The period of 3 weeks prepartum to 3 weeks postpartum in dairy cows is the transition period. During this period, feeding and management are critical factors for cows. Good feeding and management during this period benefits future milk production. However, if feeding and management are inadequate, metabolic syndromes such as ketosis and milk fever can develop in the early period of postpartum (Curtis et al., 1985; Goff and Horst, 1997).

The DMI of dairy cows starts declining at 3 weeks prepartum, as during this period a fetus grows rapidly and various stresses can adversely impact hormone secretion (Grummer, 1995). This reduction in DMI is typically apparent at 7 days prepartum. Grummer (1995) and Robinson and Garrett (1999) indicate that the DMI declines during the prepartum period can be up to 30-35%, especially in subtropical area like Taiwan, where the summer temperatures usually reach 35°C during the day.

The milk production peak is at 5-8 weeks postpartum while the diet consumption peak is at 10-14 weeks postpartum. Thus, dairy cows will typically suffer a 6-8 week period of negative energy balance during the postpartum period (Butler and Smith, 1989). This negative energy balance consequently induces catabolism of body tissue to meet energy requirements, resulting in reduced BCS, rumen fermentation, and milk production; and even worse, the possibility of metabolic syndrome (Grant and Albright, 1995; Hutjens, 1996; Robinson, 1997; Kim and Suh, 2003). Thus, we propose that supplying extra energy during this crucial transition period will benefit the energy balance of dairy cows.

Propylene glycol, which is rich in energy (4.7 Mcal NE/L) (Miyoshi et al., 2001), can rapidly supply transition dairy cows with energy. Propylene glycol is easily and rapidly absorbed and metabolized in the rumen. Roughly 50% can be metabolized 1-2 h after feeding, with approximately 80-90% usually metabolized 3h after feeding. Propylene glycol can also be converted to propionic acid in the rumen and transported to liver, where it is converted to
MATERIALS AND METHODS

Animals and treatments

This study conducted in the summer season of the subtropical area of Taiwan (averaged day time temperature was 33.25±2.56°C). Twenty-four 2-3 multiparous Holstein dairy cows were selected for this study (average body weight 565 kg, BCS about 3.6; 9 months pregnant). Selected cows were blocked by parity, month of calving, weight 565 kg, BCS about 3.6; 9 months pregnant). The water and the PG were orally drenched from 7 and 1-3 days prepartum, and 0-7, 14, 21 and 28 days postpartum at a fixed time (16:00). Milking samples (100 ml) from am. and pm. milking were taken on days 14, 21 and 28 postpartum. Milk fat, protein and somatic cells counts (SCC) were determined by an infrared machine (Foss electric Co. Milko Scan 255 A/B type, USA). BCS was discerned by three professionals and classed on a 1-5 scale (1 = thin, 5 = obese) following Wildman et al (1982).

Plasma glucose concentration was measured by a glucose-oxidase strip with a glucose analyzer (Bayer, Germany). Insulin concentration was examined using an enzyme immunoassay kit by ELISA method (Boehringer Mannheim, Germany). Blood urea nitrogen (BUN) concentration was analyzed by a kit with a serum autoanalyzer (Roche COBAS MISA, Switzerland). NEFA was determined by a modified procedure described by Chromy et al. (1977). Serum samples 100μL were added 3mL of extraction reagent (chloroform:heptane:methanol; 49:49:2), and 1 ml copper reagent (1.0 M Cu(NO3)3H2O and 5 ml triethanolamine, diluted to 100 ml with saturated NaCl; pH 8.3). Next, the mixture was shaken for 5 min and centrifuged at 1,500 g for 5 min. We next took 1 ml of supernatant added color reagent (0.25 ml of 0.1% 1-2-thiazolylazo-2-naphol, TAN) and measured at 570nm with a spectrophotometer (Hitachi, U-2000, Japan). Palmitic acid (C16:0) was used as a standard.

