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Effects of Propylene Glycol Powder on Productive Performance of Lactating Cows

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Abstract: An experiment was conducted by eight lactating Holstein cows with an average milk production of 32.75 kg day^{-1} and body weight of 643.6 kg to evaluate the effects of propylene glycol (PG) on productive performance, blood metabolites and nutrients digestibilities. In this experiment a balanced change-over design with four treatments and four periods with 21 days were employed. Treatments included: (1) Control (without PG), (2) 250 g PG/cow/day, (3) 500 g PG/cow/day and (4) 750 g PG/cow/day. Daily milk yield recorded and milk samples were taken during seven and two last days of each period. The results show that dry matter intake, milk yield, fat corrected milk yield, milk compositions were not affected ($p>0.05$) by different levels of PG. Supplementing diets with 500 and 750 g PG/cow/day, significantly increased plasma glucose ($p<0.05$) but other blood metabolites such as blood urea nitrogen, triglyceride and cholesterol were not affected ($p>0.05$) by PG. Apparent digestibility of dry matter and organic matte was not affected ($p>0.05$) by PG administration. In conclusion, plasma glucose was increased by using 500 and 750 g PG/cow/day (as powder) in the first and mid lactation stage, but the levels of 250 g PG/cow/day did not have any significant effect on dry matter intake, milk yield, milk compositions and other blood metabolites.

Key words: Propylene glycol, milk compositions, Holstein dairy cows, blood metabolites

INTRODUCTION

The continuous increase in milk production has created new challenges for the high-producing dairy cow, especially during the transition period. At the beginning of lactation, dairy cows have to cope with the high energy and protein demands for milk synthesis at a time when nutrient intake is low. Mobilizing energy and protein from body tissue stores and repartition of nutrients away from extramammary tissues are the primary alternatives to supply sufficient nutrients for milk production during the first weeks of lactation (Juchem *et al*., 2004). Excessive fat mobilization can induce an imbalance in hepatic carbohydrate and fat metabolism, which may result in ketosis (Herdt and Emery, 1992; Goff and Horst, 1997). Alternatives have been suggested to ameliorate or minimize the metabolic challenge during transition, including an increase in nutrients density of close-up dry cow diets, providing a comfortable environment that minimizes the depression in feed intake prior to calving and including feed additives in pre- and postpartum diets. Useful feed additives would be those that promote an increase in glucose availability and a decrease in body triacylglycerol mobilization. Propylene glycol (PG) is a glucogenic precursor that has been used for many years for both treatment and prevention of ketosis before and after parturition (Nielsen and Ingvartsen, 2004). Propylene glycol may affect glucogenic action in different ways. The portion of this substance is metabolized 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 (Mikula *et al*., 2008). Several experiments have been conducted to evaluate the effects of PG on metabolism. These studies differ in quantity, timeframe and method of delivery of PG. Emery *et al*. (1964) determined that cows supplemented with PG around calving and/or in early lactation had either unchanged, or a tendency towards increased milk yield. This may be due to that cow after parturition decrease feed intake with inability to face the requirements of production. So, energy supplementation is very important. But at the mid and late lactation feed intake increases so energy supplementation is not necessary especially for low and mid yielding cows (Dhiman *et al*., 1993; Cozzi *et al*., 1996; Shingfield *et al*.,

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2002). The objectives of the present study were to examine the effects of propylene glycol powder on feed intake, production and plasma metabolites and apparent nutrient digestibility in lactation Holstein dairy cows.

MATERIALS AND METHODS

Experimental site: This research project was conducted at the Animal Husbandry of Akbari (Bandar Gaz) and Agricultural and Natural Resources Research Center of Golestan Province, Iran from spring 2007 to summer 2008.

Animals and management: Eight multiparous Holstein cows in early lactation from a herd in Gorgan Iran were selected for the 84 days experiment. Eight days before the experiment, the cows were moved from the herd to individual tiestalls. Cows were individually fed diets as a total mixed ration, which provided twice daily and feed intakes were measured daily.

