

Optimization of feed production and feeding of dairy cows in the Forest Zone of Ukraine

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Abstract

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The possibility of replacing the silage-concentrate type of feeding for dairy cows with silage-hay, using silage prepared with the probiotic preparation KTL 18/1, was investigated to optimize nitrogen metabolism in the rumen and blood, thereby obtaining high-quality milk suitable for the production of hard cheeses. Modern zootechnical, physiological-biochemical, and statistical research methods were used in the experiment. It was established that the use of experimental silage in the composition of silage-hay type contributes to the optimization of nitrogen metabolism in the rumen and blood, ensuring milk production is suitable for cheese production. The obtained results allow recommending farms in the Polissia zone (Ukraine) to use a silage-hay type of feeding for feeding cows of average productivity, which will make it possible to increase the yield of milk per 1 ha of agricultural land, reduce the cost of a feed unit of the ration and save concentrated feed (up to 15-20%).

Keywords: types of rations; probiotics; dairy cows; interior indicators; milk quality

Introduction

The successful management of the dairy industry, which involves obtaining high-quality milk, is determined by scientifically based types of livestock feeding rations (Darmogray and Luchyn, 2014; Darmogray, 2016). As a rule, the deficit of the key element of nutrition – protein in diets is 20-25% (Bohdanov et al., 2012). Solving this problem at the expense of traditional high-protein crops (soy, safflower, alfalfa, etc.), the cultivation of which in the region is problematic due to soil and climatic conditions, cannot be promising, also in connection with the temporary withdrawal from the turnover of

agricultural land in the east and south of Ukraine due to hostilities, which makes the supply of high-protein components of compound feed, in particular soybeans, problematic. Because of this, there is an obvious need to establish a rational structure for the fodder base and review the types of rations for dairy livestock, taking into account the biogeochemical features of individual zones in the region, in order to conserve scarce concentrated fodder (Gnoevy, 2013; Bohdanov et al., 2013). Correction of the structure of fodder production is impossible without understanding the specifics of the mechanisms of transformation of nutrients, primarily proteins and other nitrogen-containing compounds of individual feeds and rations as

a whole, in the composition of milk in particular, based on the study of the exchange of nitrogenous metabolites, which are ultimately the precursors of milk proteins, in including casein and its fractions, the optimal ratio between which is of decisive importance in the processing of milk into hard cheeses (Chumachenko et al., 2004; Fedak et al., 2022).

In recent times, many studies have been carried out, which have provided significant theoretical and experimental material on the influence of feed on the functional state of the cow's organisms, the quantitative and qualitative composition of milk (Chumachenko et al., 2014; Fedak et al., 2018). The data obtained by scientists suggest a close connection between complete feeding and the production of high-quality milk that meets the requirements of the processing industry, particularly cheesemaking; however, these findings are currently fragmentary. Theoretical substantiation of the features of the biotransformation of feed nutrients (in particular, proteins) in the organisms of cows will make it possible to correct the structure of feed production in the Polissia zone to increase the productivity of livestock and obtain high-quality milk, suitable in particular for cheese making.

The research aimed to establish the specifics of the influence of nutrients of the silage-concentrate type of feeding on individual links of nitrogen metabolism and the fractional composition of milk proteins, and therefore to clarify the specifics of the mechanism of transformation of feed nutrients in the body of dairy cows to obtain high-quality milk suitable for the production of hard cheeses in natural -climatic zone of Polissia and investigate their quality.

Materials and Methods

The study was conducted during the winter stall period of 2022–2023 on two groups of dairy cows of the Ukrainian black-spotted dairy breed, which were matched in terms of age, live weight, and milk yield for the previous lactation (Table 1).

Research was conducted using modern methodological approaches and in compliance with the relevant requirements and standards employed in both domestic and international practice, specifically meeting the requirements of DSTU ISO/IEC 17025:2006, IDT. All animals were clinically healthy during the research.

