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Protein and energy requirements for maintenance of indigenous Granadina goats

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Sixteen adult castrated male goats of the Granadina breed, with initial live weights ranging from 26·0 to 33·3 kg were used in two experiments to determine their protein and energy requirements for maintenance. Digestibility, nitrogen and energy balance measurements were made during the experiments. Two diets, which were based on pelleted lucerne (*Medicago sativa*) hay alone or on this forage and barley, were individually given at about maintenance level once daily. Gas exchange was measured using open-circuit respiration chambers. Fasting heat production was also determined. By regression analysis endogenous urinary N and maintenance requirements for N were estimated to be 119 mg/kg body-weight (W)$^{0.75}$ per d and 409 mg total N/kg W$^{0.75}$ per d respectively. Fasting heat production was 324 kJ/kg W$^{0.75}$. The energy requirement for maintenance was calculated by regression of energy balance on metabolizable energy (ME) intake and a value of 443 kJ/kg W$^{0.75}$ per d was found. The overall efficiency of utilization of ME for maintenance was 0·73.

Energy requirement: Protein requirement: Goats

There is little information in the literature concerning nutritional requirements of goats, probably because of the minor economical importance of the goat in developed countries. In fact, most recommendations have been derived from other ruminant species, e.g. cattle and sheep. However, these extrapolations may be misleading as it is well-recognized that the goat has developed unusual physiological features in comparison with other ruminants, such as a higher capacity to degrade cell wall components of low-quality forages and a better ability to use nitrogen and water under stress conditions.

Most information on energy and protein requirements of goats has been obtained by feeding trials (Devendra, 1967; Singh & Sengar, 1970; Akinsoyinu, 1974; Rajpoot, 1979; Morand-Fehr, 1981; Aguilera *et al.* 1984). Estimates of energy needs based on calorimetry experiments are very limited. In non-lactating goats, fasting metabolism values were reported by Brody (1945), Fujihara *et al.* (1973) and Roy-Smith (1980), but no direct estimations of energy requirements for maintenance have been found in the literature. Values for nitrogen requirements, based on N balance studies in non-lactating goats, are also scarce (Itoh *et al.* 1978; Reynolds, 1981; Guerrero, 1982). Consequently, further research is needed on the nutrient requirements of goats. Some findings on the energy and protein needs of lactating goats are published in the following paper (Aguilera *et al.* 1990). The present work was undertaken with the specific aim of providing information on the protein and energy requirements for maintenance in adult castrated male goats of the Granadina breed, a native species well-adapted to arid lands in Southern Spain.

MATERIAL AND METHODS

Animals and diets

Sixteen adult castrated male goats, 2–3 years of age, of initial live weight ranging from 26·0 to 33·3 kg, were used in two consecutive experiments. In each experiment, eight goats

Table 1. *Composition of the experimental diets (g/kg)*

Diet...	Mixed diet		Lucerne (*Medicago sativa*) hay-based diet	
Expt no....	1	2	1	2
Ingredients				
Pelleted lucerne hay	570	620	985	985
Barley	415	365	—	—
Mineral mixture*	15	15	15	15
Analysis (g/kg dry matter (DM))				
DM (g)	887	902	883	906
Organic matter	930	905	895	863
Crude protein (nitrogen × 6·25)	137	171	162	212
Gross energy (MJ/kg DM)	18·5	17·9	18·7	17·5

* The mineral mixture contained (g/kg): $CaPO_4.2H_2O$ 600, NaCl 250, MgO 150.

were distributed on a body-weight (W) basis into two groups of four animals each. Following a cross-over design, each group consumed a diet based on pelleted lucerne (*Medicago sativa*) hay alone or with the addition of barley (mixed diet). A balance trial was conducted on each diet. The digestibility of barley was calculated by difference. The experimental diets (Table 1) were given at a maintenance level, which was taken as 0·548 MJ metabolizable energy (ME)/kg $W^{0.75}$, a value for lactating goats which had been obtained in our laboratory by feeding-trials (Aguilera *et al.* 1984). A previous estimation of the ME content of the diets was made from the reported energy value of the ingredients (Nehring *et al.* 1972).

