View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Journal of Advanced Veterinary Research (University Assiut, Egypt)

Journal of Advanced Veterinary Research Volume 10, Issue 2 (2020) 66-72

Journal of Advanced Veterinary Research

https://advetresearch.com

The effect of Crude Glycerin of Low Purity Replacing Corn on Goats' Diets in Feedlot in Semiarid Areas

Rayane Nunes Gomes[1], Talita Almeida de Paula[1*], Francisco Fernando Ramos de Carvalho[1], Marcelo de Andrade Ferreira[1], Ligia Maria Gomes Barreto[2], Maria Luciana Menezes Wanderley Neves[1], Giorgio Oliveira Mendes[1], Eduardo Henrique Araújo Cordeiro[1], Ana Barros de Oliveira[1], and Antonia Sherlânea Chaves Veras[1]

[1]*Department of Animal Science, Federal Rural University of Pernambuco, Recife, Pernambuco, 52171900, Brazil.*
[2]*Department of Animal Science, Federal University of Sergipe, Nossa Senhora da Glória, Sergipe, 49680000, Brazil.*

ARTICLE INFO

Original Research

Received:
05 February 2020

Accepted:
21 March 2020

Keywords:

Corn, Crude glycerin, Goats
Semiarid Areas

ABSTRACT

The objective of this study was to evaluate the effects of crude glycerin (CG) on the diet of goats in feedlot, in terms of intake and nutrient digestibility, performance, feeding behavior, and metabolic profile. Forty castrated male goats with breed undefined and an average initial body weight of 19.7±2.3 kg were used. The experimental diets consisted of inclusion of CG at 0, 6, 12 and 18 % (based on DM). The DM (g/day), DM (g/kg), organic matter, crude protein, neutral detergent fiber, non-fiber carbohydrate, total digestible nutrients, and water intakes were decreased linearly with increasing CG levels, whereas ether extract intake increased linearly. The daily time spent (%) and average duration of events (h/d) for rumination presented a linear increase, although reduced for idling, as well as feeding and rumination efficiencies. The inclusion of CG did not affect the final body weight, total weight gain, and average daily gain. Serum cholesterol concentration presented a linear increasing effect. However, beta-hydroxybutyrate level was reduced. Crude glycerin containing 63.06% glycerol may partially replace corn and be included at a concentration of up to 18% of dry matter in the diet of finished goats in feedlot when moderate weight gains are desired, especially beneficial in semiarid regions.

Introduction

Goat meat is one of the most significant protein sources and of high-quality for people living in semiarid areas. This meat has a health advantage for human consumption because it is leaner than red meats and its fat is less saturated than that of other ruminants. Also, goat meat is lower fat content, tenderness and good flavor (Ayeb *et al.*, 2016). In the semiarid climate, the pasture land available for animals is dry and dusty with scanty grass and fodder growth (Singh *et al.*, 2018). Thus, it is necessary to use food supplements to keep ruminants in these areas. It is the most important reason for the high cost of goat meat in semiarid regions.

Consequently, the livestock feed industry has voluntarily implemented alternative feed ingredients to avoid soaring prices, due to the rising cost of energy-rich feedstuffs. Alternative feed sources, such as glycerin, have become a major focus for the livestock industry (Chanjula *et al.*, 2014). Additionally, expansion of the biodiesel industry in recent years has led to a robust supply of glycerin by-product; thus, efforts directed at using its high-energy content in animal feed are seen as sustainable and having a low environmental impact (Socreppa *et al.*, 2017).

Crude glycerin (CG) may provide an opportunity for semiarid regions, where the poor availability of conventional animal feed and, in some cases, high production costs may prevent the regular supply of animal products to the market. According to Hales *et al.* (2013), CG is converted in the rumen into volatile fatty acids, mainly, propionate, a major glucogenic precursor in ruminants. In addition, any CG that escapes ruminal fermentation can be absorbed by the ruminal epithelium or pass to the omasum along with the digesta, then used as a substrate for hepatic gluconeogenesis (Krehbiel, 2008). From a glucogenic perspective, replacing corn in ruminants' diets with glycerin could increase dietary glucogenic potential (Benedeti *et al.*, 2016).

Previous studies that evaluated pure glycerol (the main component of CG) or CG supplementation on animal performance showed that the benefit is dose-dependent. The glycerol content determines the degree of CG purity, which may be

*Corresponding author: Talita Almeida de PAULA
E-mail address: talitaalmeidap@gmail.com

ISSN: 2090-6277/2090-6269/ © 2011-2020 JAVR. All rights reserved.

classified as low-purity when the glycerol content is 40 to 70%; medium-purity, with a content of 75 to 90%; or high-purity, with content above 99% (Hippen *et al*., 2008).

