamics of the development of sanitary-indicative, technically harmful and pathogenic microorganisms during the established storage period. The content of viable lactobacilli cells (including *L. acidophilus*) according to [6] in probiotic products should be at least 1×107 CFU/g of the finished product on the last day of storage. The results of the study of microbiological stability of the control and experimental samples of probiotic Suluguni cheese during 90 days of storage are given in Table 3.

Table 3 – Results of the study of the microbiological stability of probiotic Suluguni cheeses during storage (n = 3, p ≥ 95)

Indicator	Shelf life, days	DSTU Requirements 8160:2015	Sample A	Sample B
BGCP (coliforms), titer	1	Not allowed in 0.01 g of product	> 1	> 1
	5		> 1	> 1
	15		> 1	> 1
	30		> 1	>1
	45		1	>1
	60		1	>1
	75		0,1	1
	90		0,1	1
Staphylococcus aureus, CUO/g	1	No more than 500 CFU in 1 g of product	Not detected	Not detected
	5		Not detected	Not detected
	15		Not detected	Not detected
	30		Not detected	Not detected
	45		Not detected	Not detected
	60		Not detected	Not detected
	75		Not detected	Not detected
	90		Not detected	Not detected
Salmonella and *Listeria monocytogenes spp*	1	Not allowed in 25 g of product	Not detected	Not detected
	5		Not detected	Not detected
	15		Not detected	Not detected
	30		Not detected	Not detected
	45		Not detected	Not detected
	60		Not detected	Not detected
	75		Not detected	Not detected
	90		Not detected	Not detected

The data in Table 3 indicate the preservation of high microbiological stability in both probiotic Suluguni cheeses, since their microbiological indicators correspond to or exceed the microbiological indicators determined by the standard for this cheese (DSTU 8160:2015) throughout the entire storage period studied.

Thus, during the storage of both samples of probiotic Suluguni cheese, *Staphylococcus aureus* was not detected throughout the entire storage period in 1 g of cheeses, pathogenic microorganisms, such as *Listeria monocytogenes* and *Salmonella spp*., were not detected throughout the entire storage period in 25 g (Table 3). This meets the requirements of current regulatory documents and indicates the correct choice of parameters for heat treatment of raw materials (normalized milk and flax seeds), proper sanitary and hygienic conditions of cheese production, high efficiency of the technological process and the positive effect of lactobacteria, including probiotic cultures

L. acidophilus, on the suppression of foreign, including pathogenic, microflora. Also, the suppression of foreign, including pathogenic, microflora in sample B can be explained by the presence of biologically active compounds in the flax composition – phenolic acids, lignans and antioxidants, which is confirmed by studies [7] and [8]. Similar results regarding the microbiological stability of cheese with flax seeds were obtained in studies of hard Gouda cheese with flax seeds [9].

In terms of the amount of BGCP, probiotic cheese without the addition of flax seeds during 60 days of storage had a titer two orders of magnitude higher than the maximum permissible limit (0.01 g), which is determined by the standard, and on the 75th and 90th days had a titer an order of magnitude higher than that determined by the standard. That is, in terms of the content of BGCP, probiotic cheese had almost 100 times less contamination up to 60 days of age when stored at a temperature of 3±1°C than is determined by the standard. At the same time, the sample with flax seeds had such a level of contamination during the 90th day of storage, which indicates a significant impact of processed flax seeds on the microbiological stability of the probiotic cheese "Suluguni with flax seeds" with respect to BGCP.

In the production of any probiotic cheese, it is important that the number of probiotics is sufficient to survive in the product and ensure the minimum required amount until the moment of consumption. In the production process of probiotic Suluguni cheese, lactic acid bacteria, including the probiotic culture *L. acidophilus La-5*, actively develop during cheddarization (the microflora of lactobacteria in the cheese mass after cheddarization is $(6.0–7.0)\times10^9$ CFU/g) and are partially destroyed during thermoplasticization (the microflora of lactobacteria in the cheese mass after the completion of the thermoplasticization process is $(7.0–8.0)\times10^7$ CFU/g). Therefore, at the beginning of storage, there is an increase in microflora (Fig. 2) – during the first 5 days in the control sample of Suluguni cheese and during the first 15 days in the experimental sample, after which the gradual death of lactobacilli (LB) begins. More active development and higher concentration of viable lactobacilli cells in the experimental sample of probiotic cheese «Suluguni with flax seeds» throughout the entire storage period is explained by two factors: the first is the higher moisture content in sample B, which promotes active cell growth, the second is the presence of biologically active substances of flax seeds (flavonoids, alpha-linolenic acid, fructans, as well as arabinoxylans, rhamnogalacturonans and galactan polysaccharides, which are part of the «flax seed mucus» and exhibit a powerful prebiotic effect).

