An Acad Bras Cienc (2022) 94(1): e20200083 DOI 10.1590/0001-3765202220200083
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

105 anos 1916 • 2021

ANIMAL SCIENCE

Carcass characteristics and meat quality of goats fed increasing levels of crude glycerin

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Abstract: Crude glycerin is a byproduct of the biodiesel industry and has been widely used in ruminant diets as a source of energy, usually in place of corn, primarily during periods of drought in tropical regions. The objective of this study was to evaluate the effect of including levels of the crude glycerin of low purity (0, 6, 12 and 18%) replacing corn in the diets of goats on the carcass characteristics, tissue composition, meat cuts yield and physicochemical parameters of meat. Forty males castrated without defined racial pattern goats an initial average weight of 19.70 ± 2.30 kg were slaughtered after 86 days. Diets content 0 and 6% crude glycerin promoted similar responses to the analyzed variables, except for pH and breast weight. No differences were observed to total digestible nutrients, slaughter body weight, commercial cut yield leg tissue composition and physicochemical parameters of meat. Crude glycerin can be included up to 12% without losses on carcass weight and meat cuts, leg composition, and meat quality. The inclusion of crude glycerin containing 63.06% glycerol and 45.57% lipids could be effective in partial replacement of corn in diets for confined goats in tropical areas.

Key words: Ruminants, biodiesel, byproduct, meat cuts, tropical areas.

INTRODUCTION

In tropical areas, during periods of drought, producers often supplement animal feed with concentrated feed containing corn to maintain adequate livestock weight gain and meet the market's demand for animal meat (Cardoso et al. 2019). However, concentrate supplements are expensive (Matos et al. 2018), and causes increases production costs and may have a negative economic impact on animal husbandry (Cardoso et al. 2019).

Increasing the supply of food for humans consumption, it is important that distinct species ingest diverse kinds of food. Food of animal origin destined for human consumption should be changed in such a way as to improve the sources of protein and energy, using available high-quality grain and animal protein. Alternative dietary sources for animal feed include agroindustry byproducts (Romanzini et al. 2018).

According to Németh et al. (2013), depending on the refinement techniques, the production of one liter of biodiesel, results about 79 – 100 g of glycerol. Also, according to AbuGhazaleh et al. (2010), the governmental encouragement to biofuels productions has been strongly impacted the production of agriculture and animal production, due to the corn and other feedstuffs have higher prices, thus the interesting for glycerol use is growing in livestock diets.

In this context, crude glycerin (CG), a byproduct of the biodiesel industry, has been widely used in ruminant diets as a source of energy and may be a substitute for corn (Almeida et al. 2019), especially during periods of drought in tropical regions (Carvalho et al. 2015). When glycerol, the main constituent of CG, is added to the diet of ruminants, the concentration of propionate increases (Benedeti et al. 2015), which is a precursor for the synthesis of hepatic glucose. Thus, replacing corn with CG may increase the deposition of intramuscular fat in livestock (Carvalho et al. 2014). Also, according to AbuGhazaleh et al. (2010), using CG in ruminants' diets has no adverse effects on intake, ruminal digestibility or performance. Besides, it has been used to avoid metabolic problems and treatment of ketosis. In this sense, Romanzini et al. (2018), also did not see alteration on animal performance and quantitative carcass characteristics when uses CG in ruminants' diets.

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 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, Gomes et al. 2020).

According to Hales et al. (2013), CG is converted in the rumen into volatile fatty acids, mainly, propionate, a major glucogenic precursor in ruminants. Thus, the efficiency of CG as a source of energy is dependent on the glycerol content.

Although recent studies have evaluated the effects of including high purity dietary CG on ruminant carcass characteristics (Benedeti et al. 2016, Romanzini et al. 2018), a limited number of studies have evaluated the effects of low purity CG (below 80% glycerol) in goat diets. Thus, this study aimed to evaluate the effects replacing corn by low purity CG in the diet of feedlot goats on their carcass characteristics, tissue composition, the diet's economic evaluation, meat cuts yield and physicochemical traits of the meat.

MATERIALS AND METHODS

The experiment was conducted at the Federal Rural University of Pernambuco (UFRPE), Brazil. All procedures were conducted in accordance with the guidelines set by the Brazilian College of Animal Experimentation and approved by the Ethics Committee on Use of Animal for Research (CEUA) of the Federal Rural University of Pernambuco – Brazil (license) 059/2016.

