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ASSESSMENT OF THE EFFICIENCY OF FEED PROTEIN USE IN DAIRY CATTLE BASED ON THE INDICATORS OF FAT, PROTEIN, LACTOSE AND UREA NITROGEN IN MILK

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The efficiency of protein metabolism in cows, the level of consumption and the quality of 'input' protein in the diet is reflected in an indicator such as milk urea nitrogen (MUN), which is an important biomarker of these processes. MUN variability is closely related to the quality and structure of the total mixed ration (TMR), physiological and genetic factors.

The study evaluated the variability and relationship between milk yield and the main components of milk (fat, protein, lactose, MUN content), as well as the level of MNE (nitrogen efficiency).

It was found that seasonal fluctuations (year - month of calving) had the greatest impact on MNE indicators, accounting for 9.3% (P>0.999). No significant influence of genetic factors (bull influence) on this indicator was found.

The values of phenotypic correlation coefficients between daily milk yield and the main components of milk (fat, protein, lactose content), as well as MUN and MNE levels for milk production, made it possible to identify reliable dependencies. Thus, the value of MNE for milk production negatively correlates with the fat content in milk (P>0,999), protein in milk (P>0,999), lactose in milk (P>0,999), and urea nitrogen content in milk (P>0,999).

A positive correlation (P>0,999) was also found between milk yield and MNE for milk production, and a negative highly significant correlation between MNE and MUN content (P>0,999). A reliable directly proportional regression dependence of changes in daily milk yield on MNE indicators for milk production was calculated.

Analysis of the absolute values of fat, protein and lactose content proves the existence of a negative regression dependence with MNE on milk production. The results obtained indicate the need to include MUN values to optimize feeding programs and animal welfare management, and knowledge of the relationship between milk components and MNE for milk production indicates the need to model possible changes in each of these components.

Keywords: fat, protein, lactose, correlation, regression dependence, milk urea nitrogen, nitrogen use efficiency for milk production.

ОЦІНКА ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ КОРМОВОГО БІЛКА В МОЛОЧНОМУ СКОТАРСТВІ ЗА ПОКАЗНИКАМИ ЖИРУ, БІЛКА, ЛАКТОЗИ ТА АЗОТУ СЕЧОВИНИ МОЛОКА

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Ефективність білкового обміну корів, рівень споживання та якість «вхідного» протеїну в раціоні відображає такий показник як азот сечовини молока (MUN), являючись при цьому важливим біомаркером цих процесів. Мінливість MUN тісно пов'язана з якістю та структурою загально змішаного раціону TMR (Total mix ration), фізіологічними та генетичними факторами.

У роботі оцінювали мінливість та зв'язок між показниками надою та основними компонентами молока (вміст жиру, білка, лактози, MUN), рівнем MNE - ефективності використання азоту.

Встановлено, що найбільший вплив на показники MNE був з боку сезонних коливань (рік - місяць отелення), які склали 9,3% (P>0,999). Не виявлено вірогідного впливу на цей показник генетичних факторів (вплив бугая).

Значення фенотипічних коефіцієнтів кореляції між добовим надоєм та основними компонентами молока (вміст жиру, білка, лактози), а також рівнем MUN та MNE для виробництва молока, дали змогу виявити вірогідні залежності. Так значення MNE для виробництва молока від'ємно корелює з вмістом жиру в молоці (P>0,999), білка в молоці (P>0,999), лактози в молоці (P>0,999), вмістом азоту сечовини в молоці (P>0,999).

Виявлено також позитивний кореляційний зв'язок (P>0,999) між надоєм та MNE для виробництва молока, та від'ємний високо вірогідний кореляційний зв'язок між MNE та вмістом MUN (P>0,999). Розрахована вірогідна прямо пропорційна регресійна залежність змін добового надою з показниками MNE на виробництво молока.

Аналіз абсолютних значень вмісту жиру, білка та лактози доводить наявність від'ємної регресійної залежності з MNE на виробництво молока. Отримані результати свідчать про необхідність включення значень MUN для оптимізації програм годівлі та управління добробутом тварин, а знання зв'язку між компонентами молока та MNE для виробництва молока – про необхідність при моделюванні можливих змін кожної з цих компонент.

