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Influence of propylene glycol and glycerin in Simmental cows in periparturient period on milk yield and metabolic changes

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Abstract

The aim of this study was to compare the influence of propylene glycol and glycerin added to Total Mixed Ration (TMR) dose on lipid-carbohydrate metabolism, activity of selected liver enzymes and milk yield of Simmental cows in periparturient period. Forty two cows of Simmental breed were divided into 3 groups (n=14). Cows from the experimental groups were given 300 ml/d of either propylene glycol or glycerin from 7th day prepartum to 21st day postpartum. In week 5 of lactation in cows that were given propylene glycol and in week 12 in cows receiving glycerin Body Condition Score (BCS) was higher as compared to control cows. An application of glycerin resulted in the highest milk yield. Higher glucose content in groups that were given propylene glycol and glycerin would have contributed to the reduction of negative energy balance at the beginning of lactation. The lowest increase in aspartate transaminase (AST) and bilirubin level was observed in cows receiving glycerin. The study demonstrated that metabolic changes in Simmental breed cows in the periparturient period are dramatic, and an application of glucogenic precursors may improve metabolic efficiency.

Keywords: Simmental, periparturient period, propylene glycol, glycerin, blood metabolic profile

Zusammenfassung

Einfluss von Propylenglycol und Glycerin in Simmentaler Kühen im peripartalen Zeitraum auf Milchleistung und Stoffwechseländerungen

Das Ziel dieser Studie bestand darin, den Einfluss von der Totalmischration (TMR)-Dosis zugesetztem Propylenglycol und Glycerin auf den Lipid-Kohlehydrat-Stoffwechsel, die Aktivität ausgewählter Leber-Enzyme und den Milchgewinn in Simmentaler Kühen im peripartalen Zeitraum zu vergleichen. 42 Kühe der Simmentaler Rasse wurden in 3 Gruppen (n=14) aufgeteilt. Den Kühen aus der Versuchsgruppe wurden entweder 300 ml/d Propylenglycol oder Glycerin ab dem 7. Tag präpartum bis zum 21. Tag postpartum verabreicht. In der fünften Laktationswoche war der Wert der Körperkonditionsbewertung (BCS) bei Kühen, die Glycerin erhielten, im Vergleich zu den Kontrollkühen erhöht. Eine Anwendung von Glycerin ergab den höchsten Milchgewinn. Ein höherer Glucosegehalt in Gruppen, denen Propylenglycol und Glycerin verabreicht wurden, hätte zu einer Verminderung der negativen Energiebilanz zu Beginn der Laktation beigetragen. Die geringste Zunahme von Aspartat-Aminotransferase (AST) und im Bilirubinspiegel wurde bei Kühen festgestellt, die Glycerin erhielten. Die Studie zeigte, dass Stoffwechseländerungen in Kühen der Rasse Simmental im peripartalen Zeitraum erheblich sind, und dass eine Anwendung von glucogenen Vorläufern die Stoffwechseleffizienz verbessern kann.

Schlüsselwörter: Simmentaler, peripartaler Zeitraum, Propylenglycol, Glycerin, Stoffwechselprofil im Blut

Introduction

In order to reduce the negative energy balance and excessive lipolysis in periparturient period as well as at the beginning of lactation, the content of energy and protein in diet of cows was either increased or decreased in recent years (Butler *et al.* 2006, Grummer 2008). To achieve the same aim, calcium salts of conjugated linoleic acids (CLA) (Castañeda-Gutiérrez *et al.* 2005) were administered or the length of dry period with simultaneous high-energy dose feeding was shortened (Grummer 2008). Several studies concerning the use of glucogenic precursors as propionate (DeFrain *et al.* 2005), propylene glycol (Studer *et al.* 1993, Grummer *et al.* 1994, Christensen *et al.* 1997, Kristensen & Raun 2007, Kupczyński *et al.* 2005) and glycerin (Goff & Horst 2001, Chung *et al.* 2007, Osborne *et al.* 2009) were also performed.

