Impact of glucogenic additive in transition dairy cow diets of varying ruminal starch degradability on yield and composition of milk and reproductive parameters

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ABSTRACT: A two-factorial experiment was carried out on 6 groups (10 animals each) of Polish Black and White Holstein-Friesian cows in the transition period to determine the effect of glucogenic additive (GA) to the diets containing grains of varied ruminal starch degradation on cow performance. The animals from 3 control groups (C-groups) were fed the diets without any additive, whereas 3 other, experimental ones (A-groups) received the diets with additive of glucogenic preparation (450 g per head/day) comprising calcium propionate and loose propylene glycol (1 : 1). In the control groups as well as in the experimental ones, three analogical treatments, differing in concentrate composed of grain species of varying ruminal degradability of starch, i.e. maize (M) – low ruminal degradability, barley and wheat (BW) – high ruminal degradability and marriage of them (MBW) were conducted. Finally, the treatments were: C-M, C-BW, C-MBW, A-M, A-BW, and A-MBW. The rations of all groups based on maize silage, haylage, and meadow hay were mixed at 69 : 19 : 12 ratio (dry matter (DM) basis) and given *ad libitum*. Besides, all the animals received adequate concentrate rations to satisfy their nutritional requirements. The experiment started two weeks before the expected parturition and lasted till the 6^{th} lactation week. Neither GA nor a type of grain in the diets showed significant negative influence on DM intake. A glucogenic additive has positively affected some basal nutrient digestibility, elevating significantly DM and crude protein (CP) coefficients of the apparent total tract digestibility (CATTD), by about 3 percentage points. The GA × grain interactions ($P \leq 0.05$) in CATTD of CP and nitrogen-free extract (NFE) were stated, with the peak values reported in the A-BW treatment. GA increased ($P \leq 0.05$) daily milk yield by nearly 5% in comparison with the control treatments. GA × grain interaction was noted with the best effect in the treatment where GA was given along with maize-barley-wheat-based concentrate. Besides, the glucogenic additive decreased ($P \leq 0.05$) protein (PDI) expenditure per 1 kg of fat-corrected milk (FCM) by ca. 6% and raised (by 0.15 percentage point in week 6) protein content, while lowered the urea milk level in weeks 3 and 6 of lactation by approximately 15%. It showed beneficial effect on cow reproductive indicators reducing the time interval from calving to successful insemination and improving insemination index.

Keywords: cows; transition period; glucogenic additive; propylene glycol; calcium propionate; ruminal starch degradability; milk; reproduction

The suboptimal appetite characterizing high yielding dairy cows at the onset of lactation does not allow the animals to consume adequate quantity of feed to cover their energy requirements. The energy imbalance can lead to the occurrence of metabolic disorders related to nutrition and feed management problems, like ketosis (Ballard et al., 2001; Patton et al., 2004; Moallem et al., 2007). Preventive measures against this disease and its negative influence upon milk production involves dietary inclusion of various glucogenic preparations (Nielsen and Ingvertsen, 2004; Klebaniuk

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et al., 2009). Their effectiveness may depend on a type of grain, especially its starch susceptibility to ruminal degradation. This starch attribute, characterizing grains of each cereal species, conditions the quantity of ruminal bypass starch, degraded then in small intestine and absorbed to the blood in a glucose form (Orskov, 1986). Besides, lower extent of ruminal digestion of some grains (maize, sorghum) minimizes threat of decreasing ruminal digesta pH, noticed commonly when animals are fed high quantity of basic grains (wheat, barley) cultivated in many European countries. According to Orskov (1986), at least 90% of their starch is degraded in the rumen, whereas up to 40% of maize starch can occasionally be found to escape ruminal fermentation. The glucogenic additive along with susceptibility of grain starch to degradation that favours microbial development in the rumen can influence the total tract digestibility of nutrients and, indirectly, milk production as well as reproduction indices of cows.

The aim of the investigation was to evaluate the influence of a glucogenic additive to the transition dairy cow feed rations comprising grains of various starch ruminal degradation on nutrient digestibility, milk yield, and composition as well as upon reproduction parameters.

MATERIAL AND METHODS

Experimental design and animal feeding

The two-factorial experiment was carried out on sixty dry, multiparous Polish Holstein-Friesian cows allocated by the analogue method (milk yield in previous lactation and body weight) into 6 groups of 10 animals each. All the animals were fed in compliance with the IZ-INRA (2001) standards. The basal rations of all the groups were based on the same roughages – maize silage, haylage, and meadow hay at 69 : 19 : 12 mix ratio (DM basis) and given *ad libitum*.

