# Nutrient Requirements for Growth of Lambs under Hot Semiarid Environment

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**ABSTRACT :** A factorial experiment was conducted to assess nutrient utilization by growing lambs maintained on three levels each of digestible energy (high: HE, medium: ME, low: LE) and protein (high: HP, medium: MP, low: LP) in nine combinations (HEHP, HEMP, HELP, MEHP, MEMP, MELP, LEHP, LEMP, LELP). The experiment was conducted during the hot season in a semiarid location. Daily dry matter intake (DMI) was similar in all the groups in terms of unit body weight or metabolic body size. Digestibility of DM and nitrogen free extract increased ($p<0.01$) from low to medium and high energy regimen while the CF digestibility followed a reverse trend. The digestibility of crude protein (CP) decreased from high to medium and low protein regimens while it was similar in terms of energy variation. Nitrogen intake was higher in high followed by medium and low protein regime while fecal and urinary nitrogen loss were similar in all the treatment groups. Lambs in all the three levels of protein were in positive N balance and percent N retention was higher ($p<0.01$) in high followed by medium and low protein levels whereas it was similar in terms of energy variation. Initial body weight was similar in all the groups while final weight, total gain in the experiment and average daily gain (ADG) were higher in high than medium and low energy regimens. It is concluded that crossbred lambs required 75.1 g DM, 9.6 g CP, 6.3 g DCP and 711 KJ DE/kg $W^{0.75}$ or 11.0 g CP/MJ DE or 7.2 g DCP/MJ DE for 93 g average daily gain in a hot semiarid environment. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 5 : 665-671)***

**Key Words :** Feed Efficiency, Growth, Hot Environment, Lambs, Nutrient Requirement, Nutrient Utilization

## INTRODUCTION

Sheep in India are predominantly maintained on mixed grazing on community rangeland with other livestock species under extensive range management. The community grazing land is grossly overstocked and the stocking density on the land far exceeds its carrying capacity (Karim, 1999). Because of intense competition for feed and fodder, the livestock for most of the year remain underfed and as result the production traits of Indian sheep are among the lowest in the world. The native sheep under farmer management hardly achieve 50 g average daily gain (Kaushish et al., 1990) as against 300 g reported for developed countries (Graham, 1982). Under farmer management the surplus male lambs are generally marketed for slaughter around 9-12 months of age weighing about 18- 20 kg with average dressed carcass weight of 10 kg (Kondiahea and Agnihotri, 1995). The growth rate of the native and crossbred lambs could be considerably improved under intensive feeding on 50:50 roughage and concentrate based complete feed (Karim and Rawat, 1997). Considerable information is available on feed intake and nutrient utilization of stall fed native sheep under optimum feeding conditions (CSWRI, 1998). However, there is little such information covering the low plane of nutrition to which the crossbred sheep are exposed for most of the year.

The reported experiment was, therefore, conducted to assess nutrient requirement for varying rate of gain by maintaining weaner lambs on high, medium and low levels of digestible energy and protein in nine combinations.

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## MATERIALS AND METHODS

### Location

The experiment was conducted at the Central Sheep and Wool Research Institute located at 75° 22′ E longitude, 27° 17′ N latitude in a hot semiarid agro-climatic condition of western India. The experiment began in the last week of May and continue until the first week of August covering periods of hot dry and hot humid environmental conditions. Average ambient temperature and RH of the location during the experimental period ranged from 24.0-34.6°C and 12-92% RH at 0730 h, and 27.0-44.3°C and 5-92% RH at 1430 h (Table 1).

### Experimental animals and feeding management

Fifty four crossbred (Dorset X Malpura half bred) weaner (90 days old) lambs were divided into nine equal groups. Prior to weaning the lambs were maintained with the ewes and in addition to free suckling from their respective dams during morning and after noon received *ad libitum* creep mixture (DCP 12%; TDN 58%) in groups. One month after their birth the lambs were taken out for grazing on a grass legume mixed pasture during cooler parts of the day while the suckling and supplementation regimen was continued as before. The lambs were weaned at 90 days of age and used in the experiment. Before initiation of the experiment all the lambs were dewormed using Nilverm® and vaccinated against enterotoxaemia.