Ключові слова: жир, білок, лактоза, кореляційний зв'язок, регресійна залежність, азот сечовини молока, ефективність використання азоту для виробництва молока.

Introduction. Feed efficiency is assessed as the ratio of the amount of product obtained per unit of feed consumed. Recently, more resources, including energy resources, have been spent on feed production, and their prices are constantly rising (Kondratiuk et al, 2024). The ratio of prices for milk of a certain composition and feed affects the profitability of a farm. If purchase prices for milk fall and feed costs rise, farm profits decline sharply. Large farms in Ukraine with a daily production of 25-50 tonnes usually enter into long-term contracts with stable prices for milk and certain types of purchased feed, influencing production efficiency through a stable pricing policy (Ruban et al., 2021) , with feed costs ranging from 50 to 60 per cent of total milk production costs. In most countries around the world, feed remains the main item of expenditure in animal husbandry, and its conversion rates into products are becoming a constant focus of genetic improvement in virtually all types of farm animals (Van Raden et al., 2021; Rauw et al., 2025). In addition, improving feed efficiency reduces the impact of livestock farming on the environment by reducing greenhouse gas emissions (Borshch, 2023; Ruban et al., 2021). The nutritional value of feed depends on the complete composition of carbohydrates, lipids and proteins, and their use includes maintenance metabolism, growth and development, reproduction, movement and other functions (Ruban et al., 2025). Thus, feed efficiency depends on processes that are not always directly related to economically important phenotypes (Rauw et al., 2025).

The key indicator in dairy farming remains IOFC (Income over feed cost), which reflects the difference between the income received from the sale of milk and the cost of feed for lactating cows. For decades, commercially attractive milk production has traditionally been based on the use of high-yielding cows, which, according to existing standards, need to consume more protein (Ruban et al., 2021). In turn, protein feeds with an optimal amino acid profile are more expensive, and overfeeding such feed can be wasteful and costly, while underfeeding limits productivity.

According to V. Souza et al. (2021), up to 28% of the nitrogen consumed by dairy cows in their feed is converted into milk, with 5% excreted as non-protein nitrogen and the rest as true protein. The balance of amino acids in the rumen affects microbial protein synthesis, and nitrogen (N) levels remain an important factor in the digestion of feed and its utilisation by cows. According to A. Badhan et al. (2025), most of the energy and protein supplied to ruminants is the result of fermentation by the rumen microbiome, which plays a key role in determining feed efficiency and methane (CH_4)emissions. Complex biochemical methods are used to assess the level of N in the rumen, including measurements of ammonia concentration, microbial protein synthesis and rumen nitrogen balance. V. Souza et al. (2021) demonstrated that digestibility decreases with an increase in daily dry matter intake (DMI). In experiments by S. Ruban et al. (2025), a significant influence of breed was demonstrated on the following biochemical blood parameters: total bilirubin 24.7%, urea 33.2%, creatinine 49.8%, alanine aminotransferase 10.4%, aspartate aminotransferase 46.3%, albumin 35.1% and total protein 13.2%. The study was conducted under identical conditions of housing and feeding, but on breeds that were sufficiently "contrasting" with each other, such as Ukrainian Red-and-White Dairy, Simmental, and Ukrainian Black-and-White Dairy .

The MUN level depends on the concentration and consumption of crude protein in the diet. For this purpose, a mathematical algorithm was proposed, where the MNE index of lactating cows was determined as a biomarker of N utilisation efficiency for milk production. According to V. Souza et al. (2021), MUN and blood urea nitrogen (BUN) correlate with nitrogen balance and excretion; however, there is also a genetic component to MUN concentrations that may be related to differences in urea transport. It has been hypothesised that part of the variation in MUN concentrations among cows is caused by differences in gastrointestinal and renal urea clearance. According to Xiaowei Zhao et al. (2025), MUN levels were found to have a weak positive correlation with milk yield, milk protein percentage and milk protein yield, a strong positive correlation with urinary nitrogen excretion, and a negative correlation with the milk nitrogen to nitrogen intake ratio. Based on this, the authors conclude that the NFC/CP ratio in the diet significantly affects MUN concentration, and that controlling it in conjunction with non-fibre carbohydrates (NFC) and crude protein (CP) can achieve a better balance in diets, which will optimise feed formulation and improve dairy cow management.

