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Growth Rate of Carcass, Non-carcass and Chemical Components of Restricted Fed and Realimented Growing Lambs

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Abstract

This study aims to determine the impacts of feed restriction and refeeding on the growth rates of carcass tissues and non-carcass components in lambs. A total of 48 Najdi male lambs, of an average body weight 26.6±0.3 kg and approximately 3.5 months old, were used for this study. Significant ($P<0.05$) decreases in the daily weight gain of empty body, cold carcass, liver, empty stomach compartments, empty intestines, internal fats, subcutaneous fat, intermuscular fat, and separable lean were detected when the two feed restriction levels (25% and 40%) were imposed compared to the *ad libitum* fed group. Also, feed restriction levels significantly ($P<0.05$) decreased the daily accretion rate of fat, protein and moisture contents of the separable lean. In contrast, the daily weight gain of empty body, liver, empty intestines and internal fats of the feed restriction groups were significantly ($P<0.05$) higher than those values obtained from the *ad libitum* control group during the realimentation phase; whereas, lambs that moved from 40% feed restriction to *ad libitum* feeding had significantly ($P<0.05$) lower average daily deposition rates for all studied carcass tissues than control lambs. Liver and empty intestines were the fastest non-carcass components to compensate by realimentation. During the realimentation phase, average daily accretion rate of moisture and protein continued to be significantly ($P<0.05$) slower, while the accretion rate of chemical fat was higher ($P<0.05$) in the lambs that had been fed the 25% or 40% feed restriction levels than the control lambs.

Keywords: Restriction; Realimentation; Carcass; Non-carcass; Lambs

Introduction

The growth of realimented animals is manifested in the ability of animals previously restricted in feed to outgain their counterparts when given free access to good quality feed. Several studies have shown that the increase in the rate of growth observed following nutritional restriction is a result of greater accretion of protein and a lower deposition of fat during realimentation compared with continuous growth (Dashtizadeh *et al*., 2008; Al-Selbood, 2009). Other studies have shown that deposition rate of the empty body fat may be greater or similar in animals that had been restricted and then realimented, compared with continuously fed controls (Drouillard *et al*., 1991; Sahlu *et al*., 1999). Feed restriction of male goats followed by realimentation increased the dry matter and fat contents at equal slaughter weights, but decreased the protein content of the carcass soft tissues (Dashtizadeh *et al*., 2008). Reduced feed intake resulted in a decrease in the rate of internal fat deposition, while the liver and intestines were the fastest non-carcass components to compensate by realimentation in sheep (Kabbali *et al*., 1992a) and steers (Carstens *et al*., 1991). The variable responses to realimentation in the rate of catch–up growth could be attributed to genetic effect, age at restriction, severity and duration of restriction, the quality of the realimentation diet and duration of refeeding (Al-Selbood, 2009).

Objectives of this study were to determine the effects of 25% and 40% feed restriction and realimentation on (1) deposition rate of carcass and non-carcass components, (2) rate of fat, lean and bone tissue accretion, and (3) accretion rate of chemical constituents of lean in growing Najdi lambs.

Materials and Methods

Animals and Feeding Regimes

A total of 48 Najdi male lambs, of an average body weight 26.6±0.3 kg and approximately 3.5 months old, were utilized for this study. Upon arrival, lambs were individually weighed, identified, vaccinated, injected against internal and external parasites and vitamin A-D-E injections were given. All lambs were fed *ad libitum* for two weeks on a commercial pellet; thereafter, feed restriction phase was started. The pellet was formulated as a total-mixed ration with a ratio of 75% concentrate: 25% alfalfa hay. The chemical composition (DM basis) was 14.53% CP and 2.78 Mcal ME kg^{-1} DM.

