Effect of different pre-calving feeding strategies on the metabolic status and lactation performance of dairy cows

R. Mikuła[1,3], E. Pruszyńska-Oszmałek[2], P. Maćkowiak[2] and W. Nowak[1]

Poznań University of Life Sciences
[1] Department of Animal Nutrition, Wołyńska 33, 60-637 Poznań, Poland
[2] Department of Animal Physiology and Biochemistry, Wołyńska 35, 60-637 Poznań, Poland

[3] Corresponding author:
e-mail: robert.mikula@up.poznan.pl

ABSTRACT. The objective of the study was to investigate the metabolic, health and production consequences of selected pre-calving feeding strategies. Forty Polish Holstein-Friesian multiparous dairy cows were dried off at day 56 before parturition and assigned to 2 pre-calving treatments: CON – a 5-week far-off period and a 3-week close-up period, and SHORT – a 7-week far-off period and a 1-week close-up period with a fresh transition diet. Shortening the close-up period had no effect on body condition score during the dry period; however, a tendency to the lowest body condition score (BCS) losses were observed in the SHORT group during the first 56 days of lactation ($P = 0.13$). Cows from the SHORT group tended to have higher glucose concentration 3 days before calving ($P = 0.13$). Shortening the close-up period resulted in a higher insulin level ($P = 0.04$) and lower concentration of β-hydroxybutyric acid in the blood 28 days after parturition ($P = 0.03$). Cows from the SHORT group were characterized by a higher concentration of triiodothyronine 3 days before calving ($P = 0.03$) and tended to have a higher level of thyroxine 5 days after parturition ($P = 0.09$). A tendency to higher yield of energy corrected milk ($P = 0.09$) and fat content in milk was observed in the SHORT group ($P = 0.11$). There were no differences between treatments in terms of reproductive performance. Simplification of the transition period management and shortening of the close-up period led to a positive tendency to increase the yield of energy corrected milk, with no negative effect on the metabolic status and reproductive performance of dairy cows.

Introduction

In recent years, high yielding dairy cow nutritionists have focused on dry and transition periods, because feeding and management strategies in these periods could affect cows' health as well as reproductive and yield performance in consecutive lactation (Sordillo and Mavangira, 2014; Roche et al., 2015). A decrease in dry matter intake around the time of calving may lead to a negative energy balance in early lactation, which is probably the main problem of cost-effective milk production. In such a situation mobilization of fatty acids from the adipose tissue increases non-esterified fatty acids (NEFA) concentration in blood. Rising level of NEFA in dairy cows' blood during negative energy balance is often associated with the accumulation of triglycerides in hepatocytes and impairment of liver function resulting in an elevated ketone production. Moreover, increased blood NEFA levels could have a negative effect on oocyte development and reproductive performance

(Walsh et al., 2007). Sordillo and Raphael (2013) claimed that a progressive increase in the blood NEFA level before calving may be considered a significant factor affecting inflammatory responses of transition cows. Higher blood NEFA concentrations could be related to an increased risk of displaced abomasum (Chapinal et al., 2011), metritis and retained placenta (Ospina et al., 2010a), mastitis (Suriyasathaporn et al., 2000) and lower milk yield (Ospina et al., 2010b), while it may also result in early-lactation culling risk (Roberts et al., 2012). Thus, many authors have investigated potential methods to reduce blood NEFA concentration using feed additives (Adamski et al., 2011; Piantoni and Allen, 2015). In the present literature many dry cow feeding strategies have also been presented. Some authors attempted e.g., to decrease energy density in dry period diets (Dann et al., 2006; Janovick and Drackley, 2010, Nowak et al., 2013). Moreover, the results described by Zhang et al. (2015) proved a positive effect on metabolism and production during early lactation in cows fed a low energy density diet during the close-up period. Limiting energy intake before parturition may result in an improved energy status in early lactation and lead to a lower mobilization of fatty acids from the adipose tissue and decrease in the risk of metabolic disorders postpartum.

We hypothesized that simplification of the transition period management in dairy cows and shortening the close-up period to one week as well as implementation of a low energy far-off diet one week before parturition, followed by a high energy fresh transition diet with no close-up diet will reduce the negative energy balance postpartum and could have a positive effect on the metabolism of lactating cows as well as improve their fertility and milk performance.