Table 1. Experiment scheme

Group	Type of fattening
Control	Basic ration (BR) + silage from a vetch-oat mixture
Experimental	BR + silage from a vetch-oat mixture prepared with probiotic preparation KT-L 18/1

The duration of the accounting period of the experiment was 91 days. Animals from both groups received the basic ration (BR), typical of silage-hay type feeding. In addition to BR, the control group received 20 kg of silage prepared on the farm using traditional technology, and the experimental group received 19 kg of silage preserved with the use of the probiotic preparation KT-L 18/1 in a dose of 8.0 ml of suspension per 1 ton of green mass of a mixture of vetch and oats.

KT-L 18/1 is a one-component preparation based on the *Bacillus subtilis* strain (the strain is deposited in the depository of the State Scientific Control Institute of Biotechnology and Microorganism Strains); it is a brown suspension that contains live bacteria. One milliliter of this preparation contains at least 1 billion viable cells of microorganisms. Domestic product, created in a probiotics laboratory, Institute of Agricultural Microbiology and Agro-industrial Manufacture NAAS).

The rations were balanced according to detailed norms based on calculations to achieve an average daily milk yield of 16–18 kg (Bohdanov et al., 2012).

Forage, rumen contents, blood, milk, and cheese were used as research material. The chemical composition of the feed (crude protein, crude fat, crude fiber, ash, phosphorus, calcium) was determined according to the generally accepted methods of zootechnical analysis (Vudmaska and Prylutskyi, 1975). The content of fodder units was determined using a calculation method based on digestibility coefficients and the results of our chemical analysis of the feed.

To study the course of the metabolism of nitrogenous substances in the body, samples of rumen content (by an oroesophageal probe) and blood (from the jugular vein) were taken from 3 animals from each group two hours after the start of morning feeding. pH, ammonia, nitrogen fractions, amine nitrogen, and volatile fatty acid content were determined in the rumen content; in the blood, the concentration of hemoglobin, the number of erythrocytes, urea, total serum protein, and its fractions were determined according to the methods described by Vlizlo et al. (2012).

Milk productivity was monitored by individual control milking every decade. Chemical composition, density, and degree of bacterial contamination were determined in cow's milk (Vlizlo et al., 2012).

The moisture, protein, and fat content, as well as the acidity, were determined in samples of mature cheese using generally accepted methods (Vlizlo et al., 2012).

Biometric processing of the received digital material was performed using the method of variational statistics, taking into account the Student's criterion. To assess the reliability of the obtained results, P—average arithmetic values (M),

error ($\pm m$), and the probability of differences between the studied values (P) — we used the standard computer mathematical and statistical program Microsoft Excel. Changes were considered reliable at $P < 0.05$.

Results and Discussion

First, the chemical composition of the vetch-oat mixture and the silage prepared from it was determined (Table 2).

Table 2. Chemical composition and nutritional value of silage, %

Parameter	Green mixture	Group	
		Control	Experimental
Water	79.15	81.37	79.60
Dry matter	20.85	18.63	20.40
Raw protein	3.24	3.0	3.14
Raw fat	0.70	0.91	1.19
Crude fiber	5.63	5.02	4.97
Ash	0.90	1.18	1.67
Nitrogen-free extractive substances	10.38	8.50	9.43
Carotene, mg/kg	28.06	17.42	22.81
Nutrition, fodder units	0.18	0.20	0.22

As can be seen from the data in the table, 60 days after laying the silage, the experimental version contained more dry matter by 1.77%, mainly due to an increase in the concentration of crude protein (by 0.12%), nitrogen-free extractive substances (by 0.93%) and of raw ash (by 0.49%) with a simultaneous decrease in the content of crude fiber (by 0.05%), which led to an increase in its nutritional value by 0.02 fodder – unit compared to the control.

