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Effects of Restricted Feeding and Re-Feeding in Growing Lambs: Intake, Growth and Body Organs Development

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Abstract: About 48 Lori-Bakhtiari lambs were used to measure the effects of restricted feeding and re-feeding on intake, body weight and development of body organs. The feeding management was divided to Feed Restriction Period (FRP) and Re-alimentation Period (RAP). During FRP, the 18 Control (C) animals were fed a low-quality roughage, *ad libitum* and 40 g kg $BW^{-0.75}$ $day^{-1}$of concentrate and the 30 animals were only fed low-quality roughage as the Restricted (R) group. At the end of FRP and RAP, six lambs of each group were slaughtered. In the RAP, the 24 remaining lambs from restricted treatment were divided into two groups of R1 and R2 and received low-quality roughage plus 40 and 48 g kg $BW^{-0.75}$ day^{-1}, of concentrate, respectively. During FRP, Dry Matter (DMI), Metabolizable Energy (MEI) and Crud Protein Intake (CPI), Daily Gain (ADG), Final Body Weight (FBW), pelt, liver and kidneys of C group were higher ($p<0.05$) than R group. In the RAP all groups had similar FBW but feed conversion ratio, DMI, MEI, CPI and weights of all body organs of C group were higher ($p<0.05$), however ADG was lower ($p<0.05$) than R1 and R2 groups. In general, restricted feeding following re-feeding lambs caused more efficiency of performance which was associated with lower maintenance requirements.

Key words: Feed restriction, re-feeding, performance, body organs, compensatory growth, conversion ratio

INTRODUCTION

Underfeeding and following re-feeding show higher growth rate in sheep and its complicated mechanisms in this regard has been the topic of a number of studies (Hogg, 1977). There are high correlations between the level of feeding and the weight of body organs mainly the metabolic organs such as liver, heart and kidneys (Drouillard *et al*., 1991; Atti *et al*., 2000; Mahouachi and Atti, 2005). Activities of visceral organs are related to physiological changes such as growth, so weight changes of visceral organs occur when food intake alters and it consequently changes the maintenance requirements (Aziz *et al*., 1994). Studies showed that animal on dietary restriction had lower maintenance energy requirement by relatively smaller liver and kidneys (Kamalzadeh *et al*., 1998) resulting compensatory growth during re-feeding period (Ryan, 1990; Mahouachi and Atti, 2005). Report by Fattet *et al*. (1984) showed that nutrient deficiencies may cause mobilization of body tissue mass. Animals also may respond differently to re-feeding when restricted feeding is over. Comprehensive studies in sheep and cattle showed that variability in the rate of catch-up growth may be influenced by breed, age at the start of restriction, the period and severity of restriction, the duration of re-feeding and quality of re-alimentation diet (Benschop, 2000). The periodic feed deficiency in harsh lands results in weight loss of grazing animals and more specially in their offspring (Ryan, 1990). The most common native breed of sheep population in Chaharmahal and Bakhtiari province, a semi-arid region in the Southwestern Iran are predominantly fat-tailed Lori-Bakhtiari breed which is mainly used for meat production with about 1.7 million head and account for about 3.3% of the total sheep population. The feed from rangelands in this region is limited and is of low quality and periodic drought is also a constraint (Shadnoush *et al*., 2004).

Studies on the compensatory growth phenomenon and information about this trend in sheep at semi-arid conditions are rare. The objective of this study was to describe the effects of restricted feeding and re-feeding on intake, growth performance and development of body organs in Lori-Bakhtiari lambs.

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MATERIALS AND METHODS

About 48 male Lori-Bakhtiari lambs aged 4-5 months, weighing 26±0.8 kg were randomly selected from a flock in Chaharmahal and Bakhtiari province. The experiment was conducted in two periods of Feed Restriction Period (FRP), following with a Re-Alimentation Period (RAP). During the experiment periods, lambs were housed in individual pens with 60 days duration for each period. In the FRP, animals were randomly assigned to two groups of 18 and 30 as Control (C) and Restricted (R), respectively. At the end of restriction period, six lambs from each group were slaughtered. In the RAP within R group, the remaining 24 lambs were divided in two sub-groups of 12, referred as (R1) and (R2) and remaining 12 lambs were used as Control (C). At the end of re-alimentation period, six lambs from each group were slaughtered.

