

Article

Effects of Feed Restriction Duration on Growth Performance, Organ Weight, and Carcass Traits of Finishing Lambs Fed a Concentrate-Based Diet

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Simple Summary

This study investigated differing lengths of minor feed restrictions (92% of full intake for 0, 28, or 56 days) in lambs and how it affected growth, meat, and animal composition. The lambs that were restricted for the entire feeding period performed similarly to the fully fed controls but had fewer fat carcasses. The lambs that were only restricted for half the feeding period surprisingly performed the worst, with lighter carcasses and less muscle. This suggests that a short restriction period does not improve efficiency, and the lamb uses energy to rebuild its internal organ mass after restriction. To limit feed costs and produce leaner carcasses, a longer feed restriction is more beneficial in lambs than too short of a feed restriction and recovery period.

Abstract

This study evaluated the effect of limiting feed intake to 92% of ad libitum for 28 or 56 d of a 56 d finishing period on growth performance, carcass characteristics, and visceral organ mass in wethers. Thirty Polypay wethers (initial SBW = 25.6 ± 5.27 kg; 15 pens, 2 lambs/pen) were blocked by body weight and assigned to three treatments: ad libitum intake for 56 d (CON), 92% of ad libitum intake for 28 d and then ad libitum intake for 28 d (28L), or 92% of ad libitum intake for 56 d (56L). Cumulatively, DMI decreased as restriction length increased ($p < 0.001$), but the final SBW, ADG, and G:F did not differ between treatments ($p \geq 0.11$). Hot and cold carcass weights along with carcass muscle and bone masses were lesser in 28L than CON, but 56L did not differ ($p \leq 0.04$). Carcass fat mass was greatest in CON and least in 28L ($p \leq 0.04$). Relative to EBW, liver mass was greatest in 28L and least in 56L ($p = 0.03$). Limit feeding for 56 d maintained carcass weight while increasing leanness compared to CON, whereas a 28 d restriction period reduced carcass and muscle mass, possibly due to visceral organ recovery.



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1. Introduction

Global lamb production is predicted to be steady or increase slightly from 2024 to 2025 [1]. Despite sheep production primarily being focused on extensive management and traditional pastoralism, high-concentrate diets fed to lambs in a feedlot system are becoming more popular in the USA, Mexico, and Australia [2]. As sheep production shifts

away from traditional pastoral systems, reducing labor and feed costs will be critical to maintaining competitiveness in the global meat market [2]. Utilizing high-concentrate diets and limit-feeding strategies may provide an opportunity to reduce both feed and labor costs in the sheep industry. Limit feeding is a feed management strategy of restricting feed intake relative to an animal's actual or expected *ad libitum* intake [3]. In beef cattle production, limit feeding is often used in the growing phase to control growth or program gain on high-concentrate diets [3–5]; during the finishing phase to mitigate heat stress [6] and improve feed efficiency; or it is implemented through slick bunk management [3,5,7–9]. Within the finishing period, limit feeding strategies generally involve limit feeding for only a portion of the finishing period, then returning cattle to *ad libitum* feed intake, called the realimentation period. During the realimentation period, cattle experience compensatory growth and can achieve final body weights (BW) similar to *ad libitum*-fed groups [10,11]. Improving feed efficiency is especially important as sheep production shifts from a low-cost extensive system to a more intensive feedlot finishing system to remain economically and environmentally sustainable [2].

The improvements in feed efficiency, as well as the compensatory growth observed during limit feeding, are primarily due to changes in the composition of gain and changes in visceral organ mass and metabolism [12,13]. While this is beneficial for feed efficiency, cattle that are limit fed, even for a portion of the finishing period, can have decreased marbling scores and carcass quality [7,12]. In lambs fed all concentrate diets, linear reductions in average daily gain (ADG) were observed as lambs were restricted to 85% and 75% of *ad libitum* intake, but no differences were observed in feed efficiency [14,15]. In greater restrictions of 75% and 60% of *ad libitum* feed offered for 35 d, ADG was decreased by 48 and 70%, and feed efficiency decreased in a diet with a 25:75 ratio of forage to concentrate [16]. In a similar study with a 25:75 ratio of forage to concentrate, lambs restricted to 90% and 80% of *ad libitum* feed for 42 d had linear reductions in ADG, but the 80% restriction decreased feed efficiency [17]. During the realimentation period, lambs often exhibit increased ADG and feed efficiency, attributed to reduced maintenance energy costs from the restriction period, rather than a significant increase in intake above controls [16–18]. The effect of limit feeding lambs on carcass composition consistently shows reductions in carcass fat [14,16,17,19,20]. Realimentation periods allow for the recovery of lean tissue; fat depots require longer realimentation periods to recover, and 14 d of realimentation has been shown to be insufficient for fat recovery in lambs [17]. Organ mass is reduced by limit feeding, especially of the liver, kidney, and gastrointestinal tract [15,18]. The recovery of the liver during realimentation is achieved rapidly, recovering within 14 d of realimentation; however, the gastrointestinal tract can take longer to recover [17].