Experimental procedure

The male goats, previously dosed with Tetramisol (Sobrino, S.A.) against internal parasites, were kept in individual metabolism cages placed in an environmentally controlled room at 22–24°. They were fed once daily at 09·00 hours. Each digestibility trial consisted of a 15 d preliminary period followed by a 10 d balance period in which faeces and urine were collected daily and stored at −25°. At the end of the collection period, representative samples were taken for analysis. No preservative for urine was used. The goats were weighed at the beginning and end of the balance period. Food intakes were recorded daily and any refusals taken into account. Throughout each balance period, on days 17, 19, 21 or 23, after a 24 h adaptation period, oxygen consumption and carbon dioxide and methane production of each goat were measured for 24 h in open-circuit respiration chambers described elsewhere (Aguilera & Prieto, 1986), and heat production (HP) was calculated according to the equation of Brouwer (1965). Measurements of HP were staggered as only two chambers were available. At the end of each balance experiment, the goats were fasted for 72 h and then, after a concomitant 48 h adaptation period to the respiration procedures, HP was also measured for 24 h. All animals had previously been trained to confinement and to the routine procedures of the chamber operations. As difficulties had been experienced in collecting urine in the confined space of the respiration chambers, no collection of urine was made during the HP measurements.

Chemical analysis

Total N in feeds, urine and wet faeces was determined by a Kjeldahl procedure using mineralization (Block Digestor Selecta S-509) and distillation units (Büchi Laboratoriums

Technik AG, Flawil, Switzerland; working capacity from 100 to 500 ml) and titration units from Metrom AG, Herisau, Switzerland (Dosimat 655, Digital pH-Meter 632 and Impulsomat 614). Crude protein was calculated from the N content using the factor 6·25. The gross energy of feeds and freeze-dried faeces and urine was measured in an adiabatic bomb calorimeter (Gallenkamp & Co. Ltd, London). Samples were freeze-dried in a polyethylene sheet of known energy value and their gross energy values were obtained by difference. Dry matter and organic matter determinations were carried out by standard procedures (Association of Official Analytical Chemists, 1975).

Statistical treatment

The main effects of the experiments were analysed using a split-plot ANOVA (Snedecor & Cochran, 1980), which was arranged as follows: experiments (1 df); live weight blocks within experiments (2 df); between goats (12 df), in the main plot analysis, and periods (1 df); diets (1 df); experiments × diets (1 df); experiments × periods (1 df), in the sub-plot analysis. When the analysis was significant, pairwise comparisons were made using the suitable standard error of difference (SED). Regression analysis was used throughout, with values being pooled whenever appropriate.

RESULTS

Digestibility and N balance

Table 2 shows the apparent digestibility and the energy content of the experimental diets, the digestibility of barley being calculated by difference. Values from the two consecutive experiments performed with the goats (i.e. Expts 1 and 2) are presented separately. Significant differences in apparent digestibility and metabolizability of energy between diets but not between experiments were found.

The N balance results appear in Table 3. The mean N retention during Expt 2 was higher than in Expt 1 as the result of a greater dietary N content and a slightly better utilization of the N absorbed. Also, the higher N content of the diets based on lucerne hay can account for the differences in N retention observed between diets. When N retention (NR) was regressed *v*. N intake (NI) (g/kg $W^{0.75}$ per d), two separate linear relationships, one for the lucerne diet and one for the mixed diet, were calculated. As these separate regressions did not differ significantly one from the other, a composite regression was established on pooled values:

$$NR = 0.264\,(\text{SE } 0.022)\,NI - 0.108\,(\text{SE } 0.009),\ r\,0.907, \text{RSD } 0.050, \quad (1)$$

where RSD is the residual standard deviation, which suggested that at N equilibrium a daily intake of 409 mg N/kg $W^{0.75}$ per d is required. In addition, the value of N balance at zero NI from this equation gives an estimation of the total endogenous nitrogen losses (TEN; 108 mg N/kg $W^{0.75}$ per d).

