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Performance, carcass characteristics, and meat quality of lambs fed diets containing crude glycerin

Desempenho, características de carcaça e qualidade da carne de cordeiros alimentados com dietas contendo glicerina bruta

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Highlights

Crude glycerin can be successfully used in feedlot lamb diets.
The inclusion of up to 8% crude glycerin improves carcass characteristics and meat quality.
The inclusion of up to 15% crude glycerin in diet don't affect its performance.

Abstract

The aim of this study was to evaluate the effects of four crude glycerin levels in the diet of feedlot lambs on performance, carcass characteristics, and meat quality. Forty three-month-old crossbred Santa Inês x Dorper lambs weighing 18.2 ± 0.169 kg were used in a completely randomized design, with four diets and 10 replicates per diet. The animals were housed in individual pens. The trial period (42 days) was preceded by 14 days of adaptation to handling and diet. Final body weight (FBW), empty body weight (EBW), average daily weight gain, feed conversion, and feed efficiency did not differ with crude glycerin levels in the diet. Nutrient intake (dry matter (DM), ether extract (EE), crude protein (CP), and neutral detergent fiber (NDF)) did not differ depending on crude glycerin levels. In the evaluation of carcass characteristics, there was a quadratic effect due to crude glycerin levels on hot carcass yield (maximum point- maxP = 9.73%), leg perimeter (maxP = 9.45%), fat thickness (maxP = 7.41%), and leg weight (maxP = 8.69%). Loin weight and conformation showed a linear increase as a function of crude glycerin levels. The other studied variables were not affected by crude glycerin levels in the diet. In the non-carcass components, the full gastrointestinal tract, mesenteric fat, omental, and perirenal fat were not influenced

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by crude glycerin levels. Regarding meat quality, no effects were observed on the parameters evaluated in the longissimus dorsi. The addition of up to 15% crude glycerin in the lamb's diet does not affect its performance, however, the addition of up to 8% improves carcass characteristics and maintains meat quality.
Key words: Glycerol. Nutrition. Ruminants. Weight gain.

Resumo

O objetivo deste estudo foi avaliar os efeitos de quatro níveis de glicerina bruta na dieta de cordeiros confinados sobre o desempenho, características de carcaça e qualidade da carne. Foram utilizados 40 cordeiros mestiços Dorper x Santa Inês com três meses de idade e peso corporal médio de 18,2 ± 0,169 kg, distribuídos em delineamento inteiramente casualizado, com quatro dietas e 10 repetições por dieta. Os animais foram alojados em baias individuais. O período experimental (42 dias) foi precedido de 14 dias de adaptação ao manejo e às dietas. O peso corporal final, peso de corpo vazio, ganho de peso médio diário, conversão alimentar e eficiência alimentar não diferiram com os níveis de glicerina bruta na dieta. O consumo de nutrientes (matéria seca, extrato etéreo, proteína bruta e fibra em detergente neutro) não diferiu em função dos teores de glicerina bruta. Na avaliação das características de carcaça, houve efeito quadrático devido aos níveis de glicerina bruta sobre o rendimento de carcaça quente (ponto máximo-maxP = 9,73%), perímetro da perna (maxP = 9,45%), espessura de gordura (maxP = 7,41%) e o peso da perna (maxP = 8,69%). O peso do lombo e a conformação apresentaram aumento linear em função dos teores de glicerina bruta. As demais variáveis estudadas não foram afetadas pelos níveis de glicerina bruta na dieta. Nos componentes não carcaça, verificou-se que o sistema gastrointestinal completo, gordura mesentérica, omental e gordura perirrenal não foram influenciados pelos níveis de glicerina bruta. Na qualidade da carne, não foi observado efeito nos parâmetros avaliados no longissimus dorsi. A inclusão de até 15% de glicerina bruta na dieta do cordeiro não afeta seu desempenho, porém a inclusão de até 8% melhora as características da carcaça e mantém a qualidade da carne.
Palavras-chave: Ganho de peso. Glicerol. Nutrição. Ruminantes.

Introduction

Sheep farming is a major economic activity, but has low productivity rates, which are mainly governed by the seasonality of food production and nutritional management, resulting in long production cycles associated with short periods of meat supply. The productive performance of a herd depends on the availability of food in adequate proportions and quantities (NRC, 2007).