The current literature shows that limit feeding during the finishing period can improve feed efficiency but has negative effects on carcass quality. Severe restrictions > 80% result in decreased ADG and poorer feed efficiency; thus, we chose 8% restriction and a 28 d realimentation period to allow for carcass and organ recovery while maintaining improved feed efficiency during the realimentation period. This study aims to evaluate the effect of limit feeding for part of or for the entire finishing period on growth performance, carcass characteristics, visceral organ mass, carcass cutouts, and body composition in lambs. We hypothesize that limit feeding for 28 d followed by a 28 d realimentation period will result in similar growth performance to *ad libitum*-fed lambs but fewer fat carcasses, while limit feeding lambs for 56 d will result in poorer growth performance, fewer fat carcasses, and lighter visceral organs than the *ad libitum*-fed lambs.

2. Materials and Methods

This study was conducted at the South Dakota State University Sheep Unit in Brookings, South Dakota, between April 2024 and May 2024. The animal care, handling, and slaughter procedures used in this study were approved by the South Dakota State University Animal Care and Use Committee (2402-029E) on 18 March 2024.

2.1. Treatments

Thirty Polypay wethers (initial shrunk body weight [SBW] = 25.6 ± 5.27 kg) were acquired from the SDSU Sheep Unit and sorted by initial SBW into 5 blocks and assigned to pens ($n = 15$; 2 lambs/pen; 5 replicates per treatment) in a randomized complete block design. The pens were then assigned to 1 of 3 treatments:

1. Lambs fed ad libitum for 56 d (**CON**);
2. Lambs limited to 92% of ad libitum intake for 28 d followed by ad libitum intake for 28 d (**28L**);
3. Lambs limited to 92% of ad libitum intake for 56 d (**56L**).

The 92% feed restriction was determined by providing the limit-fed pens 92% of the intake of the CON group within their respective blocks from the previous day. The ad libitum-fed lambs were managed to have <5% orts remaining in the morning to minimize feed wastage by the lambs. Orts were collected daily to determine daily feed intake.

2.2. Feeding and Management

Lambs were group housed prior to study initiation and were transitioned to the treatment diet. Lambs were also offered ad libitum grass hay prior to the study. Lambs in the CON group were offered feed at 1% of their BW on an as-is basis on d 1, 2% on d 2, 2.25% on d 3 and 4, and 2.5% on d 5 and 6. After this, they were offered ad libitum feed. The feed restrictions for 28L and 56L began on d 2 where they were offered 92% of the feed offered to the CON lambs. All lambs were weighed for allotment, paint branded with their pen, and had backfat thickness (BF) and loin eye depth measured via ultrasonography (EVO III, E.I. Medical Imaging, Loveland, CO, USA) on 2 April 2024 (d 1 for group 1 and 2 for group 2, respectively); loin eye area (LEA) was calculated according to the National Sheep Improvement Program standards. The lambs were then divided into two groups and started on treatment 2 days apart to accommodate the SDSU meat lab slaughter capacity at the end of the study. Three replicates (9 pens; 18 lambs) started the study on April 2, while 2 replicates (6 pens; 12 lambs) were reweighed and started the study on April 4. Body weights were measured again on d 28 and d 56 after a 20 h fast, and backfat and loin eye depth were measured via ultrasonography on d 28.

Lambs were housed indoors in 1.5×1.5 m pens bedded with wheat straw. Lambs were fed once daily at 0800 for the first 28 d, then switched to twice-a-day feeding for the final 28 d at 0800 h and 1400 h. Feed was weighed out individually for each pen on a digital scale (Weigh-Tronix 640m, Agri-Tronix Corporation, Franklin, IN, USA; scale readability ± 9.1 g) and hand delivered to pens in buckets. Each pen was equipped with a hanging trough feeder with 0.91 m of bunk space that feed was delivered into. Lambs had ad libitum access to fresh, clean water in buckets attached to their pens. Weekly total mixed ration (TMR) samples were collected and analyzed for dry matter (DM). Actual diet formulation based upon weekly DM determination with tabular nutrient values according to Preston [21] are presented in Table 1.

Table 1. Ingredient inclusion and nutrient composition of diet fed to lambs ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L).

Item	Diet
Ingredient Inclusion	
Dry Rolled Corn	59.1
Supplement Pellet ¹	25.3
Oats	10.1
Soybean Meal	2.5
Molasses	3.0
Nutrient Composition, Dry Matter Basis	
Dry Matter, % As Fed	88.0
Crude Protein, %	18.1
Neutral Detergent Fiber, %	10.9
Acid Detergent Fiber, %	3.9
Ash, %	2.8
Ether Extract, %	3.2
Net Energy for Maintenance, Mcal/kg	2.07
Net Energy for Gain, Mcal/kg	1.40
Decoquinat, mg/kg	24.5

¹ Supplement pellet contained (DM basis) 40% crude protein, 3.2% non-protein nitrogen, 0.5% crude fat, 8.0% crude fiber, minimum 3.5% calcium, maximum 4.5% calcium, minimum 0.7% salt, maximum 1.2% salt, 0.8 ppm of selenium, 7710 IU/kg of vitamin A, 1361 IU/kg of vitamin D, 91 IU/kg of vitamin E, and 97 mg/kg of Decoquinat.