The aim of the present study was to investigate the metabolic and production consequences of shortening the close-up period to one week before calving, preceded by a fresh transition diet.

Material and methods

All animal procedures were conducted in accordance with the guidelines of the Polish Council for Animal Care. The protocol for this study was approved by the Local Animal Care Committee No. 10 of the Poznań University of Life Sciences (Poland).

Animal management, experimental design and diets

Forty Polish Holstein-Friesian multiparous high-yielding dairy cows with body weight of 650 kg at

Table 1. Treatments scheme

Group	Prepartum, week								Postpartum, week		
	−8	−7	−6	−5	−4	−3	−2	−1	+1	+2	+3
CON	Far-off diet						Close-up diet		Fresh transition diet		
SHORT	Far-off diet								Fresh transition diet		

dry-off period were included in the experiment. On the basis of their body weight, body condition score (BCS; Edmonson et al., 1989) at dry-off, previous lactation milk yield and lactation number, the cows 56 days before the expected time of parturition were randomly assigned to 1 of the 2 pre-calving treatments. The experimental treatments were: CON – a 5-week far-off period and a 3-week close-up period, and SHORT – a 7-week far-off period and a 1-week close-up period with a fresh transition diet (Table 1).

The study started 56 days before parturition and covered the far-off and close-up periods as well as the first 56 days of lactation. The nutritional values of the feed components were calculated on the basis of the analysed nutrient contents using the PrevAlim 3.23 software (Educagri/INRA, Theix, France). The diets were balanced according to the French INRA system recommendations (INRAtion 3.3 software, Educagri/INRA, Theix, France). Cows were fed a total mixed ration (TMR), which was served to the animals twice a day at 9:00 and 14:30. The diets were based on a silage made of maize, grass, alfalfa as well as concentrates (soybean meal, rapeseed meal, barley grain, triticale grain) with mineral and vitamin supplements. The animals were fed a far-off diet [(0.69 feed unit for lactation (UFL)/kg dry matter (DM), 66 g protein digested in the small intestine (PDI)/kg DM, 53.4% neutral detergent fibre (NDF)], close-up diet (0.85 UFL/kg DM, 99 g PDI/kg DM, 33.2% NDF) and fresh transition diet (0.92 UFL/kg DM, 108 g PDI/kg DM, 29.3% NDF) according to the treatment scheme (Tables 1 and 2).

During the experiment, the cows were housed in groups. Individual DM intake was unavailable. Instead, voluntary DM intake was measured daily for the whole group during the far-off and close-up periods.

Sample collection and analytical method

Weekly composite forage, concentrate and TMR samples were collected for monthly analyses using wet chemistry for crude protein (CP, method 976.05; AOAC International, 2005), neutral detergent fibre (NDF, PN-EN ISO 16472:2007), acid detergent fibre (ADF, PN-EN ISO 13906:2009), calcium

Table 2. Ingredient and nutrient composition of the experimental total mixed ration (TMR) diets

Indices	Far-off diet	Close-up diet	Fresh transition diet
Ingredients, % of DM			
wheat straw	36.6		3.3
soybean meal	6.0	6.0	6.3
alfalfa silage	8.1	11.1	11.0
maize silage	25.7	25.8	20.8
grass silage	21.1		
maize grain silage		9.4	9.6
sugar beet pulp silage		6.0	6.5
brewer's grain silage		9.0	10.2
hay		7.7	
barley grain		5.2	3.2
triticale grain		6.0	15.1
rapeseed meal		7.1	7.2
glycerol		1.9	1.1
fat			2.2
minerals and vitamins	2.5	4.8	3.5
Nutrient concentration, in kg DM			
UFL	0.69	0.85	0.92
PDIN, g	66	101	110
PDIE, g	69	99	108
CP, %	11.3	14.7	16.8
NDF, %	53.4	33.2	29.3
ADF, %	35.2	21.3	19.0
Ca, g	5.7	8.6	10.2
P, g	3.0	3.4	4.1

DM – dry matter; UFL – feed unit for lactation (1700 kcal NE_L); PDIN – dietary protein undegraded in the rumen, but truly digestible in the small intestine and microbial protein which could be synthesized in the rumen from degraded dietary nitrogen, when energy and other nutrients are not limiting; PDIE – dietary protein undegraded in the rumen, but truly digestible in the small intestine and microbial protein which could be synthesized in the rumen from the energy available in the rumen, when degraded nitrogen and other nutrients are not limiting; CP – crude protein; NDF – natural detergent fibre; ADF – acid detergent fibre

(Ca, method 968.08; AOAC International, 2005) and phosphorus (P, PN ISO 6491:2000). Body condition scoring (BCS) was performed during the far-off period (days −56 and −21), on the parturition day and on days 14 and 56 of lactation.