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At the beginning of the feed restriction phase, six lambs were slaughtered to establish the initial weights of carcass and non-carcass components, carcass tissues and chemical constituents of the dissectible carcass lean. Thereafter, the remaining 42 lambs were randomly assigned to one of three equal groups. Each group contained five replicates (pens) with two/three lambs per pen. The first feeding group was used as a control (0% restriction) and fed *ad libitum* throughout the 84-days experimental period. The second and third feeding groups were subjected to 35 days of feed restriction phase at either 25% or 40% feed restriction level of *ad libitum* intake. Feeding levels of restricted groups were calculated by determining the average DMI of the lambs with *ad libitum* access to feed the previous week. At the end of feed restriction phase, seven lambs were randomly chosen from each group and slaughtered. The remaining 7 lambs of the three groups were fed *ad libitum* and slaughtered after 49-days of feeding (realimentation phase).

Slaughtering Procedures and Carcass Traits

Lambs were slaughtered after 18 h without feed by severing the jugular vein and the carotid arteries. During evisceration, the gastrointestinal tract tied off at the oesophagus and rectum. The gastrointestinal tract was subsequently removed, weighed full and empty to calculate empty body weight by subtracting digesta weight from the fasted live weight; the gastrointestinal tract was then separated into stomach compartments (rumen, reticulum, omasum and abomasum) and intestines (small and large intestines). 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. Carcasses were then chilled at 4ºC for 24 h and the cold carcass weights were recorded; thereafter, the carcasses were carefully split longitudinally into two equal halves and the right sides were utilized for subsequent measurements.

The right side of each carcass was then physically separated into subcutaneous fat, intermuscular fat, tail fat, lean and bone. The lean tissue was ground through a 4-mm plate, mixed and reground again. During the second grinding, 10 subsamples were taken from each carcass and mixed thoroughly to obtain a 100-150 g sample, frozen and stored at -20ºC pending chemical analysis. Ground lean samples were analyzed for moisture, ash, chemical fat (ether extract) and protein according to AOAC (1995).

Statistical Analysis

Initial weights of empty body, carcass and non-carcass components, separable carcass tissues, and chemical constituents of separable lean were related to the initial fasted body weights by linear regression. Daily gain of each studied trait within each feeding group during the feed restriction phase was calculated as the difference between the initial and final weights determined for each lamb following the 35-days restriction period. As well, weights of the studied carcass traits within each feeding group at the end of the restriction phase were related to their fasted body weights by linear regression and considered as initial weights for the realimentation phase; daily gain of each trait within each feeding group during the realimentation phase was calculated as the difference between the initial and final weights determined for each lamb following the 49-days realimentation period. The collected data were analyzed by one-way ANOVA using GLM procedures (SAS, 2002). Duncan's multiple range was used to test the significant differences between means.

Results and Discussion

At the beginning of the study, the average weights of carcass and non-carcass components were: 25.92 kg for empty body, 13.62 kg for cold carcass, 720 g for liver, 1.14 kg for empty stomach compartments, 1.01 kg for empty intestines, and 971 g for internal fats. Average daily gain of empty body, carcass and non-carcass components and its weight proportions (%) relative to empty weight at the end of feeding restriction and realimentation phases are shown in Table 1. During restriction phase, significant ($P<0.05$) decreases in the daily weight gain of empty body, cold carcass, liver, empty stomach compartments, empty intestines, and internal fat were recorded when the two feed restriction levels (25% and 40%) were imposed compared to the *ad libitum* group. The lowest daily weight gain for all above mentioned characters was recorded for the 40% feed restriction group. The reduction in the weight gain of the carcass and non-carcass components during feed restriction is a function of plane of nutrition (Kamalzadeh *et al*., 1998; Njidda and Isidahomen, 2011), thereby resulting in inadequate intake of nutrients required to sustain normal growth and development. Ferrell *et al*. (1986), and Kabbali *et al*. (1992b) found decreases in the weight gains of the liver, stomach and small intestine of sheep. Empty stomach compartments, liver and empty intestines were the most organs adversely affected by feed restriction; the respective daily gain decreased by 198, 120 and 83% in the 25% restriction-fed lamb, and by 221, 180 and 133% in the 40% restriction-fed lambs, compared to the *ad libitum* fed lambs. These results are in accordance with the findings of absolute weight gain reported by Kamalzadeh *et al*. (1998) and Dashtizadeh *et al*. (2008) who indicated that liver and gastrointestinal tract are the most affected organs by feed restriction. This indicates that the internal organs especially the highly metabolically active organs such as liver and intestines were affected to a higher extent than other body components (Al-Selbood, 2009). Reduction in the liver and gastrointestinal tract weight was related to a decrease in oxygen consumption by these organs and hepatic blood flow (Tovar-Luna *et al*., 2007). As a proportion of empty body weight, feed restricted lambs had a lighter ($P<0.05$)

