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Effect of dietary crude protein concentration on milk productivity traits in early lactation dairy cows

D. Ruska* and D. Jonkus

Latvia University of Life sciences and Technologies, Faculty of Agriculture, Institute of Animal Sciences, Liela street 2, LV-3001 Jelgava, Latvia
*Correspondence: diana.ruska@llu.lv

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Abstract. The evaluation and control of nitrogen balance at the farm and its relation to milk productivity traits are becoming essential in dairy farming. Increasing in milk productivity farmers tend to increase protein content in feed. The research complied into three (A, B, C) dairy cow groups (8 cows in each group) with LB and HM breed's cows in the early lactation period divided into three phases (I, II, III) from 10 till 30 lactation days and lasting to 90 lactation days. Each group cows were feeders with total mixed ration (TMR) with different CP content (approx. 17.0%; 16.0%; 15.0% accordingly). The amount of feed consumed by each cow were recorded and feed samples collected during the study. Feed samples were analysed for CP and other feed quality descriptive traits. Milk yield (kg d^{-1}) and milk samples were collected at day 21 of each phase for analysis. Milk samples were analysed for fat (%), total protein (%), casein (%), and urea content (mg dL^{-1}). The statistical analyses were conducted using ANOVA and descriptive parameters. To evaluate the feed CP conversion efficiency estimated part of that in the yield of milk protein for each cow and on average for the study group in each study phase. The conversion efficiencies of feed CP in milk were ranged from 28.5% to 40.7% in study phase I, and from 33.0% to 39.9% in phase II, and the differences were statistically significant. In phase III, the range from 30.4% to 36.3% were not statistically significant.
The objective of this study was to evaluation of feed protein conversion efficiency for dairy cows in the early lactation phase and define the optimal crude protein (CP) content in the feed.

Key words: milk yield, milk total protein, milk urea, feed crude protein.

INTRODUCTION

One of the basic aims for the dairy industry is to develop a sustainable farming systems to provide environmentally friendly milk production. Efficient use of feed nitrogen is one of the major components of a sustainable production systems. Inefficient nitrogen use not only influences dairy cow productivity traits, but it is potentially emission to the environment (Rotz, 2004). High protein concentrations in the diet contributes to increase the production levels, but parts of nitrogen are excreted in faeces and urine (Dijkstra et al., 2011; Ruska & Jonkus, 2020). It is established that feedstuffs vary not only in their nitrogen or crude protein (CP) content, but also in their compounds. Together with CP balancing in ruminants diet need to pay attention to the rumen degradable protein (RDP) and undegradable protein (RUP) content in CP. Dietary protein is necessary to meet the nitrogen requirements of rumen microorganisms as well as a source of protein for dairy cows. Over feeding of rumen degradable protein can be extracted into the environments and therefore wasteful use of resources. This fraction of feed CP have different functions in cow diets. The RDP fraction provide optimal ruminal efficiency for microbial growth and synthesis of microbial proteins and obtain cow productivity with optimal amount of feed CP. The RUP fraction provides a direct supplier of amino acids to the animal (NRC, 2001; Schwab et al., 2003; Salo, 2018).

The objective of this study was to evaluate feed protein conversion efficiency for dairy cows in the early lactation phase and define the optimal CP content in the feed.

MATERIALS AND METHODS

The study was conducted at the LLU MPS Vecauce in 2019 and last from May until July. Three groups of dairy cows were completed, using eight animals including Latvian Brown ($n = 3$) and Holstein Black and White ($n = 5$) breeds in each group. The animals were in early lactation, from 10 to 30 days in milk (DIM) and each group including 2nd ($n = 5$) and 3rd ($n = 3$) lactation cows. The trial design was a 3x3 Latin square where three diets were conducted over three phases (I: 10–30 DIM, II: 30–50 DIM, III: 70–90 DIM) each lasting 21 days. The diets were prepared directly in the farm by total mixed rations (TMR), different for CP content (diet A: 17.0% CP; B: 16.0% CP; C:15.0% CP). Different levels of CP in diets were obtained by different amounts of soya bean meal expeller in that. Diet preparations were under production conditions and stayed had an effect on the estimated diet group chemical composition. Cows were housed in a tie stalls and individually fed. Each cow has an individual water sources with a provided counter. Cows were fed *ad libitum*. TMR samples were taken for testing every 2nd or 3rd day ($n = 72$). After sampling, there were immediately frozen and later were analysed in an accredited laboratory. The average composition of TMR is presented in Table 1.

