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Intake, Growth, Energy and Nitrogen Requirements and Amino Acid Nitrogen Availability in Growing Sheep

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Abstract: Fifty Sangsari male lambs (4 months old with mean live weight of about 25 kg) were used to measure intake, digestion, intake, growth, energy and nitrogen requirements and amino acid nitrogen availability in growing sheep. The animals were divided into two equal groups of 25 sheep: restricted (R) and a control (C). The experiment had duration of 15 and 75 days adaptation and treatment periods, respectively. The animals were individually placed in metabolism cages. All lambs were fed a ration based on pelleted concentrate mixture consisted of alfalfa, barley, cottonseed meal and barley straw. The animals of group C fed ad libitum, while animals of group R fed at maintenance level and maintained a relatively constant live weight. During the experiment, the average daily weight gain (DWG) of animals in R group was 0.22 g/day (0.03 g $kg^{-0.75}d^{-1}$). While that of animals in C group was 225.7 g/day (15.34 g $kg^{-0.75}$ d^{-1}). Nitrogen (N) was determined by both measured and regression methods. Animals of R group stayed at about zero N balance (0.03 g N $kg^{-0.75}$ d^{-1}). The N retention of animals in C group was 0.4 g N $kg^{-0.75}$ d^{-1}. Digestible organic matter intake (DOMI) and ME requirement for maintenance (MERM) were measured by both constant weight technique and regression method by regressing N balance on DOMI and ME intake on DWG. The measured DOMI during constant weight was 24.85 g DOMI $kg^{-0.75}$ d^{-1} and the calculated DOMI from regression equation was 24.64 g DOMI $kg^{-0.75}$ d^{-1}. The measured MERM was 400 kJ ME $kg^{-0.75}$ d^{-1} and the calculated MERM from regression analysis was 388 kJ ME $kg^{-0.75}$ d^{-1}. There was not significant differences between both measured and regression techniques. Digestibility values for OM, GE and CP and metabolizability were significantly ($P < 0.05$) higher in restricted feeding lambs compared with not restricted lambs.

Key words: Feed intake · Restricted feeding · Digestibility · Metabolizability · Nitrogen · Sheep

INTRODUCTION

In arid and semi-arid areas, sheep production depends mostly on natural vegetation of range and farmlands [1]. In these areas, feed shortage occurs in summer associated with thermal stress. The main feed resource is stubble grazing; animals have to walk to find feed, increasing their maintenance energy requirements [2]. Seasonal and annual fluctuations of rain cause a periodic restriction in feed quantity and quality and available feed cannot meet normal requirements of grazing animals [1].

Small ruminants (sheep and goats) form about 63% of livestock production in Iran and mainly managed under extensive system [3]. The number of sheep is about 52.3 million heads and account for about 50 percent of the livestock production. Apart from the Zel breed, which is found near the Caspian Sea, the indigenous sheep breeds are of a fat-tailed type. In general, sheep mainly bred for meat, milk and wool production, with the exception of the pelt breed of Karakul. Sangsari fat-tailed sheep is one of the most common native breeds and with about 2.2 million heads account for about 4.2 % of the total sheep population. The mature live weight of males and ewes are about 50 and 43 kg, respectively.

The energy required to maintain an animal at energy balance could be estimated from the relationship between energy intake and energy retention. Similarly, the digestible organic matter (DOM) required at zero weight gain and zero nitrogen retention could be also estimated

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from the relationship between intake of digestible organic matter (DOMI) and gain or nitrogen retention.

A value of 420-450 kJ ME $kg^{-0.75}$ d^{-1}at zero energy retention and a value of 26 g DOMI $kg^{-0.75}$ d^{-1} at zero weight gain are estimated for growing sheep [4]. However, after a period of weight stasis of 3 months, maintenance requirements of ME of weaned sheep were estimated to be decreased to about 340 kJ ME $kg^{-0.75}$ d^{-1} [5]. While, the data derived from studies of [6] and [7] on Iraqi Awassi sheep indicated a range of 350 to 490 kJ ME $kg^{-0.75}$ d^{-1}. Values of about 340 and 480 kJ ME $kg^{-0.75}$ d^{-1} also reported for maintenance requirements of ME intake for growing Swifter lamb at zero energy balance and growth, respectively [8]. Lower values of 300 kJ ME $kg^{-0.75}$ d^{-1} after a period of weight stasis of 4 to 6 months [9], 275 kJ ME $kg^{-0.75}$ d^{-1} [10] and 266 kJ ME $kg^{-0.75}$ d^{-1} [11] have also been reported for sheep. It has been shown that animals on restricted planes of nutrition have lower maintenance energy requirements [12]. During 144 days mild feed restriction, restricted lambs showed significantly ($P < 0.05$) higher digestibility value for crude protein (CP), while digestibility of dry matter (DM), gross energy (GE) and metabolizability were higher but not significant compared to not restricted lambs [13].