Endogenous urinary N losses (EUN) were calculated from the intercept of the regression of urinary N (UN) *v*. NI (g/kg $W^{0.75}$ per d). The composite regression was:

$$UN = 0.336\,(\text{SE } 0.028)\,NI + 0.119\,(\text{SE } 0.011),\ r\,0.911, \text{RSD } 0.062, \quad (2)$$

which indicates a value for EUN of 119 mg N/kg $W^{0.75}$ per d.

Energy balance

Table 4 shows the energy balance of goats fasted or fed at about maintenance level. The mean energy balance was close to maintenance and slightly negative for the mixed diet and the lucerne diet respectively. Energy intake during Expt 2 was higher than in Expt 1 and this fact is attributed to an underestimation made when predicting the ME content of the

Table 2. *Apparent digestibility (%) and energy content of the experimental diets*
(Values presented are means of eight observations)

Diet…	Mixed diet		Lucerne (*Medicago sativa*) hay-based diet		Barley*		SED (12 df)		Statistical significance of difference between:	
Expt no.…	1	2	1	2	1	2	Between experiments	Between diets	Experiments	Diets
Dry matter (DM)	62·4	63·9	48·5	50·7	81·3	86·5	1·05	1·03	NS	$P < 0·001$
Organic matter	64·6	67·3	50·5	53·1	82·0	88·8	0·97	1·13	$P < 0·05$	$P < 0·001$
Crude protein (nitrogen × 6·25)	63·0	64·2	61·1	61·9	67·0	71·2	0·95	1·20	NS	NS
DE/GE	61·1	62·2	47·5	47·8	79·9	82·9	1·23	1·12	NS	$P < 0·001$
DE (MJ/kg DM)	11·34	11·12	8·90	8·38	14·64	15·33	—	—	—	—
ME/GE	51·0	52·8	39·2	40·1	67·3	71·0	1·25	1·19	NS	$P < 0·001$
ME (MJ/kg DM)	9·46	9·45	7·34	7·02	12·33	13·62	—	—	—	—

SED, standard error of difference; NS, not significant; DE, digestible energy; GE, gross energy; ME, metabolizable energy.
* Calculated by difference.

Table 3. *Nitrogen balance of goats fed at about maintenance level (g/kg body-weight$^{0·75}$ per d)*
(Values presented are means of eight observations)

Diet…	Mixed diet		Lucerne (*Medicago sativa*) hay-based diet		SED (12 df)		Statistical significance of difference between:	
Expt no.…	1	2	1	2	Between experiments	Between diets	Experiments	Diets
N intake	1·01	1·30	1·29	2·04	0·084	0·111	$P < 0·001$	$P < 0·001$
Faecal N	0·38	0·47	0·50	0·78	0·016	0·039	$P < 0·001$	$P < 0·001$
Apparent digestible N	0·63	0·83	0·79	1·26	0·072	0·094	$P < 0·001$	$P < 0·01$
Urinary N	0·47	0·55	0·58	0·84	0·021	0·032	$P < 0·001$	$P < 0·001$
N retained	0·16	0·28	0·21	0·42	0·015	0·027	$P < 0·001$	$P < 0·01$

SED, standard error of difference.

Table 4. *Energy balance (kJ/kg body-weight$^{0.75}$ per d) of goats fed at about maintenance level or fasted*
(Values presented are means of eight observations)

Diet …	Mixed diet		Lucerne (*Medicago sativa*) hay-based diet		SED (12 df)		Statistical significance of difference between:		Fasting				Level of statistical significance
									Expt 1		Expt 2		
Expt no. …	1	2	1	2	Between experiments	Between diets	Experiments	Diets	Mean	SE	Mean	SE	
Live wt (kg)	27·6	27·3	28·6	29·2	0·72	0·72	NS	$P < 0.05$	26·1	0·35	26·5	0·65	NS
Gross energy intake	854	912	920	1067	19·2	21·4	$P < 0.001$	$P < 0.001$	—		—		
Energy in faeces	333	345	485	556	14·5	25·5	$P < 0.05$	$P < 0.001$	—		—		
Digestible energy intake	521	567	435	511	16·8	18·5	$P < 0.001$	$P < 0.01$	—		—		
Energy in urine	29	23	35	36	2·9	2·7	NS	$P < 0.01$	—		—		
Energy in methane	58	63	42	47	1·7	2·2	$P < 0.05$	$P < 0.001$	—		—		
Metabolizable energy intake	434	481	358	428	14·7	16·8	$P < 0.001$	$P < 0.01$	—		—		
Heat production	431	481	417	443	21·6	17·0	$P < 0.01$	NS	312	10·3	335	14·2	NS
Energy retained	3	0	−59	−15	23·0	12·2	$P < 0.001$	$P < 0.01$	−312	10·3	−335	14·2	NS

SED, standard error of difference; NS, not significant.