Forty castrated male goats, with breed undefined (19.70 ± 2.30 kg initial body weight, IBW), were used in a randomized study. Animals were allocated in individual pens (1.8 m^2), with individual water drinkers and feeders. The trial lasted 86 days with a 28-day adaptation to experimental facilities and diets.

The diets were formulated to achieve a weight gain of approximately 150 g day^{-1} (NRC 2007). The roughage:concentrate ratio was 50:50 in all diets, with treatments consisting of roughage + concentrate and inclusion of CG of 0, 6, 12 and 18% replacing corn (Table I). The CG used contained 20.7% water, 63.1% glycerol, 45.6% lipids, 5.9% ash, 0.3% sodium and 3.7% methanol. Feed was provided *ad libitum*, as a total mixed ration (at 0800h and 1500h), and the orts were weighed daily to obtain a maximum of 15%. Feed, orts, and feces samples were evaluated for DM, crude protein (CP),

Table I. **Proportion of ingredients and chemical composition of the 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[1]	5	7	9	10
Mineral Premix	15	15	15	15
Calcitic limestone	3	3	3	3
Chemical composition				
Dry matter[2]	905	899	894	889
Organic matter[3]	927	924	921	919
Crude protein[3]	145	143	142	141
Ether extract[3]	25.0	49.0	73.0	97.0
Neutral detergent fiber[3,4]	390	382	374	366
Non-fiber carbohydrates[3]	367	350	332	315
Total digestible nutrientes[3]	761	815	810	824

[1]nine parts of urea and one part of Sulfur (S).
[2]as fed.
[3]g/kg of dry matter.
[4]Neutral detergent fiber assayed with a heat stable amylase and corrected for ash and nitrogenous compounds.

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) were analyzed according to Van Soest et al. (1991), using the α-amylase AOAC (2005) method 973.18. The neutral detergent insoluble nitrogen was analyzed using the Kjeldahl method (Licitra et al. 1996) and, the nonfibre carbohydrate (NFC) was calculated according to Hall (2003). The TDN of intake was obtained according to Weiss (1999).

After 86 days of data collection, the animals were solid fasted for 16 hours and subsequently weighed, to obtain slaughter body weight (SBW). The animals were slaughtered following procedures in the Regulation on Industrial and Health Inspection of Products of Animal Origin, according to Brasil (2000). After skinning and evisceration, the hot carcass weight (HCW) was registered. And then, the carcasses were stored into a cold chamber for 24 hours at 4 °C, and, weighed to obtain the cold carcass weight (CCW). Carcass pH readings were taken at 24 hours post-mortem, approximately 4 cm deep in the *Longissimus lumborum* muscle (12th rib), using a Testo 205 pH meter, equipped with a penetrating electrode.

The empty body weight (EBW) was obtained by the difference between the SBW and the gastrointestinal tract content, and content of the bladder and gallbladder. HCY, CCY, and chilling losses (CL). The gastrointestinal tract content (GTC) was calculated by the difference between the full and empty gastrointestinal weight; all those variables were calculated according to Cezar & Sousa (2007).

The analysis was conducted on the left half of the carcass. To measure the *longissimus* muscle area (LMA), a cross-section between the 12th and 13th ribs was made, by tracing the muscle's contour on a transparent plastic sheet for later area determination using a digital planimeter (Haff®, Modelo Digiplan). The subcutaneous fat thickness (SFT) was measured at two-thirds of the total length of the LMA.

The leg compactness index (LCI) was calculated according to Cezar & Souza (2007), by the quotient between CCW and the internal carcass length; the relationship between rump width and leg length; the carcass compactness index (CCI); and the ratio between the CCW and the carcass internal length were calculated. Six anatomical regions, corresponding to commercial cuts (shoulder, neck, ribs, breast, loin, and leg) were weighed and the commercial cut weight and commercial cut yield were determined (Cezar & Sousa 2007). Tissue groups were separated (fat, muscle, bone and other tissues) and weighed. The relationships muscle:bone and muscle:fat, were obtained according to Brown & Williams (1979).

During the dissections, the five main muscles associated with the femur (*biceps femoris,quadriceps femoris, semimembranosus, semitendinosus,* and *adductor*) were removed and calculated according to Puchas et al. (1991).

For the physicochemical analyses, *Longissimus lumborum* muscle samples were thawed for 24 h at 4 °C. The meat color, the lightness (L*), redness (a*), and yellowness (b*), and the aspects that were assessed by the CIE L* a* b* color system were measured using a colorimeter (Minolta Chroma Meter CR-400), fallowing methodology described by Wheeler et al. (1995).