Ketone body concentration was measured using the method described by Reid (1960). 5% ZnSO4.7H2O and 0.3 N barium hydroxide were added to serum samples, which were filtered to remove protein. Put 8 ml of 7 N H2SO4 into distillation bottle then start to distillation and collected 5 ml for acetocetate and acetone determination. Next, 5 ml of 0.2% K2C2O7 was added and distillation was continued. 5 ml was also collected for β-hydroxybutyric acid study and separated for individual feeding and measurement. During the dry period (30 days of prepartum) cows were fed with 4 kg concentrate and 4kg alfalfa hay daily, and bermuda hay was accessed freely. After calving, the amount of concentrate fed was based on the milking level using a 1:3 concentrate to milk ratio (upper limit was 10 kg of concentrate). The concentrate composition is shown in Table 1. Alfalfa hay, supplied for roughage, had an upper limit of 8 kg, while bermuda hay was accessed freely. The nutrient supply followed NRC (1989). Mineral salt and water were supply ad libitum. Cows were milked twice daily and milk production was recorded for 90 days. The feed intake, calving, placenta retention, and first heat data were recorded. Cows were bred by artificial insemination at second heat; conception and pregnancy were then checked by a veterinarian each month.

Experimental procedure, sampling and analysis

About 15 ml of blood samples were taken from the tail vein at 7 and 1-3 days prepartum, and 0-7, 14, 21 and 28 days postpartum at a fixed time (16:00). Milking samples (100 ml) from am. and pm. milking were taken on days 14, 21 and 28 postpartum. Milk fat, protein and somatic cells counts (SCC) were determined by an infra-red machine (Foss electric Co. Milko Scan 255 A/B type, USA). BCS was discerned by three professionals and classed on a 1-5 scale (1 = thin, 5 = obese) following Wildman et al (1982).

Experimental procedure, sampling and analysis

About 15 ml of blood samples were taken from the tail vein at 7 and 1-3 days prepartum, and 0-7, 14, 21 and 28 days postpartum at a fixed time (16:00). Milking samples (100 ml) from am. and pm. milking were taken on days 14, 21 and 28 postpartum. Milk fat, protein and somatic cells counts (SCC) were determined by an infra-red machine (Foss electric Co. Milko Scan 255 A/B type, USA). BCS was discerned by three professionals and classed on a 1-5 scale (1 = thin, 5 = obese) following Wildman et al (1982).

Plasma glucose concentration was measured by a glucose-oxidase strip with a glucose analyzer (Bayer, Germany). Insulin concentration was examined using an enzyme immunoassay kit by ELISA method (Boehringer Mannheim, Germany). Blood urea nitrogen (BUN) concentration was analyzed by a kit with a serum autoanalyzer (Roche COBAS MISA, Switzerland). NEFA was determined by a modified procedure described by Chromy et al. (1977). Serum samples 100μL were added 3mL of extraction reagent (chloroform:heptane:methanol; 49:49:2), and 1 ml copper reagent (1.0 M Cu(NO3)3H2O and 5 ml triethanolamine, diluted to 100 ml with saturated NaCl; pH 8.3). Next, the mixture was shaken for 5 min and centrifuged at 1,500 g for 5 min. We next took 1 ml of supernatant added color reagent (0.25 ml of 0.1% 1-2-thiazolylazo-2-naphol, TAN) and measured at 570nm with a spectrophotometer (Hitachi, U-2000, Japan). Palmitic acid (C16:0) was used as a standard.

Ketone body concentration was measured using the method described by Reid (1960). 5% ZnSO4.7H2O and 0.3 N barium hydroxide were added to serum samples, which were filtered to remove protein. Put 8 ml of 7 N H2SO4 into distillation bottle then start to distillation and collected 5 ml for acetocetate and acetone determination. Next, 5 ml of 0.2% K2C2O7 was added and distillation was continued. 5 ml was also collected for β-hydroxybutyric acid

Table 1. The composition of experimental concentrate

<table>
<thead>
<tr>
<th>Ingredient (DM basis)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>66.5</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>20</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>6</td>
</tr>
<tr>
<td>Molasses</td>
<td>5</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>1</td>
</tr>
<tr>
<td>Salt</td>
<td>0.5</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>0.6</td>
</tr>
<tr>
<td>Premix</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analyzed value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>89.8</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>16</td>
</tr>
<tr>
<td>Crude fat (%)</td>
<td>7</td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>3.2</td>
</tr>
<tr>
<td>Crude ash (%)</td>
<td>7.4</td>
</tr>
<tr>
<td>NDF (%)</td>
<td>35.5</td>
</tr>
<tr>
<td>ADF (%)</td>
<td>42.3</td>
</tr>
<tr>
<td>Gross energy (MJ/kg)</td>
<td>17.2</td>
</tr>
</tbody>
</table>

*Per kg of premix contain: Vitamin A, 10,000,000 IU; Vitamin E, 70,000 IU; Vitamin D3, 1,600,000 IU; Fe, 50 g; Mn, 40 g; Cu, 10 g; Zn, 40 g; Se, 0.1 g; Co, 0.1 g.