When determining the content and ratio of the main organic acids in silages, it was established that in the experimental version the concentration of lactic acid was 12.0% higher than in the control, which is related to the increase in the number and activity of homofermentative strains of lactic acid bacteria after the introduction of starter and is consistent with the results of other scientists (Kravchenko et al., 2012; Kotsyumbas et al., 2013; Kulyk et al., 2019;). In the experimental version of silage, the optimal ratio between the content of lactic and acetic acids (74.67:21.67 %) was observed in the absence of butyric acid.

Therefore, the introduction of the KTL 18/1 probiotic preparation into the silage mass as a leavening agent contributes to the creation of the desired direction and intensity of fermentation processes, particularly lactic acid fermentation, and the accumulation of the necessary pool of lactic acid. Acid, which is the primary preservative factor and suppress-

es butyric microflora, and ultimately ensures the preservation of nutrients in silage mass; dry matter – 97.8%; protein – 96.9%; and carotene – 81.3% to 89.4%, respectively; 93.2% and 62.1% in the control.

To determine the intensity of nitrogen metabolism links in the bodies of cows under the influence of feeding different types of silos, several physiological and biochemical indicators were measured in rumen fluid and blood. It was found that the concentration of ammonia in the rumen was probably lower in the cows of the experimental group than in the control (Table 3).

Table 3. Parameters of rumen content of cows, ($M \pm m$, $n = 3$)

Parameter	Group	
	Control	Experimental
pH	6.62 $\pm$ 0.08	6.34 $\pm$ 0.06
Nitrogen, mg %:		
Ammoniac	9.24 $\pm$ 0.29	8.10 $\pm$ 0.23*
Amine	2.68 $\pm$ 0.02	2.93 $\pm$ 0.12*
General	1590.15 $\pm$ 15.54	1660.67 $\pm$ 12.34**
Residual	1526.12 $\pm$ 10.20	1586.25 $\pm$ 15.14*
Protein	64.03 $\pm$ 1.54	74.42 $\pm$ 2.00*
Volatile fatty acids, mg/100 ml	10.15 $\pm$ 0.25	11.36 $\pm$ 0.14**

Note: * $P < 0.05$; ** $P < 0.02$

A feedback relationship was noted between the content of ammonia and amine nitrogen. In experimental cows, at a probably lower level of ammonia, more (by 9.3%) amino nitrogen accumulated, which occurred as a result of the activation of the reductive amination processes of ketoacids. Perhaps the reason for the increase in the level of protein nitrogen in the rumen of cows that received silage with KTL 18/1 sourdough starter is the different rate of formation and absorption of free ammonia from the rumen because it is known that the higher the pH, the more ammonium ions are transformed into the form of free ammonia (NH_3), which is absorbed into the blood much faster than the ammonium ion (NH_4^+).

We established that the pH in the rumen of cows of the experimental group was lower (by 4.3%) than in the control. Therefore, most of the ammonia molecules were in the form of ammonium ions, which were absorbed more slowly and more completely assimilated by the symbiotic microflora. This finding is also consistent with lower blood urea levels ($P < 0.05$) in these animals compared to controls. Similar results were observed by Yirga (2015), Retta (2016), and Vovk and Polevyi (2020). At the same time, a likely higher concentration of volatile fatty acids was found in the rumen

of experimental cows, indicating an increase in fermentation levels. Studies with the use of probiotics in one form or another have established an increase, in particular, in the cellulolytic activity of microflora. (Weimer, 2015; Retta, 2016; Anee et al., 2021).

The main volatile fatty acids in the rumen are represented by acetic (65-70%), propionic (15-20%), and butyric (15-16%) acids. It is known that one of the components of milk fat is low molecular weight fatty acids (C_4 - C_{10}), which are synthesized in the udder from acetic and beta-oxobutyric acids (Kassich and Nechyporenko, 2020). Therefore, it is possible that in the cows of the experimental group, a larger amount of acetic acid than in the control group came from the rumen through the blood to the udder and took part in the synthesis of triglycerides, which mainly make up milk fat (98-99%) which affected the fat content (by 4.1%) in the milk of these animals.