Propylene glycol (PG) is a glucogenic precursor which has been used in prevention and treatment of ketosis in cows for many years. The mechanism of its action is based on lowering the non-esterified fatty acid (NEFA) and betahydroxybutyrate acid (BHBA) levels in blood as well as on increase of insulin and glucose levels (Studer *et al.* 1993, Grummer *et al.* 1994, Christensen *et al.* 1997, Rukkwamsuk *et al.* 2005). Kristensen & Raun (2007) demonstrated, that supplementation with propylene glycol results in an increased L-lactate and propionate supply for gluconeogenesis. The antilipolytic effect of propylene glycol was emphasized by Grummer *et al.* (1994). More beneficial effect of PG was observed at lowered feed intake (Grummer *et al.* 1994, Christensen *et al.* 1997). Administration of propylene glycol per os during final dry period (1 L daily for 10 days prepartum) reduced the accumulation of triglycerides in liver by 32 % and 42 % at day 1 and day 21 p.p., respectively (Studer *et al.* 1993). Similar results were obtained following the use of 400 ml of glycol 7 days a.p. until to 7 days p.p. (Rukkwamsuk *et al.* 2005).

Oral administration of glycerin can also be effective in prevention of ketosis in periparturient cows (Goff & Horst 2001). Feeding with glycerin was shown to result in increased blood glucose concentration and decreased NEFA level (Goff & Horst 2001, Osman *et al.* 2008). Glycogenic effect of glycerin was found to be depended on its dose (Goff & Horst 2001). DeFrain *et al.* (2004) and Bodarski *et al.* (2005) observed a lack of antiketogenic effect of glycerin supplied to the TMR dose. Chung *et al.* (2007) obtained different results. In their investigations, an improvement of energetic status of cows, increase in glucose level and decrease of BHBA concentration in blood was found. Up to date, there is no literature data describing the use of glucogenic precursors in Simmental breed of dairy type. Any studies concerning an application of propylene glycol or glycerin have been conducted. Metabolic

disorders in high-yielding cows of Simmental breed may occur also in perinatal period, however to a lower extent than in the case of Holstein-Friesian breed.
The aim of this study was to compare the influence of propylene glycol and glycerin, supplemented to TMR dose, on lipid-carbohydrate metabolism, activities of selected enzymes and milk yield of Simmental cows in periparturient period.

Material and methods

The experiment was conducted in Proagro Radešínská Svratka (Czech Republic) – a Simmental breed cattle farm. The farm includes 330 cows with an average milk yield of 6 990 kg with 3.8 % and 3.49 % of milk fat and protein content, respectively. Dry cows received a dose of approximately 15 kg of TMR and straw *ad libitum*, while the dose for lactating cows was set at 50.3 kg/day/per head. Nutrition dose was balanced according to the DLG standards. The nutrition value of a dose was as follows: dry matter (DM) 44.01 %, NEL 142.06 MJ, total protein 18.15 % DM, Ca 0.86 % DM, P 0.42 % DM, Mg 0.29 % DM, K 1.75 % DM. Composition of the doses was not altered during the study.

The study included 42 multiparous cows, being 1 week prior to expected calving date. The animals were clinically healthy, at the age of 4-7 years. The cows were divided into 3 groups (n=14): Control group I receiving TMR dose, Group II receiving 300 ml of propylene glycol added directly to TMR dose, and Group III receiving 300 ml of glycerin added to TMR dose.

Cows were fed propylene glycol (99.9 % of 1,2-propandiol content) or glycerin (99.7 % of 1, 2, 3-propantriol content) in fluid form once a day during morning feeding. Following the addition to TMR, the preparations were mixed thoroughly. The treatment started 7 days prior to expected calving date and continued for the first 21 days of lactation period.

