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Effect of restricted feeding and realimentation on feed performance and carcass characteristics of growing lambs[1]

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ABSTRACT - Forty Najdi ram lambs weighing 26.6±0.3 kg were utilized in this experiment to determine the effects of feed restriction followed by realimentation and body weight at the onset of feed restriction (30 and 36 kg body weights) on performance and carcass characteristics; feeding and restriction levels were *ad libitum*, 0.75 and 0.60 of the *ad libitum* intake. All lambs were slaughtered after 14 weeks of experimentation. The results showed that, during the feed restriction phase, average daily gain (ADG) and feed efficiency decreased as the level of restriction increased. During the realimentation phase, the 30 kg lambs gained weights and consumed dry matter (DM) similarly to the *ad libitum* group, whereas the ADG for the 36 kg lambs of both 0.75 and 0.60 *ad libitum* groups were 20 and 43.8% faster than the *ad libitum* group, respectively. At the end of the trial, final body weight and overall ADG of the realimented 30 kg groups were lower than *ad libitum* group, whereas the ADG of the 36 kg groups were not different compared with the *ad libitum* group. Although empty body, hot and cold carcass, empty stomach compartments, empty intestines and liver weights for the 36 kg groups were not affected by feed restriction followed by realimentation, weights of visceral fat depots, subcutaneous fat and tail fat decreased much more than those of the *ad libitum* group. Carcass composition of the realimented 0.75 and 0.60 *ad libitum* groups tended to have 5.1 and 8.8% less lean tissue than the *ad libitum* group when the restriction started at 30 kg, respectively. On the other hand, the realimented lambs of both 0.75 and 0.60 *ad libitum* groups tended to be 5.1 and 2.8% leaner than those of the *ad libitum* group when restriction started at 36 kg body weight, respectively. Feed restriction of up to 40% for a 5-week period followed by a 4-week period of refeeding in 36 kg lambs is economically feasible and does not offset production.

Key Words: compensation, growth, limited feeding, refeeding, sheep

Introduction

Possible strategies to reduce the cost of lamb production in Saudi Arabia include the imposition of feed restriction followed by compensatory growth. Compensatory growth is manifested in the ability of animals previously restricted in feed intake to outgain their better counterparts when given free access to good quality feed. Higher feed intake after a period of feed restriction has been reported (Greeff et al., 1986; Homem et al., 2007), whereas other studies have shown that feed intake does not increase after a period of feed restriction (Turgeon et al., 1986; Kabbali et al., 1992b).

The effect of compensatory growth on body composition has been studied by various researchers and conflicting results have been obtained. Some reports have indicated increases in body fat content (Ledin, 1983; Notter et al., 1983) and others have reported increases in the lean tissue of realimented animals (Dashtizadeh et al., 2008; Al-Selbood, 2009). In other reports, body composition was not affected by a period of feed restriction followed by realimentation (Rompala et al., 1985). Some contradictions could be due to different restriction levels, different periods of restriction and realimentation, and different breeds with different maturity ages. The existence of an interaction between the plane of nutrition and the physiological age would seem to explain some of the inconsistencies (Tatum et al., 1988). Searle et al. (1979) stated that young lambs are more vulnerable to feed restriction, particularly in the period immediately after weaning; the end results therefore depend on the age of the lamb and the time when restriction starts.

Because voluntary feed intake and body composition differ between breeds, it is possible that growing Najdi lambs react differently to feed restrictions. Knowledge of the effects of feed restriction on feeding performance and carcass composition can help in developing feeding strategies to optimize the use of feedstuffs by growing lambs. This study was conducted to quantify the effects of various restriction regimens on feeding performance and carcass composition of growing Najdi lambs.

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Material and Methods

A total of forty weaned Najdi male lambs, of average body weight 26.6±0.3 kg and of approximately 3.5 months of age, were selected for this study. Lambs were purchased from a local farm; upon arrival, lambs were individually weighed, identified, vaccinated against clostridial diseases, injected against internal and external parasites and vitamin A-D-E injections were given. Thereafter, lambs were randomly assigned to one of five equal groups with eight lambs in each group. Each group contained four replicates (pens) with two lambs per pen; the pen was used as an experimental unit for feed performance data. Pens (1.7 × 3.0 m) were made of metal gates and were located under a roof in an open-sided barn; lambs were kept on concrete floors without bedding.

