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Effect of short-term prepartum supplementation with propylene glycol and calcium propionate on metabolic parameters and lamb performance in multiparous ewes with a low body condition score

Efeito da suplementação pré-parto de curto prazo com propilenoglicol e propionato de cálcio nos parâmetros metabólicos e no desempenho dos cordeiros e ovelhas multíparas com baixa condição corporal

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Highlights

Prepartum gluconeogenic precursor supplementation aids during high-demand periods.
Prepartum propylene glycol (PG) reduced blood β- hydroxybutyrate (BHB) during lambing.
Prepartum calcium propionate (CP) reduces blood BHB during lambing.
Prepartum PG or CP supplementation increased lamb weight at 10 days postpartum.
Romanov ewes adapt to energy deficits and meet demands with low body condition scores.

Abstract

This study evaluated the effect of short-term prepartum supplementation of ewes with two gluconeogenic precursors propylene glycol (PG) and calcium propionate (CP) in the Chilean drylands with a Mediterranean climate. We started with 22 adult Romanov ewes with a low body condition score and synchronized in estrus. After pregnancy diagnosis, we selected 18 ewes with two or three gestations and randomly assigned them to three groups: the control group (CG; n = 6), the PG group (n = 6), and the CP group (n = 6). We supplemented the PG and CP groups for 10 days before the estimated lambing date. We measured the β-hydroxybutyrate (BHB), non-esterified fatty acids (NEFA), and glucose plasma levels as well as the body condition score (BCS) at 3 timepoints: 10 days before lambing, right after

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lambing, and day 10 postpartum. In addition, we weighed the lambs at birth and on day 10 postpartum. The BHB level right after lambing decreased in the PG and CP groups compared with the CG ($P < 0.05$). The NEFA level did not vary between the groups at the different timepoints. The glucose level increased approximately 2–3-fold ($P < 0.05$) in all ewes after lambing and decreased on day 10 postpartum, but there were no significant differences between the PG and CP groups ($p > 0.05$). In addition, the BCS did not differ between the groups at any time point ($P > 0.05$). The weight of the lambs on day 10 postpartum increased significantly ($P < 0.05$) in the PG and CP groups compared with the CG. In addition, the mean daily weight gain was approximately 50% higher in the PG and CP groups compared with the CG ($P < 0.05$). Based on these findings, short-term prepartum supplementation with PG or CP reduced the BHB level in ewes with a low BCS and multifetal gestations during lambing and improved the lamb weight on day 10 postpartum. Therefore, the administration of these additives could be a useful strategy in sheep under feed restrictions in the Chilean drylands with a Mediterranean climate at times of high nutritional requirements.
Key words: Multiparous ewe. Propylene glycol. Calcium propionate. Metabolism. Reproductive performance.

Resumo

Este estudo avaliou o efeito da suplementação pré-parto a curto prazo com dois precursores gliconeogênicos: propilenoglicol e propionato de cálcio, através de indicadores metabólicos e desempenho reprodutivo de ovelhas com múltiplos fetos e baixa condição corporal durante os últimos 10 dias de gestação e seus cordeiros no Mediterrâneo seco do Chile. Foram utilizadas 22 ovelhas Romanov adultas com baixa condição corporal, sincronizadas em estro. Após diagnóstico de gestação, 18 ovelhas com gestações duplas ou triplas foram selecionadas e distribuídas aleatoriamente em três grupos: controle (CG; n=6), propilenoglicol (PG; n=6) e propionato de cálcio (CP; n=6). A suplementação foi realizada nos grupos PG e CP durante 10 dias antes da data estimada de parto. A concentração de ß-hidroxibutirato (BHB), ácidos graxos não esterificados (AGNE), glicose sanguínea e a escore de condição corporal (ECC) foram avaliadas em três momentos: 10 dias antes do parto, logo após o parto e 10 dias pós-parto. Os cordeiros foram pesados ao nascimento e no 10º dia pós-parto. O estudo revelou que as concentrações de BHB logo após o parto nos grupos PG e CP diminuíram em comparação com o CG ($p < 0,05$). As concentrações plasmáticas de AGNE não variaram entre os tratamentos nos diferentes momentos. A glicose plasmática aumentou aproximadamente 2-3 vezes ($P<0,05$) em todas as ovelhas após o parto e diminuiu nos 10 dias pós-parto, sem diferenças significativas entre os grupos suplementados ($P>0,05$). Não houve diferenças significativas no ECC das ovelhas em todos os grupos em qualquer momento ($P>0,05$). O peso dos cordeiros no 10º dia pós-parto aumentou significativamente ($P < 0,05$) nos grupos PG e CP em comparação ao controle. O ganho de peso diário foi aproximadamente 50% maior nos grupos PG e CP comparado ao CG ($P < 0,05$). Com base nesses achados, a suplementação pré-parto a curto prazo com PG ou CP reduz a concentração de BHB durante o parto e melhora o peso dos cordeiros no 10º dia pós-parto, em ovelhas multíparas com baixa condição corporal. Portanto, a administração desses aditivos pode ser uma estratégia útil em ovelhas sob restrição alimentar em regiões secas centrais do Chile com clima mediterrâneo, em momentos de altos requisitos nutricionais.
Palavras-chave: Ovelhas multíparas. Propilenoglicol. Propionato de cálcio. Metabolismo. Desempenho reprodutivo.

