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High-grain diet and the inclusion of residual frying oil in the feeding of lambs

Dieta de alto grão e inclusão de óleo residual de fritura na alimentação de cordeiros

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Abstract
In animal production, a large part of financial resources is destined to animal feed, so the use of low-cost diets with maximum production efficiency is crucial. The present study evaluated the effects of a high-grain diet and the use of residual frying oil on the productive performance and carcass characteristics of lambs. Fifteen lambs were distributed into three groups in a completely randomized design in which they were fed a control diet, a high-grain diet, or a diet with the inclusion of residual frying oil, for 40 days. There was no difference (P > 0.05) between the control and frying-oil diets regarding the daily intakes of dry matter, crude protein, mineral matter, neutral detergent fiber, or total carbohydrates. The high-grain diet reduced the intake of dry matter and nutrients, negatively affecting weight gain. The highest means for final weight, total weight, and daily weight gain were obtained with the control diet and the diet containing residual oil, which did not differ from each other (P> 0.05). Slaughter weight and hot and cold carcass weights decreased with the high-grain diet. There was an effect (P < 0.05) of frying oil inclusion on the carcass characteristics of the lambs. The diets did not affect (P > 0.05) carcass yields. The animals on the high-grain diet showed unsatisfactory production performance, with impaired carcass characteristics. The inclusion of frying oil led to greater weight gain as well as more attractive carcass characteristics, making it the most viable alternative in this research.
Keywords: alternative feeds; evaluation of diets; sheep farming; small ruminant nutrition.

Resumo
Na produção animal, grande parte dos recursos financeiros destina-se à alimentação animal, portanto é essencial utilizar dietas de baixo custo e com máxima eficiência produtiva. O presente estudo avaliou os efeitos de uma dieta de alto grão e do óleo residual de fritura sobre o desempenho produtivo e as características de carcaça de cordeiros. Quinze cordeiros foram distribuídos aleatoriamente em três grupos e alimentados por 40 dias com uma dieta controle, dieta de alto grão ou dieta com inclusão de óleo residual de fritura. Não houve diferença (P > 0,05) entre as dietas controle e com óleo de fritura para consumo diário de matéria seca, proteína bruta, matéria mineral, FDN e carboidratos totais. A dieta de alto grão reduziu o consumo de matéria seca e nutrientes, afetando negativamente o ganho de peso. As maiores médias de peso final, ganho de peso total e diário foram obtidas nas dietas controle e com óleo residual, que não diferiram entre elas (P> 0,05). O peso corporal de abate e os pesos de carcaça quente e fria diminuíram com a dieta de alto grão. Houve efeito (P < 0,05) da inclusão de óleo de fritura sobre as características da carcaça. Não houve efeito (P > 0,05) das dietas no rendimento da carcaça. Os animais da dieta de alto grão mostraram um desempenho insatisfatório, afetando negativamente as características da carcaça. A inclusão de óleo de fritura promoveu um ganho de peso superior e características de carcaça mais atraentes, tornando-se a alternativa mais viável nesta pesquisa.
Palavras-chave: alimentos alternativos; avaliação de dietas; ovinocultura; nutrição de pequenos ruminantes.