During the FRP, the C animals received control diet consisting low-quality roughage (mixed of barley straw and alfalfa hay on an *ad libitum* basis) and 40 g kg $BW^{-0.75}$ day^{-1} concentrate supplement. The R animals were allowed to consume only the low-quality roughage, *ad libitum*, plus a mineral supplement. During the RAP, R1 and R2 animals received low-quality roughage, *ad libitum* plus 40 and 48 g kg $BW^{-0.75}$ day^{-1} concentrate based on normal growth requirement (ARC, 1980) and 20% higher, respectively. The C animals were received the same diet similar to previous period. In both periods of experiment, forage and concentrate fed twice a day at 08:00 and 16:00. Water and salt licking blocks were freely available. Forage residues were collected daily prior to the morning feeding. Animals were weighed weekly and the amount of feed offered was adjusted every weeks based on metabolic body weight.

Low-quality roughage consisted of chopped and mixed alfalfa and barley straw (30:70) with particle size of 2-3 cm to reduce selection by animals, containing 85 g CP and 4.9 MJ ME kg^{-1} DM.

To ensure an *ad libitum* feeding regimen, the animals were fed at the level of 70 g kg $BW^{-0.75}$ day^{-1} of forage which was sufficient for maintenance requirement (ARC, 1980). Refusals was approximately 25% of the amount of offered. The concentrate supplement (180 g CP and 12.1 MJ ME kg^{-1} DM) was offered in pelleted form. The concentrate consisted of corn (220 g kg^{-1}), wheat (150 g kg^{-1}), barley (80 g kg^{-1}), soybean meal (150 g kg^{-1}), wheat bran (320 g kg^{-1}), molasses (50 g kg^{-1}), calcium carbonate (10 g kg^{-1}), mineral, vitamin mixture and NaCl (20 g kg^{-1}). The chemical composition and *in vitro* (Tilley and Terry, 1963) digestibility (OM and OMD) of forages and concentrates are shown in Table 1.

Table 1: Chemical composition and *in-vitro* digestibility of roughage and concentrate

			Composition (g kg^{-1} DM)		
Diet	DM (g kg^{-1})	ME (MJ kg^{-1} DM)	OM	CP	OMD
Mixed roughage	960	4.9	861	71.6	338
Concentrate	919	12.1	838	180.6	825

Dry Matter (DM), Metabolizable Energy (ME), Organic Matter (OM), Crude Protein (CP), *in vitro* Organic Matter Digestibility (OMD)

Table 2: Least square means and (±SE) of fattening performance of the Control (C) and Restricted (R) groups during restriction period

Items	C	R
No	18	30
Initial BW (kg)	25.6±0.9	26.2±0.8
Final BW (kg)	$33.9±0.8^{a}$	$26.5±0.7^{b}$
DMI (g day^{-1})	$1275±18^{a}$	$648±16^{b}$
DMI (g $kg^{-0.75}$ day^{-1})	$102±1.5^{a}$	$55±1.2^{b}$
MEI (MJ day^{-1})	$8.8±0.08^{a}$	$2.6±0.06^{b}$
CPI (g day^{-1})	$137±1.4^{a}$	$46±1.2^{b}$
CPI (g $kg^{-0.75}$ day^{-1})	$11±0.2^{a}$	$4±0.1^{b}$
ADG (g day^{-1})	$140±6^{a}$	$4.5±6.2^{b}$
ADG (g $kg^{-0.75}$ day^{-1})	$45±2.5^{a}$	$3.2±2.1^{b}$
FCR (DM kg^{-1}BW)	8.8±0.3	--