**Table 1.** Meteorological data of the location during the experiment

| Attributes | Range | Average |
|---|---|---|
| Dry bulb temperature (°C) | | |
| 0730 h | 24.0-34.6 | 29.6 |
| 1430 h | 27.0-44.3 | 36.7 |
| Minimum temperature (°C) | 22.9-32.5 | 27.1 |
| Maximum temperature (°C) | 29.9-45.6 | 37.8 |
| Relative humidity (%) | | |
| 0730 h | 12-92 | 67.1 |
| 1430 h | 5-92 | 39.6 |
| Wind velocity (km/h) | 2.1-12.9 | 6.4 |
| Sun shine (hours) | 0.0-12.2 | 7.5 |

Throughout the study the lambs were maintained in individual chain link fencing enclosures (1.5×1.0 $m^2$) under open sided asbestos roofed animal sheds. The lambs in all the groups were fed at the fixed rate of 3.5% of their body weight and the feed offer was changed every week based on their weekly body weight changes. The fixed rate of feeding was followed in the experiment to avoid masking of treatment effect due to compensatory increase of dry matter intake in lower levels of feeding. Residue, if any, was discarded the next day before offering fresh feed. Free choice clean drinking water was provided to them in their respective cages once daily at 1430 h.

Three energy levels: high (HE), medium (ME), low (LE) and three protein levels: high (HP), medium (MP), low (LP) with all their combinations i.e. nine diets (HEHP, HEMP, HELP, MEHP, MEMP, MELP, LEHP, LEMP, LELP) in a factorial design were prepared. Both concentrate and roughage (*Cenchrus ciliaris* hay) were ground in a hammer mill to pass through 4 mm sieve. The diets were prepared in mash form as one lot and stored in gunny bags for later use in the experiment. The physical and chemical compositions of the diets are presented in Table 2. The lambs were weighed at weekly intervals on a platform balance.

### Metabolism trial

After 60 days experimental feeding, a metabolism trial was conducted on four lambs from each group in cages with provision for automatic and quantitative collection of faeces and urine separately. The metabolism trial extended over 10 days with protocol of three days adaptation to the cages followed by seven days collection period. Representative samples of faeces and urine voided in 24 h were processed, sampled, pooled for the seven days collection period and preserved for later chemical analysis. Aliquots of daily urine voided (1/100 part) over the seven days collection period were composited in Kjeldahl flasks containing 15 ml concentrated $H_2SO_4$ for nitrogen estimation. The samples of feed offered, residue, faeces and urine voided were analysed for OM, CP, ether extract and CF (AOAC, 1990). Calcium was estimated in the collected samples by the method of Talpatra et al. (1940) and phosphorus by the method of Fiske and Subbarow (1925).

### Statistical analysis

The generated data on feed intake, feed conversion efficiency and digestibility of nutrients were subjected to analysis of variance using SPSS-10 package. The significant group differences were compared using

**Table 2.** Composition of experimental ration

| Attributes | HEHP | HEMP | HELP | MEHP | MEMP | MELP | LEHP | LEMP | LELP |
|---|---|---|---|---|---|---|---|---|---|
| Physical composition (%) | | | | | | | | | |
| *Cenchrus ciliaris* | 22 | 19 | 28 | 46 | 45 | 43 | 65 | 65 | 70 |
| Barley grain | 42 | 49 | 69 | 14 | 24 | 32 | - | - | 8 |
| Wheat bran | 8 | 19 | - | 8 | 14 | 22 | - | 17 | 14 |
| Groundnut cake | 25 | 10 | - | 29 | 14 | - | 32 | 15 | 5 |
| Mineral mixture | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Common salt | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Rovimixe ® | | | | | | | | | |
| Chemical composition (%) | | | | | | | | | |
| Dry matter (DM) | 98.8 | 96.9 | 97.3 | 98.5 | 98.7 | 97.8 | 97.9 | 98.9 | 98.2 |
| Organic matter (OM) | 93.3 | 93.9 | 94.2 | 93.3 | 93.5 | 93.7 | 92.9 | 93.1 | 93.2 |
| Crude protein (CP) | 18.1 | 13.6 | 9.2 | 18.3 | 13.5 | 9.1 | 18.1 | 13.5 | 9.2 |
| Ether extract (EE) | 3.9 | 2.8 | 2.4 | 3.9 | 3.1 | 2.4 | 3.9 | 3.2 | 2.4 |
| Crude fibre (CF) | 20.7 | 18.3 | 20.4 | 32.2 | 30.5 | 28.5 | 40.9 | 40.1 | 41.1 |
| Nitrogen free extract (NFE) | 51.3 | 59.4 | 63.2 | 47.4 | 46.1 | 53.5 | 29.1 | 35.2 | 39.6 |
| Calcium (Ca) | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 |
| Phosphorus (P) | 0.5 | 0.6 | 0.4 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.7 |

