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Original article

Effects of different starch sources on metabolic profile, production and fertility parameters in dairy cows*

R. Mikuła[1], W. Nowak[1], J.M. Jaśkowski[2], P. Maćkowiak[3], E. Pruszyńska Oszmałek[3]

Poznań University of Life Sciences
[1] Department of Animal Nutrition and Feed Management, Wołyńska 33, 60-637 Poznań, Poland
[2] Department of Veterinary, Wojska Polskiego 52, 60-628 Poznań, Poland
[3] Department of Animal Physiology and Biochemistry, Wołyńska 35, 60-637 Poznań, Poland

Abstract

The objective of the study was to determine the effect of replacing triticale (high rumen degradable starch) with maize grain (low rumen degradable starch) during the transition period and the first 120 days of lactation on metabolic and hormonal profile indices, milk production and fertility performance in cows. Forty-eight Holstein-Friesian dairy cows were divided into 4 groups: TT (2.5 kg triticale grain/cow per day supplemented from 14 days prepartum to day 120 postpartum), TM (2.5 kg triticale grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg maize grain to 120 days of lactation), MT (2.5 kg maize grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg triticale grain to 120 days of lactation), MM (2.5 kg maize grain/cow per day supplemented from 14 days prepartum to day 120 postpartum). Blood samples were collected 3 weeks and 1 week before calving and on days 14, 56 and 70 of lactation, and they were analyzed in terms of concentrations of glucose, insulin, leptin, insulin-like growth factor I, nonesterified fatty acids, triglycerides, cholesterol, blood urea nitrogen and activities of aspartate aminotransferase and gamma glutamyl transpeptidase. Milk samples were collected twice a day at weekly intervals and analyzed for fat, protein and lactose. Milk yield and individual dry mater intake were recorded at weekly intervals. Body condition was estimated 3 weeks before calving, on parturition day and on days 14, 56 and 120 of lactation.

Replacing triticale grain with maize grain in the transition period and during lactation positively affected fertility of lactating cows. An increased first service conception rate and shortening of the days open period was observed in MM and TM groups in comparison to those found in group MT ($P \leq 0.05$). The lowest number of services per conception was recorded in groups MM and TM ($P \leq 0.05$). Although the impact of milk production and the most of the blood indices were not significantly affected by this treatment, the results of the study suggest that maize grain in the transition period and lactation might be a more effective energy source for dairy cows than triticale grain.

Key words: dairy cows, transition period, maize grain, starch, blood indices, fertility

Correspondence to: R. Mikuła, e-mail: r.mikula@up.poznan.pl

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Introduction

The manner, in which cows are managed in the transition period from week 3 before calving to week 3 of lactation, has a decisive effect on their health status, yields and profitability of production (Drackley 1999). Metabolic and hormonal changes taking place at that time as well as stressors result in reduced dry matter intake (Bertics et al. 1992). Transition cows often suffer from hypoglycemia and hyperlipidemia. Mobilization of body fat reserves during negative energy balance (NEB) is associated with high plasma concentrations of nonesterified fatty acids (NEFA), β-hydroxybutyrate (BHBA) and low plasma concentrations of insulin and insulin-like growth factor I (IGF-I) and also interact with reproductive hormones that control the ovarian function (Garnsworthy et al. 2008).

The most common method to reduce NEB is increasing the concentration of energy by increasing the amount of starch based concentrate in the diet. However, this strategy may have a negative effect on rumen fermentation, increasing the risk of subacute rumen acidosis.

