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Comparative Analysis of Feeding Strategies on the Growth and Carcass Quality of Turki-Qashqai Lambs: A Focus on Supplementary Feed Concentration

Research Article

A. Ahmadpour[1*], S. Forouzanfar[1], S. Ghazanfari[1], R. Hafedh Sabeeh Alrahif[1] and M. Zarrin[1]

[1] Department of Animal Science, Faculty of Agriculture and Natural Resources, Yasouj University, Yasouj, Iran

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*Correspondence E-mail: ahmadpouramir@yu.ac.ir

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ABSTRACT

This study evaluated the effects of feedlot and pasture-based systems on Turki-Qashqai lambs across two distinct phases. The first phase assessed growth performance under intensive conditions using two diets: diet 1 (50% tropical forage, 50% commercial concentrate) and diet 2 (50% tropical forage, 25% corn grain, 25% soybean meal). The second phase compared carcass and meat quality between intensively-fed and pasture-raised lambs. Lambs were randomly assigned to diets with equal replication, and data were analyzed using a completely randomized design with the SAS software package. The findings revealed no significant differences in feed intake between dietary treatments, but lambs fed diet 2 exhibited significantly higher daily weight gain (267 g/day) compared to those on diet 1 (189 g/day). At the end of the trial, diet 2 lambs also achieved a higher final live weight (33.83 kg) than diet 1 lambs (30.6 kg, $P<0.05$). Cold carcass weight was significantly greater in intensively-fed lambs compared to pasture-raised counterparts ($P<0.05$). Diets rich in concentrates produced carcasses with lower moisture content and higher levels of crude protein, fat, and minerals. This contributed to meat that was more tender and darker in color compared to meat from pasture-raised lambs. These findings highlight the advantages of incorporating concentrated feeds into lamb diets to improve growth performance and carcass quality while enhancing meat tenderness and nutritional value. The results provide valuable insights for optimizing feeding strategies to maximize production efficiency in Turki-Qashqai lambs.

KEY WORDS carcass characteristics, concentrated feed, fattening lambs, feeding system, growth performance.

INTRODUCTION

Sheep farming offers numerous advantages over cattle farming, including greater feed adaptability, smaller body size, higher reproductive efficiency, and increased economic returns for producers (Karami and Talebi, 2004). Despite these benefits, traditional sheep farming in many regions relies heavily on extensive grazing systems with minimal management or supplementation. These systems often involve indigenous breeds with limited genetic capacity, leading to suboptimal performance. Consequently, animals are frequently slaughtered at one to three years of age, exhibiting low or negative daily weight gains and reduced carcass weights, resulting in inefficiencies in meat production (Karami and Talebi, 2004).

A critical challenge in animal husbandry is ensuring sufficient and efficient nutrition through tailored diets that align with specific production objectives. Recent climatic fluctuations and prolonged droughts have further exacerbated feed shortages, significantly impacting small ruminant production systems (Ghorbani *et al*. 2022). In particular, fattening systems face elevated nutritional demands, necessitating strategies that optimize growth performance and improve meat quality while maintaining economic vi-

ability. The decline in both the quality and quantity of natural rangelands has made supplementation with concentrated feeds an indispensable strategy to address these challenges (Dadpasand and EizadiFard, 2009; Mofidi-Chelan *et al*. 2018).

Alternative feeds for animal nutrition have gained significant attention in recent years. For instance, banana by-products, abundant in tropical and subtropical regions, have been proposed as a viable alternative forage source. Ahmed-Salek *et al*. (2021) demonstrated that replacing ryegrass hay with banana by-products in the diet of Canary hair sheep lambs did not significantly affect carcass weight, dressing percentage, or tissue composition, but led to differences in the weight of empty digestive tracts and livers. This study confirms that banana by-products can serve as a suitable alternative forage for ruminants raised in subtropical conditions.

Similarly, the management of early weaning in lambs has been explored for its impact on growth performance. Simeonov and Harmon (2021) found that inducement baits and different feeding systems during early weaning of Blackhead Pleven lambs improved feed intake, with lambs weaned at an average age of 19.4 days achieving higher growth rates when fed pelleted protein concentrate and barley grain. This suggests that feeding strategies, rather than the lambs' age or initial body weight, play a more significant role in post-weaning growth.

Previous studies have demonstrated the benefits of incorporating concentrated feeds into livestock diets, particularly in improving feed conversion efficiency, daily weight gain, and carcass characteristics. For example, Rodríguez-Carías *et al*. (2014) observed a 40-gram increase in daily weight gain with commercial concentrate supplementation, while Suárez-Rodríguez (2019) reported higher crude protein, fat, and mineral content in meat from supplemented lambs. Papi and Tehrani (2017) showed that higher dietary concentrate levels significantly enhanced growth performance and carcass yield in lambs. Similarly, Arjmand *et al*. (2021) found that adjusting concentrate levels and extending fattening periods improved nutrient digestibility and lamb productivity. Prache *et al*. (2022) highlighted the influence of diet composition on carcass and meat quality attributes, while Abarghani *et al*. (2010) reported enhanced carcass characteristics with barley-based supplementation.