Therefore, due to the lower content of glycerol, it was hypothesized that low-purity CG can be included in goat feedlot diet at concentrations of up to 18% in dry matter (DM) and benefit to the animals' nutrient and water intake and digestibility, feeding behavior, metabolic profile, and performance. Therefore, the objective of this study was to evaluate the effects of CG on the diet of goats in feedlot, in terms of intake and nutrient digestibility, feeding behavior, metabolic profile, and performance.

Materials and methods

The study was approved by the ethics committee of the Federal Rural University of Pernambuco (License n° 059/2016) and was operated at the Ruminants Sector of the Animal Science Department of the same University, located at Recife, PE, Brazil.

Forty castrated male goats, with breed undefined, and average initial body weight (IBW) of 19.70±2.30 kg, were used. The animals were housed in individual pens (1.0×1.8 m), provide with a feeder and drinker. The trial lasted 86 days, with a 28-days for adaptation to experimental facilities and diets.

The experimental design was completely randomized, with four treatments and ten replicates. The CG was obtained in the CETENE industry, located in Caetés, PE, Brazil (Table 1).

Table 1. Chemical composition of crude glycerin used in experimental diets

Item	Value (%)
Glycerol	63.06
Water	20.7
Methanol	3.7
Crude protein	0.3
Total fatty-acids	45.57
Mineral matter	5.9
Sodium	0.27

The experimental diets consisted of inclusion of CG at 0, 6, 12 and 18% (based on DM). The diets, with a roughage:concentrate ratio of 500:500 g/kg, were formulated to meet the nutritional requirements of a goat with an average BW of 25 kg, and an estimated daily gain of 150 g/day (NRC, 2007). Feed was supplied ad libitum as total mixed rations, twice a day (08h00 and 15h00), allowing 15% in orts (DM basis). Table 1, presents the chemical composition of crude glycerin, and Tables 2 and 3, present the diets feed chemical composition and composition percentages.

Voluntary intake was evaluated by recording the amounts of supplied diet and orts daily. Diet ingredients and orts samples were pooled per animal and stored in plastic bags at -18°C. At the end of the experiment, the samples were oven-dried at 55°C for 72 h and processed in a Willey mill (TE-648 – Tecnal®).

The water intake and lost by evaporation was evaluated twice per week during, by measuring the difference between the water supplied and the orts per animal. To quantify evaporation, six plastic buckets of water were distributed throughout the shed, in which the available quantities and the difference in weight were recorded.

To quantify the production of fecal DM, the animals were fitted with appropriate canvas bags for the total fecal collection was performed between the 42nd and 46th days. During this period, samples of the provided feed and orts were also collected. Complete emptying of the bags was performed in two daily fecal collections in the morning (9h00) and at 16h00. The feces were homogenized and samples of 10% of the total feces collected and stored in a freezer at -18°C. At the end of the collection period, feces samples were oven-dried and ground, constituting composite animal samples. The feces, feed, and orts were analyzed by the same chemical methodologies.

The digestibility coefficients of nutrients (DCN) was obtained according to the equation: DCN (g/kg) = [(nutrient ingested–nutrient excreted)/nutrient ingested] × 1000. The total digestible nutrients (TDN) content of diets was determined as TDN content (g/kg) = (TDN intake/DM intake) × 1000, adapted by Berchielli *et al.* (2005).

Total weight gain (TWG) was calculated from the difference between final body weight (FBW) and IBW, and average daily gain (ADG) was obtained by the relationship between TWG and the total number of days in the performance trial. Feed efficiency (FE) was calculated by the relationship between ADG and DM intake, in kg/day (Andrade *et al*., 2018).

Feed, orts, and feces samples were evaluated for DM, crude protein (CP), mineral matter (MM), organic matter (OM) contents, according to AOAC (2005), methods 934.01, 990.13, 942.05, 942.05, respectively; ether extract (EE) was determined according to AOCS (2004). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) was analyzed according to Van Soest *et al.* (1991), using α-amylase AOAC (2005) method 973.18. The neutral detergent insoluble nitrogen was analyzed using the Kjeldahl method (Licitra *et al*., 1996) and, the non-fibre carbohydrate (NFC) were calculated according to Hall (2003). The TDN of intake was obtained according to Weiss (1999).

Observations of feeding behavior were recorded on the 33rd and 40th days of the experimental period, using instantaneous scanning, proposed by Martin and Bateson (2007), every 10 min, resulting in a 48 h evaluation period.