Experimental design and dietary treatment: The experimental design was a balanced change-over design with four treatment and four periods with 21 days (14 day for adaptation and 7 day for data collection) (Kaps and Lamberson, 2004). Treatments include: (1) Control (without PG) NPG, (2) 250 g PG/cow/day (PG 250), (3) 500 g PG/cow/day (PG 500) and (4) 750 g PG/cow/day (PG 750). The used PG levels in this experiment were based on previous experiments that used close ranges of PG levels to our experiment. Also, PG manufactured factory recommendations were considered. Propylene glycol blended with 0.4 kg of ground corn and fed as a part of TMR. The average milk production and body weight of cows before the experiment were 32.75 kg day^{-1} and 643.6 kg. The TMR sampled weekly during the experiment and analyzed for Dry Matter (DM), crude protein, neutral detergent fiber, acid detergent fiber, ether extract, calcium and phosphorus content (AOAC, 1990). Diets ingredients and composition are presented in Table 1.

Table 1: Ingredients and chemical composition of diet (DM basis)

Ingredients	Amount (% of DM)	Chemical	Amount (% of DM)
Alfalfa hay	14.70	CP	17.1
Corn silage	26.15	RDP	10
Cottonseed	6.04	RUD	7.1
Barley	20.08	NE_L, Mcal kg^{-2}	1.49
Ground corn	6.04	NDF	35
Cottonseed meal	10.87	ADF	22
Soybean meal	3.36	NFC[3]	40.9
Sugar beet pulp	4.03	Ca	0.6
Wheat barn	3.20	P	0.4
Wheat straw	4.38	Lys/Met	208/60
Vitamin and minerals[1]	0.51	DCAD[4] (mEq kg^{-1} DM)	144
Salt	0.16		
Sodium bicarbonate	0.48		

[1]Contained 20,000,000 IU of vitamin A kg^{-1}, 2,000,000 IU of vitamin D kg^{-1}, 15,000 IU of vitamin E kg^{-1}, 6,000 mg kg^{-1} of Mn, 6,000 mg kg^{-1} of Zn, 2,000 mg kg^{-1} of Fe, 1,500 mg kg^{-1} of Cu, 120 mg kg^{-1} of I, 50 mg kg^{-1} of Se, and 20 mg kg^{-1} of Co. [2]Net energy for lactation calculated according to NRC (2001). [3]NFC, % = 100 - (NDF, % + CP, % + fat, % + ash, %). [4]DCAD (Diet cation-anion difference), mEq kg^{-1})] = [(mEq Na mEq K)$^{-}$ (mEq Cl mEq S)]

Milk samples: Milk production recorded at each milking during the last seven days of each period. Milk samples from each animal, pooled from two consecutive milkings collected on last two days of each period. The samples was treated with 0.5 g of preservative (Sodium azide) and analyzed for milk fat, lactose, protein and total solids (AOAC, 1990).

Blood sampling and biochemical analysis: Blood samples from coccygeal vessels collected in 5 mL Vacuntainer tubes containing 5 mg of potassium oxalate and 5 mg of sodium fluoride on last day of each period, one hour after the morning feeding. Plasma was obtained from blood after centrifugation at 2000x g for 20 min and then stored at -20°C until analyzed for glucose, insulin, blood urea nitrogen, cholesterol and triglyceride.

Nutrients digestibilities analysis: Apparent DM and OM digestibility coefficients estimated using Acid Insoluble Ash (AIA) as an indirect marker (Van Keulen and Young, 1977). During the last five days of each period spot faecal sample collected twice a day from the cows. At the end of each period, samples pooled on an individual basis, thoroughly mixed, subsampled and stored at -20°C. Faecal DM, OM and AIA concentrations were determined using reference methods documented elsewhere (Van Keulen and Young, 1977).

Statistical analysis: The data analyzed using mixed procedure of SAS (1996) using the following model:

$$Y_{ijkl} = \mu + T_i + P_j + A_k + R_l + e_{ijkl}$$

Where:

Y_{ijkl} = Observation
μ = Overall mean
T_i = Treatment effects
P_j = Period effects
A_k = Animal effects
R_l = Residual effects from previous treatment
e_{ijkl} = Residual error

Differences with $p \leq 0.05$ were considered significant.