Table 1. Average composition of feed during the study

Traits	Study diet groups								
	A			B			C		
	Study phase DIM								
	I	II	III	I	II	III	I	II	III
Dry matter (DM), %, included:	45.62	44.04	46.62	40.57	39.94	41.88	38.29	43.45	39.21
Crude protein, % DM	18.02	17.83	17.06	17.89	16.78	16.28	16.99	15.08	15.14
RDP, % CP	59.88	60.01	80.93	57.84	70.86	74.26	49.55	64.48	80.33
RUP, % CP	40.12	39.99	19.07	42.16	29.14	25.74	50.45	35.52	19.67
Ash, % DM	6.88	6.94	6.70	7.14	7.40	7.38	8.40	7.49	6.47
Crude fibre, % DM	13.46	12.00	12.83	15.27	15.10	16.92	19.17	14.41	15.81
NDF, % DM	28.93	29.31	27.89	32.15	33.25	35.34	36.62	33.32	33.96
ADF,% DM	16.78	16.06	16.91	19.46	19.01	19.63	23.40	18.48	18.65
Ether extract, % DM	3.30	2.76	3.72	3.20	2.40	2.85	3.17	2.48	2.41
NEL, MJ per kg dM	7.27	7.33	7.26	7.06	7.09	7.04	6.47	7.14	7.12

The crude protein of the feed ranged from 15.08% to 18.02%, depending on the study group diet tested and met the requirements of dairy cows in the early lactation stage. Content of RDP in the CP ranged from 57.84% to 80.93% and RUP ranged from 19.07% to 50.45%, depending on the study group. RDP content were proportionally highest in CP than RUP that is incident in the diet of high productive cows (NRC, 2001).

Milk productivity traits: milk yield kg d^{-1} and sampling for testing, were taken on days 7, 11, 15, and 21, separated for each milking time. Milk samples were tested for content of total protein (%), casein (%), and urea (mg dL^{-1}) with an instrumental infrared spectroscopy method in an accredited laboratory for milk quality control.

For the obtained data, statistical processing feed DM, CP, RDP, RUP content, and milk total protein, casein, urea content was recalculated to the intake of each parameter per day in compliance with ICAR guidelines (ICAR, 2017).

$$Amount, kg = (dry\ matter\ intake, kg \times \%\ of\ content)/100 \qquad (1)$$

The obtained data was analysed using descriptive statistics and the differences between the study groups were assessed using ANOVA with Bonferroni *t*-test correction, setting the confidence level at $p < 0.05$. Statistical processing of the data was carried out with *MS for SPSS* (SPSS Inc. Chicago, Illinois, USA) and *MS Office* programme *Excel* (Microsoft Corporation, Redmond, Washington, USA).

RESULTS AND DISCUSSION

The study results were analysed separately for each group and in each study phase. Average feed compounds (DM, CP, RDP ratio to RUP) and milk productivity traits in the control days in the study are present in Table 2.

Table 2. Average cow feed intake and milk productivity traits by group

Traits	Study diet groups								
	A			B			C		
	Study phase DIM								
	I	II	III	I	II	III	I	II	III
Dry matter intake, kg	17.1± 0.87	17.6± 0.91	21.2± 1.46	16.1± 1.08	18.6± 1.18	19.3± 1.36	16.8± 0.78	20.1± 1.24	20.2± 1.64
CP feed intake, kg	3.09± 0.157	3.14± 0.162	3.61± 0.249	2.88± 0.193	3.02± 0.192	3.14± 0.221	2.86± 0.131	3.03± 0.187	3.05± 0.249
RDP ratio to RUP	1.49	1.50	4.24	1.37	2.43	2.89	0.98	1.82	4.08
Milk yield, kg d^{-1}	40.5± 3.68	38.5± 4.30	34.3± 3.48	39.8± 3.71	34.0± 3.18	34.8± 3.04	39.7± 4.36	39.7± 3.74	35.5± 3.29
Total protein content, %	3.14± 0.131	3.24± 0.119	3.24± 0.137	3.06± 0.088	2.98± 0.124	3.28± 0.133	2.83± 0.113	3.11± 0.117	3.15± 0.104
Casein content, %	2.53± 0.096	2.61± 0.089	2.62± 0.102	2.47± 0.070	2.42± 0.098	2.63± 0.103	2.31± 0.088	2.50± 0.091	2.55± 0.072
Urea content, mg dL^{-1}	27.0± 1.40	29.6± 0.88	35.2± 2.30^{a}	24.9± 1.89	30.6± 1.79	35.2± 1.44^{a}	30.9± 1.81	29.9± 0.84	25.5± 0.47^{b}

$^{a;b}$ – traits with unequal letters differed significantly among the groups in the study phase ($p < 0.05$).

