Acta Sci. Pol. Zootechnica 16(4) 2017, 39–44

www.asp.zut.edu.pl pISSN 1644-0714 eISSN 2300-6145 DOI:10.21005/asp.2017.16.4.06

ORIGINAL PAPER

Received: 18.05.2017
Accepted: 24.10.2017

PROPORTION OF MILK SAMPLES WITH A SPECIFIC PROTEIN AND UREA CONTENT DEPENDING ON SELECTED FACTORS WHEN EVALUATING DIETARY PROTEIN AND ENERGY BALANCE FOR DAIRY COWS

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ABSTRACT

Analysis was made of the effect of herd, lactation number, day of lactation, season of testing, daily milk yield, and milk somatic cell count on the proportion of cow milk samples with a specific protein and urea content. There were not enough samples of milk containing 151–300 mg · l^{-1} urea and 3.21–3.6% protein which are indicative that the dietary protein and energy are balanced. The highest percentage of milk samples with the optimum protein and urea content was observed in multiparous cows during 101–200 and 201–300 days of lactation, which had a daily milk yield of 21–30 kg and 31–40 kg in the summer season. These factors should be considered when formulating cow rations as they influence milk protein and urea levels.

Key words: cows, milk samples, proportion of urea, proportion of protein

INTRODUCTION

The determination of milk urea and protein content allows for the protein and energy balance to be regularly monitored when formulating cow rations, because these parameters reliably show whether the animals are fed correct proportions of the main feed ingredients, i.e. protein, carbohydrates, and roughage [Sablik et al. 2003, Szarkowski et al. 2009]. This is possible because milk urea concentration is proportionate to the amount of dietary protein, and contrary to the level of dietary energy [Guo et al. 2004]. This ingredient also makes it possible, when monitoring protein use in the cow's digestive tract, to reduce feeding costs as well as the loss of nitrogen from cattle farms [Guliński et al. 2015]. A reduced and/or elevated milk urea level is evidence that the feed is improperly balanced for protein and energy available to rumen microbes. Excessively high milk urea levels can result from excess dietary protein and deficient dietary energy supply, whereas low levels may be indicative of protein and/or energy deficiency in the diet [Guliński et al. 2008, 2015, Roy et al. 2011, Fleszar 2012]. High milk urea levels may be periodically caused by rapid degradation of storage protein, resulting from considerable dietary protein deficiency or feed withdrawal [Hojman et al. 2004]. Many studies have proved that milk urea level positively correlates to factors such as cow's age and number of calvings, and it is also influenced by season of the year, grazing system, milking system, milk sampling time (morning, evening), the interval between feeding and sample collection for analysis, and lactation period [Hojman et al. 2004, Mucha and Strandberg 2011, Rzewuska and Strabel 2013, Czajkowska et al. 2015, Guliński et al. 2015, Satoła and Ptak 2016].

The aim of the study was to determine the effect of selected factors (herd, lactation number, day of lactation, season of testing, daily yield, milk somatic cell count) on the proportion of cow milk samples with a specific protein and urea content (indicators of the protein and energy balance in rations for dairy cows).

MATERIAL AND METHODS

The study was performed in the Kujawsko-Pomorskie province in three herds (A, B, C) of Polish Holstein-Friesian cows of Black-and-White variety. Data on daily

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milk yield, milk protein (%) and urea (mg · l^{-1}) content, and milk quality (somatic cell count) concerned the period between January 2015 and March 2016. The analysed herds were under the A4 milk recording scheme. The results were obtained from RW-2 printouts sent by the Polish Federation of Cattle Breeders and Dairy Farmers in Minikowo. A total of 4869 milk samples was investigated.

On farm A, 26 cows were kept in medium-sized stalls on shallow litter. Animals were fed a partial mixed ration (PMR), and grazed pasture from April to October. Their yield per lactation averaged 6128 kg milk, which contained 3.31% protein, 4.27% fat and 164 mg · l^{-1} urea. On farm B, 148 cows were raised using the Grabner tethering system and fed TMR diets; their yield averaged 8054 kg milk, 4.02% fat, 3.4% protein and 156 mg · l^{-1} urea. On farm C, 201 cows were kept in a loose-housing system with outdoor access and fed TMR diets; their yield averaged 12,774 kg milk, which contained 3.21% protein, 4.23% fat and 315 mg · l^{-1} urea.