Table 2. Chemical composition of ingredients

Chemical composition (g/kg)	Tifton hay	Ground corn	Soybean meal
Dry matter[a]	923.6	881.1	878
Organic matter[b]	908.7	985.8	934.5
Crude protein[b]	96.9	93.7	487.2
Ether extract[b]	13.7	46.2	9
Neutral detergent fiber[b]	654.9	133.2	133.2
Acid detergent fiber[b]	323.6	27.7	69.9
Non-fiber carbohydrates[b]	143.3	712.7	305.1

[a]As fed
[b]Dry matter basis

Table 3. Proportion of ingredients and composition of experimental diets

Item	Crude glycerin (% DM)			
	0	6	12	18
Ingredients (g/kg)				
Tifton hay	499	499	499	499
Ground corn	380	318	256	195
Crude glycerin	0	60	120	180
Soybean meal	98	98	98	98
Urea/S[a]	5	7	9	10
Mineral Premix[b]	15	15	15	15
Calcitic limestone	3	3	3	3
Diet composition (g/kg)				
Dry matter (g/kg of NM)[c]	905	899	894	889
Organic matter	927	924	921	919
Crude protein	145	143	142	141
Neutral detergent fiber[d]	390	382	374	366
Non-fiber carbohydrates[d]	367	350	332	315
Total digestible nutrientes	761	815	810	824

[a]Nine parts of urea and one part of Sulfur (S).
[b]Components (nutrients/kg): 240g of calcium; 20g of sulfur; 71g of phosphorus; 28.2g of Potassium; 20g of Magnesium; 400mg of copper; 30mg of cobalt; 10mg of chromium; 2500mg of Iron; maximum 710mg of Fluorine; 40mg of Iodine; 1350mg of Manganese; 15mg of selenium and 1700mg of zinc.
[c]Fresh weight basis.
[d]Dry matter basis.

The time spent feeding (FT), ruminating (RT) and idling were estimated and the following relationships were calculated: FE as a function of DM intake = DM intake/FT; feeding efficiency as a function of NDF intake = NDF intake/FT; rumination efficiency as a function of DM intake = DM intake/RT; rumination efficiency as a function of NDF intake = NDF of intake/RT. FT is mean feeding time and RT mean rumination time (Bürger *et al*., 2000).

To evaluate the metabolic profile, blood samples were taken from the jugular vein on the 48th day of the experimental period, four hours after morning feeding. The samples were immediately centrifuged at 3000 rpm for 15 min, and the remaining plasma or serum was kept at -20°C for analysis of urea concentration. Metabolites were analyzed in the Laboratory of Metabolic and Nutritional Diseases of UFRPE, using commercial kits (Labtest®) in automatic biochemical analyzer (Labmax 240 Premium, Labtest®). The globulin content was obtained by the difference between total protein and albumin concentrations.

Statistical analysis

The data were submitted to analysis of variance and regression using the PROC MIXED procedure of the statistical program SAS (2009) (version 9.4, SAS Institute Inc., Cary, NC, USA), adopting $P < 0.05$ as significance level for the type I error, according to the fallowing model:

$Yij = \beta0 + B1Xij + Ti + \varepsilon ij$,

Where: Yij = observation j in treatment i, β0 = intercept, B1 = regression coefficient, Xij = the covariable effect (initial body weight), Ti = fixed treatment effect i (i = 1 at 4), εij = the experimental error.

A Dunnett test was used to compare each treatment group mean (CG-containing diets), with the control diet. Comparisons between CG-containing diets were conducted by the decomposition of sum of squares in orthogonal linear contrasts and quadratic effects, at $P < 0.05$, with subsequent adjustments of the regression equations.

Results

Voluntary and effective intake (Table 4) were similar between the control diet and the diet containing 6% CG, except for EE, NFC. More digestible material was observed for EE on the 6% CG diet. On the other hand, greater voluntary and effective intakes were observed when goats were fed the control diet, compared to 12 and 18% CG diets, except TDN. However, no differences were observed for the content of digestible material, except for EE ($P < 0.05$), in this case, greater digestibility was observed for diets containing CG. Compared with the control diet, lower water intake was only observed to the diet containing 18% CG ($P < 0.05$).

With respect to diets containing CG, the DM (g/day), DM (g/kg), OM, CP, NDF, NFC and TDN intakes decreased linearly with increasing CG ($P < 0.05$), whereas EE intake increased linearly ($P < 0.05$). The water intake (l/d) decreased linearly ($P < 0.05$).

In relation to the effective diet intake, it was observed that the intake of the nutrients CP, NDF and NFC showed a linear decrease ($P < 0.05$), while EE intake increased linearly ($P < 0.05$). No influence ($P > 0.05$) was observed for the apparent digestibility coefficients of DM, OM, CP and NDF. The digestibility coefficient of EE linearly increased ($P < 0.05$) and the NFC decreased linearly ($P < 0.05$; Table 4).

No differences were observed for time FT and idling, expressed in % and h/day ($P > 0.05$); however, more rumination time (%) was observed for the diets containing 12 and 18% CG. In terms of the parameters related to efficiency, only feeding (DM) was similar. However, greater efficiency was observed with feeding (NDF) and rumination (DM and NDF) for diet control, compared to 12 and 18% CG diets.