A glucogenic additive (GA) and type of grain, regarding starch ruminal degradability – maize (M), barley (B), wheat (W) – were the experimental factors. There were therefore 3 control C-groups (C-M, C-BW, and C-MBW), fed the diets without any additive and 3 experimental ones (A-groups), with an additive of glucogenic preparation (A-M, A-BW, and A-MBW), consisting of calcium propionate (99% purity, Pestell Minerals & Ingredients, New Hamburg, Canada) and loose propylene glycol (BASF) mixed 1 : 1, enriching the rations. It was fed in a dose of 450g per head/day. The C-M and A-M groups received maize-based concentrate (low starch rumen degradation), the C-BW and A-BW groups – barley and wheat (50 : 50, high ruminal degradation of starch), whereas the C-MBW and A-MBW – a concentrate based on maize-barley-wheat (50 : 25 : 25, Table 1). At the start of the trial, the glucogenic additive (assigned for A-M, A-BW, and A-MBW groups) was mixed at 1 : 4.5 ratio with a proper concentrate, characterized in Table 1. Supplementation of this mixture began 3 weeks prior to the expected calving. The full dose of it (2.5 kg DM per head/day) was fed in the morning and evening 2 weeks before the expected parturition till the 6th week of lactation. Besides, after calving the animals from each group received an appropriate concentrate (without glucogenic additive – see Table 1), assigned to parallel groups – concentrate

Table 1. Concentrate ingredients (in %)

Ingredient	Concentrate		
	M	BW	MBW
Barley	–	22.7	11.3
Wheat	–	22.6	11.3
Maize	45.3	–	22.7
Soybean meal (46% CP)	27.9	27.9	27.9
Rapeseed meal (35% CP)	22.3	22.3	22.3
Soybean oil	1.0	1.0	1.0
Mineral-vitamin mix[1, 2]	2.5	2.5	2.5
Sodium carbonate	1.0	1.0	1.0
Total	100.0	100.0	100.0

M = maize, BW = barley and wheat, MBW = maize + barley and wheat, CP = crude protein

[1]in 1 kg of mix for dry cows (Dolfos BZ2): vit. A 1 000 000 IU, vit. D_3 200 000 IU, vit. E 14 500 mg, calcium 63 g, phosphorus 86 g, sodium 50 g, magnesium 50 g, sulphur 74 g, manganese 1700 mg, copper 1300 mg, cobalt 10 mg, iodine 40 mg, selenium 30 mg, antioxidants, appetizers

[2]in 1 kg of mix for lactating cows (Dolfos BM Lactan): vit A 1 200 000 IU, vit. D3 200 000 IU, vit. E 7000 mg, vit. B1 100 mg, vit. B2 65 mg, vit. B6 50 mg, vit. B12 400 mg, pantothenic acid 150 mg, folic acid 12 mg, choline 100 mg, biotin 115 000 mg, nicotinic acid 2500 mg, calcium 183 g, phosphorus 20 g, sodium 88.6 g, magnesium 50 g, zinc 9000 mg, sulphur 5 g, manganese 3500 mg, copper 1000 mg, cobalt 23 mg, iodine 150.6 mg, selenium 100 mg, dry yeast 20 g, buffering substances, antioxidants, appetizers

M for C-M and A-M groups, BW for C-BW and A-BW, and MBW for groups C-MBW and A-MBW in quantity to meet their nutritional needs (0.4 kg concentrate per 1 kg milk over 20 kg milk yield).

Sampling and analysis procedures

During the trial the animals were fed individually. Daily feed intake with feed refusal control was estimated every 14 days with collecting samples for chemical analysis. Apparent digestibility of the diet basic nutrients was carried out in the 3rd week of lactation, using silica as a marker. Milk yield, with concurrent taking of milk samples for chemical analysis, was recorded at the end of the lactation weeks 1, 3, and 6. The feedstuff and faecal samples were analyzed for the basal nutrients as well as neutral detergent fibre (NDF) and acid-detergent fibre (ADF) content using the methods approved by AOAC (2000).

Energy value of 1 kg GA (consisting of propylene glycol and Ca-propionate, mixed 1 : 1) was calculated at 2.0 UFL (Feed Unit for milk production), based on energy value (computed in NE_L) by Myoshi et al. (2001) for 1 kg propylene glycol and by Liu et al. (2010) for Ca-propionate.