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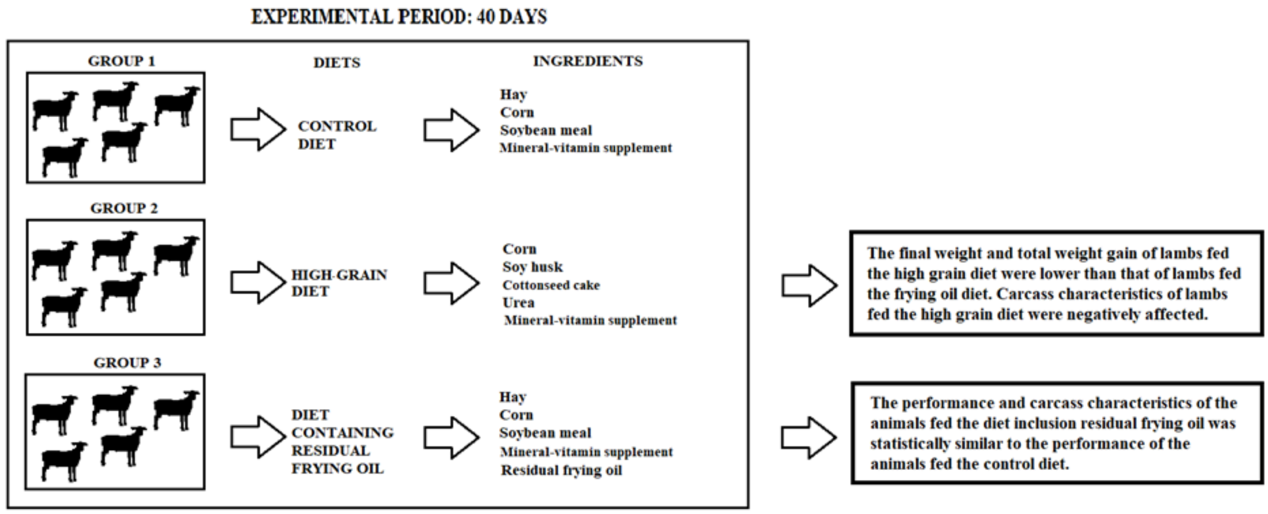

Graphical abstract: High-grain diet and the inclusion of residual frying oil in the feeding of lambs.

1. Introduction

In Brazil, the sheep production system is mostly extensive, based on natural pastures and native vegetation all year round[1]. This production model, which exclusively uses pasture to finish lambs for slaughter, is unable to meet the animals' nutritional needs, negatively impacting productivity[2]. Recent research results suggest that intensifying production systems is an efficient strategy for maximizing production rates in meat-sheep farming[1,3,4]. In addition to optimizing results, feedlotting lambs allows for achieving greater weight gains, early slaughter, improved carcass fatness and meat quality, as well as a regular supply of the product[5].

In view of the advantages of feedlotting lambs for slaughter and the increase in production costs that this system entails, means to minimize feeding costs in feedlots have become the object of studies, considering that this is one of the main factors responsible for that increase[6]. The adoption of diets with a large amount of concentrate ingredients in sheep farming has gained prominence in research developed in this area. The use of this type of diet in the finishing of lambs makes it possible to shorten their stay in the feedlot, resulting in animals with optimal slaughter weight and an adequate degree of carcass fatness for commercialization[7].

The use of high-grain diets enables the early slaughter of the animals by providing the necessary nutrients to meet their requirements, ensuring a rapid return on investment for the producer[8]. Another benefit associated with the use of high-grain diets is the reduction in dry matter intake, improving feed efficiency[9]. An additional possibility to minimize production costs in sheep feedlotting is the use of residues from industry, such as frying oil, in diets for cattle and sheep, an alternative that has shown to be promising according to studies carried out in the area in recent years[10,11].
The inclusion of frying oil in the ruminant diet offers numerous benefits, in addition to the recycling of a possible environmental pollutant, increasing the energy content of the feed, and reducing expenses, particularly on ingredients[10].

Another advantage resulting from the inclusion of lipid sources in animal feed is the improved feed conversion efficiency, reducing the intake of dry matter for weight gain[12]. Furthermore, vegetable oils, when used in the animal diet, serve as carriers of essential vitamins and fatty acids, facilitating the digestion process and improving the physical nature of the feed[13]. In this light, the objective of this study was to evaluate the effect of using a high-grain diet and residual frying oil on the intake, performance, and carcass characteristics of lambs.

