Journal of Animal and Feed Sciences, 17, 2008, 473–490

Effect of pre- and post-calving concentrate allocation and of starch source on feed intake, blood metabolite profiles and performance of transition cows

J.A. Strzetelski[1,5], S. Osięgłowski[2], Z.M. Kowalski[3], J. Kowalczyk[4], F. Borowiec[3] and E. Sosin[1]

National Research Institute of Animal Production,
[1]Department of Feed Science and Animal Nutrition
32-083 Balice, Poland
[2]Experimental Station
64-152 Pawłowice, Poland
[3]University of Agriculture in Krakow, Department of Animal Nutrition
30-059 Kraków, Poland
[4]The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences
05-110 Jabłonna, Poland

(Received 22 July 2008, accepted 27 October 2008)

ABSTRACT

A two-factorial experiment was carried out on Polish Holstein-Friesian cows from the 6th week before parturition to the 12th week of lactation, allotted into 6 groups of 8 animals that before parturition and in the first week of lactation were fed rations differentiated in protein and energy levels. Animals of each group received two kinds of concentrate (1.10-1.12 UFL/kg DM) containing barley (subgroup B) or maize (subgroup M) as the main source of energy. Cows from group I (control) were fed according to IZ-INRA (2001) standards before parturition and in early lactation. The level of concentrate in diets for every group was increased weekly either from week 3 before parturition to the first week of lactation (kg/day in week 3, 2, 1 before parturition and week 1 after parturition, respectively): in group I - 1, 2, 2, 4; group II - 1, 2, 4, 6; group III - 2, 2, 2, 4; group IV - 2, 2, 4, 6 or from week 6 before parturition to the first week of lactation (kg/day in week 6, 5, 4 3, 2, 1 before parturition and week 1 after parturition, respectively): group V - 2, 2, 2, 2, 2, 2, 4 and group VI - 2, 2, 2, 2, 2, 4, 6.

Irrespective of starch source, cows of groups II, IV and VI receiving 2 kg of concentrates more than others, both in week 1 before parturition and in the first week of lactation, consumed more

[5] Corresponding author: e-mail: jstrzet@izoo.krakow.pl

dry matter ($P<0.01$), which may suggest reduction of energy and protein deficits. Differences in the concentration of metabolites in blood serum did not differ significantly between the groups, but numerically higher values of non-esterified fatty acids, β-hydroxybutyric acid, glucose, insulin and aspartate aminotransferase in group VI, both before and after parturition, may suggest a beneficial influence of concentrate allocation method on energy balance. Milk yield did not differ among groups, although cows of group VI produced from 1.05 to 2.47 kg/day more than cows of other groups. The concentrate allocation method significantly affected ($P<0.01$) milk protein content, with the highest values for groups V and VI. On the other hand, the source of starch, irrespective of concentrate allocation method, did not influence dry matter intake or level of metabolites in blood serum. Cows fed rations containing barley produced 0.94 kg/day more milk than those fed concentrate with maize, but the differences were not statistically significant ($P>0.05$). The concentration allocation and starch source did not influence reproduction performance.

The results of this study suggest that concentrate allocation, in particular, increasing the amount of concentrate provided in the last week of pregnancy and first week of lactation, may affect production and energy metabolism of transition cows. Extension of concentrate feeding to 6 weeks before parturition may additionally improve energy balance. The source of starch plays no important role.

KEY WORDS: transition cow, concentrate allocation method, starch source, milk yield, energy

INTRODUCTION

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, foetus and placenta 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 the requirements of cows, mainly energy, 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 triacyloglyceride accumulation in the liver. Liver lipidosis decreases hepatocyte glucogenic abilities 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).

Improving NEB can be achieved by an increase in 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, prolongation of feeding diets with higher proportions of concentrates up to 6 weeks before parturition decreased nonesterified fatty and β-hydroxybutyric acid and increased glucose concentration in blood and resulted 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 promotes ruminal papillae development (Overton and Waldron, 2004; Goff, 2006).

Most feeding standards for dairy cows, including IZ-INRA (2001), recommend gradually increasing the concentrate supply starting from the 21th day 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 diets containing more concentrates than recommended by standards for this period, reduced post-partum NEB and increased milk yield, although the effects of concentrate addition over 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).

Due to the limitations in gluconeogenesis in the liver of transition cows, it may be beneficial to feed by-pass starch (such as that in maize grain) which increases the amount of starch reaching the small intestine and glucose absorbed. However, the results of feeding different starch sources on energy metabolism and milk yield in this period are still not unequivocal (Lykos et al., 1997; Reynolds et al., 1997; Knowlton et al., 1998; Arieli et al., 2001).