The content of fat and protein of the milk samples was determined using a Milko-Scan apparatus (Bentley Instruments Inc., Chaska, USA). The samples were also analyzed for the urea level using Chemspec apparatus (Bentley Instruments Inc., Chaska, USA). For better comparison of milk yield, it was converted into 4% FCM (Fat corrected milk) according to Gaines (1928) formula:

$$\text{Milk yield (FCM)} = 0.4 \times M + 15 \times F$$

where:

FCM = fat corrected milk
M = milk yield (kg/day)
F = fat yield (kg/day)

The production indices were subjected to 2-factorial analyses of variance by means of Statistica 6.1.G (Statsoft, 2003), according to the model:

$$Y_{ijk} = \mu + a_i + b_j + (ab)_{ij} + e_{ijk}$$

where:

μ = overall mean
a_i = influence of the glucogenic additive, $i = 2$ (C = control, A = glucogenic additive)
b_j = influence of a grain in concentrate, $j = 3$ (M = maize, BW = barley-wheat, MBW = maize-barley-wheat)
$a \times b$ = glucogenic additive × grain interaction
e_{ijk} = random error

RESULTS

Chemical composition and nutritive value of roughages applied in this experiment (Table 2) were typical of those given in standards (IZ-INRA, 2001).

In week 2 prior to the expected calving, the average consumption of diet dry matter (DM), similar in all treatments, amounted to 11.7 kg per head/day (Table 3). During the 6-week-lasting experimental period of lactation, the average feed intake (expressed in DM) in groups receiving glucogenic preparation was slightly higher in comparison with control treatments (18.1 kg vs. 17.5 kg on average). However, the statistically proved higher DM intake (by 1.1 kg) by the animals fed the diets with GA was noted only during the 3rd week of lactation. The difference arose mainly due to by 0.7 kg DM ($P \leq 0.05$) higher consumption of concentrate, even though somewhat higher (however not confirmed statistically) intake of roughages (by 0.3 kg DM per head/day) was also noted. The energy value of the total diet consumed that week was also higher ($P \leq 0.05$) in comparison with control animal groups (Table 3). The differences in feed intake between treatments with different species of grain proved to be insignificant. One week after calving the animals consumed 15.0 kg diet DM on average. The intake of feeds, increasing gradually with the progressing lactation, reached 18.3 kg and 19.6 kg DM at the end of the 3rd and 6th week after parturition, respectively. At the end of the 1st week postpartum, the diet consisted of ca. 70% roughages and 30% respective concentrate on average, whereas during the 3rd and 6th week this proportion oscillated around 63 : 37 and 55 : 45, respectively.

Glucogenic additive had a significant ($P \leq 0.05$) positive influence on basal organic nutrient digestibility (Table 4). In comparison with the control treatments, the average organic matter (OM) and crude protein coefficients of apparent total tract digestibility (CATTD) in the groups receiving this supplement were by about 3 percentage points higher ($P \leq 0.05$). Slightly smaller (by about 2 percentage points) differences in ether extract (EE) and NFE digestibility were observed between these treatments. The effect of grain species on crude protein and NFE digestibility was also noted. The digestibility coefficients of both these nutrients

Table 2. Chemical composition and nutritive value of the diet ingredients

Item	Maize silage	Haylage	Hay	Concentrate		
				M	BW	MBW
DM (%)	35.3	38.4	85.0	88.0	87.8	88.1
In 1 kg DM (g)						
Crude protein	74.8	110.5	90.5	274.0	291.3	282.5
Crude fiber	204.6	350.6	342.3	61.1	69.7	65.4
ADF	198.3	340.7	378.3	83.7	93.7	88.7
NDF	362.7	473.5	426.8	166.2	170.9	178.5
Ether extract	38.9	12.7	17.8	41.5	37.9	39.8
Crude ash	50.6	108.6	91.7	58.2	67.5	65.8
NFE	631.1	417.6	457.7	565.2	533.6	546.5
Nutritive value of 1 kg DM						
UFL	0.89	0.78	0.62	1.16	1.11	1.14
PDIN (g)	52	74	56	202	205	204
PDIE (g)	73	69	61	184	179	181
LFU	1.13	1.23	1.18	–	–	–

DM = dry matter, ADF = acid-detergent fibre, NDF = neutral-detergent fibre, NFE = nitrogen-free extract, UFL = Feed Unit for milk production, PDIN = protein truly digestible in the small intestine when N limits microbial protein synthesis, PDIE = protein truly digestible in the small intestine when energy limits microbial protein synthesis, LFU = fill units for cows

in the groups receiving barley-wheat-based concentrate were by about 2 percentage points higher ($P \leq 0.05$) as compared to the treatments where the concentrate based on maize was provided. A glucogenic additive × grain interaction ($P \leq 0.05$) in CATTD of crude protein and NFE was stated. The highest digestibility coefficient of these nutrients (73.4 and 84.7%, respectively) characterized the A-BW treatment, whereas the lowest (68.5 and 80.2%, respectively) was reported in C-M group.

