Journal Homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

Effect of Nutritional Restriction Levels and Glycerol on Growth Performance of Local Male Lambs

A. A. Hameed [1] **A. R. Mansoor [2]***

[1] Ministry of Agriculture, Iraq.
[2] College Agriculture, University of Anbar, Iraq.

***Correspondence to:** A. R. Mansoor, College Agriculture, University of Anbar, Iraq.
Email: ag.ammar.rahem@uoanbar.edu.iq

Article info

Received: 2025-01-21
Accepted: 2025-05-09
Published: 2025-12-31

DOI-Crossref:
10.32649/ajas.2025.189313

Cite as:
Hameed, A. A., and Mansoor, A. R. (2025). Effect of Nutritional Restriction Levels and Glycerol on Growth Performance of Local Male Lambs. Anbar Journal of Agricultural Sciences, 23(2): 1225-1243.

Abstract

This research investigated the effect of nutritional restrictions and glycerol addition on the growth performance of local male lambs. The experiment was conducted on 24 local male lambs aged 3 - 3.5 months weighing 18±1.13 kg on average. The lambs were randomly assigned to six treatment groups. In Phase 1, the findings showed that the control group was more efficient in reducing the cost of producing 1 kg of weight gain than the glycerol group. The 0% feed restriction group outperformed the 70% and 50% groups in most production traits, with the 0% and 70% groups showing better feed conversion ratios and lower production costs than the 50% group. In Phase 2, adding glycerol reduced dry matter intake but maintained the lower cost for weight gain in the control group. The 0% feed restriction outperformed other treatments in terms of weight and feed intake. However, the 50% feed restriction group showed better feed efficiency, with the best feed conversion ratio and production cost. For the combined phases of nutrition restriction and free re-alimentation, the study found the control group had a significantly lower cost for producing 1 kg of weight gain compared to the glycerol addition group. Among the feed restriction treatments, the 0% group led in effectiveness followed by the 70% and 50% groups in terms of weight gain, feed intake, and other production indicators. In

conclusion, the best treatment was recorded by the 70% feed restriction without glycerol group in terms of lowest cost for weight gain, reduced feed intake, and final weight similar to the control.

Keywords: Nutritional restriction, Glycerol, Growth performance, Male lambs.

تأثير مستوى التقنين الغذائي والكليسرول في أداء النمو للحملان الذكرية المحلية

ايمن احمد حميد [1] **عمار رحيم منصور** [2]*

[1] **مديرية الزراعة في محافظة الأنبار، وزارة الزراعة.**

[2] **كلية الزراعة، جامعة الأنبار.**

***المراسلة الى:** عمار رحيم منصور، كلية الزراعة، جامعة الأنبار، العراق.

البريد الالكتروني: ag.ammar.rahem@uoanbar.edu.iq

الخلاصة

هدفت التجربة معرفة تأثير مستوى التقنين الغذائي واضافة الكليسرول في اداء النمو للحملان الذكرية المحلية. شملت التجربة 24 حملاً ذكرياً محلياً، تراوحت اعمارها بين 3–3.5 شهراً، وبمتوسط وزن 18 ±1.13 كغم. وزعت الحملان عشوائياً الى ست معاملات متساوية. أهم النتائج: المرحلة الاولى: أظهرت النتائج تفوقًا معنويًا لمعاملة السيطرة في خفض تكلفة إنتاج 1 كغم زيادة وزنية مقارنة بإضافة الكليسرول، كما تفوقت نسبة تقنين الغذاء 0% على 70%، والتي بدورها تفوقت على 50% في معظم الصفات الإنتاجية. وسُجّل تحسن في معامل التحويل الغذائي والتكلفة الإنتاجية عند 0% و70% مقارنة بـ 50%. المرحلة الثانية: أظهرت إضافة الكليسرول انخفاضًا معنويًا في استهلاك المادة الجافة مقارنة بالسيطرة، مع بقاء تكلفة زيادة الوزن أقل في معاملة السيطرة. تفوقت معاملة التقنين الغذائي 0% في الوزنين الابتدائي والنهائي، واستهلاك العلف والمادة الجافة، بينما تفوقت 50% في كفاءة التغذية وتسجيل أفضل معامل تحويل غذائي وتكلفة إنتاج مقارنة بـ 0%. مرحلتي التقنين الغذائي واعادة التغذية الحرة: أظهرت النتائج انخفاضًا معنويًا في تكلفة إنتاج 1 كغم زيادة وزنية لصالح معاملة السيطرة مقارنة بمعاملة إضافة الكليسرول. وفيما يخص معاملات التقنين الغذائي، تفوقت معاملة 0% معنويًا على 70%، وتفوقت الأخيرة على 50% في عدة مؤشرات إنتاجية شملت: الوزن النهائي، الزيادة الوزنية الكلية واليومية، استهلاك العلف، استهلاك المادة الجافة، ونسبة استهلاك المادة الجافة إلى وزن الجسم. الملخص: أظهرت النتائج أن أفضل معاملة كانت تقنين الغذاء بنسبة 70% بدون إضافة الكليسرول، إذ حققت أقل تكلفة لزيادة الوزن، وقللت من استهلاك العلف مع الحفاظ على وزن كلي قريب من معاملة السيطرة.

كلمات مفتاحية: التقنين الغذائي، الكليسرول، اداء النمو، الحملان الذكرية.

Introduction

Nutrition is a fundamental factor in sheep farming projects, accounting for approximately 60–70% of total production costs, and directly influences animal health and product quality (19 and 33). Due to its criticality, several nutritional strategies have been adopted with the aim of reducing feed costs without negatively impacting production quality. Among these strategies is the "nutritional restriction" system, which is followed by a period of "free re-alimentation" to stimulate compensatory growth. This approach is employed in some countries to cope with forage shortages and rising feed prices, especially during drought seasons, and has been proven to lower lamb production costs (12).