HEHP: High energy and high protein; HEMP: High energy and medium protein; HELP: High energy and low protein; MEHP: Medium energy and high protein; MEMP: medium energy and medium protein; MELP: Medium energy and low protein; LEHP: Low energy and high protein; LEMP: Low energy and medium protein; LELP: Low energy and low protein; Mineral mixture contained calcium 28.0%, phosphorus 6.2%, common salt 35.8%, iron 0.4%, iodine 250 ppm, manganese 740 ppm, copper 280 ppm and sulphur 0.15%. Vitamin supplement (Rovimixe)[(R)] was added @ 20 g per 100 kg of concentrate mixture. Rovimixe[(R)] contained 40,000 IU vitamin A, 20 mg vitamin $B_2$ and 5000 IU vitamin $D_3$ per gram.

**Table 3.** Dry matter intake, nutrient digestibility and plane of nutrition of experimental lambs

| Attributes | HEHP | HEMP | HELP | MEHP | MEMP | MELP | LEHP | LEMP | LELP | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Dry matter intake (g/day) | 762.6 | 711.6 | 700.8 | 684.2 | 685.8 | 728.1 | 668.4 | 635.5 | 600.2 | 36.87 |
| Dry matter intake (g/kg body weight) | 37.3 | 33.4 | 33.1 | 37.2 | 36.1 | 35.9 | 35.8 | 36.2 | 34.9 | 1.48 |
| Dry matter intake (g/kg $W^{0.75}$) | 75.1 | 71.7 | 70.9 | 76.9 | 75.3 | 76.1 | 74.4 | 73.9 | 71.2 | 2.41 |
| Digestibility coefficient (%) | | | | | | | | | | |
| Dry matter | 66.2$^{C}$ | 65.3$^{BC}$ | 68.7$^{C}$ | 58.6$^{AB}$ | 53.5$^{A}$ | 62.1$^{BC}$ | 55.3$^{A}$ | 52.9$^{A}$ | 52.3$^{A}$ | 1.91 |
| Crude protein | 75.1$^{CD}$ | 65.6$^{BCD}$ | 53.8$^{AB}$ | 75.0$^{CD}$ | 62.1$^{AB}$ | 55.5$^{AB}$ | 78.7$^{D}$ | 72.9$^{CB}$ | 49.0$^{A}$ | 3.33 |
| Ether extract | 79.0$^{CD}$ | 73.2$^{B}$ | 77.9$^{C}$ | 81.1$^{D}$ | 71.0$^{B}$ | 69.3$^{AB}$ | 83.0$^{E}$ | 77.9$^{C}$ | 67.8$^{A}$ | 2.03 |
| Crude fibre | 45.6$^{AB}$ | 42.5$^{A}$ | 56.7$^{BC}$ | 56.9$^{BC}$ | 53.1$^{AB}$ | 62.3$^{CD}$ | 63.5$^{CD}$ | 60.4$^{CD}$ | 67.2$^{D}$ | 3.00 |
| Nitrogen free extract | 74.1$^{F}$ | 75.0$^{FG}$ | 77.3$^{G}$ | 39.5$^{B}$ | 53.7$^{D}$ | 67.3$^{E}$ | 29.5$^{A}$ | 41.9$^{B}$ | 45.9$^{C}$ | 1.49 |
| Nutritive value of the ration | | | | | | | | | | |
| DCP % | 13.6$^{D}$ | 8.8$^{B}$ | 4.9$^{A}$ | 13.7$^{D}$ | 8.1$^{B}$ | 5.1$^{A}$ | 14.2$^{D}$ | 11.1$^{C}$ | 4.7$^{A}$ | 0.58 |
| TDN % | 67.9$^{c}$ | 66.4$^{c}$ | 69.6$^{c}$ | 50.3$^{a}$ | 50.6$^{a}$ | 62.7$^{bc}$ | 56.0$^{ab}$ | 58.3$^{abc}$ | 53.8$^{ab}$ | 2.42 |
| Plane of nutrition | | | | | | | | | | |
| DCP intake (g/day) | 102.0$^{C}$ | 62.6$^{B}$ | 34.1$^{A}$ | 93.6$^{C}$ | 55.1$^{B}$ | 36.7$^{A}$ | 95.3$^{B}$ | 68.2$^{B}$ | 28.5$^{A}$ | 2.00 |
| DCP intake (g/ kg body weight) | 4.7$^{CD}$ | 2.9$^{B}$ | 1.7$^{A}$ | 5.1$^{D}$ | 2.9$^{B}$ | 1.8$^{A}$ | 5.1$^{D}$ | 4.1$^{C}$ | 1.7$^{A}$ | 0.21 |
| DCP intake (g/kg $W^{0.75}$) | 10.2$^{E}$ | 6.3$^{C}$ | 3.5$^{A}$ | 10.5$^{E}$ | 6.1$^{C}$ | 3.9$^{B}$ | 10.6$^{E}$ | 8.2$^{D}$ | 3.4$^{A}$ | 0.39 |
| TDN intake (g/day) | 513.7$^{C}$ | 470.7$^{AB}$ | 487.1$^{AB}$ | 346.8$^{A}$ | 344.7$^{A}$ | 455.1$^{A}$ | 356.9$^{A}$ | 361.2$^{A}$ | 323.3$^{A}$ | 24.38 |
| TDN intake (g/kg body weight) | 23.6$^{B}$ | 22.2$^{AB}$ | 23.0$^{B}$ | 18.7$^{A}$ | 18.6$^{A}$ | 22.5$^{AB}$ | 20.1$^{AB}$ | 20.9$^{AB}$ | 19.6$^{AB}$ | 1.01 |
| TDN intake (g/kg $W^{0.75}$) | 50.6$^{B}$ | 47.4$^{AB}$ | 49.3$^{B}$ | 39.0$^{A}$ | 37.9$^{A}$ | 47.6$^{AB}$ | 39.7$^{A}$ | 42.0$^{AB}$ | 38.4$^{A}$ | 3.78 |