2. Material and methods

The use of animals and the experimental procedures were approved by the Ethics Committee on the Use of Animals of the Federal Rural University of the Semiarid (Approval no. 23091.014462/2018-50). The experiment was conducted on a farm located in the municipality of Governador Dix-Sept Rosado, Rio Grande do Norte, Brazil. Fifteen uncastrated male Dorper × Santa Inês crossbred lambs aged six months, with a mean body weight of 23.1 ± 1.9 kg, were used. The animals were housed in collective stalls equipped with a linear feeder (0.30 m/animal), drinkers, and collective mineral troughs. A completely randomized design was adopted, involving three treatments and five replications.

Table 1 shows the percentages of ingredients and the composition of the experimental diets. The treatments were as follows: Control (CT) - Tifton hay + concentrate; High-Grain (HG) - a high-grain diet; and Residual Frying Oil (RFO) - Tifton hay + concentrate + 6% residual frying oil.

Table 1. Ingredients and nutrients in the experimental diets

Ingredient (g/kg)	Diet[1]		
	CT	HG	RFO
Hay	40.0	-	37.5
Corn	36.2	60	34.0
Soybean meal	22.0	-	20.7
Soy husk	-	25	-
Cottonseed cake	-	10	-
Urea	-	1	-
Mineral-vitamin supplement	1.8	4	1.8
Residual frying oil	-	-	6.0
Nutrient (% of total diet)			
Dry matter	89.42	86.34	89.46
Organic matter	94.04	95.29	93.68
Mineral matter	5.96	4.71	6.32
Crude protein	20.91	16.95	19.25
Ether extract	3.30	3.15	4.16
Neutral detergent fiber	33.56	24.79	34.14
Acid detergent fiber	13.89	13.26	13.73
Hemicellulose	19.67	11.53	27.66
Lignin	1.69	0.19	1.59
Cellulose	12.20	13.07	10.93
Total carbohydrates	69.83	75.19	70.27
Non-fibrous carbohydrates	36.28	50.40	36.13
Total digestible nutrients	71.22	71.49	71.29

[1]Diets: CT - control diet; HG - high-grain diet; RFO - diet with residual frying oil.

The control (CT) and residual frying oil (RFO) diets were formulated with a 60:40 forage:concentrate ratio, according to the recommendations of the NRC[(14)] to gain 200 g/day. The corn and soybean meal in the concentrate of the RFO diet were replaced at 6% with residual frying oil. The high-grain treatment (HG) consisted exclusively of a commercial high-grain diet used in sheep finishing to gain 200 g/day, as stated by the manufacturer. Ten days were used to adapt the animals to the experimental diets, followed by 40 days of data collection. To adapt the animals to the HG diet, a protocol suggested by the manufacturer was followed, with the increasing replacement of roughage with the HG diet until the total removal of roughage from the diet.

The lambs were fed twice daily, at 08h00 and 16h00, except for the high-grain diet, which had a limited supply of 3.5% of live weight (LW), according to the manufacturer's recommendation. The quantities offered in the diets were adjusted daily by the offer/leftover method, allowing a maximum of 10% of the latter in the trough. According to information from the manufacturer, the HG diet consisted of soybean meal, Soy Pass (high-rumen undegradable protein soybean meal), corn, soybean husk, cornstarch, urea, mineral-vitamin mix, a buffering agent, and monensin sodium.

Animal performance was evaluated based on total weight gain (TWG), calculated as the difference between slaughter weight (SW) and initial weight (IW); and daily weight gain (DWG), determined as the ratio between the TWG and the trial period. For each treatment, composite samples of leftovers and the feed supplied were constituted weekly. The collected samples were pre-dried at 65 °C for 72 h, then ground in a Wiley mill (1-mm sieve) and subjected to laboratory analysis to determine the chemical composition.