Nutritional restriction involves limiting an animal's feed intake to a level below ad libitum feeding (30), while compensatory growth refers to the animal's ability to recover lost growth during the restriction phase when high-quality, unrestricted feeding is resumed (3). Several studies have indicated that applying nutrition restriction levels of 10-40%, followed by a free re-alimentation period, can enhance growth rates, feed efficiency, and nutrient digestibility (1, 2 and 3).

In this context, crude glycerin is one of the main by-products of the biodiesel industry (11), containing between 45–90% glycerol, depending on the raw materials used, production conditions, and purification level (22). Glycerol was initially used to treat ketosis in dairy cows, as it serves as a direct source of glucose (17). With its increased production and reduced global market price, researchers have explored its use as an alternative energy source in ruminant diets, replacing carbohydrate-rich ingredients such as corn (18 and 26). Subsequent studies have shown that including crude or high-purity glycerol at up to 30% of dietary dry matter can improve rumen environment, enhance lamb performance, and reduce the cost of producing one kilogram of live body weight (9 and 30).

Accordingly, this study hypothesizes that incorporating high-purity glycerol into the diets of lambs subjected to different levels of nutrition restrictions may contribute to improving productive performance and reducing production costs.

Materials and Methods

The experiment was conducted at the Sheep Field of the Department of Animal Production, College of Agriculture, University of Anbar (latitude 33.42°N, longitude 43.33°E), in accordance with experimental procedures approved by its Scientific Research Ethics Committee (approval number: 236/2024). The trial covered 84 days, from April 1 to June 23, 2024, and involved 24 local male lambs aged 3 to 3.5 months weighing an average 18 ± 1.13 kg. The lambs were purchased from a sheep breeder in the city of Rutba, western Iraq, and randomly assigned to six experimental treatments of four lambs each. They were housed in a fenced barn composed of an open area and a shaded section, and each lamb was placed in an individual iron pen measuring 150 × 100 × 110 cm, equipped with a plastic feeder and water bucket.

All necessary tools and equipment required for conducting the practical aspects of the experiment were available on site. The experimental lambs were tagged with plastic ear numbers for identification. Prior to the start of the trial, the animals were

examined and treated with the necessary vaccines and veterinary pharmaceuticals. In addition, mineral salt blocks were provided for each lamb throughout the experiment. All the lambs underwent a 14-day adaptation phase to allow them to acclimate to the individual pens and the new diet. During this period, they were gradually transitioned to a locally formulated total mixed ration (TMR) prepared based on the feed ingredients and proportions (Table 1) and chemical composition as shown in Table 2.

On the first day, each lamb was offered 500 g of alfalfa hay and 100 g of TMR. The amount of hay was then gradually reduced while the TMR portion was increased until the lambs fully adapted and were completely dependent on the new diet. The free-feed intake determination phase lasted seven days to determine the average daily free-feed intake. The feed was offered once daily at 9:00 a.m. On the following day, at the same time, the leftover feed was weighed and subtracted from the amount initially offered to determine the amount of feed consumed freely per lamb per day. This was done to establish the nutrition restriction level used in the experiment. The experimental lambs were randomly divided into six equal treatments of 4 lambs each and housed in individual pens.

Table 1: Ingredients and proportions of the experimental diet.

Feed ingredient	Diet 1 (%)	Diet 2 (%)
Yellow corn	15	10
Wheat flour	10	8.8
Wheat bran	22	22
Barley	19	19
Soybean meal 46	10	11.2
Sunflower oil	1	1
Limestone	1	1
Salt	1	1
Antitoxin	0.2	0.2
Premix	0.8	0.8
Glycerol	0	5
Alfalfa hay	20	20
Total	100	100

Table 2: Chemical analysis of the experimental diet.

Chemical composition	No glycerol diet (%)	Glycerol included in diet (%)
Dry matter (DM)	88.44	88.44
Crude protein (CP)	13.6	14.11
Crude fat (ether extract) (EE)	2.77	2.67
Crude fiber (CF)	11.11	12.3
Ash	5.89	5.86
Nitrogen Free Extract (NFE)	55.07	53.5
***Metabolizable energy ME (MJ/kg dry matter)**	12.80	12.81

The ration analysis was conducted at the labs of the Erbil Feed Company. *Metabolizable energy was estimated based on the equation (16):

ME (MJ/kg DM) = 0.31CP+0.21EE+0.4NFE

The experiment was conducted over 84 days divided into two equal phases:

The first phase (42 days) involving dietary restriction comprised the following treatments:

1st (T1): 0% glycerol + 0% nutrition restriction,
2nd (T2): 0% glycerol + 30% nutrition restriction,
3rd (T3): 0% glycerol + 50% nutrition restriction,
4th (T4): 5% glycerol + 0% nutrition restriction,
5th (T5): 5% glycerol + 30% nutrition restriction, and
6th (T6): 5% glycerol + 50% nutrition restriction.

The second phase involved free re-alimentation (42 days) where feed was provided ad libitum for all treatments until the end of the experiment.

Field Measurements:

1. Lamb Weight: The experimental lambs were weighed weekly until the end of the trial. Weighing was conducted early in the morning before offering feed and water using a 200-kg field electronic scale.
2. Total Weight Gain
   Calculated as follows (5): Total Weight Gain (kg) = Final weight - Initial weight
3. Daily Weight Gain
   Calculated as follows (20):
   Daily Weight Gain (g) = Total weight gain/Duration (days)
4. Daily Feed Intake
   Calculated as follows (4):
   Daily Feed Intake (g) = Amount of feed offered – Amount of feed remaining
5. Dry Matter Consumption Rate
   Calculated as follows (4):
   Daily Dry Matter Consumption (g) = Daily feed intake × Dry matter percentage in the diet
6. Food Conversion Factor
   Calculated as follows (20):
   Food Conversion Efficiency (kg dry matter consumed per kg weight gain) = Daily dry matter intake/Daily weight gain
7. Feed Efficiency
   Calculated as follows (4):
   Weight Gain Per Kg Dry Matter Consumed = Daily weight gain/Daily dry matter intake
8. Dry Matter Intake as a Percentage of Body Weight
   Calculated as follows (6):
   Feed Intake Percentage = (Daily Dry Matter Intake/Final Weight) × 100
9. Cost of Producing 1 kg of Weight Gain
   Calculated as follows:
   Cost of Producing 1 kg Weight Gain = Total feed consumed during the trial/(Final weight – Initial weight) × Cost per kg of feed

