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Comparison of Two Protocols for Propylene Glycol Administration in Periparturient Dairy Cows: Effects on Blood Metabolites, Milk Production and Reproduction

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Abstract: Comparison of two protocols for propylene glycol administration in periparturient dairy cows was studied in 25 cross-bred Holstein Friesian cows. All cows were drenched with 400 mL of propylene glycol for 7 days before expected calving date. After calving, 12 cows were drenched with propylene glycol for 14 days and 13 cows were drenched for 30 days. Results revealed that cows in both groups did not lose their body condition scores during the periparturient period. Average milk yields during 20 weeks of lactation did not differ between the two groups. All blood metabolites at 2 weeks prepartum and at 2 and 4 weeks postpartum did not differ between the two groups. Serum triacylglycerol and glucose concentrations were higher at 2 weeks prepartum and decreased at 2 weeks postpartum. Average days from calving to first estrus were 61±10.9 and 65.5±8.3 days for cows in 14-group and 30-group, respectively and did not differ between the two groups. Results suggested that drenching propylene glycol for either 14 or 30 days postpartum had similar effect on milk production, blood metabolites and days from calving to first estrus.

Key words: Dairy cow, production, propylene glycol, reproduction, estrus, metabolites

INTRODUCTION

Dairy cows usually go into a period of energy shortage during the periparturient due to physiological and endocrinological adaptation for initiation of lactation (Bell, 1995). Decreased glucose and insulin concentrations in the blood would facilitate the cows to mobilize their body fat reserves which results in increased Non-Esterified Fatty Acid (NEFA) concentrations (Rukkwamsuk *et al*., 1998). Blood NEFA is absorbed by the liver in which the NEFA is either oxidized to form energy, CO_2 and H_2O or re-esterified to triacylglycerols (Bruss, 1993). High blood NEFA as a result of Negative Energy Balance (NEB) is closely linked to ketosis and fatty liver development in dairy cows (Rukkwamsuk *et al*., 1999).

The combination of NEB and its consequences is related to impairment of health, production and reproduction in dairy cows (Butler *et al*., 2006; Gerloff *et al*., 1986; Jorritsma *et al*., 2005). Therefore, alleviation of periparturient NEB possibly improves performances of dairy cows which may also be beneficial for the farm economics. In Thailand, most dairy cows are raised in small-scale farms in which the farmers are not well-trained in their herd health management, particularly nutrition management. Recent study showed an evident that NEB is existed in periparturient dairy cows raised in small-holder farms (Rukkwamsuk *et al*., 2006). It is possible that NEB may also have similar effects on observable health, milk production and reproduction problems as reported in western countries.

Periparturient NEB can be prevented by propylene glycol (1,3-propanediol; $C_3H_8O_2$), a viscous substance that has gluconeogenic properties. It is basically used to treat dairy cows suffering from ketosis (Emery *et al*., 1964) due to its capacity to rapidly increase blood glucose concentrations (Rukkwamsuk *et al*., 2005). Metabolism of propylene glycol and its effect on physiological parameters, feed intake, milk production and risk of ketosis in dairy cows are previously reviewed by Nielsen and Ingvartsen (2004). Butler *et al*. (2006) reported that dairy cows that were drenched propylene glycol improved metabolic status, i.e., increased glucose and insulin and decreased NEFA and liver triacylglycerol concentrations as compared to control dairy cows that were drenched with water. Similar results are also reported previously (Hoedemaker *et al*., 2004; Miyoshi *et al*., 2001; Pickett *et al*., 2003). Although, positive effects of propylene glycol on metabolic status related to NEB are markedly reported, results concerning the benefit of

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propylene glycol on health and reproduction of postparturient dairy cows are inconsistent (Butler *et al*., 2006; Castaneda-Gutierrez *et al*, 2009; Hoedemaker *et al*., 2004; Miyoshi *et al*., 2001; Moallem *et al*., 2007; Rizos *et al*., 2008).

Research concerning the use of propylene glycol in dairy cows is usually conducted in Western countries where feed and feeding management are well-practiced. Application of those results to dairy farming in Thailand which is mainly composed of poor-managed small-holder farms may not be appropriate. Therefore, the objective of this study was to compare two different protocols for propylene glycol administration during the periparturient period with particular reference to the effect on blood metabolites, milk production and reproduction in postparturient dairy cows raised in small-holder farms.

