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USING MILK UREA TO EVALUATE PRODUCTION, EFFICIENCY OF NITROGEN UTILIZATION AND URINARY NITROGEN EXCRETION DURING THE LACTATION IN DAIRY COWS

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ABSTRACT

The aim of this study was to use milk urea to evaluate production parameters, efficiency of nitrogen utilization, and urinary nitrogen excretion during lactation in Holstein dairy cows. Cows in the 1st lactation phase compared to the 2nd and 3rd lactation phases showed: increase ($P < 0.05$) in daily milk yield; decrease ($P < 0.05$) in fat and protein content in milk; decrease in milk urea content ($P < 0.05$); with a lower individual number of animals (31% of dairy cows in the 1st stage of lactation, 39 % of dairy cows in the 2nd stage of lactation, and 44 % of dairy cows in the 3rd phase of lactation) with an above-limit milk urea content (35.0 ± 4.7; 34.9 ± 4.1, 34.8 ± 4.1 $mg.dl^{-1}$); decreased urinary nitrogen excretion ($P < 0.05$); and efficiency of nitrogen utilization from feed to milk ($P < 0.05$). According to the phase of lactation, the efficiency of nitrogen utilization decreased and urinary nitrogen excretion increased with increasing milk urea content.

Key words: dairy cows; milk; nitrogen excretion; urea in milk; utilization efficiency

INTRODUCTION

The dairy industry is under constant pressure to improve efficiency and reduce its impact on the environment. At the same time, the demand for milk and dairy products is increasing. Farmers today are faced with difficult decisions in feeding animals and trying to achieve their production goals while employing social and environmental constraints [9]. Milk and milk products are a high-quality source of nutrients that provide 13 essential nutrients needed in the human diet. The bioavailability of animal proteins is 1.4 times higher than that of plant protein sources with higher protein utilization [17].

Maximizing milk production while minimizing protein intake is one of the most extreme tasks in the nutrition of dairy cows. The evaluation of protein requirements in ruminants is very important for optimizing animal performance and minimizing urinary nitrogen excretion (UNE). Nitrogen (N) released into the environment through the urine and faeces of farm animals in the form of urea represents the final product of protein metabolism. Faecal N is bound to complex and stable organic structures and thus is relatively resilient to environmental losses. On the other hand, urinary nitrogen, which is mainly formed by urea, is decomposed by urease enzymes present in animal faeces into ammonia, which is the main source of pollution of water sources as well as the atmosphere [2, 14].

Nitrogen excreted in faeces and applied in the form of fertilizers to the fields is, even under the best conditions of husbandry management, excreted into underground and surface waters, where it represents a source of pollution. Therefore, it is important to reduce the amount of N excreted in faeces and urine by improving the efficiency of nitrogen utilization (ENU) in dairy cows [11].

Evaluation of proteins requires the use of reliable diagnostic biomarkers. The amount of urea that a cow excretes in the urine is directly proportional to the concentration of urea in the blood, while this amount is proportional to the concentration of urea in the milk [3]. It follows that an increased intake of CP increases the proportion of UNE. Therefore, milk urea (MU) is a suitable indicator of UNE [11, 15].

The aim of our study was to use MU to evaluate production parameters, ENU, and UNE during lactation in dairy cows.

MATERIALS AND METHODS

Data collection

This study included 600 Holstein dairy cows from a Slovakian dairy farm with an average milk production of 10 154 kg of milk from January 2018 to December 2018. Cows were selected according to days in milk (DIM): 0–120 for the 1st lactation phase; 12–210 for the 2nd lactation phase; 211–305 for the 3rd lactation phase.

The cows were maintained in free-stall housing and fed with a total mixed ration (TMR) provided *ad libitum*. The TMR was formed monthly, depending on the nutrient requirements according to the milk yield and capacity of dry matter intake (DMI). The samples of the TMR were taken from the feed manager on the control day and were analysed for dry matter (DM), which consisted of crude protein (CP), fat, acid, and neutral detergent fibre (ADF, NDF), and starch analysed by conventional methods [4]. The DM was determined by weight upon drying the sample at 105 °C under the prescribed conditions. The CP content was determined by the Kjeldahl method using a 2300 Kjeltec Analyser Unit (Foss Tecator AB, Hoganas, Sweden). The fat was determined by the device Det-Gras (JP SELECTA, Spain). The ADF and NDF were determined using a Dosi-Fibre Analyser (JP SELECTA, Spain), and the content of starch was determined by polarimetry. The net energy of lactation (NEL) and non-fibre carbohydrates (NFC) was calculated using regression equations according to the National Research Council (NRC) [16].

