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Variability of milk urea nitrogen traits and their potential use in dairy cattle

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Abstract. Milk urea nitrogen (MUN) is an important biomarker that reflects the efficiency of protein metabolism in cows, the level of consumption and quality of “input” protein, and the energy balance in the diet. MUN fluctuations are closely related to possible discrepancies in the total mixed ration (TMR), physiological and genetic factors. The aim of the study was to determine the influence of genetic (cow’s paternal origin) and paratype (calving year-month) factors on milk yield, quality and biochemical parameters of milk, in particular urea nitrogen concentration, in Holstein cows. The research was based on data from 595 cows kept at the Kolos Agricultural Firm LLC in the Kyiv region (Ukraine). The study was conducted under standard conditions with cows fed “without restrictions” and analysis of productivity indicators and biochemical indicators of milk quality. It was found that the factor “year-month of calving” has the greatest impact on productivity indicators and milk quality parameters, causing seasonal fluctuations associated with minor changes in feeding and microclimate. The influence of the sire (cow’s father) on milk yield per lactation was noted – 12.4%, milk fat content per lactation – 13.4%, milk protein content per lactation – 12.9%. The influence of non-genetic factors was quite high for daily milk yield, fat, protein and lactose content, as well as MUN. Even with total use of standard TMR, MUN values varied widely in cows from a minimum of 2.6 mg/dl to a maximum of 32.9 mg/dl, with average values of 12.31 ± 0.24 mg/dl, and depended on the cows’ ability to separate the diet, minor changes in the diet, and the level of protein and non-structural carbohydrates. A tendency was noted whereby at high MUN values (>16 mg/dl) the absolute level of such important milk components as fat, protein and lactose content decreases, which reduces the energy value of milk – ECM (energy-corrected milk). The results obtained indicated the need to include overall average samples of MUN across the entire herd to optimise feeding programmes and animal welfare management

Keywords: protein metabolism in cows; energy value of milk; Holstein breed; influence of factors

Introduction

Basic methods of data analysis for predicting milk quantity and quality with options for making the right management decisions on dairy farms are being intensively studied. According to O. Palma *et al.* (2025), recent research has focused mainly on predicting milk yield (29%), detecting lameness (26%) and early detection of mastitis (13%). Based on the analysis of a large amount of data, it has been concluded that analytical data combined with optimisation and modelling methods offer advantages (Matvieiev *et al.*, 2025). Predictive modelling in dairy farming is increasing in practical applications (Ruban & Danshyn, 2024). This increases the relevance of finding reliable and relatively simple-to-determine predictor indicators, especially for use in accurate milk production forecasting and detection

of diseases such as mastitis and lameness in cows. M. Štolcová *et al.* (2024) provided data on the problems of negative energy balance (NEB), which is a serious problem in most dairy herds. NEB occurs after calving when cows cannot consume enough dry matter to meet their energy needs at the beginning of lactation, and the breakdown of fat reserves releases non-esterified fatty acids (NEFA) into the blood, high concentrations of which cause health problems such as ketosis, fatty liver syndrome, and susceptibility to infections. S. Ruban & V. Danshyn (2024) pointed to a genetic component (breed influence) on blood biochemical parameters and blood urea nitrogen (BUN) levels. V. Souza *et al.* (2021) have demonstrated a close relationship between blood urea nitrogen and milk urea nitrogen levels. According

to R. Jahnel *et al.* (2023), moderate heritability estimates clearly suggest possible selection for MUN, while near-zero estimates of genetic correlations indicate no risk of undesirable correlated selection responses for other milk traits. At the same time, the assessment of the nature of MUN variability together with other important milk components (fat, protein, lactose content) indicates the possibility of their use for diet adjustment.

Nitrogen use efficiency in lactating dairy cows, defined as nitrogen (N) excretion in milk as a proportion of N consumed, is low, with most of the N consumed being excreted in urine and faeces. Accordingly, A.-L. Craig *et al.* (2022) calculated the average nitrogen use efficiency. Nitrogen losses through evaporation, gaseous ammonia, can lead to acidification of water and soil, and loss of biodiversity (de Vries, 2021). Studies by M. Li *et al.* (2022) have demonstrated differences in rumen microbiota in cows with different nitrogen utilisation efficiency. Similar results were obtained for intensive protein consumption values, where cows used protein more efficiently than those with higher intensive consumption values (Risayahadi *et al.*, 2023). According to A. Zeleke *et al.* (2025), reducing the crude protein content in dairy cow diets did not affect microbial composition, diversity, and functional profiles. The crude protein content in the diets of dairy cows can be reduced from 17% to 15% to increase nitrogen use efficiency and reduce nitrogen emissions to the environment.