Blood was sampled from the jugular vein 3 h after morning feeding on days −30, −3 of the prepartum and on days 5 and 28 during lactation. Blood samples were collected into tubes with polystyrene separating granules covered with a clot activator and then the aliquots were rotated in a centrifuge. Next, serum was frozen and stored (−20 °C) for further analyses. The concentrations of glucose and β-hydroxybutyric acid (BHBA) were analysed colourimetrically using the endpoint method. The activity of aspartate aminotransferase (AST) was analysed by colourimetry applying the kinetic

method. Absorbance of the incubated samples was measured using a Marcel Media spectrophotometer (Marcel S.A., Zielonka, Poland) and a Hellma microcuvette (Hellma GmbH & Co., Müllheim, Germany). The concentrations of non-esterified fatty acids (NEFA) were analysed according to the Duncombe colorimetric method (Duncombe, 1964). Serum concentrations of insulin, insulin-like growth factor I (IGF-I), triiodothyronine (T3) and thyroxine (T4) were analysed by means of radioimmunoassay (RIA). Kits of reagents used for blood serum analyses are shown in Table 3.

Table 3. Kits of reagents used for the analysis of blood serum indices

Biochemical indices	Test	Producer
Glucose	G 7518-400	Pointe Scientific (Canton, OH, USA)
β-hydroxybutyric acid	H7587-58	
Aspartate aminotransferase	A7561-450	
Insulin	PI-12K	Millipore Corporation (Burlington, VT, USA)
Thyroxine	OCPG 07-F4	CISBIO International
Triiodothyronine	OCPE07-T3	(Codolet, France)
Insulin-like growth factor I	DSL-2800	Diagnostic Systems Lab. (Webster, NY, USA)

The cows were milked twice a day and individual milk yields were recorded daily during 56 days of lactation. Milk from morning and afternoon milkings was sampled at weekly intervals. Samples were collected into tubes with 2-bromo-2-nitropropane-1,3-diol. Next, samples were refrigerated and delivered to a commercial laboratory (Milk Quality Laboratory, the Polish Federation of Cattle Breeders and Dairy Farmers, Krotoszyn, Poland) for analyses of fat, protein, lactose and urea concentrations as well as somatic cell counts.

Energy corrected milk (ECM) was calculated according to Reist et al. (2003) as:

$$[(0.038 \times g\ crude\ fat + 0.024 \times g\ crude\ protein + 0.017 \times g\ lactose) \times kg\ milk]\ /\ 3.14.$$

Reproductive performance and health monitoring

Reproductive performance parameters (days to first ovulation, first-service conception rate, services per conception and day open) were also recorded. The first ovulation was identified with an ultrasound scanner equipped with a 7.5 MHz convex transducer (Pie Medical Scanner 200; Pie Medical Imaging BV, Maastricht, The Netherlands). During the study cows' health was monitored and recorded daily.

Statistical analysis

Results were processed statistically using Student's t-test with the PROC TTEST procedure of the SAS 9.1 (2004) SAS®/STAT software package (SAS Institute Inc., Cary, NC, USA). The PROC MEANS and PROC UNIVARIATE procedures were also applied. To interpret the results, the following criteria of significance were used: significance ($P \leq 0.05$), tendency to significance ($P \leq 0.1$) and non-significant ($P > 0.1$).

Results

Shortening the close-up period influenced neither the body condition score (BCS) nor condition changes during the dry period ($P > 0.05$). A tendency to lowest BCS losses (0.16 BCS point) was observed in cows assigned to the SHORT group during the first 56 days of lactation ($P = 0.13$; Table 4).

Average DM intake in the far-off (12.9 vs 12.7 kg) and close-up periods (12.5 vs 12.6 kg) was similar between the groups.