There was no effect ($P > 0.05$) of diet CG inclusion on daily time spent (%) and duration of events (h) for feeding. The spent time (%) and the duration of the events (h) for rumination presented a linear increase and were linearly reduced for idling ($P < 0.05$). Feeding and rumination efficiencies (DM and NDF) decreased linearly ($P < 0.05$; Table 5) with increasing concentrations of CG.

The values of the metabolic profile were similar between goats fed the control diet and CG, except for cholesterol and BHB ($P < 0.05$). Diets containing CG showed higher values of cholesterol. Greater values of BHB were observed for the control diet compared to 12 and 18% CG diets. Increasing CG caused a linear increase in serum cholesterol concentration ($P < 0.05$). Beta-hydroxybutyrate reduced linearly ($P < 0.05$; Table 6).

The FBW, TWG, and ADG were similar between treatments ($P > 0.05$). Greater FE was observed for 18% CG diet compared to the control diet ($P < 0.05$). Concentrations of CG did not affect ($P > 0.05$) the FBW, TWG, and ADG. The FE increased linearly ($P < 0.05$; Table 7) and animals fed a diet containing 18% CG were 29% more efficient compared to the animals fed the control diet.

Discussion

Glycerol fermentation favors propionate over acetate production, therefore decreasing the acetate:propionate ration. This may be more effective when the glycerol is provided with forage, contrasted to corn (Lage *et al*., 2016). There was probably a more supply of propionate to the liver, which may have contributed to satiety and, consequently, to a lower DM intake

by the animals. Also, more EE content in diets with CG may have contributed to the reduction of DM intake by goats. According to Palmquist and Jenkins (1980), ruminants are relatively intolerant to high-fat diets. Similar responses were reported by Lage *et al.* (2014), who observed a decrease in DM intake when they evaluated the inclusion of 0, 3, 6, 9 and 12% CG of low-purity (36.2 glycerol and lipids 46.5 in DM) in diets fed to lambs; the intakes were 1121; 1115; 899; 942 and 783 g/day respectively.

According to the NRC (2007), the intakes of DM, CP, and TDN for animals, of the genetic group and productivity level used, should be close to 800, 110 and 530 g/day, respectively. However, in the current study, only animals that received the control diet had DM and TDN (775.92 and 578.30 g/day) intakes close to those recommended. However, animals fed the control and 6% diets CG consumed 120.87 and 101.98 g/day CP, respectively, close to the NRC (2007) recommendations. Although, when the effective CP intake values were examined, it was clear that animals for all treatments consumed CP amounts above the intake recommended by the NRC (2007).

Dietary EE above 6% may compromise the digestibility of NDF due to protozoal and bacterial growth inhibition, especially cellulolytic bacteria, and the physical coating of the fiber by lipids, which hinders the action of microorganisms. However, this effect was not observed in this study.

These results agree with those reported by Chanjula *et al.* (2014), who evaluated digestibility in goats, and in the Benedeti *et al.* (2016) studies in which cattle fed higher, CG showed a longer retention time for the digesta in the rumen. In this context, the feed retention time in the ruminal environment strongly correlates with the feed intake (Van Soest, 1994).

Some studies have reported a negative effect on nutrient digestibility in ruminants with increasing concentrations of CG (El-Nor *et al.*, 2010), with an apparent reduction in the digestibility of NDF caused by the inhibition cellulolytic bacterial growth (*Selenomonas ruminantium* and *Butyrivibrio fibrisolvens*).

Ether extract intake and digestibility increased with the inclusion of glycerin in the goats' diets, which may be related to the fatty acid content of glycerol provides greater lipid availability to the small intestine for the formation of micelles and absorption (Barros *et al.*, 2015). According to Palmquist (1991), the increase in EE digestibility occurs due to the dilution effect of endogenous EE loss in feces, and this increase explains the correlation between ingested and fecal EE.

The addition of dietary glycerin caused a reduction in NFC and therefore caused a decreasing NFC intake. It is common to associate glycerin with a high concentration of NFC. However, the glycerin used in this study was of low-purity and partially replaced the ground corn in the diets, which was the ingredient with the highest proportion of NFC (Silva *et al.*, 2016).

According to Trabue *et al.* (2007), animals fed with CG need longer feeding times compared to those fed diets without glycerin, and this can be confirmed by the reduction in DM intake. In contrast, the duration of feeding and idling were not influenced by the inclusion of CG. Additionally, according to Benedeti *et al.* (2016), diets with higher concentrations of CG need a longer retention time in the rumen, which is confirmed by the increase in rumination time with an increase in dietary CG concentration.

