Ann. Anim. Sci., Vol. 10, No. 2 (2010) 139–155

EFFECT OF CONCENTRATE FEEDING BEFORE CALVING ON FEED INTAKE, METABOLIC PROFILE AND PERFORMANCE OF EARLY LACTATION COWS

Juliusz A. Strzetelski[1], Stanisław Osięgłowski[2], Maria Dymnicka[3]

[1]Department of Animal Nutrition and Feed Science, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[2]National Research Institute of Animal Production, Experimental Farm, 64-122 Pawłowice, Poland
[3]Department of Animal Nutrition and Feed Sciences, Warsaw University of Life Sciences, Ciszewskiego 8, 02-786 Warsaw, Poland

Abstract

A one-factorial experiment was carried out on 36 Polish Holstein-Friesian cows from 6 weeks before parturition until 8 weeks of lactation. Animals were allotted to 4 groups of 9 animals and fed rations with different protein and energy levels before parturition. Cows from the control group (C) received concentrate with barley (55%) and wheat (13%) and cows from groups W6, W4 and W1 were fed concentrate with sorghum (68%). Cows from group C before parturition and early lactation cows from all groups were fed according to IZ-INRA (2001) standards. In each group, the level of concentrates was increased weekly from 3 to 1 week before parturition and animals received 1, 2 and 2 kg/day (group C) and 1, 2 and 4 kg/day (groups W6, W4 and W1) at 3, 2 and 1 week before parturition, respectively. Additionally, 1 kg of concentrate was fed to cows from group W6 (at 6, 5 and 4 weeks before calving) and those from group W4 (at 4th week before calving). It was found that lengthening the period of feeding concentrate containing 68% of sorghum until 4 and especially 6 weeks before parturition while increasing the energy and protein levels in the ration during the last week before calving, caused the greatest decrease in NEFA and BHBA concentration and the greatest increase in serum glucose concentration and slightly improved milk performance of the cows during the first 8 weeks of lactation. This feeding procedure also reduced the number of semen doses per conception, and the costs incurred for additional concentrate given to the animals in the discussed period were completely compensated by a profit from higher milk production. It may be presumed that prolonging the period of feeding sorghum-containing concentrate until 6 weeks before calving allows the alimentary tract to better adapt to digestion of slowly fermented starch in the rumen and decreases the energy deficit in early lactation cows.

Key words: cows, transition period, concentrate with sorghum grain, feeding level, milk yield

The transition period, usually comprising three weeks before and after calving, is the most traumatic period in the production cycle of cows (Holcomb et al., 2001; McNamara et al., 2003). In this period, cows need to cover the nutrient requirements for maintenance, foetal and placental growth, uterus, colostrogenesis and milk production, and for growth in the case of young cows (Vandehaar et al., 1999; Mashek and Beede, 2001; McNamara et al., 2003; Overton and Waldron, 2004). During this time, covering mainly the energy requirements of cows depends first of all on dry matter intake. Unfortunately, in the last stage of pregnancy dry matter intake decreases as a result of changes in the cow's endocrine status (Hayirli et al., 2002; Goff, 2006). Low energy intake causes the release of free fatty acids from body fat reserves into blood, increasing triacylglyceride accumulation in the liver. Liver lipidosis decreases hepatocyte glucogenic capacity and consequently deepens the energy deficit (Goff, 2006). In the early lactation period dry matter intake is also not sufficient and a cow is usually in negative energy balance (NEB).

NEB can be improved by increasing the proportion of non-structural carbohydrates in the diet, either one week before parturition or one week before and after parturition (Vandehaar et al., 1999; Overton and Waldron, 2004; Jurkiewicz et al., 2005). Moreover, prolonged feeding of diets with higher proportions of concentrates up to 6 weeks before parturition can decrease serum non-esterified fatty acids (NEFA) and β-hydroxybutyric acid (BHBA) and increase glucose concentrations, resulting in higher milk yield (Mashek and Beede, 2001; Osięgłowski and Strzetelski, 2006). Apart from their metabolic impact, increased amounts of concentrates consumed a few weeks before calving helps ruminal microbial populations in adapting to the more fermentable diet that is typically fed in early lactation as well as promoting ruminal papillae development (Overton and Waldron, 2004; Goff, 2006).

IZ-INRA (2001) standards recommend gradually increasing the concentrate supply starting from 21 days before expected parturition. These models assume that the amount of concentrate in the last week of pregnancy should not exceed 3 kg/day. They are based more on practical approaches than on real requirements established in metabolic experiments, which are still lacking. However, feeding cows the diets containing more concentrates than it is recommended by standards for this period reduced postpartum NEB and increased milk yield, although the effects of adding concentrate beyond recommended standards were not always statistically significant (Olsson et al., 1998; Vandehaar et al., 1999; Ballard et al., 2001; Jurkiewicz et al., 2005; Osięgłowski and Strzetelski, 2006).

The source of starch and thus the site of its digestion in the alimentary tract of cows may determine whether the cow's glucose requirements are met. Due to limitations in gluconeogenesis in the liver of the transition cow, it may be beneficial to feed bypass starch, such as that in sorghum grain, which increases the amount of starch reaching the small intestine and glucose absorbed. However, the effects of feeding slowly fermented starch in the rumen on energy metabolism and milk yield in this period are still inconsistent (Knowlton et al., 1998; Reynolds et al., 1997; Lykos et al., 1997; Arieli et al., 2001).

The aim of the study was to determine the effect of allocation method of sorghum-containing concentrate pre- and post-calving on dry matter intake and metabolic profile of transition cows, as well as on milk yield and composition in early lactation. Additionally, some reproduction parameters were also studied.