Statistical Analysis: Statistical analysis was conducted using a two-way ANOVA, where the first factor examined the effect of nutritional restriction treatments on the studied traits, and the second assessed the effect of glycerol supplementation in the feed on the studied traits. General Linear Model (GLM) was applied using SAS statistical software version 9.4 (31). Significant differences between means were tested using Duncan's multiple- range test (15).

Results and Discussion

First Phase (42 days): The results of this study (Table 3) on the addition of glycerol to the diet showed no significant differences between the 5% and 0% glycerol treatments in terms of final weight, total weight gain, and daily weight gain during the 42-day feeding period. These results are consistent with (25 and 29) who also reported no significant differences but contrast with (14, 28 and 30) who noted much improvements in the same parameters. This difference in the results may be attributed to variations in the glycerol's purity, the amounts used, the method of administration, as well as the composition of the diet (27). These studies did not align with the current study. The likely reason for the discrepancy is that glycerol was added to the lambs' diet at higher concentrations in the other studies resulting in improvements in the parameters studied compared to the control treatment.

The results on the effect of nutrition restrictions showed a significant decrease in the final weight of lambs at higher restriction levels, with values of 32.8, 28.1, and 25.2 kg for the 0%, 30%, and 50% levels, respectively. Similarly, both total (12.4, 7.9, and 4.6 kg) and daily (295, 188, and 109 g) weight gains decreased with increasing severity of nutrition restriction. Compared to lambs fed ad libitum, those consuming less than the maximum dry matter intake experienced reduced daily weight gain due to insufficient nutrient intake to support normal growth and development. These findings are consistent with several earlier studies (1, 3 and 23).

However, they contradict the findings of (7) who reported that nutrition restriction severity did not affect weight gain. (13 and 33) noted that the reductions in body weight gain during nutrition restriction is a nutritional response, resulting in inadequate intake of essential nutrients necessary for supporting rapid growth and development in animals. The discrepancy between the current study results and those of (7) may be attributed to differences in the severity of the nutrition restriction applied.

Table 3: Effect of nutritional restriction level and glycerol on growth performance of the lambs during the nutritional restriction phase (42 days).

Treatments		Parameters			
		Weight (kg)		Weight gain	
		Initial	Final	Total (kg)	Daily (g/day)
Glycerol	0%	20.6	29.1	8.5	202
	5%	20.2	28.3	8.1	192
Sig. level of added glycerol		NS	NS	NS	NS
Nutritional restriction	0%	20.4	32.8a	12.4a	295a
	30%	20.2	28.1b	7.9b	188b
	50%	20.6	25.2c	4.6c	109c
Sig. level of diet restriction		NS	0.0001	0.0001	0.0001
Glycerol and restriction interaction	Glycerol 0% + Restriction 0%	20.2	32.3	12.1	288
	Glycerol 0% + Restriction 30%	21.3	29.4	8.1	192
	Glycerol 0% + Restriction 50%	20.4	25.7	5.3	126
	Glycerol 5% + Restriction 0%	20.6	33.4	12.8	304
	Glycerol 5% + Restriction 30%	19.2	26.8	7.6	180
	Glycerol 5% + Restriction 50%	20.8	24.6	3.81	90
Sig. level of interaction		NS	NS	NS	NS
Standard Error Mean		0.3523	0.7531	0.7124	16.96

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

As for the interaction between nutritional restriction level and glycerol supplementation, the results showed no significant differences in final weight, total weight gain, and daily weight gain. No previous studies were available on the effect of the interaction between the two factors on growth performance in lambs.

No significant differences were seen between the 5% and 0% glycerol treatments in terms of daily feed intake, daily dry matter intake, feed conversion ratio, feed efficiency, and dry matter intake as a percentage of body weight (Table 4). However, the 5% treatment recorded a higher feeding cost for producing 1 kg of weight gain, at 4625 Iraqi dinars, compared to the 0% treatment (2993 Iraqi dinars). It appears that adding 5% glycerol to the dry matter of the feed did not affect the feeding performance parameters. This result is consistent with (25 and 28) but varies with (29 and 30) who reported a significant decrease in dry matter intake with increased glycerol levels in the feed and a significant improvement in feed conversion efficiency.

This difference may be attributed to variations in glycerol purity and amounts applied, the nature and composition of the feed, and the method of glycerol administration. The feeding cost for producing 1 kg of weight gain was higher in the 5% than in the 0% glycerol treatment. This result differs from (30) where the cost decreased in the 10% and 5% glycerol treatments by USD1.92 and USD2.5, respectively compared to USD3.28 in the control treatment. This discrepancy may be

attributed to the high cost of the imported glycerol, which is reflected in the increased cost of the feed used in the study.

Table 4: Effect of nutritional restriction level and glycerol on feeding performance of lambs during the nutritional restriction phase (42 days).

