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Impact of short compensatory growth periods on performance, carcass traits, fat deposition, and meat properties of Najdi lambs

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Abstract: Forty-eight Najdi male lambs weighing 33.1 ± 0.06 kg and approximately 4.5 months old were divided into three groups (16 lambs in each) to study the impact of compensatory growth on performance, carcass traits, fat deposition, tissue distribution, and lean chemical composition. The control group was fed ad libitum throughout the entire 12 weeks of the trial period. The other two groups were feed-restricted by 20% and 40% of the ad libitum group intake. Lambs in restricted treatments were feed-restricted for 3 weeks followed by 4 weeks of ad libitum feeding (compensatory) and then 2 weeks of feed restriction followed by 3 weeks ad libitum. No significant differences were detected among the three groups in overall average daily gain (g/day). During the two compensatory phases, the 40% group was more efficient ($P < 0.05$) in converting feed to gain, followed by the 20% group and finally by the 0% group. In general, feed restriction regimes did not affect ($P > 0.05$) carcass traits, fat deposition, meat properties, and chemical composition. It is concluded that feed restriction up to 40% can be an important tool to improve the growth efficiency and reduce the cost of meat production from growing Najdi lambs.

Key words: Compensatory growth, restriction, Najdi, lambs, meat

1. Introduction

Meat production in Saudi Arabia depends almost entirely on imported feed ingredients. There has been a dramatic increase in global prices of animal feedstuffs that prevent most local producers from continuing in the meat business. Possible strategies to reduce the cost of meat production include the imposition of feed restriction followed by compensatory growth in meat animals (1,2). Compensatory growth is a complex metabolic function; it may be influenced by genetic factors, the age of animals, severity and duration of restriction, diet quality, and duration of the realimentation (3). There are conflict results about feed consumption during the realimentation phase; some studies reported a significant increase in feed intake (4,5) while others found no significant differences (1,6,7).

Studies conducted to evaluate the effects of different feed restriction regimens on body growth and carcass composition have yielded various results. Some reports have indicated no differences in body composition between ad libitum and re-fed steers (8) and sheep (9). On the other hand, Drouillard et al. (10) found an increase in body fat, while other researchers have reported increases in the lean tissue of compensated goats (5) and lambs (1,11) in comparison with the control-fed animals. Knowledge of the effects of feed restriction and realimentation on feeding performance and carcass composition of Najdi sheep can help in developing strategies to optimize the use of feedstuffs by local sheep producers. The Najdi sheep is fat-tailed, classified as a carpet-wool type, nonseasonal breed, adaptable to the prevailing adverse environment of Saudi Arabia and considered the most popular breed among other indigenous sheep breeds. Therefore, the objective of the present study was to assess the impact of two consecutive short nutritional restriction periods followed with realimentation on growth performance, carcass traits, fat deposition, tissue distribution, and lean chemical composition of Najdi lambs.

2. Materials and methods

2.1. Animals and housing

This work was carried out at the farm and labs of the Department of Animal Production, King Saud University, Riyadh, Saudi Arabia. Forty-eight Najdi male lambs, of an

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average body weight of 33.1 ± 0.06 kg and approximately 4.5 months old, were utilized for this study. The experimental protocol regarding the care and handling of lambs was approved by the Ethics Committee of King Saud University, Riyadh, Saudi Arabia. Lambs were purchased from a local farm; upon arrival, lambs were individually weighed, identified, vaccinated against endemic infectious diseases, injected against internal and external parasites, and given a recommended dose of vitamin AD_3E injection. Thereafter, lambs were randomly assigned to one of three equal groups with 16 lambs in each group. The lambs were confined individually in concrete-floored pens in an open-sided building with an average ambient temperature of 19.6 °C and relative humidity of 39% during the experiment.