RESULTS

Dry Matter Intake (DMI) was similar for all treatments and there were no significant difference between groups

Table 2: Effects of treatment on dry matter intake and milk yield

	Treatments				
Item (kg day^{-1})	NPG	PG 250	PG 500	PG 750	SE
Dry matter intake	21.50	21.68	21.63	21.67	0.349
Milk yield	32.68	32.46	33.12	33.25	0.438
3.5 % FCM	35.01	33.49	34.41	35.01	0.966

Values are not significant at p>0.05

Table 3: Effects of treatment on milk composition

	Treatments				
Item	NPG	PG 250	PG 500	PG 750	SE
Milk fat (%)	3.950	3.690	3.730	3.820	0.186
Milk fat (kg day^{-1})	1.290	1.200	1.230	1.270	0.058
Milk lactose (%)	4.420	4.340	4.330	4.320	0.037
Milk lactose (kg day^{-1})	1.440	1.400	1.430	1.440	0.015
Milk protein (%)	3.090	3.020	3.040	3.030	0.022
Milk protein (kg day^{-1})	1.010	0.980	1.000	1.000	0.011
Total solid (%)	12.13	11.73	11.75	11.83	0.214
Total solid (kg day^{-1})	3.960	3.800	3.890	3.930	0.072

Values are not significant at p>0.05

Table 4: Effects of treatment on blood parameters

	Treatments				
Item (mg dL^{-1})	NPG	PG 250	PG 500	PG 750	SE
Glucose	58.25^{b}	61.50^{ab}	63.25^{ab}	66.37^{a}	1.5740
Blood urea nitrogen	10.50	11.87	12.12	12.62	0.8590
Cholesterol	229.0	222.0	233.0	231.0	13.203
Triglycerides	20.87	19.12	17.75	19.62	1.7710
Insulin (μIU mL^{-1})	8.400	8.630	8.530	8.460	0.1350

Values with a different superscript in the same row are significantly different (p<0.05)

Table 5: Effects of treatment on apparent digestibility

	Treatments				
Item (%)	NPG	PG 250	PG 500	PG 750	SE
Dry matter	69.23	69.16	69.22	69.28	0.09
Organic matter	71.15	71.36	71.16	71.41	0.178

Values are not significant at p>0.05

(p>0.05, Table 2). Milk yield and fat corrected milk yield (3.5 % FCM= 0.432×kg milk+16.216×kg fat) were not affected by different levels of propylene glycol (p>0.05) (Table 2). Highest and lowest milk productions were in 750 and 250 g PG per day, but their difference was not significant compared with control group. Milk production tendency increased by increasing PG level. Milk compositions are shown in Table 3. Milk components such as fat, protein, lactose and total solids were similar between treatments (p>0.05). Administration of PG in this experiment increased concentration of plasma glucose (p<0.05) but did not affect concentration of insulin, blood urea nitrogen, cholesterol and triglyceride (p>0.05) (Table 4) Glucose concentration in PG 750 was significantly higher than control group (p<0.05), but glucose level in PG 250 and PG 500 was similar with other treatments. Effects of treatments on apparent digestibilities of dry matter and organic matter were not significant (Table 5).

DISCUSSION

Dry Matter Intake (DMI): Propylene glycol has high energy content and therefore has the potential to increase DMI, on the other hand, PG is an unpalatable additive in itself (Johnson, 1954) and mixing it into TMR could therefore decrease DMI. Dhiman *et al.* (1993) reported a significant reduction in DMI in mid-lactating cows fed 688 g PG per day via a TMR. The most effective way of allocating PG without affecting DMI is by drenching (Miyoshi *et al.*, 2001), or by mixing PG into the concentrates which may include molasses or other flavour additives to cover up the bad taste of PG. According relatively few experiments that have measured feed intake it seems clear that PG does not stimulate feed intake in early lactating cows (Fisher *et al.*, 1973; Miyoshi *et al.*, 2001; Pickett *et al.*, 2003). The result of this experiment different from the result of Miyoshi *et al.* (2001) which observed that lactating cows decreased their feed intake after 1-2 days of top-dressing 518 g PG per day, due to its low palatability, but in this experiment PG used as part of TMR and hadn't negative effect on feed intake. A most likely reason, that the used dosages do not increase the energy density of the feed sufficiently to induce an increase in feed intake. Furthermore, feed intake in early lactation is also influenced by metabolic factors and the increase in insulin triggered by PG may stimulate negative feedback signals that regulate DMI (Ingvartsen and Andersen, 2000).