The site of starch digestion in the gastrointestinal tract is interesting from the biological point of view, because propionate and glucose might have different effects on metabolic hormones (Garnsworthy et al. 2009). Feeding rations that partly shift the site of digestion from the rumen to the small intestine is in theory an attractive strategy to overcome some of the nutritional shortcomings associated with meeting nutrient needs of transition cows (Larsen et al. 2009). De Visser (1993) showed that 42% of the insoluble maize starch can escape rumen digestion, compared with 8% for wheat and barley. Reynolds (2006) reported a mean starch intestinal digestibility entering the small intestine of dairy cows to be an average of 676 g/kg. Richards (2002) noted intestinal digestibility of abomasaly infused native maize starch within the range of 540-660 g/kg. Digestion of starch in the intestine is more efficient energetically than fermentation and absorption of organic acids in the rumen (Owens et al. 1986, Nocek and Tamminga 1991). Correa et al. (2002) suggested that starch from dried maize grain could be an important glucose source for ruminants. Larsen and Kristensen (2009) stated that glucose absorption in the small intestine is an efficient source of glucose to the peripheral tissues of dairy cows in early lactation, and at least 67% of the available glucose is recovered in the portal vein without affecting hepatic gluconeogenesis. Abramson et al. (2005) concluded that energy efficiency of total nonstructural carbohydrates digested in the small intestine might be greater if they are not digested in the rumen, but rather in the small intestine. Garnsworthy et al. (2009) concluded that rumen digestible starch and rumen bypass starch can be equally effective for maintaining plasma insulin and ovarian function by high dairy cows in early lactation.

Dry off and close up period impact the ability of cows to make smooth transitions to lactation (Drackley 1999). Jouany (2006) suggested that priority of the diet management in the transition period is controlling rumen acidosis. We hypothesized that introducing into close up period low degradable starch with lower acidogenic potencial (Sauvant 1999) can be used to improve metabolic status of lactating cows.

The aim of the study was to investigate whether the site of starch digestion (triticale grain as rumen degradable starch and maize grain as rumen by pass starch) during the transition period and the first 120 days of lactation effect on metabolic indices, production and reproductive performance in cows.

Materials and Methods

Forty-eight Holstein-Friesian dairy cows were assigned to treatment 21 days before the expected calving date (estimated pregnancy period – 280 days). Primiparous cows were divided according to calving date, and multiparous cows were divided with respect to calving date, parity, previous lactation milk production, body weight and body condition scores. The treatments included: TT (2.5 kg triticale grain/cow per day supplemented from 14 days prepartum to day 120 postpartum), TM (2.5 kg triticale grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg maize grain to 120 days of lactation), MT (2.5 kg maize grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg triticale grain to 120 days of lactation), MM (2.5 kg maize grain/cow per day supplemented from 14 days prepartum to day 120 postpartum). Cows were fed individually with a TMR complete ration (close up and lactation diets) according to the INRA recommendation (Coulon et al., 1989) (Table 1). Diets were balanced using the computer program package INRAtion 3.3 (Table 1), feed nutrition value were estimated by PrevAlim 3.23. Maize, triticale and barley grain were grounded.

Blood samples were collected (four hours after morning feeding) 3 weeks and 1 week before calving and on days 14, 56 and 70 of lactation. Concentration of glucose was analyzed with an Accu-Chek Active blood glucose meter by Roche Diagnostic GmbH. Samples were collected into a tube with polystyrene separating granules covered with a clot activator, rotated in a centrifuge, frozen and stored (-20°C) for later analysis. Serum was thawed and analyzed for the concentration of nonesterified fatty acids (NEFA), according to Duncomb's colorimetric method (Duncombe 1964). The concentration of cholesterol and

Table 1. Diets composition.

Item	Close up diets[1]		Lactation diets[2]	
	Triticale	Maize	Triticale	Maize
Ingredients (% of DM)				
maize silage	38.8	38.8	31.0	31.0
alfalfa silage	19.7	19.7	15.7	15.7
sugar beet pulp silage	6.4	6.4	5.1	5.1
wheat straw	4.8	4.8	3.8	3.8
meadow hay	4.8	4.8	3.8	3.8
soybean meal	7.0	7.0	7.3	7.3
maize grain	**–**	**11.5**	**–**	**9.2**
triticale grain	**11.5**	**–**	**9.2**	**–**
barley grain	4.6	4.6	22.1	22.1
minerals and vitamins	2.4	2.4	2.0	2.0
Nutrient composition (in DM)				
DM (kg)	18.8	18.8	23.5	23.5
UFL	15.98	16.09	20.26	20.37
PDIN (g)	1621	1624	2105	2108
PDIE (g)	1571	1571	2106	2109
LFU	16.5	16.5	17.5	17.5
Ca (g)	136	135	200	199
P (g)	61.8	58.3	82.5	79.0
Nutritive value (in kg DM)				
UFL	0.85	0.86	0.86	0.87
PDIN (g)	86	87	90	90
PDIE (g)	84	84	90	90