Introduction

The soil plays a fundamental role in the sustainability and resilience of Mediterranean climate ecosystems. It acts as a reservoir for the limited water resources that are available in these regions for the growth of the plant species on which agricultural and livestock activities are based (Comino et al., 2016). However, water scarcity has been accentuated in recent decades due to climate change, which has caused a significant decrease in the production of plant biomass, and with it the delivery of organic matter to the soil by plants, reducing its capacity to retain water (García-Ruiz et al., 2013). This phenomenon has also led to the appearance of bare soil (without vegetation cover) and thus to erosion, which facilitates the advance of desertification and the loss of soil fertility, endangering the viability of agricultural systems in this type of climate. Therefore, soil degradation is the most limiting factor in the establishment and development of pastures: It affects livestock productivity in drylands with a Mediterranean climate (Committee on Nutrient Requirements of Small Ruminants, 2007).

Sheep production is very important in the Chilean drylands with a Mediterranean climate. Climate change has resulted in a water deficit in about 49% of the total area of these soils (Santibáñez, 2016). This situation has negatively affected the productive potential of the land: There has been increased erosion and the advance of desertification with loss of grassland and a marked decrease in the sustainability of these territories for the development and function of sheep production (Infante, 2013; Rivera & Arnould, 2020). The low availability of forage makes it impossible to cover the nutritional and energy requirements of sheep, especially during the last third of gestation, when energy demand increases (Dønnem et al., 2020). A negative energy balance (NEB) leads to a large amount of body fat mobilization and, consequently, elevated ketone production, resulting in metabolic diseases such as ketosis and fatty liver (Kalyesubula et al., 2019).

About 80% of fetal growth occurs during the last 6 weeks of gestation (Robinson et al., 1999). For this reason, in ewes, inadequate nutrition during the last third of gestation negatively affects productive indicators such as the body condition score (BCS) and the birth weight of lambs, and increases the mortality rate of lambs (Ahmadzadeh et al., 2020; Paganoni et al., 2014). Furthermore, as the number of fetuses increases, metabolic demands increase and thus affect the maternal plasma metabolite profile (Moallem et al., 2012), increasing the risk of hypoglycemia, hypocalcemia, and hyperketonemia (Rook, 2000). The high energy demand in the last third of gestation decreases glucose and insulin levels and increases β-hydroxybutyrate (BHB) and non-esterified fatty acid (NEFA) levels in ewes with four fetuses compared with ewes with only one fetus (Moallem et al., 2012).

One strategy to mitigate the negative effects associated with a low nutritional status at strategic physiological times in ruminants is the use of gluconeogenic precursors with specific administration protocols (Alon et al., 2020). Precursor treatments can increase plasma glucose, decrease lipolysis, and reduce the BHB level (Herdt & Emery, 1992). Propylene glycol (PG) and calcium propionate (CP) are orally administered precursors that have been used to correct metabolic problems in sheep, as they have glucogenic and antiketogenic effects (Ahmadzadeh-Gavahan et al., 2021; Mendoza-Martínez et al., 2015). They act as substrates in hepatic gluconeogenesis, causing a rapid and sustained increase in blood glucose (Nielsen & Ingvartsen, 2004) and reducing the BHB and NEFA levels (Alon et al., 2020).