High concentrations of glycerol reduce the population densities of ruminal microorganisms, in particular, fibrolytic

Table 4. Effect of the inclusion of crude glycerin on nutrient intake, effectively intake diet and digestibility of goats in feedlot

Item	Crude glycerin (%DM)				SEM	*P*-value		
	0	6	12	18		L[1]	Q[2]	D[3]
Nutrients intake (g/d)								
DM	775.9	664.3	570.9*	477.5*	37.87	0.0002	0.866	0.003
DM[4]	32.9	30.4	26.1*	21.4*	1.11	<.0001	0.507	0.0001
OM	721.4	616.3	527.2*	439.9*	35.22	0.0002	0.859	0.002
CP	120.9	102	87.6*	72.8*	5.79	0.0001	0.803	0.002
EE	22	37.6*	49.9*	55.2*	2.69	<.0001	0.091	<.0001
NDF	261.9	220.9	178.2*	149.6*	13.64	<.0001	0.741	0.001
NFC	322.6	263.1*	220.0*	171.3*	16.03	<.0001	0.809	0.0002
TDN	523.8	414.3	393.2	355.3	31.17	0.032	0.502	0.18
WI[5]	2.1	1.5	1.5	1.2*	0.13	0.0102	0.387	0.047
Effectively intake diet composition (g/d)								
CP	156.4	154.1	153.5*	152.4*	0.48	0.001	0.466	0.011
EE	28.8	56.7*	87.4*	115.4*	5.25	<0.0001	0.981	<.0001
NDF	333.2	333.2	313.9	314.2	4.31	0.042	0.985	0.149
NFC	419.4	395.6*	387.7*	358.2*	4.73	<0.0001	0.889	<.0001
Digestibility (g/kg)								
DM	743.9	784.1	736.9	711.7	12.01	0.168	0.162	0.18
OM	770.4	805.3	754.7	729.7	11.17	0.074	0.162	0.096
CP	798.7	835.7	815	817.8	7.04	0.554	0.219	0.315
EE	850.3	938.2*	950.7*	959.8*	8.2	<0.0001	<0.0001	<.0001
NDF	573	657.4	557.1	552.7	23.74	0.433	0.335	0.338
NFC	861.8	879.1	841.6	825.2	8.22	0.046	0.296	0.108

DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; NFC, non-fiber carbohydrates; TDN, total digestible nutrients; WI, water intake. [1]Linear; [2]Quadratic; [3]Dunnett test; 4g/kg; [5]l/d. *Values differ statistically from the control treatment by Dunnett test at $P < 0.05$.

bacteria, which may be related to three main factors: the development of an environment not favorable to the multiplication of these bacteria, such as osmolarity and pH; encapsulation of the fibrous particles, preventing adhesion of the bacteria; and competition or predilection for another substrate (D'Aurea *et al.*, 2017). In addition, the CG used in the current study had a high total fatty acid content, which may also have contributed to the observed increase in rumination time.

Similar responses of FBW, TWG, ADG and blood parameters indicate that the nutrient requirements of these animals were met appropriately (NRC, 2007), without the need to mobilize body reserves. This can be affirmed by reductions of beta-hydroxybutyrate with the inclusion of CG in the diet. Also, most blood parameter values were normal or close to the reference values for goats (Kaneko *et al.*, 2008). According to Costa *et al.* (2016), higher applications of dietary lipids resulted in greater availability of absorbed fatty acids, which can be converted to acetate and used in cholesterol synthesis. This was confirmed by the greater cholesterol concentrations obtained with diets contenting 12 and 18% CG; which were above the values of 80 to 130 mg/dL recommended by Kaneko *et al.* (2008). Similar effects were related by Nunes *et al.* (2010), who confirmed that diets with more fatty acids promote serum cholesterol elevation in lambs.

In the same context, the postprandial plasma glucose con-

Table 5. Effect of the inclusion of crude glycerin on the feeding behavior of goats in feedlot

Item	Crude glycerin (%DM)				SEM	*P*-valor		
	0	6	12	18		L[1]	Q[2]	D[3]
Daily time spent (%)								
Feeding	14.4	14.5	13	13.8	0.46	0.405	0.677	0.644
Rumination	20.6	22.6	27.5*	27.9*	1.03	0.003	0.681	0.021
Idling	65.4	62.9	59.4	58.3	1.07	0.01	0.749	0.072
Average duration of events (h/d)								
Feeding	3.5	3.54	3.1	3.3	0.11	0.379	0.649	0.626
Rumination	5.2	5.4	6.6*	6.7*	0.24	0.005	0.851	0.032
Idling	15.5	15.1	14.3	14	0.25	0.017	0.911	0.11
Efficiency (g/h)								
Feeding (DM)	230.8	210.3	184.9	139.7	14.12	0.008	0.608	0.06
Feeding (NDF)	78.2	69.3	57.8*	45.5*	4.93	0.005	0.836	0.001
Rumination (DM)	158.2	129.8	89.4*	69.8*	9.33	<0.0001	0.724	<.0001
Rumination (NDF)	53.6	43.4	27.9*	22.8*	3.32	<0.0001	0.563	<.0001

DM, dry matter; NDF, neutral detergent fiber. [1]Linear; [2]Quadratic; [3]Dunnett test. *Values differ statistically from the control treatment by Dunnett test at P < 0.05.

