Low-purity crude glycerin as a nutrient substitute for corn: the effect on yields of goat organs and viscera

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ABSTRACT. This study was conducted to evaluate the effects of the inclusion of low-purity crude glycerin (CG, 63.1% of glycerol) in the diets of feedlot-finished goats on the weights and yields of the non-carcass components, with are frequently used in regionals dishes (buchada and panelada). Forty castrated male goats with the initial mean body weight of 19.70 ± 2.30 kg were used. Experimental treatments consisted of inclusion of CG at levels of 0, 6, 12, and 18%, based on dry matter. The weights of the lungs, spleen, total organs (TWO), and TWO yield, as a function of the slaughter body weight, decreased linearly. It was shown that the rumen portion of the weight showed a quadratic effect, at the level of 10.71% of CG, with a minimum point of 0.37 kg. Similar behavior was observed for the reticulum, with a minimum point of 0.08 kg, at the level of 7.5% of CG. The weights and yields of the buchada and panelada were negatively influenced by the experimental diets. Low-purity crude glycerin may partially replace corn and be included in up to 6% of the dry matter of the finished goats' feedlot diet without adversely affecting weights and yields of organs, viscera, and regional dishes, such as buchada and panelada.

Keywords: buchada; co-product; glycerol; panelada.

Introduction

Goat farming is an activity of great importance in the Brazilian Northeast, providing employment and income for the local residents through the commercialization of meat, milk and skin. However, the level of production reached by producers in this region is still low, mainly due to the irregular supply of forage (Batista & Souza, 2015; Singh et al., 2018).

Thus, one of the alternatives could be the finishing of goats using a feedlot, making for good the supply and uniformity of carcasses and meat cuts for the consumer market; however, there is a need to reduce production costs. Crude glycerin is a co-product of the biodiesel industry that has been widely used as a substitute for corn in ruminant diets as an alternative source of energy, primarily during periods of drought in semi-arid regions (Eiras et al., 2014; Carvalho et al., 2015; Lage et al., 2017).

Glycerol is the main constituent of crude glycerin (40-99%). When added to the diet of ruminants, it modifies the acetate:propionate ratio in the rumen, favoring an increase in the concentration of propionate (Benedeti et al., 2015), which acts as a precursor for the hepatic synthesis of glucose (Hales, Bondurant, Luebbe, Cole & Macdonald, 2013). Mach, Bach, and Devant (2009) reported no effect of dietary glycerin inclusion (4, 8, 12 and 16% DM) on performance and feed intake of cattle finished in a feedlot and fed on a high-concentrate level. On the other hand, Parsons, Shelor, and Drouillard (2009) found that the addition of glycerin (8% on DM) to the diet reduced the final body weight (BW) and decreased the feed efficiency of cattle fed a high-concentrate level in a feedlot.

According to Moreno et al. (2011), although organs and viscera have low commercial value, when they are used to make typical dishes, the profitability of these components can be improved up to 57.5% in relation to the carcass value. In Brazil, there are some typical dishes that use these components, for example, buchada. It is a traditional meat product, mainly consisting of chopped viscera, blood, and organs (heart, lungs, liver, intestine, and stomach) (Brasil et al., 2014; Queiroz et al., 2013).

The panelada is another traditional Brazilian dish, it contains the same constituents as the buchada, with the feet and head added (Clementino et al., 2007). It is a product with great demand that can be prepared at home, also, it can be sold in restaurants, bars and open markets. These co- products are responsible for adding value to meat production and reducing the environmental impact caused by their limited disposal (Toldrá, Aristoy, Mora & Reig, 2012). Moreover, viscera and blood are recognized as sources of protein, fat, and vitamins, especially B complex vitamins, which are of great importance for health (Ockerman & Basu, 2004). Few studies have been conducted to evaluate the effects of crude glycerin on the weights and yields of organs, viscera, and adipose deposits of feeding goats, or of the co-products used in regional dishes such as buchada and panelada.

Thus, it was hypothesized that low-purity crude glycerin can be included in the feedlot goat diet, in concentrations up to 18% of the dry matter, without compromising the weights and yields of organs, viscera, co-products, adipose deposits, and regional dishes. The objective of this study was to evaluate the effects of the inclusion of low-purity crude glycerin in the diet of feedlot goats on the weights and yields of the non-carcass constituents, frequently used in regional dishes, such as buchada and panelada.

Material and methods

All the experimental procedures performed in this study were approved by the Animal Use Ethics Committee in Research (CEUA-UFRPE), under the license number 059/16. The experiment was conducted in the Small Ruminants Sector of the Animal Science Department of the Federal Rural University of Pernambuco (UFRPE), located in the city of Recife, PE, Brazil, and situated at 8º04'03''S and 34º55'00''W (Köppen & Geiger, 1928). Forty castrated male goats were used, with breed undefined, and an average initial body weight of 19.70 ± 2.30 kg. They were kept in a shed with 1.0 × 1.8 m individual feeding and water pens provided. The experimental period lasted 86 days, 28 of which were for animal adaptation to the facilities, diet and handling, and 58 days were for evaluation and data collection (initial animal weights recorded, samples taken to determine the chemical composition of the diet).