The absolute values and fluctuations of milk urea nitrogen depend on a large number of internal and external factors, affecting animal health, product quality and creating environmental problems due to increased nitrogen losses in excreta. The study was devoted to assessing the variability of MUN and its relationship with such a complex indicator as ECM, as well as the main components of milk that have a certain nutritional value and determine the economics of production.

Literature Review

In modern breeding programmes, when determining the best animals in terms of lifetime value, traits that characterise milk quality (milk fat and protein, somatic cell count) account for 47.4% of their economic (monetary) significance in the overall selection index (VanRaden *et al.*, 2021). In recent years, milk components have been considered not only as indicators of quality and nutritional value, but also as predictors of health status, control of the correctness of the diet, and indicators of environmental impact (Ruban & Danshyn, 2024). At the same time, milk quality indicators are closely related to the duration of lactation, which, in turn, depends on the age of cows, genetic factors (the influence of the sire), calving season and other paratypic factors that directly affect the formation of the lactation curve and overall animal productivity (Kramarenko *et al.*, 2025). According to L. Musembei *et al.* (2023), it is already necessary to rethink the assessment of raw milk quality through the evaluation of its microbiological parameters to ensure high quality dairy products. M. Mortazavi *et al.* (2025) state that milk urea nitrogen serves as an indicator of protein metabolism in dairy cows, and blood urea nitrogen provides an idea of the overall nitrogen balance and kidney function. Under normal circumstances, almost 28% of the nitrogen consumed by dairy cows is converted into milk components, with 5% excreted as non-protein nitrogen and the rest representing “true” protein. Reducing nitrogen emissions in milk production is crucial due to the impact of livestock farming on the environment, as nitrogen is released from cow excreta (manure, urine) and evaporates into the atmosphere or enters farm water sources (Borshch, 2023).

There are different views on the MUN level for describing the physiological characteristics of the gastrointestinal microbiota and kidneys in cows of different breeds, in different climatic zones and with different diet structures. Holstein cows, according to A. Zeleke *et al.* (2025),

are characterised by lower MUN concentrations compared to others, and the amount and composition of “input” dietary protein are considered to be the main factor influencing MUN concentration (Nousiainen *et al.*, 2004; Wattiaux *et al.*, 2011). This is explained by the peculiarities of urea synthesis by the liver, the level of which depends on the concentration of ammoniacal nitrogen ($\text{NH}_3\text{-N}$) produced in the rumen. Cows that consume a diet high in crude protein (CP) usually absorb more $\text{NH}_3\text{-N}$ through the rumen wall because rumen $\text{NH}_3\text{-N}$ production exceeds the ability of rumen microorganisms to capture it. Ammonia (NH_3) and nitrogen, ammonia ($\text{NH}_3\text{-N}$) are different expressions of the chemical forms of ammonia. The $\text{NH}_3\text{-N}$ form uses the molecular weight of nitrogen atoms only, while the NH_3 form uses the molecular weight of the entire ammonia molecule (1 nitrogen atom + 3 hydrogen atoms). This may affect certain capabilities of the animal’s microbiota, the level of nitrogen digestion, the overall health of the animal, and the quality of animal products (Sadvari *et al.*, 2024). Thus, K. Li *et al.* (2023) conducted a multi-omic analysis (biological analysis based on the use and integration of large amounts of data) on rabbits exposed to high and low concentrations of ammonia under similar environmental conditions to determine changes in the microbiota of the nose and colon, gene expression in the lungs and colon, and muscle metabolic profile. The results showed that ammonia exposure significantly affected the microbial structure, composition, and functional capacity in both the nose and colon, which may influence local immune responses and inflammatory processes. Transcriptome analysis (the set of all transcripts synthesised by a single cell or group of cells, including mRNA and non-coding RNA) showed that genes associated with cell death (MCL1, TMBIM6, HSPB1, and CD74) and immune response (CDC42, LAMTOR5, VAMP8, and CTSB) were differentially expressed in the lungs, while colon genes associated with redox status (CAT,

SELENBP1, GLUD1, and ALDH1A1) were significantly up-regulated, meaning that the gene or protein is expressed at a higher level than usual, often due to a specific trigger or signal. This increased expression causes the cell to produce more of the corresponding protein and can lead to changes in cell function or behaviour. Several key differentially abundant metabolites, such as L-glutamic acid, L-glutamine, L-ornithine, oxoglutaric acid, and isolactic acid, have been identified in the muscle metabolome, which may indicate a disruption in the influence of ammonia on amino acid synthesis, nucleotide function, and energy metabolism characteristics.