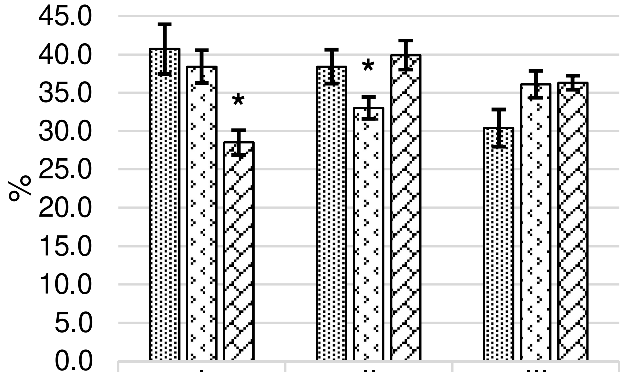
Dry matter intake (DMI) was not different among groups with different feed CP content in all study phases. DMI ranged from 16.1 kg in group B to 17.1 kg in group A in I phase DIM, from 17.6 kg in group A to 20.1 kg in group C in II phase DIM and from 19.3 kg in group B to 21.2 kg in group A in III phase DIM. In all study groups, DMI increased with DIM that corresponds to previously performed research and developed DMI prediction models (NRC, 2001).

In feed CP intake also was not significant different among study groups in all phases. CP intakes ranged from 2.86 kg in group C to 3.09 kg in group A in I phase DIM, from 3.02 kg in group B to 3.09 kg in group A in II phase DIM and from 3.05 kg in group C to 3.61 kg in group A in III phase DIM. In all phases DIM, were observed daily feed CP intake decreasing with decreased CP content in feed. Bahrami-Yekdangi (2016) with researcher group (2016) determine significant ($p < 0.01$) daily nitrogen intake decreased with decreasing dietary CP and RDP levels.

The ratio of RDP to RUP differs in each study group and phases that confirm the error in the ration preparation process by the deviation of CP content in diet groups. RDP to RUP ratio was different from 0.98 in group C to 1.49 in group A in I phase DIM, from 1.50 in group A to 2.43 in group B in II phase DIM and the highest RDP content in CP was in III phase DIM ration from 2.89 in group B to 4.24 in group A. In a previous study, researchers find out that the feed efficiency decreases with increasing ratio of RDP to RUP, where the low ratio was 1.68 and high ratio 1.74 (Savari et al., 2017).

Milk yield, ECM, total protein, and casein content did not differ significantly according to the decreasing of CP content in feed. Milk yield ranged from 39.7 kg d^{-1} to 40.5 kg d^{-1} in phase I DIM, from 34.0 kg d^{-1} to 39.7 kg d^{-1} in phase II DIM and from 34.3 kg d^{-1} to 35.5 kg d^{-1} in phase III DIM. For all study groups observed milk yield decreasing in phase III DIM, contrary total protein and casein content increase in all groups that eventually is related with lactation day influence on milk productivity traits and in previously studies it was observed that milk yield start decreases and protein and casein content increase after 60–90 DM (Ruska & Jonkus, 2013).

Urea content in milk in our study was similar in all groups in phase I and II DIM and did not exceed the optimal level between 20 and 30 mg dL^{-1} (Duinkerken et al., 2011). In phase III DIM, in groups A and B the urea content was 35.2 mg dL^{-1} for each, thereby in group C was significantly lower 25.5 mg dL^{-1}. Exceed of urea content in milk could probably explains the ration with high RDP content in feed CP with insufficient RUP content in phase III DIM (Table 1). In previous studies it was found that milk urea increased linearly when cows fed increasing amount of RDP (6.8; 8.2; 9.6; 11.0% of DM). Feeding a deficient RDP rations can decrease nitrogen extraction (Kalscheur et al., 2006).



	I	II	III
A	40.7	38.4	30.4
B	38.4	33.0	36.1
C	28.5	39.9	36.3

Phase DIM

Figure 1. CP conversion efficiency of milk total protein produced by study groups and phase (* $p < 0.05$).

One of the possible estimations of feed conversion efficiency is to determine the feed CP efficiency and evaluate how much of the feed CP consumed to produce milk total protein. Estimated feed CP intake to total protein yield in milk (Fig. 1).

Feed CP conversions in milk were ranged from 28.5% in group C and was significantly lower to 40.7% in group A in phase I DIM, from 33.0% in group B and was significantly lower, to 39.9 % in group C in phase II DIM and from 30.04% in group A to 36.3% in group C in phase III DIM. CP conversion efficiencies in our study are related to previous researcher estimation, as they evaluated nitrogen extraction in milk 27% of total nitrogen intake, and their observation was highly variable from 10% to 40% and 45% (Straalen, 1995; Calsamiglia et al., 2010; Ruska et al., 2020).

The reducing of feed CP conversion efficiency in our study in phase III DIM for all groups probably can explain with high RDP content in the ration. Together with urea content increasing in a previous study, Kalscheur et al. (2006) found that the efficiency of conversion of feed nitrogen to milk decreased.

CONCLUSIONS

Feed CP levels ranging from 15.08% to 18.02% under the study conditions and did not significantly affect the milk yield, crude protein and casein content in all study phases. The conversion efficiency of CP in milk was significantly lower 28.5% in group C (CP 16.99%) phase I DIM and 33.0% in group B (CP 16.78%) phase II DIM, which is difficult to explain by the CP content in the feed, but may have been influenced by other unexplored environmental factors as the cows were tie-stalled for the study.

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