The Santos-Silva et al. (2002) method was used to determine the water-holding capacity (WHC). To measure cooking loss (CL), three 2.54-cm-thick steaks were weighed and cooked in an industrial oven preheated to 175 °C until the internal temperature of the samples reached 71 °C. CL was calculated as the difference between the weight of the steaks before and after oven-broiling. Subsequently, two (1.27-cm diameter) cylinders were removed from each sample, parallel to the direction of the muscle fibers, and sheared perpendicularly to the orientation of the fibers, using a Warner–Bratzler shear machine (Wheeler et al. 2002). Shear force (SF) values were recorded in kgf/cm^2, then converted to Newton (N).

Samples from the *semimembranosus* muscle were used to analyses of humidity, crude protein (CP), mineral matter (MM) and ether extract (EE), following the procedures of AOAC (2000), methods 930.15, 942.05, 984.13 and 920.39, respectively.

The economical evaluation considered only fed and animal costs (Romanzini et al. 2018). It was considered the 0% CG diet, as the current situation and 6, 12 and 18% diets as alternative situations. Ingredients and animal prices were quoted in the same region of animal production and the same experiment. Also, the costs were converted considering R$ 4.20 (Brazil) equal to US$ 1.00, quote to the same period of the experiment.

Statistical analysis

The data were submitted to analysis of variance and regression using the PROC GLM and PROC MIXED 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:

$$Yij = \beta 0 + B1Xij + Ti + \varepsilon ij,$$

Where: Yij = observation *j* in treatment *i*, β*0* = intercept, *B1* = regression coefficient, *Xij* = the covariable effect (IBW), *Ti* = fixed treatment effect *i* (*i* = 1 at 4), ε*ij* = the experimental error.

A Dunnett test was used to compare each treatment group mean (CG-containing diets), with the without CG diet. Comparisons between 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

The DM, CP and total digestible nutrients (TDN) intakes decreased linearly with increasing levels of CG. Higher DM and CP intakes were observed for the 0% CG diet ($P <$ 0.05), compared to 12 and 18% CG diets.

There was a negative linear effect of the substitution of corn for GB on the slaughter body weight, empty body weight, chilling losses, longissimus muscle area, subcutaneous fat thickness, and leg compactness index ($P >$ 0.05). However, only the diet containing 18% CG resulted in lower hot carcass weight, cold carcass weight, hot carcass yield, cold carcass yield, and carcass compactness index ($P < 0.05$). The empty body weight, hot carcass weight, cold carcass weight, hot carcass yield, cold carcass yield, longissimus muscle area, carcass compactness index, and pH ($P < 0.05$) decreased linearly with the inclusion of CG. The slaughter body weight, chilling losses, subcutaneous fat thickness, and leg compactness index ($P > 0.05$) were not influenced by diets (Table II).

For the commercial cut weight, the cuts shoulder, ribs, breast, and leg presented decreasing linear behavior ($P < 0.05$) with the inclusion of GB. Greater breast weight was observed for the 0% CG diet and only the 18% CG diet showed lower leg weight ($P < 0.05$). No differences were observed in the commercial cut yield ($P > 0.05$). The yield of shoulder cuts increased linearly ($P < 0.05$, Table III).

The different diets promoted similar leg tissue compositions ($P > 0.05$). Were observed that the weights of the reconstituted leg, muscle, and bone decreased linearly ($P < 0.05$) with increasing CG levels. The relationships muscle:bone and muscle:fat, as well as the leg muscularity index, were not influenced ($P >$ 0.05, Table IV).

The humidity, MM and EE of the meat were influenced by the inclusion of CG in the diet ($P < 0.05$). Compared to the 0% CG diet, the physicochemical measurements were similar between the diets, except for the greater humidity and lower EE for the 18% CG diet. The inclusion of CG did not affect the physicochemical measurements of the meat ($P >$ 0.05), such as color (L*, a*, and b*), WHC, CL, and SF. The meat protein was not affected ($P > 0.05$) by the increase in CG levels (Table V).

The economic evaluation showed that diets containing higher CG levels showed better partial return (US$) and return rate (%) than other diets (Table VI).