2.2. Feeding treatments

The experimental groups were randomly allotted to three feeding groups to evaluate the impacts of two consecutive short feeding restrictions periods on growth performance during restriction and realimentation periods, overall growth performance, and carcass characteristics at the end of the trial. All lambs were individually fed on commercial pellets; pens were supplemented with trace-mineral mixture blocks and a supply of drinking water. The first feeding group was used as a control and fed ad libitum throughout the trial. The second and third feeding groups were subjected to 3 weeks (wk1–wk3) of feed restriction at 20% and 40% of the ad libitum intakes (first restriction period), respectively, followed by a 4-week period (wk4–wk7) of ad libitum feeding (first realimentation period). Thereafter, the former groups were subjected to the same feed restriction protocols for 2 weeks (wk8–wk9; second restriction period) followed by 3 weeks of ad libitum feeding (wk10–wk12; second realimentation period). Feeding levels of restricted groups were calculated by determining the average dry matter intake (DMI) of the lambs with ad libitum access to feed the previous week and multiplying that average by 0.80 and 0.60 to determine the amounts of feed to offer to lambs in the 20% and 40% restriction groups, respectively.

All groups were fed once daily at 0800 hours after discarding the refusals from the previous day. Refusals were weighed and sampled for DM determination before being discarded. Feeding and management practices were applied equally to all groups. The commercial pellet was formed as a pelleted total-mixed ration with a ratio of 75% concentrate and 25% alfalfa hay. Pellets were randomly subsampled immediately prior to feeding; samples were then composited across the feeding trial period. Feed composites were dried in a forced-air oven at 60 °C until they attained a constant weight before chemical analyses. The chemical composition of feed was analyzed (12). The chemical composition (DM basis) was 15.5% CP, 1.16% EE, 24.91% NDF, 14.22% ADF, and 7.46% ash. The trial period lasted for 12 weeks, during which DMI and lamb weight data were recorded weekly; lamb weight was recorded after 12 h of fasting and before feeding in the morning.

2.3. Slaughtering procedure and carcass traits

At the end of the feeding trial, all lambs were slaughtered in a commercial abattoir after fasting for 18 h. The gastrointestinal tract was collected and was weighed full and empty to calculate empty body weight. Tail fat, omental fat, mesenteric fat, and pelvic and perirenal fat were weighed immediately after dressing. Carcasses were then chilled at 4 °C for 24 h and weighed (cold carcass); thereafter, the carcasses were carefully split longitudinally into two equal halves by sawing down along the dorsal midline. The right side of each carcass was then ribbed between the 12th and the 13th ribs and an acetate tracing was made of the longissimus dorsi muscle; a planimeter was used to determine the area of the longissimus dorsi muscle (rib eye area). Body fat thickness over the center of the longissimus dorsi muscle and body wall thickness 11 cm lateral to the dorsal process between the 12th and the 13th ribs were also measured. The 9th–11th rib joints were separated and physically separated into bone, fat, and lean. The lean tissues were ground through a 4-mm plate, mixed, and reground again. During the second grinding, five subsamples were taken from each carcass and mixed thoroughly to form samples of 50–60 g that were placed in a plastic bag, frozen, and stored at –20 °C until analysis. Ground lean samples were analyzed for moisture, protein, ether extract, and ash (12).

2.4. Statistical analysis

Data on growth performance and carcass characteristics were statistically analyzed by one-way ANOVA using GLM procedures (13). Duncan's multiple range test was used to test for significant differences between means.

3. Results

3.1. Performance of lambs

Performances of Najdi lambs during the first and second feed restriction and realimentation periods and in the overall trial are presented in Tables 1 and 2. Results showed that the restriction of feeding resulted in a reduction ($P < 0.05$) in average daily gain (ADG) as the level of restriction was increased. The depressions in ADG during the second restriction period were higher than those values obtained during the first restriction period. In comparison with the ad libitum group, ADG during the first and second periods decreased by 13.9% and 25.7% when feed intakes were restricted to the 20% level, and by 60.7% and 77.7% for the 40% restriction level, respectively. The feed:gain ratios (FG) for the ad libitum lambs and the 20% restriction groups did not differ, whereas the FG ratios for the ad libitum group were averaging 49% and 166% better

Table 1. Performance of Najdi lambs during the first feed restriction and realimentation periods.