Treatments		Parameters					
		Intake		Feed conversion ratio	Feeding efficiency (g/kg)	Dry matter intake of (%)body weight	Cost of producing 1kg weight gain (IDQ)
		Feed (g/day)	Dry matter (g/day)				
Glycerol	0%	951	863.7	4.44	232	2.91	2993 b
	5%	957	863.9	4.95	212	2.98	4625 a
Sig. level of added glycerol		NS	NS	NS	NS	NS	0.0001
Nutritional restriction	0%	1368 a	1230 a	4.15 b	241 a	3.73 a	3356 b
	30%	870 b	793 b	4.30 b	235 a	2.85 b	3473 b
	50%	624 c	568 c	5.63 a	189 b	2.26 c	4598 a
Sig. level of diet restriction		0.0001	0.0001	0.0042	0.0277	0.0001	0.0023
Glycerol and restriction interaction	Glycerol 0%+ Restriction 0%	1357	1228	4.27	234	3.80	2900 c
	Glycerol 0%+ Restriction 30%	873	795	4.15	243	2.72	2799 c
	Glycerol 0%+ Restriction 50%	624	568	4.90	219	2.22	3280 bc
	Glycerol 5%+ Restriction 0%	1378	1232	4.02	248	3.67	3813 bc
	Glycerol 5%+ Restriction 30%	868	791	4.45	227	2.97	4148 b
	Glycerol 5%+ Restriction 50%	624	568	6.37	159	2.30	5915 a
Sig. level of interaction		NS	NS	NS	NS	NS	0.0454
Standard Error Mean		66.34	58.82	0.2259	0.0092	0.1325	250.12

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

As for the effect of nutritional restriction levels on feeding performance, the results showed an inverse relationship between daily feed intake of 1368, 870, and 624 g/day and the 0%, 30%, and 50% nutritional restriction levels, respectively. Similarly, daily dry matter intake decreased by 1230, 870, and 568 g/day as the nutritional restriction level increased. As for the feed conversion ratio, no significant differences were found between the 0% (4.15) and the 30% nutritional restriction level (4.30), while the ratio increased significantly by 5.63 at the 50% level. Likewise, there were no significant differences in feed efficiency between the 0% (241 g/kg) and the 30% nutritional restriction level (235 g/kg), while it decreased significantly by 189 g/kg at the 50% level. Significant differences were observed in the dry matter intake as a percentage of body weight, with values of 3.73%, 2.85%, and 2.26% respectively for the 0%, 30%, and 50% nutritional restriction levels.

For the feeding cost to produce 1 kg of weight gain, no significant differences were found between the 0% nutritional restriction level (3356 Iraqi dinars) and the 30% level (3473 Iraqi dinars), though it increased markedly at the 50% level (5498 Iraqi dinars). This is consistent with several previous studies which show a decrease

in dry matter intake and feed efficiency along with an increase in the feed conversion ratio during the nutritional restriction phase at restriction levels of 10 - 40% (1, 3, 7 and 23). For the interaction between glycerol supplementation and nutritional restriction on feeding performance, there were no significant differences between all interactions in daily feed intake, daily dry matter intake, feed conversion ratio, and feed efficiency. However, major differences were observed in the feeding cost to produce 1 kg of weight gain between the interactions with the 5% glycerol +50% nutritional restriction being the most costly at 5915 Iraqi dinars and the 0% glycerol +0% nutrition restriction being the cheapest at 2900 Iraqi dinars.

Second Phase (42 days): The results of this study (Table 5) on the addition of glycerol to the diet showed no significant differences between the 5% and 0% glycerol treatments in terms of final weight, total weight gain, and daily weight gain during the 42-day re-alimentation phase. On the effect of nutritional restriction levels during this phase, a significant decrease occurred in the initial weight of lambs in the 30% and 50% restriction treatments at 28.1 kg and 25.2 kg, respectively compared to the 0% treatment (32.8 kg). This is a natural outcome since these weights were obtained from the nutritional restriction phase. Significant differences were observed in the lambs' final weights between the 0% nutritional restriction treatment (44.1 kg) and both the 30% (39.3 kg) and 50% (36.9 kg) treatments.

No significant differences were found in the final weight between the 30% and 50% nutritional restriction treatments. This may be because the 42-day re-alimentation period was not long enough for the lambs subjected to the 30% and 50% restriction levels to regain their weight as in the ad-libitum feeding group. This result agrees with the findings of (23).

No significant differences were recorded in total and daily weight gains between the three nutritional restriction treatments, similar to the findings reported by (1, 3, 7 and 23). Regarding the interaction between nutritional restriction level and glycerol addition, the results showed no significant differences between all interactions in final weights, as well as total and daily weight gains.

Table 5: The effect of nutritional restriction level and glycerol on the growth performance of lambs during the re-alimentation phase (42 days).

Treatments		Parameters			
		Weight (kg)		Weight gain	
		Initial (kg)	Final (kg)	Total (kg)	Daily (g/day)
Glycerol	0%	29.1	40.4	11.2	267
	5%	28.3	39.9	11.5	275
Sig. level of added glycerol		NS	NS	NS	NS
Nutritional restriction	0%	32.8 a	44.1 a	11.3	268
	30%	28.1 b	39.3 b	11.1	266
	50%	25.2 c	36.9 b	11.7	279
Sig. level of diet restriction		0.0001	0.0001	NS	NS
Glycerol and restriction interaction	Glycerol 0%+ Restriction 0%	32.3	42.8	10.5	250
	Glycerol 0%+ Restriction 30%	29.4	41.3	11.8	282
	Glycerol 0%+ Restriction 50%	25.7	37.1	11.4	271
	Glycerol 5%+ Restriction 0%	33.4	45.5	12.1	287
	Glycerol 5%+ Restriction 30%	26.8	37.3	10.5	251
	Glycerol 5%+ Restriction 50%	24.6	36.7	12	287
Sig. level of interaction		NS	NS	NS	NS
Standard Error Mean		0.7531	0.7531	0.8786	0.3964

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

The results in Table 6 regarding the addition of glycerol to feed showed no significant differences between the 5% and 0% glycerol treatments in terms of daily feed intake, daily dry matter intake, feed conversion ratio, and feeding efficiency. However, dry matter intake percentage based on body weight decreased considerably in the 5% (2.93%) compared to the 0% (3.14%) glycerol treatments. The former recorded the highest feeding cost to produce 1 kg of weight gain at 4303 Iraqi Dinars compared to 3345 Iraqi Dinars for the latter.