[1] from d 14 before calving to 14 of lactation period
[2] from d 14 to d 120 of lactation period

triglycerides, blood urea nitrogen (BUN), as well as the activity of aspartate aminotransferase (ASPAT) and gamma glutamyl transpeptidase (GGTP) were analyzed with a Pointe Scientific kit reagent. Serum hormone concentrations were analyzed by means of radioimmunoassay (RIA): insulin and leptin (Millipore Corporation, USA), and insulin-like growth factor I (Diagnostic Systems Laboratories Inc., USA).

Milk samples were collected twice a day at weekly intervals and analyzed for fat, protein and lactose using a MilkoScan (Foss Electric, Hillerod, Denmark). Milk yield and individual dry matter intake were recorded once a week to 70 day in milk.

Fertility parameters were noted, cows watched for heat detection 3 times daily by visual signs of heat.

Body condition was estimated 3 weeks before calving, on parturition day and on days 14, 56 and 120 of lactation according to Edmonson et al. (1989).

The results obtained were processed statistically using the statistical computer program package SAS 9.1 (2004). One-way analysis of variance was carried out using the GLM procedure and the Duncan test. Significance was declared at $P \leq 0.05$, in turn tendencies were considered when $0.05 < P \leq 0.1$.

Results

In this study different sources of starch (triticale or maize grains) had no relevant effect on average dry matter intake (data not shown).

Maize grain (MG) did not have a significant effect on the result of serum glucose concentration during the transition period; however, a tendency to an increased concentration of glucose in group MM was observed from day 14 of lactation (Table 2). Moreover, on day 70 after calving, statistical differences were observed between groups MM and TM ($P \leq 0.05$). The highest insulin concentration was found in MM group in comparison to the TT group on day 7 prepartum ($P \leq 0.05$). Different starch sources did not have an influence on leptin and insulin-like growth factor I concentrations ($P > 0.05$). However, a tendency to an increased concentration of leptin was observed on day 7 before calving in both groups administered a diet with maize grain. In turn, the highest concentration of IGF-I was recorded in the MM group during the transition period (7 days before calving and on day 14 of lactation). Serum NEFA concentration was the lowest in groups MM and MT on days 7 prepartum and 14 postpartum; however, the differences were significant when com-

Table 2. Serum concentrations of metabolic and hormonal indices.