Despite these findings, most studies have focused on a narrow range of breeds, environmental conditions, or feeding strategies, providing limited insight into the response of locally adapted breeds such as Turki-Qashqai lambs to complete feed diets under confinement. Moreover, the interplay between diet composition—such as the inclusion of corn grain and soybean meal—and carcass and meat quality outcomes in tropical climates remains underexplored.

This study bridges these knowledge gaps by evaluating the performance of Turki-Qashqai lambs fed complete diets under confinement, specifically comparing tropical forage-based diets containing either commercial concentrates or a mixture of corn grain and soybean meal. By examining growth performance, carcass characteristics, and meat quality in comparison to pasture-raised lambs, this research provides novel insights into optimizing feeding strategies for Turki-Qashqai lambs. These findings offer practical recommendations for enhancing production efficiency and meat quality in tropical and semi-arid regions.

MATERIALS AND METHODS

Study location

The research was conducted at the Sabz Bavaran Novandish Livestock Farm, located in the Afzar Sub-District of Qir and Karzin County, Fars Province, Iran. This farm is situated at a latitude of 28.3459° N and a longitude of 52.9660° E, with an elevation of 645 meters above sea level. The climate of the area is characterized by warm weather with occasional humidity, hot summers, mild winters, and temperate springs and autumns. The annual precipitation in this region is less than 300 mm, with the majority of rainfall occurring during late autumn and winter (Iran Meteorological Organization, 2022).

Animals, housing, and experimental diets

Eighty male Turki-Qashqai lambs, with an average initial body weight (BW) of 26.0 ± 23.0 kg and an age of 1.07 ± 0.89 days, were selected for this study. Prior to the beginning of the experiment, the lambs underwent a two-week acclimatization period to adapt to the experimental environment and dietary treatments. The lambs were housed individually in pens (1.1×0.3 meters) that included a dual-tier feeding trough, a water trough, and a mineral block. The lambs had *ad libitum* access to drinking water and were allowed two hours of grazing in the paddock during the daylight hours.

The experimental setup involved two dietary treatments. Diet 1 contained 50% tropical forage (12.4% crude protein) and 50% commercial concentrate (18% crude protein), while diet 2 included 50% tropical forage and a mixture of 25% corn grain and 25% soybean meal. Both diets were formulated to ensure an equivalent crude protein content, with the primary distinction between the diets being the concentrate components (Table 1).

Experimental procedure and rationing

The lambs were randomly assigned to one of the two diet groups (n=40 lambs per group) using a completely randomized design. The daily feed was provided at a rate of 4% of each lamb's live weight (BW).

Table 1 Chemical composition of the ingredients used in the total rations

Ingredients	Chemical composition	Tropical hay	Corn grain	Soybean meal	Commercial concentrate[1]
	Portion (%)	50.0	36.1	13.9	50.0
	DM	88.9	90.2	86.6	89.1
	OM	91.8	98.3	92.3	91.0
	IM	8.21	1.70	7.71	9.01
Components (%)	CP (N*6.25)	12.4	9.11	44.9	18.0
	NDF	63.5	11.5	11.7	12.1
	ADF	34.2	3.51	8.43	7.20
	HC	29.3	8.02	3.33	4.91
	TDN	58.2	82.0	78.8	80.4

[1] Contains 18% crude protein.
DM: dry matter; OM: organic matter; IM: inorganic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; HC: hemicellulose: (NDF-ADF); TDN: total digestive nutrient.

The diet was presented in a partially mixed ration (PMR) format, which separated the fibrous and concentrate components to allow the lambs to choose their preferred proportion. The feed was administered at 06:00 each day, and feed intake was monitored by calculating the total amount consumed and the remaining feed after each meal.

The tropical forage used in the diets was harvested from natural pastures located in the southern region of Fars Province, then dried and chopped into 5 to 15 cm fragments to prevent selective feeding by the lambs. Representative samples of the forage and concentrate were sent to the Sabz Bavaran Novandish Company laboratory in Qir City for nutritional analysis. The samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and neutral detergent fiber (NDF) content using standard procedures (AOAC, 2005; Goering and Van Soest, 1970).

Carcass performance, slaughter procedure, and meat quality

At the conclusion of the 58-day trial, 14 lambs from each group (n=14) were slaughtered, reaching an average body weight of 25.0 ± 0.6 kg BW. The lambs were fasted for 12 hours before slaughter to minimize the weight of the gastrointestinal contents. The slaughtering process followed industry-standard procedures, and various measurements were taken, including hot carcass weight, dressing percentage, and tissue yield. The carcasses were chilled at 4 °C for 24 hours, and the cold carcass weight and yield were then recorded. Additionally, the weights of empty digestive tracts and livers were measured for comparison between the two dietary treatments.

For the meat quality analysis, samples of the Longissimus dorsi muscle (between ribs 12 and 13) were collected from each lamb immediately after slaughter. The following quality parameters were assessed:

The color of the meat was evaluated using a Hunter Lab Mini-Scan XE Plus colorimeter (MiniScan XE User's Guide, 2006). L*, a*, and b* values, which represent lightness, redness, and yellowness respectively, were recorded.