PG supplementation in ewes on restricted diets can increase the average daily weight gain and weaning weight of lambs (Ahmadzadeh et al., 2020). Administration of PG during the third trimester of gestation in ewes with 60% nutrient restriction resulted in heavier lambs compared with the group that did not receive supplementation (Ahmadzadeh-Gavahan et al., 2023). CP is a good source of energy to prevent metabolic disorders. It increases the concentration of propionate in the rumen, which is the main precursor required for glucose synthesis in the liver (Aiello et al., 1989). CP supplementation affects glucose flux (Sano & Fujita, 2006), fat deposition, and muscle growth in sheep (Moloney, 1998). CP supplementation in primiparous females during late gestation and early lactation significantly improves body weight, decreases NEFA and BHB, and increases glucose and insulin concentrations (Abdel-Latif et al., 2016).

Despite what has been described in the literature, there is little information available on the relative benefits of PG and CP supplementation in multiparous ewes with a low nutritional status. Thus, the present study evaluated the short-term effect of PG or CP supplementation, specifically during the last 10 days of gestation, in ewes with a low BCS and carrying multiple fetuses in the Chilean drylands with a Mediterranean climate. This endeavor involved measuring metabolic and reproductive indicators of the ewes and assessing the weight of the lambs born to the ewes.

Materials and Methods

Animals and experimental design

This study was carried out on a commercial farm located in the dry land area of Pumanque, Chile (34°6'26.57"S, W71°44'1.03"W). All animal management and sampling procedures were conducted in accordance with the guidelines approved by the Scientific Ethics Committee of Universidad Santo Tomás, Chile (26-19). The experimental group comprised 22 healthy Romanov ewes at reproductive age (2–4 years). The sample size was calculated based on Alon et al. (2020). Non-pregnant and non-lactating ewes were maintained separately from males, and with low body condition (1.5–2.5 on a scale from 1 to 5; (Russel, 1984). The synchronization and supplementation treatments were carried out during the breeding (March; 4–30°C) and non-breeding seasons (July–August; 8–14°C), respectively. The ewes were fed a diet based on direct grazing on natural Mediterranean pastures, with no additional supplementation, and water ad libitum.

All ewes were synchronized with intravaginal controlled internal drug release (CIDR; day -150) devices containing 0.3 g of progesterone (CIDR, Inter Ag. Hamilton, New Zealand) for 12 days. Subsequently, on day -137 andrologically tested rams were introduced for natural mating (Figure 1). Pregnancy and the number of fetuses were determined on the 40th day after mating by transabdominal ultrasonography (WED-

3000V, Shenzhen Well.D Medical Electronics); 18 ewes bearing at least 2 fetuses were identified. These ewes were randomly assigned to three groups: the control group (CG; n = 6), the PG group (n = 6), and the CP group (n = 6).