Material and methods

Experimental design

The one-factorial experiment was carried out on 36 Polish Holstein-Friesian cows assigned based on the analogue principle to 4 groups of 9 animals, considering parity (from 2 to 5) and peak milk yield in the previous lactation. The cows from each group were fed diets differing in the amount of concentrates allocated in the weeks before parturition (Table 1). The concentrates for cows from the control group (C) before calving and cows from all groups after calving were allocated according to IZ-INRA (2001) standards. The cows from group C received concentrate B containing 55% barley and 13% wheat (as a source of starch) and the cows from remaining groups were fed concentrate S containing 68% sorghum grain (Table 2). The level of concentrates was increased weekly from 3 to 1 week before parturition and animals received 1, 2 and 2 kg/day (group C) and 1, 2 and 4 kg/day (groups W6, W4 and W1) at 3, 2 and 1 week before parturition, respectively. Additionally, 1 kg of concentrate was fed to cows from group W6 (at 6, 5 and 4 weeks before calving) and those from group W4 (at 4th week before calving). The experiment ended at 8 weeks of lactation.

Table 1. Concentrate rations before calving (kg/day)

Group	Weeks before calving					
	–6	–5	–4	–3	–2	–1*
C	0	0	0	1	2	2
W6	1	1	1	1	2	4
W4	0	0	1	1	2	4
W1	0	0	0	1	2	4

*including: 1 kg soybean meal.

Table 2. Composition of concentrate with barley (B) or sorghum (S) (pelleted, Ø = 0.8 cm)

Feeds	%	
	B	S
Barley, ground	55.0	
Wheat, ground	13.0	
Sorghum, ground		68.0
Wheat bran	3.0	3.0
Soybean meal	18.0	18.0
Rapeseed meal	3.0	3.0
Sugar beet molasses	3.1	3.1
Premix Kuh Gold Mineral[1)]	3.4	3.4
Limestone	1.0	1.0
Binding agent[2)]	0.5	0.5

[1)] Premix Kuh Gold Mineral (SANO), in 1 kg: (g) 70 P, 140 Ca, 35 Mg, 90 Na; (mg) 1000 Cu, 12000 Zn , 4000 Mn; (i.u.) 1000000 vit. A; 130000 vit. A; (mg) 5000 vit. E,

[2)] WAFOLIN S (LIGNOTECH).

Effective degradation in the rumen of starch of barley, wheat and sorghum was determined on three permanently fistulated dry cows with a mean body weight of 670±20 kg, employing in sacco method according to Polish standards (Kowalski et al., 2008). Starch in barley, wheat and sorghum was determined according to Faisant et al. (1995).

Animal management and feeding

Cows were kept in straw-bedded tie-up stalls equipped with feeding troughs enabling the intake of feeds (concentrates and roughages separately) to be individually controlled, and with automatic drinkers and salt licks. Three or four weeks before predicted parturition, the cows were moved to a calving pen, where they were kept until the first week of lactation.

The basal diet contained whole-crop maize silage, lucerne silage, wilted lucerne silage, sugar beet pulp silage, meadow hay and fresh brewers' grains. Soybean meal was used as a protein supplement. Additionally, *Aquablend*, *Supercynk* and *Hydrovit* mineral and vitamin additives (Aquablend, The Netherlands) were supplied in water by automatic drinkers.

Rations for cows were formulated with regard to body weight 3 weeks before calving and assuming the maximum milk production at peak lactation of 43±3 kg.day^{-1}. Cows were fed individually twice a day with basal ration and three times a day with concentrate.

Measurements and collection of samples for analysis

Body weight of cows was measured on days 21, 14 and 7 before expected calving and on days 2, 21 and 56 after calving. Data on insemination index, service interval, service period and open days were collected for each cow. Milk yield was estimated daily using Milk Master equipment. Milk composition was determined in representative daily samples of each cow taken every seventh day of lactation. They were preserved and refrigerated at +4°C for no longer than 2 weeks.

Starting from 6 weeks before calving to 8 weeks of lactation, blood samples were taken every week at about 4 hours after morning feeding from the *vena jugularis* (on the third day of each week) and serum was preserved at –20°C until analysis. The refusals were collected and weighed daily before morning feeding, beginning from 1 week pre-calving to the end of 4 weeks post-calving. During the rest of lactation, refusals were collected for 1 day every 2 weeks.

Chemical analysis

Feed and refusals were analysed according to AOAC (1990) methods. Volatile fatty acids (VFA) in silages were analysed by gas chromatography using Varian 3400 apparatus, 8200CX autosampler and capillary column CP-Wax 58 (25m × 53μ × 1μ). The initial temperature of the column oven (80°C) was increased by 7°C/min to 270°C. Injection temperature was 200°C and detector temperature was 260°C. Helium was used as the carrier gas at a flow of 6 ml/min. 1mL of water extract from the silages was applied to the column. Silage pH was determined with the Auto Kjeldahl

Unit K-370 (Bischi) using pH determination function. Lactic acid was determined by high performance liquid chromatography (HPLC) after separation of water permeates with 24% metaphosphoric acid using column Lichrocart Superspher RP18 250 cm, detector UV 210nm, eluent (1µL H_2O + 100 µ/L H_2SO_4, 1ml/min) and injection 20 µL.

Milk composition (solids, fat, protein, casein, urea) was determined using a Milko-Scan FT 120 (Foss Electric, Denmark).

Non-esterified fatty acids (NEFA) in blood serum were determined colorimetrically using acyl-CoA synthetase, oxidase and peroxidase (WAKO Reagents). D-3 hydroxybutyric acid (BHBA) was determined by kinetic enzymatic reaction using a Cobas-Bio analyser (Roche) and a high-sensitivity reagent kit (RANDOX). Glucose was determined using a VITROS 950 analyser (Ortho-Clinical Diagnostic; Test Methodology Manual, 1997).

Economic analysis

Economic evaluation was conducted according to the method reported by Okularczyk (1995), based on the data for milk yield and feed costs. Non-feed expenses incurred during the study were not included because they were the same for all animals. Income from 1 litre of milk obtained during the experiment was compared.

Calculations and statistical analysis

Energy and protein values of the feeds used in the experiment as well as the composition of concentrates and diets were formulated according to the IZ-INRA (2001) standards based on chemical composition using WINWAR 1.6 (2000) and INRAtion 2.63 (1998/99) software.