The experimental treatments consisted of inclusion of crude glycerin (CG) at levels of 0, 6, 12, and 18% (based on DM). The diets were formulated to be isonitrogenized (14% CP/DM) and to meet the nutritional requirements of a goat with an average body weight of 25 kg and an estimated daily weight gain of 150 g day^{-1}, according to the recommendations of the National Research Council (NRC, 2007), and a roughage:concentrate proportion of 500:500 g kg^{-1}. The CG used in the diets was obtained from a biodiesel industry located in the city of Caetés, PE, Brazil, and it contained 20.7% water, 63.1% glycerol, 45.6% lipids, 5.9% ash, 0.3% sodium, and 3.7% methanol. The proportions of the ingredients and the chemical composition of the experimental diets are shown in Table 1.

Table 1. Proportion of ingredients and chemical composition of the experimental diets.

Item	Crude glycerin (% DM)			
	0	6	12	18
Ingredients (g kg^{-1} of DM)				
Tifton hay 85	499	499	499	499
Ground corn	380	318	256	195
Crude glycerin	0.0	60.0	120	180
Soybean meal	98.0	98.0	98.0	98.0
Urea/S[1]	5.0	7.0	9.0	10.0
Mineral Premix[2]	15.0	15.0	15.0	15.0
Calcitic limestone	3.0	3.0	3.0	3.0
Chemical composition (g kg^{-1} of DM)				
Dry matter (g kg^{-1} of NM)[3]	905	899	894	889
Organic matter	927	924	921	919
Crude protein	145	143	142	141
Ether extract	25.0	49.0	73.0	97.0
Neutral detergent fiber[4]	390	382	374	366
Non-fiber carbohydrates[4]	367	350	332	315
Metabolizable Energy (Mcal kg^{-1} DM)	2.72	2.95	2.93	2.98

[1]9 parts of urea and 1 part of Sulfur (S). [2]Assurance levels (nutrients kg^{-1}): 240 g of calcium; 20 g of sulfur; 71 g of phosphorus; 28,2 g of Potassium; 20 g of Magnesium; 400 mg of copper; 30 mg of cobalt; 10 mg of chromium; 2500 mg of Iron; maximum 710 mg of Fluorine; 40 mg of Iodine; 1350 mg of Manganese; 15 mg of selenium e 1700 mg of zinc. [3]g kg^{-1} natural matter; [4]Corrected for ash and protein.

After 86 days, the animals were solid-fasted for 16 hours and subsequently weighed to obtain the final body weight (FBW). At the time of slaughter, the animals were desensitized by brain concussion, followed by bleeding through the carotid and jugular vessels. The blood was collected in a container of known weight. After skinning and evisceration, the head (sectioned at the atlanto-occipital joint) and the feet (sectioned at the carpal and tarsometatarsal joints) were removed. The hot carcass weight (HCW) was recorded, including the kidneys and perirenal fat, which were removed and weighed after chilling of the carcasses for 24 hours. The gastrointestinal tract (GIT) was weighted, full and empty to obtain the empty body weight (EBW) (Cezar & Souza, 2007). The viscera were emptied and weighed to determine the yield of ingredients used in buchada and panelada.

The organs (tongue, trachea, lung, heart, liver, pancreas, diaphragm, spleen, testicle, penis, bladder, kidneys, and thymus), viscera (esophagus, rumen, reticulum, omasum abomasum, small intestine, and large intestine) and blood, head, feet, skin, omento, mesentery, internal fat and perirenal fat were considered as non-carcass components and were weighed.

The blood, liver, kidneys, lungs, spleen, tongue, heart, omentum, rumen, reticulum, omasum and small intestine constituted buchada (Medeiros et al., 2008), and panelada has the same components plus the head and feet (Clementino et al., 2007).

Data were submitted to analysis of variance and regression using the PROC GLM and PROC MIXED of the Statistical Analysis System (SAS, 2009) (version 9.4, SAS Institute Inc., Cary, NC), adopting 0.05 as the critical level for type I error. Dunnett's test was also applied in order to compare the means of the control group with those of the CG-containing treatments groups. The model used was:

$$Y_{ij} = \beta_0 + B_1 X_{ij} + T_i + \varepsilon_{ij},$$

where: Y_{ij} = observation j in treatment i, β_0 = intercept, B_1 = regression coefficient, X_{ij} = the covariable effect (initial body weight), T_i = fixed treatment effect i (i = 1 at 4), ε_{ij} = the experimental error.