According to V. Ishler (2023), different MUN ranges and their dynamic changes complicate the requirements for their optimal values. Frequently recommended ranges are between 10 and 14 milligrams per decilitre (mg/dl), while others recommend a range of 8 to 12 mg/dl, which is associated with a protein level in the diet of around 16%. It has been calculated that the change in nitrogen is 2 mg/dl for each percentage point change in diet from 15 to 18.5% protein. MUN values are influenced by the feeding system (total mixed ration) versus herds fed individual feed components, and feeding time relative to milking time. MUN values usually peak 3-5 hours after feeding. In addition, herds that are milked three times a day tend to have higher MUN values than herds that are milked twice a day. Another factor that affects MUN values is breed. Holstein cows usually have lower MUN values than other dairy breeds, such as Jersey cows (Ruban & Danshyn, 2024). However, this may be related to body weight rather than breed. In addition, MUN values tend to be higher in the summer months.

One strategy for interpreting MUN on a specific dairy farm is to evaluate the current diet along with the MUN results from laboratory tests. It is useful to have several MUN values over a period of time to help identify possible problems in the diet or farm management practices. Possible problem areas include high

MUN (>12-14 mg/dl) and especially highly controversial values in repeat samples, which may be related to measurement accuracy and cows' responses to external factors that are considered normal "genotype-environment" responses. According to J. Jakobsen *et al.* (2009) and R. Savickienė & A. Galnaitytė (2024), it is the effect of environmental factors that continues to influence the expression of genetic traits over a period of time. From a practical point of view, according to V. Ishler (2023), low MUN levels (<8-10 mg/dl) indicate a possible protein deficiency, which can occur when the number of bacteria in the rumen decreases, limiting milk production and milk protein yield. High MUN levels (>12-14 mg/dl) may be associated with excess dietary protein or an imbalance of rumen protein, protein fractions and energy, and especially non-structural carbohydrates, which include sugar, starch and pectin (Ruban & Vasilevsky, 2015). In addition, it may be associated with the inclusion of soda in the diet of cows as a preventive measure against ketosis. It is high MUN values that indicate additional feed protein and energy expenditure for the synthesis of additional protein when excess nitrogen is released into the environment.

Thus, milk quality indicators combined with detailed biochemical analysis allow for understanding the characteristics of such processes and identify the main influencing factors. Milk urea nitrogen is one of the convenient

and fairly accurate descriptive components that reflects the characteristics of ruminant digestion. This study determined the range of fluctuations in the main indicators of milk quality and MUN, followed by the identification of the influence of genetic and paratypic factors on the observed changes. The presented material was an attempt to subsequently determine the possibilities of using such assessments of the efficiency of feed nitrogen utilisation and animal welfare in dairy cattle farming from the point of view of preserving their health.

Materials and Methods

The research material consisted of milk production data for 595 Holstein cows at the Kolos Agricultural Firm Limited Liability Company in the Kyiv region (Ukraine). The research was conducted between December 2024 and April 2025. When conducting the experimental studies presented in this paper, all manipulations with the cows involved in the studies were carried out in accordance with the basic principles of bioethics, in accordance with the European Convention for the Protection... (1986), Law of Ukraine No. 3447-IV (2006) and Procedure for Conducting... (2012). The farm used a tethered milking system with milk piping. Milking was performed three times a day by one milker for up to 50 cows. Feeding was carried out using a total mixed ration (TMR), the characteristics of which are presented in Tables 1 and 2.

Table 1. Characteristics of the TMR mixture for Holstein cows

Diet ingredients	Weight, kg		Percentage	
	physical	dry matter	by physical weight	dry matter
Corn silage	28.000	9.240	49.36	37.5
Grain mixture	8.722	7.967	15.38	32.37
Beer lees (moisture)	5.000	0.924	8.81	3.76
Alfalfa haylage	3.500	1.838	6.17	7.47
Pomace	4.000	0.560	7.05	2.28
Corn grain with increased moisture content	2.20	1.541	3.88	6.2

Table 1. Continued

Diet ingredients	Weight, kg		Percentage	
	physical	dry matter	by physical weight	dry matter
Sunflower meal	1.500	1.385	2.64	5.63
Straw	0.80	0.703	1.41	2.86
Water	2.000	0.001	3.53	–
Beet molasses	1.00	0.45	1.76	1.83
Total	56.722	24.6	10	43

Note: the mixture was calculated for cows weighing 550-650 kg, with a milk yield of 28-30 kg, fat content of 4.00%, protein content of 3.40% and lactose level of 4.68%

Source: developed by the authors based on the results of chemical analysis dated 25 April 2025

Table 2. Biochemical characteristics of the general mixed diet for dairy cows

Component	Dry matter content, %	Content, g
CP	15.8380	3,897.6920
NDF	28.9485	7,124.1460
NDF fodder	20.4421	5,030.7430
ADF	19.41	4,777.2170
Sugar	6.1480	1,513.0130
Starch	26.0718	6,416.2060
Soluble fibre	7.9292	1,951.3560
Ash	7.6352	1,879.0090
Ca	0.6520	160.4592
R	0.3987	98.1302
Mg	0.4370	107.5504
K	1.1080	272.6834
Fodder	47.8724	–
Concentrate	52.1276	–
Total carbohydrates	73.1534	18,002.8800
Ammonia	0.4838	119.0553