Given the demand for economically viable and highly nutritious feed products, the search for food components with nutrients that meet animal requirements at lower costs has increased. Therefore, it is necessary to develop unconventional food ingredients that can be used for animal nutrition. The use of agro-industrial by-products such as glycerin is an alternative for meeting the needs of animals and reducing feed costs (Yang et al., 2021).

Crude glycerin is a by-product of biodiesel production that contains 6.32% moisture, 1.33% ether extract (EE), 2.93% ash (Zacaroni & Souto, 2019), and metabolizable energy estimated as 3.47 Mcal/kg of dry matter (DM) for ruminants (Mach et al., 2009). It serves as an alternative source of energy for ruminants (Ramos & Kerley, 2012). According to Schröder and Sudekum (1999), glycerin is composed of glycerol and depending on the percentage present in glycerin, it can be classified as low purity (70%), medium purity (80 to 90%), and high purity (99 %). When ingested, it can be fermented in the rumen to propionate or absorbed by the ruminal epithelium, and then converted to glucose by the gluconeogenic pathway (L. G. Silva et al., 2014).

The metabolism of glycerol in the rumen and liver can increase the concentration of serum glucose, reducing the time to achieve satiety, and consequently alter DM intake (Lage et al., 2010). In addition, the rapid conversion of glycerol into propionate in the rumen results in a reduction of acetate:propionate ratios, influencing the deposition of body fat (Gunn et al., 2010).

The gluconeogenic potential of glycerol can considerably contribute to daily weight gain, feed conversion, and the quantitative and qualitative characteristics of the carcass, which is directly related to the quality and quantity of the final product and is essential for the conquest and expansion of consumer markets (Costa et al., 2019). Therefore, careful evaluation of carcasses is necessary to meet the quantity and quality requirements of the consumer market.

Given the supply and characteristics of crude glycerin, its use in lamb feed may be an alternative that can wholly or partially replace conventional foods, such as corn, in periods of shortage or high prices. This study evaluates the effects of four levels of crude glycerin in feedlot lamb diets on their performance, carcass characteristics, and meat quality.

Material and Methods

The experiment was carried out at the Experimental farm, of the State University of Londrina, Paraná, Brazil, after the project had been approved by the Research Ethics Committee under protocol number CEEA 60/2010.

Animals, experimental design, and experimental diets

Forty crossbred male Dorper x Santa Ines lambs weighing 18.2 ± 0.17 kg, were used in a completely randomized design (four diets and 10 replicates per diet). They were housed in individual pens (0.80 × 1.20 m) inside a masonry shed and provided with feeders and drinking fountains. All animals were dewormed according to commercial product indications.

The experimental period (42 days) was preceded by 14 days of adaptation to management and diet. The animals were weighed every 14 days from the beginning of the experiment. The treatments consisted of four levels (0%, 5%, 10%, and 15%, based on DM) of crude glycerin in the diet (Tables 1 and 2).

Table 1
Chemical composition of the food components of experimental diets in feeding feedlot lambs

Ingredients	DM	CP	TDN	EE	NDF	ADF	Glycerol	Methanol
	%NM	%DM					%NM	
Hay (*Brachiaria dyctioneura*)	87.72	2.12	53.36	1.62	74.50	40.5	-	-
Ground corn	88.63	8.53	86.96	3.01	14.42	2.50	-	-
Soybean meal	88.98	45.20	85.71	4.13	11.01	4.1	-	-
Urea	99.99	280.98	-	-	-	-	-	-
Mineral salt	99.98	3.00	10.00	-	-	-	-	-
Crude glycerin	85.52	-	93.4	-	-	-	68.66	4.54

DM = Dry Matter; CP = Crude Protein, TDN = Total Digestible Nutrients; EE = Ether Extract; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; NM=Natural Matter.