Predicted peak milk production (PPM = mean of the "maximum" week) was calculated according to IZ-INRA (2001) equation PMP = IP × 1.33, where IP – initial production = mean yield at 4, 5 and 6 days of lactation.

The results were subjected to one-way analysis of variance using the GLM procedure of SAS (2001). The differences between treatments were then estimated using the LSM method. Significance was set at $P<0.05$.

Results

During the experiment, one cow from group W4 and three cows from group W1 were eliminated for reasons beyond our control. The difference between the predicted and actual day of calving averaged (days): 0.6 (group C), 2.2 (W6), 1.6 (W4) and 3.0 (W1). Effective rumen degradability (ERD) of starch of barley, wheat and sorghum was 0.93, 0.90 and 0.61 and content of starch in these feeds was 670, 711 and 669 g/kg, respectively.

The nutrient content of the feeds and their nutritive value are given in Table 3. The concentrate allocation method had a significant effect on DM and nutrient intake in the last week before parturition (Table 4). However, there were no differences among treatments in the intake of DM of basal ration. Cows from groups W6, W4 and W1 consumed more total DM, concentrate DM, protein as PDI and energy as UFL than cows from the control group (P<0.01/P<0.05). During the first 8 weeks of lactation the cows from groups W6 and W4 had a slightly higher intake of dry matter and nutrients than those from the other groups.

Table 3. Chemical composition and nutritive value of feeds in 1 kg DM

Feeds	Dry matter (g)	Crude protein (g)	Ether extract (g)	Crude fibre (g)	Ash (g)	PDIN (g)	PDIE (g)	UFL
Maize silage*	44.8	95	42.6	181.6	41.0	59	74	0.90
Lucerne silage*	23.8	145	28.2	342.3	122.5	85	65	0.75
Lucerne silage, wilted	44.9	174	34.1	254.1	120.0	99	66	0.74
Sugar beet pulp silage	20.0	101	14.0	231.4	47.9	61	98	1.00
Meadow hay	84.1	114	17.8	340.5	53.1	71	78	0.72
Brewers grain	23.9	257	52.2	191.3	42.6	191	173	0.91
Wheat bran	87.0	174	41.2	106.4	81.1	115	96	0.90
Wheat, ground	87.1	144	17.8	57.2	23.3	98	115	1.19
Barley, ground	87.3	129	22.2	46.5	23.8	84	105	1.18
Sorghum, ground	87.5	116	33.2	22.8	15.5	92	139	1,19
Soybean meal	88,2	490	20.1	86.7	72.6	349	243	1.19
Rapeseed meal	89.5	375	34.6	138.1	78.4	243	154	1.10
Concentrate B	86.7	196	21.3	47.0	90.0	133	126	1.11
Concentrate S	87.7	188	32.5	39.0	85.0	137	148	1.12

*) Fermentation products (FP): lactic acid + acetic acid + butyric acid,
FP of maize silage = 19.98 g/kg of feed, pH = 4.85,
FP of lucerne silage = 25.94 g/kg of feed, pH = 4.90,
FP of lucerne silage, wilted = 21.85 g/kg of feed, pH = 5.01.

No differences (Table 5) were found between the groups in initial (IP), predicted (PMP) and actual maximum milk production (AMP) at peak lactation (p>0.05), but AMP value in groups W6 and W4 was numerically about 2 kg milk higher than in groups C and W1. In all groups, the cows achieved AMP at 5.5±0.5 weeks of lactation on average.

The concentrate allocation method did not significantly influence milk yield and composition, although in the control group (C), compared to the other groups and especially groups W6 and W4, numerically lower values were observed (Table 6).

Table 4. Daily feed and nutrient intake

Group	Dry matter (kg)	Basal forage[1] (kg DM)	Concentrate (kg DM)	Crude protein (kg)	PDIN (kg)	PDIE (kg)	UFL
Final week before calving							
CG	14.60 a	12.92	1.68 a	2.47	1.53	1.29 a	12.19 a
W 6	16.52 b	13.24	3.28 b	2.77	1.74	1.53 b	14.20 b
W 4	16.00 b	12.83	3.17 b	2.68	1.69	1.48 b	13.75 b
W 1	16.14 b	12.63	3.51 b	2.76	1.75	1.54 b	14.00 b
SE	0.25	0.16	0.17	0.05	0.04	0.04	0.25
p	<0.01	0,79	<0.01	0.13	0.13	< 0.05	<0.01
From calving to 8 weeks of lactation							
	24.56 a	15.70	8.59	4.38	2.82	2.49 a	22.57 ac
	25.93 b	16.90	9.03	4.31	2.97	2.80 b	23.92 bd
	25.02 b	16.20	8.82	4.40	2.90	2.71 b	23.11 cd
	24.82 ab	15.95	8.78	4.29	2.83	2.67 b	22.93 ad
SE	0.22	0.15	0.09	0.04	0.03	0.03	0.21
p	<0.05	0.12	0.055	0.25	0.08	<0.01	<0.05

(1) Silages + meadow hay + brewers' grains.
SE = $\sqrt{S^2}$ /n, for the whole population.
Within the column: P>0.05 – non-significant differences; a, b, c, d – P<0.05.

Table 5. Peak milk production (PM)

Item	Groups				SE	p
	CG	W6	W4	W1		
IP (kg/day)	35.31	37.55	35.30	34.20	1.01	0.52
PPM (kg/day)	46.91	49.93	46.96	45.48	1.35	0.52
APM (kg/day)	46.00	47.78	47.93	45.83	0.90	0.77

P>0.05 – differences are not statistically significant.
IP – initial production, mean yield at 4, 5 and 6 days of lactation (IZ – INRA, 2001).
PPM – predicted PM (PMP = IP × 1.33), IZ – INRA (2001).
APM – actual PM.