Results and discussion

Gastrointestinal tract content (GTC) showed increasing linear behavior ($p < 0.05$); for every 1% increase of GB, GTC increased by 0.092 kg, and the goats that received 18% CG differed from the control treatment. EBW and HCW decreased linearly ($p < 0.05$), with reductions of 0.127 and 0.086 kg for every 1% increase of GB in the diet, respectively. The control treatment differed only from the 18% CG inclusion treatment (Table 2).

Goats fed higher CG concentrations had FBW similar to those without CG; however, they had lighter carcasses. Considering these results, it is possible to infer that CG was probably the most influential factor in the variation of carcass weights, since the higher GTC weights were observed in the animals that received higher levels of CG. Higher GTC with the CG diets may have occurred due to the high-fat content in these diets. According to Jenkins (1993), lipids added to ruminant diets can greatly disrupt fermentation in the rumen and promote high retention time of the digesta on GTC. However, according to AbuGhazaleh, Abo El-Nor & Ibrahim (2010), glycerol improves or does not negatively affect nutrient digestibility in the gastrointestinal tract.

The inclusion of CG in the diets did not influence ($p > 0.05$) the weights of the tongue, trachea, heart, liver, pancreas, diaphragm, testis, penis, bladder, kidneys, or thymus (Table 2).

These results can be attributed to morphological similarities and the environment in which these animals were kept during the experiment, contributing to data uniformity and final weight. According to Moreno et al. (2011), the yields of vital organs, such as the respiratory tract, brain, and heart, are not influenced by the composition of the diet, as these organs have priority in the utilization of nutrients, maintaining their integrity regardless of the nutritional status of the animals.

On the other hand, the liver and spleen have high metabolic rates and require further development to meet the demand for nutrient metabolism. Their respective sizes are related to the higher nutrients intake by the animal, especially energy and protein (Silva et al., 2016).

In this context, it is common for the weight of the liver and other highly metabolic organs, such as the heart and lungs to increase along with an increase in dietary energy intake (Medeiros et al., 2008; Fontenele, Pereira, Pimentel, & Mizubuti, 2010; Camilo et al., 2012). In contrast, Santos, Costa, Medeiros, Madruga and Gonzaga Neto (2005), working with sheep, observed that the weights of the heart and respiratory tract were maintained, because they had nutrient utilization priorities, regardless of feeding, but they also had early development.

Table 2. Effect of inclusion of crude glycerin on carcass weights, organ weights and relationships with other body components of goats in feedlot.

Item	Crude glycerin (%DM)				SEM[1]	P-value		
	0	6	12	18		L[2]	Q[3]	CXG[4]
IBW, kg	19.79	19.53	19.50	19.96	-	-	-	-
FBW, kg	25.46	23.32	23.61	24.28	0.686	0.3774	0.0671	0.2129
GTC, kg	4.28	3.99	4.55	5.61*	0.174	<.0001[a]	0.0023	<.0001
EBW, kg	21.11	19.30	19.04	18.64	0.584	0.0250[b]	0.3409	0.1024
HCW, kg	11.82	10.84	10.60	10.17*	0.324	0.0033[c]	0.4920	0.0217
Tongue, kg	0.08	0.08	0.08	0.08	0.002	0.3434	0.3463	0.5037
Trachea, kg	0.08	0.07	0.07	0.07	0.003	0.2083	0.3307	0.0982
Lung, kg	0.24	0.22	0.21	0.19	0.007	0.0067[d]	0.9015	0.0558
Heart, kg	0.10	0.10	0.09	0.09	0.003	0.1092	0.6681	0.4196
Liver, kg	0.43	0.36	0.36	0.36	0.017	0.0728	0.1482	0.1402
Pancreas, kg	0.05	0.04	0.04	0.05	0.002	0.7356	0.1794	0.3991
Diaphragm, kg	0.08	0.07	0.07	0.08	0.003	0.6467	0.0790	0.3314
Spleen, kg	0.05	0.04*	0.04*	0.03*	0.002	0.0023[e]	0.0942	0.0046
Testicle, kg	0.05	0.05	0.04	0.04	0.003	0.1114	0.3997	0.0657
Penis, kg	0.05	0.04	0.05	0.04	0.003	0.4001	0.9282	0.7516
Bladder, kg	0.03	0.03	0.03	0.03	0.001	1.0000	0.7210	0.4476
Kidneys, kg	0.08	0.07	0.007	0.07	0.003	0.1762	0.1752	0.2963
Thymus, kg	0.03	0.03	0.03	0.03	0.002	0.7914	0.5550	0.5834
TWO, kg	1.33	1.17	1.13*	1.15*	0.039	0.0184[f]	0.1097	0.0449
TWO:FBW, %	5.23	5.01	4.80*	4.73*	0.050	<.0001[g]	0.3924	0.0006
TWO: EBW, %	6.31	6.06	5.96	6.15	0.056	0.2513	0.0516	0.1584