Table 2
Chemical composition of ingredients and experimental diets (% in DM)

Composition %	Levels of Glycerin			
	0	5	10	15
Ingredients (% in DM)				
Hay (*Brachiaria dyctioneura*)	50.00	50.00	50.00	50.00
Ground corn	26.00	20.00	13.00	0.00
Soybean meal	22.00	23.00	25.00	33.00
Urea	1.00	1.00	1.00	0.00
Mineral Supplement	1.00	1.00	1.00	2.00
Crude glycerin	0	5	10	15
Total	100	100	100	100
Calculated values (% in DM)				
Dry matter (% in NM)	88.47	88.32	88.17	88.05
Crude protein	16.03	16.00	16.30	16.00
Neutral detergent fiber	43.42	42.66	41.87	40.88
Acid detergent fiber	21.80	21.69	21.60	21.60
Ether extract	2.50	2.36	2.23	2.17
Total digestible nutrients	68.24	68.55	68.85	69.17
Organic matter	94.31	94.44	94.54	94.45
Total carbohydrates	75.78	76.11	76.03	76.30

NM=Natural Matter; DM=Dry matter.

The chemical composition of the ingredients used in the formulation of the diets was determined in the Laboratory of Animal Nutrition, according to the methodology described by Association of Official Analytical of Chemists [AOAC] (2016). All diets were formulated to meet the nutrient requirements of early maturity lambs with a daily gain of 200 g kg^{-1} (National Research Council [NRC], 2007), and consisted of four levels of crude glycerin (0%, 5%, 10%, and 15%, based on DM) (Tables 1 and 2). The following ingredients were used: *Brachiaria dyctioneura* hay as roughage, ground corn, soybean meal, urea, mineral salt, and 0%, 5%, 10%, and 15% glycerin. The complete diet offered to the animals was composed of 50% roughage and 50% concentrate, on a DM basis (Table 1).

The levels of total carbohydrates (TC) were calculated according to recommendations of Sniffen et al. (1992): TC = 100 - (%CP + %EE + %Ash). The total digestible nutrients (TDN) of hay (*Brachiaria dyctioneura*), ground corn, and soybean meal used to balance the diets were estimated using the equation proposed by Patterson et al. (2000): TDN = [88.9 - (0.779 × acid detergent fiber (ADF)%)].

The commercial mineral supplementation contained the following guaranteed levels: calcium, 135 g; phosphorus, 65 g; sodium, 107 g; sulfur, 12 g; magnesium, 6,000 mg; cobalt, 175 mg; copper, 100 mg; iodine, 175 mg; manganese, 1,440 mg; selenium, 27 mg; zinc, 6,000 mg; iron, 1,000 mg; fluorine, 650 mg; crude protein (CP), 30 g; and TDN, 100 g.

Nutrients intake, performance, and carcass quality

The total diet was provided *ad libitum,* twice a day, at 07:30 and 16:30. Leftovers were weighed and sampled to determine their daily intake. During the collection period, samples of the diets were supplied and the leftovers were removed to prepare composite samples per animal, which were packed in properly identified plastic bags and stored in a freezer for later analysis.

Analyses of DM, mineral matter (MM), CP, EE, neutral detergent fiber (NDF), and ADF were conducted at the Animal Nutrition Laboratory of the State University of Londrina, according to methodologies described by AOAC (2016). The levels of TC were calculated according to recommendations of Sniffen et al. (1992): TC = 100 - (%CP + %EE + %Ashes).

At the end of the experimental period, the animals were weighed after a solid fasting period of 16 hours to obtain their final body weight (FBW). At the time of slaughter, the animals were desensitized with electronarcosis, followed by bleeding, skinning, and evisceration. After slaughter, the contents of the gastrointestinal tract were removed to determine empty body weight (EBW). Hot carcass weight (HCW) was obtained after evisceration and removal of the non-carcass components. True yield (TY) was determined using the following formula: TY (%) = HCW/EBW × 100. The quantitative carcass characteristics were determined according to the methodology described by L. F. Silva and Pires (2000).

Carcasses were kept in a cold room for 24 hours at 4 °C. Subsequently, they were weighed to determine the cold carcass weight, and the loss by cooling (LC) was calculated, where LC (%) = (HCW-FBW) × 100/HCW (Osório & Osório, 2005). The fat that surrounds the digestive system was separated and weighed. It included omental (rumen, reticulum, abomasum, and omasum), mesenteric (small and large intestine), and perirenal fat (kidney fat) (Cezar & Sousa, 2007).