MATERIALS AND METHODS

Animals and sampling: About 25 healthy, pregnant, cross-bred Holstein Friesian dairy cows raised in 9 small-holder farms were used. To avoid any farm effects all selected farms had similar herd management, feed and feeding, milking system and breeding practices. Cows were kept in tie-stall housing barn.

They were fed with commercial concentrated feed at a rate of 1 kg of feed per 2 kg of milk produced and were offered corn cob and stem as a major roughage. During the dry period, the concentrated feed was limited to 1-2 kg day^{-1}. All cows were drenched with 400 mL of propylene glycol per day for 7 days before expected calving. After calving, 12 cows were drenched with 400 mL of propylene glycol per day for 14 days (14-group) and 13 cows were drenched for 30 days (30-group). The cows had free access to clean water. All farms were regularly visited by the veterinarians to check reproductive status and to record body condition score of the cows. Milk yield were recorded weekly by the farmers. Blood samples were collected from all cows at 2 weeks prepartum and at 2 and 4 weeks postpartum to determine serum glucose, NEFA, triacylglycerol, cholesterol and urea nitrogen concentrations. Milk samples were collected from all cows once a week for 8 weeks of lactation to determine milk composition.

Blood metabolite analyses: Serum glucose (Bitech Reagent, Biotechnical Co., Ltd., Bangkok, Thailand), NEFA (NEFA FA 115, Randox Laboratories Ltd., Crumlin, UK), triacylglycerol (Biotech Reagent, Biotechnical Co., Ltd.), cholesterol (Biotech Reagent, Biotechnical Co., Ltd.) and urea nitrogen (Biotech Reagent, Biotechnical Co., Ltd.) concentrations were determined using spectrophotometric method with the use of commercially available test kits as indicated. Milk samples were collected once a week for 8 weeks to determine milk composition. Milk composition was determined using automatic milk analyzer.

Statistical analyses: Data were explored for normality using the Shapiro-Wilk W test and the homogeneity of variances was checked using the Levene's test (Petrie and Watson, 1999). Normally distributed data were subjected to ANOVA using treatment groups as a fixed main effect and sampling periods as repeated measures. Within treatment group, comparison of data between prepartum and postpartum were performed using the paired student t test. The comparisons were carried out only if the ANOVA analysis indicated significant effects. The two-sided level of statistical significance was preset at $p \leq 0.05$.

RESULTS AND DISCUSSION

Body condition score and milk production: Body condition scores of cows drenched with PG for 14 and 30 days after calving are shown in Fig. 1. At the week of calving, cows in both groups had similar BCS. The BCS of cows in both groups slightly decreased at 1 month after calving and remained at that BCS up to 6 months. When comparing BCS at 1 month after calving with BCS at the week of calving, cows in 14 days group lose 0.15 (±0.05) BCS and cows in 30 days group lose 0.19 (±0.05) BCS. Milk yields of cows drenched with PG for 14 and 30 days after calving are shown in Fig. 2. Average milk yields during 20 weeks of lactation were 16.4 (±4.6) and 17.0 (±5.1) kg day^{-1} for cows in 14 days group and in 30

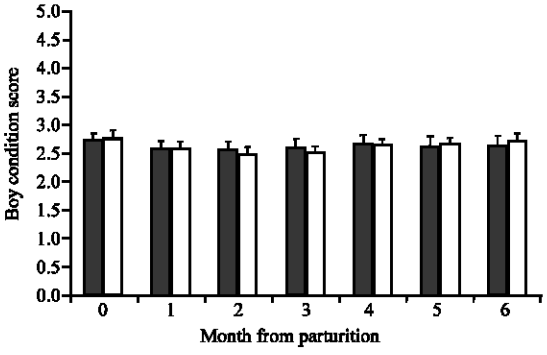

Fig. 1: Comparison of body condition scores between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

Table 1: Milk composition of cows that were drenched with propylene glycol from 7 days prepartum to 14 days postpartum (n = 12) and cows that were drenched from 7 days prepartum to 30 days postpartum (n = 13). Data represented mean (SD)