The cows were milked twice a day at 06:00 a.m. and 04:00 p.m. in a parallel milking parlour (BouMatic, Sweden) and individual milk samples were analysed once per month. The samples were cooled to 4 °C and immediately transported to the Central Analytical Laboratory of Milk with accreditation under the registration number 096/5878/2015/2 in collaboration with The Breeding Services of Slovakia, using the breeding information system. Milk samples were analysed for milk protein, fat, and MU concentration by a near-infrared spectrophotometric assay using MilkoScan FT+ (Foss Electric, Hillerød, Denmark) and BENTLEY FTS (Bentley Instruments Inc., Chaska, USA). According to Hossein-Zadeh [7], the determined amount of MU was converted to milk urea nitrogen (MUN). Efficiency of nitrogen utilization (ENU) [8] and urinary nitrogen excretion (UNE) were calculated [13] for each period.

Ethical considerations

In this study we used data obtained with the consent of the farm in collaboration with the Breeding Services of Slovakia, using the Breeding Information System.

Statistical analysis

The data were processed by GraphPad Prism 8.3 (GraphPad Software, San Diego, CA, USA). The results were expressed as the means ± standard deviations (SD). One-way analysis of variance (ANOVA) for multiple comparisons of means was conducted to evaluate the differences in parameters of milk yield, milk components, MU, ENU, and UNE where the lactation phase was set as the main factor at a significance level of $P < 0.05$.

RESULTS

The composition and average concentration of nutrients in TMR according to the stage of lactation are presented in Table 1.

Table 1. The composition and analysed nutrient content of TMR

	1st lactation phase	2nd lactation phase	3rd lactation phase
Composition of TMR			
Corn silage kg	20.0–6.0	19.0–39.0	8.0–36.0
Alfalfa silage kg	6.0–16.0	4.0–10.0	8.0–14.0
Grass silage kg	2.0–5.0	4.0–5.0	4.0–6.0
Grass hay kg	0.8–1.0	0.8–2.0	1.0–3.0
Wheat straw kg	0.5–0.8	0.5	1.0
Rapeseed meal kg	2.0–4.0	3.2–5.3	2.5–6.0
Concentrate mixture kg	4.5	1.5	0.3
Nutrients in TMR			
DMI (kg.d^{-1})	25.0 ± 0.9	22.2 ± 0.6	20.4 ± 0.7
CP (g.kg^{-1} DM)	157.6 ± 2.2	154.2 ± 3.6	157.0 ± 2.9
Starch (g.kg^{-1} DM)	251.9 ± 6.4	232.6 ± 16.5	162.3 ± 33.5
Fat (g.kg^{-1} DM)	43.3 ± 0.8	37.6 ± 0.7	35.7 ± 0.9
NDF (g.kg^{-1} DM)	341.9 ± 10.8	377.5 ± 7.8	417.8 ± 12.9
ADF (g.kg^{-1} DM)	211.8 ± 5.5	229.8 ± 5.1	267.3 ± 13.8
NFC (g.kg^{-1} DM)	382.4 ± 9.2	357.0 ± 10.5	308.9 ± 21.2
NEL (MJ.kg^{-1} DM)	6.6 ± 0.1	6.4 ± 0.1	6.1 ± 0.2

DMI – dry matter intake; CP – crude protein; NDF – neutral detergent fibre; ADF – acid detergent fibre; NFC – non-fibre carbohydrates; NEL – net energy of lactation; TMR – total mixed ration; d – day;

Table 2. Milk production and composition according to lactation phase (mean ± SD).