Plasma glucose concentration was measured by a glucose-oxidase strip with a glucose analyzer (Bayer, Germany). Insulin concentration was examined using an enzyme immunoassay kit by ELISA method (Boehringer Mannheim, Germany). Blood urea nitrogen (BUN) concentration was analyzed by a kit with a serum autoanalyzer (Roche COBAS MISA, Switzerland). NEFA was determined by a modified procedure described by Chromy et al. (1977). Serum samples 100μL were added 3mL of extraction reagent (chloroform:heptane:methanol; 49:49:2), and 1 ml copper reagent (1.0 M Cu(NO3)3H2O and 5 ml triethanolamine, diluted to 100 ml with saturated NaCl; pH 8.3). Next, the mixture was shaken for 5 min and centrifuged at 1,500 g for 5 min. We next took 1 ml of supernatant added color reagent (0.25 ml of 0.1% 1-2-thiazolylazo-2-naphol, TAN) and measured at 570nm with a spectrophotometer (Hitachi, U-2000, Japan). Palmitic acid (C16:0) was used as a standard.

Ketone body concentration was measured using the method described by Reid (1960). 5% ZnSO4.7H2O and 0.3 N barium hydroxide were added to serum samples, which were filtered to remove protein. Put 8 ml of 7 N H2SO4 into distillation bottle then start to distillation and collected 5 ml for acetocetate and acetone determination. Next, 5 ml of 0.2% K2C2O7 was added and distillation was continued. 5 ml was also collected for β-hydroxybutyric acid.
determination. Then, 4 ml of 10 N NaOH and 2 ml color reagent solution (100 ml ethanol and 20 ml salicylic aldehyde) was added to the 5 ml collected ketone body samples. After shaking, the mixture was placed in a 55°C water bath for 20 min and then rested at room temperature for 1 h. It was then measured by a spectrophotometer at 530 nm. Sodium acetoacetate and β-hydroxybutyrate were used as standard, and both ketone body values were pooled.

### Statistical analysis

Experimental data were then analyzed using the mixed model of SAS (1998) with repeated measures, according to the following model.

\[ Y_{ij} = \mu + \alpha_i + \beta_j + w_k + \beta_{wk} + e_{ijk} \]

Where \( \mu \) is the mean, \( \alpha_i \) the effect of the \( i \)th treatment, \( \beta_j \) the effect of the \( j \)th block, \( w_k \) the effect of the \( k \)th week, \( \beta_{wk} \) the interaction between week and block, and \( e_{ijk} \) is the residual error.

### RESULTS

#### Effect of administration of PG on the production traits of transitional dairy cows

Table 2 lists the effect of PG supplementation on the production traits of cows during the transition period. BCS and milk yield of the PG group were significantly greater (\( p<0.05 \)) than that of the control group. Dry matter intake, milk fat, milk protein and SCC were not significantly different (\( p>0.05 \)) between the two groups.

### Effect of administration of PG on serum metabolites

Figure 1 shows the effect of PG supplementation on blood glucose concentration of cows in the transitional period. Analytical results reveal that the PG group had a higher (\( p<0.05 \)) blood glucose concentration than that of the control group during the period of 3 days prepartum to 7 days postpartum.

Table 2. Effect of propylene glycol supplementation on production traits of cows in the transition period

<table>
<thead>
<tr>
<th>Items</th>
<th>Control</th>
<th>Propylene glycol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake (kg/day)</td>
<td>18.25±0.28</td>
<td>19.72±0.37</td>
</tr>
<tr>
<td>Body condition score(^1)</td>
<td>2.73±0.01</td>
<td>3.08±0.02*</td>
</tr>
<tr>
<td>Milk yield(^2) (kg/day)</td>
<td>26.63±1.16</td>
<td>27.24±0.13*</td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>3.53±0.09</td>
<td>3.62±0.11</td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>3.22±0.13</td>
<td>3.28±0.19</td>
</tr>
<tr>
<td>Somatic cell count (×1,000)</td>
<td>332.1±58.2</td>
<td>315.2±30.2</td>
</tr>
</tbody>
</table>

Means±SE (n = 12).