The contents of dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, and ether extract (EE) were determined following the methodologies described by Silva and Queiroz[(15)], while organic matter (OM) estimated was the difference between DM and MM. The levels of total carbohydrates (TC) were calculated according to Sniffen et al.[(16)], as follows: TC% = 100 - (%CP + %EE + %MM), and the levels of non-fibrous carbohydrates (NFC) were calculated according to the equation proposed by Berchielli et al.[(17)]: NFC% = 100 - (%CP + %MM + %EE + %NDF). To determine the levels of total digestible nutrients (TDN), the equation TDN% = 77.13 - 0.4250ADF, proposed by Cappelle et al.[(18)], was employed. At the end of the experimental period, the animals were subjected to 12 h of solid fasting, then weighed to obtain SW, and finally slaughtered according to the requirements of the Ministry of Agriculture[(19)].

After slaughter, skinning, evisceration, and removal of the head and extremities of the limbs were carried out, hot carcass weight (HCW), hot carcass yield (HCY% = (HCW/SW) x 100), and internal carcass length (ICL) were determined. Empty body weight (EBW) was obtained as the difference between SW and gastrointestinal content (GC).

The carcasses were kept in a cold chamber with plastic protection and hung by the tarsometatarsal joint on individual hooks for 24 h, at an average temperature of 4 ± 0.5 ºC, for rigor mortis to set in. After cooling, the cold carcass weight (CCW) was recorded and cold carcass yield (CCY% = (CCW/SW) × 100), true yield (TY% = (HCW/EBW) × 100), and the carcass compactness index (CCI = CCW/ICL) were calculated.

The data were subjected to analysis of variance (ANOVA) and the means were compared by the Tukey test at 5% significance using the PROC MIXED procedures of the Statistical Analysis System (SAS, Version 9.1). The statistical model for the evolution of parameters included the effect of treatment according to the following equation:

Yij = μ + Ti + εij

where: Y*ij* = observed value for response variable obtained in treatment i (1, 2, or 3) and replication j; μ = average of all possible values of the response variable; T*i* = effect of treatment i (1, 2, or 3) on the observed value Y*ij*; and Ɛ*ij* = experimental error associated with the observed value Y*ij*.

3. Results

3.1 Intake

Table 2 shows the intake of diet nutrients in grams/day (g/day) and as a percentage of live weight (% LW). The means test showed that nutrient intake in g/day and % LW was influenced by the diets (P < 0.05), with lower values being recorded in the high-grain diet (HG) and the average intake of the frying-oil diet (RFO) providing similar (P > 0.05) outcomes to the control treatment (CT).

3.2 Performance and carcass characteristics

The RFO diet did not influence (P > 0.05) final weight (FW), total weight gain (TWG), or daily weight gain (DWG), compared with the CT diet. The lowest means for these variables among the treatments were recorded using the HG diet (Table 3).

Table 2. Absolute nutrient intake and intake relative to the live weight of lambs finished on a high-grain diet and a diet containing residual frying oil

Variable[2]	Diet[1]			SEM[3]	P-value
	CT	HG	RFO		
Nutrient intake (g/day)					
DM	1416.12[a]	774.58[b]	1423.59[a]	53.75	<0.0001
CP	331.61[a]	131.33[b]	302.76[a]	15.99	<0.0001
MM	81.98[a]	36.53[b]	89.37[a]	3.03	<0.0001
EE	50.25[b]	24.45[c]	66.74[a]	2.98	<0.0001
NDF	319.03[a]	192.03[b]	329.34[a]	14.97	<0.0001
ADF	123.01[ab]	102.8[b]	132.26[a]	7.55	0.04
TC	952.26[a]	582.25[b]	964.70[a]	32.38	<0.0001
NFC	681.63[a]	390.22[b]	687.62[a]	35.57	0.0009
Nutrient intake as a percentage of live weight (%)					
DM	5.07[a]	3.24[b]	4.86[a]	0.15	<0.0001
CP	1.18[a]	0.54[b]	1.03[a]	0.03	<0.0001
MM	0.29[a]	0.15[b]	0.30[a]	0.009	<0.0001
EE	0.17[b]	0.10[c]	0.22[a]	0.007	<0.0001
NDF	1.16[a]	0.80[b]	1.14[ab]	0.09	0.0001
ADF	0.45	0.43	0.46	0.04	0.884
TC	3.42[a]	2.43[b]	3.29[a]	0.11	<0.0001
NFC	2.22[a]	1.63[b]	2.16[a]	0.09	0.0005