Table 6. Milk yield and composition

Item	Group				SE	p
	CG	W6	W4	W1		
Total milk production (kg)	2164.7	2293.3	2299.9	2200.9	42.16	0.06
Milk yield (kg/day)	38.66	40.95	41.07	39.30	0.75	0.06
Increase in milk yield (%)	100	+5.2	+5.4	+1.1		
Yield of milk components (kg/week):						
Fat	11.31	11.92	11.93	11.52	0.24	0.26
Protein	8.77	9.34	9.31	8.83	0.18	0.06
Lactose	12.72	13.79	13.88	12.87	0.22	0.09

No differences (P>0.05) were also found between the groups in the content of fat and protein in milk but lactose content was higher (P<0.01) in groups W6 and W4 compared to groups C and W1 (Table 7).

Table 7. Milk composition (%)

Group	Fat	Protein	Casein	Urea	Lactose
C	4.18	3.24	2.64	0.025	4.70 a
W 6	4.16	3.26	2.70	0.025	4.81 b
W 4	4.15	3.24	2.65	0.021	4.83 b
W 1	4.19	3.21	2.61	0.026	4.68 a
SE	0.05	0.035	0.02	0.007	0.02
p	0.14	0.14	0.07	0.08	<0.01

The concentrate with sorghum did not affect concentrate, dry matter, energy or protein conversion calculated for 1 kg of milk (Table 8) as compared to the control group.

Table 8. Concentrate and nutrient conversion (per kg milk production), mean for 8 weeks of lactation

Groups	Concentrate (kg)	Dry matter (kg)	Crude protein (g)	PDI (g)	UFL
C	0.26	0.63	113.3	64.4	0.583
W6	0.25	0.63	110.1	68.3	0.584
W4	0.25	0.61	107.1	65.9	0.563
W1	0.26	0.63	109.1	67.9	0.583
SE	0.003	0.09	2.92	1.68	0.015
p	0.68	0.62	0.44	0.30	0.65

Both before and after calving, differences in the body weight of cows between the groups were not significant (P>0.05) for all measurements (Table 9).

Table 9. Body weight before and after calving (kg)

Day from parturition	Group				p	SE
	C	W6	W4	W1		
–21	677.6	689.4	687.6	696.1	9.92	0.85
–14	686.8	710.4	675.6	696.9	6.34	0.06
–4 (average)	701.8	712.8	710.2	720.1	6.26	0.06
+2	648.4	661.2	659.0	665.4	10.39	0.43
+21	632.0	652.0	641.1	654.6	9.19	0.47
+56	614.6	642.0	635.9	616.0	8.68	0.22

P>0.05 – differences are not statistically significant.

Differences between feed costs and the value of milk produced were more beneficial for cows receiving additional concentrate with sorghum (particularly in group W6) in comparison with cows from the control group (Table 10).

Table 10. Economic analysis based on milk yield up to 56 days of lactation

Item	Groups			
	C	W6	W4	W1
Costs of feeds, €	178.66	190.86	189.75	184.06
Total milk produced, L	2025.1	2318.4	2214.9	2124.11
Value of milk produced, € (0.24 €/L)	490.29	561.29	536.23	514.25
Difference, €	311.63	370.43	346.47	330.19
Profit, €	0	58.80	34.85	18.57

Exchange rate during the study period: 1 € =3.68 PLN.

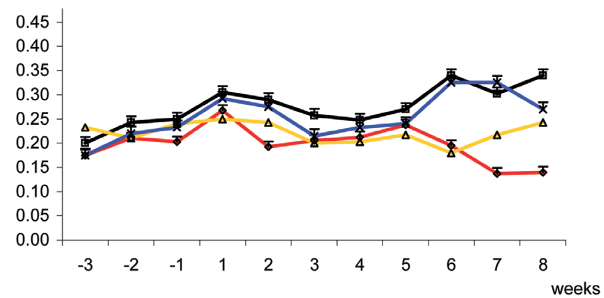
Differences between the groups in reproductive parameters were not significant (P>0.05), although cows from group W6 were characterized by numerically lower insemination index values (Table 11).

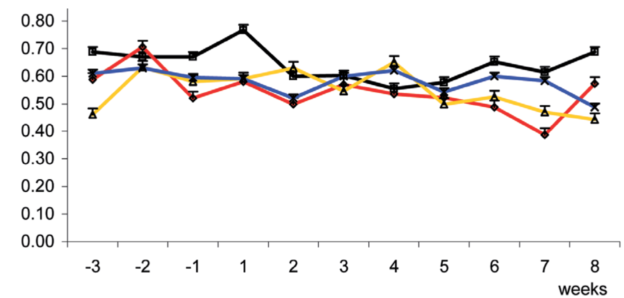
Table 11. Cow reproduction performance

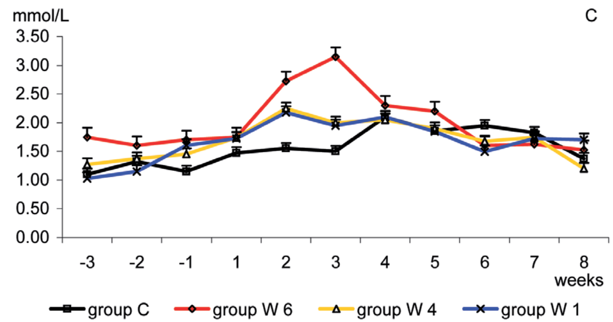
Item	Group				p	SE
	C	W6	W4	W1		
Insemination index[1]	3.00	2.29	2.71	2.83	0.79	0.25
Service interval, days[2]	83.2	72.0	86.0	68.2	0.54	13.62
Service period, days[3]	57.4	72.3	55.3	56.3	0.96	12.17
Open days[4]	140.6	144.3	141.3	124.5	0.96	13.62

P> 0.05 – differences are not statistically significant.
[1]Number of semen doses per effective insemination.
[2]Period from parturition to first insemination.
[3]Number of days from first to successful insemination.
[4]Number of days from calving to successful insemination.