Unlike superscripts in rows within protein and energy levels differ significantly: capital letter ($p<0.01$), small letter ($p<0.05$).

Duncan's Multiple Range Test (Duncan, 1955). Body weight changes of each animal were charted by fitting polynomial equations wherein the third degree was found to be best fit. The generated constants were subjected to analysis of variance to assess group differences. The pooled constants for the group are presented graphically.

## RESULTS AND DISCUSSION

The experiment was conducted by feeding the lambs on three levels each of energy and protein in nine combinations. The feed offered to all the groups was maintained at constant 3.5% of body weight throughout the study to precipitate the treatment effect as it is established that a low energy diet will elicit a compensatory increase in dry matter intake (Santra and Pathak, 1999) which would have confounded the experimental design. Further considerable information is available in India on the growth performance of weaner lambs in an active phase of growth under optimum feeding conditions (Karim, 1999) while such information covering a lower rate of gain is lacking in literature. Since the lambs under farmer's management gain per day at the rate of 40-50 g (Kaushish et al., 1990), the low levels of energy and protein were fed to generate comprehensive data covering the total spectrum of growth rate encountered under Indian conditions.

**Dry matter intake**

The lambs throughout the study were fed at a fixed rate of 3.5% of their body weight which was changed every week based on their weekly body weight changes. Hence daily dry matter intake (DMI) was similar in all the groups (Table 3). The observed non significant variation in DMI was due to the random effect of body weight changes. The DMI was also similar on its conversion in terms of unit metabolic body size. The experimental lambs on an average consumed 73.9 g DM/kg $W^{0.75}$ which would be considered adequate for their growth requirement (ARC, 1980; Kearl, 1982; ICAR, 1985).