The experimental groups were randomly allotted to five feeding regimens to evaluate the effects of feed restriction levels and body weight at the onset of the feed restriction phase on growth performance during restriction and realimentation phases, and overall growth performance, visceral fat and carcass component weights at the end of the trial. The first feeding group was used as a control and fed *ad libitum* throughout the trial. The second and third feeding groups were fed *ad libitum* until they attained 30 kg live body weight (pre-restriction phase) and then subjected to 5 weeks of feed restriction at either 0.75 or 0.60 of *ad libitum* intake. The remaining two groups were fed *ad libitum* until attaining 36 kg live body weight; thereafter, lambs were subjected to feed restriction protocols similar to that of groups 2 and 3. Following the restriction phase (5 weeks long), lambs from groups 2, 3, 4 and 5 were returned to *ad libitum* feeding (realimentation phase) until the end of the trial; the duration of realimentation phases for the 30 and 36 kg groups were 7 and 4 weeks, respectively (Figure 1). 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 0.75 and 0.60 to determine the amount of feed to offer to lambs fed at 0.75 and 0.60 *ad libitum* groups, respectively. The experimental period lasted 14 weeks, during which DM intake and lamb weight data were recorded weekly; lamb weight was recorded after 12 hours of fasting and before feeding in the morning. Fresh drinking water was available at all times.

All lambs were fed commercial pellets at 09h00 after discarding the leftovers from the previous day. Leftovers were removed, weighed, sampled for DM determination and then discarded. Feeding and management practices were applied equally to all experimental groups. The commercial pellet was formed as a pelleted total-mixed ration with a ratio of 75% concentrate and 25% alfalfa hay; the chemical composition (DM basis) was 14.53% crude protein, 1.16% ether extract, 24.91% neutral detergent fiber, 14.22% acid detergent fiber, 0.54% calcium, 0.31% phosphorus, 7.46% ash and 2.78 Mcal metabolizable energy kg^{-1} dry matter. All pens were supplemented with mineral mixture blocks.

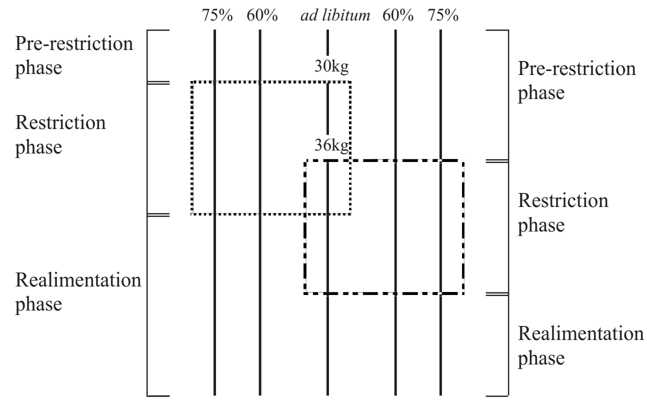

Figure 1 - The experimental design.

At the end of the trial, all lambs were slaughtered after 12 hours without feed. Hot carcass, liver, empty stomach compartments, empty intestines and internal fat, namely, omental fat, mesenteric fat, perirenal fat, pericardial fat and channel fat weights were recorded immediately after dressing. The gastro-intestinal content was weighed, and empty body weight was calculated by deducting the weight of digesta from the fasted live weight at slaughter. Carcasses were then refrigerated at 4 ºC for 24 hours and the cold carcass weights were recorded; thereafter, the carcasses were carefully divided into two equal halves along the midline and the right side was physically dissected into fat tail, subcutaneous fat, intermuscular fat, lean tissue and bone (bone plus cartilage and major tendons) portions. Data on growth performance, visceral fat weights and carcass composition were statistically analyzed by one-way ANOVA using GLM procedures of SAS (Statistical Analysis System, version 8). Duncan's multiple range test was used to test for significant differences between means.