Regardless of the type of grain in the concentrate, the glucogenic additive increased ($P \leq 0.01$) the daily milk yield in weeks 3 and 6 by 1.9 and 2.2 kg FCM, respectively, in comparison with the control treatments (Table 5). The impact of grain on milk production was also stated ($P \leq 0.05$), with average higher yield in weeks 3 and 6, obtained by the cows receiving the maize-barley-wheat-based concentrate. The GA × grain interaction in the 3rd and 6th week of lactation was stated. The glucogenic preparation was found to be the most efficient when A-MBW treatment was used, where the concentrate contained a maize, barley, and wheat mix. The mean milk yield of cows of this group in the 3rd and 6th week after calving was higher by 2.4 and 5.8 kg FCM respectively in comparison with the parallel (C-MBW) group fed the same diet but without additive of Ca-propionate and propylene glycol.

Efficiency calculations presented in Table 5 do not indicate any impact of GA or grain on energy expenditure per 1 kg FCM milk production (excluding basal requirements) in weeks 1 and 6 of lactation. The only slightly higher energy utilization, by about 0.03 UFL per 1 kg FCM, was found in treatments with GA in the 3rd week after calving, in comparison with control groups. However, the difference was not confirmed statistically. Both GA and grain species affected protein efficiency. A glucogenic additive decreased ($P \leq 0.05$) by nearly 5 g (differences statistically significant) the expenditure of PDI (PDIN) per 1 kg FCM over the control groups in weeks 1 and 6. Besides, grain species in concentrate influenced the protein utilization. The lowest protein expenditure was noted in the treatments where maize-barley-wheat-based concentrate was supplied, while the highest in the group with barley-wheat concentrate (52.3 vs. 54.8 g PDI per 1 kg FCM).

The glucogenic preparation did not have any clear influence on milk fat content in the 1st week after calving, whereas in weeks 3 and 6 the level of this additive significantly ($P \leq 0.05$) increased its level

Table 3. Daily intake of dry matter and energy (contained in total ration and consumed in roughages and concentrate form) per cow in particular treatment during the trial

Week	Treatment						Statistical significance[1]			
	C-M	C-BW	C-MBW	A-M	A-BW	A-MBW	SEM	A	G	A × G
Total ration DM (kg)										
–2	11.7	11.8	11.4	11.5	11.9	11.8	0.417	ns	ns	ns
1	15.0^{ab}	15.3^{ab}	14.5^{b}	15.7^{a}	14.4^{b}	15.0^{ab}	0.423	ns	ns	ns
3	18.0^{b}	18.8^{ab}	18.0^{b}	19.3^{a}	19.3^{a}	19.5^{a}	0.341	*	ns	ns
6	19.5	19.7	19.1	19.8	19.8	19.9	0.387	ns	ns	ns
Roughages DM (kg)										
–2	9.2	9.3	8.9	9.0	9.4	9.3	0.215	ns	ns	ns
1	10.5^{ab}	10.8^{ab}	10.0^{b}	11.2^{a}	9.9^{b}	10.5^{ab}	0.269	ns	ns	ns
3	11.5	12.0	11.5	12.2	11.7	12.2	0.221	ns	ns	ns
6	11.0	11.2	9.9	10.8	10.9	10.7	0.265	ns	ns	ns
Concentrate DM (kg)										
–1	2.5	2.5	2.5	2.5	2.5	2.5	0.000	ns	ns	ns
1	4.5	4.5	4.5	4.5	4.5	4.5	0.000	ns	ns	ns
3	6.5^{b}	6.8^{ab}	6.5^{b}	7.1^{ab}	7.6^{a}	7.3^{a}	0.382	*	ns	ns
6	8.5	8.5	9.2	9.0	8.9	9.2	0.293	ns	ns	ns
Total ration energy (UFL)										
–2	10.22	10.15	9.97	10.54	10.75	10.75	0.448	ns	ns	ns
1	13.86^{ab}	13.87^{ab}	13.54^{b}	14.90^{a}	13.73^{b}	14.34^{ab}	0.429	ns	ns	ns
3	17.23^{ab}	17.42^{ab}	17.10^{b}	18.97^{a}	18.72^{a}	18.92^{a}	0.379	*	ns	ns
6	19.16	18.65	18.94	20.10	19.47	20.13	0.396	ns	ns	ns
Roughages energy (UFL)										
–2	7.32	7.37	7.12	7.20	7.51	7.45	0.230	ns	ns	ns
1	8.64^{ab}	8.87^{ab}	8.41^{ab}	9.25^{a}	8.27^{b}	8.76^{ab}	0.272	ns	ns	ns
3	9.69	9.87	9.69	10.30	9.82	10.16	0.259	ns	ns	ns
6	9.30	9.21	8.45	9.22	9.13	9.19	0.280	ns	ns	ns
Concentrate energy (UFL)										
–1	2.90^{ab}	2.78^{b}	2.85^{ab}	3.34^{a}	3.24^{a}	3.30^{a}	0.218	ns	ns	ns
1	5.22	5.00	5.13	5.65	5.46	5.58	0.258	ns	ns	ns
3	7.54^{ab}	7.55^{ab}	7.41^{b}	8.67^{a}	8.90^{a}	8.76^{a}	0.389	*	ns	ns
6	9.86	9.44	10.49	10.88	10.34	10.94	0.270	ns	ns	ns