[1]Diets: CT, control diet, HG, high-grain diet, RFO, diet with residual frying oil. [2]Variables: DM: dry matter, CP: crude protein, MM: mineral matter, EE: ether extract, NDF: neutral detergent insoluble fiber, ADF: acid detergent insoluble fiber, TC: total carbohydrates, NFC: non-fibrous carbohydrates. [3]SEM, standard error of the mean. Different lowercase letters in the row indicate significant differences by Tukey's test (P<0.05).

Table 3. Performance of lambs finished on a high-grain diet and a diet containing residual frying oil

Variáveis[2]	Dietas[1]			SEM[3]	P-valor
	CT	AG	ORF		
PI	23.1	23.1	23.2	1.15	0.99
PF	32.68[a]	26.12[b]	33.60a	1.83	0.02
GPT	9.58[a]	3.02[b]	10.40[a]	1.10	0.0009
GPD	0.239[a]	0.075[b]	0.260[a]	0.221	0.0009

[1]Diets: CT, control diet, HG, high-grain diet, RFO, diet containing residual frying oil. [2]Variables: IW, initial weight; FW, final weight; TWG, total weight gain; DWG, daily weight gain. [3]SEM, standard error mean. Different lowercase letters in the row indicate differences by Tukey's test (P<0.05).

Table 4 shows the means for carcass weights and yields. The average slaughter weight at (BWS), empty body weight (EBW), hot carcass weight (HCW), and cold carcass weight (CCW) of CT and 6% residual frying oil diets were similar (P > 0.05). There was no effect (P > 0.05) of the diets on the yields of the hot carcass (HCY), cold carcass (CCY), and true yield (TY).

Table 4. Carcass characteristics of lambs finished on a high-grain diet and a diet containing residual frying oil

Variable[2]	[1]Diet			SEM[3]	P-value
	CT	HG	RFO		
BWS (kg)	30.72[a]	24.92[b]	33.04[a]	1.67	0.0138
EBW (kg)	27.54[a]	21.94[b]	30.09[a]	1.37	0.0038
HCW (kg)	15.19[a]	11.62[b]	15.94[a]	0.68	0.0016
CCW (kg)	14.91[a]	11.44[b]	15.65[a]	0.66	0.0017
HCY (%)	49.41	46.62	48.24	1.15	0.2443
CCY (%)	48.53	45.90	47.36	1.15	0.2854
TY (%)	55.15	52.96	52.97	0.75	0.1307
CCI (kg/cm)	0.43[a]	0.35[b]	0.44[a]	0.05	0.0022
GC (kg)	3.17	2.97	2.94	0.56	0.9515

[1]Diets: CT, control diet, HG, high-grain diet, RFO, diet with residual frying oil. [2]Variables: SW, slaughter weight; EBW, empty body weight; HCW, hot carcass weight; CCW, cold carcass weight; HCY, hot carcass yield; CCY, cold carcass yield; TY, true yield; CCI, carcass compactness index; GC, gastrointestinal content. [3]SEM, standard error of the mean. Different lowercase letters in the row indicate differences by Tukey's test (P<0.05).

4. Discussion

According to Mertens[20], two factors influence DM intake in ruminants: the physical capacity of the rumen and the energy demand of the animal. The regulation of intake by rumen fill is correlated with the intake of NDF from the diet, with values equal to or higher than 1.2% LW tending to inhibit consumption.