Carcass composition was evaluated according to the methodology of Luchiari (2000), and the carcasses were classified according to the muscle in relation to the size of the skeletal, as described by Cezar and Sousa (2007). Both were evaluated using photographic standards.

A cross section cut was performed between the 12th and 13th ribs in the right half of the carcass, exposing the cross section of the *longissimus dorsi* muscle, whose area was marked on vegetable paper for loin eye area (LEA) determination. The maximum width (A) and maximum depth (B) were obtained using a ruler and the measurements were applied in the formula: LEA= (A/2*B/2) to calculate the LEA. The cover fat thickness was measured in the region of the 12th to 13th rib cut above the *longissimus dorsi* muscle, with the aid of a caliper.

The carcass length, thoracic depth, length, and perimeter, and leg depth were measured (Osório & Osório, 2005). The right half of the carcass was subdivided into five anatomical regions that were weighed individually (neck, leg, shoulder, loin, and rib). Each portion was weighed to obtain the cut weight relative to that of the carcass.

The *longissimus dorsi* was obtained after deboning a portion of the spinal column. The muscle was then divided into sections to measure shear force, color, pH, marbling, loss of water by pressure, and centesimal analysis. The intermediate portion of the *longissimus dorsi* muscle was used to determine softness by measuring shear force using a Brookfield® CT3 Texture Analyser with a 3 mm shear probe blade.

The evaluation of the color after cooling of carcasses was performed after the cross section of the *longissimus dorsi* muscle, using a portable colorimeter (Konica Minolta, Colour reader CR10) by means of the components L* (brightness), a* (intensity of the color red), and b*(intensity of the color yellow), which were expressed in the CieLAB color system.

The pH of the meat in the *longissimus dorsi* muscle was measured 24 hours after slaughter using an electronic potentiometer equipped with a metallic penetration sensor. The loss of water by pressure was measured using the pressure method on the filter paper. In the centesimal analysis of the meat, moisture, CP, EE, and MM were determined according to the methodologies described by AOAC (2016).

Marbling was assessed using photographic standards of the American Meat Science Association [AMSA] (2001). The scores ranged from 1 to 10 (1=traces of marbling and 10=abundant marbling).

Statistical analysis

Data were analyzed using analysis of variance and regression. The assumptions of homogeneity and homoscedasticity of data were checked, and when necessary, transformation of the data was performed. The

R software (R Core Team [R], 2023) was used for statistical analysis. When crude glycerin levels had a quadratic effect on the studied characteristics, equations were derived to obtain the maximum (maximum point=MaxP) or minimum (minimum point=MinP) levels that affected these characteristics.

Results and Discussion

The FBW, EBW, weight gain per day, and feed efficiency were not influenced (P>0.05) by the level of glycerin in the diet (Table 3). There was no difference (P>0.05) in the intake of DM, EE, CP, and NDF (g/day, % BW, and g/kgBW$^{0.75}$; Table 3).

Table 3
Performance and nutrients intake in lambs fed diets containing crude glycerin

	Levels of glycerin in the diets (% in DM)				CV, %	P-value
	0	5	10	15		
Final body weight (kg)	30.70	29.7	31.72	32.01	15.68	0.390
Empty body weight (kg)	26.48	25.31	27.30	28.27	15.01	0.203
Weight gain per day (g)	305.12	277.09	321.05	314.21	13.56	0.235
Feed conversion	3.86	4.36	3.82	3.68	14.95	0.201
Feed efficiency	0.26	0.23	0.26	0.28	12.92	0.089
Intake of nutrients						
Dry matter intake						
g/day	1155.10	1173.20	1220.10	1178.30	12.12	0.571
%BW	3.76	4.01	3.81	3.63	8.85	0.100
g/kgBW$^{0.75}$	88.33	93.11	90.39	86.40	10.59	0.444
Crude protein intake						
g/day	169.7	158.0	138.1	125.0	17.01	0.480
%BW	0.54	0.54	0.51	0.49	11.36	0.131
g/kgBW$^{0.75}$	12.84	12.48	12.12	11.58	13.68	0.390
Ether extract intake						
g/day	23.01	24.08	25.11	24.07	17.78	0.402
%BW	0.07	0.08	0.07	0.07	8.91	0.421
g/kgBW$^{0.75}$	1.72	1.84	1.76	1.78	11.45	0.831
Neutral detergent fiber intake						
g/day	553.07	573.02	601.10	556.01	12.51	0.713
%BW	1.83	1.96	1.86	1.77	9.15	0.120
g/kgBW$^{0.75}$	43.10	45.56	44.23	42.26	11.61	0.516

CV=coefficient of variation.