Periparturient cows from group W6 were characterized by the lowest serum concentration of NEFA (P<0.01) and BHBA (P<0.088) and the highest glucose level (P<0.01), especially during the first several weeks of lactation (Figure 1). During the same period, cows from group C had greatest NEFA and BHBA concentrations and lowest glucose concentration of all groups.







Group	Average before and after calving, mmol/L					
	before	after	before	after	before	after
	A		B		C	
W 6	0.20	0.20 b	0.59	0.52	1.68b	2.11 b
W 4	0.22	0.22 b	0.60	0.54	1.37c	1.82 a
W 1	0.21	0.27 a	0.61	0.58	1.26ac	1.84 a
SE	0.007	0.009	0.023	0.016	0.073	0.054
p	0.463	<0.01	0.560	0.088	<0.01	<0.01

Figure 1. Serum concentration of non-esterified fatty acids (A), β-hydroxy-butyric acid (B) and glucose (C) during successive weeks of experiment and mean values of these parameters for all weeks (in the table)

Discussion

Increasing the amount of concentrates with sorghum grain by 2 kg in the last week before calving in groups W6, W4 and W1, compared with group C in which cows were fed concentrate with barley and wheat resulted in higher concentrate proportion (by about 9 percentage units) in DM of daily ration. The cows from groups W6, W4 and W1 consumed overall about 1.79 UFL, 0.26 kg CP and 0.23 kg PDI more than those from group C. This result was mainly due to the higher consumption of concentrates with sorghum because the intake of the basal ration was similar among treatments.

The concentrate with sorghum affected DM, PDIE and UFL intake postpartum to a greater extent than concentrate containing barley and wheat. Some authors reported higher DM intake when maize or sorghum replaced barley (Khorasani et al., 1994; Mitzner et al., 1994; Yang et al., 1997; Silveira et al., 2007). However, Grings et al. (1992) and Casper et al. (1999) did not find differences in DM intake when comparing barley and maize in diets for early lactation. Such contradictory results can be attributed to differences in the proportions of these feeds in the ration or concentration of starch in the diet (De Visser et al., 1990; Grings et al., 1992). It can also be suggested that reasonably high proportions of forages in the diet, particularly prepartum, stimulating rumination and saliva secretion could mask the effect of starch source on rumen fermentation. The higher PDIE intake postpartum by cows fed sorghum-containing concentrate could be attributed to the higher content of this component, because daily intake of both concentrate mixtures was similar.

Decreasing DM intake by cows from group C resulted in numerically lower yields of milk and milk components compared to the other groups, especially W6 and W4. As for DM intake, the best milk yield was observed for cows fed increasing amounts of concentrates with sorghum in the last week before parturition, particularly when fed from 4 or 6 weeks before calving. Also Ryan (1999) found that cows fed rations enriched in energy before parturition produced more milk, protein and fat for 8 weeks after calving. The actual milk yield at the peak of lactation also indicates an advantageous influence of a higher amount of concentrates with sorghum in diets given one week before parturition, particularly together with prolonged allocation of concentrates from 4 or 6 weeks before parturition (groups W4 and W6).

The results observed for group W1 suggested that increasing concentrate with sorghum grain by 2 kg in the last week before parturition compared with cows fed concentrate containing barley and wheat had no strong effect on milk yield. In addition, the differences among treatments were not statistically proved. In numerous studies carried out on cows from weeks 3, 4 or 6 before calving until weeks 4 or 8 of lactation it was found that feeding rations enriched in energy and protein resulted in higher milk production but the differences, although in many cases quite high, were not often significant (Olsson et al., 1998; Vandehaar et al., 1999; Ballard et al., 2001; McNamara et al., 2003). In such experiments the management conditions as well as physiological stage should be clearly defined (Ballard et al., 2001). Although cows from groups W6, W4 and W1 consumed more DM compared with group C and produced somewhat more milk, the concentrate and nutrient expenditure for production of 1 kg milk was similar among groups.

Comparing the effect of increasing the amount of concentrate with sorghum in the last week before parturition and lengthening concentrate allocation (group W1 vs. W6 and W4) it seems that the second factor had a much stronger effect on milk yield when the cows were fed slowly fermented starch. Higher doses of concentrate with sorghum in these periods may improve the energy balance and better prepare the rumen environment (rumen papilla growth and adaptation of rumen microorganisms) to digest diets rich in sorghum starch fed post-calving (Overton and Waldron, 2004). Although the effect of extending the feeding of concentrate with sorghum was not significant, the cows from groups W6 and W4 produced numerically more milk.

The extended feeding of concentrate with sorghum before calving could provide the rumen with more substrates for growth of rumen papillae and bacteria, which could be beneficial in the precalving period. On the other hand, lower fermentation of sorghum starch could provide cows with more glucose absorbable in the small intestine, which could improve the energy balance. However, it should be considered that pancreatic secretion of amylase in cattle is limited and starch passing to the small intestine may be entirely digested (Reynolds et al., 1997; Hungtington et al., 2006) and digestibility of starch may gradually decrease with increasing amounts of starch passing to the small intestine (Matthé et al., 2003). Considering the starch content in sorghum grain and starch degradation in the rumen we can calculate that during lactation, the bypass of starch of sorghum could amount to about 3.0 kg/day. Perhaps this has contributed to limiting the increase in milk performance of the cows fed the sorghum-containing mixture. In one study conducted with dairy cows, it was demonstrated that if the bypass of starch did not exceed 1.3–1.8 kg/day/animal, it was more effectively utilized in the small intestine. On the other hand, the longer the adaptation of rumen microorganisms to digestion of concentrates before calving, the more of slowly-fermented starch was subjected to degradation in the rumen and less passed to the small intestine (Matthé, 2001). Perhaps extending the feeding of concentrate with sorghum before calving increased starch fermentation in the rumen. It may be supposed that it had a favourable effect on development of the absorptive surface of the rumen wall, gluconeogenesis and intestinal digestibility of sorghum starch. This was partially confirmed by a higher level of blood serum glucose and numerically higher milk yield in cows from groups W6 and W4, which was connected with the higher milk lactose level.