Table 4. The effect of shortening close-up period on body condition score (BCS)

Group	Days from calving				
	−56	−21	0	+14	+56
CON	3.65	3.64	3.54	3.37	3.25
SHORT	3.65	3.57	3.50	3.38	3.37
SEM	0.04	0.03	0.03	0.04	0.04
P-value	0.99	0.35	0.59	0.90	0.16

Group	BCS changes				
	−56 → −21	−21 → 0	−56 → 0	0 → 14	0 → 56
CON	−0.01	−0.10	−0.11	−0.17	−0.29
SHORT	−0.08	−0.07	−0.15	−0.12	−0.13
SEM	0.02	0.04	0.04	0.04	0.04
P-value	0.17	0.74	0.68	0.82	0.13

Groups: CON – 5-week far-off period and 3-week close-up period, SHORT – 7-week far-off period and 1-week close-up period; SEM – standard error of mean

Cows from the SHORT group tended to have higher blood glucose concentrations at 1.50 mmol/l vs 1.02 mmol/l on day 3 before calving ($P = 0.13$; Table 5). Shortening the close-up period resulted in higher blood insulin levels on day 28 after parturition ($P = 0.04$). Lower concentrations of β-hydroxybutyric acid (0.752 mmol/l vs 0.977 mmol/l) were recorded in blood from cows assigned to the SHORT group at day 28 after calving ($P = 0.03$). Cows from the SHORT group were characterized by higher concentrations of T3 on

Table 5. The effect of shortening close-up period on serum hormones and metabolites

Indices	Group	Time of blood sample collection			
		prepartum		postpartum	
		−30 day	−3 day	5 day	28 day
Glucose, mmol/l	CON	2.52	1.02	1.10	1.62
	SHORT	2.99	1.50	1.23	1.46
	SEM	0.17	0.16	0.16	0.16
	P-value	0.21	0.13	0.68	0.64
Insulin, µU/ml	CON	14.4	23.2	9.19	7.50
	SHORT	18.4	18.2	8.66	10.2
	SEM	1.23	2.24	0.88	0.06
	P-value	0.09	0.29	0.77	0.04
IGF-I, ng/ml	CON	334	351	215	274
	SHORT	339	343	218	251
	SEM	11.9	11.3	14.4	17.4
	P-value	0.82	0.72	0.91	0.50
NEFA, mmol/l	CON	0.166	0.244	0.634	0.391
	SHORT	0.189	0.283	0.718	0.406
	SEM	0.02	0.03	0.06	0.06
	P-value	0.61	0.49	0.28	0.90
BHBA, mmol/l	CON	0.658	0.657	0.842	0.977
	SHORT	0.649	0.719	0.849	0.752
	SEM	0.02	0.03	0.06	0.05
	P-value	0.84	0.29	0.96	0.03
AST, U/l	CON	75.3	36.7	82.3	58.8
	SHORT	75.4	35.9	55.8	105
	SEM	3.8	3.34	7.16	13.1
	P-value	0.99	0.91	0.06	0.07
T3, ng/ml	CON	1.16	1.22	0.879	1.06
	SHORT	1.27	1.38	0.820	1.18
	SEM	0.04	0.04	0.06	0.05
	P-value	0.15	0.03	0.62	0.28
T4, ng/ml	CON	46.9	40.4	18.3	31.7
	SHORT	51.7	38.1	22.1	37.0
	SEM	1.91	1.64	1.06	2.27
	P-value	0.19	0.46	0.09	0.27

Groups: CON – 5-week far-off period and 3-week close-up period, SHORT – 7-week far-off period and 1-week close-up period; IGF-I – insulin like growth factor I, NEFA – non-esterified fatty acids, BHBA – β-hydroxybutyric acid, AST – aspartate aminotransferase, T3 – triiodothyronine, T4 – thyroxine; SEM – standard error of mean

day 3 before calving ($P = 0.03$) and tended to have higher T4 levels 5 days after parturition ($P = 0.09$). The activity of AST tended to be lower at day 5 of lactation in the SHORT group ($P = 0.06$), while it tended to be higher at day 28 of lactation in the CON group ($P = 0.07$). Shortening of the close-up period had no effect on blood IGF-I or NEFA concentrations ($P > 0.05$).