Table 6: The effect of nutritional restriction level and glycerol on the feeding performance of lambs during the re-alimentation phase (42 days).

Treatments		Parameters					
		Intake		Feed conversion ratio	Feeding efficiency (g/kg)	Dry matter intake of (%)body weight	Cost of producing 1kg weight gain (IDQ)
		Feed (g/day)	Dry matter (g/day)				
Glycerol	0%	1432	1266	4.85	213	3.14 a	3345 b
	5%	1379	1176	4.35	237	2.93 b	4303 a
Sig. level of added glycerol		NS	NS	NS	NS	0.0188	0.0007
Nutritional restriction	0%	1580 a	1400 a	5.35 a	191 b	3.16	4313 a
	30%	1341 b	1182 b	4.51 b	225 ab	3.01	3749 ab
	50%	1294 b	1080 b	3.95 b	259 a	2.93	3410 b
Sig. level of diet restriction		0.0014	0.0001	0.0032	0.0035	NS	0.0185
Glycerol and restriction interaction	Glycerol 0%+ Restriction 0%	1608	1422	5.85	173	3.32	4017
	Glycerol 0%+ Restriction 30%	1406	1243	4.42	227	3.02	3068
	Glycerol 0%+ Restriction 50%	1283	1134	4.27	238	3.07	2952
	Glycerol 5%+ Restriction 0%	1553	1379	4.85	208	3.00	4610
	Glycerol 5%+ Restriction 30%	1277	1122	4.60	224	3.00	4430
	Glycerol 5%+ Restriction 50%	1306	1027	3.62	280	2.80	3869
Sig. level of interaction		NS	NS	NS	NS	NS	NS
Standard Error Mean		37.20	36.15	0.1890	0.0090	0.0090	167.062

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

The results on the level of dietary restrictions during the free feeding period showed a significant decrease in daily feed intake for the 30% (1341 g/day) and the 50% (1294 g/day) treatments compared to the 0% treatment at 1580 g/day. Similarly, feed and dry matter intake were lower in the 30% and 50% than in the 0% restriction treatments. It is noted that although all lambs in the experiment had free-feeding conditions, the average feed and dry matter intake in the 30% and 50% restriction treatments remained lower than in the 0% treatment. The results for the level of dietary restriction during the free-feeding period showed considerable decreases in

daily feed intake for the 30% (1341 g/day) and the 50% (1294 g/day) restriction treatment compared to the 0% at 1580 g/day. Similarly, the 30% and 50% restriction treatments differed from the 0% treatment in dry matter intake.

The average feed and dry matter intake of the lambs in the 30% and 50% restriction treatments was lower than in the 0% treatment under free-feeding conditions could be attributed to restrictions decreasing the size of internal organs, particularly the liver and digestive tract (4 and 21). During the free-feeding phase, the lambs under dietary restriction felt mechanical or chemical satiety with a smaller quantity of feed than those under free-feeding conditions.

This result aligns with (23) who noted a significant decrease in daily dry matter intake for the 25% and 40% restriction treatments compared to the free feeding treatment for both groups of lambs, whose average weights at the start of dietary restriction were 20 and 25 kg, respectively. However, this result does not agree with (1) who found no significant differences in dry matter intake between the free feeding treatment and the 25% and 40% restriction treatments in Najdi lambs, whose average weights at the start of dietary restriction were 30 kg and 36 kg.

Likewise, (3) did not observe significant differences in dry matter intake during the free feeding and the 10% and 20% restriction treatments in Najdi lambs while (7) noted the same in the 25% dietary restriction treatment during the free-feeding phase. The variation in these results may be attributed to differences in breed, age, sex, initial weight at the start of dietary restriction, level of dietary restriction, duration of dietary restriction and free feeding phase, and diet type (ratio of concentrates to roughage) (8 and 24). Regarding the feed conversion ratio (FCR) during the free feeding period, significant differences were observed between the 0% (at 5.35), 30% (4.15), and the 50% (3.95) restriction treatments. No differences in FCR were found between the 30% and 50% restriction treatments, suggesting that they were more efficient in feed conversion than the 0% restriction treatment. Likewise, the 50% restriction treatment recorded the highest feeding efficiency (259 g weight gain per kg dry matter consumed) compared to the 0% treatment (191 g weight gain per kg dry matter consumed). However, no significant differences in feeding efficiency were observed between the 30% and 50% restriction treatments.

During the free feeding period, the 30% and 50% restriction treatments responded to compensatory growth, as evidenced by the improvement in feed conversion and feeding efficiency. This was reflected in total weight gain, similar to the 0% restriction treatment. This result is supported by (4) who noted that animals undergoing compensatory growth are more efficient at utilizing feed than normal-growth ones. These findings are consistent with those reported in several previous studies (1 and 3), but not those of (7) who did not observe significant differences in the FCR and feeding efficiency between the 25% dietary restriction and free feeding treatments during the free feeding phase. No significant differences were found in the dry matter intake as a percentage of body weight at 3.16%, 3.01%, and 2.93% for the 0%, 30%, and 50% dietary restriction treatments, respectively.

This result is consistent with (7 and 23). Significant differences were observed in feeding costs, at 4313, 3749, and 3410 dinars for producing 1 kg of weight gain, for the 0%, 30%, and 50% dietary restriction treatments, respectively. Regarding the

interaction between glycerol supplementation and dietary restriction, no significant differences in feed intake, dry matter intake, FCR, feeding efficiency, dry matter intake as a percentage of body weight, or the cost of feeding to produce 1 kg of weight gain were seen across all interactions. This is consistent with the findings during the dietary restriction phase.