The lack of significant differences in milk fat and protein content between concentrate allocation methods was probably caused by similar roughage to concentrate DM ratio in the rations during the lactation period (65%:35%). Feeding diets with sorghum lowered starch fermentation in the rumen and probably did not cause changes in milk fat content in the sorghum-fed cows compared with barley- and wheat-fed cows. Other authors (Matthé et al., 2003; Strzetelski et al., 2008) demonstrated a higher milk fat content in a maize diet compared with wheat or barley that is easily fermented in the rumen. Santos et al. (1997) have not found any differences in fat and protein content in the milk from the cows fed rations containing crushed sorghum grain or barley. The similar content of protein in the milk of cows from all groups during the analysed period of lactation (8 weeks) may be indicative of similar energy balance of these animals. However, compared with cows from group C the consumption of total DM, basal ration DM, concentrates, energy and PDI in the 8-week period of lactation was higher from the sorghum-fed cows, particularly in groups W6 and W4. This suggests a better energetic status of these cows, as also indicated by the serum concentration of NEFA and BHBA and higher serum glucose content (mainly in early lactation). It can be assumed that these cows were less prone to ketosis and may also indicate a positive effect of extending concentrate feeding before calving. Holcomb et al. (2001) found that cows fed high-concentrate rations before calving were characterized by low serum concentration of NEFA after calving compared to cows receiving low amounts of concentrate. According to these authors, this may suggest a limitation in the use of body fat reserves. On the other hand a lower BHBA content may be indicative of better energy balance. The cows from the control group had the highest serum BHBA, which brought them close to ketosis. McNamara et al. (2003 a) showed a non-significant correlation between serum NEFA concentration and negative energy balance and suggested that NEFA was not a sufficiently accurate indicator of negative energy balance in early lactation. On the other hand, a significant negative correlation between BHBA concentration in the blood and the negative energy balance found by these authors, allows considering BHBA a more useful indicator of energy balance compared with glucose or NEFA. Other studies showed a negative correlation between blood NEFA level and the energy balance (Vanderhaar et al., 1999). Grummer (1993) and Herdt et al. (1995) reported that the low serum level of NEFA limited the risk of fatty liver degeneration.

The low level of blood serum glucose in all groups before and after calving can be attributed to the increased mammary gland requirement for glucose needed for lactose production (Ballard et al., 2001; Manderbru et al., 2003). Nevertheless, in group W6 the glucose level remained the highest. Whitaker (1997) suggests, however, that glucose is not as sensitive an indicator of energy balance of periparturient cows as NEFA and BHBA. Meanwhile, prolonging the concentrate feeding period to 6 weeks before calving and increasing the feeding level during the final week before calving probably improved the energy and protein balance and fulfilled the nutrient requirements of late pregnancy and early lactation cows to a greater degree than the cow feeding method used in the other groups.

The urea level in the milk of cows from all the groups indicates that the energy-protein balance in the rumen, which reflects diet formulation, did not deteriorate.

The absence of differences between treatments in body weight of cows may suggest that the diets sufficiently covered the requirements of the cow and foetus. Early concentrate allocation (6 weeks before calving) could expose the cows to overconditioning, which was not observed in our study, probably due to the low dose of concentrates given between weeks 6 and 4 prepartum. Mashek and Beede (2001) did not find a negative effect on BCS of a high energy diet fed during the whole six-week dry period.

The better insemination index in group W6 suggests improved energy balance of the cows fed during 6 weeks of dry period with additional concentrate with slowly fermented starch. Reksen et al. (2001) reported that in high-yielding cows, the improvement of energy balance after calving enabled the ovulatory ovarian activity to occur earlier, while the prolonged energy deficit made this process considerably slower. Other authors also showed an inverse relationship between the energy balance and resumption of ovarian activity in dairy cows (Senatore et al., 1996; De Vries et al., 1998).

Although there were no significant differences between the cows from different groups in milk production during lactation, the increase in milk production, observed in group W6 from calving day to 8 weeks of lactation was the highest compared to the control group (about +6%) and enabled an extra profit of €58.80 per cow on average from additional milk production. According to Agenäs et al. (2003), the increased proportion of concentrates in feeding ration administered before calving may negatively affect the economic results as the costs of the additional concentrates would not be compensated by the increased milk production.

The results of the present experiment suggest that addition of sorghum meal (68%) to concentrates instead of ground barley and wheat and the simultaneous feeding of cows with the increased proportion of this diet (in relation to IZ-INRA 2001 standards) during the last week before parturition, had only a small favourable effect on cow productivity and metabolic profile. More favourable effects were obtained when the cows were fed the sorghum-containing mixture for 4 weeks (group W4) and especially for 6 weeks (group W6) before parturition. These cows produced about 6% more milk during 8-week lactation and were characterized by numerically higher fat and protein yield. In addition, the serum NEFA and BHBA content was the lowest, glucose concentration was the highest and the insemination index was somewhat improved when the cows were fed sorghum during 6 weeks before calving. The cost of additional concentrate offered during the 6 or 4 weeks before calving was compensated by the income from higher milk production.

In conclusion, the results of the present study show that when feeding cows with concentrate containing slowly fermented starch from sorghum grain it is appropriate to prolong the concentrate feeding period before calving from 3 to 6 weeks and meanwhile to increase the amount of concentrate during the last week of pregnancy in relation to the IZ-INRA standards (2001). Such feeding caused the lowest serum NEFA and BHBA, the highest serum glucose, and improved the insemination index. These tendencies may indirectly indicate better energy balance of the cows.

References

Agenäs S., Brstedt E., Holtenius K. (2003). Effects of feeding intensity during the dry period. 1. Feed intake, body weight, and milk production. J.Dairy Sci., 86: 870–882.

AOAC (1990). Association of Official Analytical Chemists. Official methods of analysis, Arlington. VA. 15 ed., 1, 684.

Arieli A., Abramson S., Mabjeesh S.J., Zamwel S., Bruckental I. (2001). Effect of site and source of energy supplementation on milk yield in dairy cows. J. Dairy Sci., 84: 462–470.