2.3. Growth Performance

Lamb BWs were assumed to be SBW because they were fasted for 20 h prior to weighing, so no pencil shrink was applied. Lambs were weighed on a platform scale with a scale break of 0.45 kg. Average daily gain was calculated as final SBW—initial SBW/days on feed (DOF) and gain to feed (G:F) was calculated as ADG/dry matter intake (DMI). Growth responses were calculated for the cumulative feeding period, from d 1 to 28 and from d 28 to 56.

2.4. Carcass Characteristics

Lambs were harvested at the SDSU meat lab on d 56. Lamb viscera were individually collected and weighed during harvest, and the gastrointestinal tract including the digesta, internal fat, and perirenal fat with the kidneys were collected and stored overnight in a cooler. The following morning, digesta was washed from the gastrointestinal tract, the fat was removed, and the tract was separated into the forestomach, small intestine, and large intestine and weighed. The weight of the digesta was subtracted from the final SBW to determine empty body weight (EBW).

Carcasses were weighed prior to chilling to obtain a hot carcass weight (HCW) and weighed the following morning after chilling for a cold carcass weight (CCW). They were then ribbed between the 12th and 13th ribs for evaluation of LEA, BF, and body wall thickness (BWT). Flank fat streaking and leg conformation score were also recorded for each carcass.

Calculated yield grade equations were obtained via the USDA Yield Grade [22] equation for lambs: Yield Grade = $0.4 + (10 \times \text{BF, in})$. The percentage of red meat yield (RMV) was calculated via the equations in the study by Jones et al. [23]: $\text{RMV} = 80.33 - (0.35 \times \text{BWT, mm}) + (0.83 \times \text{leg conformation score})$. Additionally, the percentage of boneless closely trimmed retail cuts (BCTRCs) was calculated via the equation in the study by Boggs [24]: $\text{BCTRC} = 49.936 - (0.0848 \times \text{HCW, lbs}) - (4.376 \times \text{BF, in}) - (3.53 \times \text{BWT, in}) + (2.453 \times \text{LEA, in}^2)$.

After chilling, lambs were sectioned according to the Institutional Meat Purchase Specifications (IMPS) to determine the forequarter and hindquarter of the left side. The forequarter was divided into the neck, shoulder IMPS206, rack IMPS204, breast IMPS209, and ribs IMPS209a, and the hindquarter was divided into the loin IMPS231, leg IMPS233, and flank IMPS232 [25]. The left side shoulder was then manually dissected into muscle, fat, and bone according to Luaces et al. [26]. Carcass composition was then determined from the shoulder composition according to Carrasco et al. [20] to determine carcass composition on a percentage basis and on a half-carcass weight basis.

2.5. Statistical Analysis

Data were analyzed as a randomized complete block design using the MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC, USA). Pen was the experimental unit with treatment as the fixed effect and block as the random effect. Individual measurements from the two lambs within each pen were averaged, and the resulting pen mean was used as the observational unit for statistical analysis. Least square means were generated with the LSMEANS option of PROC MIXED and means were separated using Tukey's HSD adjustment and denoted differently ($p \leq 0.05$). Flank streaking and leg conformation were analyzed using the GLIMMIX procedure of SAS 9.4 with pen as the experimental unit using a multinomial distribution. Significance was determined at $p \leq 0.05$ and tendencies at $0.05 < p \leq 0.10$.

3. Results

Initial, d 28, and d 56 SBW did not differ between treatments ($p \geq 0.11$; Table 2). Dry matter intake was greatest for CON and least for the 28L and 56L lambs from d 1 to 28 ($p < 0.01$). From d 28 to 56, the CON and 28L lambs had the greatest intakes ($p < 0.01$), and cumulatively, CON had the greatest, 28L was intermediate, and 56L had the least DMI ($p < 0.01$). Average daily gain and G:F did not differ from d 1 to 28 or from d 1 to 56 ($p \geq 0.24$) but tended to differ from d 28 to 56 ($p \leq 0.07$).