Note: CP – crude protein; NDF – neutral detergent fibre; ADF – acid detergent fibre

Source: developed by the authors based on the results of chemical analysis dated 25 April 2025

Energy-corrected milk calculations were calculated using the formula by M. Hall (2023) (1):

$$ECM = [(fat\ content, \% \times 383 + protein\ content, \% \times 242 + lactose\ content, \% \times 165.4 + 20.7) / 3,140] \times milk\ yield, kg. \quad (1)$$

The analysis of the qualitative and biochemical indicators of milk was determined using the EKOMILK Bond ultrasonic analyzer (Bulgaria). The amount of urea in milk was determined using the diacetylmonoxime method. Its level was judged by the content of

the red complex formed by urea with diacetylmonoxime in an acidic environment in the presence of thiosemicarbazide and trivalent iron according to the method of N. Langenfeld *et al.* (2025). The molar concentration of urea (C) in mmol/l was determined from the optical density data of sample A relative to standard B using formula (2):

$$C = 8,33 \frac{A}{B}. \quad (2)$$

Statistical analysis (descriptive statistics, variance analysis, correlation and regression analysis) was performed using the

RStudio-2023.03.0-386 programme. The effects of the year-month of calving, sire (father) and lactation number were analysed using a linear model (3):

$$y_{ij} = a_i + b_j + c_k + e_{ij} \quad (3)$$

where y_{ij} is the determined factor; a_i is the effect of the i -th year-month of calving; b_j is the effect of the j -th bull-sire (father); c_k is the effect of the k -th lactation number; e_{ij} is the residual.

The degree of influence of factors on the studied traits of beef cattle was calculated using formula (4):

$$\eta^2 = (SSA/SSIT) \cdot 100\%, \quad (4)$$

where SSA – sum of squares of deviations caused by the factor; $SSIT$ – total sum of squares of deviations.

Tables 3 and 4 present descriptive statistics of the studied traits.

Table 3. Descriptive statistics of milk productivity and live weight of cows in terms of standard lactations (n = 595)

Trait	Min	Max	M ± m	σ ²	σ	Cv, %
First lactation						
Yield for 305 days of lactation, kg	2,873	11,348	8,538.3 ± 90.83	1,897,643.5	1,377	16
Amount of milk fat, kg	143	409	288.9	2,028.8	45	15.6
Live weight of cows, kg	396	515	508.3 ± 0.64	284.1	16	3.31
Second lactation						
Yield for 305 days of lactation, kg	3,627	12,083	8,531.9	3,265	1,807	2,162
Amount of milk fat, kg	130	436	290.9 ± 4.6	3,585.5	59.9	20.6
Live weight of cows, kg	521	532	528.4 ± 0.57	292.3	17	3.24
Third lactation						
Yield for 305 days of lactation, kg	2,457	1,210	8,721.4	2,748	1,658	19
Amount of milk fat, kg	134	425	298.7	3,300.5	57.4	19.2
Live weight of cows, kg	532	543	537.1 ± 0.52	298.2	17	3.22
Fourth lactation and older						
Yield for 305 days of lactation, kg	3,364	1,266	7,835.0	3,458	1,859	23.7
Amount of milk fat, kg	168	420	269.0 ± 9.2	3,910	62.5	23.2
Live weight of cows, kg	541	650	620.3 ± 0.49	311.6	17	2.84

Source: developed by the authors based on research

Table 4. Descriptive statistics of the studied milk indicators (n = 595)

Feature	Min	Max	M ± m	σ ²	σ	Cv, %
Daily yield, kg	10	56	27.7 ± 0.36	70.2	8.4	30
DNMR, %	3.11	10.6	8.74 ± 0.02	0.34	0.58	6.6
Fat content, %	3.17	5.7	4.39 ± 0.08	0.6	0.82	16.7
Protein content, %	2.4	4	3.40 ± 0.01	0.03	0.17	5
Freezing point, °C	0.4	0.7	0.58 ± 0.01	0.001	0.03	5.2
Lactose content, %	0.5	5.8	4.68 ± 0.01	0.10	0.32	6.8
pH	2.1	7.4	7.09 ± 0.01	0.06	0.24	3.4
Titrateable acidity, Th	1.5	10.5	6.46 ± 0.04	0.75	0.87	13.5
Conductivity	3.3	8.4	3.98 ± 0.02	0.15	0.39	9.8
MUN* (1 st level), 8-11.99 mg/dl	8.7	11	9.90 ± 0.07	1.17	1.0	10.9
MUN* (2 nd level), 12-15.99 mg/dl	12	15	13.89 ± 0.10	1.2	1.1	7.9