On all the farms, the diets were formulated to meet the requirements of different groups of animals according to their milk yield.

On farms A and B, cows were milked twice daily in stalls with a pipeline milking machine. On farm C, animals were milked three times daily in a 2 x 8 herringbone milking parlour.

FREQ procedure of the SAS package was used in the statistical calculations [SAS, 2014], which accounted for the effect of herd (A, B, C), lactation number (primiparous vs. multiparous cows), day of lactation (≤100, 101–200, 201–300, >300 days), daily yield (≤20 kg, 20.1–30, 30.1–40, 40.1–50, >50 kg milk), season of testing (spring – March to May, summer – June to August, autumn – September to November, winter – December to February), and somatic cell count (≤400,000 · ml^{-1}, >400,000 · ml^{-1}) on milk protein and urea content.

RESULTS AND DISCUSSION

From a zootechnical and economic point of view, recording the protein and urea levels in test-day milk is a rapid, inexpensive, convenient and non-invasive, but above all a commonly used method that informs the breeder about dietary protein efficiency and provides the basis for correct balancing of dietary rations [Czajkowska et al. 2015]. Analysis of our results (Table 1) showed a low (14.8% – group 2b) proportion of milk samples with the optimum urea and protein levels (150–300 mg · l^{-1} and 3.2–3.6%, respectively), which is considered [Sablik et al. 2003, Litwińczuk et al. 2006] to confirm that the ration had been properly balanced for protein and energy. Their proportion was 15.0% on farm A, 17.8% on farm B and 12.8% on farm C. The herds more often showed dietary protein deficiency (urea ≤ 150 mg · l^{-1}, groups 1a, 2a, 3a) than excess (≥150 mg · l^{-1}, groups 1c, 2c, 3c).

Analysis of the effect of cows' age revealed that in both primiparous and multiparous cows, the highest proportion was formed by milk samples in which protein and urea content showed dietary energy deficiency (group 1b). Their proportion was 16.0 and 17.2%, respectively (tab. 2). Compared to multiparous cows, primiparous cows showed a higher proportion of samples that showed evidence of excess energy (group 3 b) and excess protein and energy (group 3c). Litwińczuk et al. [2003] and Borkowska et al. [2006] demonstrated that the milk from primiparous cows contained less urea compared to that from multiparous cows. The same authors attributed this to the fact that primiparous cows make efficient use of amino acids for the growing body, which is a priority for them. The reverse situation was observed in older cows, in which milk production is given preference.

When analysing the effect of lactation period, it was found that up to 100 days, almost 76% of the milk samples showed different degrees of energy deficiency (groups 1a, 1b, 1c and 2c). This proportion decreased gradually with advancing lactation and amounted to 21.8% during the period beyond 300 days (Table 2). Up to 100 days of lactation, in 19.6% of the samples the inadequate dietary energy supply was associated with protein deficiency (group 1a), and in 17.9% the energy deficiency was paralleled by excessive supply (group 1c). In successive lactation periods the proportion of these groups decreased, but the rate of this decrease was higher in group 1a. The proportion of samples that showed a well balanced ration (group 2b) was highest (over 18%) during 101–200 and 201–300 days of lactation. During this period, in particular between 201 and 300 days of lactation, there was a high proportion of samples that showed evidence of excess protein and a slight dietary energy deficiency (group 2c). After 300 days of lactation, there was a high (21.1%) proportion of milk samples that showed protein deficiency and energy excess in the diet (group 3a), as well as an even higher proportion (29.5%) of the samples showing excess dietary energy (group 3 b).