Table 2. The growth performance of lambs fed ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L). ^{a,b,c} Means within a row lacking a common superscript differ ($p \leq 0.05$)

	CON	28L	56L	SEM	<i>p</i> -Value
Shrunk Body Weight, kg					
Initial	25.6	25.2	26.1	2.48	0.64
d 28	32.7	32.3	32.3	2.83	0.72
d 56	43.1	41.5	42.1	2.73	0.11
Dry Matter Intake, kg/d					
d 1 to 28	1.07 ^a	0.99 ^b	0.99 ^b	0.104	<0.01
d 28 to 56	1.73 ^a	1.69 ^a	1.59 ^b	0.092	<0.01
d 1 to 56	1.40 ^a	1.34 ^b	1.29 ^c	0.098	<0.01
Average Daily Gain, kg/d					
d 1 to 28	0.25	0.25	0.22	0.029	0.47
d 28 to 56	0.37	0.33	0.35	0.014	0.07
d 1 to 56	0.31	0.29	0.29	0.015	0.24
Gain:Feed					
d 1 to 28	0.245	0.259	0.22	0.0261	0.51
d 28 to 56	0.217	0.197	0.224	0.0157	0.06
d 1 to 56	0.227	0.22	0.224	0.0147	0.87

Hot carcass weight and CCW were greatest for CON and least for 28L, with 56L not differing ($p \leq 0.04$; Table 3). Empty body weight on a kg basis tended to differ ($p = 0.06$), but on a percentage basis, EBW and DP did not differ ($p \geq 0.12$). Yield grade, RMY, and BCTRC did not differ ($p \geq 0.23$). Backfat and LEA did not differ on d 1, 28, or 56 ($p \geq 0.23$). Flank streaking and leg conformation distributions did not differ between treatments ($p \geq 0.39$).

Table 3. The carcass characteristics and distribution of flank streaking and leg conformation scores of lambs fed ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L). ^{a,b} Means within a row lacking a common superscript differ ($p \leq 0.05$)

	CON	28L	56L	SEM	<i>p</i> -Value
Hot Carcass Weight, kg	23.0 ^a	21.6 ^b	22.3 ^{ab}	1.68	0.03
Cold Carcass Weight, kg	22.5 ^a	21.0 ^b	21.7 ^{ab}	1.71	0.04
Empty Body Weight, kg	38.5	36.9	38	2.55	0.06
Empty Body Weight, %	89.4	88.8	90.2	0.47	0.12
Dressing Percent, %	53.4	51.9	52.9	0.86	0.31
Yield Grade	2.31	2.49	2.18	0.412	0.48
Red Meat Yield, %	82.1	83.1	82.7	0.85	0.23
Boneless Closely Trimmed Retail Cuts, %	42.2	42.7	42.5	0.84	0.4
Backfat Thickness, cm					
Initial	0.25	0.24	0.23	0.022	0.8
d 28	0.33	0.3	0.31	0.03	0.58
d 56	0.49	0.57	0.45	0.115	0.34
Loineye Area, cm ²					
Initial	5.9	6	6.3	0.45	0.52
d 28	8.4	8.4	9.2	0.68	0.33
d 56	15	13.5	15	0.64	0.23
Flank Streaking					0.71
Select	77.9	78	60.2	-	
Choice	22.1	22	39.8	-	
Leg Conformation					0.39
Low Choice	98.2	98.2	87.3	-	
Average Choice	1.8	1.8	12.7	-	

The shoulder and carcass composition on a percentage basis did not differ ($p \geq 0.16$; Table 4). The shoulder muscle on a kg basis was greatest for CON and 56L lambs ($p = 0.02$), the weight of the fat differed ($p = 0.05$), and bone tended to differ ($p = 0.07$). The carcass composition on a half-carcass weight basis had the greatest muscle and bone in the CON and 56L groups ($p \leq 0.03$), and the fat was significantly affected by overall treatment ($p = 0.04$), with the CON group having the greatest mean value; however, pairwise differences did not reach statistical significance following Tukey's HSD adjustment ($p > 0.05$).

Table 4. The shoulder and carcass composition of lambs fed ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L). ^{a,b} Means within a row lacking a common superscript differ ($p \leq 0.05$).

	CON	28L	56L	SEM	<i>p</i> -Value
Shoulder composition, kg					
Muscle	1.53 ^a	1.41 ^b	1.53 ^a	0.113	0.02
Fat ¹	0.81	0.71	0.69	0.098	0.05
Bone	0.76	0.7	0.76	0.058	0.07
Shoulder composition, %					
Muscle	49.6	50.5	51.3	1.1	0.24
Fat ¹	25.8	24.6	23.1	1.63	0.18
Bone	24.6	25	25.6	0.8	0.37
Carcass composition, kg					
Muscle	6.36 ^a	5.91 ^b	6.35 ^a	0.425	0.02
Fat	5.31	4.65	4.69	0.585	0.04
Bone	2.12 ^a	1.98 ^b	2.12 ^a	0.125	0.03
Carcass composition, %					
Muscle	46.5	47.6	48.4	1.21	0.17
Fat	37.9	36.4	35.4	1.73	0.17
Bone	15.5	16	16.2	0.54	0.16

¹ Main effect of treatment was significant ($p \leq 0.05$), but no pairwise differences were detected among individual treatment means following Tukey's HSD adjustment ($p > 0.05$).