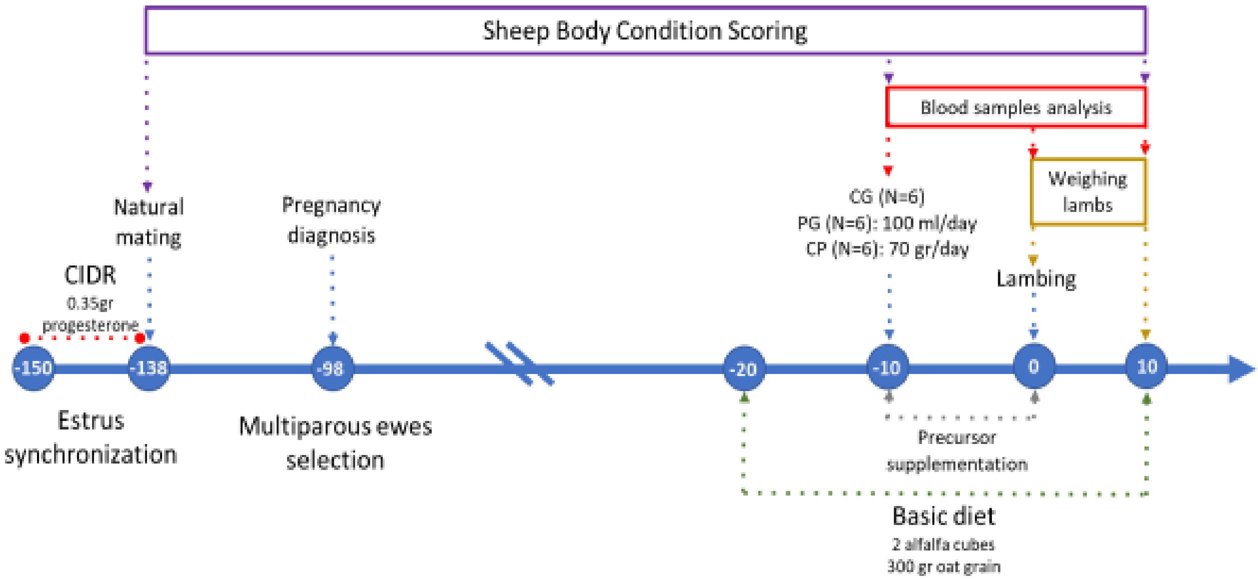

Figure 1. Schematic of the experimental procedure. Ewes were synchronized with controlled internal drug release (CIDR; day -150) and then mated by natural mating on day -138. Pregnancy was diagnosed and the number of fetuses quantified on day -98. Ewes with multiple fetuses received a basal diet 20 days prior to the estimated day of lambing (day -20) and were supplemented with propylene glycol (PG) or calcium propionate (CP) depending on the group during the last 10 days of gestation (day -10). The body condition score of the females was measured on the day of mating (day -138), day -10, at lambing (day 0), and 10 days postpartum (day 10). Blood samples were taken from the females on days -10, 0, and 10 to measure blood metabolites. Offspring were weighed on days 0 and 10.

Supplementation

The 18 pregnant ewes were group housed in facilities designed for the species beginning at 20 days prior to the estimated lambing date. Supplementation started with a base diet of 2 kg day^{-1} head^{-1} of alfalfa cubes, distributed between the morning and evening, and 300 g day^{-1} head^{-1} of oat grains in the evening (Table 1). It is recommended that in the last third of gestation, ewes with an average body weight of 60 kg and gestating 2 fetuses have an intake of at least 2.0 kg of dry matter (DM), with a minimum of 200 g of crude protein and 17 MJ of metabolizable energy (Committee on Nutrient Requirements of Small Ruminants, 2007). Regarding minerals, a daily intake of 10 g of calcium and 4 g of phosphorus is recommended (Committee on Nutrient Requirements of Small Ruminants, 2007). The diet used in this study satisfied the minimum DM requirements of ewes with multifetal gestations considering an average weight of 60 kg for Romanov ewes.

Table 1
Ingredients and chemical composition of the basal diets fed to the pregnant ewes

Item	Alfalfa cubes	Oat grains
Dry matter (% of fresh weight)	88	88
Metabolizable energy (MJ kg^{-1} of dry matter)	10.6	13.8
Crude protein (g kg^{-1} of dry matter)	210	119
Calcium (g kg^{-1} of dry matter)	21	2.1
Phosphorus (g kg^{-1} of dry matter)	2.8	2.5
Dry matter intake (kg d^{-1})	2	0.3

Between day -10 (prepartum) and day 0 (lambing), additional supplementation with gluconeogenic precursors was carried out in the PG and CP groups, consisting of 100 mL day^{-1} $animal^{-1}$ of 99.8% monopropylene glycol (PG USP, Quality Pro, Chile) and 70 g day^{-1} $animal^{-1}$ of 99% CP (Quality Pro), respectively, according to manufacturer's instructions. The supplements were mixed with alfalfa cubes previously soaked in water to ensure proper homogenization of the ration. After lambing, all ewes were housed for 10 days together with their offspring and received only the base diet (Figure 1; Table 1).

BCS and weight

The BCS of the ewes was measured at mating and on days -10, 0, and 10, using a 5-point scale (Russel, 1984). The body weight of the lambs was measured at birth and on day 10 with a digital hanging scale.

Blood sampling and laboratorial analysis

Jugular vein blood samples were collected in 10-mL ethylenediaminetetraacetic acid (EDTA) vacutainer tubes on days -10, 0, and 10 (Figure 1). The samples were centrifuged at room temperature for 15 min at 3500 rpm; then, plasma was collected and stored at -20°C for subsequent assays. The BHB, NEFA, and glucose levels were measured using commercial enzymatic colorimetric kits (respectively: Ranbut®, Randox, UK; NEFA Assay®, Randox; Glucose-Liquiform®, Labtest, Brazil). All samples were evaluated in duplicates. The intra-assay coefficient of variation was < 5% for BHB, < 3.5% for NEFA, and 1.25% for glucose.