	Week from parturition							
Milk parameters	1	2	3	4	5	6	7	8
Lactose (%)								
14-d drench	5.01 (0.33)	4.91 (0.26)	4.41 (1.23)	4.72 (1.37)	4.73 (0.24)	4.74 (0.34)	4.63 (0.39)	4.64 (0.39)
30-d drench	4.79 (0.79)	4.71 (0.34)	4.68 (0.37)	4.67 (0.26)	4.43 (0.62)	4.58 (0.45)	4.57 (0.34)	4.52 (0.56)
Protein (%)								
14-d drench	3.42 (0.18)	3.42 (0.15)	3.15 (0.76)	3.27 (0.17)	3.30 (0.10)	3.32 (0.20)	3.26 (0.26)	3.26 (0.27)
30-d drench	3.37 (0.48)	3.34 (0.19)	3.31 (0.15)	3.26 (0.12)	3.12 (0.39)	3.20 (0.25)	3.16 (0.33)	3.20 (0.36)
Fat (%)								
14-d drench	2.99 (0.53)	3.08 (0.48)	3.39 (0.53)	3.52 (0.59)	3.42 (0.41)	3.38 (0.62)	3.58 (0.70)	3.57 (0.72)
30-d drench	2.95 (0.64)	3.44 (0.62)	3.45 (0.56)	3.51 (0.47)	3.67 (0.59)	3.68 (0.82)	3.73 (0.68)	3.78 (1.02)

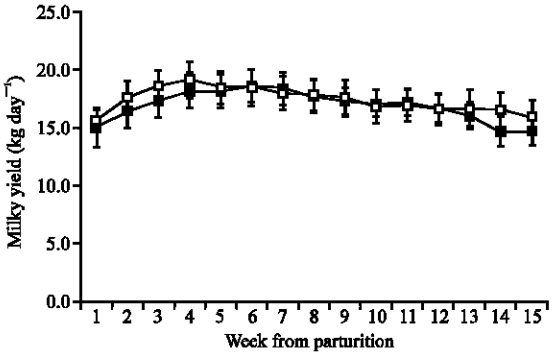

Fig. 2: Comparison of milk yield (kg day^{-1}) between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

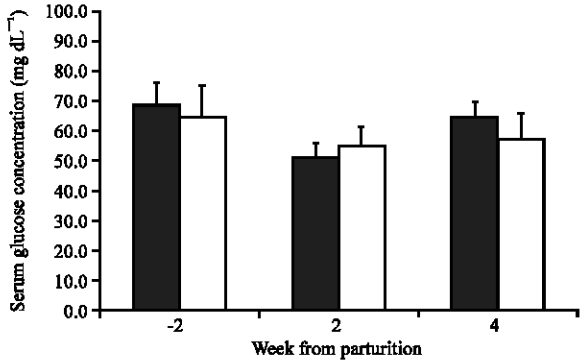

Fig. 3: Comparison of serum glucose concentration (mg dL^{-1}) between cows that were drenched with propylene glycol for 14 day (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

day group, respectively and the averages did not differ between the two groups. In addition, milk composition of cows in 14 days group did not differ from that of cows in 30 days group (Table 1).

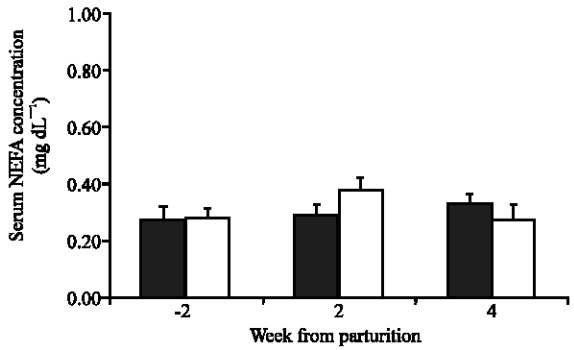

Fig. 4: Comparison of serum Non-esterified Fatty Acids (NEFA) concentration (mEq L^{-1}) between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

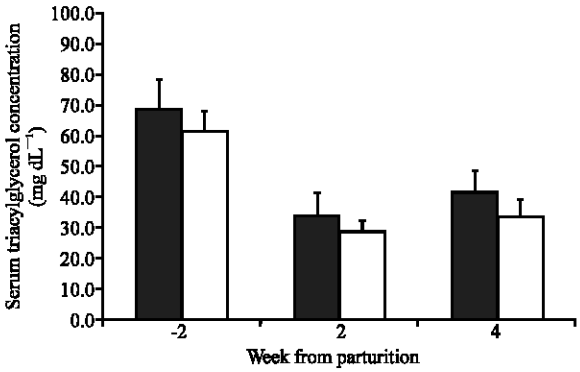

Fig. 5: Comparison of serum triacylglycerol concentration (mg dL^{-1}) between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