Heart weight was greatest for the CON and 56L lambs and least for the 28L ($p = 0.02$; Table 5) but did not differ on an EBW basis ($p = 0.58$). Liver weight was greatest for the CON and least for the 56L with the 28L not differing ($p = 0.02$), and on an EBW basis, 28L was greatest, 56L the least, and CON did not differ from either ($p = 0.03$). All other viscera weights, on an as-is and an EBW basis, did not differ ($p \geq 0.19$).

Table 5. The visceral organ weights of lambs fed ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L). ^{a,b} Means within a row lacking a common superscript differ ($p \leq 0.05$).

	CON	28L	56L	SEM	<i>p</i> -Value
Viscera, kg					
Hide	3.85	3.85	4.11	0.332	0.38
Limbs	0.68	0.65	0.68	0.037	0.29
Head	2	2.02	2.02	0.095	0.9
Blood	1.61	1.53	1.62	0.09	0.37
Heart	0.24 ^a	0.22 ^b	0.24 ^a	0.01	0.02
Lung	0.72	0.68	0.72	0.044	0.54
Liver	0.86 ^a	0.85 ^{ab}	0.81 ^b	0.037	0.02
Spleen	0.08	0.08	0.08	0.004	0.6
Kidney	0.14	0.14	0.14	0.007	0.89
Visceral fat	1.72	1.7	1.54	0.22	0.42
Perirenal fat	0.25	0.23	0.26	0.037	0.65
Caul fat	0.09	0.11	0.12	0.02	0.29
Forestomach	1.09	1.06	1.06	0.05	0.72
Small intestine	0.9	0.85	0.88	0.035	0.63

Table 5. *Cont.*

	CON	28L	56L	SEM	<i>p</i> -Value
Large intestine	0.43	0.46	0.44	0.017	0.6
Viscera, g/kg of empty body weight					
Hide	100.2	104.3	107.4	3.43	0.37
Limbs	17.6	17.8	18.1	0.56	0.76
Head	52.2	55.2	53.5	1.68	0.28
Blood	42.3	41.8	42.7	1.58	0.78
Heart	6.3	6	6.3	0.22	0.58
Lung	18.7	18.6	19.1	0.81	0.91
Liver	22.5 ^{ab}	23.2 ^a	21.3 ^b	0.66	0.03
Spleen	2.2	2.2	2.2	0.13	1
Kidney	3.7	3.7	3.6	0.17	0.87
Visceral fat	44.1	45.4	40.1	3.48	0.34
Perirenal fat	6.3	6	6.7	0.62	0.67
Caul fat	2.4	3.1	2.9	0.36	0.19
Forestomach	28.3	29	28.2	1	0.67
Small intestine	23.9	23.5	23.5	2.06	0.95
Large intestine	11.4	12.5	11.8	0.84	0.48

The only cutout that differed was the breast on both an as-is and an EBW basis, with the CON and 56L lambs having the greatest weight ($p < 0.01$; Table 6). The leg on an as-is basis tended to be different ($p = 0.07$). All other cutout measurements were not different ($p \geq 0.11$).

Table 6. The individual meat cutout weights of lambs fed ad libitum for 56 d (CON), restricted to 92% of CON for 28 d followed by 28 d of realimentation (28L), or restricted to 92% of CON for 56 d with no realimentation (56L). ^{a,b} Means within a row lacking a common superscript differ ($p \leq 0.05$)

	CON	28L	56L	SEM	<i>p</i> -Value
Cutouts, kg					
Shoulder	6.31	5.85	6.05	0.465	0.14
Leg	6.6	6.22	6.56	0.413	0.07
Loin	1.96	1.81	1.82	0.175	0.39
Rack	2.12	2.22	2.15	0.173	0.64
Ribs	1.54	1.35	1.31	0.156	0.12
Flank	1.59	1.52	1.56	0.194	0.68
Breast	0.89 ^a	0.72 ^b	0.84 ^a	0.079	<0.01
Neck	0.7	0.76	0.74	0.067	0.43
Front trotters	0.25	0.2	0.19	0.019	0.11
Back trotters	0.29	0.27	0.29	0.013	0.19
Cutouts, g/kg of empty body weight					
Shoulder	163	159.7	159	3.9	0.76
Leg	171.3	168.7	173.1	2.45	0.48
Loin	50.4	48.8	48	1.98	0.68
Rack	55.1	59.5	56.6	2.25	0.33
Ribs	39.6	36	34.4	2.17	0.17
Flank	40.6	40.5	40.6	2.69	1
Breast	23.0 ^a	19.5 ^b	22.0 ^a	0.77	<0.01
Neck	18	20.6	19.4	0.83	0.14
Front trotters	6.8	5.4	5	0.81	0.25
Back trotters	7.6	7.4	7.8	0.35	0.47