The mean FBW was 31.26 kg. This result is consistent with that of Vieira et al. (2010), who studied Santa Inês lambs and concluded that the standard weight of lambs in confinement should be 30 to 32 kg. The absence of an effect of crude glycerin on the average weight gain (g/day) and feed conversion was positive, as the diet was formulated for a weight gain of 200 g/day and the animals showed a slightly higher mean gain in all diets studied.

Confined animals receiving feed that meets their production requirements may present better results of average daily gain and feed conversion. Given that food efficiency is related to DM intake and daily weight gain, and that these presented similarities, the hypothesis that the mean daily gain was due to DM intake was supported. Similarly, Lage et al. (2014), who studied male Santa Inês lambs and used crude glycerin containing 36.2% glycerol at levels of 0%, 3%, 6%, 9%, and 12%, based on DM, found an average daily weight gain of 254 g and feed conversion of 2.5.

The inclusion of crude glycerin in the diet of lambs did not compromise nutrient intake (g/day and % BW), which remained within the standards established by the NRC (2007). The recommended value for DM intake, for example, is 1.2 kg/day or 3.99% of the BW, considering a daily weight gain of 200 g for this category of lambs (NRC, 2007). Furthermore, the FBW was not compromised by the evaluated diets.

There was no effect of crude glycerin levels (P>0.05) on HCW, cold carcass weight, carcass finishing, flank fat streaking, full gastrointestinal tract, mesenteric fat, and omental fat (Table 4). However, the hot carcass yield and perirenal fat presented a quadratic effect (P<0.05) with the inclusion of crude glycerin (maxP=9% and minP=5%, respectively). The conformation score presented a linear increasing effect (P<0.05) with the levels of crude glycerin in the diets (Table 4).

Table 4
Carcass characteristics of lambs fed diets containing levels of crude glycerin

Variable	Levels of glycerin in the diets (% in DM)				CV, %	P-value
	0	5	10	15		
Hot carcass weight, kg	13.72	14.97	15.48	14.60	9.01	0.293
Cold carcass weight, kg	12.67	13.93	14.98	14.00	8.91	0.360
Hot carcass yield,%[A]	42.66	45.42	47.49	45.35	5.78	0.002
Conformation score (1 to 5) [B]	2.07	2.07	2.37	2.35	16.96	0.017
Carcass Finishing (1 to 5)	3.62	3.65	3.92	3.75	11.32	0.392
Flank fat streaking	1.70	2.00	2.10	1.50	9.02	0.213
Full gastrointestinal tract, kg	6.75	6.04	7.06	6.84	23.59	0.510
Perirenal fat, g [C]	170.1	142.2	177.2	177.0	23.96	0.001
Mesenteric fat, g	338.0	324.2	377.2	313.0	16.49	0.753
Omental fat, g	426.7	384.2	428.2	350.1	17.41	0.089

[A]$\hat{Y}$=42.44+0.90x-0.05x^2 (R^2=0.90; maxP= 9.0%);[B] $\hat{Y}$= 2.05+0.0225x; [C] $\hat{Y}$= 0.166-0.0070x+0.0007x^2 (R^2=0.91; minP=5.0%), CV=coefficient of variation.

The hot carcass yield values obtained are commonly found in Brazil lambs (Pellegrin et al., 2013). The conformation values indicated that the carcasses were concave; however, it is desirable that the carcasses are visually convex with a lower fat content and higher percentage of muscle mass: bone. This observation may be due to greater fluid loss, shortening of muscle fibers, and darkening of the meat during the cooling process, in addition to a lower muscle: bone ratio (Cezar & Sousa, 2007).