Each sample was exposed to air for 15 minutes and placed on a flat surface for readings. Three separate readings were taken from each sample. Additionally, the color hue angle was calculated using the formula tan-1(b*/a*), and the color saturation was calculated with the formula $(a^2+b^2)^{1/2}$ (Ge *et al.* 2021). Tenderness was measured by determining the shear force of the meat samples using a Warner-Bratzler device (WBS, Salten model 3000) (Warner *et al.* 2021).

The Warner-Bratzler test measures the resistance of the meat samples to shearing, which serves as an indicator of tenderness. The nutrient composition of the meat samples was analyzed for moisture content, crude protein, fat, and mineral content. Moisture content was determined by drying the meat samples at 105 °C until they reached a constant weight. The crude protein content was determined using the Kjeldahl method, and fat content was determined using ether extraction. The mineral content was analyzed using atomic absorption spectrophotometry (Suárez-Rodríguez 2019).

Statistical analysis

The data obtained from this study were analyzed using the SAS software package (SAS, 2013). The analysis was conducted using a completely randomized design, with diet (diet 1 *vs.* diet 2) as the main factor. The statistical model used in the analysis included the effect of diet as a fixed factor, with the lamb serving as the experimental unit.

Carcass weight, dressing percentage, tissue weight, meat quality parameters (color, tenderness, and nutrient composition), and other performance metrics were analyzed using analysis of variance (ANOVA). The assumptions of normality and homogeneity of variance were assessed using the SAS UNIVARIATE procedure (SAS, 2013). If significant differences were detected ($P \leq 0.05$), post-hoc comparisons of means were performed using the Tukey-Kramer test, which is a commonly used method for multiple comparisons. For all analyses, the results are presented as means ± standard error of the mean (SEM). Statistical significance was set at $P \leq 0.05$. Trends where P-values fell

between 0.05 and 0.10 were considered to indicate a tendency toward significance.

RESULTS AND DISCUSSION

The diets employed in this study for feeding Turki-Qashqai breed lambs were formulated to contain 15% crude protein and 5.69% TDN (Table 2). The nutritional composition of the ingredients in diet 1 was adjusted to match the predetermined percentage content. In diet 2, the dietary components were formulated with 66.0 and 11.0% higher units of protein and TDN, respectively. The difference in protein content may be due to the higher protein level in the soybean meal.

Table 2 Nutrient contribution of the ingredients used in the total rations

Ingredients	Treatments[1]	
	1	2
Tropical hay	50.0	50.0
Commercial concentrate[2]	50.0	0.00
Soybean meal	0.00	13.9
Corn grain	0.00	36.1
Chemical composition[3]		
DM	89.1	89.1
OM	91.4	94.2
IM	8.52	5.81
CP (N*6.25)	15.2	15.7
NDF	37.7	37.5
ADF	20.7	19.6
HC	17.0	17.9
TDN	69.4	69.7

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively
[2] Contains 18% crude protein.
DM: dry matter; OM: organic matter; IM: inorganic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; HC: hemicellulose: (NDF-ADF); TDN: total digestive nutrient.

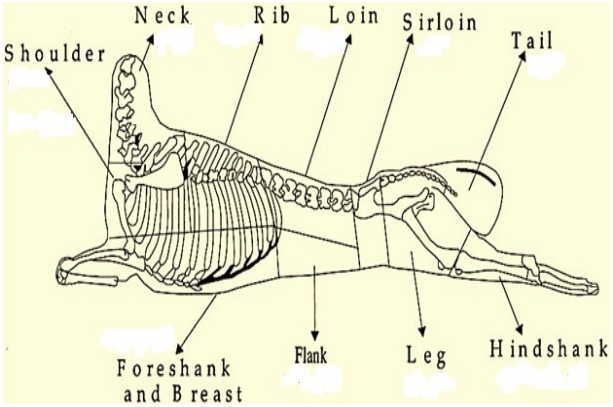

Figure 1 How to segment the wholesale and retail parts of the treated lamb carcasses (Esenbuga *et al.* 2001)

The voluntary dry matter intake of lambs in this study was equivalent to 39.3 and 57.3% of their live weight for those fed with diet 1 and diet 2, respectively. These values corresponded to the consumption of 89.0 and 85.0% of the feed offered (4%), for treatments 1 and 2. In research involving Dorper and Merino breeds, where animals were individually housed similar to the present study, a nearly 60.3% voluntary intake of live weight was calculated (Brand *et al.* 2017). In another study with Katahdin breed lambs receiving full feed under heat stress conditions, a 14.3% voluntary dry matter intake was reported (Suárez-Rodríguez, 2019).

No significant differences (P>0.05) were observed in the feed offered, refused, or consumed between the two experimental diets or their feed components (forage or concentrate) (Table 3). Both diets, regardless of the concentrate source, were well-tolerated, and no metabolic issues were observed.

Table 3 Voluntary intake of the experimental diets and their individual ingredient

Components (g/d)	Treatments[1]		SEM	*P*-value
	1	2		
Feed				
Offered	1170	1318	46.6	0.311
Refused	132	110	22.7	0.532
Consumed	1039	1208	33.8	0.173
Forage part				
Offered	585	663	17.4	0.131
Refused	132	110	21.7	0.602
Consumed	454	554	34.2	0.481
Concentrate part				
Offered	585	663	27.4	0.232
Refused	0.00	0.00		
Consumed	585	663	27.4	0.232

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
SEM: standard error of the means.