Data analysis

The data were analyzed using SPSS Statistics version 18 (SPSS Inc., USA). The Shapiro–Wilk test was used to determine whether the data followed a normal distribution. The differences in blood biochemical metabolites and hormones, BCS, and body weight between groups were analyzed with a repeated-measures analysis of variance (ANOVA). The Benjamini–Hochberg post hoc test was used to determine significant differences between the groups (GC, PG, and CP) on different days. The association between blood metabolites and the BCS of the ewe and the lamb body weight on days 0 and 10 were analyzed using Pearson correlation coefficients. Statistical significance was set at $P < 0.05$. All results are expressed as the arithmetic mean ± standard error.

Results and Discussion

Ewe blood metabolites

Figure 2 presents the BHB, NEFA, and glucose plasma levels in the ewes. The BHB level decreased during lambing in the PG (0.31 ± 0.08 mmol L^{-1}) and CP (0.29 ± 0.06 mmol L^{-1}) groups compared with the CG (0.64 ± 0.08 mmol L^{-1}; $P < 0.05$). The NEFA level did not vary between the groups on days -10, 0, and 10 ($P > 0.05$). However, the total NEFA level during the supplementation days was higher in the PG group (0.23 ± 0.10 mmol L^{-1}) compared with the CG and the CP group (0.15 ± 0.08 mmol L^{-1}; $P < 0.05$). The NEFA level remained at physiological concentrations throughout the prepartum supplementation (< 0.45 mmol L^{-1}; Nozière et al., 2000; Patterson et al., 1964). The glucose level increased approximately 2–3-fold ($P < 0.05$) in all ewes at lambing and then decreased during the next 10 days of lactation (Figure 2). The glucose level was not affected by short-term prepartum supplementation of PG or CP ($P > 0.05$). The glucose levels correlated negatively with the BHB levels on days -10 and 0 ($r = -0.6$; $P < 0.05$), but not on day 10.