The quadratic response for perirenal fat suggests that crude glycerin causes a low deposit at the 5% level (minP, Table 4), but at higher levels, it can increase the internal fat. This fat is not desirable because, besides not being used for human consumption, it increases production costs and undervalues the carcass. The increase in fat when using more than 5% glycerin may be due to the increased availability of energy in the form of glucose, favoring lipogenesis and increased perirenal fat deposition. Although this result was expected, no effect was observed on the inclusion of crude glycerin in mesenteric and omental adipose tissues.

Leg perimeter (cm), fat thickness (mm), and leg weight (kg) presented a quadratic effect ($P<0.05$), with maximum values of 9.5%, 7.41%, and 8.69%, respectively, although the loin (kg) increased linearly ($P<0.05$) with crude glycerin levels in the diets. The other variables were not influenced by crude glycerin levels (Table 5).

Table 5
Linear measurements and weight of lambs cuts maintained in diets with crude glycerin

Variable	Levels of glycerin in the diets (% in DM)				CV, %	P-value
	0	5	10	15		
Carcass length, cm	57.71	59.50	59.10	58.70	5.91	0.691
Thoracic depth, cm	24.40	25.25	23.90	24.20	7.39	0.393
Leg length, cm	37.46	37.49	37.65	36.85	6.95	0.910
Leg depth, cm	10.11	9.80	9.93	9.19	13.71	0.462
Leg perimeter, cm[A]	33.30	36.44	37.94	36.06	9.42	0.030
Arm length, cm	18.63	18.56	18.79	18.59	6.93	0.985
Arm perimeter, cm	16.66	17.22	16.92	17.12	7.91	0.802
Arm depth, cm	4.37	4.50	4.71	4.63	9.11	0.291
Fat thickness, mm[B]	2.01	2.24	2.49	1.91	19.84	0.008
Neck, kg	0.54	0.63	0.60	0.64	18.25	0.091
Leg, kg[C]	2.08	2.33	2.49	2.21	16.79	0.011
Shoulder, kg	1.24	1.34	1.44	1.30	17.52	0.412
Loin, kg[D]	0.86	1.01	1.03	1.21	15.1	0.000
Rib, kg	1.56	1.51	1.58	1.50	12.57	0.639

[A]$\hat{Y}= 33.21+0.95x-0.05x^2$ ($R^2=0.99$; maxP=9.5%);
[B]$\hat{Y}=1.97386550+0.1194071x-0.0080531x^2$ ($R^2=0.89$; maxP=7.41%);
[C]$\hat{Y}=2.0141075+0.1019865x-0.00586450x^2$ ($R^2=0.92$; maxP=8.69%);
[D]$\hat{Y}=0.86873+0.0213060x$, CV=coefficient of variation.

The variables related to the longissimus dorsi muscle and centesimal composition did not influence the experimental diets (P>0.05) (Table 6).

Table 6
Quality parameters of the longissimus dorsi muscle from lambs fed diets containing crude glycerin

Variable	Levels of glycerin in the diets (% in DM)				Mean	CV,%	P-value
	0	5	10	15			
Muscle depth (mm)	50.30	51.70	51.20	51.00	51.11	8.9	0.922
Muscle width (mm)	23.88	25.36	26.72	24.20	25.04	16.1	0.401
Loin eye area (cm)	10.40	11.48	11.15	10.35	10.84	17.2	0.855
Marbling	1.70	1.90	1.60	1.30	1.62	9.8	0.543
Loss of water by pressure (%)	18.94	19.85	19.05	18.93	19.19	13.1	0.855
Loss of water by cooking (%)	29.53	25.65	27.53	28.08	27.70	14.9	0.231
Loss of water by thawing (%)	9.21	6.80	9.12	7.95	8.27	13.2	0.560
Shear strength	5.90	5.22	5.90	5.27	5.57	18.2	0.410
pH	5.56	5.73	5.55	5.59	5.61	6.8	0.711
Color L	41.04	40.52	41.25	40.22	40.76	5.9	0.760
Color A	12.86	12.30	13.62	11.85	12.66	11.2	0.062
Color B	7.84	7.18	7.95	7.25	7.56	16.5	0.411
Centesimal composition of the *longissimus dorsi* muscle							
Moisture (%)	76.91	77.14	76.73	77.15	76.98	1.94	0.913
Crude protein (%)	23.99	23.88	23.24	24.21	23.83	8.46	0.742
Mineral matter (%)	1.65	1.62	1.62	1.72	1.65	13.7	0.696
Ether extract (%)	1.94	1.90	1.84	2.35	2.00	25.7	0.138

CV=coefficient of variation.