IBW = initial body weight; FBW = final body weight; GTC = gastrointestinal tract content; EBW= empty body weight; HCW= hot carcass weight. [1]SEM = standard error mean; TWO = total weight of organ; EBW= empty body weight. [1]SEM = standard error mean; [2]L = linear effect; [3]Q = quadratic effect; [4]CXG = contrast between control x levels of crude glycerin. Values differ statistically from the control treatment by Dunnett test at p < 0.05. [a]$\hat{Y}$ = 4.262 – 0.092GB; R^2 = 0.99; [b]$\hat{Y}$ = 20.673 – 0.127GB; R^2 = 0.82; [c]$\hat{Y}$ = 11.636 – 0.086GB; R^2 = 0.91; [d]$\hat{Y}$ = 0.238 – 0.002GB; R^2 = 0.99; [e]$\hat{Y}$ = 0.046 – 0.0007GB; R^2=0.90; [f]$\hat{Y}$ = 1.288 – 0.010GB; R^2= 0.68; [g]$\hat{Y}$ = 5.196 – 0.028GB; R^2= 0.95. R^2 = determination coefficient.

Corroborating this finding, Medeiros et al. (2008) evaluated the effect of concentrate levels on the non-carcass components of Morada Nova sheep. They observed a linear increase in liver and gallbladder weights with an increase in the level of concentrate in the diet, which did not occur with other organs (lungs + trachea, heart, spleen, pancreas, diaphragm, reproductive system, thymus and kidneys), proving that these organs are more related to body weight and maturity of the animals.

The weights of the lungs, spleen, total weight of organs (TWO), and the TWO yield as a function of FBW, decreased linearly (p < 0.05) with CG addition. Also, treatments with 12% and 18% CG provided lower TWO and TWO yield as a function of FBW than those obtained in the control treatments and the 6% CG group. According to Silva et al. (2019), the spleen is influenced by the feed intake and, consequently, the blood quantity. After ingestion, feed goes through various physical and chemical processes along the gastrointestinal tract, allowing the degradation of the more complex structures. After this transformation, the smaller particles are easily absorbed into the bloodstream, and all nutrients are transported through the blood with greater efficiency.

In this way, an increase in flow through the venous system directly affects the liver, which is responsible for the processing of nutrients that will be converted into other products. Nutrient conversion in the liver is a consequence of digestion and the nutrient absorption processes, and it is influenced by diet composition and blood flow (Kozloski, 2016). Thus, although the treatment did not affect the liver and heart weights, there was an effect on the spleen, blood, and, consequently, TWO.

The weight of the rumen showed a quadratic effect with the lowest value (0.37kg) estimated by the regression equation for diets containing 9.55% glycerin. Similar behavior was observed for the reticulum, with a minimum point of 0.08 kg, at the level of 8.93% CG (Table 3).

The similar weights in some of the non-carcass components may be explained by the fact that the animals were the same sex and were slaughtered with similar weights and ages, since the FBW was not influenced. According to Moreno et al. (2011), animals with similar weights show equivalence in the weights of the non-carcass components. However, according to Jenkins (1993), several factors can influence the weight of the organs and viscera of the animal, such as diet changes, which alters the intake and digestibility of feed. Thus, it is believed that the energy (2.98 Mcal/kg DM) and protein (141 g kg⁻¹) density of the diets may have contributed to the greater reticulum development when higher levels of GB were included in the goat diet.

Table 3. Effect of inclusion of crude glycerin on viscera weights, weights of co-products and adipocyte deposits and relationships with other body components of goats in feedlot.

Item	Crude glycerin (%DM)				SEM[1]	P-value		
	0	6	12	18		L[2]	Q[3]	CXG[4]
Esophagus, kg	0.05	0.05	0.04	0.05	0.002	0.4192	0.5543	0.7820
Rumen, kg	0.45	0.38	0.39	0.43	0.016	0.6404	0.0284[a]	0.1543
Reticulum, kg	0.10	0.08	0.08	0.10	0.003	0.9322	0.0042[b]	0.0373
Omasum, kg	0.07	0.07	0.07	0.07	0.003	0.9107	0.3609	0.8049
Abomasu, kg	0.13	0.10	0.10	0.10	0.006	0.0944	0.0597	0.0884
Small intestine, kg	0.43	0.38	0.40	0.38	0.012	0.1566	0.4301	0.3058
Large intestine, kg	0.25	0.21	0.20	0.20	0.010	0.0534	0.3008	0.1783
TWV, kg	1.48	1.26	1.27	1.33	0.043	0.1347	0.0410[c]	0.0836
TWV:FBW, %	5.80	5.42	5.39	5.49	0.066	0.0985	0.0576	0.0946
TWV:EBW, %	7.01	6.56	6.69	7.15	0.094	0.4675	0.0126[d]	0.0738
Blood, kg	0.97	0.83*	0.75*	0.81*	0.030	0.0032	0.0123[e]	0.0015
Skin, kg	1.56	1.50	1.55	1.48	0.044	0.5115	0.9879	0.8611
Feet, kg	0.76	0.71	0.69	0.67	0.019	0.0085[f]	0.6032	0.0644
Head, kg	1.56	1.49	1.47	1.54	0.033	0.8397	0.1077	0.1720
TWBP, kg	4.85	4.53	4.45	4.50	0.115	0.0944	0.2061	0.2187
TWBP:FBW, %	19.29	19.54	18.91	18.61	0.194	0.1196	0.4715	0.3234
TWBP:EBW, %	23.32	23.64	23.49	24.20	0.239	0.2362	0.6794	0.5703
Omentum, kg	0.57	0.59	0.51	0.50	0.038	0.2984	0.8111	0.6823
Mesentery, kg	0.29	0.25	0.22	0.22	0.018	0.1074	0.5590	0.3914
Internal Fat, kg	0.16	0.16	0.13	0.14	0.009	0.0539	0.3458	0.4412
Perirenal fat, kg	0.29	0.27	0.31	0.21	0.022	0.3447	0.3167	0.3914
TWDA, kg	1.31	1.27	1.16	1.08	0.076	0.1574	0.8478	0.5467
TWDA:FBW, %	4.99	5.30	4.77	4.41	0.224	0.2474	0.4440	0.5309
TWDA:EBW, %	6.01	6.40	5.90	5.71	0.262	0.5440	0.5764	0.8124