Previous analytical reports by Xiaowei Zhao et al. (2024) show that CP concentration in the diet is not the only nutritional factor that affects MUN concentration. The level of NFC in the diet, which includes sugar, starch and pectin, also plays an important role. The authors presented a linear regression analysis (R) for 91 sets of experimental data on the ratio of NFC/CP in the "input" diet to MUN concentration mg/dL, which was R=0.681. It is noted that when the MUN level exceeds 14 or 16 mg/dl, the corresponding CP content in the diet usually exceeds 17%, which often leads to increased N excretion in urine.

Thus, MUN monitoring allows: 1) to predict possible metabolic problems and adjust the diet to improve the health of the herd; 2) to reduce the impact of nitrogen on the environment by minimising nitrogen excretion and ammonia emissions; 3) optimise feeding strategies and improve herd health.

The aim of the research was to determine the level of variability and the relationship between the main components of milk (fat, protein and lactose content), milk yield, live weight of cows, and MUN and MNE levels in milk.

Materials and methods. The material for the research was data from an experiment conducted on 595 Holstein cows at the limited liability company "Agrofirma "Kolos" in the Kyiv region. When conducting the experimental studies described 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 Article 26 of the Law of Ukraine No. 3447 "On the Protection of Animals from Cruel Treatment" (2006), the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (1986) and the Procedure for conducting research and experiments on animals by scientific institutions (2012). The farm uses a tethered milking system with milk pipeline. Milking is carried out three times a day by one machine milking operator for up to 50 cows. Feeding is carried out using 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
Brewer's grains (moist)	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
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

Notes. calculated for cows weighing 550-650 kg, milk yield 28-30 kg, fat content 4.00%, protein content 3.40%, lactose level 4.68%

Source: *based on the results of chemical analysis by abm on 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
NFC/CP	2	-

Notes. CP - crude protein; NDF - neutral detergent fibre; ADF - acid detergent fibre
Source: *based on the results of chemical analysis by abm on 25 April 2025*

The NFC/CP ratio is important because it affects milk production, especially milk protein, and can pose risks to the health and reproduction of cows. A balanced NFC/CP ratio ranges from 2.15 to 3.60, which is usually desirable for maintaining optimal MUN levels. According to generally accepted standards, the level of NFC in TMR was determined by subtracting the level of these components as a percentage of dry matter in TMR from 100%. NFC includes starch, sugar and pectin, and their determination was based on the calculation of the remaining percentage after taking into account the level of fibre, protein, fat and ash.

To assess the efficiency of nitrogen use in milk production, model (1) was used for forecasting according to P. Huhtanen et al. (2015), which was developed on the basis of residual dispersion to forecast the multifactorial instability of MNE production data and most logically describes this process:

$$MNE\ (g/kg) = 238 + 7{,}0 \times (MY\ kg/day) - 0{,}064 \times (MY2) - 2{,}7 \times (MUN\ \mathrm{mg/dl}) - 0{,}10 \times (W) \quad (1)$$

where MY is milk productivity, kg; MUN is milk urea nitrogen level, mg/dl; W is cow weight, kg.

In this case, MNE is considered as an indicator of the efficiency of nitrogen use, which comes from feed for milk production.

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. (2021). 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):

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

Dispersion analysis of the effect of year-month of calving, bull-sire (father) and lactation number on the MNE of the diet for milk production was performed using a linear model (3):

$$yij = ai + bj + ck + eij \quad (3)$$

where y_{ij} – MNE of the diet for milk production; $a_{(i)}$ - effect of the i-th year-month of calving, which reflects the influence of the level of feeding and management in the herd, $b_{(j)}$ - effect of the j-th bull-sire (father), $c_{(k)}$ – effect of the k-th lactation number, $e_{(ij)}$ - residual.

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

$$\eta 2 = (SSA/SS\Pi) \cdot 100\% \quad (4)$$

where SSA is the sum of squares of deviations caused by the influence of the factor;

SSP - total sum of squares of deviations.

Statistical analysis (descriptive statistics, analysis of variance, correlation and regression analysis) was performed using the RStudio-2023.03.0-386 programme.

To study the relationship between the dependent variable (result) and one or more independent variables (factors), the classical regression equation (5) was used:

$$y = a + bx + e \quad (5)$$

where a is the free term of the model; b is the regression coefficient; x is the variable; e is the error.