Trait[2]	Feed restriction level, %[1]		
	Ad libitum	20	40
First restriction period (wk1–wk3)			
Initial weight, kg	33.3 ± 1.61	32.9 ± 1.28	33.0 ± 1.44
ADG, g day^{-1}	252 ± 18.45 [a]	217± 14.84 [b]	99 ± 12.59 [c]
DMI, g day^{-1}	1388 ± 101.41[a]	1089 ± 91.12 [b]	811 ± 84.49 [c]
Feed:gain, g g^{-1}	5.51 ± 0.35 [b]	5.02 ± 0.49 [b]	8.21 ± 0.55[a]
First realimentation period (wk4–wk7)			
Initial weight, kg	38.3 ± 2.04 [a]	37.5 ± 1.84 [a]	35.1 ± 1.45[b]
ADG, g day^{-1}	242 ± 16.44 [c]	279 ± 18.25 [b]	301 ± 20.11 [a]
DMI, g day^{-1}	1394 ± 47.58	1447 ± 48.01	1438 ± 47.21
Feed: gain, g g^{-1}	5.76 ± 0.14 [a]	5.19 ± 0.16 [b]	4.78 ± 0.21 [c]
Final weight, kg	45.1 ± 2.01	45.3 ± 1.87	43.5 ± 1.79

[1] Restriction level as a percentage of ad libitum intake.
[2] Mean ± standard error.
[a,b,c] Means in the same row bearing different superscripts differ (P < 0.05).

Table 2. Performance of Najdi lambs during the second feed restriction, realimentation periods, and overall.

Trait[2]	Feed restriction level, %[1]		
	Ad libitum	20	40
Second restriction period (wk8–wk9)			
Initial weight, kg	45.1 ± 2.01	45.3 ± 1.87	43.5 ± 1.79
ADG, g day^{-1}	202 ± 20.31 [a]	150 ± 19.87 [b]	45 ± 11.51 [c]
DMI, g day^{-1}	1632 ± 124.11 [a]	1306 ± 119.57 [b]	965 ± 109.35 [c]
Feed:gain, g g^{-1}	8.08 ± 2.46 [b]	8.71 ± 2.39 [b]	21.47 ± 7.58 [a]
Second realimentation period (wk10–wk12)			
Initial weight, kg	47.9 ± 1.88 [a]	47.4 ± 1.74 [a]	44.1 ± 1.54 [b]
ADG, g day^{-1}	216 ± 20.14 [c]	248 ± 18.54 [b]	305 ± 22.51 [a]
DMI, g day^{-1}	1619 ± 88.21	1607 ± 85.78	1674 ± 86.47
Feed:gain, g.g^{-1}	7.50 ± 0.51 [a]	6.48 ± 0.29 [b]	5.49 ± 0.37 [c]
Final weight, kg	52.4 ± 1.98	52.7 ± 1.59	50.5 ± 1.74
Overall trial (wk1–wk12)			
ADG, g day^{-1}	231 ± 12.54	234 ± 11.57	208 ± 11.14
DMI, g day^{-1}	1488 ± 75.48 [a]	1380 ± 68.18 [b]	1271 ± 64.52 [c]
Feed: gain, g g^{-1}	6.44 ± 0.31 [a]	5.90 ± 0.25 [b]	6.11 ± 0.26 [a]

[1] Restriction level as a percentage of ad libitum intake.
[2] Mean ± standard error.
[a,b,c] Means in the same row bearing different superscripts differ (P < 0.05).

($P < 0.05$) than the 40% restriction groups during the first and second restriction periods, respectively. During the realimentation periods, ADG and FG improved ($P < 0.05$) as the level of previous feed restriction increased. The compensated Najdi lambs during the first and second realimentation periods were capable of retrieving their weight loss compared to control lambs when they had free access to feed.

