EFFECTS OF PROPYLENE GLYCOL SUPPLEMENTATION ON BLOOD BIOCHEMICAL PARAMETERS IN DAIRY COWS

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Abstract

The objective of this study was to determine the effect of propylene glycol supplementation as powder top dressing during the transition period on selected blood parameters in dairy cows and to evaluate the optimum time of the administration of this glucose precursor. Forty-eight Holstein–Fresian cows were divided into four groups: control with no glycol supplementation, glycol administered from day 14 before parturition until calving, glycol supplemented from calving to day 14 postpartum, and glycol fed from day 14 prepartum to day 14 of lactation. Blood samples were collected three weeks and then one week before parturition and on 14th, 56th, and 70th d of lactation, then concentrations of glucose, non-esterified fatty acids, cholesterol, triglycerides, insulin, and the activity of aspartate aminotransferase and γ-glutamyl transpeptidase were analysed. Propylene glycol, which was supplemented as top dressing during transition period, had no major effects on biochemical variables throughout this period. However, there was observed a positive glycol effect on glucose concentration and the activity of aspartate aminotransferase during lactation.

Key words: dairy cows, transition period, propylene glycol, blood indices.

The transition period, lasting from the 3rd week before to the 3rd week after parturition, is especially important and heavily affects the health state and yields of dairy cows and the profitability of their production (6). A 30% reduction of dry matter intake a week before calving and a high energy requirement connected with milk production in lactation results in a negative energy balance (5). Excessive utilisation of fatty reserves may increase the incidence of metabolic disorders and reduce the yields of dairy cows (12). The energy deficiency also causes the atony or hypotony of the uterus and this is the main cause of its late involution and cleaning (21).

Ketosis is a metabolic disorder that mostly occurs 2–7 weeks after calving (13) and is diagnosed 24–28 d postpartum (11). This metabolic disorder is characterised by higher concentration of ketone bodies (acetoacetate, β-hydroxybutyrate and acetone) in blood, milk, and urine. Ketosis is also connected with an increased concentration of non-esterified fatty acids (NEFA) and a decreased level of blood glucose (19).

Oetzel (26) suggests that ketosis is often poorly defined and thus he categorises this disorder into three types on account of different aetiology and prevention strategy. The first ketosis type is correlated with high negative energy balance during lactation and is characterised by low glucose and high ketone body concentration in blood. The period of the highest risk of the occurrence of this type of ketosis is 3–6 weeks postpartum. The second ketosis type is a consequence of an increase in negative energy balance and higher mobilisation of body fat from adipose tissue before calving. When high lipid mobilisation exceeds the metabolising capacity of the liver, it leads to an increased triglyceride accumulation (17) and develops fatty liver. Hepatic lipidosis is connected with decreased metabolic functions of the liver (14). In dairy cows, this metabolic disease occurs mostly in the first month after calving (14). Indices of metabolic profile could be helpful as the diagnostic key to define ketosis type.

Ketosis and fatty liver often decreases health status, milk yield, and reproductive performance of dairy cows (33). The frequency of subclinical ketosis occurrence in Polish cow herds amounts to 31.2% (10).

Propylene glycol (PG) is a glucoplastic substance for ruminants, which has been used in the treatment of ketosis since the 1950s and is still used today. It may be used to reduce the negative energy balance after calving and limiting the risk of ketosis and fatty liver. Propylene glycol may affect glucogenic action in different ways. The portion of this substance is...
metabolised in the rumen to lactic acid and propionic acid, which are converted to glucose by hepatocytes; the PG, which escapes rumen fermentation, is absorbed by the rumen wall or from the gastrointestinal tract and is converted to glucose by the liver (4). Christensen et al., (3) observed greater metabolic effects of propylene glycol applied as a drench compared to feeding in a TMR. Long-term glycol drenching is expensive and labour demanding while PG top dressing may cause a reduced feed intake (24).

The aim of the study was to determine the effect of propylene glycol supplementation (powder top dressing) during the transition period on metabolic and hormonal profile indices in cows and to determine the optimum time of the administration of this glucose precursor.

Material and Methods

Primiparous cows were divided according to calving date, whereas multiparous ones were divided by calving date, parity, prior milk production, BW and BCS. The following treatment groups were formed: control without propylene glycol, G+G- (glycol supplemented only from day 14 before parturition to calving), G-G+ (glycol administered from calving until day 14 of lactation), and G+G+ (glycol supplied from day 14 prepartum to day 14 of lactation). Cows were fed a TMR complete ration according to the INRA recommendation. PG in the dry powder form on a silica carrier with a 70% content of active components (NEL 11.75 MJ/kg) was fed at 400 g per animal per day, applied as top dressing. Blood was collected (4 h after morning feeding) three weeks and one week before calving and on 14th, 56th, and 70th d of lactation. The concentration of glucose was analysed by a blood glucose meter (glucometer) Accu – Chek Active (Roche Scientific reagent). Serum insulin concentration was analysed through radioimmunoassay (RIA) method with Linco Research kit. Body condition was estimated three times before calving and on parturition day, and on 14th and 56th d of lactation according to Edmonson et al., (9).