In our study, the highest proportion of milk samples that showed concurrent protein and energy deficiency was observed up to 100 days of lactation. Similar results were obtained by Sawa et al. [2010], who found that the highest proportion of milk samples indicating that the ration had been improperly balanced for protein and energy, occurred up to 100 days of lactation, mainly in the second month. Arunvipas et al. [2003] noted a lower urea level during the first month of lactation, which peaked in the 4th month and again decreased further in the lactation. Also Borkowska et al. [2006] noted the lowest urea content of the milk samples from cows in the first and second month of lactation. The same authors attributed

Table 1. Classification of milk samples according to protein and urea levels [Osten-Sacken 2000]

Tabela 1. Podział prób mleka ze względu na poziom białka i mocznika [Osten-Sacken 2000]

Group Grupy	Proportion of protein, % Udział białka, %	Level of urea, $mg \cdot l^{-1}$ Poziom mocznika, $mg \cdot l^{-1}$	Protein and energy balance of the dietary ration Bilans białko-energetyczny w dawce pokarmowej
1 a	≤ 3.2	≤ 150	Protein and energy deficiency Niedobór białka i energii
1 b	≤ 3.2	151–300	Energy deficiency Niedobór energii
1 c	≤ 3.2	≥ 301	Excess protein and energy deficiency Nadmiar białka i niedobór energii
2 a	3.21–3.6	≤ 150	Protein deficiency and slight energy surplus Niedobór białka i nieznaczna nadwyżka energii
2 b	3.21–3.6	151–300	Balanced protein and energy levels Zbilansowany poziom białka i energii
2 c	3.21–3.6	≥ 301	Excess protein and slight energy deficiency Nadmiar białka i nieznaczny niedobór energii
3 a	≥ 3.61	≤ 150	Protein deficiency and excess energy Niedobór białka i nadmiar energii
3 b	≥ 3.61	151–300	Excess energy Nadmiar energii
3 c	≥ 3.61	≥ 301	Excess protein and excess energy Nadmiar białka i nadmiar energii

Table 2. Percentage of milk samples with a specific protein and urea content depending on herd, lactation number, and day of lactation

Tabela 2. Udział prób mleka o określonej zawartości białka i mocznika w zależności od obory, kolejnej laktacji, dnia laktacji

Treatment Czynnik	Treatment classes Klasy czynnika	Measures Miary	Proportion of milk samples with specific protein (%) and urea content, $mg \cdot l^{-1}$ Udział prób mleka o określonej zawartości białka (%) i mocznika, $mg \cdot l^{-1}$								
		% n	1a	1b	1c	2a	2b	2c	3a	3b	3c
Herd Obora $chi^2 = 276.98^{xx}$	A	%	19.4	13.1	0.9	15.9	15.0	1.9	12.2	19.1	2.5
		320	62	42	3	51	48	6	39	61	8
	B	%	14.3	12.5	0.1	16.2	17.8	0.4	17.1	21.0	0.6
		1930	277	241	2	312	343	8	330	406	11
	C	%	1.9	20.5	23.8	0.2	12.8	27.4	0.1	3.4	9.9
		2619	50	536	624	4	336	720	2	90	257
Next lactation Kolejna laktacja $chi^2 = 43.71^{xx}$	primiparous cows pierwiastki	%	8.8	16.0	10.3	8.7	14.4	13.7	9.9	12.7	5.5
		1616	143	258	166	140	232	222	160	205	90
	multiparous cows wieloródki	%	7.6	17.2	14.2	7.0	15.2	15.7	6.5	10.8	5.8
		3253	246	561	463	227	495	512	211	352	186
Day of lactation Dzień laktacji $chi^2 = 179.81^{xx}$	≤ 100	%	19.6	31.4	17.9	7.3	11.4	6.6	1.5	3.2	1.1
		1457	286	458	261	106	166	96	22	47	15
	101–200	%	6.2	18.0	15.4	9.6	18.1	17.0	4.3	7.2	4.2
		1411	88	254	217	136	256	240	61	100	59
	201–300	%	1.1	7.2	10.3	7.5	18.4	22.8	9.9	13.4	9.5
		1195	13	86	123	90	220	273	118	172	100
	> 300	%	0.2	2.6	3.5	4.3	10.5	15.5	21.1	29.5	12.7
		806	2	21	28	35	85	125	170	238	102
Means – Średnia			8.8	15.4	10.7	8.5	14.8	13.5	9.2	13.4	5.7

^{xx} significant at P ≤ 0.01 – ^{xx} istotność przy P ≤ 0,01.

these results to the fact that early lactation cows exhibit a higher demand for protein, which is necessary for recovery of the mammary gland and the whole organism. Szarkowski et al. [2009] concluded that during the first months of lactation milk has a low urea content, which is due to cow physiology after calving, and with advancing lactation milk yield increases as does the milk urea content.