Blood biochemistry: Serum glucose, NEFA, triacyglycerol, cholesterol and urea nitrogen concentrations are shown in Fig. 3-7, respectively. Serum

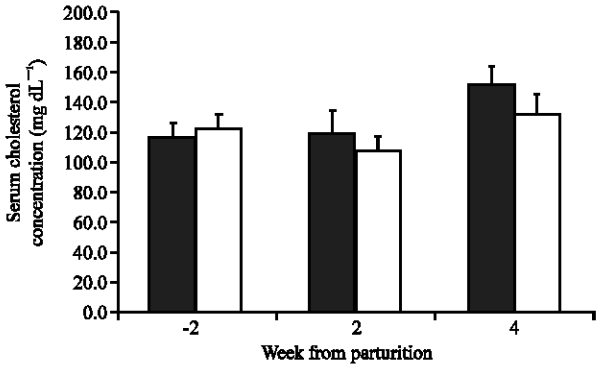

Fig. 6: Comparison of serum cholesterol concentration (mg dL^{-1}) between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

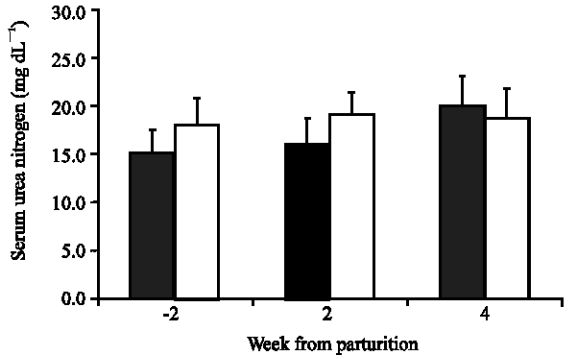

Fig. 7: Comparison of serum urea nitrogen concentration (mg dL^{-1}) between cows that were drenched with propylene glycol for 14 days (■; n = 12) and cows that were drenched for 30 days (□; n = 13) after calving. Data represent means and SEM as error bars

glucose concentrations at each sampling period did not differ between cows drenched with PG for 14 or for 30 days (Fig. 3). Serum glucose concentrations during the experimental period ranged from 50.9 (±4.9) to 68.6 (±7.7) mg dL^{-1} and from 55.1 (±6.1) to 64.6 (±10.5) mg dL^{-1} for cows in 14 days group and cows in 30 days group, respectively. As compared with concentrations at 2 weeks before calving, the concentrations in both groups decreased at 2 weeks after calving. In this study, serum NEFA concentrations between cows drenched with PG for 14 days and cows drenched with PG for 30 days did not differ during all sampling periods (Fig. 4) indicating that both treatment protocols could result in reduction of fat mobilization. Serum triacylglycerol concentrations did not differ between cows drenched with PG for 14 days and cows drenched with PG for 30 days at all sampling periods (Fig. 5). The concentrations ranged from 33.8 (±7.4) to 68.8 (±10.1) mg dL^{-1} and from 28.5 (±3.8) to 70.0 (±6.8) mg dL^{-1} for cows in 14 days group and cows in 30 days group, respectively. The concentrations in both groups at 2 weeks before calving were higher than the postpartum concentrations.

Serum cholesterol concentrations did not differ between cows drenched with PG for 14 days and cows drenched with PG for 30 days at all sampling periods (Fig. 6). The concentrations ranged from 116.0 (±9.7) to 151.4 (±11.7) mg dL^{-1} and from 107.6 (±9.6) to 131.5 (±13.3) mg dL^{-1} for cows in 14 days group and cows in 30 days group, respectively. Serum cholesterol concentrations of cows in both groups at 2 weeks before calving were lower than the concentrations at 4 weeks of lactation (Fig. 6). Serum urea nitrogen concentrations did not differ between cows drenched with PG for 14 days and cows drenched with PG for 30 days at all sampling periods (Fig. 7). The concentrations ranged from 15.1 (±2.3) to 19.9 (±3.1) mg dL^{-1} and from 18.1 (±2.6) to 19.2 (±2.1) mg dL^{-1} for cows in 14 days group and cows in 30 days group, respectively.