**Nutrient digestibility**

Digestibility of DM and nitrogen free extract were higher ($p<0.01$) in high energy fed groups irrespective of protein variation due to the increase in concentrate component in the diet formulation (Table 3). Increased digestibility of DM and soluble carbohydrate at higher levels of concentrate feeding is a consistent finding in

**Table 4.** Nitrogen and mineral balance of the experimental lambs

| Attributes | HEHP | HEMP | HELP | MEHP | MEMP | MELP | LEHP | LEMP | LELP | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen intake (g/d) | 22.1 [C] | 15.2 [B] | 10.3 [A] | 20.0 | 14.3 [B] | 10.6 [A] | 19.4 | 15.1 [B] | 9.3 [A] | 1.35 |
| Faecal nitrogen loss (g/d) | 5.8 | 5.2 | 4.8 | 5.0 | 5.4 | 4.8 | 4.1 | 4.2 | 4.7 | 0.58 |
| Urinary nitrogen loss (g/d) | 3.4 | 2.0 | 0.9 | 2.6 | 1.8 | 1.4 | 1.6 | 2.7 | 1.7 | 0.52 |
| Nitrogen retained (g/d) | 13.0 [EF] | 8.0 [D] | 4.5 [B] | 12.4 [E] | 7.0 [C] | 4.4 [B] | 13.6 [EF] | 8.2 [D] | 2.8 [A] | 0.72 |
| Per cent nitrogen retention | 60.0 [CD] | 53.0 [BCD] | 44.6 [ABC] | 62.4 [D] | 49.5 [BC] | 42.1 [AB] | 69.8 [D] | 55.2 [BCD] | 30.8 [A] | 4.54 |
| Calcium intake (g/d) | 8.1 | 7.5 | 7.7 | 7.8 | 8.2 | 8.9 | 8.4 | 8.2 | 7.8 | 2.44 |
| Calcium retained (g/d) | 4.6 | 4.3 | 4.4 | 2.6 | 3.2 | 4.3 | 3.6 | 3.1 | 2.4 | 0.56 |
| % Calcium retained | 57.5 [b] | 56.2 [b] | 57.5 [b] | 33.3 [a] | 39.6 [a] | 49.1 [a] | 43.5 [a] | 38.6 [a] | 32.1 [a] | 6.63 |
| Phosphorus intake (g/d) | 4.1 [F] | 4.0 [F] | 2.9 [ABC] | 3.3 [BCD] | 3.3 [BCD] | 3.7 [DEF] | 2.7 [AB] | 2.9 [ABC] | 2.4 [A] | 0.17 |
| Phosphorus retained (g/d) | 2.3 | 2.5 | 1.7 | 1.1 | 1.4 | 1.5 | 0.9 | 0.9 | 0.5 | 0.04 |
| % Phosphorus retained | 58.5 [BC] | 61.1 [C] | 58.8 [BC] | 34.2 [AB] | 42.3 [ABC] | 40.7 [ABC] | 34.4 [AB] | 34.2 [AB] | 22.2 [A] | 6.64 |

Unlike superscripts in rows within protein and energy levels differ significantly: capital letter ($p<0.01$), small letter ($p<0.05$)

several earlier studies (Colucci et al., 1989; Santra and Pathak, 1999). Digestibility of CP was generally higher ($p<0.01$) in high and medium than low protein fed groups. The observed variation was due to incorporation of variable levels of groundnut cake, a highly degradable protein supplement in the diet formulation (Table 2) or possibly a reflection of low CP intake. Under similar conditions the increase in crude fibre digestibility from high to medium and low energy regimens reflected the increase in the roughage content in the diet formulation. It is established that higher concentrate levels in diet formulation depress the fibre digestibility (Collucci et al., 1989; Santra and Pathak, 1999). Depression in ruminal fibre digestibility observed by adding grain or concentrate to forage diet has been attributed to a lower pH leading to a delay in the onset of fibre digestion in the rumen (Mertens and Loften, 1980; Hoover, 1986). Additionally the retention time of digesta in reticulo-rumen will be reduced under a high concentrate regimen, and this could have contributed to the observed difference.

**Nutritive value of ration and plane of nutrition**

Digestible crude protein (DCP) percentage of the ration and daily DCP intake of the lambs increased ($p<0.01$) from low to medium and high protein regimens irrespective of energy variation (Table 3). Similarly the total digestible nutrient (TDN) value of the test diets and its intake per day as well as in terms of unit weight or metabolic body size was higher ($p<0.01$) in high than medium and low energy regimens. However the TDN intake was found to be similar when pooled in terms of protein variation. The observed differences were also due to diet formulation and the variations were expected as per the experimental protocol.