	Group	Time of sample collection				
		- 21 days	- 7 days	14 days	56 days	70 days
Glucose (mmol/l)	TT	3.55	3.55	2.53	2.74	2.93^{ab}
	TM	3.49	3.62	2.41	2.72	2.73^{b}
	MT	3.58	3.47	2.53	2.82	2.83^{ab}
	MM	3.44	3.61	2.69	2.98	3.10^{a}
	SD	0.329	0.307	0.438	0.488	0.419
Insulin µU/ml	TT	18.2	9.12^{b}	6.6	14.3	19.1
	TM	18.2	11.1^{ab}	7.2	11.1	15.3
	MT	18.1	11.8^{ab}	5.3	14.0	12.1
	MM	17.8	13.9^{a}	5.1	15.3	16.2
	SD	9.72	4.88	4.20	5.94	8.53
Leptin ng/ml	TT	3.32	2.72	3.16	3.51	2.90
	TM	3.67	2.58	3.17	2.87	3.24
	MT	3.41	2.94	3.42	2.98	2.78
	MM	4.21	3.55	3.48	3.49	3.33
	SD	0.87	0.97	0.93	0.82	0.85
IGF-I ng/ml	TT	300	185	57.3	110	127
	TM	290	187	53.0	140	139
	MT	309	171	43.7	96.5	142
	MM	266	199	66.8	126	108
	SD	74.7	78.2	23.7	56.2	31.2
Nonesterified fatty acids (mmol/l)	TT	0.11	0.23	0.49^{a}	0.10^{b}	0.18^{ab}
	TM	0.10	0.23	0.34^{ab}	0.18^{a}	0.11^{b}
	MT	0.10	0.17	0.22^{b}	0.08^{b}	0.13^{b}
	MM	0.09	0.14	0.20^{b}	0.10^{b}	0.23^{a}
	SD	0.053	0.161	0.322	0.055	0.098
Triglycerides (mmol/l)	TT	0.21	0.16^{b}	0.10^{ab}	0.10	0.08
	TM	0.25	0.19^{ab}	0.09^{b}	0.09	0.15
	MT	0.20	0.24^{a}	0.13^{ab}	0.08	0.12
	MM	0.25	0.20^{ab}	0.14^{a}	0.12	0.13
	SD	0.081	0.095	0.049	0.048	0.082
Cholesterol (mmol/l)	TT	2.26	1.84^{a}	1.87	3.60^{b}	3.81
	TM	2.09	1.63^{ab}	2.05	4.66^{a}	4.49
	MT	2.56	1.38^{bc}	1.79	3.29^{b}	3.49
	MM	2.06	1.19^{c}	1.85	3.29^{b}	4.88
	SD	1.35	0.51	0.76	1.17	1.83
BUN (mmol/l)	TT	2.22	2.72	2.24^{b}	2.49	1.74
	TM	2.57	3.18	4.17^{a}	2.68	2.37
	MT	2.24	2.99	2.90^{ab}	3.54	2.02
	MM	2.35	2.33	3.85^{a}	1.94	2.45
	SD	1.16	1.65	1.82	1.85	1.76
ASPAT (U/l)	TT	57.5	64.1^{a}	100	58.0^{ab}	60.1
	TM	53.7	44.8^{b}	91.1	56.2^{ab}	60.1
	MT	53.1	53.8^{ab}	113	65.4^{a}	54.1
	MM	53.7	59.8^{a}	81.5	53.3^{b}	50.5
	SD	11.7	16.8	40.9	12.9	15.3
GGTP (U/l)	TT	57.9	58.5	69.2	72.5	81.3
	TM	55.7	58.6	71.2	71.9	78.2
	MT	59.5	55.2	76.5	73.2	80.1
	MM	55.0	56.7	70.2	74.5	80.4
	SD	8.05	10.5	14.3	12.7	12.7

Values are given as means, SD – standard deviation
Statistically significant differences ($P \leq 0.05$) between groups at each sampling time are indicated by different letters
TT (2.5 kg triticale grain/cow per day supplemented from 14 days prepartum to day 120 postpartum), TM (2.5 kg triticale grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg maize grain to 120 days of lactation), MT (2.5 kg maize grain/cow per day supplemented from day 14 before parturition to calving, and then 2.5 kg triticale grain to 120 days of lactation), MM (2.5 kg maize grain/cow per day supplemented from 14 days prepartum to day 120 postpartum)

pared to group TT only in week 2 of lactation ($P \leq 0.05$). The highest NEFA concentration was detected on day 56 of lactation in the TM group ($P \leq 0.05$). In turn, on day 70 postpartum the TM and MT groups were characterized by the lowest NEFA concentration in comparison to the MM group ($P \leq 0.05$). The serum triglycerides concentrations were higher in the MT and MM groups in the transition period. Moreover, statistical differences were recorded between the MT and TT groups on day 7 before calving and the MM compared to TM groups on day 14 of lactation ($P \leq 0.05$). MG had an effect on a decreased serum cholesterol concentration on day 7 before parturition ($P \leq 0.05$). The highest concentration of cholesterol in the TM group was observed on day 56 of lactation ($P \leq 0.05$). On day 14 the serum BUN concentration was the lowest in the TT group, compared with groups which had been supplemented maize grain in this period ($P \leq 0.05$). The lowest activity of ASPAT during lactation was found in the MM group; however, statistical differences were detected only on day 56 after calving between the MT and MM groups. Moreover, maize grain did not significantly affect gamma glutamyl transpeptidase activity (Table 2).