[1]Probability of factor impact (A = glucogenic additive, G = grain) and interaction of factors: *$P \leq 0.05$, ns = $P > 0.05$

^{a,b}values in the rows with different letters differ significantly ($P \leq 0.05$)

DM = dry matter, UFL = Feed Unit for milk production

in milk (by 0.19 and 0.20 percentage points, respectively, Table 6). The type of grain had an impact on milk fat content ($P \leq 0.05$) with the highest level of it in treatments where the maize-barley-wheat-based concentrate was served. Significant effect of GA on protein and urea content in milk was found (Table 6), demonstrated with 0.15 percentage point increase of protein in week 6 ($P \leq 0.05$) and by ca. 16 and 20% decrease ($P \leq 0.05$) of milk urea level in comparison with the control treatments in weeks 3 and 6. The impact of grain on milk urea content in week 6 was also observed, exhibiting by a 12% lower level

Table 4. Apparent total tract nutrient digestibility coefficients (in %) of particular diets in the 3rd week of lactation

Nutrients	Treatment						Statistical significance[1]			
	C-M	C-BW	C-MBW	A-M	A-BW	A-MBW	SEM	A	G	A × G
Organic mater	76.7[b]	77.2[b]	77.0[b]	79.8[ab]	80.3[a]	80.1[a]	4.85	*	ns	ns
Crude protein	68.5[b]	70.6[ab]	69.6[b]	71.2[ab]	73.4[a]	72.4[a]	2.34	*	*	*
Ether extract	71.6[ab]	70.7[b]	71.1[ab]	71.5[ab]	73.5[a]	74.0[a]	2.65	*	ns	ns
Crude fibre	63.4[ab]	62.8[b]	63.1[ab]	63.9[ab]	63.3[ab]	65.6[a]	2.84	ns	ns	ns
NFE	80.2[b]	83.8[ab]	81.9[b]	83.6[ab]	84.7[a]	83.1[ab]	2.37	*	*	*

[1]Probability of factor impact (A = glucogenic additive, G = grain) and interaction of factors: *$P < 0.05$, ns = $P > 0.05$
[a,b]values in the rows with different letters differ significantly ($P \leq 0.05$)
NFE = nitrogen-free extract

Table 5. Milk yield, energy and protein utilization per 1 kg FCM production (excluding basic requirements) in particular treatment during trial

Item	Week	Treatment						Statistical significance[1]			
		C-M	C-BW	C-MBW	A-M	A-BW	A-MBW	SEM	A	G	A×G
Milk yield (FCM, kg/day)	1	29.0	25.1	26.2	27.5	26.5	28.4	5.17	ns	*	ns
	3	29.7[b]	32.4[ab]	31.6[b]	33.1[ab]	32.2[ab]	34.0[a]	1.87	*	*	*
	6	32.5[b]	33.9[b]	32.3[b]	33.9[b]	33.4[b]	38.1[a]	1.39	**	*	*
Energy utilization (UFL/kg FCM)	1	0.32[b]	0.37[a]	0.34[ab]	0.37[a]	0.34[ab]	0.33[ab]	0.04	ns	ns	ns
	3	0.42[ab]	0.39[b]	0.39[b]	0.43[ab]	0.44[a]	0.41[ab]	0.03	ns	*	*
	6	0.45[ab]	0.41[b]	0.44[ab]	0.46[a]	0.44[ab]	0.40[b]	0.03	ns	ns	ns
Protein utilization (PDI, g/kg FCM)	1	41.8[b]	49.7[a]	45.8[ab]	42.3[b]	42.0[b]	39.6[b]	2.32	*	*	ns
	3	56.8[ab]	55.4[ab]	53.7[b]	53.2[b]	57.6[a]	53.0[b]	3.04	ns	*	ns
	6	63.4[ab]	61.9[ab]	66.8[a]	61.1[ab]	62.1[ab]	55.0[b]	2.71	**	*	ns