During the first 5 days of storage, the biomass of lactobacteria increases in both cheese samples by an order of magnitude (Fig. 2), to a greater extent due to *S. thermophilus* cells, which is explained by the presence of lactose residues in the cheese, which can be fermented by both *S. thermophilus* and *Lactobacillus* cultures. Subsequently, by the 15th day of storage, a decrease in the total number of lactobacilli cells is noted in sample A (Fig. 2, a), while the number of *S. thermophilus* cells decreases, which is explained by the absence of lactose, which they ferment, and the number of *L. helveticus* + *L. acidophilus La-5* cells increases, since *Lactobacillus* cultures are able to use a wide range of nutrients as a source of nutrition, including calcium lactate, peptides, amino acids, vitamins, etc. In sample B, by the 15th day of storage, a further increase in the total number of lactobacilli cells is noted (Fig. 2, b), which is explained by the increased moisture content in the cheese and, accordingly, a greater amount of lactose in it, as well as a wide range of BAS of flax seeds. The presence of lactose in the experimental sample of cheese after the 5th day of storage causes further growth of *S. thermophilus* cells, and a wide range of BAS causes active development of *L. helveticus* + *L. acidophilus La-5* – on the 15th day of storage, their number in the cheese mass exceeds 1.0×10^9 CFU/g (Fig. 2, b), which determines the high probiotic properties of the product (in the control sample of cheese on the 15th day we note $(4.0…5.0)\times10^8$ CFU/g of *L. helveticus* + *L. acidophilus La-5* cells – Fig. 2, a). Further storage of probiotic cheeses leads to the death of the starter microflora, but in the experimental cheese sample (sample B) on the 75th day we note $(8.0…9.0)\times10^7$ CFU/g of *S. thermophilus* cells and $(4.0…5.0)\times10^8$ CFU/g of *L. helveticus* + *L. acidophilus La-5* cells (Fig. 2, b), which determines the high probiotic properties of the developed cheese

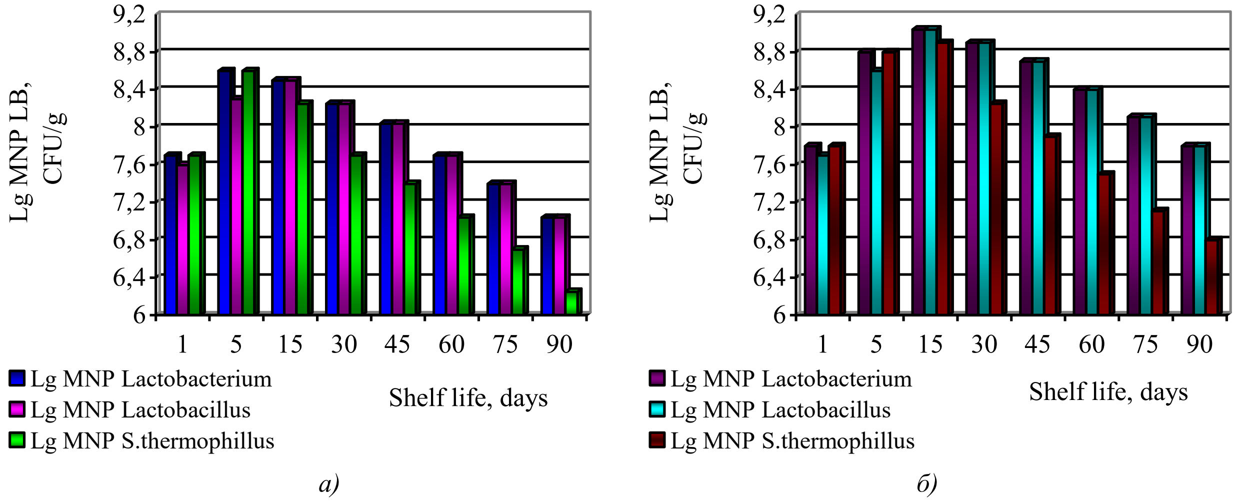

Fig. 2 – Change in the number of viable lactobacilli cells in samples of probiotic Suluguni cheese during storage: a) – control (sample A); b) – experimental (sample B)

«Suluguni with flax seeds», as well as high organoleptic indicators (Table 1), while in the control cheese sample (sample A) on the 60th day the number of *S. thermophilus* and *L. helveticus* + *L. acidophilus La-5* cells is (1.04…1.10)×10^7 and (6.0…7.0)×10^7 CFU/g, respectively, which is almost an order of magnitude lower than in the experimental sample. Such dynamics indicate a pronounced stabilizing effect of flaxseed components, which create favorable conditions for the long-term viability of lactobacteria, including probiotic cultures *L. acidophilus La-5* in Suluguni cheese.