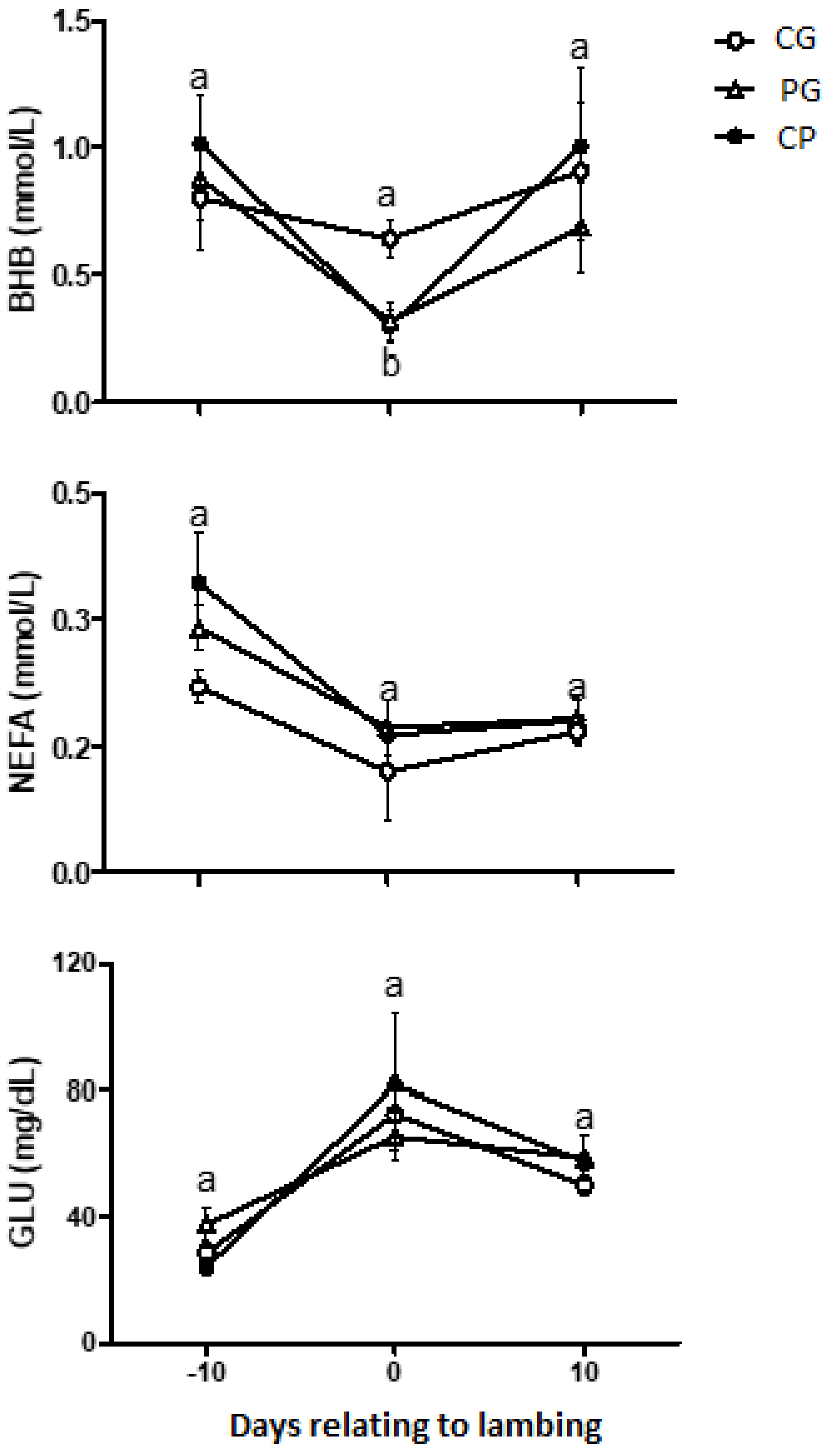

Figure 2. The effect of short-term prepartum supplementation with propylene glycol (PG) or calcium propionate (CP) on β-hydroxybutyrate (BHB), non-esterified fatty acid (NEFA), and glucose (GLU) plasma levels in ewes with multifetal gestations and a low body condition score. CG = control group. Each group included 6 ewes. [a b] Means with different superscripts indicate a significant difference between the treatments.

Ewe and lamb performance

Table 2 shows the evolution of the BCS of the ewes from the time of placement to day 10 postpartum. There were no significant differences between the groups at any time point (P > 0.05). The mean BCS in all groups remained consistently below the minimum recommended for finishing (3.5) and for the last third of gestation, parturition, and early lactation (3.0). These results demonstrate that the diet provided did not meet the nutritional requirements for the ewes with multifetal gestations in the last third of gestation, which is consistent with the experimental design proposed in this study.

Table 2
Effect of short-term prepartum supplementation with propylene glycol or calcium propionate on the body condition score of ewes with multifetal gestations and the body weight of lambs

Item		Treatment			P-value
		Control group	Propylene glycol	Calcium propionate	
Body condition score of the ewes	Mating	2.25 ± 0.5[a]	2.50 ± 0.61[a]	2.17 + 0.29[a]	> 0.05
	Day -10 prepartum	1.88 ± 0.48[a]	2.50 ± 0.71[a]	1.83 ± 0.29[a]	> 0.05
	Day 0 (lambing)	1.75 ± 0.5[a]	2.14 ± 0.55[a]	1.83 ± 0.29[a]	> 0.05
	Day 10 postpartum	2.00 ± 0.0[a]	2.14 ± 0.55[a]	1.83 ± 0.29[a]	> 0.05
Number of lambs		15	18	12	
Birth weight (kg)		2.48 ± 0.39[a]	3.32 ± 0.77[a]	2.70 ± 0.40[a]	> 0.05
Weight at 10 days old (kg)		3.99 ± 0.63[a]	5.60 ± 0.89[b]	5.11 ± 1.34[b]	< 0.05
Average daily weight gain (kg)		0.15 ± 0.04[a]	0.23 ± 0.08[b]	0.24 ± 0.12[b]	< 0.05

Each group included 6 ewes.
[a b c] Means within the same column with different superscripts are significantly different.