The data on energy and protein requirements of the most Iranian sheep breeds are not available; and the common feed allowance tables such as Agricultural Research Council (ARC) and National Research Council (NRC) are being used to formulate rations. The data used as the basis for the ARC and NRC common feed allowance tables are mostly upon the results of experiments in developed and temperate regions. These data may not fit well to sheep production systems in arid and semi-arid areas.

Therefore, the present experiment was designed to measure the intake, nitrogen balance and ME requirements, digestibility values, metabolizability and amino acid nitrogen absorption during restricted feeding (maintenance level) and growth in Iranian Sangsari sheep.

MATERIALS AND METHODS

Fifty male sheep (4 months old with live weight of about 25 kg) were used. The animals were selected from a flock of about 650 Sangsari sheep. The animals were divided into two equal groups of 25 sheep: restricted (R) and a control (C). During the experiment, the animals were placed alternatively in metabolism cages. Environmental temperature was kept constant at approximately 20°C. Relative humidity was maintained at approximately 50%.

Table 1: The Dry matter (DM), organic matter (OM), gross energy (GE), crude protein (CP) and ash contents of the diet

DM (g kg^{-1})	860
OM (g kg^{-1} DM)	895
GE (MJ kg^{-1} DM)	17.49
CP (g kg^{-1} DM)	137
Ash (g kg^{-1} DM)	105

A lighting regime was imposed of 12/12 day/night to avoid seasonal effect of day length. The animals offered a pelleted concentrate mixture, consisted of 34% alfalfa, 28.5% barley, 12% barley straw, 21% cottonseed meal, 5% sugar beet molasses and 0.5% minerals and vitamin mixture. The DM content of the diet was 860 g per kg and was formulated to provide 17.49 MJ of GE and about 137 g CP per kg DM. The composition of the diet is presented in Table 1. The choice of pelleted diet was to inhibit possible selectivity and waste and to accurately measure feed intake.

At the onset of the experiment, all lambs were treated against gut parasites. Animals were weighed weekly. The amount of feed offered was adjusted once every week, based on metabolic weight. During both adaptation and treatment periods, animals of group C were fed ad libitum to achieve their normal growth and animals of group R were fed at a level, adequate for maintaining constant live weight. Fresh water and salt licking blocks were freely available. Feeds were offered twice a day at 07.00 and 16.00. The quantity of feeds offered and refused by individual lambs was recorded daily. Refusals were removed and weighed before the morning feeding. The experiment consisted of a 15 day adaptation period followed by three consecutive 25 day balance trials. Each balance trial consisted of a preliminary period of 15 days and a collection period of 10 days. During each collection period, representative samples were taken of the feed offered. Daily feed intake for each lamb was recorded. The feed refusals, faeces and urine of each lamb were collected and weighed daily, pooled over each collection period and representative samples were taken and retained for subsequent chemical analyses. A small amount of 30% formalin was added to the faeces container for preservation. Before collection of urine, one litre of water acidified by 20 ml (6N) HCL was put in the collection bucket, to prevent evaporation of ammonia.

The collected samples of feed, refusals and faeces were analyzed for DM, ash, N and energy contents. Urine was analyzed for N and energy contents. Samples of feed offered and refused and faeces were dried at 50°C until they attained a constant weight before chemical analyses.

The DM content of the feed offered and refused and faeces was determined by drying representative sub-samples to constant weight at 103°C, while OM was calculated as weight loss of the same sub-samples during ashing at 550°C for 3h. The N content of the feeds, refusals, faeces and urine was determined according to the kjeldahl method [14].

GE contents were determined using an adiabatic bomb calorimeter. Digestible energy (DE) and ME intake per lamb were determined from the energy contents of feed eaten and the amount of energy losses through faeces, urine and methane. The amount of energy loss through methane was set at 7% of the GE intake [15, 8]. Digestibility of OM defined as the ratio of DOMI and OMI. The ratio of DE and GE and the ratio of digestible CP and the CP intake were used to define GE and CP digestibility, respectively.