liver, empty stomach compartments and internal fat compared to the *ad libitum* fed lambs; however, the differences between 25% and 40% restriction levels were not significant (P>0.05). Palsson and Verges (1952) found that the late developing tissues such as internal fat and stomach compartments were proportionately more affected by the low plane of nutrition than the earlier developing ones, which can only be explained in the same way as Kamalzadeh *et al*. (1998) did in sheep, that the earlier maturing tissues have a priority claim for the limited nutrients available in the blood stream when the growing animal is insufficiently fed to provide all tissues with an adequate nutritive supply for normal growth. Another explanation was reported by Hambly and Speakman (2005) who found that with less food entering the digestive system, the weight of the stomach was significantly lower during the 20% dietary restriction in relation to body mass without altering the ability to process the diet. Regarding the relative size of liver, previous studies, however have reported decreases in its proportion by feeding restriction (Dashtizadeh *et al*., 2008).

Internal fat continued in realimentation phase to grow slower (P<0.05) than the *ad libitum* group. In contrast, the daily weight gains of empty body, liver and empty intestines of the feed restriction groups were significantly (P<0.05) higher than the values of the *ad libitum* group during the realimentation phase; the liver and empty intestines in the 40% restriction group significantly grew faster (P<0.05) than those of the 25% restriction group. Generally, liver and empty intestines were the fastest non-carcass components to compensate by realimentation. Similar trends in the growth rate of liver and intestine tissues in sheep (Kabbali *et al*., 1992a) and steers (Carstens *et al*., 1991) have been reported in realimented animals. The higher growth rates for these tissues exhibited by compensatory-grown lambs reflect hypertrophy of visceral organ tissues upon realimentation after a period of growth restriction (Johnson *et al*., 1985). Turgeon *et al*. (1986) and Kabbali *et al*. (1992b) showed that during the refeeding period, energy is diverted mainly to replenish protein and glycogen reserves; thus, the empty gut and visceral organs were completely compensated, whereas the internal fat depots were the most dramatically affected by weight loss followed by realimentation. There were no significant differences (P>0.05) between the three studied groups in the percentages of the carcass and non-carcass components relative to the empty body weight except the internal fat, which was significantly (P<0.05) higher in *ad libitum* group. It seems that, upon realimentation the visceral organs were rapidly compensated and their proportions became comparable to that of *ad libitum* group, whereas the internal fat proportion did not recover completely. This observation is in line with the results of Kabbali *et al*. (1992b), who suggested a different partitioning of nutrient intake among non-carcass components of refed lambs, as indicated by an increase in the proportions of visceral organs at the expense of internal fat.