\(^*\) Means in the same row differ significantly (\( p<0.05 \)).

\(^1\) 1 to 5 scale where 1 = thin, 5 = fat (Wildman et al., 1982).

\(^2\) Milk was collected from calving to 90 days milking period.

Figure 1. Effect of propylene glycol supplementation on plasma glucose concentration of cows in the transition period. Means±SE (n = 12). * Means differ significantly between groups (\( p<0.05 \)).

Figure 2 displays the effect of PG supplementation on serum insulin concentration in the two groups of cows in the transition period. Over most of the sample period no significant difference (\( p>0.05 \)) existed between two groups. However, serum insulin concentration on day 5 and 6 postpartum in the PG group was higher than in the control group.

Figure 3 exhibits the effect of PG supplementation on serum NEFA concentration of the cows in the transition period. Serum NEFA concentration in the PG group was markedly different (\( p<0.05 \)) than in the control group across all sampling points, except for the last sampling point (day 28 postpartum).

Figure 4 shows the effect of PG supplementation on the serum ketone body concentration in the cows over the transition period. The two groups did not exhibit significant differences in serum ketone body concentration at most
However, on day 7 postpartum the ketone body levels in the PG group were lower (p<0.05) than those of the control group.

Table 3 displays the effect of PG supplementation on the reproductive traits of the cows. No significant difference (p>0.05) between the two groups was noted.

**DISCUSSION**

**Effect of supplementation of PG on production traits**

The palatability of PG is poor and its supplementation to the diet may negatively affect feed consumption (Dhiman et al., 1993; Girschewski et al., 1977). Thus, we employed oral drenching PG mixed with molasses. DMI was not significantly different between the two groups in our study, consistent with the results of Miyosh et al. (2001) and Pickett et al. (2003), who found that feed intake was not affected by PG supplementation.
Throughout the study period, the BCS of cows in the PG group was approximately 3.0, higher than that of the control group. Thus, PG supplementation appeared to have a positive effect on cow BCS. BCS is a methodology used to estimate the quantity of body reserves of fat, as it is the largest source of energy, but also the major reserve of body protein. Thus, BCS may be used as an indicator of the nutritional status of a cow or ewe. According to Caldeira et al. (2007a), ewe BCS at 3.0 indicates a balanced metabolic status. PG supplies energy rapidly, thereby improving the negative energy balance, reducing the catabolism of body tissue. The experimental results were similar to those obtained by Barllard et al. (2001).

Cows in the transition period have a negative energy balance, and the supplementation of PG can rapidly supply the energy required for milk production. Thus, the milk yield of the PG group was higher than that of the control group. Miyoshi et al. (2001) also indicated that PG supplementation increases milk production. Salem et al. (2005) reported that supplementing PG to goats increased the apparent digestibility of crude protein. Nitrogen retention and daily gain also appeared to increase. Notably, analytical results showed that PG supplementation did not affect milk composition. Pickett et al. (2003) also had similar experiment results. Cozzi et al. (1996) and Barllard et al. (2001) reported that PG supplementation during weeks 7 and 8 of the milking period reduces SCC. However, no reduction in SCC of the PG group was observed in this study.

**Table 3. Effect of propylene glycol supplementation on reproductive traits of cows in the transition period**

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Propylene glycol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days of first oestrus (day)</td>
<td>77.44±5.83</td>
<td>63.88±7.92</td>
</tr>
<tr>
<td>Days open (day)</td>
<td>115.33±9.01</td>
<td>105.56±10.71</td>
</tr>
<tr>
<td>Retain placenta (%)</td>
<td>25 (3/12)</td>
<td>8 (1/12)</td>
</tr>
</tbody>
</table>

Means±SE (n = 12).

Effect of supplementation of PG on serum metabolites

Cows fed a diet supplemented with oral PG had significantly elevated plasma glucose concentration. Grummer et al. (1994), Myoshi et al. (2001) and Juchem et al. (2004) found that cows fed with PG in the transition period exhibited significantly increased plasma glucose concentration. Propylene glycol is rapidly absorbed and metabolized by cows. In the rumen, PG is converted to propionic acid (Grummer et al., 1994), then transported to the liver and metabolized into glucose through glycogenesis.