The number and weight of the lambs per group measured on days 0 and 10 in each treatment group are also shown in Table 2. In all groups, the lamb weight increased significantly between day 0 and day 10 (P < 0.05; Table 2). Short-term prepartum supplementation with PG and CP significantly (P < 0.05; Table 2) increased the lamb weights by 1.4 and 1.3 times, respectively, compared with the CG on day 10. There was no significant difference between the CP and PG groups on days 0 and 10 (P > 0.05; Table 2). Supplementation with either precursor also resulted in an average daily weight gain that was approximately 50% greater than the CG (P < 0.05; Table 2). The interactions between the ewe BCS and lamb weight correlated positively and significantly with the lamb birth weight (r = 0.4; P < 0.05) and the lamb weight on day 10 (r = 0.7; P < 0.05).

The high energy demand during late gestation in ewes generates an NEB, which is related to the high glucose demands of the fetoplacental unit (Alon et al., 2020). This is why inadequate nutrition in ewes directly impacts the survival rate of lambs, negatively affecting their birth weight (Paganoni et al., 2014). In ewes, an NEB can be evidenced through metabolic indicators, including the NEFA level and the presence of ketone bodies such as BHB in the blood (Roche et al., 2009). PG and CP are used in ruminants because of their gluconeogenic effect: They favor glucose production in the liver and regulating ketogenesis (El-Kasrawy et al., 2020).

In this study, we examined the short-term effects of PG or CP supplementation in ewes with multifetal gestations and a low BCS. We found that supplementation of ewes with a low BCS with PG or CP during the 10 days prior to lambing significantly decreased the BHB plasma level during lambing ($P < 0.05$; Figure 2), similarly to what has been described in the literature (Ahmadzadeh-Gavahan et al., 2021; Alon et al., 2020). The effects of PG at lambing on ketosis could be explained by reduced adipose tissue mobilization and ketone body formation (Kalyesubula et al., 2019). On the other hand, CP functions as a primary precursor for hepatic glucose synthesis (Kennedy et al., 2021). A reduction in the BHB plasma level in the CP group during lambing could be explained by the metabolism of propionate to glucose, which decreases fat mobilization either by providing glucose or by stimulating pancreatic insulin secretion (de Souza Guagnini et al., 2017). The gluconeogenic potential of each supplement counteracts the effects of NEB and ketosis that occurs in the last third of gestation in ewes, when energy needs are not met by the diet (Ahmadzadeh-Gavahan et al., 2021).

These results agree with the observed glucose levels, which increased during lambing in all groups (Figure 2). However, short-term prepartum supplementation with PG or CP did not have a sustained effect over time on the metabolic status of the ewes under the conditions of this trial. Indeed, they presented an NEB during the lactation period, after 10 days without ingesting the supplement. Factors such as the dose, duration of treatment, method of administration, and timing of blood sampling may explain these results (Nielsen & Ingvartsen, 2004). In contrast, the ewes continued to have a high glucose plasma level during the first 10 days of lactation (Figure 2).

It has been widely described in the literature that in ruminants, an increase in the BHB blood level above physiological concentrations is indicative of an NEB, a situation commonly associated with late pregnancy and early lactation, especially in animals with nutritional restricted or multifetal gestations (Cal-Pereyra et al., 2015; Cárcamo et al., 2019; Pesántez-Pacheco et al., 2019). Therefore, we expected the BHB level to be above the ovine physiological range (< 0.7 mmol L^{-1}) (Ramin et al., 2007) at the beginning of the trial for the three groups, and there were no differences between the groups ($P > 0.05$).

The plasma NEFA level increases gradually as pregnancy progresses, peaks at lambing, and then decreases gradually (Moallem et al., 2012; Patterson et al., 1964).

On the contrary, we found no variation in the NEFA level in our ewes. The NEFA level is usually maintained at < 0.45 mmol L^{-1} (Nozière et al., 2000; Patterson et al., 1964), and this was the case for our study, even though the treated ewes had a low BCS (1.5–2.5 on a 5-point scale scale) and multifetal gestations. Moallem et al. (2012) measured metabolic parameters during the prepartum period in properly fed ewes gestating 1–4 fetuses. In females with four fetuses, the NEFA level increased until week 4 prepartum, but then remained constant until lambing, even though the BHB level continued to increase. The authors proposed that the cessation of the NEFA increase was due to a depletion of body reserves earlier in pregnancy to allocate glucose for fetal growth. This phenomenon could explain the behavior of the NEFA level during our experiment. A higher prepartum NEFA level, although not significant, demonstrates the high energy demand and higher fat mobilization during the prepartum period compared with the postpartum period, similarly to what has been reported in the literature (Karagiannis et al., 2014; Petterson et al., 1994).