Table 6. Effect of the inclusion of crude glycerin on the metabolic profile of goats in feedlot

Item	Crude glycerin (% DM)				SEM	*P*-value		
	0	6	12	18		L[1]	Q[2]	D[3]
Glucose (mg/dl)	53	46.7	49.2	46.4	1.53	0.212	0.582	0.405
Cholesterol (mg/dl)	104.5	134.1*	132.1*	149.4*	4.44	0.0004	0.425	0.002
Triglycerides (mg/dl)	17.8	23.2	20.8	22.9	1.1	0.198	0.455	0.302
BHB (mmol/l)	0.3	0.3	0.2*	0.2*	0.02	0.0005	0.274	0.004
NEFA (mg/dl)	0.6	0.5	0.5	0.7	0.06	0.805	0.356	0.812
Urea (mg/dl)	39.1	41.7	39.2	35.8	1.21	0.244	0.213	0.377
Total protein (g/dl)	6.4	6.6	6.6	6.6	0.06	0.49	0.571	0.843
Albumin (g/dl)	2.5	2.6	2.6	2.6	0.04	0.738	0.414	0.814
Globulin (g/dl)	3.9	3.9	4	4	0.07	0.659	0.938	0.974
Creatinine (mg/dl)	0.7	0.7	0.6	0.7	0.03	0.973	0.779	0.924
AST (U/l)	89.2	96.5	99.9	118	5.25	0.062	0.612	0.265
ALT (U/l)	20.5	26	23.2	23.5	0.97	0.466	0.172	0.242
GGT (U/l)	52.5	45.9	48.5	42.4	2.61	0.197	0.96	0.495
Calcium (mg/dl)	7.5	7.6	7.6	7.6	0.08	0.552	0.775	0.908
Sodium (mmol/l)	158.7	154.2	158.7	154.1	1.22	0.404	0.989	0.34
Phosphorus (mg/dl)	7.9	8	8.4	8.4	0.22	0.482	0.86	0.885
Magnesium (mg/dl)	2.2	2.2	2.1	2.1	0.05	0.099	0.953	0.309

BHB, beta-hydroxybutyrate; NEFA, non-esterified fatty acids; AST, aspartate aminotransferase; ALT, alanine aminotransferase; GGT, gama glutamyl transferase. [1]Linear; [2]Quadratic; [3]Dunnett test. * Values differ statistically from the control treatment by Dunnett test at P < 0.05.

Table 7. Effect of the inclusion of crude glycerin on the performance of goats in feedlot

Item	Crude glycerin (% DM)				SEM	*P*-value		
	0	6	12	18		L[1]	Q[2]	D[3]
Initial body weight (kg)	19.8	19.5	19.5	19.9	-	-	-	-
Final body weight (kg)	25.7	23.4	23.8	24.4	0.7	0.408	0.113	0.308
Total weight gain (kg)	5.9	4.7	4.3	4.9	0.41	0.292	0.216	0.446
Average daily gain (kg/d)	0.1	0.1	0.1	0.1	0.01	0.284	0.218	0.442
Feed efficiency	0.1	0.1	0.1	0.2*	0.01	0.012	0.056	0.023

[1]Linear; [2]Quadratic; [3]Dunnett test. *Values differ statistically from the control treatment by Dunnett test at $P < 0.05$.

centrations (49.29 mg/dL), which were slightly below the reference values (50-75 mg/dL) (Kaneko *et al*., 2008) may be a consequence of the increase in blood glucose, since glycerol is converted to propionate in the rumen and used as a precursor for the production of glucose by the gluconeogenic route (Hales *et al*., 2013).

According to Thrall (2007), hepatic, muscular, erythrocytic and renal damage may elevate AST and ALT, and liver damage may elevate serum GGT, effects that were not observed in this study, even for the higher concentrations of CG.

Likely, the values found for calcium, sodium, phosphorus, and magnesium were insufficient to cause serious metabolic syndromes, as the animal performance was not compromised. Furthermore, the DM intake decreased, and the alimentary efficiency increased with the inclusion of CG in diets.

Although there was a reduction in the intake of DM, CP, and TDN, animals showed similar ADG, of 0.09±0.01 kg/day; however, this was lower than that recommended by the NRC (2007) for the animal category and expected weight gain (0.15 kg/day). Analogous findings were reported by Ramos and Kerley (2012), who described a reduction in DM intake without any influence on the performance of steers fed with different percentages of CG (5, 10, 15 and 20%). The authors emphasized that the substitution of corn by up to 20% CG does not affect animal performance. According to Hsu *et al*. (1987), a higher proportion of propionate can result in improved feed conversion because there is less energy loss, attributed to decreased adenosine triphosphate (ATP) need by ruminal microbes and less heat loss.