The conducted studies show that the presence of processed flax seeds ensured the preservation of high organoleptic and standardized physicochemical indicators in the probiotic cheese «Suluguni with flax seeds» during 75 days of storage, as well as a higher survival rate of all lactobacteria, including probiotic cultures *L. acidophilus La-5*, in the experimental sample of Suluguni cheese compared to the control, which determines the presence of high probiotic characteristics in the experimental sample of cheese during 75 days. Summarizing the conducted studies, it is recommended to set the shelf life of probiotic cheese «Suluguni with flax seeds» in vacuum packaging at a temperature of 3±1ºC and a relative humidity of 85±5% for no more than 75 days, which is 15 days longer than for Suluguni cheese according to DSTU 8160:2015.

Conclusions

It has been established that the addition of 2% steamed flax seeds to probiotic Suluguni cheese increases the microbiological stability of the product, inhibits the development of undesirable microflora, in particular BGKP, and ensures compliance with safety standards for 90 days of storage.

It has been proven that the inclusion of flax seeds in the composition of probiotic Suluguni cheese has a positive effect on the preservation of the viability of lactobacteria (including the probiotic culture *Lactobacillus acidophilus La-5*) throughout the entire storage period. High probiotic properties of «Suluguni with flax seeds» cheese are noted for 75 days of storage. The recorded dynamics confirm the pronounced prebiotic effect of bioactive components of flax seeds, which contribute to the creation of optimal conditions for the long-term viability of lactobacteria, including probiotic cultures.

Studies of organoleptic indicators have shown that the addition of flax seeds to probiotic Suluguni cheese contributes to the preservation of elasticity and layering of the cheese mass, creamy color and the formation of a characteristic soft nutty flavor, which increases the sensory appeal of the product.

It has been shown that the presence of 2% steamed flax seeds in probiotic Suluguni cheese ensured the preservation of high organoleptic and standardized physicochemical indicators of the product during 75 days of storage.

Based on the totality of studies of microbiological, probiotic, organoleptic and physicochemical indicators, it was established that the use of processed flax seeds is appropriate for expanding the range of probiotic cheeses for health purposes.

It is recommended to set the shelf life of probiotic cheese «Suluguni with flax seeds» in vacuum packaging at a temperature of 3±1ºC and a relative humidity of 85±5% to no more than 75 days, which is 15 days longer than that for Suluguni cheese according to the current standard.

REFERENSES

1. Aggarwal, A., Verma, T., Dhyani, P., & Singh, M. K. (2024). Exploring the probiotic and prebiotic dynamics of cheese: An updated review. *Annals of Phytomedicine: An International Journal*, 13(1), 360–369. https://doi.org/10.54085/ap.2024.13.1.36
2. Medved'ová, A., Koňuchová, M., Kvočiková, K., Hatalová, I., & Valík, L. (2020). Effect of lactic acid bacteria addition on the microbiological safety of pasta-filata types of cheeses. *Frontiers in Microbiology*, 11, 612528. https://doi.org/10.3389/fmicb.2020.612528
3. Tiscareño-Ortega, K., Chávez-Vela, N. A., Domínguez-Soberanes, J., & Rodríguez-Serrano, G. M. (2024). Development of functional panela cheese enriched with prebiotics and probiotics. *Revista U.D.C.A Actualidad & Divulgación Científica*, 27(2), 26–56. https://doi.org/10.31910/rudca.v27.n2.2024.2656
4. Soltani, M., Sadeghi, E. & Shirvani, H. (2025). A comparative study of flaxseed gum effect on *Lactobacillus acidophilus* genes expression, and textural, sensory, structural, and microbiological properties of synbiotic Iranian white cheese. *Sci Rep,* 15, 31902. https://doi.org/10.1038/s41598-025-17819-z.
5. Kly`menko, O. G.; Tkachenko, N. A. (2025). Texnologiya sy`ru suluguni z nasinnyam l`onu. *Tavrijs`ky`j naukovy`j visny`k. Seriya: Texnichni nauky`,* 2, 368-375. https://doi.org/10.32782/tnv-tech.2025.2.36
6. DSTU 2212:2003. (2003). Molochna promy`slovist`. Vy`robny`cztvo moloka ta ky`slomolochny`x produktiv. Terminy` ta vy`znachennya ponyat`. *K: DP «UkrNDNCz»*. 22.
7. Nan Wang, Xiaoyong Liu, Yan Ma, Xianqing Huang, Lianjun Song, Hongtao Guo, Xiaodong Sun, Xinyu Sun, Dan Hai, Peijun Zhao, Yue Shen (2024). Identification of polyphenol extracts from flaxseed and study on its bacteriostatic mechanism. *Food Bioscience*, 58, 103618. ISSN 2212-4292, https://doi.org/10.1016/j.fbio.2024.103618.
8. Akl, E.M., Mohamed, S.S., Hashem, A.I. *et al* (2020). Biological activities of phenolic compounds extracted from flaxseed meal. *Bull Natl Res Cent*, 44, 27. https://doi.org/10.1186/s42269-020-0280-x
9. Kuxty`n M., Arutyunyan D., Pokoty`lo O., Kravchenyuk K., Salata V., Goryuk Yu., Karpy`k G., Daliyevs`ka D. (2024). Mikrobiologichna xaraktery`sty`ka tverdogo sy`ru z nasinnyam l`onu. *Potravinarstvo Slovak Journal of Food Sciences*, 18, 281–296. https://doi.org/10.5219/1956