Table 4. Continued

Feature	Min	Max	M±m	σ ²	σ	Cv, %
MUN* (3 rd level), 16.0 mg/dl and above	16	32	21.96±0.39	18.5	4.3	19
MUN for the entire sample	2.6	32	12.31±0.24	35.6	5.97	48.5
Live weight of cows, kg	488	650	526.4±0.75	308	17	3
Energy-corrected milk (ECM)	10.3	66	29.13±0.35	70	8.3	28

Note: *MUN (milk urea nitrogen) gradations and number of observations by groups: 1st level – 217 heads; 2nd level – 120 heads; 3rd level – 122 heads

Source: developed by the authors based on research

Based on milk quality indicators, the studied animals were combined into a general sample (Table 4), which made it possible to calculate the influence of such factors as “year-month of calving”, “bull-breeder”, “lactation number” using a “mixed” model. To determine possible changes in milk composition in relation to MUN levels, this indicator was divided into three levels based on a range of values: Level 1: 8-11.99 mg/dl; Level 2: 12-15.99 mg/dl; Level 3: 16.0 mg/dl and above.

According to DSTU 3662:2018 (2019), the following was additionally included in the milk analysis: (1) dry non-fat milk residue (DNMR) – or the dry mass of milk remaining after fat removal, consisting of proteins, lactose and minerals. SDF can range from 8.0 to 9.5% and is often used as an indicator of milk quality and to calculate dry matter content; (2) milk freezing point (°C), the temperature at which it begins to freeze, averages -0.540°C to -0.570°C, and for higher, first and extra grades -0.520°C; (3) lactose content – plays an important role in the production of dairy products, is about 5 g per 100 ml or 4.6-5.2%; (4) milk pH, which is usually in the range of 6.5-6.7, indicating a slightly acidic environment. A decrease in pH below

6.5 may indicate health problems, and an increase in pH may indicate rumen alkalosis, i.e. a digestive disorder characterised by impaired metabolism and dysfunction of the liver and other organs. An alkaline environment forms in the rumen at an ammonia concentration of more than 16.1 mg%, which leads to a decrease in the number of microorganisms and a decrease in their activity. Total protein in the blood increases to 113 g/l, and the reserve alkalinity of the blood and the pH of milk and urine increase; (5) titrated acidity of milk, or Turner degrees (T) – the number of millilitres of 0.1 M alkali solution required to neutralise the acids in 100 ml of milk. The titrated acidity of freshly milked milk is 16-18°T, with an acceptable value of 15.99-20.99°T.

Results and Discussion

A large number of factors affect milk quality, forcing specialists to find ways to understand the mechanisms of such influence and their significance. Table 5 presents the results of a variance analysis of the influence of such seasonal factors as the year and month of calving, the origin of daughters by sire (progenitor), which is a genetic factor, and the number of lactations.

Table 5. Impact of year-month of calving, sire (father of cows) and lactation number on milk production and reproduction indicators (n = 595)

Factor, indicator	Sum of squares of deviations	Number of degrees of freedom	Mean square of deviations	Fisher's F-test	η ² , %
Daily milk yield					
Year-month of calving	15,751	25	630.1	15.424***	80.7
Buhai	2,979	44	67.7	1.657**	15.3

Table 5. Continued

Factor, indicator	Sum of squares of deviations	Number of degrees of freedom	Mean square of deviations	Fisher's F-test	η^2 , %
Lactation number	779	6	129.8	3.177**	4
Balance	19,975	489	40.8		
Milk yield per lactation					
Year-month of calving	378,318,037	22	17,196,274	8.509***	24.5
Buhai	191,039,506	44	4,341,807	2.148***	12.4
Lactation number	8,578,626	6	1,429,771	0.707	0.01
Balance	968,079,307	479	2,021,042		
Fat content in milk during lactation					
Year-month of calving	4.260	22	0.19364	49.53***	66
Buhai	0.189	44	0.00430	1.10	3
Lactation number	0.056	6	0.00938	2.40	0
Balance	1.873	479	0.00391		
Amount of milk fat per lactation					
Year-month of calving	318,450	22	14,475	5.988***	18.5
Buhai	229,563	44	5,217	2.158***	13.4
Lactation number	12,340	6	2,057	0.851	0.7
Balance	1,157,855	479	241		
Protein content in milk during lactation					
Year-month of calving	1.0362	22	0.04710	39.351***	59
Buhai	0.0973	44	0.00221	1.847**	5.6
Lactation number	0.0249	6	0.00415	3.468**	1
Balance	0.5733	479	0.00120		
Amount of milk protein per lactation					
Year-month of calving	350,078	22	15,913	7.426***	22
Buhai	206,319	44	4,689	2.188***	12.9
Lactation number	10,720	6	1,787	0.834	0
Balance	1,026,389	479	214		
Service period					
Year-month of calving	8,520,826	23	370,471	141.145***	86
Buhai	130,619	42	3,110	1.185	1
Lactation number	35,538	5	7,108	2.708	0
Balance	1,215,259	463	262		