[1]Probability of factor impact (A = glucogenic additive, G = grain) and interaction of factors: *$P \leq 0.05$, **$P \leq 0.01$, ns = $P > 0.05$
[a,b]values in the rows with different letters differ significantly ($P \leq 0.05$)
FCM = fat corrected milk, UFL = Feed Unit for milk production, PDI = protein digested in the small intestine

Table 6. Fat, protein, and urea content in cow milk in particular treatment during the trial

Item	Week	Treatment						Statistical significance[1]			
		C-M	C-BW	C-MBW	A-M	A-BW	A-MBW	SEM	A	G	A × G
Fat (%)	1	4.79[ab]	4.76[ab]	5.48[a]	5.37[a]	4.19[c]	5.46[a]	1.24	ns	*	ns
	3	4.44[b]	4.64[b]	4.78[ab]	4.79[ab]	4.73[ab]	4.92[a]	0.89	*	*	*
	6	4.10[b]	4.40[a]	4.50[a]	4.55[a]	4.44[a]	4.59[a]	0.92	*	ns	ns
Protein (%)	1	3.26[b]	3.24[b]	3.41[ab]	3.45[ab]	3.29[b]	3.55[a]	0.73	ns	ns	ns
	3	3.31[b]	3.30[b]	3.44[ab]	3.44[ab]	3.29[b]	3.53[a]	0.32	ns	ns	ns
	6	3.27[b]	3.27[b]	3.38[ab]	3.49[a]	3.33[ab]	3.57[a]	0.55	*	ns	ns
Urea (mg/kg)	1	200[a]	193[ab]	188[ab]	187[ab]	184[b]	191[ab]	12.3	ns	ns	ns
	3	283[a]	250[b]	220[bc]	211[bc]	198[c]	223[bc]	17.4	*	ns	ns
	6	361[a]	322[ab]	312[ab]	250[b]	229[b]	316[ab]	16.3	*	*	ns

[1]Probability of factor impact (A = glucogenic additive, G = grain) and interaction of factors: *$P \leq 0.05$, ns = $P > 0.05$
[a,b,c]values in the rows with different letters differ significantly ($P \leq 0.05$)

Table 7. Reproductive indicators of cows

Item	Treatment						Statistical significance[5]			
	C-M	C-BW	C-MBW	A-M	A-BW	A-MBW	SEM	A	G	A × G
Days to first ovulation	56[a]	55[a]	57[a]	52[b]	51[b]	52[b]	5.81	*	ns	ns
Open days[1]	78[a]	73[ab]	79[a]	63[b]	68[ab]	67[ab]	5.31	*	ns	*
Reproductive cycle (days)[2]	368[a]	360[ab]	366[a]	348[b]	357[ab]	352[b]	18.5	*	ns	ns
Conception (%)[3]	63[b]	64[b]	67[ab]	68[ab]	67[ab]	70[a]	4.87	*	*	*
Insemination index[4]	1.71[ab]	1.75[a]	1.68[ab]	1.63[b]	1.66[ab]	1.62[b]	0.12	*	ns	*

[1]number of days from calving to successful insemination

[2]number of days between calving

[3]conception at the first artificial insemination

[4]number of semen portions to successful insemination

[5]probability of factor impact (A = glucogenic additive, G = grain) and interaction of factors: $*P \leq 0.05$, ns = $P > 0.05$

[a,b]values in the rows with different letters differ significantly ($P \leq 0.05$)

in the treatments where barley-wheat concentrate mixture was used as compared to the groups fed maize-based concentrate. The glucogenic additive × grain interaction dealing with this parameter was also noted ($P \leq 0.05$). A significantly positive influence of GA was noted in the treatments with concentrates based on either maize or barley-wheat, whereas no impact was reported in the treatment with maize-barley-wheat-based concentrate.

Glucogenic additive had also considerable positive influence on the reproductive indicators of cows (Table 7). The cows receiving the additive showed a significantly ($P \leq 0.05$) lower number of days from calving to the first artificial insemination (by 4.3) as well as to successful insemination (by 4.0) and, finally, lower (by 0.07) insemination index but higher (by nearly 4 percentage points) conception at the first insemination. The grain type did not have much effect on the reproductive parameters, except by 3 percentage points ($P \leq 0.05$) higher conception rate at the first insemination in the treatment where maize-barley-wheat-based concentrate was used, in comparison with the other two grain treatments.