**Nitrogen balance**

As per the experimental design the N intake was higher ($p<0.01$) in high followed by medium and low protein regimen while faecal N excretion was similar in all the groups (Table 4). Likewise urinary N excretion increased from low to medium and high protein regimens. Since the groundnut cake used in diet formulation as a protein supplement was of highly degradable nature, the faecal N loss was similar in all the three levels of protein while higher urinary N loss in the high protein regimen indicated that the digestible protein in excess of body requirement was used in energy cycle and excreted as urinary N. Although the animals on all the three levels of protein were in positive N balance, still the percent N retention was higher ($p<0.01$) in high (64%) followed by medium (52%) and low (39%) protein level. The N intake, its excretion in faeces and urine was however similar in lambs under the three levels of energy with an average N retention of 52%. Moreover the lowest N retention was recorded in LELP (31%) possibly due to limitation of energy availability required for optimum N retention. The N retention value exceeding 50% would be considered optimum for the growing lambs (Graham, 1980), hence the lambs maintained on medium and high levels of energy were able to meet their protein requirement. However, relatively higher nitrogen retention with comparatively poor average daily gain in these lambs was probably due to additional loss of nitrogen through sweating evaporative cooling (Karim, 1990) which was not accounted for in this study. Further, high N retention and urea synthesis at high ambient temperature, as was the case in this study, will have higher heat production adversely affecting growth.

**Mineral balance**

With similar levels of Ca intake and its excretion in urine under all the levels of energy and protein, higher faecal Ca loss in low energy fed groups was reflected in their low Ca retention efficiency (Table 4). Likewise, higher P intake in high energy fed lambs with similar faecal and urinary P excretion in the three levels was reflected in better ($p<0.01$) retention in high than medium and low energy

**Table 5.** Growth performance and feed conversion efficiency of the experimental lambs

| Attributes | HEHP | HEMP | HELP | MEHP | MEMP | MELP | LEHP | LEMP | LELP | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial body weight (kg) | 15.7 | 15.0 | 15.7 | 15.3 | 15.3 | 15.7 | 16.9 | 15.7 | 15.7 | 1.61 |
| Final body weight (kg) | 24.0 | 22.9 | 21.3 | 18.6 | 18.7 | 21.4 | 20.8 | 18.9 | 16.8 | 1.87 |
| Total body weight gain (kg) ** | 8.3 $^{f}$ | 7.9 $^{ef}$ | 5.6 $^{cde}$ | 3.3 $^{ab}$ | 3.4 $^{bc}$ | 5.7 $^{de}$ | 3.9 $^{bcd}$ | 3.2 $^{ab}$ | 1.1$^{a}$ | 0.78 |
| Average daily gain (g)** | 98.6 $^{f}$ | 93.4 $^{ef}$ | 67.1$^{cde}$ | 39.7$^{abc}$ | 41.1$^{bc}$ | 68.2$^{de}$ | 45.8$^{bcd}$ | 38.1$^{ab}$ | 13.6$^{a}$ | 9.346 |
| Total dry matter intake (kg) | 58.7 | 52.3 | 48.2 | 51.8 | 53.4 | 58.3 | 56.2 | 51.8 | 44.9 | 5.21 |
| Feed efficiency ratio (kg DM intake/kg body weight gain)* | 7.3$^{A}$ | 6.7 $^{A}$ | 9.1 $^{A}$ | 18.4 $^{A}$ | 19.0 $^{A}$ | 12.3$^{A}$ | 23.3 $^{A}$ | 16.6 $^{A}$ | 80.7$^{B}$ | 10.13 |
| Total DCP intake (kg) | 8.0 | 4.6 | 2.4 | 7.1 | 4.3 | 2.9 | 8.0 | 5.8 | 2.1 | 0.51 |
| DCP intake (kg)/kg body weight gain | 0.99 | 0.60 | 0.45 | 2.52 | 1.54 | 0.62 | 3.32 | 1.85 | 3.84 | 0.65 |
| Total TDN intake (kg) | 39.9$^{d}$ | 34.7$^{bcd}$ | 33.5$^{abcd}$ | 26.1$^{ab}$ | 27.1$^{abc}$ | 36.5$^{cd}$ | 31.5$^{abcd}$ | 30.2$^{abcd}$ | 24.2$^{a}$ | 3.24 |
| TDN intake(kg)/kg body weight gain | 4.9$^{A}$ | 4.5$^{A}$ | 6.3$^{A}$ | 9.3$^{A}$ | 9.6$^{A}$ | 7.7$^{A}$ | 13.1$^{A}$ | 9.7$^{A}$ | 43.4$^{B}$ | 5.47 |

Unlike superscripts in rows within protein and energy levels differ significantly: capital letter ($p<0.01$), small letter ($p<0.05$).

regimens. The Ca and P metabolism was found to be similar in terms of protein variation. The Ca and P balance was however positive in all the nine groups as they received 2% mineral supplement.