Growth and feeding performance during the nutritional restriction and re-alimentation periods (84 days): Table 7 shows that there were no significant differences between the 5% and 0% glycerol treatments in terms of final weight, total weight gain, and daily weight gain during both the nutritional restriction and re-alimentation periods (the total duration of the experiment). Adding glycerol at 5% of the dry matter in the diet did not affect the growth performance of local male lambs, possibly because the level was inadequate to significantly affect their growth and feeding performance. Alternatively, it might be due to the nature of the diet used in the experiment, which consisted of 80% rapidly fermentable concentrates and 20% alfalfa hay (80 concentrate: 20 roughage). (10) stated that glycerol may enhance digestibility in roughage-based diets, but might have a marginal effect on the digestibility of highly fermentable concentrate-based diets.

The results of this study showed significant differences in the final weight of the lambs, which reached 44.1, 39.3, and 36.9 kg for the 0%, 30%, and 50% nutritional restriction treatments, respectively over the total duration of the experiment. However, there was no significant difference in final weight between the 30% and 50% restriction treatments. Similarly, significant differences were observed in total weight gain at 23.7, 19, and 16.2 kg and daily weight gain at 282, 226, and 193g for the 0%, 30%, and 50% restriction treatments, respectively.

Table 7: Effect of nutritional restriction level and glycerol on the growth performance of lambs during the nutritional restriction and re-alimentation periods (84 days).

Treatments		Parameters			
		Weight (kg)		Weight gain	
		Initial	Final	Total (kg)	Daily (g/day)
Glycerol	0%	20.6	40.4	19.7	234
	5%	20.2	39.9	19.6	233
Sig. level of added glycerol		NS	NS	NS	NS
Nutritional restriction	0%	20.4	44.1 a	23.7 a	282 a
	30%	20.2	39.3 b	19 b	226 b
	50%	20.6	36.9 b	16.2 c	193 c
Sig. level of diet restriction		NS	0.0004	0.0001	0.0001
Glycerol and restriction interaction	Glycerol 0%+ Restriction 0%	20.2	42.8	22.5	268
	Glycerol 0%+ Restriction 30%	21.3	41.3	19.9	238
	Glycerol 0%+ Restriction 50%	20.4	37.1	16.6	198
	Glycerol 5%+ Restriction 0%	20.6	45.5	24.9	296
	Glycerol 5%+ Restriction 30%	19.2	37.3	18.1	215
	Glycerol 5%+ Restriction 50%	20.8	36.7	15.9	189
Sig. level of interaction		NS	NS	NS	NS
Standard Error Mean		0.3523	0.8786	0.7792	9.2866

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

The results indicate that the 42-day 30% and 50% nutritional restriction treatments followed by 42 days of re-alimentation, despite achieving compensatory growth during the latter period, did not reach the same final weights as the lambs in the 0% restriction treatment. This may be because the re-alimentation period was insufficient to allow the lambs to fully compensate for the weight lost during the nutritional restriction phase. This finding is consistent with (3) that subjecting lambs to a 20% nutritional restriction for six weeks followed by two weeks of re-alimentation, was insufficient for complete weight compensation during the total experimental period.

This study's findings, however, do not align with (7), who found that a 25% nutritional restriction for 42 days followed by 27 days of re-alimentation had no negative effect on lamb growth performance. Nonetheless, weight recovery trends after re-alimentation in growing lambs may depend on the duration of the re-alimentation period. The results of this study showed that the interaction between nutritional restriction level and glycerol supplementation had no significant effect on final weight, total weight gain, or daily weight gain across all treatment combinations.

The results in Table 8 on showed no significant differences between the 5% and 0% glycerol diet treatments in terms of daily feed intake, daily dry matter intake, feed conversion ratio, feed efficiency, or dry matter intake as a percentage of body weight.

However, the 5% glycerol treatment recorded a higher feeding cost per 1 kg weight gain (4,263 Iraqi dinars) than the 0% treatment at 3,088 Iraqi dinars. This aligns with previous findings observed during the nutritional restriction and re-alimentation periods.

Regarding the effect of nutritional restriction level on feeding performance over the whole experimental period, a significant decrease in daily feed intake was observed with higher levels of nutritional restrictions at 1,474, 1,106, and 959 g/day for the 0%, 30%, and 50% restriction treatments, respectively. Similarly, daily dry matter intake decreased as nutritional restriction increased, reaching 1,315, 987, and 824 g/day for the 0%, 30%, and 50% restriction treatments, respectively.

No significant differences were recorded in feed conversion ratio, feed efficiency, or the cost of producing 1 kg weight gain. However, significant differences were observed in dry matter intake as a percentage of body weight between the 0%, 30%, and 50% restriction treatments at 2.98%, 2.51%, and 2.23%, respectively.

Table 8: Effect of level of nutritional restriction and glycerol on feeding performance of lambs during nutritional restriction and re-alimentation periods (84 days).

Treatments		Parameters					
		Intake		Feed conversion ratio	Feeding efficiency (g/kg)	Dry matter intake of (%) body weight	Cost of producing 1kg weight gain (IDQ)
		Feed (g/day)	Dry matter (g/day)				
Glycerol	0%	1191	1065	4.50	222	2.61	3088 b
	5%	1168	1020	4.40	230	2.54	4263 a
Sig. level of added glycerol		NS	NS	NS	NS	NS	0.0001
Nutritional restriction	0%	1474 a	1315 a	4.67	215	2.98 a	3775
	30%	1106 b	987 b	4.38	229	2.51 b	3606
	50%	959 c	824 c	4.30	235	2.23 c	3645
Sig. level of diet restriction		0.0001	0.0001	NS	NS	0.0001	NS
Glycerol and restriction interaction	Glycerol 0%+ Restriction 0%	1482	1325	4.92	202	3.10	3369
	Glycerol 0%+ Restriction 30%	1139	1018	4.30	233	2.45	2951
	Glycerol 0%+ Restriction 50%	953	851	4.30	232	2.30	2942
	Glycerol 5%+ Restriction 0%	1466	1305	4.42	227	2.87	4181
	Glycerol 5%+ Restriction 30%	1073	956	4.47	225	2.57	4261
	Glycerol 5%+ Restriction 50%	965	798	4.30	237	2.17	4347
Sig. level of interaction		NS	NS	NS	NS	NS	NS
Standard Error Mean		49.173	45.763	0.0916	0.00470	0.0722	141.49

NS: Non-significant.

a, b, c: Means in the same column with different letters differ (P<0.01).