Table 5. *Estimates of energy requirements for maintenance (ME_m) of adult goats fed at two fixed levels of intake*

(All energy values are expressed as kJ/kg body-weight$^{0.75}$ per d)

Diet	Linear regression equations	RSD	r	ME_m*	SE
Lucerne hay	RE = −326 (SE 8)+0·730 (SE 0·05) MEI	35·69	0·966	447	52·9
Mixed diet	RE = −325 (SE 9)+0·739 (SE 0·04) MEI	38·95	0·969	440	56·3
Overall	RE = −324 (SE 8)+0·732 (SE 0·04) MEI	39·29	0·969	443	56·1

RE, total energy retention; MEI, metabolizable energy intake; RSD, residual standard deviation.
* Value for MEI when RE = 0.

lucerne hay. Significant differences in live weight between diets were observed, which can be accounted for by differences in gut fill. In order to convert fasted weight into weight at maintenance, empty-body-weight (EBW, kg) was related to live weight (LW, kg) by the equation: EBW = LW/1·08 (Blaxter *et al.* 1966). In the experiments with animals fed at about maintenance level, the overall apparent body energy balance was negative. In a small number of cases slightly positive energy retentions were found and then a correction for the intake of ME (MEI) above maintenance was made, as the efficiency of use of ME for production (k_f) is much lower than that for maintenance (k_m). To this purpose, k_f was estimated according to the equation: $k_f = 0{\cdot}78\ q_m + 0{\cdot}006$ (Blaxter, 1974), where q_m is the metabolizability of the diet.

Mean values of fasting HP were 312 and 355 kJ/kg W$^{0.75}$ per d in Expts 1 and 2 respectively (Table 4). EUN was assumed to be 119 mg/kg W$^{0.75}$ per d (equation 2). No statistical differences with respect to fasting HP between experiments were found.

Measurements of energy balance of goats at the two feeding levels considered (about maintenance and fasting) have been used to predict the energy intake at zero energy retention, using a linear regression of energy retention (RE) *v*. MEI:

$$\text{RE}\,(\text{kJ/kg W}^{0.75}\text{ per d}) = -a + b \times \text{MEI}\,(\text{kJ/kg W}^{0.75}\text{ per d}), \qquad (3)$$

where RE = MEI − total HP in kJ/kg W$^{0.75}$ per d, b is k_m, and a is fasting HP. The equation predicts ME for maintenance (ME_m) when RE = 0 and also provides an estimate of the efficiency of utilization of ME for maintenance (k_m). Table 5 summarizes the values obtained for ME_m and k_m for the lucerne diet and for the mixed diet (447 and 440 kJ/kg W$^{0.75}$ per d and 0·73 and 0·74 respectively). As no statistical differences attributable to the diet were found, a composite regression was calculated giving for ME_m a value of 443 kJ/kg W$^{0.75}$ per d and for k_m a value of 0·73.

DISCUSSION

Digestibility and N balance

The digestibility and metabolizability coefficients for energy and the energy values of lucerne hay and barley were within the range of expected values.

Values for the intercepts from equations 1 and 2 were not statistically different. Thus estimates of both the TEN (equation 1) and EUN (equation 2) suggest that at the MEI close to maintenance, EUN is the main endogenous N loss, in agreement with studies by Ørskov & MacLeod (1982).