C = Control animals, R = Restricted animals, DMI = Dry Matter Intake, MEI = Metabolizable Energy Intake, CPI = Crud Protein Intake, ADG = Average Daily Gain, FCR = Feed Conversion Ratio; *Means with different superscripts differ significantly ($p<0.05$) between groups

Table 3: Least square means and (±SE) of fattening performance of the Control (C) and Restricted (R) groups during re-alimentation period

Items	C	R1	R2	SE
No	12.0	12.0	12.0	-
Initial BW (kg)	34.1^{a*}	25.6^{b}	25.8^{b}	0.9
Final BW (kg)	42.7	40.0	41.3	1.3
DMI (g day^{-1})	1360.0^{a}	1215.0^{b}	1274.0^{b}	17.0
DMI (g $kg^{-0.75}$ day^{-1})	88.0	90.0	92.0	1.4
MEI (MJ day^{-1})	13.4^{a}	11.1^{b}	11.9^{c}	0.1
CPI (g day^{-1})	205.0^{a}	170.0^{b}	183.0^{c}	1.5
CPI (g $kg^{-0.75}$ day^{-1})	12.9	12.5	13.4	0.3
ADG (g day^{-1})	148.0^{a}	240.0^{b}	256.0^{b}	10.0
ADG (g $kg^{-0.75}$ day^{-1})	45.0^{a}	73.0^{b}	78.0^{b}	4.5
FCR (DM kg^{-1}BW)	9.2^{a}	5.2^{b}	5.5^{b}	0.2

C = Control animals, R1 and R2 = Restricted and Re-alimented animals, DMI = Dry Matter Intake, MEI = Metabolizable Energy Intake, CPI = Crud Protein Intake, ADG = Average Daily Gain, FCR = Feed Conversion Ratio; *Means with different superscripts differ significantly ($p<0.05$) between groups

Animals were weighed and slaughtered following 12 h fasting period. All the abdominal and thoracic organs were removed after skinning. Full gut (digestive tract) was removed and after removing the surrounding fat weighted. Full and empty complex stomach and intestines were separated and weighed. Liver, lungs, heart, kidneys, pelt, head and feet were weighed separately. The difference in weight of full and empty gut used to determine the gut content weight.

Empty Body Weight (EBW) was calculated as the difference between slaughter BW and gut content weight. Warm carcasses were weighed immediately after dressing and removal of the offal parts.

The data were analyzed by the GLM procedure of SAS (2001) and comparisons between groups' means were made using LSM procedure. Because feedlot performance factors (Table 2 and 3) were measured over the time, a repeated measures approach using ANOVA with mixed linear model of SAS (2001) was used. The model used was:

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where:

- Y_{ij} = The individual observation
- μ = The overall mean
- A_i = The effect of treatment
- e_{ij} = The remainder effect

RESULTS AND DISCUSSION

Growth performance and feed intake: Results for growth traits during Feed Restriction Period (FRP) are shown in Table 2. Final Body Weight (FBW) of the Restricted group (R) was almost constant but FBW and Average Daily Gain (ADG) g day^{-1} and g kg$^{-0.75}$ day^{-1} of Control group (C) increased significantly ($p<0.05$). Lambs in C group consumed all offered concentrate therefore, difference in Dry Matter Intake (DMI) g day^{-1} and g kg$^{-0.75}$ day^{-1} between the two groups were significantly different ($p<0.01$). Means of Metabolizable Energy Intake (MEI) MJ day^{-1} and Crud Protein Intake (CPI) g day^{-1} and g kg$^{-0.75}$ day^{-1} in C group was significantly higher ($p<0.01$) than R group. Data of Feed Conversion Ratio (FCR) was not analyzed due to restricted group feeding.

In Re-alimentation Period (RAP) Table 3, there were significant differences in initial BW mean of lambs in C and R1, R2 groups ($p<0.05$) but FBW was not significant among these groups. DMI (g day^{-1}), MEI (MJ day^{-1}) and (CPI) g day^{-1} were significantly ($p<0.01$) greater for C than R1 and R2 lambs but DMI (g kg$^{-0.75}$ day^{-1}) was not significant among these groups.