TWV = total weight of viscera; FBW = final body weight; TWBP = total weight of by-products; EBW= empty body weight; PTDA = total weight of adipocyte deposits. [1]SEM = standard error mean; [2]L = linear effect; [3]Q = quadratic effect; [4]CXG = contrast between control x levels of crude glycerin. Values differ statistically from the control treatment by Dunnett test at p < 0.05. [a]$\hat{Y} = 0.449 - 0.015GB + 0.0007GB2; R^2 = 0.96$; [b] $\hat{Y} = 0.099 - 0.003GB + 0.0002GB2; R^2 = 0.99$; [c]$\hat{Y} = 1.475 - 0.042GB + 0.001GB2; R^2 = 0.94$; [d]$\hat{Y} = 6.996 - 0.105GB + 0.006GB2; R^2 = 0.98$; [e]$\hat{Y} = 0.977 - 0.034GB + 0.001GB2; ; R^2 = 0.98$; [f] $\hat{Y} = 0.752 - 0.005GB; R^2 = 0.94$. R^2 = determination coefficient.

The replacement of corn with crude glycerin in the diet affected the TWV, promoting a quadratic effect, with an estimated maximum TWV of 1.24 kg, at 10.96% CG. The same behavior was observed for the TWV yield as a function of the EBW, decreasing at the level of 8.25% CG, with a value of 6.54 kg. It is worth noting that in relation to the viscera yield, due to the EBW, the results show that when FBW and EBW were compared, the latter showed a higher absolute value, since it does not consider the GTC, which, according to some authors, can vary from 10% to 20% of the BW, according to the feeding system.

The weights of the esophagus, rumen, omasum, abomasum, and small and large intestines were not affected (p > 0.05) by the inclusion of CG. It was observed that the blood weight was influenced quadratically (p < 0.05), with the lowest value (0.75 kg) estimated by the regression equation for diets containing 15% CG. Blood weight was greater in the treatment without CG, when compared to the other treatments (Table 3). The similar rumen, omasum and abomasum weights may mean the energy and digestibility of the diet was not a limit for the animals. According to Moreno et al. (2011), low diets energy and digestibility result in more feed retention time, and consequentially more developed for these organs.

CG levels in the diet did not influence the goats' skin weight (p > 0.05). The use of the non-carcass components contributes to increased values obtained per animal; for example, the skin can represent 10% to 12% of this value in the skin processing market (Costa, et al., 2018). The inclusion of CG reduced the weight of the feet (p < 0.05). The head weight showed a quadratic effect, with the lowest value of 1.41 kg estimated by the regression equation for diets containing 14.35% CG.

Regarding fat deposits, there was no influence of treatments (p > 0.05) on the mesentery, omentum, or internal and perirenal fat. A change in the fat deposits of the animals fed with CG was expected. In the literature consulted, it has been reported that the inclusion of CG in the diet of ruminants can modify the formation of fatty acids in the rumen, favoring the production of propionate in relation to acetate (Benedeti et al., 2015). According to Kozloski (2002), the increase in the concentration of propionic acid in the rumen results in a greater availability of energy in the form of glucose, which favors lipogenesis and consequent deposition of internal and visceral fat. However, in the present study, the inclusion of CG did not promote differences in the deposition of fat in the mesentery, omentum, or internal and perirenal fat, indicating that the lipogenesis in these tissues was similar.

Carvalho et al. (2015), in research with feedlot lambs fed 0, 7.5, 15, 22.5, and 30% CG, also found no influence on omental, mesenteric, and perirenal fat or organs such as the heart, kidneys, and pancreas; however, the liver was influenced.