In this study, the proportion of feed components provided in both diets was similar, comprising 50% tropical forage and 50% commercial concentrate or corn-soybean meal mixture. Results indicated a comparable voluntary intake percentage in both treatments, with 59% from the concentrate portion and 41% from the forage portion of the diet. As presented in Table 3, the lambs consumed 100% of the concentrate portion and consumed 49.77% and 47.83% of the forage portion in Experimental diets 1 and 2, respectively. A study with Katahdin sheep fed complete diets consisting of 30% forage and 70% grain revealed a similar response in the percentage consumption of dietary components as observed in this study (Suárez-Rodríguez, 2019). The intake of 20% for the forage portion and 80% for the concentrate portion in the experimental diets was reported in the present study.

The live weight of lambs in both experimental groups was similar during the first 36 days of the trial (P>0.05). However, from the ninth day of the study onwards, higher live weights were observed in lambs of group 2 compared

to group 1 (Figure 2). At the end of the trial period, a significant difference (P<0.05) in live weights was noted, with group 2 lambs being 3224 grams heavier than group 1 lambs on day 42.

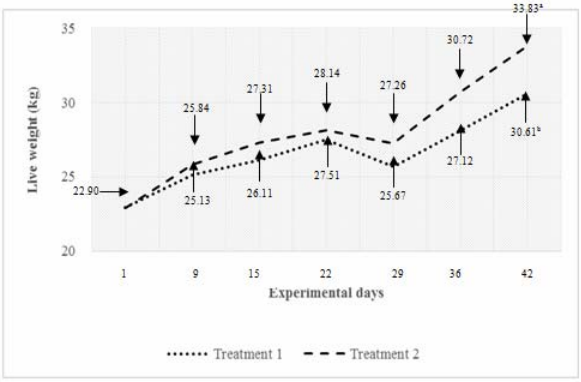

Figure 2 Change in weight of lambs fed diets containing 50% tropical hay + 50% commercial concentrate (treatment 1) and 50% tropical hay + 50% of corn grain and soybean meal premix (treatment 2). Each time point with distinct superscripts exhibits a statistically significant difference at the 5% level

This 3224-gram difference in live weight on the final day of the trial demonstrated significantly higher final weights (P<0.05) and greater daily weight gain in group 2 lambs compared to group 1 (Table 4; 266.58 grams/day *vs.* 188.08 grams/day). The average daily weight gain in group 2 lambs was approximately 5.78 grams higher than group 1 lambs in this study (P<0.05).

Table 4 Daily and total weight gain and feed conversion ratio of lambs fed the total rations

Items	Treatments[1]		SEM	P-value
	1	2		
Initial weight (kg)	22.9	22.9	0.431	0.871
Final weight (kg)	30.6[b]	33.8[a]	0.871	0.0312
Total weight gain (kg)	7.91[b]	11.2[a]	0.473	0.0081
Daily weight gain (g/d)	188[b]	267[a]	18.4	0.0113
Feed conversion ratio	5.52	4.53	1.43	0.282

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

As Khan *et al.* (2016) suggested, the processing of the feed, such as pelleting, can influence its palatability, rumen fermentation, and nutrient digestibility, which in turn affects animal feed consumption and growth. In the present study, lambs fed diet 2 (pelleted concentrate) exhibited significantly higher weight gain and feed intake compared to those on diet 1, which aligns with findings by Porter *et al.* (2007) and Babker *et al.* (2009), where pelleted concentrate led to improved feed consumption and weight gain. As observed in the study by Asadi *et al.* (2024), lambs fed a pelleted concentrate showed significantly higher live weight, daily weight gain, and feed conversion efficiency compared to those fed mash concentrate. This finding aligns with the results in the present study, where group 2 lambs, fed a diet rich in concentrates, exhibited a higher daily weight gain and better feed conversion ratio. The physiological response to higher energy intake includes the enhanced activation of anabolic pathways for protein synthesis and fat deposition. Higher energy availability supports muscle growth and tissue development, which aligns with our findings that lambs fed a concentrate-based diet exhibited higher muscle mass and organ development. This could be related to increased secretion of insulin-like growth factors (IGF-1), which are key regulators of muscle growth and differentiation (Bauché *et al.* 2021).

While no significant difference in the mean feed conversion ratio of the experimental treatments was observed, the feed conversion ratio in group 2 lambs was 1.12 units lower compared to the other group.

Within both experimental treatments, feed conversion ratios were evaluated within the optimal range for individually housed lambs fed a complete diet (Lins-Lima *et al.* 2017). In a similar study, De Carvalho *et al.* (2017) prepared maize and soybean meal mixtures with four types of silage in equal proportions and evaluated their impact on lamb weight.

They reported that among the four forage silages used, the best results were observed after feeding a combination of *Cenchrus ciliaris L.* silage and maize + soybean meal mixture. Differences in digestibility of complete diets can stem from positive associative effects, negative antagonistic effects, or independent effects of diet components (Sayed, 2009). The observed associative effects could explain the differences in live weights of the experimental diets in the present study.