At the end of the trial, overall ADG and final body weight of the 20% and 40% restriction levels were not different compared with the ad libitum lambs. On the contrary, DMI decreased ($P < 0.05$) as the level of restriction increased. In addition, lambs at the 20% restriction level were the most efficient in overall FG ratio in comparison with other groups.

3.2. Carcass traits and fat deposition

No effects were found between restriction groups and the ad libitum group in the weights of empty body and cold carcass (Table 3); empty body and carcass weights followed the same trends observed for final slaughter weights. Neither the 20% nor the 40% level of feed restriction had an effect on the percentages of dissected lean and bone tissues from the 9th–11th rib joints compared to the control group (Table 4). Unchanged percentages of chemical constituents in dissected lean tissue were found among ad libitum, 20%, and 40% restriction levels.

4. Discussion

The differences in ADG are probably due to different restriction durations; the depression in ADG might have started strong at the initial period of restriction and then with increasing restriction duration, lambs began to compensate partially, causing more noticeable dilution effects for the ADG depression in the first 3 weeks than those in the second 2-week restriction period. The average ad libitum DMI during the trial (89 g $kg^{-0.75}$) was close to the value (86 g $kg^{-0.75}$) predicted by the National Research Council (14). The effect of DMI restriction on lamb performance has been studied (15,16). Relative to lambs fed ad libitum, lambs held to less than maximal DMI had decreased ADG as a function of the plane of nutrition, thereby resulting in inadequate intake of nutrients required to sustain normal growth and development (1). In addition, Gonzaga Neto et al. (17) reported that the growth of an animal could be delayed if any nutrient in the diet is missing, especially if energy and protein availability limit weight gain.

The improving in ADG and FG ratio during the realimentation periods is in line with the results of previous studies (1,15). Lambs can be feed-restricted at up to 40% and the loss in weight can be recouped with the phenomenon of compensatory growth (2). However, the superior ADG could not be attributed to DMI because

Table 3. Effect of the compensatory growth on the carcass traits in Najdi lambs at the end of the trial.

Trait[2]	Feed restriction level, %[1]		
	Ad libitum	20	40
Empty body weight, kg	46.9 ± 1.05	47.0 ± 0.91	46.5 ± 0.61
Cold carcass weight, kg	28.9 ± 0.54	27.8 ± 0.44	27.1 ± 0.42
Dressing, %	56.5 ± 0.43	54.7 ± 0.38	54.9 ± 0.35
Chilling loss, %	2.50 ± 0.11	2.52 ± 0.08	2.55 ± 0.05
Body fat thickness, mm	13.00 ± 0.84 [a]	11.60 ± 0.75 [a]	8.80 ± 0.76 [b]
Body wall thickness, mm	25.67 ± 0.88 [a]	23.80 ± 0.79 [ab]	20.60 ±0.81 [b]
Rib eye area, cm^2	12.69 ± 0.55	13.82 ± 0.61	12.99 ± 0.54
Tail fat, kg	3.96 ± 0.21 [a]	3.15 ± 0.18 [b]	3.07 ± 0.15 [b]
Omental fat, kg	1.43 ± 0.11 [a]	1.33 ± 0.08 [ab]	1.19 ± 0.06 [b]
Mesenteric fat, kg	0.66 ± 0.03	0.68 ± 0.04	0.69 ± 0.06
Pelvic and perirenal fat, kg	0.93 ± 0.04	0.82 ± 0.04	0.94 ± 0.05

[1] Restriction level as a percentage of ad libitum intake.
[2] Mean ± standard error.
[a,b,c] Means in the same row bearing different superscripts differ ($P < 0.05$).

Table 4. Effects of the compensatory growth on the tissue distribution and chemical composition of dissected lean tissue in Najdi lambs at the end of the trial.