The amount of amino acid nitrogen available for absorption in the small intestine (AAN) was estimated based on microbial AAN synthesized in the rumen (AAN_m) and dietary N (AAN_d) escaping rumen degradation, as follows [16]:

$$AAN_m = (A*B*C*D*DOMI)/E$$

In which A = 0.7: partial digestion in the rumen (rumen degraded organic matter (RDOM)) [17]. B = 0.15: efficiency of microbial protein synthesis [18, 16]. C = 0.75: true protein in microbial protein [17]. D = 0.85: true small intestinal digestibility of microbial protein [17]. E = 6.25: protein to N conversion factor. DOMI: digestible organic matter intake (g $kg^{-0.75}$ d^{-1}).

$$AAN_d = F * G * N$$

In which F = 0.4: proportion of N escaping rumen degradation. G = 0.75: true digestibility in the small intestine. N: nitrogen in feed offered (g $kg^{-0.75}$ d^{-1}).

Data were subjected to analysis of variance [19] and comparison between groups means were made using Student "t" test. Prediction equations were derived by regression linear models. The combined data of both C and R groups were used to estimate the requirements. Weekly data of live weight and the average data of other measurements in 3 balance trials were used.

RESULTS

Animals on restricted feeding level maintained at a relatively constant live weight and had a significantly (P < 0.001) lower whole diet organic matter intake (OMI), digestible organic matter intake (DOMI) and nitrogen intake (NI) (Table 2). During the experiment, the average DWG of animals in R group was 0.22 g/day (0.03 g $kg^{-0.75}d^{-1}$). While that of animals in C group was 225.7 g/day (15.34 g $kg^{-0.75}$ d^{-1}). The pattern of the live weight and daily weight gain (DWG) during the experiment is shown in Fig. 1 and 2. The average daily dry matter intake was 87.3 and 40.24 g DM $kg^{-0.75}$ d^{-1} for C and R groups, respectively (Table 2). The pattern of daily dry matter intakes of both C and R groups is presented in Fig. 3. The N retention of animals in C group was 0.4 g N $kg^{-0.75}$ d^{-1}. While that of animals in R group was 0.03 g N $kg^{-0.75}$ d^{-1}(about zero N balance). Faeces and urine nitrogen losses was lower (P < 0.05) in R animals. The measured DOMI during constant weight was 24.85 g DOMI $kg^{-0.75}$ d^{-1}, for R animals (Table 2).

Table 2: Means of live weight, intake of dry matter (DM), organic matter (OM), digestible organic matter (DOM) and nitrogen (N), N losses in faeces and urine, N balance, amino acid nitrogen availability for absorption (AAN) and daily weight gain of Sangsari sheep in control (C) and feed restricted (R) groups

	C	se	R	se
Live weight (kg)				
Initial	25.88 ^{a}	0.36	25.93 ^{a}	0.19
Final	46.19 ^{a}	0.13	25.95 ^{b}	0.15
Intake (g $kg^{-0.75}$ d^{-1})				
DM	87.30 ^{a}	1.79	40.24 ^{b}	0.30
OM	78.13 ^{a}	1.59	36.01 ^{b}	0.27
DOM	49.29 ^{a}	0.30	24.85 ^{b}	0.19
N	1.91 ^{a}	0.04	0.88 ^{b}	0.01
N losses (g $kg^{-0.75}$ d^{-1})				
Faeces	0.72 ^{a}	0.02	0.30 ^{b}	0.01
Urine	0.79 ^{a}	0.04	0.56 ^{b}	0.02
N balance *(g $kg^{-0.75}$ d^{-1})*	0.40 ^{a}	0.01	0.03 ^{b}	0.01
AAN (mg $kg^{-0.75}$ d^{-1})				
Microbial	528 ^{a}	3.27	266 ^{b}	2.05
Feed	483 ^{a}	8.53	263 ^{b}	2.66
Total	1011 ^{a}	9.11	529 ^{b}	4.29
Gain *(g /day)*	225.7 ^{a}	3.49	0.22 ^{b}	0.83
Gain *(g $kg^{-0.75}$ d^{-1})*	15.34 ^{a}	0.3	0.03 ^{b}	0.07

^{ab} values within line with different superscripts differ significantly (P<0.001).