The difference in feed conversion ratio may be due to the shorter rearing period in this study compared to previous studies. Previous studies have shown that younger animals have higher growth rates and better feed conversion ratios compared to older animals (Alemzadeh *et al.* 2007). Nourollahi (2007) reported a significant effect of the rearing period on feed conversion ratio in Turki-Qashqai male lambs. Imam-Jome *et al.* (2007) noted a decrease in feed efficiency with prolonged rearing periods and increasing age of lambs. Zaheri-Khosroshahi *et al.* (2007) reported feed conversion ratios of 5.5 at 3-4 months, 7 at 6-7 months, and 10.5 at 9-10 months of age for Turki-Qashqai lambs. Dadpasand and EizadiFard, (2009) also highlighted the significant impact of increasing age on the feed conversion ratio and daily growth rate in Turki-Qashqai lambs. The increased digestibility observed in the

pelleted concentrate diet by Asadi *et al.* (2024) supports the finding that lambs fed diet 2 exhibited enhanced performance in terms of nutrient digestibility and feed conversion, which may have contributed to the better weight gain observed in this study. In line with previous findings, who reported no substantial difference in FCR despite increased weight gain in pelleted-fed lambs, this study observed that diet 2 lambs exhibited improved weight gain with a slight reduction in feed conversion ratio. This suggests that the improved growth performance was primarily due to increased feed intake, similar to the results reported.

While ruminal or total tract digestibility of diets or their components was not assessed in this study, the higher weight gain observed in group 2 lambs compared to group 1 could be attributed to differences in digestibility and observed feed conversion ratios between treatments.

In addition to the influence of concentrate type (commercial concentrate or a mixture of corn + soybean concentrate) on the production parameters of lambs, their effects on carcass characteristics, different carcass parts, and meat quality were also investigated (Table 5). These factors were also compared with grazing lambs in warm-season natural pastures.

Table 5 Effect of the feeding system on the carcass characteristics of the lambs

Items	Feeding system			SEM	P-value
	Grazing	Total rations[1]			
		1	2		
Weight (kg)					
Slaughter	31.7	30.6	33.8	1.89	0.311
Hot carcass	16.2	16.8	17.4	0.616	0.0656
Cold carcass	14.7[b]	16.1[a]	16.6[a]	0.577	0.0433
Performance (%)					
Hot carcass	50.9	54.3	52.2	1.98	0.114
Cold carcass	44.9[b]	52.8[a]	50.4[a]	2.49	0.0286

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The average slaughter weight was 32.03 kg, with treatment 1, treatment 2, and Grazing lambs weighing 43.0 ± 6.1 kg, 51.0 ± 8.3 kg, and 73.0 ± 6.9 kg, respectively. It is important to note that the age of lambs fed with complete rations in this study was less than one year (10 months), while the grazing lambs were 12 to 18 months old. The observed difference in the higher hot carcass weight of treatment 2 lambs compared to grazing lambs tended to be significant (P<0.05).

However, statistically significant differences in mean hot carcass weight between treatment 1 lambs and grazing lambs, as well as between treatment 1 and treatment 2 lambs, were not evaluated.

A significant difference (P<0.05) was observed in the mean cold carcass weight and carcass yield between experimental lambs and grazing lambs. The carcass yield was 82.7% and 48.5% in treatment 1 and treatment 2 lambs, respectively, higher than grazing lambs (P<0.05). The obtained carcass yield with Turki-Qashqai sheep in this experiment, regardless of the diet, is in line with the reported results of other studies (Nourollahi, 2007; Rodríguez-Carías *et al.* 2014). In the present study, it was reported that the average carcass yield of 57 Creole lambs raised under free grazing conditions was 11.52%, which is similar to the average carcass yield obtained in this experiment. Oliveira *et al.* (2013) also reported a hot and cold carcass yield of 19.51% and 83.51%, respectively, with 24 Santa Ines sheep raised under free grazing conditions on pasture. It has been established that sheep carcass performance is influenced by genetics and nutrition (Brand *et al.* 2017).

As expected, feedlot-fed lambs had better hot carcass performance than pasture-raised lambs (Savell *et al.* 2005). Kim *et al.* (2013) reported a greater decrease in hot carcass performance compared to cold carcass performance in sheep fed in pastures compared to those fed a higher proportion of grains in the diet. It is reported that the duration of feeding affects the percentage and composition of the carcass of male Turki-Qashqai sheep (Nourollahi, 2007), which can be attributed to the noticeable difference between lambs fed with complete diets and grazing lambs.

Regardless of the feeding system, as expected, the hind legs (thighs) had a higher average weight than other wholesale cuts of the carcasses and were not influenced by experimental treatments (Table 6). The average neck, and forelegs and shoulder weights did not differ significantly between groups. Nevertheless, treatment 1 and treatment 2 lambs had heavier loin compared to grazing lambs (P<0.05). The average ribs weight (ribs 5 to 12) in treatment 2 was higher and tended towards significance compared to other groups (P<0.08). On the other hand, grazing lambs had a higher average fat-tail weight compared to the lambs fed *in situ* (treatment 1 and treatment 2). This difference may be due to differences in the duration of feeding (Nourollahi, 2007) and age differences (Eilami, 2004; Farzad *et al.* 2004) present in the experimental groups.