Ballard C.S., Manderbru P., Sniffen C.J., Emanuele S.H., Carter M.P. (2001). Effect of feeding and energy supplement to dairy cows pre- and postpartum on intake, milk yield and incidence of ketosis. Anim. Feed Sci. Tech., 93, 1–2: 55–69.

Casper D.P., Maiga H.A., Brouk M.J., Schinogoethe D.J. (1999). Synchronization of carbohydrate and protein sources on fermentation and passage rates in dairy cows. J. Dairy Sci., 82: 1779–1790.

De Visser H., Van Der Tagt P.L., Tamminga S. (1990). Structural and non-structural carbohydrates in concentrate supplements of silage-based dairy cow rations: 1. Feed intake and milk production. Neth. J. Agr. Sci., 38: 487–498.

De Vries M.J.,Van Der Beek S., Kaal L.M.T.E., Ouweltjes W., Wilmink J.B.M. (1998). Modeling of energy balance in early lactation and the effect of energy deficits in early lactation on first detected estrus postpartum in dairy cows. J. Dairy Sci., 80: 1927–1934.

Faisant N., Champ M., Buléon A., Colonna P., Molis C., Lartigue S., Galmiche J.P., Champ M. (1995). Digestion of raw banana starch in the small intestine of healthy humans: structural features of resistant starch. Br. J. Nutr., 73: 111–123.

Goff J.P. (2006). Major advances in our understanding of nutritional influences on bovine health. J. Dairy Sci., 89: 1292–1301.

Grings E.E., Roffler R.E., Deitelhoff D.P. (1992). Evaluation of corn and barley as energy sources for cows in early lactation fed alfalfa-based diets. J. Dairy Sci., 75: 193–200.

Grummer R.R. (1993). Etiology of lipid-related metabolic disorders in periparturient dairy cows. J. Dairy Sci., 76: 3882–3896.

Hayirli A., Grummer R.R., Northeim E.V., Crump P.M. (2002). Animal and dietary factors affecting feed intake during the pre-fresh transition period in Holsteins. J. Dairy Sci., 85: 3430–3443.

Herdt T.H., Vandehaar M.J., Yousif G., Sharma B.K., Emery R.S., Allen M.S., Liesman J.S., Lansing E. (1995). Effects of prepartum diet and parity on plasma lipid dynamic and liver triglyceride concentrations in dairy cows. Proc. IX Int. Conf. Production diseases farm animals, Berlin (Germany), 11–14.09.1995, p. 48.

Holcomb C.S., Van Horn H.H., Head H.H., Hall M.B., Wilcox C.J. (2001). Effects of prepartum dry matter intake and forage percentage on postpartum performance of lactating dairy cows. J. Dairy Sci., 84: 2051–2058.

Huntington G.B., Harmond L., Richard C.J. (2006). Sites, rates and limits of starch digestion and glucose metabolism in growing cattle. J. Anim. Sci., 84, E Suppl.: E14–E24.

IZ-INRA (2001). Feeding value of feedstuffs for ruminants (in Polish). In: Feeding of cattle, sheep and goats. National Research Institute of Animal Production, Krakow (Poland), pp. 21–47.

Jurkiewicz A., Strzetelski J., Kowalczyk J., Bilik K. (2005). Concentrate-enriched diets for calving heifers in the periparturient period increase milk yield and improve blood metabolite profile. J. Anim. Feed Sci., 14, Suppl. 1: 259–262.

Khorasani G.R., Okine E.K., Kennelly J.J. (1994). Effects of substituting barley grain with corn on ruminal fermentation characteristics, milk yield and milk composition of Holstein cows. J. Dairy Sci., 84: 2760–2769.

Knowlton K.F., Glenn B.P., Erdman R.A. (1998). Performance, ruminal fermentation, and site of starch digestion in early lactation cows fed corn grain harvested and processed differently. J. Dairy Sci., 81: 1972–1984.

Kowalski Z.M., Strzetelski J.A., Niwińska B., Nowak W., Pająk J., Szyszkowska A. (2008). Standard methods of estimating protein degradability in digestive tract of ruminants. Wiad. Zoot., 4: 53–58.

Lykos T., Varga G., Casper D.P. (1997). Varying degradation rates of nonstructural carbohydrates: Effects on ruminal fermentation, blood metabolites, and milk production and composition in high production Holstein cows. J. Dairy Sci., 80: 3341–3355.

Manderbru P., Ballard C.S., Sniffen C.J., Tsang D.S., Valdes F., Miyoshy S., Schlatter L. (2003). Effect of feeding and energy supplement prepartum and postpartum on milk yield and composition and incidence of ketosis of dairy cows. Anim. Feed Sci. Tech., 105: 81–93.

Mashek D.G., Beede D.K. (2001). Peripartum responses of dairy cows fed energy-dense diets for 3 or 6 weeks prepartum. J. Dairy Sci., 84: 11–125.