Experimental data concerning milk yield and its chemical composition (protein, fat, lactose) were obtained from the first three experimental milkings. The representative milk samples were subject to analysis. Milk chemical composition was determined using Bentley 150 – Infrared Milk Analyzer (Bentley Instruments Inc., Chaska, MN, USA). Somatic cells count (SCC) was marked with the use of Somacount 150 (Bentley Instruments Inc.). The condition score of cows was estimated by means of BCS method (1-5 pts.) on the first day of the study as well as in the 3rd, 5th and 12th week of lactation. The assessment of a condition was performed by the same person.

Blood samples were taken from *vena jugularis externa* in morning hours (before feeding) on the first day of the study (one week prior to expected calving date) and again on day 21 postpartum. The blood samples were centrifuged for 15 min at 3 000 g at room temperature, and the serum samples were frozen (–20 °C) until use. The laboratory analyses were performed using Pentra 400 biochemical analyser (Horiba ABX Diagnostics, Montpellier Cedex, France). The following parameters were estimated in the blood serum:
- glucose by oxidase method using HORIBA ABX reagents (Glucose PAP, Cat. No. A11A016979),
- β-hydroxybutyric acid (BHBA) and non-esterified fatty acids (NEFA) by enzymatic method using Randox reagents, Ireland (RANBUT, Cat. No. RB1007 and NEFA Cat. No. FA 115, Randox Laboratories, Crumlin, Co. Antrim, UK),
- levels of triglycerides (TG) and total cholesterol by enzymatic methods, HORRIBA ABX (TAG, Cat No. A11A01640 and Cholesterol, Cat. No. A11A01634)

- enzymatic activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), γ-glutamylotransferase (GGT) – by means of kinetic methods according to IFCC recommendation with HORIBA ABX reagents (AST Cat. No. A11A01629, GGT Cat. No. A11A01630, ALP Cat. No. A11A01626),
- total bilirubine, total protein, albumin and urea concentrations – by means of colorimetric methods using ABX reagents (Total bilirubine A11A01639, Total protein Cat. No. A11A01669, Albumins Cat. No.A11A01664, Urea A11A01641).

Statistical comparisons between the groups were performed via one-way analysis of variance (ANOVA) using Statistica ver. 8.0 (Statistica for Windows, StatSoft, Tulsa, USA). All the data are reported as mean ± standard deviation ($\bar{x}$±SD). The effects were considered significant at a probability of $P≤0.05$ and $P≤0.01$. Differences among treatment means were tested for significance using Duncan's multiple range test.

Results

The cows' condition score in particular groups (estimated by BCS method) was balanced before calving. In weeks 5 and 12 of the lactation period, there was a significant decrease in the cows' condition score ($P≤0.01$) in the control group and the groups receiving glucogenic supplements (Table 1). In week 5 of lactation in cows that were given propylene glycol and in week 12 in cows receiving glycerin BCS was higher ($P≤0.01$) as compared to control cows. Both in the control group and in group receiving propylene glycol, the highest milk yield was observed in the third month of lactation, whereas in the group of cows receiving glycerin, the highest value was found in the second month of lactation. The increase of milk yield resulted from entering the period of peak lactation. The highest milk yield during the first three months was found in the group of cows receiving glycerin (31.0 kg), while in the group receiving glycol and in the control group the milk yield was lower, 30.73 kg and 29.44 kg, respectively. No significant differences in fat, protein and lactose content in milk between individual groups were found (Table 2). In all three groups, the lactose content reached the highest values in the first month of lactation.