There were no differences between the two treatment groups (CON and SHORT) in milk yield (Figure 1) or milk composition during the first 56 days of lactation ($P > 0.05$; Figure 2). However,
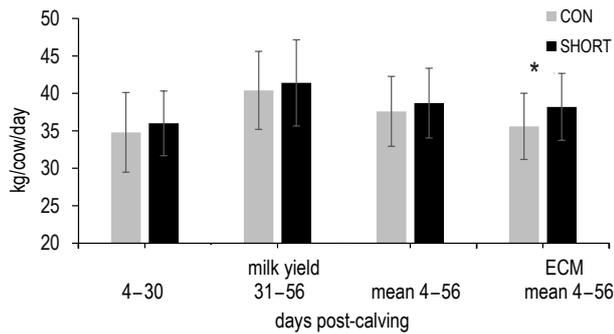
Figure 1. The effect of shortening the close-up period on milk yield and mean energy corrected milk yield (ECM)

Groups: CON – 5-week far-off period and 3-week close-up period, SHORT – 7-week far-off period and 1-week close-up period; mean ± standard deviation; * – indicates the tendency at $P ≤ 0.1$
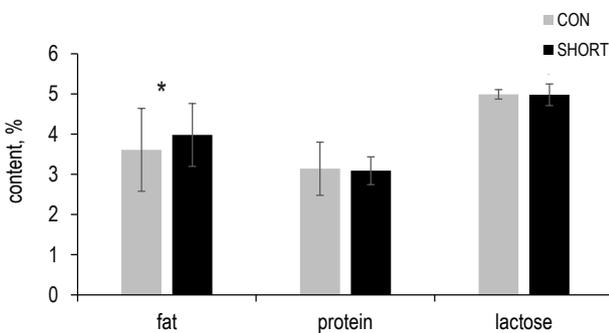
Figure 2. The effect of shortening close-up period on mean (days 4–56) fat, protein and lactose contents in milk

Groups: CON – 5-week far-off period and 3-week close-up period, SHORT – 7-week far-off period and 1-week close-up period; mean ± standard deviation; * – indicates the tendency at $P ≤ 0.1$

cows from the SHORT group tended to produce higher mean energy corrected milk at 38.2 vs 35.6 kg ($P = 0.09$) with higher fat contents of 3.98 vs 3.69% ($P = 0.11$). During the first 56 days of lactation the mean milk urea concentrations and somatic cell counts were similar between the treatment groups ($P > 0.05$, data not shown).

Shortening the close-up period had no effect on fertility indices, days to first ovulation, first service conception rate, services per conception and day open ($P > 0.05$; Table 6).

Table 6. The effect of shortening the close-up period on reproductive performance

Group	Days to first ovulation	First-service conception rate	Services per conception	Days open
CON	23	0.45	2.36	124
SHORT	19	0.33	2.62	144
SEM	2.27	0.10	0.41	15.5
P-value	0.48	0.57	0.45	0.49

Groups: CON – 5-week far-off period and 3-week close-up period, SHORT – 7-week far-off period and 1-week close-up period; SEM – standard error of mean

The total incidence of health problems (dystocia, displaced abomasum, hypocalcemia, mastitis, metritis, ketosis, foot and leg problems) after parturition were similar between thein both groups and amounted 8 and 6 cases, respectively for the CON and SHORT group (data not shown). No predisposition to specific health problems was observed in the groups.

Discussion

We hypothesized that simplification of dairy cow transition period management, shortening the close-up period to one week and implementation of a low energy far-off diet one week before parturition, followed by a high energy fresh transition diet with no close-up diet could have a positive effect on the metabolism of lactating cows as well as improve their fertility and milk production.

The cows in both groups were dried 56 days before the expected calving date to a similar BCS of 3.65. Shortening the close-up period had no effect on BCS or condition changes during the dry period; however, cows assigned to the SHORT group tended to experience the lowest BCS losses during the first 56 days of lactation. Similar results, greater BCS and body weight losses were observed in cows fed high density close-up diets (Zhang et al., 2015). The basic role of the adipose tissue is connected with fatty acids storage supporting productivity. Extreme condition losses after calving could reflect excessive mobilization of body fat reserves from the adipose tissue and indicate clinical signs of ketosis. Thus, a decrease in body condition after calving could be a marker of the energy status of a cow. In the present study BCS losses during the first 56 days of lactation in both groups were moderate (CON – 0.29 and SHORT – 0.13) and reasonably expected as physiological changes (Šamanc et al., 2010). Body condition losses were consistent with the NEFA concentrations, which were comparable in both groups, showing no statistical differences. da Fonseca et al. (2004) claimed that when energy balance is stabilized during lactation the NEFA value may be up to 0.25 mmol/l. In spite of lower body condition losses, the NEFA level exceeded 0.26 mmol/l in both groups during early lactation, which may be used for subacute ketosis diagnosis (Asl et al., 2011). Ketotic cows are immuno-suppressed during the postpartum period. Elevated blood NEFA concentrations mimic intense lipomobilization and thus could be diagnostic tools for impaired periparturient immunity markers, suggesting an increased risk of infection (Ospina