The increase in daily yield was accompanied by increases (from 2.5% to 37.0%) in the proportion of milk samples being indicative of dietary energy deficiency (group 1b) and (from 0.7% to 36.0%) in the proportion of samples (group 1c) showing energy deficiency and the concurrent protein excess (Table 3). At the same time, there were decreases from 26.3% to 0.0% in the proportion of milk samples that showed dietary protein deficiency and energy excess (group 3a) and from 39.4% to 1.2% in the proportion of samples showing excess energy (group 3b). In the case of the daily yields of 20.1–30 kg and 30.1–40 kg milk, the samples showing that the rations were balanced for energy and protein were most frequent (17 and 16.9%, respectively) compared to the other milk yield ranges. The decrease and the increase in daily milk yield were paralleled by a reduction in the proportion of milk samples with the optimum protein and urea content. Osten-Sacken [2000] concluded that urea level is higher in high-yielding cows because their rations contain more protein than those intended for lower producing cows. The increase in the amount of protein in dairy cow diets may increase milk production because increased protein supply in the rations may adversely affect cow fertility [Guo et al. 2004]. Furthermore, excess protein intake contributes to environmental pollution and higher costs of feeding [Burgos et al. 2007]. Similar conclusions were drawn by Szarkowski et al. [2009] who noted the urea level to be higher in high yielding cows and to increase with increasing milk yield of the cows. Sawa et al. [2010] observed that the increase in milk yield was paralleled by the increasing proportion of the samples that showed energy deficiency. Arunvipas et al. [2003] reported that urea concentration correlated positively to milk yield and negatively to milk protein content.

When examining the effect of season on frequency of milk samples with specific protein and urea levels, it was observed that their frequency varied considerably especially between the summer and winter seasons (Table 3).

Table 3. Percentage of milk samples with a specific protein and urea content depending on daily milk yield, season of testing, and somatic cell count

Tabela 3. Udział prób mleka o określonej zawartości białka i mocznika w zależności od wydajności dobowej, sezonu oceny, liczby komórek somatycznych

Treatment Czynnik	Treatment classes Klasy czynnika	Measures Miary	Proportion of milk samples with specific protein (%) and urea content, mg l^{-1} Udział prób mleka o określonej zawartości białka (%) I mocznika, mg l^{-1}								
		% n	1a	1b	1c	2a	2b	2c	3a	3b	3c
Daily yield, kg milk Wydajność dobowa, kg mleka chi^2 = 242.99[xx]	≤ 20	%	2.5	2.5	0.7	9.7	12.6	2.5	26.3	39.4	3.8
		683	17	17	5	66	86	17	180	269	26
	20.1–30	%	8.3	11.5	4.4	12.8	17.0	13.9	11.6	13.7	6.8
		1583	131	182	70	202	269	220	183	217	109
	30.1–40	%	15.0	17.3	12.0	7.5	16.9	18.8	0.6	3.8	8.1
		1262	190	219	151	95	213	237	8	48	101
	40.1–50	%	3.5	25.8	26.6	0.3	13.6	23.5	0.0	2.00	4.7
		852	30	220	227	3	116	200	0	17	39
	> 50	%	4.3	37.0	36.0	0.2	8.8	12.3	0.0	1.2	0.2
		489	21	181	176	1	43	60	0	6	1
Season of testing Sezon oceny chi^2 = 754.02[xx]	III–V	%	15.1	10.5	14.1	11.6	12.3	10.9	11.3	12.4	1.8
		1022	154	107	144	119	126	111	116	127	18
	VI–VIII	%	6.5	33.9	9.9	4.0	21.5	7.7	2.4	10.9	3.2
		1184	77	401	117	47	255	91	29	129	38
	IX–XI	%	5.4	16.1	12.4	8.3	15.1	16.4	7.5	11.6	7.2
		1235	67	199	153	103	187	203	93	143	87
	XII–II	%	6.4	7.8	15.1	6.9	11.1	23.0	9.3	11.1	9.3
		1428	91	112	215	98	159	329	133	158	133
Somatic cell count Liczba komórek somatycznych chi^2 = 169.05[xx]	≤ 400	%	8.0	17.8	14.2	6.9	14.6	16.7	6.7	9.8	5.3
		3966	316	706	562	275	579	664	264	390	210
	≥ 401	%	8.1	12.5	7.4	10.2	16.4	7.7	11.8	18.5	7.4
		903	73	113	67	92	148	70	107	167	66
Means – Średnia			7.5	17.5	13.9	7.1	14.5	13.9	8.0	12.3	5.3

[xx] significant at P ≤ 0.01 – [xx] istotność przy P ≤ 0,01.