The regression equation of N balance on DOMI estimated a zero N balance at 22.97 g DOMI $kg^{-0.75}$ d^{-1} for R animals (Fig. 4). The following equation was found:

$$Y = -0.35\ (0.03) + 0.02\ (0.01) * X, \ (n = 50 \text{ and } R^2 = 0.91)$$

in which: Y = N balance (g $kg^{-0.75}$ d^{-1})
X = DOMI (g $kg^{-0.75}$ d^{-1})

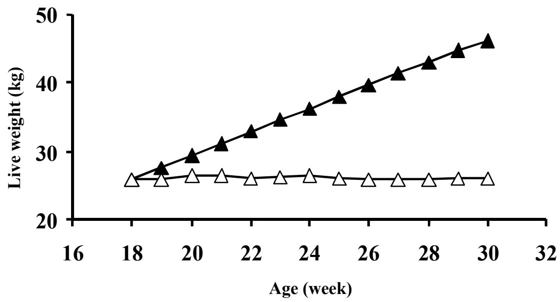

Fig. 1: Relationship between live weight (kg) and age (week), in control (C) (▲) and restricted feed (R) (Δ) sheep.

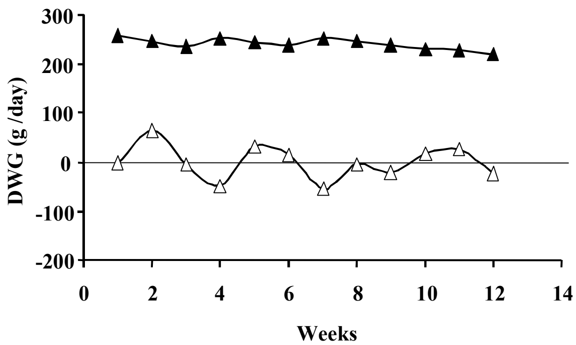

Fig. 2: Average daily weight gain (DWG) (g $kg^{-0.75}$ d^{-1}) of control (C) (▲) and restricted feed (R) (Δ) sheep during experiment.

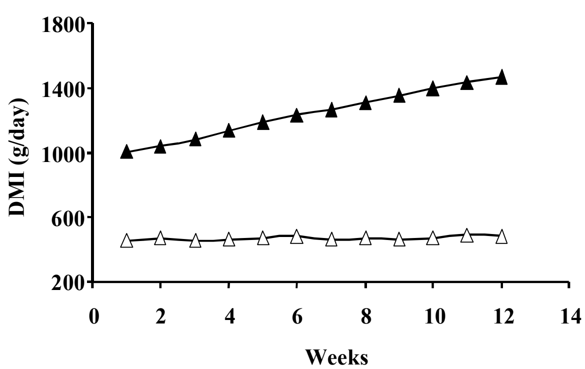

Fig. 3: Total dry matter intake (DMI) (g/day) of control (C) (▲) and restricted feed (R) (Δ) sheep during experiment

The regression of DWG on DOMI suggested a zero DWG at DOMI 24.64 g DOMI $kg^{-0.75}$ d^{-1}. (Fig. 5). The derived regression equation was:

Y = - 15.23 (0.70) + 0.62 (0.02) * X, (n = 50 and R^2 = 0.96)

in which: Y = DWG (g $kg^{-0.75}$ d^{-1})
X = DOMI (g $kg^{-0.75}$ d^{-1})

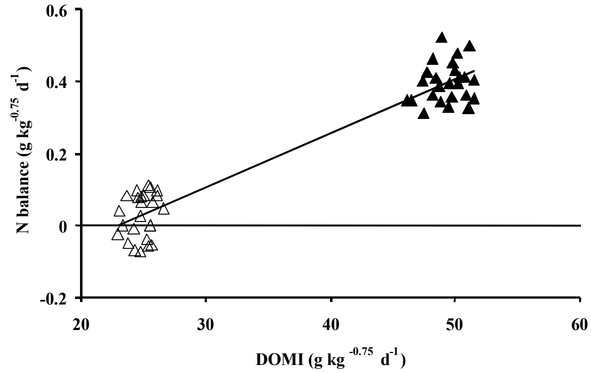

Fig. 4: Relationship between N balance (g $kg^{-0.75}$ d^{-1}) and digestible organic matter intake (DOMI) (g $kg^{-0.75}$ d^{-1}), combined data of both C (▲) and R (Δ) groups. Lines (—) present the predicted value.