Table 1
Estimation of cows' condition score based on the BCS method (points), $\bar{x}$±SD

Estimation term	Group		
	Control	Propylene glycol[1]	Glycerin[2]
Number of cows, n	14	14	14
Prepartum	$3.74±0.34^{aA}$	$3.90±0.51^{aA}$	$3.70±0.49^{aA}$
Lactation, week 3	$3.50±0.42^{bA}$	$3.56±0.50^{bA}$	$3.45±0.24^{bA}$
Lactation, week 5	$3.15±0.41^{*B}$	$3.36±0.45^{*B}$	$3.25±0.39^{B}$
Lactation, week 12	$3.05±0.53^{*B}$	$3.28±0.43^{B}$	$3.30±0.37^{*B}$

[1]300 ml/d of propylene glycol added to TMR, [2]300 ml/d of glycerin added to TMR, *: statistically significant differences between groups, $P<0.05$, $^{a, b}$: within the columns, means that do not have common superscript differ, $P<0.05$, ^{A,B}: within the columns, means that do not have common superscript differ, $P<0.01$.

Table 2
Milk yield and composition ($\bar{x}$±SD)

Group	Months of lactation	Milk, kg	Fat, %	Protein, %	Lactose, %
Control	I	26.90±2.43^{A}	3.64±0.37	3.43±0.21	5.06±0.67
	II	29.24±3.20	3.89±0.56	3.53±0.28	4.97±0.45
	III	32.18±3.60^{B}	3.76±0.87	3.54±0.38	4.95±0.34
Propylene glycol	I	28.73±3.11^{A}	3.81±0.90	3.43±0.48	5.08±0.39
	II	31.44±2.85	3.90±0.58	3.62±0.21	4.92±0.43
	III	32.02±2.67^{B}	3.87±0.62	3.60±0.34	5.02±0.36
Glycerin	I	27.50±4.00^{A}	3.79±0.73	3.33±0.22	4.96±0.42
	II	34.21±2.78^{B}	3.75±0.50	3.43±0.43	4.94±0.35
	III	31.29±3.04^{B}	3.87±0.56	3.51±0.28	4.98±0.35

^{A,B}: within the columns, means that do not have common superscript differ, $P<0.01$.

On the first day of the study (approx. 1 week prepartum), the values of analyzed parameters in individual groups were within the reference range for cattle (Winnicka 2004). After parturition, the concentration of glucose in blood serum decreased significantly ($P\leq0.01$) in all the groups. Nevertheless, its level was higher ($P\leq0.05$) in groups of cows receiving supplements (propylene glycol, glycerin) as compared to the control group. In terms of the BHBA and NEFA levels in blood serum, no significant changes were observed, neither in the group of cows receiving glycerin nor in the control group during the postpartum period. On the other side, the increased level of BHBA and NEFA was found in blood of cows receiving propylene glycol (Table 3) as compared to prepartum period. Nevertheless, the observed increased level of NEFA did not indicate excessive lipolysis. Similarly, the cut point of BHBA concentration in blood, i.e. 1 400 µmol/l (Carrier *et al.* 2003), was not exceeded. Up to week 3 of lactation period, the content of triglycerides in blood serum tended to be lower ($P\leq0.01$) in each group. Concerning cholesterol content, different dependencies were observed (Table 3).

At the beginning of lactation, the AST activity increased (Table 4). There was a decrease in ALP activity in the third week of lactation, and the biggest decrease was found in the control group. The ALP activity in the control group was significantly lower ($P\leq0.01$) as compared to both supplemented groups. None of the glucogenic preparations had a significant effect on the GGT activity. The lack of disorders of liver secretion functions was confirmed by low total bilirubine concentration in blood serum (Table 4).

The prepartum total protein concentration in blood serum was lower as compared to the one measured during the postpartum period, which was the result of the diet fed. The preparations used in the present study did not affect this parameter in blood. During the investigation period, no significant differences in albumin level were observed. In week 3 of the lactation period, the blood serum concentration of urea increased in all three groups, which was associated with the protein content in the diet (Table 5).