Feeding MG resulted in an improvement of fertility indices (Table 3). Maize grain fed before calving and during lactation (MM), as well as only during lactation (TM), had a positive effect on an increased first service conception rate and a shortening of the days open period; however, statistically significant differences were observed only in comparison to group MT. The lowest number of services per conception was recorded in groups MM and TM ($P \leq 0.05$).

MG did not have a significant effect on body condition score and condition changes during the transition period (Table 4); however, a positive tendency to the lowest condition losses was observed in groups MM and TM.

Weekly milk yield in all groups was similar in the 3 weeks of lactation (Table 5). Afterwards, milk yield tended to be lower in the MM group. Moreover, statistical differences were detected at weeks 9 and 10 ($P \leq 0.05$). There was no treatment effect on the concentration of fat and lactose in milk. The highest concentration of protein in milk was observed in group TT during the first month of lactation, with statistically significant differences at week 1, 2 and 4 after calving ($P \leq 0.05$).

Table 3. Reproductive performance.

Group	Days to first ovulation	First service conception rate	Services per conception	Days open
TT	28.5	0.45^{ab}	1.91^{a}	130^{ab}
TM	34.8	0.80^{a}	1.20^{b}	104^{b}
MT	35.7	0.25^{b}	1.94^{a}	156^{a}
MM	31.6	0.78^{a}	1.26^{b}	115^{b}
SD	11.0	0.50	0.86	42.4

Values are given as means
SD – standard deviation
Statistically significant differences ($P \leq 0.05$) between groups are indicated by different letters

Table 4. Body condition scoring.

Group	Time of estimating BCS					Condition changes		
	-21 days	0	+14 days	+56 days	+120 days	-21 → 0	0 → +14	-21 → +14
TT	3.75	3.54	3.38	3.40	3.46	0.21	0.17	0.38
TM	3.63	3.49	3.38	3.27	3.35	0.17	0.08	0.25
MT	3.69	3.48	3.33	3.29	3.35	0.21	0.16	0.37
MM	3.63	3.54	3.46	3.31	3.33	0.08	0.08	0.16
SD	0.27	0.20	0.25	0.26	0.25	0.21	0.17	0.27

Values are given as means
SD – standard deviation
Statistically significant differences ($P \leq 0.05$) between groups are indicated by different letters

Table 5. Daily milk yield, and fat, protein and lactose concentrations.

	Group	Time of sample collection (in weeks)									
		1	2	3	4	5	6	7	8	9	10
Yield (kg)	TT	27.4	32.5	31.4	32.2	33.2	34.3	34.8	33.9	33.0^{ab}	32.1^{ab}
	TM	27.1	30.4	33.5	34.5	33.9	34.1	35.4	35.6	35.8^{a}	33.8^{ab}
	MT	25.8	32.1	32.5	33.8	35.1	33.6	35.8	36.8	36.8^{a}	35.9^{a}
	MM	27.8	33.0	31.8	30.8	31.6	32.5	32.0	30.8	28.8^{b}	29.2^{b}
	SD	7.06	6.59	7.12	7.38	7.29	7.42	7.24	7.44	6.93	6.36
Fat (%)	TT	2.35^{b}	3.14	3.00	2.46^{b}	2.33	2.83	2.87	2.32	1.86^{b}	2.69
	TM	3.80^{a}	3.32	3.57	3.81^{a}	3.18	3.10	2.59	2.38	2.63^{ab}	2.65
	MT	3.38^{ab}	4.15	3.04	3.10^{ab}	3.80	2.67	2.77	2.67	2.83^{ab}	2.72
	MM	4.10^{a}	3.50	3.19	3.03^{ab}	3.21	3.07	2.98	2.37	3.05^{a}	2.64
	SD	1.50	1.81	1.76	1.20	1.93	1.61	1.91	1.12	1.20	1.54
Protein (%)	TT	4.04^{a}	3.45^{a}	3.22	3.24^{a}	3.07^{a}	3.19^{a}	3.16	3.06	3.14	3.20
	TM	3.41^{b}	3.22^{ab}	2.99	2.95^{b}	2.83^{b}	2.80^{c}	2.98	3.00	3.15	3.19
	MT	3.42^{b}	3.10^{b}	3.06	3.01^{ab}	3.03^{a}	2.92^{bc}	3.06	3.19	3.23	3.25
	MM	3.67^{b}	3.08^{b}	3.12	3.02^{ab}	3.08^{a}	3.09^{ab}	3.23	3.19	3.19	3.24
	SD	0.41	0.40	0.32	0.32	0.25	0.32	0.31	0.38	0.25	0.26
Lactose (%)	TT	4.62^{ab}	4.59^{c}	4.74	4.72	4.73	4.74	4.62	4.68^{b}	4.67^{b}	4.70
	TM	4.71^{a}	4.86^{a}	4.79	4.78	4.80	4.75	4.77	4.81^{a}	4.75^{a}	4.71
	MT	4.51^{b}	4.77^{ab}	4.76	4.78	4.60	4.66	4.72	4.76^{ab}	4.67^{b}	4.68
	MM	4.59^{ab}	4.66^{bc}	4.30	4.63	4.74	4.75	4.64	4.70^{b}	4.70^{ab}	4.69
	SD	0.22	0.22	0.59	0.22	0.27	0.19	0.20	0.12	0.08	0.05