Results and Discussion

Initial body weight and performance indices for the different levels of feed restriction and weight groups during the pre-restriction phase were not significantly (P>0.01) different (Table 1). The actual feed intake restrictions during the restriction phase for the 30 kg group were 24.2

and 41.4% for the lambs with 0.75 and 0.60 *ad libitum* intake, respectively; the corresponding values for the 36 kg group were 26.6 and 40.4%. During the restriction phase, average daily gain (ADG) decreased (P<0.01) as the level of feed restriction was increased; in comparison with the group fed *ad libitum*, the growth rates of the 30 and 36 kg groups decreased by 48 and 49% when feed intakes were restricted to 0.75 *ad libitum* intake, and by 70 and 67% for the 0.60 *ad libitum* fed groups, respectively. Similar results have been reported by several other authors. Yakubu et al. (2007) and Dashtizadeh et al. (2008) stated that the decrease in the body weight gain during feed restriction period is a function of the plane of nutrition, thereby resulting in inadequate intake of nutrients required to sustain rapid growth and development.

Feed efficiency for the 30 kg weight group decreased (P<0.01) by 31.1 and 48.9% when feed intakes were restricted to 0.75 and 0.60 of *ad libitum* intakes, respectively; the corresponding decreases (P<0.01) were 29.8 and 43.8% for the 36- kg weight group. In other words, the depressions in feed efficiency for the 36 kg lambs due to feed restriction were numerically smaller than those values obtained for the 30 kg lambs. This trend in feed efficiency probably relates to their better ADG in comparison with the 30 kg lambs, indicating that they were still at the surge of their growing stage. Similar results were reported by Kamalzadeh et al. (1997), who found that the feed efficiency in lambs was not decreasing with increasing body weight, but there was a breakpoint in the efficiency of feed utilization as body weight increased over 50 kg.

The realimented 30 kg lambs gained weights and consumed feed similarly (P>0.01) to the *ad libitum* feeding group, whereas the realimented 36 kg lambs gained weights (P<0.01) faster than the *ad libitum* fed lambs. This trend in compensatory growth for Najdi lambs probably relates to the effect of different ages or weights at the onset of the restriction phase. Supporting this postulate are results from Ryan (1990), who stated that there appears to be a critical period in cattle and sheep from birth to three months of age when nutritional restriction will not trigger a compensatory growth; following this period, animals can exhibit catch-up growth until they reach maturity. The ADG of the 36 kg lambs fed 0.75 and 0.60 *ad libitum* intakes were 20 and 43.8% faster than those of the *ad libitum* fed group, respectively. However, this superior gain could not be attributed to DMI because intake values were not different (P>0.01) between restricted and *ad libitum* groups, but possibly due to the better feed efficiency of the realimented lambs and/or the decreased heat production during the restriction and its continuation during realimentation (Ryan, 1990; Yambayamba et al., 1996). These results are in agreement with those of Turgeon et al. (1986) and Kabbali et al. (1992b), but not with those of Greeff et al. (1986) and Homem et al. (2007), who reported that rapid gain during realimentation was associated with increased feed intake. The apparent inconsistency may be explained by the differences in restriction levels, the composition of the diets, the periods of restriction and realimentation, and the physiological age and time that restriction started (Hornick et al., 2000).

Table 1 - Feeding performance of growing lambs during restriction and realimentation phases

Parameter	Feeding level				Feeding level			
	ad libitum	0.75	0.60	SEM	*ad libitum*	0.75	0.60	SEM
	30 kg live weight				36 kg live weight			
Initial body weight, kg	26.7	26.9	26.6			26.7	26.8	.9
Pre-restriction phase:								
Days	14	14	14		35	35	35	
Average daily gain, g	279	272	286	9	291	290	292	8
Dry matter intake, g	1325	1335	1320	63	1414	1430	1446	78
Feed efficiency, $g.kg^{-1}$	210	204	216	8	206	203	202	9
Restriction phase:								
Days	35	35	35		35	35	35	
Average daily gain, g	275a	143b	82c	110	301a	154b	100c	102
Dry matter intake, g	1525a	1156b	894c	120	1690a	1239b	1006c	144
Feed efficiency, $g.kg^{-1}$	180a	124b	92c	18	178a	125b	100c	22
Realimentation phase:								
Days	49	49	49		28	28	28	
Average daily gain, g	306	315	325	21	306c	367b	440a	34
Dry matter intake, g	1857	1838	1770	91	1918	1882	1801	88
Feed efficiency, $g.kg^{-1}$	165	172	183	23	159c	195b	244a	18

Means in the same row and within each live weight followed by different superscripts differ (P<0.01).
SEM - standard error of the mean.