Table 3
Metabolite concentrations in serum of dairy cows ($\bar{x}$±SD)

Item	Group		
	Control	Propylene glycol[1]	Glycerin[2]
Number of cows, n	14	14	14
Glucose, mmol/l			
Prepartum	3.54±0.34**a	3.90±0.51**a	3.50±0.49**a
Postpartum	2.68±0.42**b	2.91±0.50**b	2.96±0.24**b
β-hydroxybutyrate, mmol/l			
Prepartum	0.44±0.12	0.37±0.11A	0.52±0.14
Postpartum	0.63±0.23	0.53±0.29B	0.52±0.16
Non- esterified fatty acids, mmol/l			
Prepartum	0.41±0.14	0.37±0.14a	0.36±0.06
Postpartum	0.42±0.09	0.48±0.12b	0.39±0.18
Triglycerides, mmol/l			
Prepartum	0.33±0.08A	0.31±0.07A	0.37±0.06A
Postpartum	0.10±0.09B	0.12±0.09B	0.15±0.03B
Total cholesterol, mmol/l			
Prepartum	2.78±0.35	2.59±0.53	2.92±0.42
Postpartum	3.80±0.47	3.81±0.49	3.66±0.50

[1]300 ml/d of propylene glycol added to TMR, [2]300 ml/d of glycerin added to TMR, Prepartum: 1 week, Postpartum: 3 first weeks, **: statistically significant differences between groups, *P*<0.01, [a,b]: within the columns, means that do not have common superscript differ, *P*<0.05, [A, B]: within the columns, means that do not have common superscript differ, *P*<0.01

Table 4
Enzymatic activities and total bilirubine content in blood serum ($\bar{x}$±SD)

Item	Group		
	Control	Propylene glycol[1]	Glycerin[2]
Number of cows, n	14	14	14
AST, U/l			
Prepartum	56.63±4.19A	60.95±8.66A	64.78±8.13a
Postpartum	70.81±9.09B	77.60±5.18B	72.69±8.15b
ALT, U/l			
Prepartum	19.11±3.22	19.34±3.37	20.62±3.31
Postpartum	23.36±2.95	23.24±1.64	23.50±4.49
ALP, U/l			
Prepartum	72.94±13.66**a	74.81±16.02	113.20±29.35**A
Postpartum	56.77±9.78**b	81.37±8.40**	78.58±14.23**B
GGT, U/l			
Prepartum	23.89±6.03	19.07±3.49	21.81±7.63
Postpartum	21.78±5.09	20.57±2.77	20.16±3.02
Total bilirubine, μmol/l			
Prepartum	4.32±1.31	3.11±0.98	4.11±1.41
Postpartum	3.64±1.00	3.60±1.02	4.45±1.15

[1]300 ml/d of propylene glycol added to TMR, [2]300 ml/d of glycerin added to TMR, Prepartum: 1 week, Postpartum: 3 first weeks, **: statistically significant differences between groups, *P*<0.01, [a,b]: within the columns, means that do not have common superscript differ, *P*<0.05, [A,B]: within the columns, means that do not have common superscript differ, *P*<0.01

Table 5
Total protein, albumins and urea concentrations in blood serum ($\bar{x}$±SD)

Item	Group		
	Control	Propylene glycol[1]	Glycerin[2]
Number of cows, n	14	14	14
Total protein, g/l			
Prepartum	63.16±6.01[a]	60.79±9.76	68.17±3.91
Postpartum	71.92±4.14[b]	67.60±5.18	66.84±4.69
Albumins, g/l			
Prepartum	31.40±2.29	30.79±2.66	32.51±1.40
Postpartum	30.68±1.10	30.84±1.64	30.52±1.88
Urea, mmol/l			
Prepartum	5.10±1.03	5.20±1.01	5.14±0.78
Postpartum	6.17±1.07	6.40±0.73	6.12±1.31

[1]300 ml/d of propylene glycol added to TMR, [2]300 ml/d of glycerin added to TMR, Prepartum: 1 week, Postpartum: 3 first weeks, [a,b]: within the columns, means that do not have common superscript differ, $P<0.05$.