et al., 2010a). LeBlanc et al. (2005) stated that the NEFA concentration during the first week after parturition exceeding 1.0 mEq/l is a critical threshold for displaced abomasum; however, Ospina et al. (2010a) set ≥0.72 mEq/l as the cut-off point for NEFA levels. In the present study, blood NEFA concentrations in both groups were below this threshold. In addition, no case of displaced abomasum was reported. Moreover, González et al. (2011) stated that BHBA concentration is a better maker of energy imbalance postpartum than NEFA, while ketosis in cows may be diagnosed at a blood BHBA concentration exceeding 1.2 mmol/l (Sevınç et al., 1998). Additionally, when fat infiltrates the liver the activity of enzymes (AST, γ-glutamyltransferase and glutamate dehydrogenase) is higher, which indicates liver injury (Bobe et al., 2004). In the present study the activity of AST was moderate below the cut-off point of 100 U/l, which is used to indicate hepatic lesions (González et al., 2011). Lipid metabolism is controlled by glucose, insulin and growth hormone as well as epinephrine and norepinephrine. Lower blood insulin concentration was connected with increased lipolysis and elevated blood NEFA concentration (Chapinal et al., 2012). Additionally, Vernon (2005) argued that insulin is involved in the lipid metabolism of cows in the perinatal period, reducing blood NEFA and BHBA concentrations. The observed metabolite changes in our study partially confirm this hypothesis. Shortening the close-up period had a positive effect on higher insulin concentrations and the lowest BHBA levels at day 28 of lactation.

Complete NEFA oxidation generates metabolites (acetyl-CoA), which may be used to generate energy *via* the Krebs cycle or the tricarboxylic acid cycle. The lowest BHBA concentration with a similar NEFA level observed in the SHORT group seems to confirm better NEFA oxidation for energy and the lowest conversion to ketones in the liver, which is a positive effect. Glucose is widely acknowledged as a factor determining complete NEFA oxidation. In the present study glucose concentrations at day 28 of lactation in both groups were comparable with no significant differences and were observed. A similar observation, showing no effect of the prepartum energy density diet on blood glucose concentration during early lactation was reported by Zhang et al. (2015). This result confirmed that blood glucose concentration is not an effective marker of energy balance and thus it cannot be used as a marker of the glucose pool. Our observation was similar to that obtained by Chung et al. (2009) who argued that there are only slight changes in glucose concentration, which may

result from the high effectiveness of the system regulating the blood level of this marker. A similar theory was postulated by LeBlanc (2010) who argued that the application of glucose as a marker of metabolic status is questionable in view of the homeostatic glucose regulation. Thus, it likely seems that insulin is the key hormone in NEFA oxidation. Insulin also facilitates glucose passage through cell membranes, which affects endocrine regulation of blood glucose concentrations. It is known that both thyroid hormones (T3 and T4) are involved in the adaptation of energy metabolism in dairy cows and as such may reflect the energy balance of dairy cows (Mohebbi-Fani et al., 2009). Blood concentrations of T3 and T4 decrease after calving and then begin to rise. Thus, a higher T3 blood concentration 3 days before parturition and a tendency to higher blood T4 level at day 5 of lactation partly confirmed the better energy balance in cows assigned to the SHORT group. Many authors have shown the effect of thyroid hormones on ovarian activity in cattle (Kafi et al., 2012). Additionally, Huszenicza et al. (2002) indicated that low T3 and T4 concentrations may have a negative effect on postpartum reproductive functions. This concurs with Reist et al. (2003) who showed that high plasma levels of both thyroid hormones were associated with early ovarian activity and onset of ovulation in dairy cows. Kafi et al. (2012) hypothesized that a higher postpartum serum T4 concentration could result in the disturbance of gonadotrophin releasing hormone (GnRH) and luteinizing hormone (LH) secretions. Mohebbi-Fani et al. (2009) found a positive correlation between serum T4 and BHBA concentrations in fresh dairy cows. In turn, Kafi et al. (2012) reported higher serum BHBA levels and BCS loss as a reflection of higher lipolysis in anoestrus cows. Gerloff et al. (1986) showed that thyroid hormone serum concentrations were negatively correlated with liver triglycerides and blood NEFA concentrations. In our study the slight positive metabolic effect observed in cows assigned to the SHORT group did not result in any improvement of fertility parameters. Chapinal et al. (2012) found no relationship between NEFA and BHBA blood concentrations around calving and first insemination efficiency. Generally, an association between fertility and NEFA and BHBA blood concentration is known; however, Chapinal et al. (2012) indicated that the underlying mechanism of negative energy balance during the transition period influencing reproductive performance some weeks later is unclear. Probably, poor fertility is connected with the toxic effect of NEFA and BHBA on oocyte maturation, as was shown by Leroy et al. (2006).