The feeding system also caused significant differences in the percentage of carcass yield in slaughterhouse cuts (wholesale cuts) in cold carcasses (P<0.05). The cold shoulder yield in sheep fed in pasture was higher than sheep fed in a feedlot (P<0.05). However, the loin yield for animals fed in a feedlot was higher (P<0.05). The hind legs yield in sheep fed in a feedlot was lower compared to grazed sheep and tended to be significant (P<0.10). Group

2 animals had larger back muscles (eye muscles) compared to Group 1. A similar study by Macías-Cruz *et al.* (2010) also reported the distribution of the five main parts (hind legs, ribs, loin, shoulder, and neck) in line with the results of this study. Papi and Zahedifar (2024) reported that as the slaughter weight increased, there was a significant increase in backfat thickness, longissimus thoracic area, and internal fat. Similarly, lambs fed diet 2 in this study showed improved carcass quality, including enhanced loin and back muscle development, particularly compared to grazing lambs. This indicates that the higher-energy diet (pelleted concentrate) promoted greater fat deposition in diet 2 lambs.

Table 6 Effect of the feeding system on the performance of wholesale cuts of lambs

Items	Feeding system			SEM	P-value
	Grazing	Total rations[1]			
		1	2		
Weight of wholesale cuts (kg)					
Neck	0.577	0.706	0.749	0.142	0.121
Forelegs and shoulder	4.60	4.58	4.52	0.219	0.408
Ribs (5-12)	2.13	2.34	2.49	0.259	0.0821
Loin	1.11^{b}	2.02^{a}	2.01^{a}	0.132	0.0175
Hind legs	4.82	5.18	5.41	0.444	0.113
Fat-tail	1.47^{a}	1.26^{b}	1.36^{b}	0.0872	0.0279
Yield of wholesale cuts in relation to the weight of the cold carcass (%)					
Neck	3.93	4.51	4.50	0.591	0.114
Forelegs and shoulder	31.3^{a}	28.4^{b}	27.2^{b}	0.528	0.0076
Ribs (5-12)	14.5	14.5	15.0	0.687	0.521
Loin	7.55^{b}	12.5^{a}	12.1^{a}	1.186	0.0332
Hind legs	32.7	32.2	32.8	1.10	0.0879
Fat-tail	10.0^{a}	7.84^{b}	8.43^{b}	0.589	0.0472
Rib eye muscle area (cm^2)	26.2^{ab}	25.4^{b}	26.8^{a}	0.245	0.0061

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The weight and performance of retail cuts (butchery cuts) of the carcass in the three treatments in this experiment were within normal ranges regardless of the sheep feeding system (Table 7; Safari *et al.* 2001). As expected, the shortcut leg had the highest performance when the hindshank were removed without taking into account the feeding system. The shoulder chops segmentation had the highest weight after the short cut leg, with its performance being higher in grazed sheep than in other groups (P<0.05). There was no significant difference in loin chops and foreshank weight after segmentation between the treatments. However, the weight of cutouts was lower in sheep from the feedlot (P<0.01). The pattern of effect on the percentage of butcher cuts' performance in different treatments based on cold carcass weight was similar to the weight of the cuts. In all three treatments, the hindshank and shoulder cuts had the highest performance. Except for the hindquarter yield, the independent effect of treatment on cuts' performance based on cold carcass weight was observable. lambs from the feedlot had higher performance in the shoulder and hindshank, while lower performance was observed for cutouts.

Table 7 Effect of the feeding system on the performance of retail cuts of lambs fed total rations or on pasture

Items	Feeding system			SEM	P-value
	Grazing	Total rations[1]			
		1	2		
Weight of retail cuts (kg)					
French chops	1.24	1.22	1.31	0.0775	0.0692
Shoulder chops	3.03^{a}	1.77^{b}	1.89^{b}	0.248	0.0102
Loin chops	1.05	0.914	0.578	0.179	0.354
Short cut leg	4.08	4.19	4.48	0.343	0.172
Fore shank	1.21	0.982	0.878	0.0703	0.109
Hind shank	1.35^{b}	4.01^{a}	4.48^{a}	0.204	0.0084
Cutouts	0.324^{b}	0.647^{a}	0.806^{a}	0.119	0.0132
Yield of retail cuts in relation to the weight of the cold carcass					
French chops	9.33	8.26	8.63	0.414	0.0586
Shoulder chops	22.9^{a}	12.0^{b}	12.5^{b}	1.74	0.0104
Loin chops	7.92^{a}	6.13^{a}	3.84^{b}	1.49	0.0517
Short cut leg	30.8	28.3	29.5	1.21	0.162
Fore shank	9.12^{a}	6.64^{b}	5.73^{b}	0.488	0.0109
Hind shank	10.2^{b}	27.1^{a}	29.5^{a}	1.97	0.0092
Cutouts	2.38^{b}	4.36^{a}	5.32^{a}	0.556	0.0081

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The feeding system also caused some significant differences in the percentage of slaughterhouse cuts' performance (wholesale cuts) in cold carcasses (P<0.05). The shoulder yield in sheep fed in pasture was higher than sheep fed in a feedlot (P<0.05). However, the loin yield for animals fed in a pasture was higher (P<0.05). Moreover, our finding of a higher shoulder and brisket yield in diet 2 lambs suggests that muscle distribution is affected by feeding systems. The deposition of muscle in specific areas of the carcass could be related to the hormonal environment driven by diet composition. Growth hormones, along with nutrient availability, regulate muscle accretion in specific areas such as the loin and shoulder (Fitzhugh *et al.* 2021). The hormonal environment in diet 2 lambs, driven by higher feed intake, likely resulted in changes in muscle and fat deposition patterns, promoting higher yield in specific carcass cuts.