Postpartum reproductive performance: Average days from calving to first estrus were 61±10.9 and 65.5±8.3 days for cows in 14 and 30-group, respectively and did not differ between the two groups. Although, a normal range of 30-50 days is known, drenching with PG at the dosage of 400 mL day^{-1} for either 14 or 30 days after calving did strongly improve postpartum fertility. However, some cows showed their estrus during expected period.

The loss of BCS in this study was moderate (Kim and Suh, 2003). Rukkwamsuk *et al.* (2006) studied negative energy balance in periparturient dairy cows raised in small-holder farms and found that average change of BCS (BCS at 1 week prepartum-BCS at 4 weeks postpartum) of 45 dairy cows was 0.60. As compared with the study of Rukkwamsuk *et al.* (2006), drenching propylene glycol for either 14 or 30 days could reduce the loss of BCS.

In general, supplementing with PG has no significant effects on milk yield and milk composition as reviewed by Nielsen and Ingvartsen (2004). Most studies from that review compared milk yield and milk composition between cows that were drenched with PG and control cows that were not drenched with PG. The present study added more information that drenching PG for 30 days did not have any positive effects on milk yield and milk composition as compared with drenching PG for 14 days. This study confirmed that dairy cows in both groups

entered a period of NEB postpartum, particularly during the first 2 weeks of lacation which caused a reduction in blood glucose concentrations (Rukkwamsuk *et al*., 2003, 2006). However, the reduction of blood glucose concentrations after calving did not obvious, implying that drenching PG could improve energy balance during periparturient period. Decreased blood glucose concentrations as a result of NEB, postparturient dairy cows increased mobilization of energy reserves by increasing lipolysis of adipose tissue (McNamara and Hillers, 1986; Rukkwamsuk *et al*., 1999). Increased adipose tissue lipolysis resulted in an increase of blood NEFA concentrations. It is known that PG has a negative effect on serum NEFA concentrations as reviewed by Nielsen and Ingvartsen (2004). This study indicated that cows in both groups lose a limited BCS which corresponded well with slightly decrease in serum glucose and slightly increase in serum NEFA concentrations.

The lower serum triacylglycerol concentrations were related to the milk fat synthesis because circulating triacylglycerols are used to synthesize milk fat (Glascock *et al*., 1966). Therefore, cows in lactating period drain their blood triacylglycerols through the udder, resulting in lower triacylglycerol concentrations in the blood as compared with the concentrations during the dry period. Ruegg *et al*. (1992) also reported that serum cholesterol concentrations increased when dairy cows start their milk production right after calving and were negatively related to their loss of body condition score. Dairy cows in this study lose their body condition score after calving; thus, increasing serum cholesterol concentrations which was in agreement with Kim and Suh (2003).

In general, elevation of serum urea nitrogen concentrations is associated with consumption of high protein, especially quickly degradable protein in the rumen (Godden *et al*., 2001). Dairy cows during the last 3 weeks of the dry period are fed limited amount of concentrates whereas during early lactation, they were fed on high concentrates. It was observed that serum concentrations of urea nitrogen were higher in early postpartum cows than in dry cows (Kim and Suh, 2003) but the serum urea nitrogen concentrations observed in this study did not differ between prepartum and postpartum levels. Drenching with PG had no effect on serum urea nitrogen concentration during 4 weeks of lactation as also reported by Chibisa *et al*. (2008).

Because the number of cows in each group was small, therefore it was not possible to demonstrate other parameters related to reproductive performances such as conception rate and number of services per conception. However, Miyoshi *et al*. (2001) reported that first ovulation of cows treated with PG occurred earlier than that of cows without PG treatment. As compared with the previous data of average days from calving to first estrus (72±65 days), cows drenched with PG in both groups had shorter days from calving to first estrus. This notion might be due to the fact that PG treatment would shorten days from calving to first ovulation in the studied cows (Miyoshi *et al*., 2001).

CONCLUSION

In this study, although negative energy balance is an inevitable phenomenon in periparturient dairy cows, drenching with 400 mL day^{-1} of PG for either 14 or 30 days after calving would improve the negative energy balance status as observed by serum glucose and NEFA concentrations. Drenching propylene glycol for either 14 or 30 days postpartum had similar effect on milk production, blood metabolites and days from calving to first estrus. At the economical point of view, it would be suggested from this study that drenching PG for 14 days was sufficient to reduce negative energy balance and its consequences with satisfactory outcomes.

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