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ВПЛИВ НАСІННЯ ЛЬОНУ (Linum usitatissimum L.) НА РОЗВИТОК МІКРОФЛОРИ ПРИ ЗБЕРІГАННІ ПРОБІОТИЧНОГО СИРУ СУЛУГУНІ

Анотація

У роботі наведено результати дослідження впливу обробленого парою насіння льону (Linum usitatissimum L.) на якість та безпечність пробіотичного сиру Сулугуні у процесі зберігання у вакуумному пакуванні за температури 3±1℃ та відносної вологості повітря 85±5%. Встановлено, що додавання 2% обробленого парою насіння льону до пробіотичного сиру Сулугуні підвищує мікробіологічну стабільність продукту, стримує розвиток небажаної мікрофлори, зокрема БГКП, та забезпечує відповідність стандартам безпечності протягом 90 днів зберігання. Доведено, що включення насіння льону до складу пробіотичного сиру Сулугуні позитивно впливає на збереження життєздатності лактобактерій (у т.ч. пробіотичної культури Lactobacillus acidophilus La-5) протягом усього терміну зберігання. Високі пробіотичні властивості сиру «Сулугуні з насіння льону» відзначаються протягом 75-ти діб зберігання, оскільки кількість життєздатних клітин S. thermophilus та L. helveticus + L. acidophilus La-5 протягом зазначеного терміну складає $1,1\times10^7…9,0\times10^8$ *та* $8,0\times10^7…1,04\times10^9$ *КУО/г відповідно. Зафіксована динаміка підтверджує виражений пребіотичний ефект біоактивних компонентів насіння льону, які сприяють створенню оптимальних умов для тривалої життєздатності лактобактерій, у т.ч. пробіотичних культур. Дослідження органолептичних показників продемонстрували, що додавання насіння льону до пробіотичного сиру Сулугуні сприяє збереженню еластичності та шаруватості сирної маси, кремового кольору та формуванню характерного м'якого горіхового присмаку, що підвищує сенсорну привабливість продукту. Наявність 2% обробленого парою насіння льону у пробіотичному сирі Сулугуні забезпечила збереження високих органолептичних та нормованих фізико-хімічних показників продукту протягом 75-ти діб зберігання. Тому рекомендовано встановити термін зберігання пробіотичного сиру «Сулугуні з насінням льону» у вакуумному пакуванні за температури 3±1℃ та відносної вологості повітря 85±5% не більше 75-ти діб, що на 15 діб перевищує таку для сиру Сулугуні згідно діючого стандарту.*

Ключові слова: сир; Сулугуні; насіння льону; продукт оздоровчого призначення; пробіотик; фізико-хімічні, органолептичні, мікробіологічні показники якості; мікробіологічна стабільність; безпечність; зберігання.

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Agri-Food Outlook 2025. GLOBAL OVERVIEW

Despite Challenges, Feed Production Increased in 2024

After a stagnant 2023, global feed production rebounded in 2024, according to Alltech's 2025 Agri-Food Outlook, which estimates that feed production expanded by 16.7 million metric tons (mt) in 2024, an **increase of 1.2%**. This growth — achieved despite challenges such as **highly pathogenic avian influenza** (HPAI), **climate fluctuations** and **economic uncertainty** — underscores the resilience and adaptability of the international agriculture industry.

The growth in global feed production was **driven largely by the poultry sector**, which retained its outsized command of the market share, **accounting for 42.7% of all feed tonnage**, although the sector's growth slowed somewhat this year due to HPAI. The ruminant (beef: +1.8%; dairy: +3.2%) and pet food (+4.5%) sectors also performed impressively.

From a regional perspective, **resilience led to notable growth in Europe (+2.7%), Latin America (+3.6%) and Africa and the Middle East (+5.4%)**. In Oceania, Australia recorded a record 11% growth in its beef feed volumes.

The overall **decline in production seen in Asia-Pacific** (-0.8%) stemmed from sharp contrasts amongst species. Gains in dairy (+2.4%) and pet feeds (+11%), for example, were largely offset by declines in aquaculture (-1.7%) and beef (-6.0%), resulting in a net decrease for the region.