In this context, and considering that the test diets were energetically similar (Table 1), the difference observed in the DM intake between the diets cannot be attributed to chemical regulation. Considering also that NDF intake from the high-grain diet (HG) (0.80% LW) was lower than the value suggested by Mertens[20], the possibility of intake in this treatment group having been regulated by the physical capacity of the rumen is discarded, suggesting that the lower DM intake recorded with the HG diet is due to other factors.

It is worth mentioning that although the supply of the HG diet was limited to 3.5% of live weight (LW), as recommended by the manufacturer. We can exclude this fact as the cause of the lower DM intake in this diet, considering that throughout the experimental period the animals had leftover feed in the trough. In addition, DM intake relative to live weight (% LW) recorded in this diet (3.24%) was lower than 3.5% LW, so the limitation in supply does not justify the observed DM intake. Thus, it is suggested that the reduction in the DM intake of the animals on the HG diet in this study could be due to a possible metabolic disorder, caused by the lower content of NDF and physical form of the diet since a reduction in intake can be an important subclinical sign of metabolic alteration.

Throughout the experimental period, we observed that on certain days the animals of the HG treatment consumed almost all the feed offered in the trough, refusing part of the diet in the following days. This behavior can be explained by a possible initial condition of ruminal acidosis in some moments that induced the animals to reduce consumption. When diets rich in starch and sugar are used, glucose can accumulate in the rumen fluid and be converted into lactic acid, changing the rumen pH and leading to episodes of ruminal acidosis[17], which confirms the hypothesis of intake depression due to a metabolic disorder. According to Mobiglia et al.[21], ruminant animals can associate metabolic effects after ingestion with the feed, showing preference for or avoiding it. This corroborates the idea that a possible metabolic disorder may have negatively influenced DM intake from the HG diet and caused fluctuation in intake during the trial period.

It is also noteworthy that the physical form of the HG diet possibly influenced the maintenance of normal rumen metabolism. A smaller feed particle size implies greater exposure of carbohydrates to the rumen microbiota, with a consequent imbalance in the rumen fermentation process when compared to whole grains[22], favoring the onset of metabolic disorders. In this sense, Carvalho et al.[23] report that animals subjected to diets with reduced particle size and low NDF devote less time to food consumption and rumination, confirming that the lower NDF content and the fact that HG is a mesh diet resulted in the lower observed intake.

Dry matter intake may also have been influenced by the NFC content of the HG diet, considering that the digestion of diets rich in concentrate feeds produces, in the rumen, greater amounts of propionic acid, pointed out as the main responsible for satiety in ruminants[17] due to its glycogenic character. Therefore, the physical form of the HG diet, coupled with the lower NDF content and the higher amount of NFC, contributed to the lambs' lower capacity to maintain normal rumen metabolism, and consequently, to the DM intake recorded. The lower DM intake in g/day and the lower weight gain (Table 3) observed with the HG diet also demonstrate the lower DM intake expressed as % LW of the animals in this treatment group since this variable considers both parameters in the calculation.

Based on the DM intake and animal performance results of this study (Table 3), it is also inferred that the use of additives in the high-grain diet to minimize the occurrence of metabolic changes and ensure performance animal satisfactory was possibly ineffective. The lower CP intake obtained with the HG diet may be attributed to its lower CP content associated with the lower DM intake of the animals subjected to this diet. Likewise, the MM intake observed with the HG diet was lower than the values achieved with the CT and RFO diets.

The increase in EE levels in the diet containing 6% frying oil may explain the higher EE intake recorded in this treatment group (Table 2). The same behavior was observed by Peixoto et al.[12], who studied different levels of inclusion of residual oil (20, 40, 60, and 80 g/kg) in diets for sheep. The authors highlighted that the increase in the lipid content of the diet tends to increase its consumption. However, it is important to note that the EE concentration of the HG diet is only 0.15% and 1.01% lower when compared to those of CT and RFO diets, respectively. Following the average reduction of 45.4% in DM intake from the high-grain diet when compared to the others, the EE intake of animals subjected to this diet also declined by 58.2%.