Based on the regression equation, the coefficient of determination (r^2) was calculated, which is equal to the square of the correlation coefficient between the actual and predicted values of the resulting feature (in our case, MNE), under the influence of such predictor features as: daily milk yield; fat content in milk; protein content in milk; lactose content in milk; MUN; live weight of the cow; milk yield adjusted for energy content.

Based on the quality indicators of milk, the studied animals were combined into a general sample, which made it possible to calculate the influence of such factors as "Year-month of calving", "Bull-breeder" and "Lactation number" using a "mixed model" (Table 3).

Table 3

Descriptive statistics of the studied traits, n=595

Trait	Min	Max	M±m	σ^2	σ	Cv, %
Daily yield, kg	10	56	27.7 ± 0.36	70.2	8.4	30.3
Fat content, %	3.17	5.7	4.39±0.08	0.68	0.82	16.7
Protein content, %	2.4	4	3.40±0.01	0.03	0.17	5
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
MUN mg/dl	2.6	32.9	12.31±0.24	35.60	5.97	48.5
Live weight of cows, kg	488	650	526.4±0.75	308	17	3
MNE*ration for milk production	116.6	365.5	287.6±1.65	1622.6	40	14

Notes: ** MNE - nitrogen efficiency for milk production is defined as the ratio of nitrogen consumption to nitrogen in milk*

Source: developed by the authors based on research

The analysis of the qualitative and biochemical indicators of milk was determined using the EKOMILK Bond ultrasonic analyser.

Research results. Table 4 presents the results of a variance analysis of the effect of the year and month of calving, paternal origin, and lactation number on the MNE of the diet for milk production.

Table 4

The effect of the year and month of calving, sire (father) and lactation number on the MNE of the diet for milk production, n = 595

Factor, indicator	Sum of squares of deviations	Number of degrees of freedom	Mean square of deviations	Fisher's F-test	η^2 , %
Year-month of calving	220.2	25	8.81	2.375 ***	9
Bull (father of the cow)	177.9	45	3.95	1.060	7.5
Lactation number	42.9	7	6.13	1.652	1.7
Balance	1908.8	515	3.7		

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

Source: developed by the authors based on research

Of the factors studied, only the year and month of calving had a significant effect on the MNE of the diet for milk production. 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 the temperature regime on the farm during different periods of the year. To assess the genetic component of the impact on 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 values of phenotypic correlation coefficients between daily milk yield and the main components of milk (fat, protein, lactose content), MUN and MNE levels for milk production (Table 5) made it possible to identify reliable dependencies.

Thus, the MNE value for milk production negatively correlates with the fat content in milk, protein in milk, lactose in milk, and MUN content. A positive correlation was also found between milk yield and MNE for milk production, and a negative highly probable correlation between MNE and MUN content.

For more practical application of the results presented in Table 5, we calculated the regression dependence (b) of the main components of milk (x) on MNE, which are presented in Table 6.

The coefficient of determination (r^2) is considered as the proportion of MNE variance that is explained by the influencing traits (daily milk yield, milk fat content, milk protein content, milk lactose content, MUN, live weight of the cow). According to Table 6, significant changes in MNE depended on the daily milk yield and the level of milk urea nitrogen (MUN).

Based on the regression equations, the following reliable dependencies were obtained: MNE = 201.82 + 3.29*(daily milk yield) + e; MNE = 319.80 - 5.93*(milk fat content) + e; MNE = 437.16 - 42.32*(milk protein content) + e; MNE = 374.90 - 17.45*(milk lactose content) + e; MNE = 323.49 - 2.49*MUN + e; MNE = 330.05 - 0.07*(live weight of cow) + e, where e is the error.