Note: * – $P > 0.95$; ** – $P > 0.99$; *** – $P > 0.999$

Source: developed by the authors based on research

A significant impact on productivity indicators of factors such as the year and month of calving has been proven in almost all cases (Table 5). Despite the use of a generally mixed diet, which was standard throughout the calendar year, the season of the year had a significant impact on daily milk yield, lactation yield, fat and protein content. The origin of the cows' sires also had a significant impact, although in most

cases it was significantly smaller than seasonal fluctuations. The influence of the sire (father of the cow) on lactation yield was 12.4%, milk fat content during lactation was 13.4%, and milk protein content during lactation was 12.9%. Seasonal fluctuations (year-month of calving) had a significant and probable effect on milk quality indicators (Table 6), with minimal influence from genetic factors such as paternal origin.

Table 6. Influence of the year and month of calving and the sire (father) on milk quality indicators

Factor	Sum of squares of deviations	Number of degrees of freedom	Mean square of deviations	Fisher's F-test	η^2 , %
Daily milk yield					
Year-month of calving	15,751	25	630.1	15.444***	4
Buhai	2,979	44	67.7	1.659**	7.7
Balance	19,975	489	40.8		
SZMZ					
Year-month of calving	30.33	25	1.2132	3.914***	0
Buhai	7.33	45	0.1630	0.526	0.02
Balance	160.25	517	0.3100		
Fat content					
Year-month of calving	4.260	22	0.19364	49.524***	67
Buhai	0.189	44	0.00430	1.100	3
Balance	1.873	479	0.00391		
Protein content					
Year-month of calving	3.505	2	0.14018	5.488***	19
Buhai	1.032	45	0.02293	0.898	5.7
Balance	13.206	517	0.02554		
Freezing point					
Year-month of calving	0.0631	25	0.0025236	3.578***	13
Buhai	0.0234	45	0.0005196	0.737	5.08
Balance	0.3647	517	0.0007053		
Lactose content					
Year-month of calving	7.09	25	0.28375	2.962***	11
Buhai	3.11	45	0.06910	0.721	5.1
Balance	49.52	517	0.09579		
Conductivity					
Year-month of calving	6.95	25	0.2779	2.113**	7
Buhai	9.33	45	0.2074	1.577	10.6
Balance	68.0	517	0.1315		
pH					
Year-month of calving	14.569	25	0.5827	16.345***	42
Buhai	1.111	45	0.0247	0.693	3.2
Balance	18.432	517	0.0357		
Titrated acidity					
Year-month of calving	29	25	1.1638	1.588	6
Buhai	35.1	45	0.7793	1.063	7
Balance	379	517	0.7331		
MUN					
Year-month of calving	1,982	25	79.28	2.386***	9
Buhai	1,601	45	35.57	1.070	7
Balance	17,179	517	33.2		

Note: * – $P > 0.95$; ** – $P > 0.99$; *** – $P > 0.999$

Source: developed by the authors based on research

It can be stated that there is a significant influence of such organised factors as minor changes in feeding in different seasons and

months of the year and even changes in temperature conditions on the farm during different periods of the year. The influence of

non-genetic factors was quite high in terms of daily milk yield, fat, protein and lactose content, as well as MUN. To assess the genetic component of these indicators, the authors believe it is necessary to use not the absolute values of these indicators, but the nature of their change over a certain period of time in terms of genetic groups, linking such changes to the norm of the “genotype-environment” reaction.

The MUN control system was developed in the United States by the Dairy Herd Improvement

Association DHI (Dairy Herd Improvement), which provides dairy farmers with information for managing and improving their herds based on the analysis of “input data” that records the characteristics of animal feeding and milk quality indicators (Fig. 1). In addition, DHI includes the collection and analysis of data on milk production and quality, cow health and breeding factors. DHI programmes are often managed by DHIA (Dairy Herd Improvement Associations).

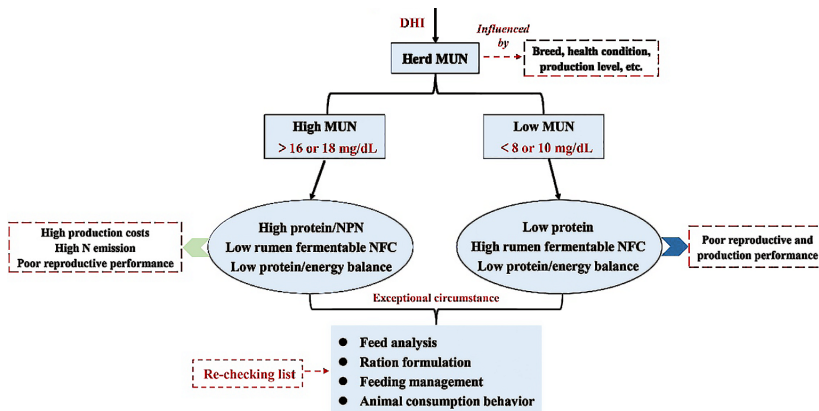


Figure 1. Process for identifying the causes of high or low MUN concentrations, as applied by the consulting company DHI (Dairy Herd Improvement), USA