In the summer season, the composition of 21.5% samples indicated that the ration was balanced, and in winter the proportion of such samples was 11.1%. In the summer, 58% of the samples (groups 1a, 1b, 1c and 2c) showed dietary energy deficiency, whereas 20.8% of the samples (groups 1c, 2c, 3c) had excess protein. This can be explained by the fact that protein-rich forages are added to the rations during the summer season. Similar results were obtained by Baset et al. [2010] and Litwińczuk et al. [2006]. In the winter season, the proportion of milk samples that exhibited excess dietary energy and protein was 9.3% (group 3c) and this was the highest percentage compared to the other seasons. In addition, in the winter season as much as 47.4% of the milk samples (groups 1c, 2c and 3c) showed evidence of excess dietary protein, whereas 36.6% (groups 2a, 3a, 3b and 3c) exhibited excess energy. The high level of protein that we observed in the autumn and winter seasons is supported by Czajkowska et al. [2015] and Szarkowski et al. [2009], who attributed this to seasonal feed change.

The higher percentage of the samples with deficient energy (group 1b) and those exhibiting excess protein along with different degrees of energy deficiency (groups 1c and 2c) was observed when the somatic cell count (SCC) did not exceed 400,000 · ml^{-1}. When SCC was higher than 400,000 · ml^{-1}, there was a considerably higher proportion of milk samples that showed evidence of excess energy (groups 2a, 3a, 3b, 3c). Szarkowski et al. [2009] concluded that excess dietary energy increases milk somatic cell count. Fleszar [2012] reported that excess milk urea occurs with improper feeding and adversely affects the quality of milk by increasing the somatic cell count.

CONCLUSIONS

Lactation number, day of lactation, daily milk yield, season of testing and somatic cell count had a significant effect ($P \leq 0.01$) on the proportion of samples with a specific protein and urea content. There were not enough samples of milk containing 151–300 mg · l^{-1} urea and 3.21–3.6% protein which is indicative that the dietary protein and energy are balanced. Therefore, it would be appropriate to pay greater attention to the determination of protein and urea in milk when formulating the rations for cows. The highest percentage of milk samples with the optimum protein and urea content was observed in multiparous cows during 101–200 and 201–300 days of lactation, which had a daily milk yield of 21–30 kg and 31–40 kg in the summer season. These factors should be considered when formulating cow rations as they influence milk protein and urea levels.

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UDZIAŁ PRÓBEK MLEKA O OKREŚLONEJ ZAWARTOŚCI BIAŁKA I MOCZNIKA W ZALEŻNOŚCI OD WYBRANYCH CZYNNIKÓW W OCENIE BILANSU BIAŁKA I ENERGII W DAWCE DLA KRÓW MLECZNYCH

STRESZCZENIE

Analizowano wpływ stada, kolejnej laktacji, dnia laktacji, sezonu oceny, wydajności dobowej i liczby komórek somatycznych w mleku na udział próbek mleka krowiego o określonej zawartości białka i mocznika. Stwierdzono zbyt mały udział próbek mleka o zawartości mocznika 151–300 mg · l^{-1} i białka 3,21–3,6%, świadczących o zbilansowaniu białka i energii w dawkach pokarmowych. Największy udział próbek mleka o optymalnej zawartości białka i mocznika wystąpił u krów wieloródek, w okresach 101–200 oraz 201–300 dni laktacji, przy wydajności dobowej 21–30 kg oraz 31–40 kg mleka, w sezonie letnim. Powinno się uwzględniać te czynniki jako wpływające na poziom białka i mocznika w mleku przy układaniu dawek pokarmowych dla krów.

Słowa kluczowe: krowy, próby mleka, udział mocznika, udział białka