Table 5

Phenotypic correlation coefficients between the studied traits, n = 595

Traits	Daily milk yield	Milk fat content	Milk protein content	Lactose content in milk	Live weight of cows	MUN content	MNE for milk produc-tion
Daily milk yield	1						
Fat content in milk	-0.2829± 0.0404 ***	1					
protein content in milk	-0.3167± 0.0399 ***	0.0540± 0.0420	1				
Lactose content in milk	-0.2653± 0.0406 ***	-0.1167± 0.0418 **	0.8105± 0.0246 ***	1			
Live weight of cows	-0.0400± 0.0421	-0.0648± 0.0421	0.0556± 0.0421	0.0900± 0.0420*	1		
MUN content	0.0502± 0.0420	-0.0985 0.0419	-0.0711± 0.0420	-0.0693± 0.0420	-0.0696± 0.0420	1	
MNE for milk production	0.8449± 0.0225 ***	-0.1980± 0.0412 ***	-0.2234± 0.0410 ***	-0.1719± 0.0414 ***	-0.0511± 0.0421	-0.4489± 0.0376 ***	1

*Note. * - P>0.95; ** - P>0.99; *** - P>0.999*
Source: *developed by the authors based on research*

Table 6

Regression dependence (b) of the main components of milk (x) and live weight of cows on MNE for milk production

Influencing feature (x)	Regression equation where:		t	Coefficient of determination, r^2
	free term (a)	regression coefficient (b)		
Daily yield	201.82256 ± 2.54039	3.29221 ± 0.08769	37.55 ***	0.7139
Fat content in milk	319.798 ± 5.714	-5.928 ± 1.235	2.02	0.0392
Protein content in milk	437.157 ± 26.472	-42.322 ± 7.769	7.63	0.0499
Lactose content in milk	374.904 ± 19.764	-17.454 ± 4.209	3.88	0.02954
MUN	323.490 ± 2.822	-2.495 ± 0.209	11.94 ***	0.2016
Live weight of cow	330.04894 ± 20.10700	-0.07038 ± 0.03825	1.84	0.006

*Note. *** - P>0.999*
Source: *developed by the authors based on research*

A probable directly proportional regression dependence of changes in daily milk yield on MNE indicators for milk production has been identified. This dependence does not fully reflect the peculiarities of feed nitrogen utilisation. According to A. Bougouin et al. (2022), models based on DMI consumption or nitrogen consumption can accurately predict nitrogen excretion in faeces and urine. However, the accuracy of the prediction can be slightly improved by adding diet or milk composition parameters to the consumption parameters in complex models. Based on analytical and experimental data from Peter J. Van Soest (1994); P. Huhtanen et al. (2015); Xiaowei Zhao et al. (2025), we propose a scheme for analysing studies evaluating the impact of key feed factors on the rate of TMR digestion in ruminants and changes in the main components of milk (Fig. 1).

<table>
<tr><td colspan="2">Chemical components</td><td colspan="3">Individual components or groups of components</td><td>Effect of component groups on digestion rate</td></tr>
<tr><td colspan="2">Inorganic substances (minerals)</td><td colspan="3"></td><td>Contribute</td></tr>
<tr><td rowspan="5">Organic substances Cell cytoplasm and its organelles</td><td>Crude protein</td><td>CP</td><td rowspan="5" colspan="2"></td><td rowspan="5">Increase the rate in certain ratios</td></tr>
<tr><td>Crude fat</td><td></td></tr>
<tr><td>Sugar</td><td rowspan="3">NFC</td></tr>
<tr><td>Starch</td></tr>
<tr><td>Pectins</td></tr>
<tr><td rowspan="4">Organic substances Plant cell walls</td><td>Organic residue</td><td colspan="3"></td><td rowspan="4">Reduce the rate in certain ratios</td></tr>
<tr><td>Hemicellulose</td><td rowspan="3">NDF</td><td colspan="2"></td></tr>
<tr><td>Cellulose</td><td rowspan="2">ADF</td><td></td></tr>
<tr><td>Lignin</td><td>ADL</td></tr>
</table>

Figure 1. **Schematic diagram of the distribution of plant-based feed into basic chemical components and their possible effect on the rate of digestion in ruminants and the level of basic milk components.**

Note: *CP- crude protein; NFC -non-fibre carbohydrate; NDF- neutral detergent fibre; ADF- acid detergent fibre; ADL- acid detergent lignum*

Source: *summarised and developed by the authors based on research*

Fig. 2 shows the regression dependence of the main indicator MUN on MNE in milk production.

According to our data, there is a clear regression dependence (trend) between high MNE levels (300-340 g/kg) and optimal MUN values, which should be at the level of 8-12 mg/dl (Fig. 2).