Values are given as means
SD – standard deviation
Statistically significant differences ($P \leq 0.05$) between groups at each sampling time are indicated by different letters

Discussion

We hypothesized that the site of starch digestion, i.e. the rumen vs. the small intestine, can affect metabolic profile indices, hormones, milk production and fertility in dairy cows.

Blood glucose concentrations in dairy cows depend on energy uptake (Yelich et al. 1996); in turn, a low insulin concentration in the early lactation reflects a negative energy balance (Canfield and Butler 1991).

In our experiment, no effect of maize grain starch on glucose concentration was observed up to the 8th week of lactation, whereas on day 7 before calving a statistically significant elevation of insulin concentration was observed only in the group, which was fed maize grain in the diet (MM) in comparison to the group receiving triticale grain (TT). This agrees with the findings of Lemosquet et al. (1997), who observed an increase in the concentration of glucose and insulin after duodenal administration of 1500g glucose, but in this study the rise of glucose concentration was only numerical.

Theoretically, efficiency of energy utilization from intestinal digestion of starch is higher than that of starch fermented in the rumen, what was confirmed by Owens et al. (1986). Nocek and Tamminga (1991) presented that rumen undegradable starch could be enzymatically digested in the small intestine, increasing directly the pool of available glucose. An opinion on a higher energetic efficiency of starch digested in the small intestine when compared with ruminal degradation was given by Harmon and McLeod (2001), mainly in view of carbon losses during ruminal fermentation. Larsen et al. (2009) observed that a reduced rumen degradation of starch was not associated directly with an increase in starch digestion in the small intestine. In turn, Knowlton et al. (1998) showed that insulin concentration increased when starch was administered to the rumen or to the abomasum, but without differences between the site of infusion. The results, showing no effect of the site of starch digestion on glucose and insulin concentrations were reported by Garnsworthy et al. (2009), who compared the influence of five diets containing similar starch quantities, but varied from high rumen degradable starch (wheat grain) to high rumen bypass starch (flint maize grain). Metabolic hormone changes have an effect on reproductive hormones, which control ovarian functions (Webb et al. 2004). Insulin and the growth hormone play critical roles in the process of follicular development and maturation (Shimizu et al. 2008). Poff et al. (1998) stated that insulin is necessary for the optimal steroidogenesis in follicular and luteal cells. Gong et al. (2002) were of the opinion that feeding a feed ration resulting in an increased insulin concentration contributes to an advantageous increase in the first service conception rate. In this experiment maize grain fed before calving and during lactation (MM), and only during lactation (TM) had a positive effect on an increase in the effectiveness of the first insemination, which contributed to an improvement in the insemination index and a shortening of the days open period. Moreover, Grummer and Carroll (1988) documented the importance of cholesterol as the precursor of steroidogenesis and this suggestion was confirmed in our experiment. The cows which received maize grain after parturition (TM) were characterized by the best fertility indices and the highest cholesterol concentration on days 14 and 56 of lactation, but statistical differences were found only on day 56 ($P \le 0.05$). Block et al. (2003) suggested that insulin is also an important positive regulator of leptin synthesis in dairy cows. In this study thesis was confirmed only on day 7 before calving, then a tendency to the highest insulin and leptin concentrations was observed in groups which were fed diets with low rumen degradable starch due to their maize grain content, before and after parturition (MM) and only before calving (MT). Liefers et al. (2003) showed that a higher concentration of leptin is associated with a higher dry matter intake. In the opinion of McGuire et al. (1995), a sustained period of negative energy balance results in a reduced concentration of plasma IGF-I. In the present study, a tendency to the highest concentration of IGF-I was found in group MM (maize grain supplemented before and after parturition) on day 7 before calving and day 14 in milk. Insulin like growth factor I is also linked with ovarian activity (Webb et al. 2004) and a decline in the concentration of this hormone is connected with reduced fertility (Butler 2000). This hypothesis was partly confirmed in this study, as the worst fertility parameters were recorded in the group receiving triticale grain during lactation (MT), which had the lowest IGF-I concentration on day 7 before calving and also on days 14 and 56 of lactation.