The weights and yields of the buchada showed a decreasing linear effect (p <0.05), declining 0.025 kg and 0.066% for each additional 1% inclusion of glycerin, respectively. Similar behavior was observed in the panelada weights and yields, with each additional 1% glycerin inclusion leading to reductions of 0.031 kg and 0.080%, respectively. The treatments with 12% and 18% of CG provided lower yields of the buchada and panelada when compared to the control treatment (Table 4). It can be inferred that these results followed the same behavior observed with the weights of the components (organs, viscera and co-products) of the regional dishes.

Table 4. Effect of the inclusion of crude glycerin on weights and yields of regional dishes of goats in feedlot.

Item	Crude glycerin (%DM)					P-value		
	0	6	12	18	SEM[1]	L[2]	Q[3]	CXG[4]
Buchada, kg	3.57	3.18	3.02	3.12	0.114	0.0411[a]	0.1313	0.0946
Buchada, %	13.93	13.51	12.68*	12.89*	0.158	0.0033[b]	0.2663	0.0124
Panelada, kg	5.89	5.38	5.18	5.33	0.159	0.0481[c]	0.1184	0.0994
Panelada, %	23.22	23.05	21.89*	22.00*	0.141	<.0001[d]	0.5252	<.0001

[1]SEM = standard error mean; [2]L = linear effect; [3]Q = quadratic effect; [4]CXG = contrast between control x levels of crude glycerin. [4]CXG = contrast between control x levels of crude glycerin. Values differ statistically from the control treatment by Dunnett test at $p < 0.05$. [a]$\hat{Y} = 3.451 - 0.025GB$; $R^2 = 0.65$; [b]$\hat{Y} = 13.847 - 0.066GB$; $R^2 = 0.79$; [c]$\hat{Y} = 5.731 - 0.031GB$; $R^2 = 0.62$; [d]$\hat{Y} = 23.262 - 0.080GB$; $R^2 = 0.81$. R^2 = determination coefficient.

The average bunchada weights was 3.22 kg and the yield 13.25%. Medeiros et al. (2008) and Pinto et al. (2011) observed buchada weights for sheep of the Morada Nova and Santa Inês breeds of 4.72 kg and 5.84 kg and yields of 15.26% and 17.70%, respectively; these values are larger than those found in this study. Clementino et al. (2007), evaluating concentrate levels in the sheep diet, obtained buchada weights of 3.36 kg and a yield of 15%, while the panelada weights was 5.81 kg with a yield of 24.06%.

According to Cruz et al. (2014), the maximum substitution level of corn for glycerin, without an effect on animal performance, is dependent on factors such glycerin quality. The CG quality can be affected by the production process, resulting in a high methanol content. According to the Food and Drug Administration (FDA, 2006), glycerin is safe to use, and it is recognized component of animal feed. The methanol content of glycerin should not exceed 150 mg kg^{-1}; this value was higher in the present study. However, the health risk associated with methanol intake does not apply to ruminant animals, as methanol is naturally produced in the rumen as a result of pectin fermentation (Pol & Demeyer,1988). Lage et al. (2010) worked with CG with high methanol content (8.66%) and found no problems related to intoxication in lambs fed diets containing up to 12% CG.

The importance of non-carcass components is not only related to increasing the economic return from the marketing of goat products, but also to recover raw materials that are lost and that could improve of the nutritional level of populations (Fontenele et al., 2010). In small ruminant production systems, the use of non-carcass components is more important than in other animal production systems, since many culinary dishes are prepared with the organs of these species and can generate a source of income for the producer (Cezar & Sousa, 2007).

The use of CG instead of corn is important, especially during periods of forage shortage. During these times, corn becomes more expensive, leading to a higher cost of finishing goats in a feedlot, especially in semi-arid regions of Brazil (Benedeti et al., 2016). Thus, CG is an economically viable alternative that helps to reduce the amount of waste discarded in the environment.

Conclusion

Low-purity crude glycerin containing 63% glycerol may partially replace corn and be included in up to 6% of the dry matter of the finished goats' feedlot diet without negatively influencing the weights and yields of organs, viscera, and regional dishes, such as buchada and panelada.

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References

AbuGhazaleh, A. A., Abo El-Nor, S., & Ibrahim, S. A. (2010). The effect of replacing corn with glycerol on ruminal bacteria in continuous culture fermenters. *Journal of Animal Physiology and Animal Nutrition, 95*(3), 313-319. doi: 10.1111/j.1439-0396.2010.01056.x

Batista, N. L., & Souza, B. B. (2015). Caprinovinocultura no semiárido brasileiro - fatores limitantes e ações de mitigação. *Agropecuária Científica no Semiárido*, *11*(2), 01-09. doi: 10.30969/acsa.v11i1.522.