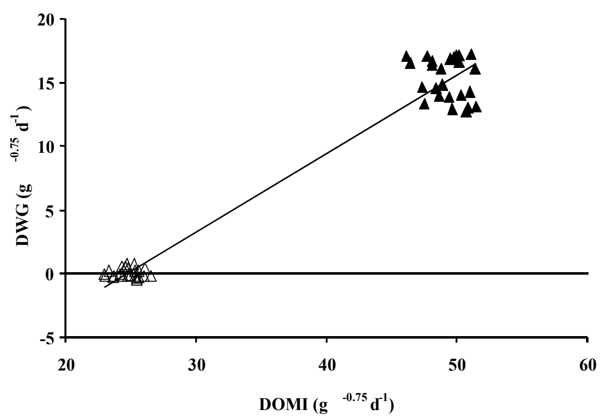

Fig. 5: Relationship between DWG (g $kg^{-0.75}$ d^{-1}) and digestible organic matter intake (DOMI) (g $kg^{-0.75}$ d^{-1}), combined data of both C (▲) and R(Δ) groups. Lines (-) present the predicted value

The energy intake of animals in R group decreased ($P<0.001$). The measured MERM was 400 kJ ME $kg^{-0.75}$ d^{-1} (Table 3). Energy losses through faeces, urine and methane significantly ($P < 0.001$) decreased in feed restricted animals compared with C animals. The relationship between ME and DWG is presented in Fig. 6. The estimated ME required for maintenance (zero growth) was 388 kJ ME $kg^{-0.75}$ d^{-1}. The derived regression equation was:

Y = - 14.22 (0.96) + 0.04 (0.01) * X (n = 50 and R^2 = 0.92)

in which: Y = DWG (g $kg^{-0.75}$ d^{-1})
X = ME (kJ $kg^{-0.75}$ d^{-1})

Table 3: Means of live weight, intake of gross energy (GE), digestible energy (DE), metabolizable energy (ME) and energy losses of Sangsari sheep in control (C) and feed restricted (R) groups

	C	se	R	se
Live weight (kg)				
Initial	25.88 [a]	0.36	25.93 [a]	0.19
Final	46.19 [a]	0.13	25.95 [b]	0.15
Energy intake (kJ kg$^{-0.75}$ d^{-1})				
GE	1527[a]	31.31	704 [b]	5.30
DE	956 [a]	14.43	494 [b]	3.53
ME	798 [a]	11.89	400 [b]	3.59
Energy losses (kJ kg$^{-0.75}$ d^{-1})				
Faeces	571 [a]	21.39	210 [b]	2.63
Urine	51.33[a]	3.80	44.6 [b]	2.69
Methane	106.9 [a]	2.19	49.3[b]	0.37

[ab] values within line with different superscripts differ significantly ($P < 0.05$)

Table 4: Digestibilities, metabolizability and content of metabolizable energy in digestible energy (ME/DE) of Sangsari sheep in control (C) and feed restricted (R) groups

	C	se	R	se
Digestibilities (%)				
OM	63.7 [a]	1.30	69.0 [a]	0.35
GE	62.9 [a]	0.01	70.2 [b]	0.01
CP	62.0 [a]	0.01	66.0 [b]	0.01
Metabolizability (%)	53 [a]	0.01	57 [b]	0.01
ME/DE	83.5 [a]	0.42	81.02[b]	0.54

[ab] values within line with different superscripts differ significantly ($P < 0.05$)

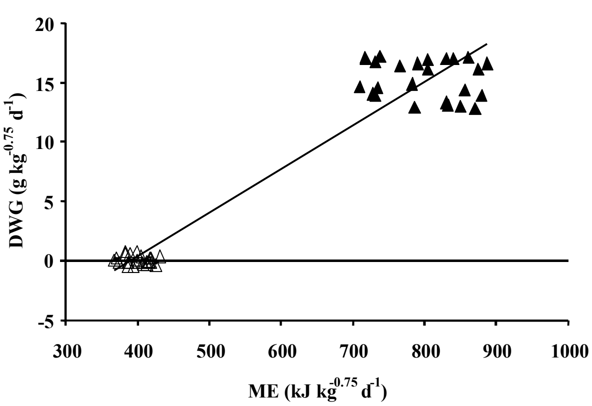

Fig. 6: Relationship between DWG (g kg$^{-0.75}$ d^{-1}) and metabolizable energy (kJ kg$^{-0.75}$ d^{-1}) intake, combined data of both C (▲) and R (Δ) groups. Lines (—) present the predicted value.