DISCUSSION

Propylene glycol (PG) and calcium propionate are glucogenic precursors. PG, according to Kristensen et al. (2002), is quickly absorbed from the rumen wall or partly transformed into propionate in the rumen before being absorbed and converted in the liver into glucose. Propionate is easily released from calcium propionate, absorbed into blood in the rumen wall and transported to the liver, where it is converted into glucose via gluconeogenesis (Van Soest, 1994). However, both glucogenic agents may have detrimental influence on feed intake. According to Oba and Allen (2003), propionate may elicit hypophagia via effects on both satiety and hunger, whereas propylene glycol is itself an unpalatable additive (Girschewski et al., 1977). Even so, its low palatability can be masked by thoroughly mixing with other feed components (Nielsen et al., 2004). In many studies, neither negative impact of PG (Miyoshi et al., 2001; Moallem et al., 2007), nor propionate (DeFrain et al., 2005) or both of them (Ballard et al., 2001) on feed intake was noted. In the experiment carried out by Cozzi et al. (1996), dry matter intake was even increased by feeding PG in the diet. Similarly, in our study, a glucogenic preparation (given 450 g per head/day) applied as a blend (1 : 1) of propylene glycol and Ca-propionate mixed with a concentrate, did not have any negative influence on feed intake. In week 3 of lactation the amount of DM consumed by cows receiving this preparation was even by about 6% higher ($P \leq 0.05$) in comparison with control animals. A nearly 3% increase of roughages consumption was observed. The differences were however statistically insignificant. The significantly higher intake (by about 10%) regarded only the concentrates.

The effect of GA was investigated in the diets with concentrates based on grains (maize, barley, and wheat) of different ruminal starch digestion. Herrera-Saldana et al. (1990) reported that the effective rumen degradability of maize, barley, and wheat amounted to 62, 90, and 95, respectively. Grain species rich in starch easily degradable in the rumen increase the level of propionic acid (the only glucogenic VFA (volatile fatty acids)) in ruminal fluid (Overton et al., 1995). Allen (2000) found propionate to be more hypophagic than absorbed from small intestine glucose. Excessive fermentation of starch to VFA in the rumen may, therefore, lower the dry matter intake (DMI) of high producing dairy cows (McCarthy et al., 1989; Overton et al., 1995). Other studies (Herrera-Saldana et al., 1990; Strzetelski et al., 2008), however, have shown no change in intake as degradation of starch in the rumen increased. The type of grain species of differentiated ruminal starch degradation used in our trial did not have any negative impact on feed DM intake, too.

The trial results have revealed significantly higher (by 2–3 percentage points) coefficients of the apparent total tract digestibility of OM, CP, EE, and NFE of the diets supplemented with GA. A similar increase in the CATTD of nutrients of the diets including propylene-glycol was reported by Cozzi et al. (1996), but these differences in comparison with the control treatment were not confirmed statistically. Liu et al. (2009) observed also an improvement in organic matter and crude protein digestibility coefficients, when Ca-propionate in 100, 200 or 300 g dose per head/day was added to beef cattle diet. They speculated that this additive stimulates the digestive microorganisms or enzymes in a dose-depended manner. The grain type influenced the digestibility coefficients of dietary crude protein as well as NFE being significantly lower (by about 2 percentage points) in the treatments with maize-based concentrate in comparison with the treatment based on barley-wheat. Similar results regarding dry matter digestibility were obtained by Khorosani et al. (2001) who studied the effect of barley grain substitution by corn on total tract digestibility of nutrients on cows, as well as the results obtained by Matras et al. (1991) in the trial on sheep fed the diets based on barley vs. sorghum.