Glucose is considered to be the main substrate of fetal metabolism. The energy requirement for the fetoplacental unit can be as much as 45% of the maternal glucose supply and 72% of the maternal amino acid supply (Bell & Ehrhardt, 2002). The increase in energy requirements at the end of gestation is because about 85% of fetal growth occurs during the last 6 weeks (Robinson, 1999; Rook, 2000). The increased fetal demand can be so great that during late gestation, the energy requirements of ewes increase up to 150% in single gestations and up to 200% in double gestations relative to the maintenance requirements (Rook, 2000). An increase in total fetal body mass in ewes with multifetal gestations increases the glucose demand. Consequently, ewes with twin pregnancies have a glucose plasma level that is 30% lower than in ewes with a single fetus during late gestation (Edwards & McMillen, 2002). In addition, in lactating ewes, glucose is used to synthesize milk lactose, and if nutrient intake during this phase is not sufficient, then blood glucose tends to decrease (Antunović et al., 2011).

The ewes we selected for our study presented a low BCS (Table 2), which could be directly related to the amount of fat reserves available (Kenyon et al., 2014) and the feed supplied (Table 1). In prior studies, ewes with evident malnutrition, with a BCS of 1.5–2.5, had a low glucose plasma level (Caldeira et al., 2007; Hu et al., 1990). However, despite the low BCS and multifetal gestations of our ewes, their glucose plasma level was within the physiological range for the species (25–70 mg dL^{-1}) (Alonso et al., 1997; Kaufman & Bergman, 1974). Furthermore, our results contradict those reported in the literature: There was no decrease in the glucose plasma level at day 10 (Figure 2).

Our results could be associated with the rusticity of the breed we used in this study. The Romanov breed is known for its ability to adapt to extreme environments (Korkmaz & Emsen, 2016; Ricordeau et al., 1990), which may explain its ability to maintain a physiological glucose plasma level despite a low BCS. Studies have shown that the Romanov breed may have a greater ability to mobilize and oxidize fatty acids during periods of an NEB compared with other sheep breeds (Bahnamiri et al., 2018). This suggests that even with a low BCS and multifetal gestations, Romanov ewes have the physiological ability to adapt to an NEB and to meet nutrient demands during gestation and lactation. Lamb mortality is known to increase with the number of fetuses per ewe (Thomson et al., 2004). However, lower mortality of Romanov lambs compared with other breeds has been demonstrated, especially because of their high maternal ability and capacity to nurse two or three lambs (Ricordeau et al., 1990). Thus, for the same type of lambing or weight, Romanov lambs have higher viability compared with that of other breeds or crossbreeds.

Ewes with a low BCS during the last third of gestation, associated with an NEB, have smaller lambs (i.e., a lower birth weight) compared with a positive energy balance (Azambuja Ribeiro et al., 2021; Pesántez-Pacheco et al., 2019). Therefore, there is a close relationship between the level of ewe nutrition during this period and lamb birth weight (Osgerby et al., 2002). We found that short-term prepartum supplementation with PG or CP significantly increased lamb weight at day 10 postpartum compared with the CG ($P < 0.05$). These results coincide with significant improvements in the weight of the lambs and a reduction in the mortality rate based on PG (Ahmadzadeh-Gavahan et al., 2023) or CP (Lee-Rangel et al., 2012) supplementation compared with the respective control groups. However, the importance of our study is that we evaluated ewes with multifetal gestations, which imply different physiological conditions compared with single gestations (Smith et al., 2009; Thomson et al., 2004).

Conclusions

Short-term prepartum supplementation with PG or CP could be a useful strategy to deal with the higher nutritional restrictions of sheep herds in central dryland areas at times of high nutritional requirements. We demonstrated that short-term prepartum supplementation with PG or CP in ewes with a low BCS decreased the BHB plasma level during lambing and increased the lamb weight at day 10 postpartum. The glucose level was not affected by short-term prepartum supplementation with PG or CP. The importance of these results lies in the economic feasibility of their implementation in production systems, unlike other studies in which the supplementation was administered for prolonged periods, resulting in a higher cost. In addition, this study demonstrates the high adaptive capacity of Romanov ewes to feed restriction, managing to cover nutrient demands during gestation and lactation, despite their low body condition.

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