The effects of feed restriction and realimentation on the average deposition rate of carcass tissues and its weight distribution relative to cold carcass weight are presented in Table 2. During feed restriction, the average deposition rates of subcutaneous and intermuscular fats in the restriction-fed groups declined significantly (P<0.05) by an average of 52 and 81.7%, respectively than the *ad libitum* group; the differences between the 25 and 40% groups were not detectable (P>0.05). The 40% level of restriction had pronounced negative effects (P<0.05) on the deposition rate of tail fat and bone; the 40% feed restriction decreased the average deposition rates of tail fat and bone by 162 and 45%, respectively than the control lambs. The average daily lean gain decreased (P<0.05) as the level of restriction increased; the daily deposition rate of the dissectible lean declined by 31 and 75% in the 25 and 40% groups, respectively than in the *ad libitum* group. These results confirm the general conclusions that, the effect of feed restriction on carcass composition results in significant decreases in the deposition rates of carcass bone, lean and fats (Murphy *et al*., 1994), and carcass fat depots mobilized faster than bone and lean tissues when the feed intake was not adequate (Dashtizadeh *et al*., 2008). When feed intake is restricted, there is a coordinated decrease in tissue turnover, but some tissues react more than others (Palsson and Verges, 1952). However, the largest decreases in the deposition rates at the 25% and 40% feed restriction were found for the intermuscular and tail fat depots, respectively. These results probably indicated that, the mobilization of tail fat as a source of energy at the 25% feed restriction was delayed to a higher level of restriction leaving the intermuscular and subcutaneous fats as immediate sources of energy utilization at the 25% restriction level. These results have agreed with an earlier study by Abouheif *et al*. (1993) who reported that the adaptation capacity of the fat-tailed Najdi sheep to feed shortage, and the importance of the tail fat as a source of energy generation at higher levels of malnutrition. This could be especially important for sheep grazing in arid and semi-arid areas, where dry periods can last for months and feed availability is therefore limited. The proportions of carcass lean, bone and fats as percentages of the cold carcass weight indicated that feed restriction had no effects (P>0.05) on the weight distribution of all studied carcass components when it compared with those of the *ad libitum* group at the end of restriction phase.

During the realimentation, lambs that moved from 40% feed restriction to *ad libitum* feeding had significantly (P<0.05) lower average daily deposition rates for all carcass tissues than control lambs. On the other hand, lambs that had been on 25% feed restriction level and moved thereafter to *ad libitum* feeding had variable compensation responses; the deposition rates for subcutaneous and intermuscular fats and bone in the 25% restriction group were fast and equaled (P>0.05) those rates in the control group, while the rates for tail fat and lean were slower (P<0.05) than those rates in the control group. However, it seems that the accretive rates for

Table 1: Average daily gain of carcass and non-carcass components and its weight proportions (%) relative to the empty weight at the end of feeding restriction and realimentation phases in Najdi lambs

Character	Restriction phase[1]				Realimentation phase[2]			
	0%	25%	40%	SEM	0%	25%	40%	SEM
Empty body weight								
$g.d^{-1}$	255[a]	146[b]	85[c]	8.42	304[b]	321[a]	315[a]	6.34
Cold carcass								
$g.d^{-1}$	107[a]	72[b]	35[c]	4.13	198[a]	182[b]	188[ab]	4.19
%	49.9	52.0	51.4	1.21	54.4	53.6	54.3	1.19
Liver								
$g.d^{-1}$	5.0[a]	-1.0[b]	-4.0[c]	0.36	2.1[c]	4.0[b]	6.2[a]	0.33
%	2.6[a]	2.2[b]	2.0[b]	0.07	2.0	1.9	2.0	0.07
Empty stomach compartments								
$g.d^{-1}$	4.2[a]	-4.1[b]	-5.1[b]	0.54	8.2	8.3	7.6	0.24
%	3.7[a]	3.2[b]	3.3[b]	0.11	3.4	3.0	3.0	0.09
Empty intestines								
$g.d^{-1}$	6.0[a]	1.0[b]	-2.0[c]	1.11	2.2[c]	3.0[b]	5.2[a]	0.32
%	3.5	3.4	3.3	0.07	2.7	2.5	2.7	0.09
Internal fats								
$g.d^{-1}$	60.0[a]	33.5[b]	32.3[b]	3.71	48.8[a]	36.5[b]	33.8[c]	1.94
%	8.8[a]	6.9[b]	7.3[b]	1.05	11.0[a]	8.4[b]	8.5[b]	1.22