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

MATERIAL AND METHODS

Design of experiment, animal feeding and management

The two-factorial experiment was carried out on 48 Polish Holstein-Friesian cows allotted by the analog method into 6 groups of 8 animals, considering parity (mean parity 2.4) and maximal milk yield in the previous lactation. The cows of each group were fed diets differing in the amount of concentrates allocated in the weeks before parturition and in the first week of lactation (Table 1). The concentrates for cows of group I (control) were allocated according to IZ-INRA (2001) standards. Each group was also divided into two subgroups of 4 cows that received one of two kinds of concentrate containing barley (subgroup B) or maize (subgroup M) as the main source of starch (Table 2). From week 2 of lactation the diets for each group were formulated according to IZ-INRA (2001) standards. The experiment were conducted until the end of week 12 of lactation.

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 weeks before predicted parturition, cows were moved to a calving pen, where they stayed until the first week of lactation.

Table 1. Concentrate allocation method - amount of concentrates in the basic ration in periods from six weeks before parturition until the end of the first week of lactation, kg/day

Group, feeding level	Weeks before and after parturition						
	before						after
	-6	-5	-4	-3	-2	-1[1]	1[1]
I				1	2	2	4
II				1	2	4	6
III				2	2	2	4
IV				2	2	4	6
V	2	2	2	2	2	2	4
VI	2	2	2	2	2	4	6

[1] contained 1 kg of soyabean meal

Table 2. Composition of concentrates, %

Feeds	Starch source	
	barley (B)	maize (M)
Ground barley	65.0	-
Ground maize	-	50.0
Wheat bran	5.0	20.0
Soyabean oilmeal	18.0	18.0
Rapeseed oilmeal	4.0	4.0
Molasses	3.0	3.0
VITAMIX KW-ZZD (Polmass)[1]	3.0	3.0
Calcium phosphate	1.0	1.0
Limestone	1.0	1.0

[1] in kg, g: P 60, Ca 150, Mg 30, Na 10; mg: Cu 1000, Zn 12000, Mn 8000, vit. E 3000; IU: vit. A 1000000; vit. D 13000; [2] in kg DM, g: B - CP 205, EE 30.8, CF 46, NFE 644.9, PDIN 140, PDIE 127, UFL 1.10; M - CP 202, EE 32.2, CF 50, NFE 639.2, PDIN 146, PDIE 142, UFL 1.12

The basal diet was composed of maize silage, lucerne silage, whole plant barley (45%) and lucerne (55%) mixture silage, sugar beet pulp silage and, additionally, wet brewer's grains and meadow hay. Soyabean meal was used as a protein equalizing component. Additionally, *Aquablend*, *Supercynk* and *Hydrovit* mineral and vitamin additives (Aquablend, The Netherlands) were supplied in water by automatic drinkers.

Daily rations for cows before parturition contained from 9.47 to 9.87 kg DM from the basal diet and from 0 to 3.52 kg DM from concentrate, whereas during lactation, from 12.3 to 13.6 kg DM and from 3.52 to 11.44 kg DM, respectively. Cows were fed individually twice a day. In the morning maize silage, sugar beet pulp silage and wet brewer's grains were fed, whereas in the afternoon, lucerne silage, whole plant barley and lucerne mixture silage and meadow hay were provided. The concentrates were fed three times a day.

Body weight of cows was measured on day 21 and 7 before expected calving and on day 2 after calving. Data on insemination index, days to first service, insemination 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. On day 5 before expected parturition and on day 5 after parturition blood samples were taken at about 4 h after morning feeding from the *vena jugularis* and serum was preserved at -20^{o}C until analysis. The refusals were collected and weighed daily before morning feeding, beginning from week 1 pre-calving to the end of week 4 post calving. During the rest of lactation, refusals were collected for 1 day every 3 weeks.

Chemical analysis

Feed and refusals were analysed according to AOAC (1995) methods and the fermentation products in silages by gas chromatography (Varian 3400 and Autosampler 8200CX, column DB-SFAP Megabore 30 meters long and ID 53µ; initial temperature of column was 80^{o}C increased by 7^{o}C/min until 270^{o}; injection temperature was 200^{o}C, detection, 260^{o}C). The pH value of silages was measured potentiometrically. Milk composition and somatic cell count (SCC) were determined using a Milko-Scan FT 120 (Foss Electric, Denmark).

Non-estrified 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 analyzer (Roche) and a high-sensitivity reagent kit (RANDOX). Glucose, urea, albumin and aspartate aminotransferase (AST) were determined using a VITROS 950 analyzer (Ortho-Clinical Diagnostic; Test Methodology

Manual, 1997). Insulin and progesterone were determined by radioimmunoassay (BioSource INS-IRMA Kit and BioSource PROG-RIA-CT Kits).

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.

The results were subjected to two-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.

Since data on blood metabolites, SCC and the difference between predicted and real time of parturition were not normally distributed, they were analysed after logarithmic transformation.