Note: MUN – milk urea nitrogen; NPN – non-protein nitrogen; NFC – non-fibre carbohydrates

Source: X. Zhao et al. (2024)

According to experimental data by V. Ishler (2023), the possible ranges for MUN can complicate their interpretation, as some researchers recommend a MUN range of 10 to 14 milligrams per decilitre (mg/dl), while others recommend a range of 8 to 12 mg/dl. The latter range reflects diets that are formulated according to the protein requirements of cows and have an excellent balance of protein (16%), protein fractions and carbohydrates to capture excess ammonia in the rumen. A study by C. Müller et al. (2021) showed that a one percent increase in crude protein in the diet resulted in an increase in MUN concentration of 1.04 and 1.24 mg/dl at milk yields of 40 and 30 kg/day, respectively. One strategy for meaningful

interpretation of MUN on a specific dairy farm is to evaluate the current diet and MUN across the entire herd from the milk storage tank. It is useful to have several MUN values to compare with a specific diet as a baseline. Two possible problem areas are high (>12-14 mg/dl) and highly unstable MUN values. Low MUNs (<8-10 mg/dl) indicate a possible protein deficiency in the diet, which can occur when rumen bacteria activity decreases, limiting milk production and milk protein synthesis. High MUN levels (>12-14 mg/dl) may be associated with excess protein in the diet or an imbalance of protein in the rumen, protein fractions and energy (non-structural carbohydrates). These factors may also be associated with reduced milk yield, true protein content

and feeding efficiency. High MUN values indicate a loss of feed protein and cows using more energy to excrete this excess protein through milk and excreta, which means excess nitrogen is released into the environment.

A key factor is ensuring sufficient amounts of available carbohydrates in the rumen to provide energy to the rumen microbiota for converting ammonia into microbial protein. According to X. Zhao *et al.* (2024), MUN control serves as a reliable indicator of the nutritional characteristics of dairy herds due to its impact on reproductive function, health and nitrogen utilisation efficiency, and nitrogen utilisation efficiency itself is associated in ruminants with methane (CH₄), carbon dioxide (CO₂), nitrogen

(N₂), and ammonia (NH₄). According to A. Plomaritou *et al.* (2025), dairy cows typically sort TMR, selecting smaller particles over longer ones, resulting in higher consumption of highly fermentable carbohydrates and lower consumption of effective fibre than expected, which affects rumen pH and changes in milk composition. The ECM is a comprehensive indicator for determining the commercial attractiveness of milk, as it generally determines the price range for products according to the following formula: the higher the ECM, the higher the price per unit of product. The data in Table 7 reveal the relationship between ECM and the main components of milk, including changes in MUN levels across the three control groups.

Table 7. Correlation coefficients between ECM and other studied characteristics (n = 595)

Daily milk yield	Milk fat content	Milk protein content	Lactose content in milk	Live weight of cows	Urea nitrogen content in milk (MUN)
Across the entire sample (n = 595)					
0.9077 ± 0.0177***	0.1127 ± 0.0418**	-0.2180 ± 0.0411***	-0.2172 ± 0.0411***	-0.0511 ± 0.0432	-0.0005 ± 0.0421
With urea nitrogen content in milk of 8-11.99 mg/dl, (n = 207)					
0.8926 ± 0.0315***	0.1412 ± 0.0691*	-0.3054 ± 0.0665***	-0.3155 ± 0.0663***	-0.0461 ± 0.0423	+0.0134 ± 0.0698
With urea nitrogen content in milk of 12-15.99 mg/dl, (n = 112)					
0.9253 ± 0.0362***	0.0351 ± 0.0953	-0.2290 ± 0.0928*	-0.2395 ± 0.0926**	-0.0502 ± 0.0436	+0.1069 ± 0.0948
with urea nitrogen content in milk of 16 mg/dl and above (n = 248)					
0.9371 ± 0.0333***	-0.0034 ± 0.0953	-0.1129 ± 0.0947	-0.1191 ± 0.0946	-0.0451 ± 0.0431	-0.1344 ± 0.0945

Note: * – P > 0.95; ** – P > 0.99; *** – P > 0.999

Source: developed by the authors based on research

There is a logical correlation between milk yield and the main components of milk with virtually no correlation with MUN (data for the entire sample). However, in the variants with an increase in MUN threshold values from 8 to 16 mg/dl and above, there is a tendency towards a negative value of this relationship between MUN and ECM, which was -0.1344 ± 0.0945 (Table 7). Obviously, high MUN values (16 mg/dl and above) are a potential problem area, as they are associated with a decrease in the levels of important milk components such as fat, protein and lactose.