## Growth performance

Initial body weight was similar in all the groups while final body weight, total gain in the experiment and average daily gain (ADG) were higher ($p<0.01$) in high than medium and low energy regimens (Table 5). Generally protein variation in the diets did not reflect such differences while lowest weight gain was observed in LELP regimen. Although total feed intake in the experiment was similar in all the groups, the feed efficiency ratio was generally wider in lower levels of both energy and protein in the diet, particularly in LELP. The calculated feed efficiencies in LEHP and LELP regimens were wider due to very high individual variation. Further, the generated data on feed conversion efficiency were not aquantitative reflection of table values of total gain and feed consumed as some lambs in LEHP and LELP showed loss in weight during the experiment. The DCP intake/kg gain in body weight was more in low levels of energy possibly due to lower biological value of the protein used in the feed formulation for the group or wider energy and protein ratio. Wider energy and protein ratio is known to disturb nutrient utilization of growing lambs for production (Kearl, 1982).

The growth pattern of the lambs is presented in Figure 1. It is evident that the growth profile of the lambs was superior under high energy and it was poor in medium and low energy regimens. Irrespective of the protein variation in the diet their growth pattern was of medium order. The growth pattern of the lambs in all the groups was almost similar till the 14th day of experimental feeding and the treatment effect was evident thereafter. The lambs after weaning require about a fortnight time to adjust to the weaning stress and the new feeding regimen (Karim, 1999) hence their similar response till the 14th day was expected.

**Table 6.** Dry matter, CP, DCP and DE intake and growth rate of lambs

| Feeding regimen | DMI (g/day) | CPI (g/day) | DCPI (g/day) | DEI[1] (MJ/day) | ADG (g) | Feed efficiency ratio |
|---|---|---|---|---|---|---|
| HEHP | 698.3±66.41 | 126.3$^{E}$±12.00 | 94.9$^{F}$±9.03 | 8.7$^{c}$±0.83 | 98.6$^{f}$±11.64 | 7.3$^{A}$±0.53 |
| HEMP | 622.6±64.25 | 83.8 $^{C}$±8.64 | 55.2$^{CD}$±5.68 | 7.6 $^{bc}$±0.78 | 93.4$^{ef}$±8.37 | 6.7 $^{A}$±0.51 |
| HELP | 573.9±73.64 | 52.3 $^{A}$±6.72 | 28.3 $^{A}$±3.62 | 7.3 $^{bc}$±0.94 | 67.1$^{cde}$±6.24 | 9.0 $^{A}$±1.79 |
| MEHP | 617.2±60.37 | 112.6$^{DE}$±11.01 | 84.6 $^{EF}$±8.28 | 5.7 $^{a}$±0.55 | 39.7$^{abc}$±6.93 | 18.4 $^{A}$±3.68 |
| MEMP | 635.7±44.45 | 83.1 $^{C}$±5.81 | 51.6$^{C}$±3.61 | 5.9 $^{a}$±0.41 | 41.1$^{bc}$±7.75 | 18.9 $^{A}$±4.08 |
| MELP | 693.9±38.99 | 63.3 $^{B}$±3.55 | 35.2 $^{B}$±1.97 | 7.9 $^{c}$±0.44 | 68.3$^{de}$±12.29 | 12.3 $^{A}$±2.44 |
| LEHP | 669.2±30.86 | 121.1$^{E}$±5.58 | 95.3 $^{F}$±4.39 | 6.9$^{b}$±0.32 | 45.8$^{bcd}$±11.51 | 23.3 $^{A}$±11.76 |
| LEMP | 616.1±74.11 | 94.1 $^{CD}$±11.31 | 68.7 $^{DE}$±8.26 | 6.6 $^{a\,b}$±0.79 | 38.1$^{ab}$±3.43 | 16.6 $^{A}$±2.71 |
| LELP | 534.9±54.15 | 52.0 $^{A}$±5.26 | 25.5 $^{A}$±2.58 | 5.3 $^{a}$±0.53 | 13.6$^{a}$±5.45 | 80.7$^{B}$±29.64 |

Unlike superscripts in rows within protein and energy levels differ significantly: capital letter ($p<0.01$), small letter ($p<0.05$).