The higher NDF intake from the CT and RFO diets can be attributed to the higher DM intake observed as well as the higher NDF concentration of these diets in relation to the HG diet. The similar ADF content between the three diets (Table 1) may explain the absence of statistical difference in the test diets in relation to the CT diet regarding ADF intake; however, the difference in ADF intake between the HG and RFO diets is due to the higher DM intake of the animals that received the latter treatment. Despite the NFC content in the HG diet being higher than those of the other diets, it is observed that due to the lower DM intake, the intake of NFC was reduced, which also explains the higher NFC intake from the CT and RFO diets compared to the higher DM intake from these diets.

According to Cabral et al.[24], nutrient intake is the variable that most affects animal performance, which indicates that the lower DM intake recorded with the HG diet, which consequently reduced nutrient intake, negatively influenced the performance indices of these animals. In addition, the possibility of the occurrence of ruminal acidosis at certain moments in the experimental period may have contributed to this result, which by inhibiting feed intake, would not allow the animals to meet their nutritional needs, thus compromising their weight development.

The absence of statistical differences for final weight (FW), total weight gain (TWG), and daily weight gain (DWG) between the CT and RFO diets allows us to conclude that the similar DM intake from these diets, as well as the fact that these diets are isoproteic and similar in nutritional composition, provided similar gains for the animals receiving these treatments.

According to Kuss et al.[25], hot carcass weight (HCW) and cold carcass weight (CCW) are highly correlated with body weight at slaughter (BWS). Thus, the absence of difference in BWS between the CT and RFO diets, provided similarity between the mean HCW and CCW, as well as the lower BWS of the animals of the HG treatment, contributed to the lower HCW and CCW values in this study.

According to Queiroz et al.[26], among the carcass yield calculations, for the scientific environment, the one of greatest accuracy is true yield (TY). This is because, as opposed to the calculation of hot carcass yield (HCY) and cold carcass yield (CCY), this considers empty body weight (EBW) by subtracting the weight of the gastrointestinal content (GC). The GC can be influenced by the rate of passage of the feed, which in turn, is related to higher levels of NDF in diets as this leads to a lower rate of passage and, consequently, less disappearance of gastrointestinal content during the pre-slaughter fast[27]. However, in the present study, the weight of the GC was not changed by the diets ($P > 0.05$). Therefore, the HCY and CCY values were not influenced by this parameter, making it reliable.

Carcass compactness index (CCI) is a parameter that allows for a more accurate assessment of the carcass muscle composition. Considering the market preference for carcasses with greater compactness[26], and the results obtained in this work, it is possible to conclude that the carcasses of animals fed the HG diet, which had a lower CCI when compared to those obtained in other carcasses, are less attractive to the market. The lower index is also inferred to be due to the lower amount of muscle tissue in the carcass, as it measures the amount of muscle tissue deposited per unit of length and this was probably also directly related to the reduction in the DM intake observed in the animals in the HG treatment group.

The diet with partial substitution of conventional ingredients for 6% of residual frying oil provided better production performance. The high-grain diet decreased total weight gain, negatively affecting the lambs' productive indices due to the depression of voluntary intake.

5. Conclusions

The results of this research show that the use of frying oil in the feeding of lambs offers productive advantages, and that lambs fed high-grain diets in the conditions of this study have their productive performance impaired, which is not interesting when aiming at efficient production.

Declaration of conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

Conceptualization: N. V. Batista and P. O. Lima. *Data curation:* N. V. Batista and P. O. Lima. *Investigation:* N. V. Batista, V. L. L. Melo, N. L. Silva, P. V. C. Oliveira, N. O. Santos, E. A. Silva, and M. C. T. Fernandes. *Methodology:* N. V. Batista and P. O. Lima. *Project administration:* N. V. Batista. *Supervision:* P. O. Lima. *Writing (original draft):* N. V. Batista. *Writing (proofreading & editing):* N. V. Batista and P. O. Lima.

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