The digestibility, metabolizability and the content of metabolizable energy in the digestible energy (ME/DE) are shown in Table 4. Digestibility of OM, GE and CP and

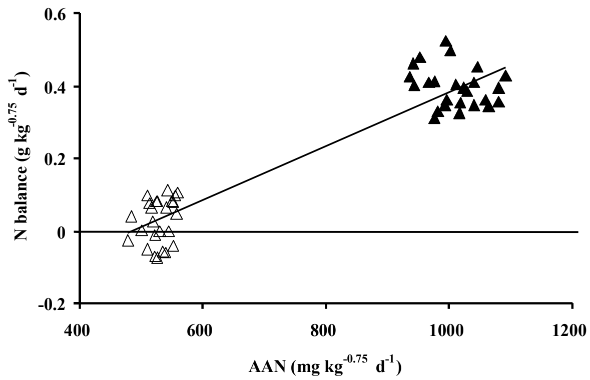

Fig. 7: Relationship between N balance (g kg$^{-0.75}$ d^{-1}) and amino acid nitrogen (AAN) availability (mg kg$^{-0.75}$ d^{-1}), combined data of both C (▲) and R (Δ) groups. Lines (—) present the predicted value

metabolizability in R group improved and were significantly higher ($P < 0.05$) compared with C group. Metabolizable energy (ME) content of the diet for C and R animals was 83.5 and 81.02 % of digestible energy (DE), respectively.

The estimated amount of amino acid nitrogen available for absorption in the small intestine (AAN) was 529 mg kg$^{-0.75}$ d^{-1} for animals in R group (Table 2). The efficiency of AAN availability for deposition was estimated by regression of N balance on AAN (Fig. 7). When N balance was regressed on AAN, estimated AAN required for zero N balance was 521 mg AAN kg$^{-0.75}$ d^{-1}. The derived regression equation was:

$$Y = - 0.36\,(0.03) + 0.001\,(0.00) * X, \quad (n = 50 \text{ and } R^2 = 0.89)$$

in which: Y = N balance (g kg$^{-0.75}$ d^{-1})
X = AAN (mg kg$^{-0.75}$ d^{-1})

DISCUSSION

Maintenance requirements of restricted animals can be reduced to a level that approaches their basal metabolic rate [11, 16]. If under restricted feeding, no weight gain is possible, usually maintenance energy requirements decrease. The results obtained in this experiment show that efficiency of feed utilization and the amount of feed required maintaining live weight influenced by plane of nutrition. These findings suggest that feed required maintaining body weight may be altered by plane of nutrition and is not a constant function of body weight. These observations supported by several reports including those of [9], [12] and [8] which have shown that maintenance requirements decrease in response to low levels of feed intake. Some reports [20, 21] however, indicate maintenance requirements were not influenced by nutritional levels.

The values of DOMI obtained in both measured (24.85 DOMI $kg^{-0.75}$ d^{-1}) and regression methods (22.97 DOMI $kg^{-0.75}$ d^{-1}) were not significantly different ($P < 0.05$). These values are considerably lower than the maintenance energy requirements of 26 g DOMI $kg^{-0.75}$ d^{-1} [4], 29.7 g DOMI.$kg^{-0.75}d^{-1}$ [18] and 26.4 g DOMI $kg^{-0.75}d^{-1}$ [22] at zero N balance in sheep.

During the maintenance feeding, the regression of DWG on DOMI also suggested a zero DWG at 24.64 g DOMI $kg^{-0.75}$ d^{-1}. This value is lower than the generalized range (25-30 g $kg^{-0.75}$ d^{-1}) reported by [4] and [17] for sheep at zero DWG. A value of 22.1 g DOMI $kg^{-0.75}$ d^{-1} also reported for lamb [16], which is appear to be due to imposing a relatively sever feed quality restriction for a period of 3 months to growing 4 months old lambs. The results of this experiment indicate that animals may decrease their maintenance requirements as a result of feed restriction. Most likely, during a period of weight stasis, sheep is able to maintain N balance beyond the level of DOMI where weight gain is zero.