[1] Calculated by using conversion factor: 1 kg TDN=18.4 MJ DE

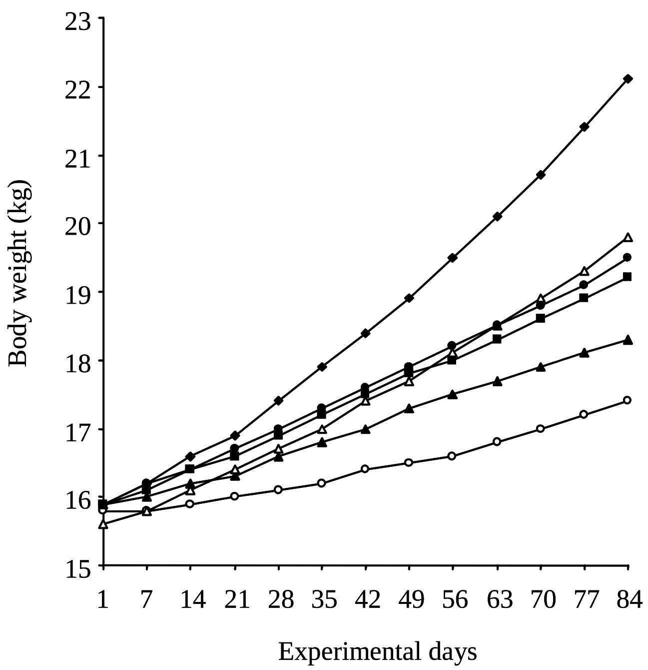


**Figure 2.** Body weight changes of experimental lambs

High energy, ■ =Y=15.824+0.048X+0.00032X $^2$($R^2$ = 0.84)
Medium energy, Δ=Y=15.823+0.0385X+0.00002X$^2$ ($R^2$ = 0.71)
Low energy, o=15.749+0.0096X+0.00012X$^2$ ($R^2$=0.74)
High protein, ▲=15.857+0.0278X+0.00002X$^2$ ($R^2$=0.79)
Medium protein, ■=15.607+0.0340X+0.00019X$^2$ ($R^2$=0.78)
Low protein, ●=15.915+0.0371X+0.00006X$^2$ ($R^2$=0.74)

The best growth performance was recorded under high energy high protein (HEHP) and high energy medium protein (HEMP) regimens (Table 6). Accordingly, lambs in HEHP and HEMP consumed 14.5 and 11.0 g CP or 10.9 and 7.2 g DCP/MJ DE for average daily gains of 99 and 93 g respectively. However regression of protein energy ratio (g DCP/MJ DE consumed) and average daily gain (Fig. 2) indicated that the growing lambs had highest gain on 9 g DCP/MJ DE intake. Santra and Karim (2000) also reported the DCP intake of growing lambs at the same location to be 7.2 g/MJ DE consumed for average daily gain ranging from 102 to 160 g. Kearl (1982) by expressing the DCP requirement of tropical lambs in terms of DE consumed reported the value to be 11.7 g while it was 10.5 g DCP/MJ DE in the NRC (1981) recommendation. Although the protein to energy ratio was 8.7 in MEMP regimen, the lambs had a relatively poor rate of gain (41 g ADG) which was possibly due to their lower energy intake. Comparatively lower DCP requirement in terms of energy of growing lambs under hot semiarid environment in this study could be ascribed to their relatively poor growth rate. Higher DCP intake of the lambs in terms of energy consumed under the low energy regimen with poor rate of gain is indicative of possible use of a portion of DCP in energy cycles. It is established that in the absence of adequate energy some portion of DCP is deaminated and used in energy cycles.

It is concluded that crossbred lambs under hot semiarid environment on an average required 9 g DCP/MJ DE consumed to gain at 64 g/day. However, best growth performances of 99 and 93 g ADG were obtained under HEHP and HEMP regimens wherein the growing lambs required 10.9 and 7.3 g DCP/MJ DE consumed, respectively.

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