The results observed for leg perimeter (cm), leg weight, and fat thickness may be due to the rapid conversion of crude glycerin into propionate in the rumen, which leads to a decrease in the acetate:propionate ratio, thereby affecting body fat deposition (Gunn et al., 2010). The findings of this study support the statement that glycerol is a an essential gluconeogenic substrate in lamb feeding. The data demonstrate that feeding levels of 8.69% to 9.5% crude glycerin can have a positive impact on these cuts for lambs. The best way to verify and distribute tissues in the different anatomical regions is through yield of cuts. Given that the yields of the cuts were similar, we can suggest that the inclusion of crude glycerin in the diet of lambs positively affected the distribution of carcass tissue components. The lack of effect on LEA was linked to slaughter weight, which is a reliable indicator of muscle growth. These results were similar to those obtained by Costa et al. (2019), who evaluated the levels of crude glycerin in the diet of feedlot lambs.

The uniformity of slaughter weight may explain the absence of effects of crude glycerin on the carcass, indicating that the inclusion of glycerin did not affect the different parameters studied.

The quality parameters of the longissimus dorsi muscle have been used as a good estimate of carcass musculature, which is related to the muscle:bone ratio of the most important cuts of the carcass, influencing carcass classification and evaluation of the final price of meat (Costa et al., 2019).

One factor that interferes with the intensity of muscle contractions during rigor mortis is pH. The intensity of this contraction reflects the quality of the final product, including its softness and water retention capacity (Cezar & Souza, 2010). Water retention capacity is the ability of meat to retain water when cut, heated, ground, or pressured. According to Osório (1998), 24 hours after slaughter, the muscle pH is between 5.8 and 5.5. The pH values found in this study were within this range. However, the addition of crude glycerin in the diet did not lead to major changes in pH, which was essential to impede considerable changes in water losses by cooking, pressure, and shear force on the lamb meat.

According to Tatum et al. (1999), the longissimus dorsi muscle must present a shear force of less than 5 kgf to be considered soft. The results found in this study were 5.92, 5.27, 5.83, and 5.25 kg, in the meat of lambs receiving 0%, 5%, 10%, and 15% glycerin in the feed, respectively. This may have occurred because the animals in the experiment were uncastrated males, and had more collagen in their muscle fibers (Sainz et al., 2006).

Color is the main indicator of the freshness and quality of meat, and various factors interfere with meat color, including nutrition, production systems, pH, freezing process, time to maturity, and age. The subjective measures are determined by scoring charts; thus, the higher the values of L*, the paler the meat, and higher values of a* and b* indicate increased intensity of the red and yellow colors. There were no differences in color variables, and the mean L*, a*, and b* values of meat from lambs fed diets with 0%, 5%, 10%, and 15% glycerin were 40.76, 12.66, and 7.56, respectively. According to Souza et al. (2004), the color parameters of lamb meat vary as follows: L*, 30.6 to 38.0; a*, 12.3 to 18.0, and b*, 3.3 to 5.7. According to Kadim et al. (2013), the L * value, which corresponds to the brightness of meat, can be affected by pH, which can change the light scattering properties. The results observed with the L* color reflect what happened with the pH. According to Khliji et al. (2010), when the value L* is equal to or greater than 34, consumers consider the meat color acceptable.

The absence of effects on the proximate composition of the longissimus muscle may be associated with the EE and CP contents in the diets. This suggest that the meat is of good quality, as it is within the quality standards of lamb meat. Other studies have reported no differences in the muscle chemical composition of lambs fed diets containing crude glycerin (Rocha et al., 2015).

Conclusion

Although the addition of up to 15% crude glycerin in the lamb diet does not affect performance, the addition of up to 8% is recommended because it improves carcass traits and maintains meat quality.

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