Kabbali et al. (1992a) found that the daily feed intake of realimented lambs seemed to vary with age. Also, Drew & Reid (1975) reported no increase in daily intake per unit of metabolic body weight after refeeding immature lambs. Thus, the lack of effect on DMI during the realimentation phase of this study may be due to their age (<6 months). After refeeding the 30 kg lambs, feed efficiency (g gain.kg^{-1} DMI) was slightly improved (P>0.01) by 4.2 and 10.9% for the 0.75 and 0.60 *ad libitum* groups and (P<0.01) by 22.6 and 53.5% for the 36 kg lambs, respectively compared with *ad libitum* fed lambs. Enhanced feed efficiency during compensatory growth has been reported in several studies (Turgeon et al., 1986; Ryan, 1990; Kabbali et al., 1992a; Homem et al., 2007).

The final weight and overall ADG of the realimented 30 kg group (Table 2) were lower (P<0.01) than those values from the *ad libitum* group, whereas weight and ADG of the realimented 36 kg lambs were not different (P>0.01) compared with *ad libitum* fed lambs. These results indicated that feed restrictions followed by 4 weeks of realimentation in the 36 kg lambs induced reversible growth restriction with almost complete catch-up for body weight. In contrast, the realimented 30 kg lambs after 7 weeks of realimentation were unable to fully compensate and continued to be lighter in body weight than the *ad libitum* fed lambs. However, the trends of weight recovery after feed realimentation in growing Najdi lambs probably depended on the age/weight of lambs at the start of the restriction period. These results agreed with the general findings of Kabbali et al. (1992a) and Remmers et al. (2008), that the end weight of a compensated animal will depend on the physiological age and the time that restriction started. Lambs in the 0.60 *ad libitum* fed group of both 30 and 36 kg weight treatments had significantly lower (P<0.01) overall DMI throughout the trial than the *ad libitum* fed lambs; the average reduction in DMI for these groups was 16.4% compared with the *ad libitum* fed lambs. The overall feed efficiency value of the 0.60 *ad libitum* group was higher (P<0.01) for the 36 kg lambs than those values obtained from the other realimented and *ad libitum* treatments. The enhanced feed efficiency in this group can be explained in terms of a decreased overall DMI.

At the end of the experiment, weights of empty body, hot and cold carcass, empty stomach compartments and intestines and liver for the realimented groups of both studied weights (Table 2) approached (P>0.01) those from *ad libitum* fed lambs; the exception was the 0.60 *ad libitum* treatment of 30 kg lambs which had lower (P<0.01) weights than the *ad libitum* intake group. The highest weight depressions due to the restriction treatment in the latter

Table 2 - Growth performance, carcass components and visceral fat distribution in realimented Najdi lambs