4. Discussion

The dry matter intake restrictions were successful, although slightly less than the targeted 8% with the 28L lambs being restricted 7.4% and the 56L lambs being restricted 8.0% during their respective restriction periods. Cumulatively, this resulted in a linear decrease in feed intake as we lengthened the restriction time. Due to a lack of published research on limit feeding with a realimentation period in finishing lambs, comparisons in this discussion rely mostly on feedlot cattle research. Despite potential differences in how cattle and sheep respond to limit feeding, cattle data offers the most robust literature for interpreting these results. As observed in previous studies, the limit-fed group's intake was similar to the ad libitum group during the realimentation period; however, unlike in those studies, we did not observe an increase in feed efficiency during this period [8,10–12]. This response is consistent in the sheep literature as well, with no difference in intake but improved feed efficiency during realimentation [16–18]; however, in more severe restrictions in cattle, intake often increases during the realimentation period and may account for a more significant portion of the compensatory gain response [13,27]. Despite the apparent differences in intake, there was no difference in SBW and only a tendency for the 28L lambs to be slower growing and less efficient during the realimentation period. This is generally not in agreement with previous studies in lambs during the realimentation period, where animals go through compensatory growth with greater gain and feed efficiency [16–18]. Although speculative, it is possible that the 28 d restriction period was too short for the lambs to fully adapt to their lower intakes and, as a result, could not recover during the realimentation period. The initial restriction period often results in poorer performance, and it is not until after an adaptation period that improvements in feed efficiency are observed in limit feeding studies [10–12]. Lambs that were restricted to 80% of ad libitum feed for 42 d then went through 14 d of realimentation were not able to recover to the same final BW as the control group; however, the group that was limited to 90% of ad libitum feed was able to recover after only 14 d [17], supporting the theory that a 28 d realimentation period might have been sufficient to recover BW at only an 8% restriction, but the restriction length might have been too short. Further supporting this theory is the fact that the 56L lambs are often intermediate or even closer to the CON lambs than the 28L lambs in many of the measured variables. A 28 d restriction period followed by a 28 d realimentation period did not result in improved performance, but interestingly, the full 56 d restriction period also did not result in decreased performance relative to the ad libitum-fed group. Although bunk management was designed to minimize feed sorting and loss, because of behavioral characteristics of confined lambs, feed loss was observed which may have introduced variation in the feed intakes and growth performance. Additionally, gut fill can be a confounding factor when comparing limit-fed to ad libitum-fed animals. While this was minimized through a 20 h fast prior to weighing, the carcass weights of the lambs are likely a stronger indicator of performance than live weights.

Although there were no differences in final SBW, carcass weights did differ. The CON lambs had a 3.2% improvement over the 56L lambs, and the 56L lambs had a 3.1% improvement over the 28L lambs for HCW. Although EBW also accounts for gut fill, it retains non-carcass components such as the hide, head, blood, feed, and organs, which introduces additional biological variation and likely explains why HCW and CCW statistically differed while EBW only tended to differ. The HCW, CCW, and EBW demonstrated similar treatment responses despite EBW only tending to differ. No other carcass traits differed, including flank streaking, LEA, and backfat thickness. However, when the shoulder was dissected, the CON and 56L lambs had greater muscling, with the 56L lambs also having the least fat on both a shoulder and carcass basis. Slowing down growth through limit feeding often results in leaner carcasses in cattle [7,8,28] and sheep [14,16,17,20]. The leaner

carcasses in the 56L lambs were achieved without affecting muscle growth but by decreasing fattening. It is interesting that the 28L lambs responded the worst, with decreased muscle and bone compared to the other two treatments. Despite the differences in muscle mass observed in the whole carcass, individual cutouts do not reflect this difference, apart from the breast, which was the greatest for the CON and 56L treatments. The apparent lack of differences in the individual cutouts despite HCW differences may be caused by greater introduced human error as more processing is done to each cut.

Overall, most visceral organ masses did not differ, except for the liver and heart. The heart has not shown a response to daily feed intake levels in previous studies in both sheep and cattle [7,13,18]. Since the heart weight does not differ relative to EBW, it is likely a function of the lighter EBW of the 28L lambs. The liver followed a linear trend, with the CON group having the greatest liver mass and the 56L group the least. When analyzed relative to EBW, the 28L lambs have the greatest liver mass. Limit feeding decreases liver mass, primarily through the decreased size of hepatic cells [13]. Much less is known about how the liver responds during the realimentation period. Part of the hypothesis behind compensatory gain is that the liver takes a while to grow back to its pre-limit feeding size, and during this time it is consuming less energy, resulting in decreased maintenance energy requirements [7,13]. Although the metabolic activity of the liver was not measured directly, the metabolic activity of the liver during changes in feed intake has been shown to be related to the size of the liver and not the metabolic activity of the hepatic tissue itself [29]. During such a short restriction and realimentation period, it is possible that the 28L lambs were not in a state where maintenance energy costs were decreased during either period. In fact, the 28L lambs had the greatest liver mass relative to BW, indicating potentially greater maintenance requirements during the realimentation period, and the rapid recovery of liver weight has been observed previously in lambs [16,17]. However, it is important to note that this proposed mechanism remains speculative, as other factors may have played an important role in the poor performance of the 28L lambs. Whether the poor response from the 28L lambs is a result of too short of a restriction or realimentation period or simply due to differing responses to limit feeding between sheep and cattle requires further investigation. A limitation of the present study is that the sample size of five pens per treatment limits the statistical power for detecting small differences. Future research using a larger number of pens may provide greater sensitivity for detecting smaller treatment differences.