Elevation of blood NEFA concentrations in the periparturient period may partly result from hormonal changes and stress connected with parturition, and a reduced dry matter intake in the feed (McNamara et al. 2003). The concentration of NEFA in the transition period was lowest in the MM and MT groups (maize grain before calving and during lactation, and also only before parturition), which was confirmed statistically in comparison to the group receiving triticale grain (TT) in the diet two weeks after calving ($P \le 0.05$). This result corresponded with the lowest body condition losses during the transition period, which were recorded in the MM and TM groups (maize grain administrated before and after calving and only during lactation). Butler (2003) reported that higher BCS losses are associated with conception rate reduction. We observed this relationship in groups TT (triticale grain before and after calving) and MT (maize grain before calving and next triticale grain during lactation), which were characterized by the highest body condition losses during the transition period as well as the worst fertility indices. Knowlton et al. (1998) observed a trend towards a more effective influence of starch administration to the abomasum on the reduction of NEFA concentration in comparison to ruminal starch administration. A statistically significant reduction of NEFA concentration on day 14 of lactation was observed in the group receiving maize grain (MM) in comparison to the cows which were fed triticale grain in the diet (TT). According to a theory that a lowering of NEFA concentration would indicate a reduced mobilization of lipid reserves accumulated in adipocytes (Canfield and Butler 1991), we suggest that energy efficiency of maize grain by-pass starch entering the small intestine is higher in comparison to ruminally degraded starch. This hypothesis seems to be confirmed by the results reported by Lemosquet et al. (1997), from which it may be concluded that duodenal glucose infusion causes reduced NEFA concentrations, because lypolysis is inhibited by glucose absorbed in the small intestine, irrespective of the total energy balance in cows. Different results were reported by Lykos et al. (1997), who found that NEFA concentration decreases in a linear manner with an increase in the proportion of rapidly fermenting non fiber carbohydratec (NFC) in the rumen. Excessive NEFA mobilization results in an accumulation of triglycerides in the liver and has a negative effect on cows; health (Drackley et al. 2001). In turn, the highest blood triglyceride concentrations in the transition period were observed in groups MT (maize grain before calving and triticale grain after calving) and MM (maize grain before and after calving), which could support our hypothesis, because blood triglycerides may be inversely proportional with NEFA (Seifi et al. 2007).

Summing up, the highest concentrations of glucose, insulin, leptin, IGF-I, blood triglycerides as well as the lowest NEFA level observed from day 7 before calving to day 14 of lactation and the lowest condition losses during the transition period could confirm the positive influence of MG supplemented before and after parturition on energy balance.