DISCUSSION

Crude glycerin can increase the available energy of the diet, due to higher production and absorption of propionate, promoting satiety regulator effect (Almeida et al. 2019). It can be the reason for the reduction in DM, CP and TDN intakes observed for diets containing

Table II. Nutrients intake and carcass characteristics of goats fed diets containing increasing levels of crude glycerin containing 63.06% glycerol and 45.57% lipids.

Item	Crude glycerin (%)				SEM	*P*- Value		
	0	6	12	18		L	Q	D
Daily intake								
DM	775.92	664.30	570.88	477.55	37.868	0.0002	0.8662	0.003
CP	120.87	101.98	87.61	72.83	5.792	0.0001	0.8026	0.002
TDN	523.77	414.35	393.20	355.33	29.93	0.0320	0.5018	0.180
Carcass characteristcs								
SBW (kg)	25.46	23.32	23.61	24.28	0.686	0.416	0.121	0.309
GTC (kg)	4.28	3.99	4.55	5.61	0.174	0.0002	0.0095	0.0003
EBW (kg)	21.11	19.30	19.04	18.64	0.584	0.025	0.341	0.102
HCW (kg)	11.82	10.84	10.60	10.17*	0.324	0.006	0.495	0.039
CCW (kg)	11.13	10.17	10.01	9.59*	0.305	0.007	0.473	0.041
HCY (%)	46.48	46.46	44.89	41.99*	0.388	<.0001	0.011	<.0001
CCY (%)	43.77	43.63	42.37	39.64*	0.381	<.0001	0.030	<.0001
CL (%)	5.81	6.09	5.63	5.64	0.220	0.633	0.777	0.882
LMA (cm^2)	9.14	8.58	8.64	7.34	0.271	0.020	0.455	0.081
SFT (mm)	0.54	0.56	0.47	0.48	0.019	0.094	0.870	0.231
LCI (cm/cm)	0.45	0.45	0.45	0.47	0.006	0.428	0.478	0.755
CCI (kg/cm)	0.18	0.17	0.17	0.16*	0.004	0.007	0.848	0.043
pH 24 hours	5.76	5.60*	5.58*	5.51*	0.026	0.0004	0.346	0.003

***SEM*, standard error of the mean; *L*, linear effect; *Q*, quadratic effect; *D*, Dunnett effect; *DM*, dry matter; *CP*, Crude protein; *TDN*, total digestible nutrients; *SBW*, slaughter body weight; *GTC*, gastrointestinal tract content; *EBW*, empty body weight; *HCW*, hot carcass weight; *CCW*, cold carcass weight; *HCY*, hot carcass yield; *CCY*, cold carcass yield; *CL*, chilling losses; *LMA*, longissimus muscle area; *SFT*, subcutaneous fat thickness; *LCI*, leg compactness index; *CCI*, carcass compactness index.**

higher CG levels. Although, similar DM intake was observed for diets with 0 and 6% CG. In opposite, Chanjula et al. (2016) found different results: the authors observed lower DM intake when animals were fed with 6% CG diets. They referred to the potential problem of methanol in GC, due to the toxicity and clinical consequences to animals. In the current study, the effect of methanol was probably minimal, may be because of the minor methanol content in CG and, the animals used had lower weights, consequently, lower DM intake.

In addition, according to Almeida et al. (2019), the use of CG in diets to ruminants avoids subacute acidosis. It is possible because of the reduction of the DM, resulting in lower starch-based ingredients intake. Also, lower DM intake may be related with the ether extract in the diets, according to Palmquist & Jenkins (1980), ruminants are intolerant to high-fat levels in the diet and food intake tends to reduce when lipid levels exceed 6% in the diet.

Goats fed higher CG concentrations presented SBW similar to those not fed CG, however, they resulted in lighter carcasses. In

Table III. Commercial cut weight and yield of goats fed diets containing increasing levels of crude glycerin containing 63.06% glycerol and 45.57% lipids.