Parameter	1st lactation phase	2nd lactation phase	3rd lactation phase
DIM	75 ± 26	165 ± 26	253 ± 26
Milk yield (kg.d^{-1})	39.9 ± 9.2^{a}	36.3 ± 8.1^{b}	30.4 ± 7.6^{c}
MUN (mg.dl^{-1})	12.7 ± 3.2^{a}	13.1 ± 3.3^{b}	13.4 ± 3.3^{b}
MU (mg.dl^{-1})	27.2 ± 7.0^{a}	28.1 ± 7.1^{b}	28.6 ± 7.1^{b}
MU < 25 (mg.dl^{-1})	20.6 ± 3.6	20.5 ± 3.9	20.1 ± 3.9
% of group	39.0	33.0	28.0
MU 25–30 (mg.dl^{-1})	27.4 ± 1.4	27.5 ± 1.4	27.6 ± 1.4
% of group	30.0	28.0	28.0
MU > 30 (mg.dl^{-1})	35.0 ± 4.7	34.9 ± 4.1	34.8 ± 4.1
% of group	31.0	39.0	44.0
Protein (%)	3.0 ± 0.3^{c}	3.2 ± 0.3^{b}	3.4 ± 0.3^{a}
Fat (%)	3.4 ± 0.8^{c}	3.6 ± 0.7^{b}	3.9 ± 0.7^{a}
UNE (g.d^{-1})	213.9 ± 54.2^{c}	222.1 ± 55.5^{b}	226.0 ± 55.6^{a}
ENU (%)	31.0 ± 2.0^{a}	30.2 ± 2.3^{b}	28.7 ± 2.6^{c}

DIM – days in milk; MUN – milk urea nitrogen; MU – milk urea; d – day; UNE – urinary nitrogen excretion; ENU – efficiency of nitrogen utilization; ^{a,b,c} Means within the same row with different superscripts differ significantly at P < 0.05

The analysed nutritional composition of TMR showed a balanced content of CP for the 1st, 2nd, and 3rd stages of lactation, and a decrease in NEL, which was ensured by a decrease in the proportion of starch and an increase in the proportion of NDF.

Milk production, components, and concentration of MU, ENU, and UNE in milk dairy cows during lactation are summarized in Table 2.

Daily milk yield during lactation was 35.7 ± 9.2 kg.d^{-1} with a peak in the 3rd month of lactation (40.8 ± 9.2 kg.d^{-1}). According to the stage of lactation, a significant (P < 0.05) decrease in milk yield (39.9; 36.3; 30.4 kg.d^{-1}) was confirmed.

The lowest content of protein and fat in milk (P < 0.05) was analysed in the 1st lactation phase and increased with continued lactation.

Evaluation of the MU confirmed an increase (P < 0.05) as lactation progressed. Exceeding MU content in dairy cows in the 1st stage of lactation (> 30 kg.dl^{-1}) was found in 31 % of animals compared to the group of dairy cows in the 2nd and 3rd stages of lactation, where 39 % and 44 % of the dairy cows showed an above-limit MU content.

By evaluating ENU during lactation, confirmed a significant (P < 0.05) decrease (31.0; 30.2; 28.7 %) with increasing DIM. According to the stage of lactation, a significant ($P < 0.05$) increase in UNE (213.9; 222.1; 226.0 $g.d^{-1}$) was confirmed.

The evaluation of ENU according to MU during lactation is summarized in Fig. 1. According to the phase of lactation with increasing MU content, ENU decreased. The amount of ENU in individual stages of lactation decreased at MU concentrations up to 25 $mg.dl^{-1}$ (32.2; 31.3; 30.1 %), at MU concentrations of 25–30 $mg.dl^{-1}$ (31.4; 30.9; 29.1 %) and MU above 30 $mg.dl^{-1}$ (31.0; 30.0; 28.1 %).

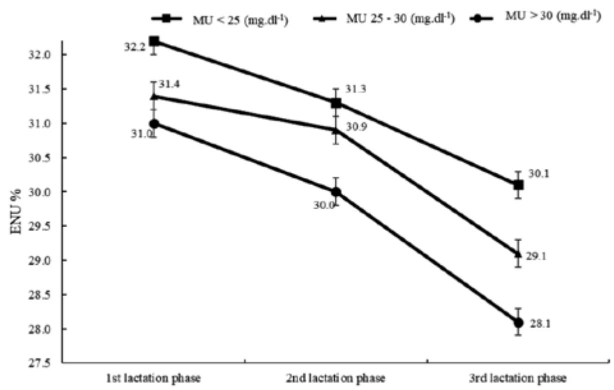

Fig. 1. ENU (%) depending on MU during lactation

The evaluation of UNE according to MU during lactation is summarized in Fig. 2. According to the phase of lactation with increasing MU content, UNE increased. The amount of UNE in individual stages of lactation contains comparable values at MU concentrations up to 25 $mg.dl^{-1}$ (162.3; 161.9; 159.0 $g.d^{-1}$), at MU concentrations of 25–30 $mg.dl^{-1}$ (216.3; 217.2; 217.7 $g.d^{-1}$) and MU above 30 $mg.dl^{-1}$ (276.4; 275.7; 274.5 $g.d^{-1}$).