Table 2: Average deposition rate of carcass tissues and its weight proportions (%) relative to the cold carcass weight at the end of feeding restriction and realimentation phases in Najdi lambs

Character	Restriction phase[1]				Realimentation phase[2]			
	0%	25%	40%	SEM	0%	25%	40%	SEM
Subcutaneous fat								
$g.d^{-1}$	21.71[a]	10.86[b]	10.00[b]	0.97	38.16[a]	43.88[a]	24.69[b]	2.24
%	14.14	12.79	13.78	0.82	15.39	13.81	14.07	0.72
Intermuscular fat								
$g.d^{-1}$	8.57[a]	1.14[b]	2.00[b]	1.45	25.51	21.22	24.60	1.07
%	7.10	6.03	6.74	0.43	8.85	8.88	9.57	0.51
Tail fat								
$g.d^{-1}$	2.29[a]	2.01[a]	-1.43[b]	0.55	43.47[a]	35.51[b]	22.24[c]	2.67
%	8.71	9.41	9.32	0.46	12.96[a]	11.40[ab]	10.70[b]	0.54
Lean								
$g.d^{-1}$	55.43[a]	38.29[b]	14.00[c]	1.33	84.49[a]	66.73[b]	70.12[b]	3.11
%	49.26	49.24	47.85	1.46	45.24	47.83	46.88	1.66
Bone								
$g.d^{-1}$	18.86[a]	19.71[a]	10.29[b]	1.89	26.94[a]	25.90[a]	21.0[b]	1.85
%	20.79	22.53	22.31	0.73	17.57	18.09	18.78	0.68

Table 3: Daily accretion rate of chemical constituents of lean and its proportions (%) relative to the dissectible carcass lean weight at the end of feeding restriction and realimentation phases in Najdi lambs

Character	Restriction phase[1]				Realimentation phase[2]			
	0%	25%	40%	SEM	0%	25%	40%	SEM
Chemical fat								
$g.d^{-1}$	2.96[a]	-1.50[b]	-2.86[c]	0.64	6.93[c]	8.06[b]	12.42[a]	1.23
%	8.76[a]	6.54[b]	5.71[b]	0.47	8.29	8.87	9.89	0.57
Protein								
$g.d^{-1}$	10.10[a]	8.64[b]	4.48[c]	1.82	16.88[a]	12.36[b]	9.82[b]	1.80
%	18.05[b]	19.11[ab]	20.15[a]	0.23	19.05	18.83	18.64	0.27
Moisture								
$g.d^{-1}$	41.44[a]	30.74[b]	12.54[c]	3.25	58.62[a]	44.56[b]	45.23[b]	3.52
%	72.10	73.13	72.95	0.39	71.42	71.02	71.14	0.26
Ash								
$g.d^{-1}$	0.59[a]	0.62[a]	0.28[b]	0.13	1.30	1.23	1.53	0.11
%	1.09	1.21	1.19	0.05	1.24	1.29	1.32	0.06

[1]Levels of feeding restriction during the 35 days of restriction phase

[2]Levels of previous feeding restriction; realimentation phase lasted for 49 days of *ad libitum* feeding

[a,b,c]Means in the same row within each feeding phase bearing different superscripts differ ($P<0.05$)

the various carcass tissues may respond differently to realimentation when nutritional restriction is removed. Extensive studies in sheep have shown that this variability in the rate of catch-up growth may be influenced by genetic factors, the age at which restriction is imposed, the severity and duration of restriction, the quality of realimentation diet and duration of refeeding (Al-Selbood, 2009). As in the restriction phase, non-significant differences (P>0.05) among the three groups in the weight distribution of all carcass tissues were found in the realimentation phase; only tail fat weight percentage in the control group had a significantly (P<0.05) higher proportion compared to the 40% feed restriction group (12.96 vs. 10.70%).