Parameter		Feeding level		Feeding level		
	ad libitum	0.75	0.60	0.75	0.60	SEM
		30 kg live weight		36 kg live weight		
Performance						
Final weight, kg	55.3a	51.2b	49.4b	52.4ab	52.9ab	2.1
Average daily gain, g	291a	247b	233b	262ab	266ab	18
Dry matter intake, g	1663a	1505ab	1391b	1508ab	1390b	89
Feed conversion, g.kg^{-1}	175b	164b	168b	174b	191a	14
Empty body, kg	49.7a	46.7ab	44.3b	48.0a	48.2a	2.10
Hot carcass, kg	27.7a	25.9ab	24.7b	26.1ab	26.1ab	0.83
Cold carcass, kg	27.0a	25.1ab	24.0b	25.6ab	25.4ab	0.81
Dressing, %	50.1	50.6	49.9	49.8	49.4	0.45
Empty stomach compartments, kg	1.53a	1.41a	1.28b	1.48a	1.33ab	0.09
Empty intestines, kg	1.33a	1.22ab	1.19b	1.32a	1.29a	0.08
Liver, kg	1.09a	0.96ab	0.85b	1.10a	1.04a	0.02
Visceral fat, g						
Perirenal fat	1412a	983b	878b	1009b	889b	143
Channel fat	214a	158b	146b	162b	154b	51
Pericardial fat	105	110	114	110	102	49
Omental fat	1977a	1337b	1364b	1388b	1440b	173
Mesenteric fat	880a	691b	633b	580b	602b	138
Total visceral fat	4588a	3279b	3135b	3249b	3177b	218
Separable tissue, kg[1]						
Subcutaneous fat	2.08a	1.81a	1.69b	1.53b	1.61b	0.21
Intermuscular fat	1.13	1.11	1.18	1.10	1.08	0.08
Tail fat	1.75a	1.58b	1.28c	1.54b	1.60b	0.23
Lean tissue	6.12a	5.81ab	5.58b	6.43a	6.29a	0.36

[1] Physical separation of the carcass right side.
Means in the same row followed by different superscripts differ (P<0.01).
SEM - standard error of the mean

group were 16.3 and 22% for empty stomach compartments and liver, respectively. Several studies have reported decreases in the weight of empty stomach, intestines and liver due to feed restriction of young animals (Mora et al., 1996; Yambayamba et al., 1996; Dashtizadeh et al., 2008).

Reduction in the liver weight of lambs was related to a decrease in oxygen consumption by the liver and hepatic blood flow (Burrin et al., 1989). Also, it has been shown that moderate feed restriction resulted in appreciable changes in the metabolism of the liver and gastrointestinal tissues (Tovar-Luna et al., 2007). In other reports, liver and empty gut weights were not affected by a period of feed restriction followed by realimentation (Hicks et al., 1990; Kabbali et al., 1992ab; Murphy et al., 1994). However, this catch-up growth was explained by Turgeon et al. (1986) and Mora et al. (1996), who found that during the first phase of the realimentation period, energy was diverted mainly to replenish protein and glycogen reserves in gut and liver tissues. Also, Wester et al. (1995) reported that livers of lambs were completely replenished in two days, but according to Ryan et al. (1993), the liver of cattle and sheep were replenished in 90 days. These apparent contradictions arise from the diversity of factors involved in compensatory growth and may represent the true spectrum of results that can be expected from trials using a limited number of animals with variable ages and weights at the onset of restriction and a variety of conditions of nutritional restriction and realimentation.

Thus, the significant effect on empty gastrointestinal and liver weight in the latter realimented group may be related to the interaction between age and level of restriction; younger or lighter Najdi ram lambs at the onset of restriction treatment (30 kg) were dramatically affected by the 40% feed restriction, resulting in lambs that remained lighter in empty body weight and produced lighter carcass, liver and empty gut weights than the 0.75 *ad libitum* group, whereas older or heavier lambs (36 kg) were probably less susceptible to a period of low nutrient intake than their younger counterpart. Feed restriction later in life is known to induce reversible growth restriction with complete catch-up growth (Hambly & Speakman, 2005; Remmers et al., 2008).

Overall, empty body and carcass weights followed the same trends observed in final slaughter weights. Dressing percentages of lambs in various feeding restrictions and weight groups were not significantly ($P>0.01$) different and ranged from 49.4 to 50.6%. This result agreed with previous reports that dressing percentages were not significantly affected by feed restriction (Murphy et al., 1994; Dashtizadeh et al., 2008; Al-Selbood, 2009).

Upon the end of the realimentation period, weights of visceral fat, namely, perirenal, channel, omental and mesenteric, were reduced ($P<0.01$) by the previous restriction treatment (Table 2). Weights of total visceral fat for the 0.75 and 0.60 *ad libitum* intakes were 28.5 and 31.7% lower ($P<0.01$) than the *ad libitum* fed lambs of the 30 kg group, whereas these reductions ($P<0.01$) were 29.2 and 30.8% in the 36 kg lambs, respectively. These results are in agreement with those of Turgeon et al. (1986), Drouillard et al. (1991) and Kabbali et al. (1992ab), who found that the weight of internal fat depots were dramatically affected by restriction followed by refeeding.