Item	Crude glycerin (%)				SEM	*P*-Value		
	0	6	12	18		L	Q	D
Commercial cuts (kg)								
Shoulder	1.08	0.99	1.00	0.95	0.030	0.024	0.580	0.111
Neck	0.42	0.40	0.39	0.37	0.013	0.068	0.981	0.331
Ribs	0.99	0.92	0.89	0.83	0.036	0.030	0.992	0.174
Breast	0.77	0.64	0.63	0.60	0.025	0.003	0.166	0.010
Loin	0.40	0.36	0.38	0.35	0.011	0.153	0.731	0.357
Leg	1.91	1.74	1.77	1.62	0.051	0.009	0.895	0.045
Commercial cut yield (%)								
Shoulder	19.36	19.65	19.76	20.11	0.128	0.046	0.918	0.238
Neck	7.57	798	7.76	7.72	0.192	0.895	0.580	0.909
Ribs	17.55	18.23	17.49	17.42	0.261	0.622	0.467	0.654
Breast	13.94	12.46	12.39	12.81	0.245	0.108	0.053	0.094
Loin	7.34	7.14	7.57	7.51	0.140	0.434	0.788	0.658
Leg	34.24	34.54	35.03	34.44	0.205	0.557	0.292	0.581

SEM, standard error of the mean, L, linear effect, Q, quadratic effect, COV, covariable effect.

view of the results, it is possible to infer that CG was probably the most influential factor on the variation in carcass weight and yield, since lower EBW weights were observed for animals that received higher levels of CG. Although, the animals evaluated in the present study presented carcass yields within the range of 40% to 50%, described by Silva Sobrinho (2001), as ideal for specialized meat production breeds.

According to Osório et al. (2009), the values of CL observed in the present study, were considered satisfactory, in this context, the use of CG diet may not alter the meat succulence. According to Mach et al. (2009), about 80% of the glycerol in CG is converted to short-chain fatty acids, which improve the osmotic pressure in the rumen, increasing the intracellular water content, and, subsequently, increasing the WHC. Previous studies have shown that CG does not affect the CL (Gomes et al. 2011, Lage et al. 2014).

Although the use of CG has been related to increases proportions of propionate, a precursor of glucose in the rumen, that promotes an increase in lipogenesis (Krehbiel 2008), however, it was not observed on the SFT. Additionally, the subcutaneous adipose tissue in goat species is poorly developed or scarce (Silva et al. 2011). Also, the period of the experiment and the animal's age, could not be enough or appropriate to reflect the impact of the CG diets in the subcutaneous adipose tissue of the animals. Another situation is the DM reduction intake that not promoted differences in the SFT.

Factor such as the retention of GB in the gastrointestinal tract could be one more consequence of reduction intake and the results of the similar results in SBW. Therefore, the GTC was higher although no differences were observed to SBW.

Table IV. An economic evaluation of goats fed diets containing increasing levels of crude glycerin containing 63.06% glycerol and 45.57% lipids.

Item	Crude glycerin (%)				SEM	P-Value		
	0	6	12	18		L	Q	D
Leg (kg)	1.82	1.67	1.70	1.56	0.048	0.016	0.982	0.068
Muscle (kg)	1.20	1.08	1.12	1.04	0.033	0.020	0.607	0.056
Bone (kg)	0.38	0.37	0.36	0.33	0.010	0.017	0.641	0.102
Fat (kg)	0.16	0.15	0.16	0.13	0.008	0.352	0.501	0.655
Muscle (%)	66.37	64.57	65.59	66.33	0.365	0.775	0.086	0.265
Bone (%)	21.27	22.13	21.30	21.27	0.283	0.739	0.440	0.644
Fat (%)	8.50	9.05	9.04	8.57	0.314	0.944	0.445	0.895
Other tissues (%)	5.85	5.80	5.47	4.85	0.249	0.123	0.554	0.425
Muscle:bone	3.13	2.94	3.10	3.16	0.051	0.554	0.218	0.407
Muscle:fat	8.52	7.31	8.02	8.17	0.383	0.921	0.396	0.746
Leg muscularity index	0.33	0.33	0.34	0.34	0.004	0.452	0.840	0.886

***SEM*, standard error of the mean, *L*, linear effect, *Q*, quadratic effect, *D*, Dunnett effect.**

According to López-Carlos et al. (2014), the visceral fat is the adipose depot that is first developed, followed by intermuscular, subcutaneous, and intramuscular fat; therefore, when the goats have poor subcutaneous cover they are susceptible to high moisture losses during post-mortem chilling. The similar cooling loss promoted between the treatments was probably because the external fat was unaffected.

In addition, according to Sen et al. (2004), in general, the adapted tropical animals in order to facilitate thermolysis by cutaneous evaporative cooling deposit more fat in the viscera rather than in the subcutaneous region.

The decreased LMA is consistent with the decreased weight and carcass yields, as this) parameter is highly correlated with the total muscle of the carcass. Similarly, decreased CCI indicates a reduction in muscle tissue deposition per unit length, particularly in the posterior region, which has the greatest concentration of muscles (Cezar & Sousa 2007). These results corroborate the carcass weights and yields, as well as the LMA and commercial cut weight, we obtained.