A direct relationship between the level of ammonia nitrogen in the rumen and urea in the blood was noted (Table 4).

Table 4. Parameters of cows ($M \pm m$, $n = 3$)

Parameter	Group	
	Control	Experimental
Erythrocytes, million/mm ³	8.62±0.30	8.80±0.23
Hemoglobin, g %	13.80±0.14	13.92±0.60
Total serum protein, g%	7.65±0.30	7.96±0.17
Albumins, g %	3.37±0.37	3.55±0.12
Globulins, g %:	0.99±0.09	0.79±0.06
α		
β	2.17±0.13	1.65±0.10
γ	1.12±0.18	1.57±0.09*
Protein index	0.78	0.88
Urea, mmol/l	4.18±0.14	3.79±0.09*
Amino nitrogen, mg%	2.84±0.10	3.10±0.06*
Volatile fatty acids, mg%	8.01±0.15	9.35±0.12*
Ketone bodies, mg%	6.25±0.10	5.76±0.15*
Volatile fatty acids:ketones ratio	1.28	1.62

Note: *P < 0.05

Thus, the levels of ammonia and urea in the experimental cows were probably lower than in the control, which can be evidence of a more efficient use of nitrogenous substances in the bodies of these animals as a whole. Additionally, in cows that received silage with a probiotic preparation, a likely higher concentration of amino nitrogen in the blood was observed, indicating an increase in the pool of free amino acids in these animals' blood. It is known that free blood amino acids are the primary substrates for the synthesis of milk proteins (casein, β-lactoglobulin, and α-lactoalbumin). The amount of absorption by the mammary gland of indi-

vidual free amino acids in dairy cows is within 55-60% of their content in the blood. Therefore, it can be assumed that in experimental cows, more free amino acids participated in the synthesis of milk proteins, which was reflected in an increase in the levels of both total protein (by 2.3%) and casein (by 6.1%).

Since the liver is the primary producer of the most important blood plasma proteins, understanding its protein-synthesizing capacity is of great importance. Our studies did not reveal significant intergroup differences in the concentration of total blood protein. However, there was a tendency for both total protein and albumin content to increase in the cows of the experimental group, resulting in a 12.8% increase in the protein index, which is considered a positive outcome. Along with this, a probable ($P < 0.05$) increase in the concentration of the γ-globulin fraction, which takes part in the formation of the body's nonspecific immunity, was found. Our data are consistent with the results of research on the use of BPS-L preparation during the ensiling of high-moisture vetch-oat mixtures (Kravchenko et al., 2012).

Therefore, feeding silage with sourdough has a positive effect on the course of nitrogen metabolism in the cow's body, causing an increase in the digestibility of nutrients in the diet and the transformation of nitrogenous substances into milk proteins.

It is known that the ratio between the concentration of volatile fatty acids and ketone bodies in the blood can be an indicator of the direction of fermentation processes in the rumen and the use of energy in the body. It depends on the rate of entry of ketogenic acids (acetic and butyric) from the rumen and glucogenic propionate. (Weimer, 2015; Retta, 2016). We found that the cows in the experimental group had a higher ketone body ratio (by 26.6%) compared to the control, which can indicate an increase in rumen fermentation and an increase in the production of volatile fatty acids.

Optimizing the processes of nitrogen exchange in the cows of the experimental group had a positive effect on the chemical composition of their milk, particularly on the content of total protein and casein, as well as on its technological properties (Table 5).

The milk of experimental cows contained 4.8% more dry matter, mainly due to total protein – 2.3%, fat – 4.1%, and lactose – 2.9%. This led to a 2.2% increase in milk density, with the same acidity and a sufficient supply of calcium and phosphorus. The average daily milk yield for 91 days of the accounting period in the experimental group was 17.4 kg, which was 5.5% higher than in the control group, at 16.5 kg (Table 6).