Discussion

During the periparturient period and at the beginning of lactation, sudden increase in requirement for nutrient and energy needed for foetus development as well as for production of milk and colostrum is observed. Concurrently, hormonal changes which cause subordination of organism to the lactation process take place (Studer *et al.* 1993, Butler *et al.* 2006). Energy deficiency and/or decreased feed intake during the periparturient period result in increased lipolysis of deposited fat and release of NEFA to the blood (Hayirli *et al.* 2003, Grummer 2008). An excessive increase of NEFA concentration leads to an accumulation of triglycerides (TG) in liver and significant increase of ketonic compounds production (Rukkwamsuk *et al.* 2005).

Studies on short-term feeding of cows with propylene glycol did not reveal any influence of PG on body mass, BCS condition or milk yield (Studer *et al.* 1993, Pickett *et al.* 2003). Similarly, the milk yield of lactating cows (7 to 42 days) was not influenced by feeding with PG (Miyoshi *et al.* 2001). The lower condition score of Holstein-Friesian (Hoedemaker *et al.* 2004) and Simmental cows (Jílek *et al.* 2008) reflects the level of energy deficiency. In the present study, was found that the lower condition score of cows after the parturition was within the physiologic range for this breed (Jílek *et al.* 2008). The BCS was higher in cows receiving glucogenic precursors as compared to control cows. Feeding cows with PG for a period from 3 weeks prepartum until 3 weeks postpartum in a dose of 500 ml/day (per os) contributed to an improvement of colostrum composition and higher milk yield (Kupczyński *et al.* 2005). In our study, the highest milk yield was observed in the group of cows which were given glycerin during the whole experimental period. Also the highest milk yield at the peak of lactation (2nd month) was observed (34.21 kg).

Studies concerning the application of glucogenic precursors were conducted solely on Holstein-Friesian breed cows. Therefore, it is very difficult to compare the results obtained with any other findings. In cows, propylene glycol was found to cause an increase in glucose level and decrease in blood BHBA and NEFA concentrations (Kupczyński *et al.* 2005, Rizos *et al.* 2008, Castañeda-Gutiérrez *et al.* 2009). The hyperglycemic and hyperinsulinemic effects of PG are most likely caused by insulin resistance induced by increased concentrations of PG and propanol and a decreased ratio of ketogenic to glucogenic metabolites in arterial blood plasma (Kristensen & Raun 2007). Cows drenched with propylene glycol in periparturient period reduce fat mobilization as evidenced by the reduction in plasma NEFA and reduce triacylglycerol accumulation in the liver (Studer *et al.* 1993, Rukkwamsuk *et al.* 2005). PG showed to be more effective when administered per os than as a part of a concentrate or being added to the TMR dose. Similar results in the case of short-term (3 days postpartum) PG feeding were found by Picket *et al.* (2003). The use of PG in the form of dry powder added to the TMR dose resulted in an increased glucose concentration (Miyoshi *et al.* 2001). PG had no significant effect on any other biochemical parameter of blood. Hoedemaker *et al.* (2004) reported lowered concentrations of NEFA and BHBA in the periparturient period in cows receiving PG as compared to controls. Propylene glycol leads to an increase in propionate and butyrate level in rumen (Picket *et al.* 2003) The increase in BHBA content observed in the present study would have resulted from that tendency.

Many various studies have shown postprandial increases in systemic concentrations of insulin following administration of PG to dairy cows (Studer *et al.* 1993, Christensen *et al.* 1997, Miyoshi *et al.* 2001). Enhanced production of glucose stimulates the secretion of insulin, which in turn, leads to the reduction of NEFA release. The importance of high systemic glucose and insulin concentrations in early lactation in reducing the incidence of metabolic diseases is the rapid initiation of oestrous cycle as well as the success of subsequent pregnancy. Miyoshi *et al.* (2001) and Rizos *et al.* (2008) did not find any significant effect of PG administration on cows' fertility. Despite the evidence of improved metabolic status, PG failed to increase LH pulse frequency, and failed to increase the proportion of first postpartum follicle waves resulting in ovulation (Butler *et al.* 2006).