The curves showing changes in daily milk yield in subsequent days of lactation in dependence on the concentrate allocation method and starch source for each cow were calculated using Quick Statistica ver. 5.1 (1992), according to equation:

$$Y = a \log x + b x + c$$

where: Y and x mean daily milk yield and lactation day, respectively.

RESULTS

The concentrate allocation method, irrespective of starch source, had a significant effect on DM and nutrient intake in the last week before parturition (Table 3). However, there were no differences among treatments in the intake of DM of basic ration. Cows of groups II, IV and VI consumed more total diet DM, concentrate DM, protein and energy than cows of groups I, III and V. On the other hand, the starch source did not significantly affect any intake parameter in this period.

Also in the first week of lactation, cows of groups II, IV and VI consumed significantly more total diet DM, protein and energy (Table 3). Moreover, the effect of starch source was only seen considering total DM intake, with slightly (P=0.06) more DM consumed by cows on barley diets. In the period of the first 12 weeks of lactation there were also no significant effects of either concentrate allocation method or starch source on DM and UFL intake, although the cows of groups I and II consumed less DM than others, particularly cows of group VI (P=0.07). Moreover, the cows of group VI also consumed significantly more crude protein (P=0.02) than cows of group I and II and PDIN compared with cows of group I, II and IV (P=0.02). Regardless of the concentrate allocation method, the cows on diets

Table 3. Daily dry matter and nutrients intake before and after parturation

Items	Concentrate allocation						P	Starch source		P	SE	Interaction
	I	II	III	IV	V	VI		B	M			
Last week before parturition												
total DM, kg	10.09^{a}	11.81^{b}	10.35^{a}	11.96^{b}	10.33^{a}	12.44^{b}	<0.01	11.3	11.15	0.99	0.24	0.44
DM of basic ration, kg	8.29	8.48	8.56	8.47	8.54	8.89	0.63	8.54	8.5	0.81	0.14	0.59
DM of concentrate, kg	1.79^{a}	3.33^{b}	1.79^{a}	3.49^{b}	1.79^{a}	3.55^{b}	<0.01	2.76	2.64	0.58	0.20	0.59
crude protein, kg	1.53^{a}	1.87^{b}	1.55^{a}	1.90^{b}	1.56^{a}	1.95^{b}	<0.01	1.76	1.72	0.92	0.04	0.62
PDIN[1], kg	0.99^{a}	1.22^{b}	1.00^{a}	1.25^{b}	1.01^{a}	1.28^{b}	<0.01	1.14	1.13	0.58	0.03	0.50
PDIE[1], kg	0.94^{a}	1.16^{b}	0.95^{a}	1.18^{b}	0.96^{a}	1.22^{b}	<0.01	1.07	1.08	0.19	0.03	0.29
UFL[1]	9.11^{a}	11.97^{b}	9.35^{a}	11.13^{b}	9.31^{a}	11.58^{b}	<0.01	10.36	10.26	0.77	0.25	0.41
First week of lactation												
total DM, kg	12.65^{a}	14.47^{b}	12.77^{a}	14.47^{b}	12.68^{a}	14.46^{b}	<0.01	13.67	13.50	0.06	0.14	0.08
DM of basic ration, kg	9.11	9.17	9.22	9.16	9.13	9.16	0.986	9.24	9.07	0.07	0.43	0.82
DM of concentrate, kg*	3.55	5.31	3.55	5.31	3.55	5.31		4.43	4.42			
crude protein, kg	1.95^{a}	2.32^{b}	1.95^{a}	2.32^{b}	1.95^{a}	2.31^{b}	<0,01	2.15	2.12	0.12	0.03	0.87
PDIN[1], kg	1.28^{a}	1.54^{b}	1.29^{a}	1.54^{b}	1.28^{a}	1.54^{b}	<0.01	1.41	1.41	0.59	0.02	0.59
PDIE[1], kg	1.23^{a}	1.47^{b}	1.24^{a}	1.47^{b}	1.23^{a}	1.47^{b}	<0.01	1.33	1.37	0.13	0.02	0,16
UFL[1]	11.81^{a}	13.80^{b}	11.90^{a}	13.80^{b}	11.83^{a}	13.79^{b}	<0.01	12.85	12.79	0.43	0.15	0,75
From parturation to 12th week of lactation												
total DM, kg	20.61	20.56	21.25	21.14	21.10	21.62	0.07	21.13	20.97	0.48	0.11	0.88
DM of basic ration, kg	11.22	11.13	11.68	11.45	11.54	11.86	0.19	11.53	11.43	0.60	0.09	0.92
DM of concentrate, kg	9.39	9.43	9.57	9.69	9.57	9.76	0.11	9.6	9.54	0.50	0.04	0.96
crude protein, kg	3.68^{ab}	3.67^{a}	3.80^{bc}	3.77^{ac}	3.79^{ac}	3.88^{c}	0.02	3.78	3.75	0.38	0.02	0.88
PDIN[1], kg	2.44^{a}	2.43^{a}	2.51^{ab}	2.50^{a}	2.50^{ab}	2.57^{b}	0.02	2.47	2.51	0.08	0.01	0.88
PDIE[1], kg	2.18	2.18	2.24	2.24	2.23	2.28	0.07	2.17	2.28	<0.01	0.01	0.87
UFL[1]	19.68	19.67	20.22	20.19	20.09	20.56	0.08	20.05	20.09	0.84	0.10	0.88