When the ME intake regressed on DWG, the estimated ME requirements for maintenance (MERM) was 388 kJ ME $kg^{-0.75}$ d^{-1} for animals in R group. This finding is supported by several reports including those of [6] and [7]. Values derived from studies of [6] and [7] on Iraqi Awassi sheep ranged between 350 to 490 kJ ME $kg^{-0.75}d^{-1}$. A range of 369 to 373 kJ ME $kg^{-0.75}d^{-1}$ also estimated by [13]. However, [5] and [8] reported a value of 340 kJ ME $kg^{-0.75}$ d^{-1} for Merino and Swifter sheep after a relatively severe (below maintenance) period of 3 months feed restriction. Lower values of 300 kJ ME $kg^{-0.75}$ d^{-1} after a period of weight stasis of 4 to 6 months [9], 275 kJ ME $kg^{-0.75}$ d^{-1} [10] and 266 kJ ME $kg^{-0.75}$ d^{-1} [11] have also been reported for sheep. These findings are not supported by the results of this study. It is appear that the above reported low values are occurred when the duration and or severity of restricted feeding are increased. A range of 420-450 kJ ME $kg^{-0.75}$ d^{-1} also suggested for sheep when offered ad libitum feeding [4]. It seems that the generalized range proposed by ARC is higher than the actual requirements of sheep used in this experiment. The variations between above reports probably relate to estimation of the values in different experimental conditions. Relative to metabolic weight, energy losses through faeces, urine and methane decreased in restricted feed animals. This mainly caused by a low level of N intake and decreased N excretion through faeces, urine and methane.

The digestibility values observed in the present experiment are supported by several reports including those of [23] and [18]. A higher ($P<0.05$) value for digestibilities of OM, GE and CP and metabolizability occurred in feed restricted animals compared to controls. An improvement in the digestibilities and metabolizability in feed restricted compared to control sheep has been also noted by [13]. Normally, digestibilities and metabolizability improve during restricted feed intake. This probably due to an increased efficiency of feed utilization as a result of decreased rumen feed passage. The metabolizability values obtained in this experiment were 53 and 57 % for C and R animals, respectively. These results are in the range (40 to 64 %) proposed by several reports including those of [4,13,18,8].

The ME content in the DE (ME/DE) was slightly, although not significantly ($P > 0.05$) higher in C animals compared with R animals. In general, the content of ME of the diet was 81 and 83.5 % of DE in R and C animals, respectively. Similar results were found by [10] and [13]. These values are similar to the generalized value of 82 % recommended by [4].

The results of the present experiment showed a zero N balance at an AAN of about 529 mg AAN $Kg^{-0.75}$ d^{-1} for R group (Table 2). The regression equation of N balance on AAN predicts a zero N balance at 521 mg AAN $Kg^{-0.75}$ d^{-1}. As Fig.7 shows, the line is quit fit to both data of the C and R groups. There was not a significant difference between values for AAN in both measured and regression methods ($P > 0.05$). These results are in line with the range (380-620 mg AAN $kg^{-0.75}$ d^{-1}) suggested by [24]. Similar values of 520 and 555 mg AAN $kg^{-0.75}$ d^{-1} also reported by [18] and [16], respectively. However, [25], based on the total urinary and faecal N excretion of animals fed on N free diets, proposed a range of 250-430 mg AAN $kg^{-0.75}$ d^{-1} as net maintenance requirements for truly absorbed AAN, which is considerably lower than the above results.

CONCLUSIONS

The results found in this experiment show that during restricted feeding, sheep can decrease maintenance requirements as a result of feed restriction. Part of the large variations in maintenance requirements of sheep among the literature sources probably relates to estimation of the values in different experimental conditions (length and severity of feed restriction, type of diet used and environmental conditions). It seems that the generalized maintenance requirements values recommended in common feed allowance tables such as ARC are not fit well to sheep used in this experiment.