The substitution of an expensive ingredient with a cheap and readily available by-product can be an excellent way to reduce costs. Also, reducing the water intake, without compromising the animals' performance, may be particularly beneficial for semiarid areas, where water availability and quality are often deficient (Nefzaoui *et al*., 2014).

Conclusion

Crude glycerin containing 63.06% glycerol may partially replace corn and be included at a concentration of up to 18% of dry matter in the diet of finished goats in feedlot. This strategy may be, especially beneficial in semiarid regions, where feed and water are scarce, as it improves feed efficiency and promotes moderate weight gains without compromising animal metabolism.

Conflict of interest

Authors declared no conflict of interest exist.

References

Andrade, G.P., Carvalho, F.F.R., Batista, A.M.V., Pessoa, R.A.S., Costa, C.A., Cardoso, D.B., Maciel, M.V., 2018. Evaluation of crude glycerin as a partial substitute of corn grain in growing diets for lambs. Small Ruminant Res. 165, 41–47.

Ayeb, N., Ghrab, A., Barmat, A., Khorchani, T., 2016. Chemical and tissue composition of meat from carcass cuts of localgoats affected by different feeding in Tunisian arid lands. Turk. J. Vet. Anim. Sci. 40, 95–101.

AOAC, 2005. Official Methods of Analysis. Arlington, VA, USA: AOAC.

AOCS, 2004. Official Methods and Recommended Practices of the American Oil Chemists' Society. Champaign, IL, USA: AOCS.

Barros, M.C.C., Marques, J.A., Silva, F.F., Silva, R.R., Guimarães, G.S., Silva, L.L., Araújo, F.L., 2015. Crude glycerin in diets for wethers in feedlot: intake, digestibility, performance, carcass and meat traits. Semina Ciênc. Agrár. 36, 453–466.

Benedeti, P.D.B., Paulino, P.V.R., Marcondes, M.I., Maciel, I.F.S., Silva, M.C., Faciola, A.P., 2016. Partial Replacement of Ground Corn with Glycerol in Beef Cattle Diets: Intake, Digestibility, Performance, and Carcass Characteristics. PLoS One 11(1): e 0148224.

Berchielli, T.T., Oliveira, S.G., Carrilho, E.N.V.M., Feitosa, J.V., Lopes, A.D., 2005. Comparison of markers used to estimate fecal production and digesta flow of cattle "(in Portuguese)". Rev. Bras. Zootec. 34, 987–996.

Bürger, P.J., Pereira, J.C., Queiroz, A.C., Silva, J.F.C., Valadares Filho, S.C., Cecon, P.R., Casali, A.D.P., 2000. Ingestive behavior in Holstein calves fed diets with different concentrate levels "(in Portuguese)". Rev. Bras. Zootec. 29, 236–242.

Chanjula, P., Pakdeechanuan, P., Wattanasit, S., 2014. Effects of dietary crude glycerin supplementation on nutrient digestibility, ruminal fermentation, blood metabolites, and nitrogen balance of goats. Asian Austral. J. Anim. 27, 365–374.

Costa, J.B., Oliveira, R.L., Silva, T.M., Ayres, M.C.C., Estrela-Lima, A., Carvalho, S.T., Ribeiro, R.D.X., Cruz, G.A.M., 2016. Liver metabolic and histopathological profile in finishing lambs fed licuri (Syagrus coronata(Mart.)Becc.) cake. Trop. Anim. Health Prod. 48, 501–507.

D'Aurea, A.P., Ezequiel, J.M.B., D'Aurea, E.M.O., Fávaro, V.R., Homem Júnior, A.C., Van Cleef, E.H.B., Paschoaloto, J.R., Almeida, M.T.C., 2017. Glycerin associated with urea in finishing cattle: ruminal fermentation, digestibility and microbial mass "(in Portuguese)". Arq. Bras. Med. Vet. Zootec. 69, 146–154.

El-Nor, S.A., AbuGhazaleh, A.A., Potu, R.B., Hastings, D., Khattab, M.S.A., 2010. Effects of differing levels of glycerol on rumen fermentation and bacteria. Anim. Feed Sci. Tech. 162, 99–105.

Hales, K.E., Bondurant, R.G., Luebbe, M.K., Cole, N.A., Macdonald, J.C., 2013. Effects of crude glycerin in steam-flaked corn-based diets fed to growing feed lot cattle. J. Agric. Sci., Cambridge 91, 3875–3880.

Hall, M.B., 2003. Challenges with non-fibre carbohydrate methods. J. Agric. Sci., Cambridge 81, 3226–3232.

Hippen, A., Defrain, J.M., Linke, P.L., 2008. Glycerol and Other Energy Sources for Metabolism and Production of Transition Dairy Cows. In: Florida Ruminant Nutrition Symposium – Best Western Gateway Grand Gainesville, Florida. Proceedings... Gainesville: University of Florida.