* data were not subjected to statistical analysis as daily intake of concentrate was the same for each cow means marked with different letters differs at $P<0.05$

[1] units of IZ-INRA (2001) standards

Table 4. Milk and milk components yield in a period from first to 12th week of lactation

Items	Concentrate allocation						P	Source of starch		P	SE	Interaction
	I	II	III	IV	V	VI		B	M			
Total milk yield, $kg \cdot cow^{-1}$	2959.4	2996.4	2934.1	3062.6	2943.4	3150.9	0.71	3048.8	2966.8	0.37	42.45	0.88
Daily milk yield, $kg \cdot d^{-1}$	35.23	35.77	34.93	36.46	35.04	37.51	0.71	36.29	35.35	0.39	0.50	0.90
Daily milk components yield, $kg \cdot d^{-1}$												
dry matter	4.59	4.58	4.32	4.57	4.52	4.99	0.21	4.63	4.56	0.64	0.7	0.53
non-fat solids	3.17	3.13	2.90	3.12	3.12	3.48	0.13	3.20	3.11	0.46	0.06	0.46
protein	1.14	1.11	1.08	1.17	1.15	1.24	0.09	1.17	1.12	0.12	0.02	0.69
fat	1.42	1.44	1.41	1.45	1.40	1.52	0.54	1.43	1.45	0.74	0.02	0.72
lactose	1.65	1.66	1.64	1.72	1.65	1.75	0.85	1.70	1.25	0.41	0.03	0.96

with concentrate based on maize consumed significantly more PDIE. There were no significant interactions of concentrate allocation method and starch source on any intake parameter studied either before or after parturition.

The concentrate allocation method and source of starch did not significantly influence the yield of milk and milk components, although the cows of groups II, IV and particularly VI produced numerically more milk (about 1-2.5 kg/d) and milk components (group VI; Table 4). There was also no effect of starch source on the studied milk parameters, however the cows fed concentrate containing barley produced daily slightly more milk (0.94 kg d^{-1}) than those fed maize. There were no significant interactions of concentrate allocation method and starch source on any milk yield parameter studied.

The curve of lactation (Figure 1A) indicates an advantageous influence of a higher amount of concentrates in diets given one week before and after parturition

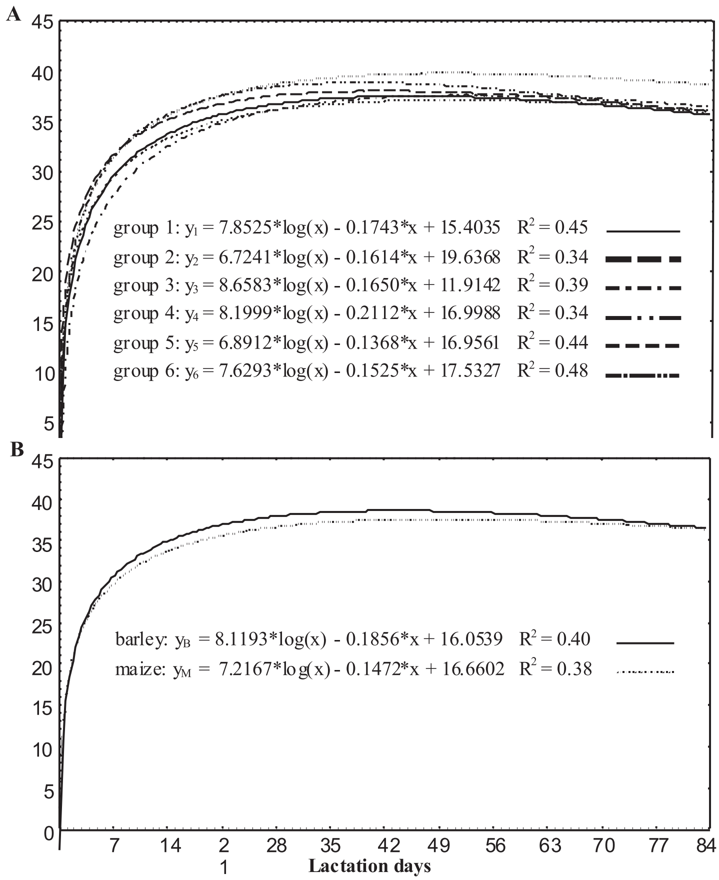

Figure 1. Changes in milk yield, kg·d^{-1}: A. during lactation depending on starch source, B. depending on concentrate allocation method

(groups II, IV and VI), particularly together with prolonged allocation of concentrates from 3 to 6 weeks before parturition (group VI).