The results of the most investigations with GA application around calving time have indicated either unchanged (Miyoshi et al., 2001; DeFrain et al., 2005; Moallem et al., 2007) or slightly increased milk yield (Emery et al., 1964; Fisher et al., 1973). This study also showed a positive impact (proved statistically) of a glucogenic preparation in the 3rd and 6th week on milk production during a 6 week postpartum (ca. 6% increase). It could be connected with higher energy value of the consumed rations (Table 3). These differences arose mainly due to higher energy value of glucogenic preparation replacing regular concentrate mixtures. This preparation used in a daily dose of 0.45 kg per head, instead of similar amount of concentrate, increased the ration energy by nearly 3%. Besides, in week 3, a significantly higher (by 0.7 kg) DM amount of consumed concentrate was noted. In this study the glucogenic preparation did not have any considerable impact on energy expenditure per 1 kg FCM. The energy additives, however, can alleviate a negative energy balance in cows, noted usually at the beginning of lactation (DeFrain et al., 2005; Liu et al., 2010). In the study on mid-lactating dairy cows carried out by Cozzi et al. (1996) the average daily gains increased from 64 to 206 and 302 g/day when 200 or 400 g propylene glycol was added. The influence of grain species was demonstrated as well, with the highest yield in the 3rd and 6th week of lactation in the groups fed the maize-barley-wheat-based concentrate. These results correspond partly with those obtained by Overton et al. (1995), who researched the lactating cows diets containing maize and barley starches at different ratio (from 100 : 0 to 0 : 100). The highest milk yield they obtained from group that received diets with maize and barley starches at 75 : 25 ratio. Both these results and the data from the other studies (McCarthy et al., 1989; Overton et al., 1995; Huntington, 1997; Allen, 2000) show that mixture of grain species differing in the rate of ruminal starch degradation promote sufficient ruminal fermentation with, at the same time, high portion of starch digested to glucose in small intestine. In our study, the highest milk production was obtained in the treatment where the marriage of glucogenic additive and concentrate containing both starches, i.e. easily (barley and wheat) and slowly (maize) degradable in the rumen was used. The lowest energy and protein (PDI, g) expenditure per 1 kg FCM yield was also determined in this treatment.

Propylene glycol and/or Ca-propionate, employed as glucogenic additives in the studies carried out by Ballard et al. (2001), DeFrain et al. (2005) or Moallem et al. (2007) did not have any significant influence on fat content in milk. In the present study the GA elevated this milk component in weeks 3 and 6 of lactation by about 0.2 percentage point ($P \leq 0.05$). A slight increase (by 0.15 percentage point, $P \leq 0.05$) of protein level in milk of cows receiving this preparation was observed in the 6th week of lactation as well. An increased percentage of this milk component when supplying GA can be justified by decreased utilization of amino acids for gluconeogenesis (Grinari et al., 1997). However, the results reported in most studies have not confirmed positive impact of GA on milk protein content (Patton, 2004; DeFrain et al., 2005; Moallem et al., 2007). Milk urea nitrogen is closely correlated with its level in blood plasma. It is a good indicator of energy and protein balance of the diet (Whitaker et al., 1995). The average content of this milk constituent in all the treatments (240 mg/kg) in our experiment was consistent with the results obtained by De Campeneere et al. (2006) who used the energy-protein-balanced diet based on maize or maize-grass silage. A glucogenic additive had a beneficial influence on this parameter, as its content was significantly lower in the treatment with GA in comparison with the control one (221 vs. 259 mg/kg), respectively. An increased level, exceeding 190 mg MUN (milk urea nitrogen; i.e., about 400 mg urea) per litre of milk may have negative influence on the reproductive indices (Butler et al., 1996).

The studied dietary glucogenic supplement has improved the reproductive parameters of cows decreasing the number of days until the first insemination, days open as well as insemination index. The results of the other studies on the influence of GA on cow reproductive indices have not been unequivocal. The investigations by Lucci et al. (1998), who used "days to first oestrus" to assess the effects of GA on reproduction, did not find any significant differences between GA and the control treatment. In the study carried out by Miyoshi et al. (2001), a daily dose of 518 g GA did not affect days to the first service, days open, and services per conception as compared to the control cows, however it significantly (by 12 days) reduced the time to the first ovulation. Also Pehrson et al. (1992), who studied the dietary inclusion of an energy additive containing glycerol and calcium propionate to cow feeding to improve energy balance, reported a shorter (by 11 days) time interval to the first insemination. Similarly, Reksen et al. (2001) demonstrated that such supplementation in cows of high productivity improved energy balance after parturition, and, consequently, induced earlier ovulation process. A source of starch did not have considerable influence on the reproduction indices that agrees with the result achieved by Strzetelski et al. (2008), who conducted comparative studies on barley and maize.

CONCLUSION

Summing up, the glucogenic additive comprising propionate and propylene glycol (1 : 1) used in transition period of dairy cows fed the diets differing in grain starch ruminal degradability was shown not to have any negative influence on feed dry matter intake. The GA inclusion in the diets increased the coefficients of apparent total tract digestibility of basic nutrients. Besides, glucogenic supplementation promoted milk yield growth, noted in weeks 3 and 6 by over 6% with the peak effect in the treatment, where the GA was employed in the diet containing mixture of grain species (maize, wheat, barley) of different rumen starch degradation rate (maize – low degradability, whereas wheat and barley – high degradability). The glucogenic additive has also increased a protein level and decreased milk urea content. To achieve the optimum cow performance, marriage of GA is recommended to be used with the diet containing both, grain of easily degradable ruminal starch (barley, wheat) and that characterized by low starch degradability in the rumen (maize).

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