Matthé A. (2001). Nährstoffumsetzungen im Verdauungstrakt des Rindes nach Einsatz unterschiedlicher Mengen an Mais- und Weizenstärke. Dissertation. Justus Liebig Universität Giesen.
Matthé A., Lebzien P., Hric I., Flachowsky G. (2003). Influence of prolonged adaptation periods on starch degradation in the digestive tract of dairy cows. Anim. Feed Sci. Tech., 103: 15–27.
McNamara S., O'Mara F.P., Rath M., Murphy J.J. (2003). Effects of different transition diets on dry matter intake, milk production, and milk composition in dairy cows. J. Dairy Sci., 86: 2397–2408.
McNamara S., Murphy J.J., Rath M., O'Mara F.P. (2003 a). Effect of different transition diets on energy balance, blood metabolites and reproductive performance in dairy cows. Livest. Prod. Sci., 84: 195–206.
Mitzer K.C., Owen F.G., Grant R.J. (1994). Comparison of sorghum and grains in early and midlactation diets for dairy cows. J. Dairy Sci., 77: 1044–1051.
Okularczyk S. (1995). Minimization of milk production costs (in Polish). CDiER, Poznań, 8, 35 pp.
Olsson G., Emanuelson M., Wiktorson H. (1998). Effects of different nutritional levels prepartum on the subsequent performance of dairy cows. Livest. Prod. Sci., 53: 279–290.
Osięgłowski S., Strzetelski J. (2006). Effect of the period of feeding higher energy diets to prepartum cows on early-lactation milk yield. Pol. J. Nat. Sci., Suppl. 3: 211–217.
Overton T.R., Waldron M.R. (2004). Nutritional management of transition cows: Strategies to optimize metabolic health. J. Dairy Sci., 87, E Suppl.: E105–E119.
Reksen O., Grohn Y.T., Hawrevoll O.S., Bolsad T.,Waldmann A., Ropstad E. (2001). Influence of concentrate allocation and energy balance on postpartum ovarian activity in Norwegian cattle. J. Dairy Sci., 84: 1060–1068.
Reynolds C.K., Sutton J.D., Beever D.E. (1997). Effect of feeding starch to dairy cattle on nutrient availability and production. In: Recent advances in animal nutrition. P.G. Garnsworthy, J. Wiseman and W. Haresign eds Nottingham University Press, Leughborough, UK, 105–134 SAS, 2001.
Ryan T.G. (1999). Strategies for the feeding and management of dairy cows for both seasonal and non-seasonal milk production systems in Ireland. Ph.D.thesis, National University of Ireland, Dublin.
Santos F.A.P., Huber J.T., Thurer C.B., Swingle R.S., Wu Z., Simas J.M., Chen K.H., Chan S.C., Santos J., De Peters E.J. (1997). Comparison of barley and sorghum grain processed at different densities for lactating dairy cows. J. Dairy Sci., 80, 9: 2098–2103.
Senatore E.M., Butler W.R., Oltenacu P.A. (1996). Relationships between energy balance and postpartum ovarian activity and fertility in first lactation dairy cows. J. Anim. Sci., 62: 17–23.
Silveira C., Oba M., Beauchemin K.A., Helm J. (2007). Effects of grains differing in expected ruminal fermentability on the productivity of lactating dairy cows. J. Dairy Sci., 90: 2852–2859.
Strzetelski J.A., Osięgłowski S., Kowalski Z.M., Kowalczyk J., Borowiec F., Sosin E. (2008). Effect of pre- and post-calving concentrate allocation method and of starch source on feed intake, blood metabolite profiles and performance of transition cows. J. Anim. Feed Sci., 17: 473–490.
Vandehaar M.J., Yousif G., Sharma B.K., Herdt T.H., Emery R.S., Allen M.S., Liesman J.S. (1999). Effect of energy and protein density of prepartum diets on fat and protein metabolism of dairy cattle in the periparturient period. J. Dairy Sci., 82: 1282–1295.
Whitaker D.A. (1997). Interpretation of metabolic profiles in dairy cows. Cattle Practice, 5: 57–60.
Yang W.Z., Beauchemin K.A., Farr B.I., Rode L.M. (1997). Comparison of barley, hull-less barley, and corn in the concentrate of dairy cows. J. Dairy Sci., 80: 2885–2895.

Accepted for printing 22 IV 2010

JULIUSZ A. STRZETELSKI, STANISŁAW OSIĘGŁOWSKI, MARIA DYMNICKA

Wpływ zadawania paszy treściwej przed wycieleniem na pobranie paszy, profil metabolitów krwi i produkcyjność krów we wczesnej laktacji

STRESZCZENIE

Przeprowadzono jednoczynnikowe doświadczenie na 36 krowach rasy polski HF w okresie od 6. tygodnia przed wycieleniem do 8. tygodnia laktacji. Zwierzęta przydzielono do 4 równo liczebnych grup i żywiono przed porodem dawkami o zróżnicowanym poziomie białka i energii. W grupie kontrolnej (C) krowy otrzymywały mieszankę paszową zawierającą jęczmień (55%) i pszenicę (13%), którą skarmiano zgodnie z zaleceniami norm IZ-INRA (2001) zarówno przed wycieleniem, jak i we wczesnej laktacji. W grupach W6, W4 i W1 krowy otrzymywały mieszankę paszową z udziałem sorga (68%). W każdej grupie zwiększano tygodniowo, począwszy od 3. do 1. tygodnia przed wycieleniem poziom zadawanej mieszanki paszowej (kg/dzień w 3., 2. i 1. tygodniu przed porodem): w grupie C – 1, 2, 2; w grupach W6, W4 i W1 – 1, 2, 4. Dodatkowo w grupie W6 krowy otrzymywały 1 kg mieszanki paszowej w 6., 5. i 4. tygodniu przed wycieleniem, a krowy z grupy W4 w 4. tygodniu przed porodem. Stwierdzono, że wydłużenie do 4, a szczególnie do 6 tygodni przed porodem okresu skarmiania mieszanki treściwej zawierającej 68% sorga, przy równoczesnym zwiększeniu poziom energii i białka w dawce w ostatnim tygodniu przed wycieleniem, spowodowało największe obniżenie stężenia NEFA i BHBA oraz największy wzrost stężenia glukozy w surowicy krwi i poprawiło nieco wydajność mleczną krów w pierwszych 8 tygodniach laktacji. Żywienie takie spowodowało także niższe zużycie nasienia na jeden skuteczny zabieg inseminacyjny, a koszty poniesione na dodatkową paszę treściwą skarmioną w tym okresie zostały w całości zrekompensowane zyskiem z wyższej produkcji mleka. Można przypuszczać, że wydłużenie do 6 tygodni przed wycieleniem okresu zadawania paszy treściwej zawierającej sorgo pozwala na lepszą adaptację przewodu pokarmowego do trawienia skrobi wolno fermentowanej w żwaczu i zmniejsza deficyt energetyczny krów we wczesnej laktacji.