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), e0148224. doi: 10.1371/journal.pone.0148224

Benedeti, P. D. B., Silva, L. G., Paula, E. M., Shenkoru, T., Marcondes, M. I., Monteiro, H. F., ... Faciola, A. P. (2015). Effects of Partial Replacement of Corn with Glycerin on Ruminal Fermentation in a Dual-Flow Continuous Culture System. *PLoS One 10*(11), e0143201. doi: 10.1371/journal.pone.0143201

Brasil, L., Queiroz, A., Silva, J., Bezerra, T., Arcanjo, N., Magnani, M., ... Madruga, M. (2014). Microbiological and nutritional quality of the goat meat by-product "sarapatel". *Molecules*, *19*(1), 1047-1059. doi: 10.3390/molecules19011047

Camilo, D. A., Pereira, E. S., Pimentel, P. G., Costa, M. R. G. F., Mizubuti, I. Y., Ribeiro, E. L. A., ... Moreno, G. M. B. (2012). Peso e rendimento dos componentes não-carcaça de ovinos Morada Nova alimentados com diferentes níveis de energia metabolizável. *Semina: Ciências Agrárias, 33*(6), 2429-2440. doi: 10.5433/1679-0359.2012v33n6p2429

Carvalho, V. B., Leite, R. F., Almeida, M. T. C., Paschoaloto, J. R., Carvalho, E. B., Lanna, D. P. D., ... Ezequiel, J. M. B. (2015). Carcass characteristics and meat quality of lambs fed high concentrations of crude glycerin in low-starch diets. *Meat Science, 110*, 285-292. doi: 10.1016/j.meatsci.2015.08.001

Cezar, M. F., & Sousa, W. H. (2007). *Carcaças ovinas e caprinas: obtenção, avaliação e classificação.* Uberaba, MG: Editora Agropecuária Tropical.

Clementino, R. H., Souza, W. H., Medeiros, A. N., Cunha, M. G. G., Neto, S. G., Carvalho, F. F. R., & Cavalcante, M. A. B. (2007). Influência dos níveis de concentrado sobre os cortes comerciais. os constituintes não carcaça e os componentes da perna de cordeiros confinados. *Revista Brasileira Zootecnia, 36*(3), 681-688. doi: 10.1590/S1516-35982007000300023

Costa, H. H. A., Saliba, E. O. S., Galvani, D. B., Landim, A. V., Lima, L. D., Borges, A. L. C. C., ... Silva, F. A. (2018). Efeito da suplementação com sulfato de zinco ou propilenoglicol em ovinos em uma pastagem nativa da Caatinga no período chuvoso: desempenho, características da carcaça e da carne. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 70*(3), 993-1003. doi: 10.1590/1678-4162-8998

Cruz, O. T. B., Valero, M. V., Zawadzki, F., Rivaroli, D. C., Prado, R. M., Lima, B. S., & Prado, I. N. (2014). Effect of glycerine and essential oils (*Anacardium occidentale* and *Ricinus communis*) on animal performance, feed efficiency and carcass characteristics of crossbred bulls finished in a feedlot system. *Italian Journal of Animal Science, 13*(4), 3492. doi: 10.4081/ijas.2014.3492

Eiras, C. E., Barbosa, L. P., Marques, J. A., Lima, B. S., Zawadzki, F., Perotto, D., & Prado, I. N. (2014). Glycerine levels in the diets of crossbred bulls finished in feedlot: apparent digestibility, feed intake and animal performance. *Animal Feed Science and Technology, 197*, 222-226. doi: 10.1016/j.anifeedsci.2014.07.004

Food and Drug Administration [FDA] (2006). *Code of Federal Regulations, Title 21-Food and Drugs*. Retrieved from http://edocket.access.gpo.gov/cfr_2002/aprqtr/21cfr582.1320.htm

Fontenele, R. M., Pereira, E. S., Pimentel, P. G., & Mizubuti, I. Y. (2010). Níveis de energia metabolizável em rações de ovinos Santa Inês: peso dos órgãos internos e do trato digestório. *Semina: Ciências Agrárias, 31*(4), 1095-1104. doi: 10.5433/1679-0359.2010v31n4p1095

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. *Journal of Animal Science, 91*(8), 3875-3880. doi: 10.2527/jas.2012-596 5944

Jenkins, T. C. (1993). Lipid metabolism in the rumen. *Journal of Dairy Science, 76*(12), 3851-3863. doi: 10.3168/jds.S0022-0302(93)77727-9.

Köppen, W., & Geiger, R. (1928). *Klimate der Erde.* Gotha, AL: Verlag Justus Perthes.

Kosloski, G. V. (2002). *Bioquímica dos ruminantes* (2a ed.). Santa Maria, RS: Revista ampliada.

Kozloski, G. V. (2016). *Bioquímica dos ruminantes* (3a ed.). Santa Maria, RS: Revista ampliada.