Feed restriction treatments and weights of lambs at the onset of restriction had no effect ($P>0.01$) on pericardial fat weight after realimentation. There were no variations in response to various fat depots between the 30 kg and 36 kg lambs. The largest reduction in fat weight was found for perirenal depot of the 0.60 *ad libitum* fed lambs; the corresponding average value was 37.5% less weight than the *ad libitum* group. The reduction in weights for other fat depots after the realimentation period ranged from 25 to 30% less than their counterpart *ad libitum* fed lambs.

At the end of the trial, subcutaneous fat weights for the 0.60 *ad libitum* fed lambs of both weight groups were lighter ($P<0.01$) than for the *ad libitum* fed lambs; the corresponding reductions in subcutaneous fat weight for the 30 kg and 36 kg lambs were 18.8 and 22.6% compared with the *ad libitum* fed lambs, respectively. Feed restriction depressed ($P<0.01$) fat deposition in the tail depot; the highest reduction was 26.9%, for the 30 kg lambs of the 60% of *ad libitum* intake. Overall, these results are in agreement with those of Turgeon et al. (1986), Carstens et al. (1991) and Kabbali et al. (1992a), who found that restriction regimens decreased the proportion of carcass fat in realimented lambs compared with continuous fed lambs. Also, Marais et al. (1991) reported that the deposition rate of carcass fat progressively declined with feeding restriction, and the magnitude of the increase during the realimentation phase was not large enough to better or equal the fat contents of the *ad libitum* group. However, these results are at variance with those reported by Ledin (1983) and Notter et al. (1983), who indicated higher fat content in realimented animals. This discrepancy may be related to the severity of restriction, the degree of maturity of lambs and the realimentation intensity. No differences in the carcass fat component weights, namely, subcutaneous, intermuscular and tail fat could be detected between the 30 and 36 kg weight groups.

Although the 0.75 and 0.60 *ad libitum* treatments of the 36 kg group were similar ($P>0.01$) to the *ad libitum* group with respect to carcass lean weight, they had 5.1 and 2.8% more lean tissue in their carcasses than the *ad libitum* lambs, respectively. Opposite to this trend, the 0.75 and 0.60 *ad libitum* fed lambs of the 30 kg group had 5.1 (P>0.01) and 8.8% (P<0.01) less lean weight in their carcasses than the *ad libitum* fed group, respectively. Several studies have reported that animals that exhibited compensatory growth were leaner (Dashtizadeh et al., 2008; Al-Selbood, 2009). Rompala et al. (1985), however, found that the empty body composition at final slaughter weight was unaffected by a period of growth restriction, although a transitory increase in leanness was noted during the early phase of compensatory growth. The inconsistencies in results regarding the amount of lean tissue deposited in the 30 and 36 kg lambs at the end of the trial and those from the literature cited above implicate degree of maturity at the point of growth restriction as an important determinant directing compositional changes that occur during the realimentation phase. Supporting this postulate are results from Thornton et al. (1979), who noted that empty body composition of compensatory-growth lambs tended to have less lean tissue when the weight-loss period started at 23 kg, whereas the compensatory-growth lambs tended to be leaner than the continuously fed control lambs when the restriction period started at 43 kg. Thus the severity of growth restriction in Najdi lambs seems greater when a period of growth restriction is imposed at an earlier stage of maturity (30 kg) when the impetus for lean tissue growth is higher. Bone weight from the restriction treatments was 5-10% lower than those from *ad libitum* fed lambs; however, no differences (P>0.01) were detected between different lambs due to restriction level or weight of lambs.

Conclusions

The results obtained in this study have shown that feeding performance was better in the 36 kg limited-fed lambs which underwent compensatory growth, and these lambs had leaner carcasses than the 30 kg lambs at the end of the trial. This indicates that feed restriction of up to 40% for five weeks followed by four weeks of refeeding in the 36 kg Najdi lambs would not offset production and that it would be economically feasible.

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