At the end of the experiment, two versions of Bukovynskyi cheese were made from the milk of the control and ex-

Table 5. Chemical composition of milk during the winter-stall and pasture periods ($M \pm m$, $n = 10$)

Parameter	Winter-stall period		Pasture period
	control	experimental	
Dry matter	11.55 $\pm$ 0.05	12.10 $\pm$ 0.09	11.43 $\pm$ 0.08
Fat	3.39 $\pm$ 0.08	3.53 $\pm$ 0.10	3.27 $\pm$ 0.09
Total protein	3.48 $\pm$ 0.07	3.56 $\pm$ 0.11	3.59 $\pm$ 0.10
Casein	2.30 $\pm$ 0.11	2.44 $\pm$ 0.09	2.47 $\pm$ 0.05
Lactose	4.20 $\pm$ 0.05	4.3 $\pm$ 0.07	4.08 $\pm$ 0.07
Ash	0.69 $\pm$ 0.07	0.77 $\pm$ 0.05	0.55 $\pm$ 0.01
Calcium, mg/%	125.54 $\pm$ 10.34	127.38 $\pm$ 11.47	124.51 $\pm$ 11.31
Phosphorus, mg/%	105.20 $\pm$ 9.27	107.31 $\pm$ 9.31	105.50 $\pm$ 9.20
Density, °A	27.7 $\pm$ 0.04	28.3 $\pm$ 0.02	27.4 $\pm$ 0.03
Acidity, °T	16	16	17

Table 6. Milk productivity of cows, ($M \pm m$, $n = 10$)

Parameter	Group	
	control	experimental
Production of natural milk, kg: general	1501.5 $\pm$ 9.31	1583.4 $\pm$ 10.12
daily average	16.5 $\pm$ 1.05	17.4 $\pm$ 1.15

perimental groups. The duration of ripening of the cheeses was 40 days. The chemical composition and leading indicators characterizing microbiological processes were determined in the cheeses, and an expert evaluation of the mature cheese was conducted (Table 7).

As can be seen, the sample of mature cheese from the milk of the cows in the experimental group contained 2.4% more dry matter, primarily due to increased protein and fat content. The degree of protein degradation, the accumulation of free amino acids in the ripening process, and the degree of maturity of the cheese are judged by the amount of buffering of the water extract of the cheese and its acidity. In our research, cheese from the milk of the experimental group had a higher degree of maturity, which was 7.7% higher than in

the control. This cheese had an 8.4% higher acidity index during ripening due to intense lactic acid fermentation. After the expertise, Bukovynskyi cheese made from the milk of experimental cows received a higher overall score of 97 points compared to 90 points in the control group. Furthermore, it was rated higher for taste and smell. The experimental version of milk yielded a mature cheese of 11.6 kg, a 9.4% increase compared to the control's 12.8 kg.

The use of silage-hay-type rations in feeding lactating cows in the Polissya zone, including silage from vetch-oat mixtures prepared with the probiotic preparation KT-L 18/1, helps optimize the exchange of nitrogenous compounds and the transformation of feed nutrients into milk components. This, in turn, ensures the production of milk that meets the requirements for processing into hard cheeses, both in terms of chemical composition and organoleptic properties.

Additionally, we analyzed the farm's pasture grass cover, which we subsequently improved. In 2023, a leguminous-cereal pasture provided 14.7 t/ha of fodder biomass for two cattle grazing cycles with complete N45P45K45 fertilization. The formed pasture herbage is 21-27% saturated with

Table 7. Chemical composition and expert evaluation of cheese obtained from milk of the winter-stable and pasture periods ($M \pm m$)