The obtained results were processed statistically using the statistical computer programme package SAS (1996), SAS®/STAT. One-way variance analysis was carried out using GLM Procedure and the Duncan test. Statistical significance was established at P≤0.05.

Results

The effect of PG on biochemical variables is showed in Table 1. PG did not have a significant influence on the result of glucose concentration when it was supplemented in the transition period. Moreover, 14 d after calving, the mean blood glucose concentration was the highest in control group. On days 56 and 70 post partum, the highest glucose concentration was observed in group G+G+, but differences were statistically significant only on day 70 compared to control group (P≤0.05).

PG did not influence significantly the serum insulin concentration; however, the highest insulin concentration was observed 7 d before calving in both groups supplemented with PG in this period (groups G+G- and G+G+). Fourteen days after parturition all experimental groups (with PG) showed tendency to decreased level of this hormone. On days 56 and 70 of lactation, the concentration of insulin was increased in all groups.

There was no significant effect (P>0.05) of PG supplementation in transition period on the mean plasma concentration of NEFA on day 7 before and day 14 after calving. The level of NEFA in all the experimental groups on the 14th d of lactation tended to be higher than that observed in control group. In all the groups mean NEFA concentration continuously declined until the end of the study (day 70).

The mean cholesterol concentration in blood was not affected by the treatment during transition period. In all groups mean cholesterol concentration decreased before parturition and then continuously increased. Statistically significant differences were detected on the days 56 and 70 between the control group and the group where PG was supplemented only before calving (G+G-).

No significant differences between groups were observed in plasma triglyceride concentration. Mean triglyceride concentration increased before calving and remained lower throughout the postpartal study period than during the dry period.

There were no group differences with regard to mean activity of ASPAT on 7th d before parturition. PG supplemented after calving (G-G+; G+G+) decreased mean activity of ASPAT in 2nd week of lactation. However, the differences were detected only between G+G- and G+G+ groups (P≤0.05). In all experimental groups ASPAT activities on days 56 and 70 of lactation were significantly (P≤0.05) lower when compared to control group.

In all groups, GGTP activity increased from 7th d prepartum to 70th d of lactation. No treatment effect was noted for the mean GGTP activity except for 70th d postpartum, when the mean activities were slightly lower in G+G- group.
Table 1
Plasma concentration of metabolic parameters

<table>
<thead>
<tr>
<th>Group</th>
<th>Glucose (mmol/L)</th>
<th>Non-esterified fatty acids (mmol/L)</th>
<th>Cholesterol (mmol/L)</th>
<th>Triglycerides (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>before</td>
<td>after</td>
<td>before</td>
<td>after</td>
</tr>
<tr>
<td>Control</td>
<td>3.50</td>
<td>3.50</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>G+G-</td>
<td>3.68</td>
<td>3.68</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>G+G+</td>
<td>3.75</td>
<td>3.75</td>
<td>0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>G+G+</td>
<td>3.65</td>
<td>3.50</td>
<td>0.24</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Note: Different letters in the same column (sampling time) indicate statistically significant differences (P≤0.05).

Discussion

The blood glucose concentration in dairy cattle is affected by energy intake and yielding because glucose is a primary substrate for mammary lactose synthesis.

Propylene glycol is a glucogenic precursor, which is quickly absorbed from the rumen wall or partly transformed to propionate before being absorbed and converted to glucose (25).

At the beginning of the trial (21 d prior calving), no significant differences were observed for all blood parameters evaluated. The blood glucose concentration prepartum and postpartum was not significantly affected by glycol supplementation. On the contrary, Grummer et al. (15) noted a significant increase in blood glucose concentration after glycol treatment. However, Juchem et al. (20) observed lower glucose concentration in prepartum cows treated with glucoplastic substances. The limited effect of the PG on glucose blood level could be explained by a large increase in insulin concentration that maintains plasma glucose (1) or by the concentration of insulin peaking before that of glucose. PG is more effective at increasing blood glucose content during negative energy balance than during positive energy balance (2). Nielsen and Ingvarsten (25) stated that glucose response is rather limited compared with insulin, even if blood samples were collected shortly after administration of PG.
Blood insulin level could be the parameter of dairy cows energy status. Low concentration of this hormone is associated with negative energy balance in early lactation. Insulin is also especially important in pituitary-ovarian function. Poff et al., (28) suggest that insulin is necessary for optimal steroidogenesis in follicular and luteal cells. We observed increase in plasma insulin concentration 7 d before calving in both groups supplemented by glycol in dry period, although the differences were not significant (P≤0.05). Pickett et al., (27) reported no significant effect of glycol administration on blood serum insulin level. In contrast, Christensen et al., (3) observed increased concentration of insulin after glycol treatment. Miyoshi et al., (24) concluded that mechanism where propylene glycol affects insulin has not been established.