Milk yield and fat corrected milk yield: Present results agree with Studer *et al.* (1993) and Burhans *et al.* (1997), who reported no effect of PG administration on DMI, milk yield and milk composition. In contrast, Stokes and Goff (2001) reported that milk yield of cows on a commercial dairy farm was increased by administration of PG on the first 2 day postpartum. However, milk production and composition frequently affected by nutrition, but it can be affected by other factors such as genetic, season, age and disease.

Milk compositions: In most studies, despite the positive effect on blood biochemistry, administration of PG pre- and/or postpartum has not been shown to significantly affect yields of milk and milk compositions in lactating dairy cows (Fisher *et al.*, 1973; Studer *et al.*, 1993; Formigoni *et al.*, 1996). One could expect an increased milk protein percentage when supplying PG, under the assumption that PG decreases amino acid requirements for gluconeogenesis and that the spared amino acids would be limiting for increased protein synthesis in the mammary gland (Griinari *et al.*, 1997). Milk lactose content usually

varies very little, although nutritional practices have been shown to have some effect on it. Generally, feeding PG during lactation has no effect on content of milk lactose (Sauer *et al*., 1973). Early lactating cows had a tendency to decreased milk fat content and in fact, result of this experiment disagrees from Fisher *et al*. (1973) which observed a significant reduction in the fat percentage when allocating 360 g of PG per day. They pointed that tendency towards reduced milk fat content could be due to the decrease in plasma Non-esterified fatty acids, since lowed NEFA concentrations lead to decreased NEFA-uptake by the mammary gland (Nielsen and Ingvartsen, 2004). Another reason for the tendency to a lower milk fat content could be that PG leads to a lower proportion of acetate in the rumen. This might reduce the amount of acetate available for de novo fatty acid synthesis in the mammary gland.

Blood parameters: 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 is a glucogenic precursor, which is quickly absorbed from the rumen wall or partly transformed to the propionate before being absorbed and converted to glucose (Nielsen and Ingvartsen, 2004). Propylene glycol is more effective at increasing blood glucose content during negative energy balance than during positive energy balance (Butler *et al*., 2006). Nielsen and Ingvarsten (2004) stated that glucose response is rather limited compared with insulin, even if blood samples collected shortly after administration of PG. Blood insulin level could be the parameter of dairy cows energy state. Low concentration of this hormone is associated with negative energy balance in early lactation. Pickett *et al*. (2003) reported no significant effect of PG administration on blood serum insulin level. In contrast, Christiansen *et al*. (1997) observed increased concentration of insulin after PG treatment. Miyoshi *et al*. (2001) conducted that mechanism were propylene glycol affects insulin has not been established. Nielsen and Ingvarsten (2004) suggested 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 PG in TMR, similarly to present experiments. Propylene glycol did not affect the concentration of cholesterol and triglycerides, which is agree with results of Rukkwasmsuk *et al*. (2005) and Cozzi *et al*. (1996).

Apparent digestibility: The lack of effect of PG feeding level on apparent digestibility of dry matter and organic matter is consistent with results reported by Cozzi *et al*. (1996), who found no changes in apparent digestibility in mid-lactating cows receiving different levels of PG. The objective of this research was to evaluate the effects of PG on feed intake, production and plasma metabolites and apparent nutrient digestibility in lactation dairy cows that just as indicated high level of PG had significant effect on glucose concentration but had no significant effect on other factors.

CONCLUSION

In lactating Holstein cows supplementing propylene glycol had no significant effect on blood metabolites except glucose. Administrations of PG don't have any significant effect on dairy cows feed intake, milk production and composition, some plasma metabolites and apparent nutrient digestibility. The important result that we found in this experiment which mixing PG into the ratio has a low effect on lactation dairy cows in early lactation.

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