Prolongation alone, without increasing the amount of concentrate, had no such effect (group V). On the other hand, the curve of lactation within 12 weeks of lactation presented in Figure 1B shows a beneficial influence of concentrate containing barley.

There were no treatment effects on milk composition and SCC except for the effect of concentrate allocation method on milk protein content ($P<0.01$) and starch source on milk fat content ($P=0.02$; Table 5). The highest protein milk content was shown for cows of groups V and VI, but compared with other groups the differences were statistically proved only clearly for group VI. Moreover there was a significant interaction of concentrate allocation method and starch source on milk protein content. On the other hand, feeding cows concentrate containing maize increased the fat content and tended to decrease the level of protein in milk ($P=0.18$).

The concentrate allocation method and starch source did not affect concentrate, energy or crude protein conversion calculated for 1 kg of milk (Table 6). On the other hand, conversion of PDI was significantly higher ($P<0.01$) in cows fed concentrate containing maize.

The concentrate allocation method and starch source did not influence the content of metabolites in blood serum of cows either in the last week before parturition or on days 1-2 and 21-28 of lactation (Table 7). The only exception was a significant effect of concentrate allocation method on BHBA content in blood sampled on day 1-2 postpartum ($P=0.02$). Lower BHBA results were shown for cows of groups II, IV and particularly VI, and higher for cows of groups III and V. Moreover, the highest BHBA content was found in control group (I). It is also worth noticing that in every period studied, the level of glucose and insulin was numerically higher, but the level of NEFA lower in the blood serum of cows belonging to groups II, IV and VI.

There were no differences among treatments in reproduction performance (Table 8), BCS, body weight of cows and calves (Table 9).

DISCUSSION

Increasing the amount of concentrates by 2 kg in one week before calving and in first week of lactation (groups II, IV and VI), compared with groups I, III and V, which were fed according to IZ-INRA standards (2001) during these periods, resulted in an increase in concentrate proportion in dietary DM by about 10 percentage units. The cows of groups II, IV and VI consumed overall about 2 UFL, 0.36 kg CP and 0.25 kg PDI more than the others and this effect resulted

Table 5. Milk composition (%) and somatic cells counts (SCC; thousands of cells ml^{-1}) in milk

Items	Concentrate allocation						P	Starch source		P	SE	Inter-action
	I	II	III	IV	V	VI		B	M			
Dry matter	13.02	12.85	12.37	12.56	12.90	13.31	0.17	12.78	12.89	0.62	0.11	0.17
Non-fat solids	8.99	8.80	8.31	8.55	8.91	9.26	0.06	8.82	8.79	0.86	0.09	0.06
Fat	4.03	4.06	4.06	4.01	3.99	4.05	0.97	3.96	4.10	<0.02	0.03	0.97
Protein	3.21^{ac}	3.12^{ab}	3.08^{b}	3.20^{ac}	3.29^{cd}	3.31^{d}	<0.01	3.23	3.18	0.18	0.02	<0.01
Lactose	4.68	4.66	4.70	4.70	4.71	4.66	0.91	4.69	4.68	0.95	0.02	0.91
Urea, mg dl^{-1}	22.60	23.45	20.28	22.33	20.66	20.85	0.21	22.37	20.99	0.10	0.43	0.21
SCC	334.31	133.94	164.99	207.42	141.06	223.25	0.28	232.03	169.63	0.28	22.57	0.33

Table 6. Conversion of concentrate and nutrients for milk production, per 1 kg of milk

Items	Concentrate allocation						P	Starch source		P	SE	Interaction
	I	II	III	IV	V	VI		B	M			
Concentrate, kg	0.303	0.301	0.316	0.304	0.311	0.297	0.85	0.302	0.309	0.42	4×10^{-3}	0.95
DM, kg	0.587	0.580	0.619	0.584	0.605	0.580	0.67	0.586	0.599	0.44	8×10^{-3}	0.94
Crude protein, kg	0.105	0.103	0.111	0.104	0.108	0.104	0.64	0.105	0.107	0.45	1×10^{-13}	0.92
PDI, kg	0.062	0.062	0.065	0.062	0.064	0.061	0.72	0.060	0.065	<0.01	9×10^{-4}	0.92
UFL	0.561	0.555	0.589	0.558	0.576	0.551	0.72	0.556	0.574	0.27	7×10^{-4}	0.94