This relationship is quite logical, describing the manifestation of optimal MUN values at 8-12 mg/dl and high MNE values for milk production.

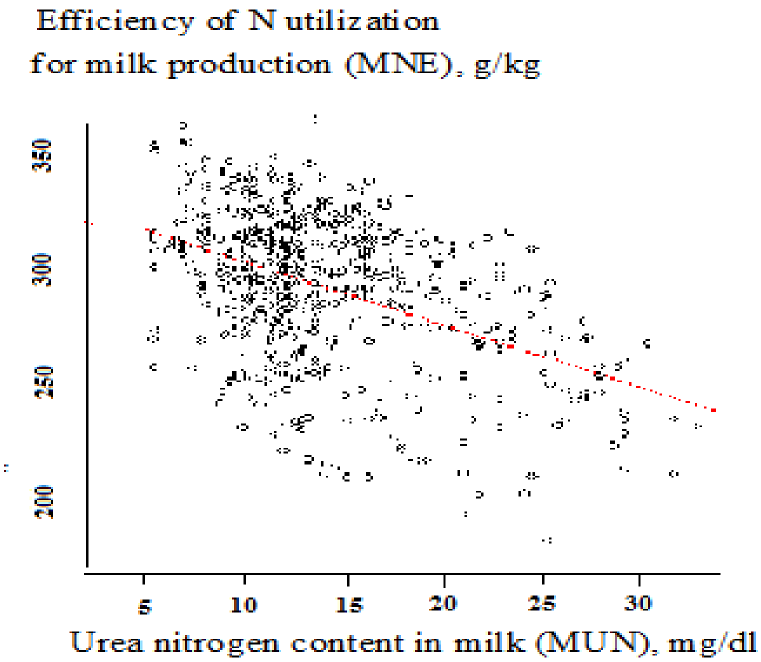

Figure 2. **Regression dependence (b = - 2.495 ± 0.209) of the effect of MUN on MNE on milk production**
Source: *developed by the authors based on research*

Discussion. The speed of digestion in cows is influenced by factors mainly related to diet and the physiological condition of the cow (Huhtanen et al., 2009, Souza et al., 2018). Thus, the main influencing factors of feed include: 1) the vegetation phase during hay or haylage harvesting; 2) the content (concentration) of various feeds and the ratio of NDF, ADF, ADL in them; 3) the content and ratio of CP, NFC; 4) the type and quality of feed. It is clear that in most cases, the rate of digestion depends on the efficiency of the cow's rumen microbiota. According to the results of experiments by P Huhtanen *et al. (*2015), in which RAN (rumen ammonia N concentration) and MUN were analysed, it was shown that RAN concentration led to a slightly better prediction of MNE compared to MUN concentration, and the MNE prediction improved when both MUN and RAN concentrations were included in the model as independent variables, especially when milk yield was also included in the model. L. Musembei et al. (2023) cite a correlation that illustrates the relationship between milk composition parameters and rumen bacterial taxa with a positive correlation of such an effect. The study also revealed different responses of rumen bacteria to an increase in the proportion of concentrates in the diet, further illustrating the potential link between the rumen microbiome, dietary nutrients and milk production.

According to analytical data from Xiaowei Zhao et al. (2024) and J. Spek et al. (2013), it can be concluded that: 1) any factors that cause changes in MUN may affect milk components; 2) an increase in CP consumption, accompanied by an increase in MUN concentration, does not affect milk protein yield, while low CP content can reduce urea excretion at the phenotypic level without negatively affecting milk protein content; 3) at the beginning of lactation, dairy cows experience a period of negative energy balance, which leads to an increase in the percentage of milk fat due to the mobilisation of adipose tissue; during this period, MUN usually shows relatively low values due to insufficient feed intake compared to other periods of lactation; 4) There may be a strong positive genetic correlation (+0.85) between MUN and somatic cell count, as the occurrence of mastitis can affect the concentration of MUN in milk, and the average genetic correlation between MUN and lactose depends on this. 5) The correlation between MUN and milk composition is influenced by the stage of lactation and health status, making the relationship between MUN and milk component traits weak or even insignificant. According to Xiaowei Zhao et al. (2024), the potential for selecting cows with a low MUN phenotype to reduce nitrogen excretion does not adversely affect milk production and quality. When reducing MUN traits through selective breeding, it is necessary to evaluate their correlation with other traits.