ADG (g day^{-1} and g kg$^{-0.75}$ day^{-1} of R1 and R2 group were higher than C group and the difference was significant between C and R1, R2 groups ($p<0.05$). FCR was improved for previously R animals and the difference was significant ($p<0.05$) between C and R1, R2 groups.

Body composition: During 2 months of FRP, slaughter BW, pelt, liver and kidneys of R animals reduced ($p<0.05$) relative to C animals (Table 4). Similarly, feed restriction resulted in a decreased ($p<0.05$) in Empty Body Weight (EBW) and warm carcass weight. Table 5 shows the percent means of EBW and body organs as proportion of live body weight throughout the FRP. Increasing percent of EBW in the C group caused higher proportion of pelt and liver, whereas proportion of intestines, head, feet, heart and lung decreased ($p<0.05$). The mean of warm carcass weight proportional to live body weight in C and R group was significantly ($p<0.05$) different.

Table 4: Least square means and (±SE) of body weight and body organs (kg) of the Control (C) and Restricted (R) groups, during restriction period

Items	C	R	SE
No	6.00	6.00	-
Slaughter body weight	30.20[a]	25.40[b]	1.90
Empty body weight	23.50[a]	18.80[b]	0.30
Warm carcass	13.50[a]	9.50[b]	0.70
Stomach complex	1.00	0.90	0.10
Intestines	0.60	0.50	0.10
Head	1.80	1.80	0.10
Feet	0.90	0.90	0.10
Pelt	2.80[a]	2.00[b]	0.20
Heart	0.12	0.12	0.00
Lung	0.32	0.37	0.00
Liver	0.45[a]	0.40[b]	0.02
kidneys	0.09[a]	0.07[b]	0.00

C = Control animals, R = Restricted animals, SE = Standard Error; [a]Means with different superscripts differ significantly ($p<0.05$) between groups

Table 5: Least square means and (±SE) of percent of empty body weight and body organs as proportion of live body weight of the Control (C) and Restricted (R) groups during restriction period

Items	C	R	SE
No	6.0	6.0	-
Empty body weight	77.2	74.6	2.2
Warm carcass	57.2[a]	50.6[b]	1.1
Cold carcass	56.5[a]	48.9[b]	1.2
Stomach complex	4.2[a]	4.7[b]	1.0
Intestines	2.6[a]	2.9[b]	1.0
Head	8.2[a]	9.7[b]	0.3
Feet	4.0[a]	5.1[b]	0.2
Pelt	12.1[a]	10.9[b]	0.4
Heart	5.1[a]	6.0[b]	0.0
Lung	1.3[a]	1.9[b]	0.2
Liver	1.9[a]	1.7[b]	0.1
Kidneys	4.2	4.1	0.0

C = Control animals, R = Restricted animals, SE = Standard Error. [a]Means with different superscripts differ significantly ($p<0.05$) between groups

In RAP, slaughter BW and EBW of re-alimented groups (R1, R2) increased rapidly relative to FRP but weights of all body organs (stomach complex in testine, head, feet, pelt, liver and kidneys) were remain lower ($p<0.05$) than C group at the end of this period. Therefore, re-alimentation affected body weight prior to body organs (Table 6). The percent weight of body organs for each re-alimented groups (R1, R2) as a proportion of live body weight throughout RAP are showed in Table 7. The percents of EBW, warm and cold carcass were similar among different groups. Excluding liver, diets had no significant effect on percentage of all body organs.