Table 7. Metabolites in blood serum of cows before and after parturation

Items	Concentrate allocation						P	Starch source		P	SE	Interac-tion
	I	II	III	IV	V	VI		B	M			
Last week before parturition												
glucose, mmol l^{-1}	2.76	2.98	2.82	2.99	2.94	3.03	0.98	2.77	3.07	0.22	0.11	0.99
NEFA, mmo ·l^{-1}	0.37	0.30	0.32	0.26	0.25	0.23	0.48	0.28	0.30	0.73	0.03	0.89
BHBA, mmol l^{-1}	0.71	0.63	0.78	0.65	0.69	0.51	0.46	0.66	0.67	0.97	0.04	0.96
insulin, U l^{-1}	8.89	9.30	8.74	9.90	9.14	9.92	0.97	9.17	9.45	0.77	0.53	0.82
BUN, mmol l^{-1}	4.42	3.39	3.77	4.15	3.69	3.20	0.11	3.88	3.66	0.42	0.15	0.12
Lactation, day 1-2												
glucose, mmol l^{-1}	2.72	2.90	2.85	2.93	2.87	2.98	0.83	2.84	2.91	0.56	0.03	0.99
EFA, mmol l^{-1}	0.47	0.32	0.35	0.25	0.33	0.25	0.69	0.34	0.32	0.82	0.04	0.79
BHBA, mmol l^{-1}	1.74[a]	0.81[bcd]	1.40[ac]	0.75[cd]	0.90[bcd]	0.70[d]	0.02	1.19	0.92	0.11	0.10	0.96
insulin, U l^{-1}	5.92	8.42	8.34	11.60	10.06	12.35	0.33	7.74	11.15	0.11	0.94	0.99
albumin, g l^{-1}	26.75	26.62	25.75	26.25	26.12	26.37	0.99	26.21	26.41	0.83	0.46	0.36
AST, U l^{-1}[,1]	120.75	134.87	119.12	144.87	130.87	177.00	0.97	132.54	143.29	0.89	12.59	0.60
Lactation, day 21-28												
albumin, g l^{-1}	28.37	27.00	27.75	29.00	28.25	28.37	0.64	28.17	28.08	0.90	0.33	0.45
AST, U l^{-1}	98.75	111.95	92.25	110.87	103.12	160.25	0.44	109.04	120.03	0.97	25.95	0.88
BUN[2], mmol l^{-1}	4.65	5.62	4.99	4.55	4.68	4.79	0.79	4.86	4.89	0.95	0.21	0.77
progesterone, ng ml^{-1}	0.94	2.47	1.36	2.01	3.22	3.63	0.08	2.15	2.38	0.24	0.04	0.77

[1] aspartate aminotransferase

Table 8. Reproduction performance of cows

Items	Concentrate allocation						P	Starch source		P	SE	Inter-action
	I	II	III	IV	V	VI		B	M			
Insemination index[1]	2.75	2.00	2.75	2.87	2.75	2.25	0.74	2.63	2.58	0.91	0.18	0.99
Service interval, days[2]	84.2	82.2	80.4	75.4	71.0	78.4	0.92	80.6	77.4	0.75	3.58	0.37
Service period, days[3]	39.8	33.0	75.4	53.1	69.1	52.6	0.36	49.7	58.0	0.61	8.04	0.88
Open days[4]	124.0	115.3	148.4	128.5	140.1	131.0	0.94	130.3	135.4	0.66	8.33	0.72

[1] number of semen portions for effective insemination; [2] period from parturation to first insemination; [3] number of days from first to successful insemination; [4] number of days from calving to successful insemination

Table 9. Feeding day, body weight and body condition

Items	Concentrate allocation						P	Starch source		P	SE	Inter-action
	I	II	III	IV	V	VI		B	M			
Body weight, kg												
day 21 before parturation	641.1	656.5	640.1	643.5	630.4	608.1	0.68	630.5	642.7	0.47	8.10	0.55
day 7 before parturation	668.3	656.3	655.4	656.4	640.9	625.5	0.79	644.5	656.4	0.50	8.33	0.72
day 7 after parturation	616.1	610.9	606.0	611.4	588.9	579.5	0.75	597.8	606.4	0.60	7.83	0.53
Calf body weight												
at parturition, kg[1]	43.0	41.8	41.8	42.5	40.7	41.0		42.1	41.5			
BCS, points												
day 21 before parturition	3.50	3.54	3.51	3.62	3.54	3.40	0.38	3.50	3.35	0.38	0.03	0.76
day 7 before parturition	3.63	3.57	3.58	3.72	3.58	3.46	0.37	3.61	3.63	0.58	0.03	0.86
day 7 after parturation	3.31	3.32	3.34	3.46	3.36	3.23	0.36	3.32	3.35	0.62	0.02	0.75

[1] data were not subjected to statistical analysis

was mainly from the higher consumption of concentrates, irrespective of starch source, since the intake of the basal ration was similar among treatments.