According to P. Huhtanen et al. (2015), MUN concentration is not a useful phenotyping tool for improving MNE, but measuring MUN concentration at the herd level allows for fine-tuning the diet to improve digestibility or MNE . Sharing the author's opinion that it is difficult to judge whether MUN concentrations can be measured for individual cows and used for reliable ranking based on nitrogen efficiency, we consider it appropriate to use these values in evaluation and selection programmes for reliable prediction of the effect on milk yield, milk composition and nitrogen efficiency. According to a meta-analysis by Xiaowei Zhao et al. (2025), elevated MUN values may indicate excessive CP in the diet or insufficient NFC, while low MUN values indicate the need to evaluate CP and carbohydrate sources in the diet (Fig. 3).

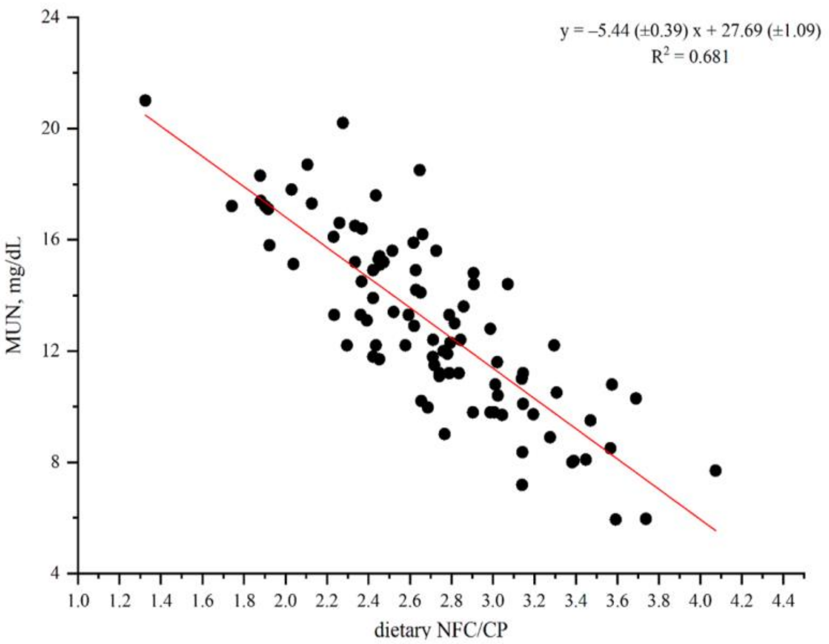

Figure 3. **Linear regression analysis of the NFC/CP ratio in the diet and MUN content for the data set, n = 91**

Note. Each dot represents a separate observation included in the meta-analysis.
Source: Xiaowei Zhao et al. (2025)

These results indicate that the NFC/CP ratio in the diet has a significant effect on MUN concentration. Furthermore, it seems likely that by jointly monitoring MUN, NFC and CP levels, dairy producers can achieve a better balance of NFC and CP in diets, thereby optimising feed formulation and improving dairy cow management.

In cases where MUN exceeds 16 mg/dL or falls below 8 mg/dL, this indicates an NFC/CP ratio in the diet of less than 2.15 or greater than 3.60. By monitoring MUN concentrations, farmers can more effectively manage their feeding programmes, control production costs and reduce N emissions into the environment.

Conclusions. Analysis of milk components (fat, protein, lactose) and MUN and MNE indicators confirmed the presence of significant fluctuations, which are primarily due to physiological and seasonal factors rather than genetic variability by origin. Seasonal fluctuations had the greatest impact on nitrogen utilisation efficiency (MNE), indicating the need to adapt feeding rations depending on the lactation period and housing conditions. The established correlations prove that an increase in protein metabolism efficiency (MNE) is accompanied by an increase in daily milk yield, but is associated with a decrease in the absolute values of MUN and the fat, protei n and lactose content in milk. The negative correlation between MNE and MUN indicates the possibility of using MUN as a marker for operational control of protein nutrition and assessment of diet balance.

The results obtained provide grounds for recommending the inclusion of MUN and MNE indicators in the system for monitoring the productivity and welfare of cows, which will optimise protein nutrition and predict the qualitative and quantitative characteristics of milk.

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