Lage, J. F., Vito, E. S., Reis, R. A., Delevatti, L. M., Pierre, N. S., & Berchielli, T. T. (2017). Ruminal fermentation of Nellore steers fed crude glycerine replacing starch vs. fibre-based energy ingredient in low or high concentrate diets. *Acta Scientiarum. Animal Sciences, 39*(1), 57-64. doi: 10.4025/actascianimsci.v39i1.32895

Lage, J. F., Paulino, P. V. R., Pereira, L. G. R., Valadares Filho, S. C., Oliveira, A. S., Detmann, E., ... Lima, J. C. M. (2010). Glicerina bruta na dieta de cordeiros terminados em confinamento. *Pesquisa Agropecuária Brasileira, 45*(9), 1012-1020. doi: 10.1590/S0100-204X2010000900011

Mach, N., Bach, A., & Devant, M. (2009). Effects of crude glycerin supplementation on performance and meat quality of Holstein bulls fed high-concentrate diets. *Journal of Animal Science, 87*(2), 632-638. doi: 10.2527/jas.2008-0987

Medeiros, G. R., Carvalho, F. F. R., Ferreira, M. A., Alves, K. S., Mattos, C. W., Saraiva, T. A., & Nascimento, J. F. (2008). Efeito dos níveis de concentrado sobre os componentes não carcaça de ovinos Morada Nova em confinamento. *Revista Brasileira de Zootecnia*, *37*(6), 1063-1071. doi: 10.1590/S1516-35982008000600017

Moreno, G. M. B., Silva Sobrinho, A. G., Leão, A. G., Perez, H. L., Loureiro, C. M. B., & Pereira, G. T. (2011). Non-carcass components yield of lambs fed corn silage or sugar cane under two levels of concentrate. *Revista Brasileira de Zootecnia, 40*(12), 2878-2885. doi: 10.1590/S1516-35982011001200035

National Research Council [NRC]. (2007). *Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids.* Washington, DC: National Academy Press.

Ockerman, H. W., & Basu, L. (2004). Carcass chilling and boning. In W.K. Jensen (Ed.), *Encyclopedia of meat sciences,* Oxford, MS: Elsevier.

Parsons, G. L., Shelor, M. K., & Drouillard, J. S. (2009). Performance and carcass traits of finishing heifers fed crude glycerin. *Journal of Animal Science, 87*(2), 653-657. doi: 10.2527/jas.2008-1053.

Pol, A., & Demeyer, D. I. (1988). Fermentation of methanol in the sheep rumen. *Applied and Environmental Microbiology, 54*(3), 832-834.

Pinto, T. F., Costa, R. G., Medeiros, N. A., Medeiros, G. R., Azevedo, P. S., Oliveira, R. L., & Treviño, I. H. (2011). Use of cactus pear (*Opuntia fícus indica*, Mill) replacing corn on carcass characteristics and non-carcass components in Santa Inês lambs. *Revista Brasileira Zootecnia, 40*(6), 1333-1338. doi: 10.1590/S1516-35982011000600023

Queiroz, A. L. M., Brasil, L. M. S., Silva, J., Magnani, M., Souza, E. L., & Madruga, M. S. (2013). Microbiological and nutritional quality of "buchada caprina", an edible goat meat by-product. *Small Ruminant Research, 115*, 62-66. doi: 10.1016/j.smallrumres.2013.08.006

Statistical Analysis System [SAS]. (2009). *SAS/STAT: user's guide. Version 9.2.* Cary, NC: SAS Institute.

Santos, N. M., Costa, R. G., Medeiros, A. N., Madruga, M. S., & Gonzaga Neto, S. (2005). Caracterização dos componentes comestíveis não constituintes da carcaça de caprinos e ovinos. *Agropecuária Técnica, 26*(2), 77-85.

Silva, D. G., Macedo, V. P., Silveira, M. F., Fluck, A. C., Costa, O. A. D., Piran Filho, F.A., ... Franzosi, P. (2019) Non-carcass component yield of lambs finished in distinct production systems. *Semina: Ciências Agrárias, 40*(3), 1215-1224. doi: 10.5433/1679-0359.2019v40n3p1215

Silva, U. L., Pereira Filho, J. M., Bandeira, P. A. V., Cordão, M. A., Ferreira, R. C. & Ramos, J. M. (2016) Carcass and non-carcass componentes of lambs fed with Cenchrus ciliares and Mimosa tenuiflora. *Revista Brasileira de Ciências Agrárias, 11*(4), 381-387. doi: 10.5039/agraria.v11i4a5398

Singh, S. P., Dass, G., Natesan, R., Kushwah, Y., Sharma, N., & Kumar, A. (2018). Endocrine and hematobiochemical profile of lambs raised in a semiarid region with different growth potentials during the postweaning period. *Turkish Journal of Veterinary and Animal Sciences, 42*, 120-129. Doi:10.3906/vet-1709-38

Toldrá, F., Aristoy, M. C., Mora, L., & Reig, M. (2012). Innovations in valueaddition of edible meat by products. *Meat Science, 92*(3), 290-296. doi: 10.1016/j.meatsci.2012.04.004