5. Conclusions

Lambs that were limit fed during the entire finishing period performed similar to ad libitum-fed lambs but had leaner carcasses with similar muscle mass. The lambs that were only limit fed for 28 d had the poorest results, with decreased carcass, muscle, and bone weights. Although speculative, the greater liver weight relative to EBW in the 28L lambs suggests that the realimentation period may have resulted in visceral organ recovery rather than muscle growth. These results indicate that the duration of restriction and realimentation is important in lambs, and a 28 d period may not be sufficient to capture energy efficiencies in either the restricted or realimentation period. However, a full 56 d feed restriction of 8% resulted in similar carcass-adjusted growth performance and increased carcass leanness compared to ad libitum-fed lambs.

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References

1. FAO. *Food Outlook—Biannual Report on Global Food Markets*; Food Outlook; FAO: Rome, Italy, 2025.
2. Morris, S.; Montossi, F. Overview of Sheep Production Systems. In *Advances in Sheep Welfare*, 2nd ed.; Ferguson, D., Lee, C., Doyle, R., Fisher, A., Eds.; Woodhead Publishing Series in Food Science, Technology and Nutrition; Woodhead Publishing: Cambridge, UK, 2026; pp. 23–42.
3. Galyean, M.L.; Hatfield, E.E.; Stanton, T.L. Review: Restricted and Programmed Feeding of Beef Cattle—Definitions, Application, and Research Results. *Prof. Anim. Sci.* **1999**, *15*, 1–6. [\[CrossRef\]](#)
4. Sip, M.L.; Pritchard, R.H. Nitrogen Utilization by Ruminants during Restricted Intake of High-Concentrate Diets. *J. Anim. Sci.* **1991**, *69*, 2655–2662. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Galyean, M.L.; Hales, K.E. Feeding Management Strategies to Mitigate Methane and Improve Production Efficiency in Feedlot Cattle. *Animals* **2023**, *13*, 758. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Holt, S.M.; Mader, T.; Gaughan, J.; Lisle, A.; Scott, T. Limit Feeding of Feedlot Cattle during the Summer. *Asian-Australas. J. Anim. Sci.* **2000**, *13*, 421–424.
7. Murphy, T.A.; Loerch, S.C. Effects of Restricted Feeding of Growing Steers on Performance, Carcass Characteristics, and Composition. *J. Anim. Sci.* **1994**, *72*, 2497–2507. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Loerch, S.C.; Fluharty, F.L. Effects of Programming Intake on Performance and Carcass Characteristics of Feedlot Cattle. *J. Anim. Sci.* **1998**, *76*, 371–377. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Pritchard, R.H.; Bruns, K.W. Controlling Variation in Feed Intake through Bunk Management. *J. Anim. Sci.* **2003**, *81*, E133–E138. [\[CrossRef\]](#)
10. Delver, J.J.; Thompson, L.R.; Rusche, W.C.; Francis, B.B.; Francis, F.L.; Leeson, R.J.; Ribeiro, T.L.L.M.; Olinger, G.H.; Smith, Z.K. The Effect of Limit Feeding and Delaying Implanting until D-63 of the Finishing Period on Growth Performance and Carcass Characteristics of Backgrounded Beef Steers Weighing 478 Kg Initially. *J. Anim. Sci.* **2025**, *103*, 227–228. [\[CrossRef\]](#)
11. Delver, J.J.; Rusche, W.C.; Thompson, L.R.; Francis, F.L.; Francis, B.B.G.; Leeson, R.J.; Ribeiro, T.L.L.M.; Olinger, G.H.; Ross, C.R.; Smith, Z.K. Evaluating the Effect Limit Feeding Yearling Beef Steers for 56 or 86 d of a 140-d Finishing Period on Growth Performance and Carcass Trait Responses. *J. Anim. Sci.* **2024**, *102*, 361–362. [\[CrossRef\]](#)
12. Hicks, R.B.; Owens, F.N.; Gill, D.R.; Martin, J.J.; Strasia, C.A. Effects of Controlled Feed Intake on Performance and Carcass Characteristics of Feedlot Steers and Heifers. *J. Anim. Sci.* **1990**, *68*, 233–244. [\[CrossRef\]](#)
13. Sainz, R.D.; Bentley, B.E. Visceral Organ Mass and Cellularity in Growth-Restricted and Refed Beef Steers. *J. Anim. Sci.* **1997**, *75*, 1229–1236. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Murphy, T.A.; Loerch, S.C.; McClure, K.E.; Solomon, M.B. Effects of Restricted Feeding on Growth Performance and Carcass Composition of Lambs. *J. Anim. Sci.* **1994**, *72*, 3131–3137. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Fluharty, F.L.; McClure, K.E. Effects of Dietary Energy Intake and Protein Concentration on Performance and Visceral Organ Mass in Lambs. *J. Anim. Sci.* **1997**, *75*, 604–610. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Abouheif, M.; Al-Owaimer, A.; Kraidees, M.; Metwally, H.; Shafey, T. Effect of Restricted Feeding and Realimentation on Feed Performance and Carcass Characteristics of Growing Lambs. *Rev. Bras. Zootec.* **2013**, *42*, 95–101. [\[CrossRef\]](#)
17. Abouheif, M.; Al-Sornokh, H.; Swelum, A.; Yaqoob, H.; Al-Owaimer, A. Effect of Different Feed Restriction Regimens on Lamb Performance and Carcass Traits. *Rev. Bras. Zootec.* **2015**, *44*, 76–82. [\[CrossRef\]](#)
18. Shadnoush, G.R.; Alikhani, M.; Rahmani, H.R.; Edriss, M.A. Effects of Restricted Feeding and Re-Feeding in Growing Lambs: Intake, Growth and Body Organs Development. *J. Anim. Vet. Adv.* **2011**, *10*, 280–285. [\[CrossRef\]](#)
19. Carrasco, S.; Ripoll, G.; Sanz, A.; Álvarez-Rodríguez, J.; Panea, B.; Revilla, R.; Joy, M. Effect of Feeding System on Growth and Carcass Characteristics of Churra Tensina Light Lambs. *Livest. Sci.* **2009**, *121*, 56–63. [\[CrossRef\]](#)