Growth performance and feed intake: Usually, under restricted feeding, little or constant weight gain is excepted and maintenance energy requirements will decrease. Response of C animals with positive ADG and R animal with constant or little weight observed during FRP in this trail has also been showed in previous studies (Dashtizadeh *et al*., 2008; Ryan *et al*., 1993). The R lambs consumed two fold less DMI (g day^{-1} and g kg$^{-0.75}$ day^{-1}) and significantly lower MEI (MJ day^{-1}) and CPI (g day^{-1} and g kg$^{-0.75}$ day^{-1}) than C group during feed restriction

Table 6: Least square means and (±SE) of body weight and body organs (kg) of the Control (C) and Restricted (R) groups during re-alimentation period

Items	C	R1	R2	SE
No	6.00	6.00	6.00	-
Slaughter body weight	45.70[a*]	37.70[b]	39.00[b]	1.70
Empty body weight	39.70[a]	30.30[b]	32.30[b]	1.50
Warm carcass	22.40[a]	16.80[b]	17.10[b]	0.80
Stomach complex	1.50[a]	1.20[b]	1.20[b]	0.10
Intestines	0.80[a]	0.70[b]	0.60[b]	0.04
Head	2.70[a]	2.30[b]	2.20[b]	0.10
Feet	1.40[a]	1.20[b]	1.10[b]	0.10
Pelt	4.80[a]	4.00[b]	3.80[b]	0.20
Heart	0.17[a]	0.16[b]	0.16[b]	0.01
Lung	0.53[a]	0.46[b]	0.48[b]	0.02
Liver	0.65[a]	0.55[b]	0.58[b]	0.02
kidneys	0.12[a]	0.10[b]	0.11[a]	0.00

C = Control animals, R1 and R2 = Restricted and Re-alimented animals, SE = Standard Error. *Means with different superscripts differ significantly ($p<0.05$) between groups

Table 7: Least square means and (±SE) of percent of empty body weight and body organs as proportion of live body weight of the Control (C) and Restricted (R) groups during re-alimentation periods

Items	C	R1	R2	SE
No	6.0	6.0	6.0	-
Empty body weight	83.2	80.1	82.8	0.8
Warm carcass	56.5	55.5	54.2	1.2
Cold carcass	54.5	54.0	53.0	1.3
Stomach complex	3.6	3.8	3.6	1.1
Intestines	2.2	2.3	2.1	0.1
Head	6.8	7.0	7.1	0.2
Feet	3.6	3.8	3.4	0.2
Pelt	12.0	12.6	11.7	0.4
Heart	0.4	0.4	0.4	0.0
Lung	1.4	1.4	1.4	0.0
Liver	1.6[a]	1.8[b]	1.8[b]	0.0
Kidneys	0.3	0.3	0.3	0.0

C = Control animals, R1 and R2 = Restricted and Re-alimented animals, SE = Standard Error. *Means with different superscripts differ significantly ($p<0.05$) between groups

period. These may be related to higher body weight of C animals and reducing maintenance requirements of restricted animals at the level of basal metabolic rate. These results are in line with results of other researchers (Dashtizadeh *et al*., 2008; Ryan, 1990).

In RAP of this experiment, DMI (g $kg^{-0.75}$ day^{-1}) and CPI (g $kg^{-0.75}$ day^{-1}) of different group was similar but MEI (MJ day^{-1}) of R1 and R2 groups was lower than C group, whereas capability of compensatory growth and ADG (g day^{-1} and g $kg^{-0.75}$ day^{-1}) of them was higher (Table 3). Improvement in dry matter intake (g $kg^{-0.75}$ day^{-1}) which observed in R1 and R2 was similar to the results reported in other studies (Drouillard *et al*., 1991; Kamalzadeh *et al*., 1997) which may be related to differences in relative gastrointestinal capacity. Increase in ADG of R1 and R2 groups may be due to increased efficient energy and protein usage, reduced maintenance requirement and decreased heat production which could be the consequence of FRP. These findings are in agreement with other data reported for sheep (Kamalzadeh *et al*., 1997, 1998; Mahouachi and Atti, 2005).

Re-alimentation caused better FCR in previously restricted lambs (R1, R2) compared to controls. The results demonstrate that the amount of feeding affects its efficient utilization and requirement for maintaining live weight. These findings suggest that required feed is not a constant function of body weight but may be altered by nutritional plan. These observations are supported by several reports which have shown maintenance requirements decrease in response to low levels of feed intake (Kamalzadeh and Aouladrabiei, 2009).