The results of feeding performance over the total experiment duration indicate that, although lambs in the 30% and 50% nutritional restriction treatments did not reach final weights comparable to those in the 0% treatment, their feed conversion

ratio and feeding efficiency were mainly similar. Also, the interaction between nutritional restriction level and glycerol addition had no significant effect on any feeding performance parameters across all interactions throughout the experiment.

Conclusions

This study concluded that adding glycerol at a 5% level to the diet did not improve the growth or feeding performance of local male lambs. Additionally, implementing a 42-day 30% nutritional restriction period followed by a similar free re-alimentation duration could be a viable strategy to reduce feeding costs and enhance feed utilization efficiency.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Ammar R. Mansoor: study concept, design analysis, and interpretation of results; Aymen A. Hameed: data collection and draft manuscript preparation. Both authors reviewed the results and approved the final version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted in accordance with the protocol authorized by the Central Committee of Research Ethics, University of Anbar, Iraq.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Data available upon request.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors would like to thank the Dean of the College of Agriculture for providing the materials used in this study. Our gratitude also to the University of Anbar for the encouragement and support extended to us during the entire duration of the study.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Abouheif, M., Al-Owaimer, A., Kraidees, M., Metwally, H., and Shafey, T. (2013). Effect of restricted feeding and realimentation on feed performance and carcass characteristics of growing lambs. Revista Brasileira de Zootecnia, 42(2): 95-101.doi: 10.1590/S1516-35982013000200003.
2. Abouheif, M., Al-Sornokh, H., Swelum, A., Shafey, T., Mahmoud, A., Alshamiry, F., and Haroon, R. (2016). Effects of intake restriction and

realimentation on diet digestion and ruminal fermentation by growing lambs. Global Advanced Research Journal of Agricultural Science, 5(4): 2315-5094.

3. Abouheif, M., Al-Sornokh, H., Swelum, A., Yaqoob, H., & Al-Owaimer, A. (2015). Effect of different feed restriction regimens on lamb performance and carcass traits. Revista Brasileira de Zootecnia, 44(3), 76–82. https://doi.org/10.1590/S1806-92902015000300001
4. Addah, W., Ayantunde, A., and Okine, E. K. (2017). Effects of restricted feeding and re-alimentation of dietary protein or energy on compensatory growth of sheep. South African Journal of Animal Science, 47(3): 389-398. doi:10.4314/sajas.v47i3.15.
5. Adeniji, Y. A., Sanni, M. O., Abdoun, K. A., Samara, E. M., Al-Badwi, M. A., Bahadi, M. A., Alhidary, I. A., and Al-Haidary, A. A. (2020). Resilience of lambs to limited water availability without compromising their production performance. Animals, 10(9): 1491. doi:10.3390/ani10091491.
6. Al-Obeidi, B. N. R. (2022). Effect of nutritional restriction with or without melatonin in blood characteristics and growth of local male lambs. MSc. Thesis, College of Agriculture, University of Anbar.
7. Al-Obeidi, B. N. R., and Mansoor, A. R. (2023). Effect of melatonin implants and nutritional restriction on growth performance of local male lambs. Archives of Razi Institute, 78(2): 571- 579.doi: 10.22092/ARI.2022.359330.2402.
8. Al-Selbood, B. A. (2009). Effect of feeding program on performance and carcass characteristics of Najdi lambs. PhD. Thesis, King Saud University, Riyadh, Saudi Arabia.
9. Almeida, M. T. C., de Santos Torres, R. N. S., de Valença, R. L., de Almeida, R. A. T., Falcão, T. T., Hemerly, V. P., and de Carvalho, L. M. S. (2024). PSXIII-25 Exploring crude glycerin as an alternative to corn in high-concentrate diets: Effects on performance and ruminal health in feedlot lambs. Journal of Animal Science, 102(Supplement-3): 793-794. doi: 10.1093/jas/skae234.892.
10. Avila-Stagno, J., Chaves, A. V, He, M. L., Harstad, O. M., Beauchemin, K. A., McGinn, S. M., and McAllister, T. A. (2013). Effects of increasing concentrations of glycerol in concentrate diets on nutrient digestibility, methane emissions, growth, fatty acid profiles, and carcass traits of lambs. Journal of Animal Science, 91(2): 829-837. doi: 10.2527/jas.2012-5215.
11. Chilakamarry, C. R., Sakinah, A. M. M., and Zularisam, A. W. (2022). Opportunities of biodiesel industry waste conversion into value-added products. Materials Today: Proceedings, 57(3): 1014-1020. doi: 10.1016/j.matpr.2021.08.248.
12. Cui, K., Wang, B., Ma, T., Si, B. W., Zhang, N. F., Tu, Y., and Diao, Q. Y. (2018). Effects of dietary protein restriction followed by realimentation on growth performance and liver transcriptome alterations of lamb. Scientific Reports, 8(1): 15185. doi: 10.1038/s41598-018-33407-w.
13. Dashtizadeh, M., Zamiri, M. J., Kamalzadeh, A., and Kamali, A. (2008). Effect of feed restriction on compensatory growth response of young male goats. Iranian Journal of Veterinary Research, 9(2): 109-120.
14. de Andrade, G. P., de Carvalho, F. F. R., Batista, Â. M. V., Pessoa, R. A. S., da

Costa, C. A., Cardoso, D. B., and do Vale Maciel, M. (2018). Evaluation of crude glycerin as a partial substitute of corn grain in growing diets for lambs. Small Ruminant Research, 165: 41-47.doi: 10.1016/j.smallrumres.2018.06.002.

15. Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics, 11(1): 1-42.
16. Ellis, N. (1980). The nutrient composition of Sudanese animal feedsNo Title. Bulletin No. 1. Northern and Central Sudan. Animal Nutrition Research Laboratory, Kuku, Khartoum North, (Appendix 1): 19.
17. Goff, J. P., and Horst, R. L. (2003). Oral glycerol as a gluconeogenic precursor in the treatment of ketosis and fatty liver. Acta Veterinaria Scandinavica, 44(Suppl 1): 214-215.doi: 10.1186/1751-0147-44-S1-P40.
18. Gunn, P. J., Neary, M. K., Lemenager, R. P., and Lake, S. L. (2010). Effects of crude glycerin on performance and carcass characteristics of finishing wether lambs. Journal of Animal Science, 88(5): 1771-1776. doi: 10.2527/jas.2009-2325.
19. Karadağ, E., and Okur, A. A. (2022). Bazı Gıda Endüstrisi Yan Ürünlerinin Besin Madde İçerikleri ve Hayvan Beslemede Alternatif Yem Hammaddesi Olarak Kullanım Olanakları. Turkish Journal of Agriculture-Food Science and Technology, 10(11): 2180–2187. doi: 10.24925/turjaf.v10i11.2180-2187.5387.
20. Karthik, D., Suresh, J., Reddy, Y. R., Sharma, G. R. K., Ramana, J. V, Gangaraju, G., Pradeep Kumar Reddy, Y., Yasaswini, D., Adegbeye, M. J., and Reddy, P. R. K. (2021). Farming systems in sheep rearing: Impact on growth and reproductive performance, nutrient digestibility, disease incidence and heat stress indices. Plos One, 16(1): e0244922. doi: 10.1371/journal.pone.0244922.
21. Keogh, K., Waters, S.M., Kelly, A.K., and Kenny, D.A. (2015). Feed restriction and subsequent realimentation in Holstein Friesian bulls: I. Effect on animal performance; muscle, fat, and linear body measurements; and slaughter characteristics. Journal of Animal Science, 93(7): 3578-3589. doi: 10.2527/jas.2014-8470.
22. Knothe, G., Van Gerpen, J. H., and Krahl, J. (2005). The Biodiesel Handbook (Vol. 1). AOCS press Champaign, IL.
23. Lima, H. B., Costa, R. G., Dias-Silva, T. P., da Cruz, G. R. B., de Carvalho, F. F. R., Guerra, R. R., Ribeiro, N. L., de Araújo Filho, J. T., and Teixeira, A. J. C. (2022). Performance and ruminal and intestinal morphometry of santa ines sheep submitted to feed restriction and refeeding. Tropical Animal Health and Production, 54(1): 1-9. doi: 10.1007/s11250-022-03053-6.
24. Luzardo, S., Clariget, J., and Banchero, G. (2019). Can compensatory growth mitigate a feeding restriction in growing lambs? Chilean Journal of Agricultural and Animal Sciences, 35(3): 238–244. doi: 10.4067/S0719-38902019005000403.
25. Merlim, F. A., Silva Sobrinho, A. G., Borghi, T. H., Cirne, L. G. A., Valença, R. L., Almeida, F. A., Endo, V., Viegas, C. R., and Zeola, N. M. B. (2021). Crude glycerin is an efficient alternative to corn in the diet of feedlot lambs. Archives Animal Breeding, 64(2): 387–393. doi: 10.5194/aab-64-387-2021.
26. Musselman, A. F., Van Emon, M. L., Gunn, P. J., Rusk, C. P., Neary, M. K., Lemenager, R. P., and Lake, S. L. (2008). Effects of crude glycerin on feedlot

performance and carcass characteristics of market lambs. Proceedings, Western Section, American Society of Animal Sciences, 59: 353-355.

27. Omazic, A. W., Tråven, M., Bertilsson, J., and Holtenius, K. (2013). High-and low-purity glycerine supplementation to dairy cows in early lactation: effects on silage intake, milk production and metabolism. Animal, 7(9): 1479-1485.
28. Qi, H., Ye, C., Nan, Y., Xie, M., Jiang, B., Abulizi, N., and Zhao, Z. (2024). Effect of dietary glycerol addition on growth performance, serum biochemical indexes, carcass traits, fat deposition, and meat quality in fattening period Kazakh sheep. Kafkas Universitesi Veteriner Fakultesi Dergisi, 30(2): 275-282. doi: 10.9775/kvfd.2023.31020.
29. Qoja, A., and Hussein, A. A. (2022). Effect of crude glycerol supplementation via drinking water on lambs performance, some blood haematology, and biochemical metabolites. Zanco Journal of Pure and Applied Sciences, 34(1): 110-119.
30. Saleem, A. M., and Singer, A. M. (2018). Growth performance and digestion of growing lambs fed diets supplemented with glycerol. Animal, 12(5): 959–963. doi:10.1017/S1751731117001793.
31. SAS, S., and Guide, S.U.S. (2003). Version 9. Cary, NC: SAS Institute, 9th Ed(9). doi: 10.1093/ps/82.9.1383.
32. Simões, J., Abecia, J. A., Cannas, A., Delgadillo, J. A., Lacasta, D., Voigt, K., and Chemineau, P. (2021). Review: Managing sheep and goats for sustainable high yield production. Animal, 15(Supplement 1): 100293. doi: 10.1016/j.animal.2021.100293.
33. Yakubu, A., Salako, A. E., Ladokun, A. O., Adua, M. M., and Bature, T. U. K. (2007). Effects of feed restriction on performance, carcass yield, relative organ weights and some linear body measurements of weaner rabbits. Pakistan Journal of Nutrition, 6(4): 391-396. doi: 10.3923/pjn.2007.391.396.