Use of glycerin in powder form (162.5 g of glycerin per day) in transition period resulted in an improvement of energy status underlined by higher concentration of plasma glucose, lower concentrations of plasma BHBA, and lower concentrations of urine ketones (Chung *et al.* 2007). This glucogenic effect of dry glycerin did not result in any statistical increase in feed intake or milk yield during the first 3 weeks of lactation. Nevertheless, the milk yield of cows which were given glycerin was 52 kg/d while the one of control cows was 46 kg/d. DeFrain *et al.* (2004) failed to show any glucogenic effect of glycerin, yet they reported an increased propionate production and decreased ratio of acetate to propionate in rumen. Glycerol added to drinking water (Osborne *et al.* 2009) or to TMR dose (Chung *et al.* 2007) did not affect milk yield or its composition. On the other hand, Bodarski *et al.* (2005) observed, that the glycerin supplementation to TMR dose of dairy cows during periparturient period (from 2 weeks a.p. to 10 weeks after calving) increased the dry matter intake, milk production and protein content in milk. An application of glycerin and propylene glycol also resulted in a higher milk yield observed in the present study.

Glycerin administration (per os) also decreased plasma glucagon and NEFA on day 1, 7, and 13, and plasma β-hydroxybutyrate acid content on day 1 postpartum, relative to the saline group (Osman *et al.* 2008). An application of glucagon in the form of injection (s.c.) together with glycerin resulted in intensified effect on metabolism (Osman *et al.* 2008). In the most recent studies, glycerin was added to drinking water in doses of 20 g/L from 7 days prepartum to 7 days postpartum (Osborne *et al.* 2009). No significant glucogenic effect of such a short-time glycerin administration was found, yet the BHBA level tended to be lower postpartum. DeFrain *et al.* (2004) reported increased level of BHBA following the glycerin administration via TMR doses. Higher dose of glycerin caused an insignificant decrease of NEFA and increase in insulin level in blood (DeFrain *et al.* 2004). In the present study, a postpartum decrease in blood glucose was observed in all groups of cows, although the cows receiving glucogenic preparations maintained higher glucose concentrations as compared to the control group. No statistically significant changes of BHBA and NEFA concentration were observed. In the present study, higher glucose content in groups that were given propylene glycol and glycerin would have contributed to the reduction of negative energy balance during postpartum phase.

There was no significant effect of energy supplements administered to cows in transition period on AST nor AP activity (Ballard *et al.* 2001). Previously, the use of propylene glycol in periparturient period caused a decrease in AST activity in blood (Mikuła *et al.* 2008). In our present study, a decreased ALP activity was observed, especially in cows fed with glycerin. The GGT activity in blood of Simmental cows was found to be significantly lower when compared to the one of Holstein–Friesian breed (Mikuła *et al.* 2008). In the present work, neither total bilirubine nor enzyme activity indicated any liver function disorders.

The cows willingly took propylene glycol and glycerin when the preparations were thoroughly mixed with TMR dose (following the habituation period). On the first days of supplementation, glycerin was taken more willingly than propylene glycol. This finding was observed earlier by Spörndly & Åsberg (2006), who compared the willingness of 25 feeds consumption by cows, including the mix of glycerin and barley.

The present study demonstrated, that metabolic changes in Simmental breed cows in the periparturient period are not as significant as in the case of Holstein–Friesian breed. It may be concluded that an application of glycerin and propylene glycol resulted in higher milk yield observed. In postpartum period BCS was higher in cows that were given glucogenic precursors. Higher glucose content in groups that were given propylene glycol and glycerin would have contributed to the reduction of negative energy balance at the beginning of lactation. The lowest increase in AST and bilirubin was observed in cows receiving glycerin.

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