The concentration of BUN reflects the diet energy and nitrogen balance for rumen microorganisms to protein synthesis. DePeters and Ferguson (1992) claimed that BUN concentration is reduced with an increase in the amount of rapidly fermenting NFC in the feed ration. This theory was confirmed in the present experiment on day 14 after calving, in which maize grain resulted in an increased blood BUN concentration in comparison to the TT group, which was given triticale grain, rapidly degraded in the rumen.

The activity of both ASPAT and GGTP may reflect the clinical status of the liver. The lowest ASPAT activity was observed in the MM group (maize grain administrated before and after parturition) during the evaluated lactation period; however, statistically significant differences were recorded on day 56 between groups which had maize grain supplemented before calving and maize grain or triticale grain during lactation (MT and MM). Rico et al. (1977) suggested that GGTP activity increases during a negative energy balance; it may also be a valuable test determining hepatocellular damage. However, no effect of different starch sources on changes in GGTP activity was observed in the present experiment.

Glucose availability and uptake by the mammary gland is the main factor limiting milk synthesis (Kronfeld et al. 1976), since lactose is an osmoregulator during the uptake of water by the mammary gland. In the opinion of Rigout et al. (2002), duodenal infusion of glucose may be a key factor increasing glucose uptake by the mammary gland and milk yield. However, propionic acid formed in the rumen during starch degradation, as the main precursor of gluconeogenesis, by increasing glucose concentration may also result in an increased milk yield (Lemosquet et al. 2004). In the present experiment milk yield was similar up to week 3 of lactation. Next, a trend was observed for yield to decrease in the group receiving maize grain before and after calving (MM), although these changes were statistically significant only in weeks 9 and 10 of lactation ($P \leq 0.05$). This agrees with an observation of Garnsworthy et al. (2009), who reported that the site of starch digestion had no effect on milk yield. In spite of potentially greater benefits of starch digestion in the small intestine to glucose, Nocek and Tamminga (1991) expressed an opinion that results of production experiments were inconclusive and did not show that starch digested in the small intestine has an effect on an improved milk yield or the chemical composition of milk. Similarly, Knowlton et al. (1998) did not observe differences in milk yield between starch infusion to the rumen or the abomasum in cows in the lactation peak, whereas a trend was observed for lactose and protein concentrations to increase in milk after starch administration to the abomasum. A reduction of milk fat concentration may be a consequence of the enhanced availability of glucose for the synthesis of lactose in milk without an accompanying increase in volatile fatty acids or long chain fatty acids for butterfat synthesis. According to Lemosquet et al. (1997), in consistence with the glucogenic theory a reduced butterfat concentration may result from an enhanced synthesis of propionic acid or the availability of glucose obtained from starch digested in the intestine, which stimulates insulin secretion. An elevated level of insulin causes a reduction of lipolysis or an increase of lipogenesis and reduced availability of butterfat precursors. In the present experiment no effect of maize grain was recorded on the concentration of fat or lactose in milk. Lemosquet et al. (1997) did not observe changes in milk yield after duodenal infusion of 1500 g glucose; however, glucose infusion had a significant effect on a reduction of butterfat concentration and an increase of protein concentration in milk. The highest protein concentration in milk was recorded in the first month of lactation in the TT group (triticale grain in diet before and after calving), although statistically significant differences were found for weeks 1, 2 and 4 of lactation. Similar results, showing no effect of the site of starch digestion, were recorded by Garnsworthy et al. (2009). Different results were reported by Reynolds et al. (1994), in whose opinion increased amounts of starch digested in the small intestine may result in an increase of protein production in milk.

Summing up, we concluded that maize grain had no influence on milk yield and milk composition.

Conclusion

Replacing triticale grain with maize grain in the transition period and during lactation positively affected fertility of lactating cows. Although the impact of milk production and the most of the blood indices were not significantly affected by this treatment, the results of the study suggest that maize grain in the transition period and lactation might be a more effective energy source for dairy cows than triticale grain.

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