Conclusions

Milk components such as fat, protein, lactose, and milk urea nitrogen (MUN) have a wide range of phenotypic expression, which characterises the complex biochemical processes in the body of ruminants with significant factors influencing such environmental fluctuations. Within the confidence intervals of the analysed sample, the fluctuations (min-max) in the main characteristics, together with their mean values and errors, were as follows: daily milk yield 10.0-56.0 kg (27.7 ± 0.36); fat content

3.17-5.73% (4.39 ± 0.08); protein content 2.4-4.0% (3.40 ± 0.01); lactose content 0.5-5.8% (4.68 ± 0.01); pH 2.1-7.4 units (7.09 ± 0.01); MUN 2.6-32.9 mg/dl (12.31 ± 0.24); live weight of cows 488.0-650.0 kg (526.4 ± 0.75); energy-corrected milk yield (ECM) 10.3-66.6 kg, (29.13 ± 0.35). Within the specified ranges of the experimental sample, no significant correlation was found between the energy value of milk (ECM) and the urea nitrogen content in milk (-0.0005 ± 0.0421).

When selecting cows from the general sample within the MUN values of 8-11.99 mg/dl, (first group – 207 heads) and 12-15.99 mg/dl (second group – 112 heads), the correlation coefficient with ECM indicators was $+0.0134 \pm 0.0698$ and $+0.1069 \pm 0.0948$, respectively (the estimate is unreliable). There was a tendency for high MUN values (>16 mg/dl) to reduce the absolute level of such important milk components as fat, protein and lactose content, which reduces the energy value of milk (ECM). No significant influence of the genetic component (paternal origin) on MUN values was found. The very principle of searching for genetic influence on such fluctuations should be based on the analysis of the dynamics of MUN estimates over time in

the context of such genetic groups. In further studies, it is advisable to conduct long-term monitoring of changes in the level of milk urea nitrogen in the daughters of different sires to identify the genetic component of the influence on the efficiency of feed nitrogen utilisation, as well as to create predictive models that combine the genotypic characteristics of cows (by origin), seasonal factors and MUN indicators to optimise breeding programmes, which will make it possible to expand the set of analytical data and, in combination with optimisation and modelling methods, provide specific recommendations for the use of such comprehensive assessments.

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Conflict of Interest

The authors declare no conflict of interest.

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Мінливість ознак азоту сечовини молока та можливості їх використання в молочному скотарстві

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Анотація. Азот сечовини молока (MUN) – важливий біомаркер, який відображає ефективність білкового обміну корів, рівень споживання та якість «вхідного» протеїну, баланс енергії в раціоні. Коливання MUN тісно пов'язані з можливими розбіжностями в загально змішаному раціоні TMR (total mixed ration), фізіологічними та генетичними факторами. Мета роботи полягала у визначенні впливу генетичних (походження корів за батьком) та паратипових (рік-місяць отелення) факторів на молочну продуктивність, якісні та біохімічні показники молока, зокрема концентрацію азоту сечовини, у корів голштинської породи. Матеріалом для досліджень слугували дані 595 корів, що утримувались в умовах ТОВ «Агрофірма «Колос» Київської області (Україна). Дослід проведено у стандартних умовах при годівлі корів «без обмежень» з аналізом продуктивних показників та біохімічних показників якості молока. Встановлено, що найбільший вплив на продуктивні показники та параметри якості молока має фактор «рік-місяць отелення», що зумовлює сезонні коливання, пов'язані з незначними змінами годівлі та мікроклімату. Відзначено вплив плідника (батька корови) на надій за лактацію – 12,4 %, кількість молочного жиру за лактацію – 13,4 %, кількість молочного білка за лактацію – 12,9 %. Вплив

не генетичних факторів був доволі високим за добовим надоєм, вмістом жиру, білка та лактози, а також MUN. Значення MUN навіть при тотальному використанні стандартного TMR варіювали у корів у широких межах від min 2,6 мг/дл до max 32,9 мг/дл, при середніх значеннях $12,31 \pm 0,24$ мг/дл, і залежали від можливостей сепарування раціону коровами, незначними змінами раціону, рівнем протеїну та неструктурних вуглеводів. Відзначена тенденція, коли при високих значеннях MUN (16 мг/дл, та >) знижується абсолютний рівень таких важливих компонентів молока, як вміст жиру, білка та лактози, що знижує енергетичну цінність молока – ECM (energy-corrected milk). Отримані результати свідчать про необхідність включення загальних середніх проб MUN по всьому стаду для оптимізації програм годівлі та управління добробутом тварин

Ключові слова: білковий обмін корів; енергетична цінність молока; голштинська порода; вплив факторів