Trait[2]	Feed restriction level, %[1]		
	Ad libitum	20	40
Tissue distribution, %[3]			
Lean	49.1 ± 1.12	51.9 ± 0.98	52.6 ± 0.89
Fat	28.8 ± 0.94 [a]	26.7 ± 0.87 [ab]	25.4 ± 0.84 [b]
Bone	22.1 ± 0.74	21.4 ± 0.81	22.1 ± 0.75
Dissected lean composition, %			
Moisture	65.2 ± 0.66	63.2 ± 0.58	64.4 ± 0.61
Protein	18.5 ± 0.25	19.8 ± 0.27	20.2 ± 0.28
Ether extract	15.3 ± 0.29	16.0 ± 0.31	14.5 ± 0.35
Ash	1.0 ± 0.02	1.0 ± 0.01	0.9 ± 0.01

[1] Restriction level as a percentage of ad libitum intake.
[2] Mean ± standard error.
[3] Dissected tissues from 9th–11th rib joints.
[a,b] Means in the same row bearing different superscripts differ ($P < 0.05$).

intake values were not different between the previously restricted and ad libitum groups, but it was possibly due to the better FG of the realimented lambs and/or the decreased heat production during the restriction and its continuation during refeeding (18). During compensatory growth, the animal's metabolism continues to adjust to low food ingestion while the animals are not restricted; the base energetic metabolism of the animal remains low and increases slowly, adjusting to the new regimen (4). Thus, energy and protein use becomes more efficacious while the energetic needs for growth remain low, which could explain the greater weight gain in these animals. Similarly, sheep subjected to feed restriction reduced their energy need for maintenance by about 29% compared to the control; after realimentation, these reduced maintenance requirements during restriction only persisted at the initial stages of realimentation and temporarily resulted in comparatively more energy for gain (15).

Carcass traits and fat deposition results agreed with previous reports that empty and carcass weights (1,2,11) and dressing percentages (5,19) were not affected by feed restriction. Feeding restrictions did not have effects on mesenteric, pelvic, and perirenal fats. The depression in tail fat due to feed restriction has been reported (1); fat deposition in the tail was dramatically affected by restriction and did not recover after refeeding. Various restriction regimens depressed the accumulation of body and carcass fats in realimented lambs because the magnitude of fat increases during the refeeding period was not large enough to better or equal the fat contents of the ad libitum control group (9,20). Feeding restriction at 20% had no effects on the body fat and wall thicknesses and omental fat weight as compared to the ad libitum group. On the contrary, fat accumulation in pelvic and perirenal depots were delayed during restriction (2,11), but thereafter, they recovered from their weight loss during the realimentation phase and became equal to the control group.

Restricting feed by 40% decreased ($P < 0.05$) the percentage of dissected fat compared to the ad libitum control group. The reduction in separable fat percentage followed the same trend observed for body and wall fat thicknesses and tail and omental fat weights. The unchanged percentages of chemical constituents in dissected lean tissue between control, 20%, and 40% restriction levels agreed with results reported earlier (10,20). These results, however, disagreed with the conclusions of other studies (9,21), which found that the relationship of lean chemical composition was changed by feed restriction followed by realimentation, and that realimented lambs had higher protein percentages than the controls. The discrepancy may be related to the differences in growth patterns of different body tissues. Wright and Russel (22) showed that a greater proportion of protein was made during the early period of the realimentation phase followed by increased fat deposition during the next stages. The length of each stage and the amount of deposition differ according to species, breed, age, stage of maturity, sex, level and restriction

duration, and level and duration of refeeding (23,24). However, there was a consensus that after the first period of realimentation was over, the chemical constituents of lean tissue from the realimented lambs become similar in proportion to that of control lambs (25).

In conclusion, the phenomenon of compensatory growth can be employed in order to minimize feeding costs from fattening Najdi lambs by using a restriction regime of up to 40% without adverse effects on lambs' performance, carcass traits, fat deposition, meat properties, and chemical composition.

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