This study investigates the nutritional composition, chromatic attributes, and tenderness as metrics for evaluating meat quality. The moisture content of meat obtained from lambs grazed on pasture was significantly

greater than that of lambs subjected to diets comprising 50% tropical forage and 50% commercial concentrate, or a blend of corn grain and soybean meal, ultimately leading to a diminished dry matter content (P<0.05) (refer to Table 8). The incorporation of 50% concentrate into the dietary regimen—whether derived from commercial concentrate or a composite of corn grain and soybean meal—resulted in lamb meat exhibiting elevated levels of CP, lipid content, and mineral composition (P<0.05) in comparison to lambs raised on pasture.

Table 8 Effect of the feeding system on the nutrient content, color and tenderness of the meat of lambs fed with total rations or on pasture

Items	Feeding system			SEM	P-value
	Grazing	Total rations[1]			
		1	2		
Dry matter	23.2[b]	33.3[a]	31.1[a]	0.866	0.0057
Moisture	76.8[a]	66.7[b]	68.9[b]	1.00	0.0061
Protein	20.4[b]	27.5[a]	25.7[a]	1.17	0.0070
Fat	0.372[b]	1.23[a]	1.03[a]	0.201	0.0056
Minerals	0.954	1.42	1.18	0.122	0.0703
Color					
L*	37.7[b]	41.8[a]	38.6[ab]	1.46	0.0317
a*	15.9	15.9	16.4	0.614	0.659
b*	12.3[b]	14.9[a]	14.0[a]	0.460	0.0115
Tenderness (kg/force)	3.55[a]	2.59[b]	2.73[b]	0.512	0.0105

[1] Treatments 1 and 2 contain 50% tropical hay + 50% commercial concentrate and 50% tropical hay + mixture of corn grain and soybean meal, respectively.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Mirdehghan and Rahemi (2007) attributed the higher ash content in sheep diets to the presence of phenolic compounds and flavonoids, which are associated with their osteogenic properties (bone formation), leading to improved mineral absorption and deposition in bones. No differences were observed in the nutrient content of meat between animals fed with these two concentrates. The levels of crude protein (CP) and fat content in sheep meat obtained in this experiment are consistent with the values reported by Germano *et al*. (2011), who reported crude protein and fat content of 7.23% and 3.2%, respectively, in sheep fed with 45% Calotropis procera as a replacement for corn and soybean meal. Other studies (Germano *et al*. 2011; Smeti *et al*. 2018) have also reported differences in protein and fat content in sheep meat attributed to the feeding system. Karami and Bagheri (2020) in their study comparing the carcass performance of Lory Bakhtiari sheep and crossbred Lory Bakhtiari sheep with Romane, attributed the lower fat content in the carcass of Lory Bakhtiari sheep to the larger proportion of tail fat in their carcasses compared to the crossbred sheep. Papi and Zahedifar (2024) reported a decrease in the ratio of unsaturated fatty acids (UFA) to saturated fatty acids (SFA) in LT fat as slaughter weight increased. In the present study, similar trends were observed, with diet 2 lambs showing a higher fat content, including a lower UFA/SFA ratio in the longissimus thoracic (LT) muscle, which may reflect the higher energy intake from the concentrate-based diet. The higher energy intake from pelleted concentrates likely promoted insulin secretion, leading to increased muscle protein synthesis and fat deposition. Additionally, the activation of mTOR (mechanistic target of rapamycin) signaling in muscle tissue could have facilitated muscle hypertrophy (Bauché *et al*. 2021). Increased lipogenesis due to high concentrate intake led to higher intramuscular fat levels, which in turn improved meat tenderness and marbling (Hernández *et al*. 2021).

The investigation of color determination criteria with its lightness (L*), redness (a*), and yellowness (b*) values showed significant effects of feeding system and dietary treatments on the L* and b* values. Grazed sheep had lower L* values in their meat compared to Group 1 sheep (P<0.05). However, these values did not show a statistical difference between the grazed group and group 2. No significant difference among treatments was observed for the a* value, but the b* value in the meat of animals fed with forage diets was lower compared to animals fed with 50% grain or concentrate (P<0.05). The color values obtained in this study were similar to the findings of the study by Burke and Apple (2007), where the meat color of grazed sheep was reported to be darker compared to those fed a complete diet in a feedlot. The difference in meat color is mostly attributed to myoglobin content, which can be influenced by species, age, gender, muscle type, and physical activity of the animal. Reduction in lipid oxidation and color change in meat is attributed by researchers to the presence of phenolic compounds and antioxidants in the diet.