The source of starch in the concentrate did not affect DM and energy intake both pre- and post-partum. Also 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. However, other authors reported higher DM intake when maize replaced barley (Khorasani et al., 1994; Yang et al., 1997; Silveira et al., 2007). Such contradictory results can be attributed to differences in the proportions of maize or barley in the ration (De Visser et al., 1990; Grings et al., 1992). It can also be suggested that reasonably high proportions of forages in the diet, particularly pre-partum, stimulating rumination and saliva secretion could mask the effect of starch source on rumen fermentation. The higher PDIE intake by cows fed concentrate containing maize could be attributed to the higher content of this component, as daily intake of both concentrate mixtures was similar.

Increasing DM intake by cows of groups II, IV and VI resulted in numerically higher milk and milk component yields than in other groups. As for DM intake, the best milk yield was observed for cows fed the highest amounts of concentrates in the last week before parturation and in the first week of lactation, particularly when started 6 weeks before calving (group VI). Also Ryan (1999) found that cows fed rations enriched in energy before parturition produced more milk, protein and fat for 8 weeks after calving. Unfortunately, the differences among treatments in our trial 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 similarly as in our experiment the differences, although in many cases quite high, were not always statistically 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 of group VI consumed more DM compared with other groups, and produced more milk, the concentrate and nutrient expenditure for production of 1 kg of milk was similar among groups.

Comparing the effect of increasing the amount of concentrates in the last week before and first week after parturation or elongation of concentrate allocation (groups III vs IV and V vs VI) it seems that the former factor had a much stronger effect on milk yield. Higher doses of concentrates in these periods may positively improve energy balance (Overton and Waldron, 2004). Moreover, feeding concentrates before calving may better prepare the rumen environment (rumen papilla growth and adaptation of rumen microorganisms) to digest diets rich in starch fed post-calving (Overton and Waldron, 2004). Although the effect of starch source was not significant, the cows fed concentrate based on barley produced slightly more milk. A lack of differences between sources of starch in early or mid lactation were was also shown by Grings et al. (1992), Khorasani et al. (1994), Mitzner et al. (1994). Others (Overton et al., 1995; Casper et al., 1999; Silveira et al., 2007) found higher milk yield when diets for early lactation were based on maize. These contradictory results could be caused by using different maize genotypes or by grain harvesting and processing methods (Wilkerson et al., 1997; Knowlton et al., 1998). A higher rate of barley starch fermentation in the rumen compared with maize starch, could provide the rumen with more substrates for rumen papillae and bacteria growth, which could have been beneficial in the period pre-calving. On the other hand, the lower fermentation of maize starch could provide cows with more glucose absorbable in the small intestine, which could have improved the energy balance. However, it should be considered that pancreatic secretion of amylase in cattle is limited and starch by-passed into the small intestine is not entirely digested (Reynolds et al., 1997; Hungtington et al., 2006).

The lack of significant differences in milk fat content between concentrate allocation methods was probably caused by a similar proportion of concentrates in the diets in the lactation period. Feeding diets with maize lowered starch fermentation in the rumen which probably caused a higher milk fat content in the maize-fed cows. Similarly Matthe et al. (2003) demonstrated a higher milk fat content on a maize diet compared with easily ruminally fermented wheat.

The significantly higher mean milk protein content in the studied period of lactation (12 weeks) in cows of groups V and VI, particularly VI, may testify to the better energy balance of these animals. Since the consumption of total DM, basic ration DM and concentrates in the twelve-week-period of lactation was similar among groups, the differences in milk protein content might have resulted from a better energetic status of cows, determined by concentrate allocation before calving. In this particular parameter, the extension of concentrate feeding for 6 weeks (groups V and VI) could be advantageous. McNamara et al. (2003) demonstrated that feeding cows with 3 kg concentrate during the last 4 weeks of pregnancy increased not only protein but also fat levels in milk during 8 weeks of lactation.

Although there were no significant effects of concentrate allocation method and starch source on the blood serum content of the majority of metabolites studied, it is worth noting that higher doses of concentrates (group II, IV and particularly VI), irrespective of starch source, given in the last week before parturation and in the first week of lactation reduced the content of ketone bodies measured on days 1-2 of lactation. It can be assumed that these cows were less prone to ketosis. The low BHBA content in the blood serum of cows of group V may also indicate a positive effect of extension of concentrate feeding before calving. Lower BHBA content may testify to better energy balance. The cows of group I (control) had the highest serum BHBA, close to ketosis. McNamara et al. (2003a) showed a nonsignificant correlation between NEFA concentration in the serum 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, let BHBA be considered a more useful indicator of energy balance compared with glucose or NEFA.

The lack of significant differences in serum metabolites between starch sources may suggest that feeding cows with slowly fermented starch (maize) in properly balanced rations does not improve energy balance of cows in the transition period.