Parameters	Winter-stable period		Pasture period
	Control	Experimental	
Humidity, %	46.15 $\pm$ 1.23	45.08 $\pm$ 1.35	46.25 $\pm$ 1.95
Protein, %	24.30 $\pm$ 1.00	25.53 $\pm$ 1.07	24.87 $\pm$ 1.78
Fat, %	23.87 $\pm$ 1.18	24.95 $\pm$ 1.75	23.70 $\pm$ 2.03
Acidity, °T	196.05 $\pm$ 9.54	212.51 $\pm$ 10.03	203.45 $\pm$ 9.57
Buffer capacity of the water extract, °	120.54 $\pm$ 2.37	129.35 $\pm$ 2.51	121.36 $\pm$ 1.53
Expert evaluation, score			
general	90	97	95
taste and smell	40	44	42
Yield of mature cheese, kg	12.8	11.6	13.0

legumes, 64-69% with cereal-sown grasses, and has a minimal (9-10%) amount of forbs.

Table 5 provides information on the chemical composition and technological properties of milk obtained from cows grazing on improved cultural pastures.

As can be seen, the chemical composition of the milk met the standard for the black and spotted breed. A slight reduction in fat content and an increase in milk protein content, along with an adequate supply of calcium and phosphorus, are in line with the features of keeping cows on pasture. Moreover, the milk density indicator met the requirements for processing milk into hard cheeses.

A batch of Bukovynsky cheese was produced using milk from cows grazed on pasture. Table 9 presents the expert evaluation and chemical composition of mature cheese.

After analyzing the data presented in Table 7, it can be observed that the sample fully met the technical specifications for the “Bukovynskyi” cheese variety in terms of moisture, protein, and fat content. The high buffer capacity of the water extract and acidity levels suggest an optimal amount of protein degradation, accumulation of free amino acids, and degree of cheese maturity. According to the results of the expert assessment, the cheese received a high overall score of 95, with 42 points allocated to taste and smell. The yield of mature cheese was 13.0 kg. Thus, the grass structure of cultivated pastures consists of 21-27% legumes, 64-69% cereals, and 9-10% forbs. This mixture supplies the essential nutrients for lactating cows, yielding milk with a suitable protein and fat content. Additionally, the optimal density of the milk, which is a key factor in determining its suitability for processing into hard cheeses, is also maintained by this grass mixture.

Conclusions

As a result of the measures taken to improve cultivated pastures fundamentally, the structure of the formed herbage consisted of 64-69% cereals, 21-27% legumes, and 9-10% grasses, which in general meets the needs of dairy farming. Cows make it possible to obtain milk suitable for cheese production.

The use of probiotic preparation KT-L 18/1 helps to achieve an optimal level of lactic acid fermentation in ensiled vetch-oat mixtures. This leads to a higher accumulation of lactic acid (70-75%) and acetic acid (22-25%), while effectively suppressing the microflora of butyric acid.

The introduction into the diets of dairy cows of silage prepared with a probiotic preparation contributes to the optimization of nitrogen metabolism in the rumen (due to more efficient use of ammonia nitrogen), has a positive effect on

the course of redox processes in the blood and contributes to an increase in the concentration of total protein in the serum (by 4.0%) and its albumin (5.3%) and γ -globulin (40.1%) fractions, which indicates a high protein-synthesizing capacity of the liver.

The experimental animals exhibited an increase in metabolic intensity in both their rumen and blood. This resulted in a higher level of nutrient transformation from their rations through metabolites of nitrogen and lipid metabolism, ultimately leading to the production of proteins and milk fat. The increase in both milk protein content and milk fat content supports this.

Milk from cows receiving silage inoculated with probiotic KT-L 18/1 in all experiments contained more dry matter (by 4.7%), protein (by 2.3%), and fat (by 4.1%) than the controls, which led to an increase in milk density by 2.2%.

Cheese of the Bukovynsky variety, which is made from the milk of cows that were given experimental silage, as well as from milk obtained from improved cultural pastures, contains moisture levels of 45.0% and 46.15%, protein levels of 25.52% and 24.87%, and fat levels of 24.95% and 23.70%, respectively. These meet the standard requirements for cheese of this variety.

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