Similar results for the L*, a* and b* values, indicate that the nature of the food did not influence the coloring of the goat meat (Table V). In addition, the pH values of the meat were within the normal range of 5.5 to 5.8 (Silva Sobrinho et al. 2005). This is a promising result since color has been reported to be one of the most important fresh meat characteristics recognized by the consumer at the time of purchase (Yalcintan et al. 2018).

According to the values found for SF, all diets promoted meat that may be regarded as tender (Cezar & Sousa 2007). Also, the EE values were considered low, according to Bezerra et al. (2016) are classified as being lean, possibly due to the animals being young.

Diets containing higher levels of GC showed better economic viability, promoting higher partial return (US$) and return rate (%). This is possible due to the high energy availability

Table V. Physicochemical parameters of *Longissimus lumborum* muscle and chemical composition of *Semimembranosus* muscle of goats fed diets containing increasing levels of crude glycerin containing 63.06% glycerol and 45.57% lipids.

Item	Crude Glycerin (% DM)				SEM	*P* Valor		
	0	6	12	18		L	Q	D
L*	35.39	34.92	35.01	35.35	0.331	0.989	0.560	0.949
a*	13.31	13.48	12.13	12.96	0.230	0.244	0.467	0.172
b*	6.78	6.62	6.98	6.75	0.152	0.850	0.913	0.879
WHC (%)	29.91	29.44	29.70	29.65	0.589	0.914	0.849	0.992
CL (%)	26.33	30.55	22.17	28.07	1.695	0.830	0.799	0.339
SF (Newton/cm^2)	21.67	22.75	20.30	20.98	0.165	0.274	0.841	0.297
Humidity	75.69	76.03	75.79	76.68*	0.136	0.021	0.284	0.038
MM	1.70	1.81	1.52	1.37	0.062	0.019	0.252	0.052
CP	19.93	19.99	19.77	19.68	0.106	0.316	0.734	0.725
EE	2.12	1.94	2.05	1.36*	0.104	0.019	0.198	0.039

***SEM*, standard error of the mean, *L* linear effect, *Q* quadratic effect, *D*, Dunnett effect; *L**, brightness, fresh color; *a**, red contet, fresh color; *b**, yellow content, fresh color; *WHC*, water holding capacity; *CL*, cooking loss; *SF*, shear force; *MM*, mineral matter; *CP*, crude protein; *EE*, ether extract.**

Table VI. An economic evaluation of goats fed diets containing increasing levels of crude glycerin containing 63.06% glycerol and 45.57% lipids.

Item	Crude glycerin (% DM)			
	0	6	12	18
Animal cost (US$)	32.83	32.83	32.83	32.83
Diet cost (US$/kg of DM)	0.40	0.39	0.38	0.37
Diet cost/head (US$)	17.83	14.86	12.46	10.16
Diet cost/head + animal cost (US$)	50.66	47.69	45.29	42.99
Cost/kg of carcass (US$)	4.96	4.67	4.43	4.21
Revenues (US$/head)	53.00	48.43	47.67	45.67
Gross Profit (US$)	2.34	0.74	2.38	2.68
Return rate (%)	4.62	1.55	5.25	6.22

promoted by GC diets. It is significant importance due to meeting animal requirements in tropical areas. These areas are familiar with a significant reduction in the quality and availability of fodder in the dry season, a fact associated with high animal morbidity and lower protein consumption of the population living in tropical zones, especially in marginalized areas common in poorer countries.

CONCLUSION

The results indicate that the inclusion of CG containing 63.06% glycerol and 45.57% lipids, could be effective in partially replacing corn, up to 12%, in the diet of feedlot goats in tropical area.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001. The authors would like to thank the Centro de Tecnologias Estratégicas do Nordeste (CETENE), and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financing this assay.

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How to cite

GOMES RN, DE PAULA TA, DE CARVALHO FFR, FERREIRA MA, BARRETO LMG, NEVES MLMW, DE OLIVEIRA AB, MENDES GO, CORDEIRO EHA & VÉRAS ASC. 2022. Carcass characteristics and meat quality of goats fed increasing levels of crude glycerin. An Acad Bras Cienc 93: e20200083. DOI 10.1590/0001-3765202220200083.

Manuscript received on January 18, 2020;
accepted for publication on May 6, 2020

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