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REFERENCES

1. Kamalzadeh, A., 2005. Modeling the productivity of a breeding sheep flock for different production systems. Asian-Australasian J. Animal Sci., 18(5): 606-612.
2. Mahouachi, M. and N. Atti, 2005. Effects of restricted feeding and re-feeding of Barbarine lambs: intake, growth and non-carcass components. Animal Sci., 81: 305-312.
3. Kamalzadeh, A. and A. Shabani, 2007. Maintenance and growth requirements for energy and nitrogen of Baluchi sheep. Intl. J. Agric. Biol., 9(4): 535-539.
4. Agricultural Research Council (ARC), 1980. The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Farnham Royal, England.
5. Graham, N. McC. and T.W. Searle, 1979. Studies of weaned lambs before, during and after a period of weight loss. I. Energy and nitrogen utilization. Australian J. Agril. Res., 30: 513-523.
6. Mohammad, H.H., A.S. Ahmad and E.D. Salman, 1989. Determination of maintenance energy requirement of Awassi sheep. Proc. 5th Scientific Conference, Sci. Res. Council, Baghdad, pp: 176.
7. Al Jassim, R.A.M., S.A. Hassan and A.N. Al-Ani, 1996. Metabolizable energy requirements for maintenance and growth of Awassi lambs. Small Ruminant Res., 20: 239-245.
8. Kamalzadeh, A., 2004. Energy and nitrogen metabolism in lambs during feed restriction and realimentation. J. Agril. Sci. Technol., 6: 21-30.
9. Graham, N. McC. and T.W. Searle, 1975. Studies of weaner sheep during and after a period of weight stasis. I. Energy and nitrogen utilization. Australian J. Agril. Res., 26: 343-354.
10. Gingins, M., H. Bickel and A. Schurch, 1980. Efficiency of energy utilization in undernourished and realimented sheep. Livestock Production Sci., 7: 465-471.
11. Ryan, W.J., 1990. Compensatory growth in cattle and sheep. Nutrition Abstract and Review Seri B, 60: 653-664.
12. Ferrell, C.L., L.J. Koong and J.A. Nienaber, 1986. Effect of pervious nutrition on body composition and maintenance energy costs of growing lambs. British J. Nutr., 56: 595-605.
13. Thomson, E.F., H. Bickel and A. Schürch, 1982. Growth performance and metabolic changes in lambs and steers after mild nutritional restriction. J. Agril. Sci. Cambridge, 98: 183-194.
14. AOAC, 1989. Official Methods of Analysis (14th edition). Association of Official Analytical Chemists, Arlington, VA, pp: 152-157.
15. CSIRO, 2001. Testing sheep for methane production, science image, CSIRO Division, GA 1334.
16. Kamalzadeh, A., J. Van Bruchem, W.J. Koops, S. Tamminga and D. Zwart, 1997. Feed quality restriction and compensatory growth in growing sheep: feed intake, digestion, nitrogen balance and modelling changes in feed efficiency. Livestock Production Sci., 52: 209-217.
17. Van Bruchem, J., L.J.G.M. Bongers, J.D. Van Walsem, W. Onck and P.W.M. Van Adrichem, 1985. Digestion of proteins of varying degradability in sheep: 3. apparent and true digestibility in the small intestine and ileal endogenous flow of N and amino acids. Netherlands J. Agril. Sci., 38: 35-42.
18. Oosting, S.J., J. Van Bruchem and X.B. Chen, 1995. Intake, digestion and small intestine protein availability in sheep in relation to ammoniation of wheat-straw with or without protein supplementation. British J. Nutr., 74: 347-368.
19. Steel, R.G.D. and J.H. Torrie, 1982. *Principles and Procedures of Statistics*. A Biometric Approach. 2nd Edition. McGraw-Hill, New York, pp: 139-145.
20. Drew, K.R. and J.T. Reid, 1975. Compensatory growth in immature sheep. III. Feed utilization by sheep subjected to feed deprivation followed by realimentation. J. Agril. Sci. Cambridge, 85: 215-220.

21. Webster, A.J.F., 1980. The energetic efficiency of growth. Livestock Production Sci., 7: 243-252.
22. Ketelaars, J.J.M.H. and B.J. Tolkamp, 1991. Toward a new theory of feed intake regulation in ruminants. PhD thesis, Agricultural University, Wageningen, The Netherlands.
23. Zemmelink, G., B.J. Tolkamp and N.W.M. Ogink, 1991. Energy requirements for maintenance and gain of West African Dwarf goats. Small Ruminant Res., 5: 205-215.
24. Rohr, K. and P. Lebzien, 1991. Present knowledge of amino acid requirements for maintenance and production. In: Eggum, B.O. *et al*. (Eds), Protein Metabolism and Nutrition, Vol. 1. Proceeding of the 6th international symposium on protein metabolism and nutrition, Herning, Denmark. *EAAP-Publication* No. 59, Main reports, pp: 127-134.
25. Orskov, E.R., 1982. *Protein Nutrition in Ruminants*. Academic Press, Harcourt Brace Jovanovich Publishers, London, UK, pp: 160.