Hsu. J.T., Faulkner, D.B., Garleb, K.A., Barclay, R.A., Fahey Jr., C.C., Berger, L.L., 1987. Evaluation of corn fiber, cottonseed hulls, oat hulls and soybean hulls as roughage sources for ruminants. J. Anim. Sci. 65, 244-255.

Kaneko, J.J., Harvey, J.W., Briss, M.L., 2008. Clinical biochemistry of domestic animals. In: Academic Press, 6th ed. San Diego, pp. 916.

Krehbiel, C.R., 2008. Ruminal and physiological metabolism of glycerin. J. Anim. Sci. 86 (E-Suppl. 2), 392 (abstracts).

Lage, J.F., Paulino, P.V.R., Pereira, L.G.R., Duarte, M.S., Valadares Filho,

S.C., Oliveira, A.S., Souza, N.K., Lima, J.C., 2014. Carcass characteristics of feedlot lambs fed crude glycerin contaminated with high concentrations of crude fat. Meat Sci. 96, 108–113.

Lage, J.F., San Vito, E., Reis, R.A., Dallantonia, E.E., Simonetti, L.R., Carvalho, I.P.C., Berndt, A., Chizzotti, M.L., Friguetto, R.T.S., Berchielli, T.T., 2016. Methane emissions and growth performance of young Nellore bulls fed crude glycerine- v. fibre-based energy ingredients in low or high concentrate diets. J. Agric. Sci. Cambridge 154, 1280–1290.

Licitra, G., Hernandez, T.M., Van Soest, P.J., 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Tech. 57, 347–358.

Martin, P., Baterson, P., 2007. Measuring Behaviour: An Introductory Guide, 3rd Ed. Cambridge, UK: Cambridge University Press.

National Research Council (NRC), 2007. Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids. In: The National Academies Press, Washington, DC, USA: NRC.

Nefzaoui, A., Louhaichi, M., Ben Salem H., 2014. Cactus as a tool to mitigate drought and to combat desertification. J. Arid. Land, 24, 121–124.

Nunes, A.S., Oliveira, R.L., Ayres, M.C.C., Bagaldo, A.R., Garcez Neto, A.F., Barbosa, L.P. 2010. Hepatic condition of lambs fed diets with palm kernel cake from biodiesel production "(in Portuguese)". Rev. Bras. Zootec., 39, 1825–1831.

Palmquist, D.L., Jenkins, T.C., 1980. Fat in lactation rations: review. J. Dairy Sci. 63, 1–14.

Palmquist, D.L., 1991. Influence of source and amount of dietary fat on digestibility in lactating cows. J. Dairy Sci. 74, 1354–1360.

Ramos, M.H., Kerley, M.S., 2012. Effect of dietary crude glycerol level on ruminal fermentation in continuous culture and growth performance of beef calves. J. Agric. Sci. Cambridge 90, 892–899.

SAS Institute, 2009. SAS/STAT: user's guide. Version 9.2. Cary, NC, USA: SAS Institute.

Singh, F., Sonawane, G.G., Meena, R.K., 2018. Molecular detection of virulent Mannheimia haemolytica and Pasteurella multocida in lung tissues of pneumonic sheep from semiarid tropics, Rajasthan, India. Turk. J. Vet. Anim. Sci. 42, 556-561.

Silva, T.M., Oliveira, R.L., Nascimento Jr, N.G., Pellegrini, C.B., Trajano, J.S., Rocha, T.C., Bezerra, L.R., Borja, M.S., 2016. Ingestive behavior and physiological parameters of goats fed diets containing peanut cake from biodiesel. Trop. Anim. Health Prod. 48, 59–66.

Socreppa, L.M., Moraes, K.A.K., Oliveira, A.S., Batista, E.D., Drosghic, L.C.A.B., Botini, L.A., Paula, D.C., Stinguel, H., Moraes, E.H.B.K., 2017. Crude glycerine as an alternative energy feedstuff for beef cattle grazing tropical pasture. J. Agric. Sci. Cambridge 155, 839–846.

Thrall, M.A., 2007. Hematologia e Bioquímica Clínica Veterinária. 1st ed. Ed Roca, p. 582.

Trabue, S., Scoggin, K., Tjandrakusuma, S., Rasmussen, M.A., Reilly, P.J., 2007. Ruminal fermentation of propylene glycol and glycerol. J. Agr. Food. Chem. 55, 7043–7051.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.

Van Soest, P.J., 1994. Nutritional ecology of the ruminant. Ithaca, NY, USA: Cornell University Press, pp. 476.

Weiss, W.P., 1999. Energy prediction equations for ruminant feeds. In: Cornell Nutrition Conference Feed Manufactures, 61. Ithaca. Proceedings, Ithaca: Cornell University, pp. 176–185.