Feeding restriction levels significantly (P<0.05) decreased the daily accretion rate of chemical fat, protein, moisture, and ash contents of the dissectible carcass lean in growing lambs (Table 3). The highest adverse effects on daily accretion rate due to feed restriction were detected for chemical fat followed by moisture contents. Similar results were reported by Kabbali *et al.* (1992b) and Dashtizadeh *et al.* (2008) who found that the rate of fat loss increased as the level of feed restriction increased. The reduction in the accretive rate of fat and protein constituents of the dissectible carcass lean are consistent with the results reported by the other authors (Marais *et al*., 1991; Al-Selbood, 2009) and support the notion of a priority of accretion of protein over fat when nutrient supply is limited (Greenwood *et al*., 1998). Kabbali *et al.* (1992b) showed that fat was the tissue most affected during feed restriction and that protein was affected little. Initially proteins are mobilized which lasts for some days until a new equilibrium is reached, paralleled by a decrease in basal metabolism; thereafter, fat is mobilized dependent on the severity of feed restriction, whereas the protein pool is conserved as much as possible (Dashtizadeh *et al*., 2008). There were a decline (P<0.05) in chemical fat and an increase (P<0.05) in protein proportions of the dissectible lean at the end of the restriction phase. Similarly, Murphy *et al.* (1994) and Dashtizadeh *et al.* (2008) stated that feed restriction was associated with an increase in protein and a decrease in fat proportions of the carcass soft tissue. On the other hand, Drouillard *et al.* (1991), and Sahlu *et al.* (1999) reported that the level of feed intake during the restriction period did not affect the proportions of the chemical constituents of the soft tissue. The discrepancy in the results between experiments may be explained by the degree of animal maturity, species and the period or severity of feed restriction.

During the realimentation phase, daily accretion rates of moisture and protein continued to be significantly (P<0.05) slower in the lambs that had been fed the 25% and 40% feed restrictions than the *ad libitum* fed lambs. This result confirms data reported by Marais *et al.* (1991) who found that the rate of protein growth in the lambs that were feed restricted could not equal or better the rate of the *ad libitum* group during the compensatory growth. The accretion rate of chemical fat increased (P<0.05) during the realimentation phase to such an extent that the rate of the previously restricted lambs bettered that of the *ad libitum* lambs; the fastest rate was recorded for the 40% group followed by the 25% and *ad libitum* groups. The progressive increases in chemical fat deposition rate during the realimentation probably caused by an improved efficiency of utilization of metabolizable energy for fat deposition (Greeff *et al*., 1986; Marais *et al*., 1991). The weight proportions of the four chemical constituents did not differ significantly (P>0.05) among the three feeding groups at the end of realimentation. Our findings are in agreement with those of Thornton *et al.* (1979) and Drouillard *et al.* (1991) who found no differences in body lean composition between refed and normally grown lambs. These results, however, disagree with the conclusions of Greeff *et al.* (1986), and Marais *et al.* (1991) that the relationship of lean composition is upset by feed restriction followed by refeeding, and that refed lambs had more protein than controls. This discrepancy may be related to the degree of maturity of the lambs; less mature lambs would be expected to have a longer protein growth phase than more mature lambs (Palsson and Verges, 1952). There is a general consensus that after this first period is over, the chemical constituents of lean from the realimented lambs become similar in proportions to that of continuous fed lambs (Kabbali *et al*., 1992a; Sahlu *et al*., 1999). Thus, the extent to which lean composition of realimented lambs will be different from that of *ad libitum* fed lambs depends on how far the realimented lambs have gone into this second phase of growth before they are slaughtered.

Conclusion

Feed restriction at either 25 or 40% reduced the growth rate of carcass, non-carcass and chemical components of young Najdi lambs. This negative effect was compensated during the 7-week realimentation phase for the 25% feed restriction level indicating that, this routine can be adopted as a nutritional management practice for young Najdi lambs, followed by compensatory gain.

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