Shingfield et al. (2002) and Picket et al. (2003) reported that feeding transitional cows 518 g or 200 g PG daily did not influence serum insulin concentration; their findings are consistent with those obtained in this study. However, Grummer et al. (1994) fed transitional cows with 0, 307, 613 and 918 g PG, and found that as PG intake increased, serum insulin concentration increased.

Transitional cows fed PG had significantly reduced serum NEFA concentration, consistent with the results of Grummer et al. (1994), Formigoni et al. (1996), Miyoshi et al. (2001) and Hoedemaker et al. (2004). The experimental results indicated that transitional period cows had a negative energy balance, with degraded body fat, and released NEFA to use as energy. Since PG rapidly supplies energy, this improved the degree of negative energy balance, resulting in decreased body fat catabolism and serum NEFA levels (Miyoshi et al., 2001). When degraded body fat releases large amounts of NEFA, as the quantity of NEFA exceeds the liver burden or sufficient glucose is unavailable, NEFA is converted to ketone bodies. Grummer et al. (1994) indicated that when cows received 613-919 g PG daily during the milking peak period, markedly reduced serum ketone body concentrations resulted. In this study, the serum ketone body concentration in the two groups were not significantly different at most measured times. However, on day 7, ketone bodies in the PG-treated group were lower than in the control group.

If the negative energy balance increases, then the catabolism of body tissue also increases, resulting in degradation not only the body fat but also the body protein. BUN levels are then increased. In the PG group the BUN level was lower than that of the control group. Since both groups of cows received the same diet, elevated BUN levels may be the result of degraded body protein, which implies that PG can improve negative energy balance, a finding in agreement with that of Barllard et al. (2001).

Caldeira et al. (2007a) indicated that ewes in poor nutritional condition will have lower plasma glucose, serum insulin, and higher serum NEFA and BUN. When in a balanced status, plasma glucose and insulin are at intermediate levels, and BUN will be low. Thus, when nutrition is balanced, it will be reflected in the metabolite profile. Chimonyo et al. (2002) also reported that plasma glucose declined and NEFA and BUN levels increased, when BCS of cows was reduced. In a state of inferior nutrition, glucose is insufficient for energy expenditure. As a result, body fat and protein will degrade, yielding high plasma NEFA and BUN. Thus, plasma glucose, NEFA and BUN concentrations offer valuable diagnostic information for the interpretation of the nutritional status of animals and may be used to improve the nutritional management and prevent metabolic disorders (Caldeira et al., 2007b).

**Effect of supplementation of PG on the reproductive traits**

Butler and Smith (1989) and Britt (1992) indicated that negative energy balance can reduce progesterone secretion, prolong postpartum anestrus, and interfere with cow...
pregnancy. Negative energy balance in the early postpartum period affected follicular development (Britt, 1992). Markusfeld et al. (1997) demonstrated that reduction in the body condition score during the transition period increased the incidence of postpartum reproductive disease and inactive ovaries. Gillund et al. (2001) and Domecq et al. (1997) reported that loss of BCS during early lactation had negative effects on reproductive performance. Kim and Suh (2003) also found that the number of days to first breeding after calving was longer in cows with marked BCS loss than in those with moderate BCS loss. In addition, Miyoshi et al. (2001) found that transition cows fed PG have an earlier estrus onset, because insulin is important in normal ovarian function.

In this study, days to first oestrus (77.44 vs. 63.88 days), and placental retention (25 vs. 8 heads) were reduced, and the pregnancy ratio was higher in the PG group than in the control group. This may explain why the insulin level in the PG group at day 5 and 6 of early postpartum was increased. However, the difference between the PG and control groups was not significant. Perhaps the sample size was not large enough.

CONCLUSION

Feeding PG to transition period cows resulted in reduced serum NEFA and BUN levels, implying reduced catabolism of body tissue, increased plasma glucose concentration, BCS and milk yield, and did not affect DMI. This study offers evidence that oral drenching with PG of cows in the transition period could reduce negative energy balance and benefits dairy cows. However, long-term study is need for future research.

REFERENCES