Nielsen and Ingvartsen (25) suggest that the different results could be explained by the time of blood sampling or by the allocation method. The oral administration created more pronounced effect on insulin compared with feeding glycol as a pouring glycol in TMR, similarly to our experiments. A study by Grummer et al., (15) indicated that plasma concentration of glucose and insulin peaked within 75 and 30 min after glycol drenching, respectively. Miyoshi et al., (24) reported that after drenching with propylene glycol, plasma glucose and insulin increased rapidly by 30 min and continued to increase gradually to the 90th min. The long interval between blood sampling and administration of glycol (4 h) may explain minor effects observed in our study. Kristensen and Raun (22) concluded that propylene glycol infusion did not affect hepatic and splanchnic glucose output and that the hyperglycaemic and hyperinsulinaemic effects of glycol most likely are caused by insulin resistance induced by increased concentrations of glycol and propanol and decreased ratio of ketogenic and glucogenic metabolites in arterial blood plasma.

Whitaker (34) suggested that blood glucose concentration was less sensitive to changes during negative energy balance than the concentration of non-esterified fatty acids or β-hydroxybutyric acid. Stephenson et al., (32) concluded that NEFA increases gradually as parturition approaches, reaching a peak at the day of calving and then decreases as lactation proceeds. Results of the current study indicate that propylene glycol supplementation as a top dressing in the transition period had no beneficial effects on NEFA concentration in blood. In all groups mean NEFA concentration increased 7 and 14 d after calving and then continuously declined until the end of the study period. The concentration of NEFA measured in this study was within targets - below 0.7 mmol/L for lactating cows and below 0.4 mmol/L for cows in the late pregnancy (35). Previous studies reported decreased NEFA in plasma when propylene glycol was administered during transition period, Grummer et al., (15). Christensen et al., (3) did not observe the influence of glycol added to TMR complete ration on NEFA concentration in plasma. Nielsen and Ingvartsen (25) suggested that the propylene glycol reduces NEFA in plasma, especially in cows that are too fat at calving.

Juchem et al., (20) observed that drenching cows with glycol was an efficient method to reduce NEFA concentration most likely because the inhibition of adipose adenylate cyclase activity and lipolysis by elevated insulin concentration. In the presented study, the cows were in adequate condition (3.25–3.50) according to BCS scale before calving, and therefore, the mobilisation of fat reserves was probably not too high. The NEFA plasma concentration after calving is correlated with the decrease in fat reserves from adipose tissue and can be used as a dairy cow energy balance indicator. Moreover, the concentration of non-esterified fatty acids before calving can be a diagnostic key of the second type of ketosis (26). The rise of NEFA level in blood in parturition period partly can be also a result of hormonal changes and stress associated with pregnancy and reduced dry matter intake (23). An excessive NEFA mobilisation causes triglyceride accumulation in the liver and has negative influence on overall cow health and performance (7). Dyk et al., (8) described the association between NEFA concentration and risk of incidence of ketosis, displaced abomasum, and retained placenta.

Grummer and Carroll (16) documented the importance of cholesterol as a precursor of ovarian steroidogenesis. In the current study, there was observed the higher cholesterol concentration (upper reference level) in days 56 and 70. The increase in cholesterol concentration after calving was confirmed by Pysera and Opalka (29). The group supplied with glycol from day 14 before parturition to calving (G+G-), differed significantly from the control group and it did not differ significantly from other experimental groups. Rukkwamsuk et al., (31) also did not observe any influence of PG on cholesterol concentration.

Propylene glycol did not affect the concentration of triglycerides. However, a declining tendency in the level of the compounds was observed after calving. Similar results were noted by Cozzi et al., (4).

No group differences were observed in the ASPAT activity in the transition period. On days 56 and 70 of lactation, the lowest ASPAT activity in all experimental groups was observed with statistically significant differences (P≤0.05) in comparison to control group. In all groups, mean activity of ASPAT increased from 3rd week before calving to day 14 of lactation and then decreased to day 70 d lactation. Hoedemaker et al., (18) found no significant effect of PG on the activity of ASPAT. The activities of ASPAT and GGTP reflect the health status of the liver. Rico et al., (30) suggested that GGTP activity is as valuable test of hepatocellular damage and could be a diagnostic test for hepatic disorders in the cows and its activity in plasma may rise at energy deficiency. No significant effect of glycol supplementation on GGTP activity during transition period was observed in our experiment.

Kristensen and Raun (22) suggested that recognition of the different mode of action might be a key to explaining of some of the peculiarities related to PG as a feed additive for ruminants. They concluded that rapid delivery of PG to the rumen as an oral drench,
The lack of positive effect is probably due to the method no major effects on biochemical variables in this period. The lack of positive effect is probably due to the method of application as a top dressing supplementation.

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