Despite the slightly positive metabolic changes observed in cows with shortened the close-up period to 1 week, no statistical milk performance differences were observed. Cows assigned to both groups had NEFA concentrations below 0.5 mEq/l (day 28), which was stated by Chapinal et al. (2012) to be a threshold for predicting a reduction in milk yield. Similarly, Mann et al. (2015) investigated different energy requirements during the dry period and observed no milk performance differences between cows, in spite of significantly relevant metabolic changes. In turn, Zhang et al. (2015) found no statistical effects of prepartum energy density diet on milk yield or composition, despite the fact that cows fed low (1.25 Mcal NE_L/kg) or medium (1.41 Mcal NE_L/kg) density diets during the close-up period produced approx. 2 kg/d more milk in comparison to cows from the high density (1.55 Mcal NE_L/kg) pre-calving group.

Additionally, cows fed a high-energy diet (150% of requirement) during the transition period had higher postpartum NEFA and BHBA blood concentrations (Mann et al., 2015). These results partially confirm our findings in the present study, where cows with the close-up period shortened to 1 week were simultaneously fed higher energy diets and as a result had lower BHBA concentrations 28 days after calving. Shortening of the close-up period to 1 week had no effect on milk composition; however, a tendency to higher fat content in milk was observed in cows from the SHORT group. This fact could explain a tendency to higher ECM yields recorded in the SHORT group. The effect of prepartum feeding on milk fat contents during lactation is not clear (Zhang et al., 2015). Janovick and Drackley (2010) reported a higher fat content milk of overfed cows, which was associated with greater BCS losses. Mann et al. (2015) interpreted higher milk fat contents by increasing mobilization of fat depots in the first weeks of lactation. Then, the dietary supply of fatty acids precursors, such as acetate and glucose, decreased causing lower synthesis of short chain fatty acids by the mammary tissues and an increased mobilization of fatty acids from adipocytes. It seems that cows assigned to the SHORT group experienced a higher negative energy balance than the CON group; however, this was not confirmed by BCS changes or blood parameters. Moreover, it is generally known that during a negative energy balance an increased fat concentration and decreased protein content in milk it is observed. Thus according to Heuer et al. (1999) fat and protein ratios might be used as potential indicators of lack of energy supply through feed. Duffield et al. (1997) reported that a fat:protein ratio greater than 1.5 is indicator of energy deficiency. In the present study the mean milk fat:protein ratio in the SHORT group was 1.29, which is below this threshold.

Conclusions

Simplification of the transition period management in dairy cows and shortening the close-up period did not improve fertility or milk performance, although it resulted in a positive tendency to higher energy corrected milk yields with no negative influence on the metabolic status or reproductive performance in dairy cows. Based on the obtained results we can suggest the use of shortened pre-calving feeding strategy (7 weeks of far-off diet and then a fresh transition diet from 1 week before calving to 21 days after parturition), which allows to omit the close-up diet and is easy to implement in practice.

In a similar, earlier study (Nowak et al., 2012) we implied that cow energy nutrition during the dry period with the close-up period reduced to 1 week exerts no negative effect on colostrum quality or the immune status of calves, however, further studies are necessary to confirm this hypothesis concerning the described feeding strategy.

Acknowledgments

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