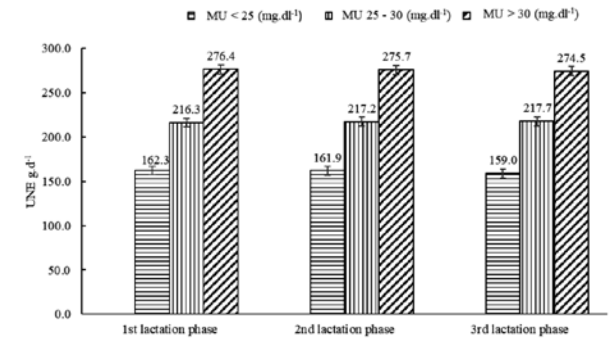

Fig. 2. UNE ($g.d^{-1}$) depending on MU during lactation

DISCUSSION

The stage of lactation is one of the important causes of fluctuations in the concentration of blood metabolites and subsequent fluctuations in milk components in dairy cows [21, 23].

The decrease in milk production and the increase in milk components (proteins and fat) during lactation are related to changes in hormones during lactation, the requirements of the foetus for nutrients, or insufficient intake of nutrients for milk production. The increasing content of milk components at the same time as the decrease in lactation is the result of the dilution of the content. Milk fat can fluctuate depending on the composition of the feed ration during lactation. At the beginning of lactation, cows mobilize body reserves, and by feeding a feed ration with a low NDF content, milk fat decreases [5]. The milk protein content is influenced genetically and nutritionally. Improvement of dry matter intake, energy intake, and energy balance leads to an increase in milk proteins [19].

By evaluating the content of MU during lactation, the content increased. According to [10], the lowest level of MU was found in the first month of lactation, and then the content of MU relatively rapidly increased, and the maximum concentration was achieved in the 5th month of lactation. Our results show the balanced CP content in the feed ration of dairy cows in the individual lactation phase, which points to the influence of protein quantity and quality as nutritional influences on MU [20].

With the increasing number of lactation days with balanced CP (157.6; 154.2; 157.0 $g.kg^{-1}$ DM) and rumen degradable protein (RDP) (101.4; 100,4; 106.2 $g.kg^{-1}$ DM) in proportion to the decrease in milk production, the concentration of MU increased, and at the same time, UNE increased and ENU decreased as a result of a balanced intake of CP and RDP and decreased intake of starch in feed ration during lactation. The ENU represents the ratio between the N content in milk and the received amount of N from the feed ration. The main reason for the increased MU content is the excess of protein in the diet of dairy cows and their protein-energy imbalance [1, 12]. Increased MU content occurs with increased intake of CP and RDP in the TMR, low rumen nondegradable protein content or inappropriate composition of amino acids, and insufficient intake of fermentable carbohydrates in the TMR. A low content occurs when there is insufficient protein intake there is a low production of protein in the rumen due to the growth of the rumen microflora at the same time as excessive energy intake [22]. Increased protein intake in TMR from 13 % of DM to 18 % is accompanied by an increase in MU from 80 mg to more than 150 mg per 1 litre of milk [6]. With increased CP content in the feed ration, there is a decrease in ENU and increased UNE and MU.

Improving ENU means higher N uptake and a reduction in urinary N loss. Inefficient ENU is the reason why dairy cows represent the main source of environmental pollution by excreting N into the environment [18].

CONCLUSIONS

Nitrogen transformation on dairy farms is interrelated and complex. To control nitrogen losses through pathways that have the least negative environmental impact and optimize nitrogen utilization, trade-offs between nitrogen conservation and nitrogen loss must be taken into account.

Regular checking of MU content in dairy farms is a suitable tool for evaluation of ENU and UNE, with subsequent use in the elimination of health disorders or minimizing the negative impact on the environment.

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Conflict of interest

The authors declare that there is no conflict of interest.

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