The increased concentration of serum AST in cows of group VI could be a sign of increased accumulation of triglycerides in the liver and possible dysfunction of hepatocytes. However, in the period of early lactation elevated AST, together with no appearance of diseases, may indicate increased metabolic activity of the liver (El-Sherif and Assad, 2001). The elevated serum progesterone level in groups V and VI, although not statistically significant (P=0.08), might suggest improved reproduction status, which is closely related to energy balance. Reksen et al. (2001) demonstrated in cows of high productivity that improvement in energy balance after calving enabled earlier ovulation while prolonged energy deficit slowed this process. Although there were clear tendencies for higher serum progesterone in groups V and VI, there were no treatment effects on fertility performance.

The absence of differences between treatments in body weight and condition of cows in the studied periods may suggest that the diets sufficiently covered the requirements of the cow and foetus. Early concentrate allocation (6 weeks before calving) might create a risk of overconditioning of cows, which was not observed in our study, probably due to the low dose of concentrates given between weeks 6 and 4 pre-partum. Meshek and Boode (2001) did not find a negative effect on BCS of a high energy diet fed through the whole six-week dry period.

The results of the present study suggest that the model of feeding marked as group VI, irrespective of a starch source, was the most advantageous. The cows produced the highest amount of milk with a significantly higher milk protein content. The serum BHBA content of these animals was the lowest, whereas progesterone, the highest. Despite concentrate feeding lasting 6 weeks before calving, the cows did not increase their BCS. These tendencies may indirectly testify to a better energy balance of cows. The results obtained in this study may also show that the requirements suggested by the IZ-INRA standards (2001) for transition cows (group I) can be questioned. On the other hand, the source of starch in the diets fed 3-6 weeks prepartum and in the first weeks of lactation seemed to have no effect on the energy status of the cows if the diets were balanced according to requirements.

CONCLUSIONS

The results of experiment suggest that increasing the amount of concentrate in the diet over IZ-INRA (2001) standards for the last week before and one week after parturation may improve the energy status of cows. Moreover, prolonged feeding of concentrate from 3 to 6 weeks prepartum may be additionally beneficial. The source of starch is not important in this period.

REFERENCES

AOAC, 1995. Association of Official Analytical Chemists, Official Methods of Analysis, 16th Edition. Arlington, VA

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 an energy supplement to dairy cows pre -and postpartum on intake, milk yield and incidence of ketosis. Anim. Feed Sci. Tech. 93, 55-69

Casper D.P., Maiga H.A., Brouk M.J., Schingoethe 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-srtructural carbohydrates in concentrate supplements of silage-based dairy cow rations: 1. Feed intake and milk production. Neth. J. Agr. Sci. 38, 487-498

El-Sherif M.M., Assad F., 2001. Changes in some blood constituents of Barki ewes during pregnancy and lactation under semi arid conditions. Small Ruminant Res. 40, 269-277

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 diers. J. Dairy Sci. 75, 193-200

Hayirli A., Grummer R. R., Nordheim E.V., Crump P.M., 2002. Animal and dietary factors affecting feed intake during the prefresh transition period in Holsteins. J. Dairy Sci. 85, 3430-3443

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

Hungtington G.B., Harmon D.L., Richard C.J., 2006. Site, rates and limits of starch digestion and glucose metabolism in growing cattle. J. Anim. Sci. 84, E Suppl., E14-E24

IZ-INRA, 2001. In: Feeding of Cattle, Sheep and Goats. Feeding Value of Feedstuffs for Ruminants (in Polish). 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

Lykos T., Varga G.A., Casper D., 1997. Varying degradation rates of total nonstructural carbohydrates: Effects on ruminal fermentation, blood metabolites, and milk production and composition in high producing Holstein cows. J. Dairy Sci. 80, 3341-3355
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, 115-125
Matthė 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., 2003a. Effect of different transition diets on energy balance, blood metabolites and reproductive performance in dairy cows. Livest. Prod. Sci. 84, 195-206
Mitzner 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
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., Cameron M.R., Elliott J.P., Clark J.H., 1995. Ruminal fermentation and passage of nutrients to the duodenum of lactating cows fed mixture of corn and barley. J. Dairy Sci. 78, 1981-1998
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., Gröhn Y.T., Havrevoll O.S., Bolstad T., Waldmann A., Ropstad E., 2001. Influence of concentrate allocation and energy balance in 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: P.C. Garnsworthy, W. Haresign, J. Wiseman (Editors). Recent Advances in Animal Nutrition. Nottingham University Press, pp. 105-134
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
SAS, 2001. SAS User's Guide: Statistic Release 8.2 SAS Inst., Inc. Cary, NC
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
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
Wilkerson V.A., Glen B.P., McLeod K.R., 1997. Energy and nitrogen balance in lactating cows fed diets containing dry or high moisture corn in either rolled or ground form. J. Dairy Sci. 80, 2487-2496
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