EUN can be estimated by direct measurement (Rajpoot, 1979; Mudgal & Singh, 1981) or by regression (equation 2), the former approach giving values somewhat lower than the latter. Reported values for EUN in non-lactating goats range from 40 mg N/kg W$^{0.75}$ per d in dry dwarf goats (Akinsoyinu *et al.* 1976) to 240 mg N/kg $W^{0.75}$ per d in castrated male goats (Itoh *et al.* 1978). The value of 119 mg N/kg $W^{0.75}$ per d obtained in the present paper from equation 2 is close to those obtained by Rajpoot *et al.* (1980), Reynolds (1981) and Guerrero (1982) in castrated male goats (115, 120 and 123 mg N/kg $W^{0.75}$ per d respectively) and somewhat lower than those of Majumdar (1960) and Devendra (1982) in dry goats (126 and 133 mg N/kg $W^{0.75}$ per d respectively). Our value for EUN is higher than EUN losses of 97 mg N/kg $W^{0.75}$ per d, which can be calculated for a sheep of 30 kg live weight (LW) from the following equation (Agricultural Research Council, 1980): EUN = 0·02348 LW + 0·54.

The maintenance requirement for N estimated in the present paper from equation 1 is lower than the values of 485 mg dietary N/kg $W^{0.75}$ per d (Itoh *et al.* 1978) and 688 mg dietary N/kg $W^{0.75}$ per d (Reynolds, 1981). Akinsoyinu *et al.* (1976) obtained a value as low as 140 mg dietary N/kg $W^{0.75}$ per d in West African dwarf goats.

As discussed later, in our experiments ME_m was estimated as 443 kJ/kg $W^{0.75}$ per d. According to the Agricultural Research Council (1980), this amount of ME would yield 555 mg rumen microbial N, supplying 233 mg/kg $W^{0.75}$ of net amino acid-N for tissue synthesis, a value which exceeds the TEN obtained in our experiments. Consequently, the goat's requirement for amino acid-N would be met by rumen microbial protein synthesis, which is in agreement with statements by Roy *et al.* (1977) for other ruminants fed at an energy level close to maintenance.

Respiration measurements

There are very few direct estimations of fasting HP for adult non-lactating goats in the literature. Our overall value of 324 kJ/kg $W^{0.75}$ per d is close to that of Roy-Smith (1980) (331 kJ/kg $W^{0.75}$ per d) but lower than those reported by Brody (1945) and Fujihara *et al.* (1973) (386 and 357 kJ/kg $W^{0.75}$ per d respectively) and higher than the values for fasting metabolism in sheep published by the Agricultural Research Council (1980). In addition, in our laboratory (Aguilera *et al.* 1986) a value of 272 kJ/kg $W^{0.75}$ per d was estimated for adult wethers following the same experimental approach as that described in the present paper, a value which was also found by Roy-Smith (1980) in his comparative study between goats and sheep.

In addition, following the equation proposed by the Agricultural Research Council (1980) for mixed diets: $k_m = 0{\cdot}207\ q_m + 0{\cdot}62$, values of k_m ranging from 0·73 to 0·75 would be derived from our experiments, which compare very well with those reported in the present paper (0·73) (Table 5).

As shown in Table 5, ME_m values were 447 and 440 kJ/kg $W^{0.75}$ per d for goats fed on the lucerne hay and the mixed diet respectively. As no statistical differences attributable to the diet were found, a composite regression was calculated giving for ME_m a value of 443 kJ/kg $W^{0.75}$ per d.

To our knowledge, all reported values on ME_m for goats have been obtained by feeding trials. Our value of 443 kJ/kg $W^{0.75}$ per d, which is based on calorimetry results, is slightly higher than that estimated by the National Research Council (1981) for goats (424 kJ ME/kg $W^{0.75}$ per d), a value which is derived from pooled means of experimental values. The ME_m obtained in the present work is in the range of published values on fattening cattle and dry cows (from 418 to 469 kJ/kg $W^{0.75}$ per d), which have been summarized by the Agricultural Research Council (1980). From our results, a maintenance requirement of 5·7 MJ ME/d can be derived for goats of 30 kg LW. This value is higher than that reported by the Agricultural Research Council (1980) for sheep of similar weight (5·0 MJ ME/d) a finding which is in agreement with the higher fasting metabolism observed in goats.

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