As expected, the measured tenderness in lambs fed with a higher grain content in their diet was lower (P<0.05). The tenderness values in lambs fed with diets 1 and 2 were 0.96 and 0.82 kg per force lower than the conventional lambs. Geesink *et al*. (2011) reported similar values for tenderness in the Longissimus dorsi muscle (7.3 kg per force) in nearly yearling lambs compared to the tenderness values measured for grazing animals in this study (5.3 kg per force). In another study (Sousa *et al*. 2012), Dorper lambs fed with Santalands at two energy levels with Bermuda grass, corn, and soybean husks showed tenderness values of 4.2 kg per force and colorimetry values of L* 47.2, a* 70.2, and b* 8.4.

The tenderness values obtained in this study are consistent with the findings of Malveira-Batista *et al*. (2010), which indicated that lamb meat from feedlot

animals fed with higher energy concentration is tougher. The difference in tenderness may be due to the more active lifestyle of pasture-raised lambs. The higher fat content in the muscle fibers acts as a lubricant, reducing the shear force required to cut the meat (Geesink *et al*. 2011).

The results of this experiment indicate that Texel-cross lambs receiving recommended daily nutrition from a complete diet (NRC, 2007) will have expected daily weight gains of over 180 grams. Daily weight gain was influenced by the type of concentrate fed to the lambs (commercial concentrate or corn-soybean mix) and differed in optional dry matter intake (on average 3.9% live weight). Lambs fed in the feedlot system showed higher carcass performance compared to the grazing system. Although the percentage yield values of carcass cuts were within the range reported in previous studies, lambs fed in the grazing system had higher leg performance. As expected, feeding lambs with high concentrate diets resulted in producing carcasses with lower water content and higher percentages of raw protein, fat, and minerals compared to grazing lamb carcasses. Additionally, grain-fed lambs produced meat that was more tender and darker in color.

This study provides valuable insights into the effects of supplementary feed concentration on the growth performance, carcass characteristics, and meat quality of Turki-Qashqai lambs. One of the major strengths of this study is its robust experimental design, with clear comparison between feedlot-based feeding systems and pasture-based systems, using a well-controlled setup. The use of pelleted concentrate diets, particularly those with higher corn and soybean meal content, demonstrated significant benefits in terms of growth performance and carcass quality, which have practical implications for improving lamb production efficiency.

Additionally, the study employed detailed meat quality analysis, including the examination of moisture content, crude protein, fat, and mineral content, which allows for a comprehensive evaluation of how feeding systems affect the nutritional value of the meat. The integration of both physical performance (growth and carcass yield) and meat quality attributes (tenderness, color, and nutritional content) makes this study highly relevant for livestock producers and offers a holistic view of lamb production.

Despite the strengths, the study has some limitations that should be acknowledged. First, ruminal or total tract digestibility of the diets and their components was not assessed, which could provide additional insights into how different diets influence nutrient absorption and metabolic efficiency. Future studies could consider incorporating detailed digestibility trials to better understand how the form and composition of feed impact nutrient utilization in lambs.

Secondly, while the study compared two major feeding systems, intensive feedlot and extensive pasture-based, it did not explore the effects of different intensity levels of supplementary feeding (e.g., varying levels of concentrate inclusion) or alternative feeding strategies that might balance both growth and sustainability. The long-term effects of such feeding strategies, including their impact on animal welfare, environmental sustainability, and cost-effectiveness, remain unexplored in this study.

Moreover, this study was conducted with Turki-Qashqai lambs, and while the results are promising for this breed, the generalizability of the findings to other sheep breeds or regions with different climates, management systems, or local feed resources could be limited. Further research with different breeds and geographic locations would be useful to establish broader applicability.

Lastly, the study used a fixed duration for the experimental period (42 days), which might not fully capture the long-term effects of the feeding systems on lamb development and meat quality. A more prolonged experimental design might provide more comprehensive data on the long-term benefits and potential drawbacks of different feeding systems.

In conclusion, while this study demonstrates the clear advantages of concentrated feeding in improving lamb growth and meat quality, acknowledging its limitations allows for a more nuanced understanding of the broader context and encourages future studies to address these gaps. The strengths of the study, particularly its well-controlled experimental design and comprehensive analysis, make it a valuable contribution to lamb production research, with important implications for optimizing feeding strategies to enhance meat quality and production efficiency.

CONCLUSION

This study investigated the impact of supplementary feed concentration on the growth performance, carcass characteristics, and meat quality of Turki-Qashqai lambs. The results indicate that feeding complete diets, especially those containing higher proportions of corn and soybean meal, significantly enhances growth rates, carcass quality, and meat composition in comparison to pasture-based feeding systems. Lambs fed complete diets showed improved daily weight gain, final live weight, and carcass yield, confirming that concentrated feeding can optimize growth performance and meat production. Additionally, the study highlights the importance of feeding systems in shaping meat quality, with lambs on complete diets producing meat with higher nutritional value—characterized by increased protein, fat, and mineral content—along with superior tenderness and color. The findings suggest that supplementary feeding sys-

tems, particularly those utilizing concentrated feeds, offer significant advantages for enhancing lamb production efficiency and meat quality. These results have important implications for livestock producers, emphasizing the potential benefits of concentrated feed for improving both growth performance and meat attributes in Turki-Qashqai lambs. Further research should explore the long-term effects of concentrated feeding on lamb health, sustainability, and cost-efficiency to optimize feeding strategies for this breed.

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