Body composition: During feed restriction period of this experiment the weight of pelt, liver and kidneys compared to of stomach complex and intestines reduced considerably (Table 4), these are supported by other reports (Dashtizadeh *et al*., 2008; Kamalzadeh *et al*.,1998). In the study, weight and the percentage of liver proportion to live weight was decreased in lambs during feed restriction period which indicate, the reduction in size of liver during feed restriction period may be related to lower energy expenditure (Table 4 and 6).

In another report (Burrin *et al*., 1989) in lambs, the estimated cost of liver energy accounted for 41 and 22% of whole body energy expenditure with *ad libitum* and maintenance feeding level, respectively. Burrin (1987) found similar relationship between liver weight and BW in lambs fed at maintenance level. However, he reported that weight of unrestricted animals' liver increased in proportion to BW. This latter findings of Burrin (1987) is not supported by the present results. The findings of this experiment have shown liver is a more important organ in reduction of metabolic rate of the animal during feed shortage. This observation is supported with results of other studies (Atti *et al*., 2000; Drouillard *et al*., 1991; Kabbali *et al*., 1992; Ryan *et al*., 1993).

In this experiment, restricted diet increased the percentage weight of stomach complex and intestines as proportion of live weight (Table 6). Several studies have reported contradictory results in gut changes. Kamalzadeh *et al*. (1998) reported that the small intestine had the highest reduction compared to the other component of gut. However, some studies have shown that digestive tract had the same proportional weight in sheep despite the difference in diet level and growth rate (Mahouachi and Atti, 2005). Similar to this results, some studies reported an increase in percent weight of the stomach complex in sheep fed low energy diets relative to those fed higher energy diets (Rompala *et al*., 1985; Wilson and Osbourn ,1960). In the experiment, the weight of kidneys was smaller for restricted animals (Table 4) but the proportion of kidneys in live weight was not affected by the treatments (Table 6). The finding of this experiment is similar to the results reported by Dashtizadeh *et al.* (2008). The effect of feed restriction on kidneys size has been variable and it may be related to the intensity of restriction which is in line with other studies (Yambayamba *et al*., 1996). It may suggest that visceral organs are minimally affected by nutrient restriction and it may conclude that these organs are relatively early maturating components and had higher priority to the available nutrients during feed restriction period. This can be explained by the fact that the functional activities of these organs were essential for the survival of the animal under low nutrition plan.

At the end of the re-alimentation period, the heavier weights of stomach in testines, liver, head, feet and pelt in C group (Table 5) may be due to heavier weight of C animals at slaughter and their correlation with body organs. These finding are supported by several other reports (Burrin, 1987; Rompala *et al*., 1985). However, no differences between groups were observed for lungs, kidneys, head, feet and pelt as proportion of live weight (Table 7) which is in agreement with results of other authors (Dashtizadeh *et al*., 2008; Kamalzadeh *et al*., 1998; Mahouachi and Atti, 2005). The results show that the lowered maintenance requirement continues during re-alimentation period until protein is fully replenished in these organs. In general, early maturing parts (head, feet and visceral organs) have higher priority in usage of available nutrients in blood and are less affected than late maturing parts. These observation are supported by several reports including those of Hornick *et al.* (2000) and Kamalzadeh *et al.* (1998) which have shown that when growth rate is reduced, there is a coordinated decrease in tissue turnover but some tissues react more than others. In re-alimentation period, the reactions were mostly due to the restriction responses of animals and the most affected organs with the greatest retardation, responded faster than those of less affected. These findings are supported by other reports (Hornick *et al*., 2000; Kamalzadeh *et al*., 1998).

CONCLUSION

It is very likely that in sheep production systems in semi-arid region of Iran, the weight of lambs body and some their visceral organs decrease during feed shortage periods. restriction changes in the pattern of fattening performance and organs growth although, each acts differently. Delay in growth will be compensate with adequate feeding. Complimentary effects of compensatory growth and feeding strategies could increase feed efficiency and daily gain in feed restricted animals during re-feeding period. Further studies are needed to reveal different aspects of compensatory growth in this breed.

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