20. Carrasco, S.; Ripoll, G.; Panea, B.; Álvarez-Rodríguez, J.; Joy, M. Carcass Tissue Composition in Light Lambs: Influence of Feeding System and Prediction Equations. *Livest. Sci.* **2009**, *126*, 112–121. [CrossRef]
21. Preston, R.L. 2017 Feed Composition Tables. Available online: <https://www.beefmagazine.com/cattle-nutrition/feed-composition-tables-how-to-use-the-2017-data-to-mix-the-best-feed-for-your-cattle> (accessed on 16 January 2026).
22. USDA AMS. United States Standards for Grades of Lamb, Yearling Mutton, and Mutton Carcasses, 1992. Available online: https://www.ams.usda.gov/sites/default/files/media/Lamb%2C_Yearling_Mutton_and_Mutton_Standard%5B1%5D.pdf (accessed on 30 April 2026).
23. Jones, S.D.M.; Robertson, W.M.; Price, M.A. The Assessment of Saleable Meat Yield in Lamb Carcasses. In Proceedings of the 39th International Congress of Meat Science and Technology (ICoMST), Calgary, AB, Canada, 1–6 August 1993.
24. Boggs, D.L. *Livestock and Carcasses: An Integrated Approach to Evaluation, Grading and Selection*; Kendall/Hunt Publishing Company: Dubuque, IA, USA, 2006.
25. USDA AMS. Institutional Meat Purchase Specifications (IMPS) for Fresh Lambs (Series 200), 2014. Available online: https://www.ams.usda.gov/sites/default/files/media/IMPS_200_Fresh_Lamb_and_Mutton%5B1%5D.pdf (accessed on 30 April 2026).
26. Luaces, M.; Calvo, C.; Fernández, B.; Fernández, A.; Viana, J.; Sánchez, L. Predicting equations for tisular composition in carcass of Gallega breed lambs. *Arch. Zootec.* **2008**, *57*, 3–14.
27. McGregor, E.M.; Campbell, C.P.; Miller, S.P.; Purslow, P.P.; Mandell, I.B. Effect of Nutritional Regimen Including Limit Feeding and Breed on Growth Performance, Carcass Characteristics and Meat Quality in Beef Cattle. *Can. J. Anim. Sci.* **2012**, *92*, 327–341. [CrossRef]
28. Lofgreen, G.P.; Garrett, W.N. A System for Expressing Net Energy Requirements and Feed Values for Growing and Finishing Beef Cattle. *J. Anim. Sci.* **1968**, *27*, 793–806. [CrossRef]
29. Burrin, D.G.; Ferrell, C.L.; Britton, R.A.; Bauer, M. Level of Nutrition and Visceral Organ Size and Metabolic Activity in Sheep. *Br. J. Nutr.* **1990**, *64*, 439–448. [CrossRef] [PubMed]

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