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Protein and energy metabolism of lactating Granadina goats

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Twelve goats of the Granadina breed in mid- and late lactation were used in two consecutive years to determine their protein and energy requirements for lactation. The animals were individually fed on diets based on pelleted lucerne (*Medicago sativa*) hay and barley. A total of six balance experiments were carried out. Gas exchange was measured using open-circuit respiration chambers. Milk yield ranged widely from 0·649 to 1·742 kg/d in the first year and from 0·222 to 1·989 kg/d in the second year, a steady decline in milk output being observed as lactation progressed. Milk composition remained rather constant during the midstage of lactation, with an average content (/kg milk) for total solids, total nitrogen, fat and gross energy of 149·7 g, 5·39 g, 58·8 g and 3·59 MJ respectively. Total endogenous N, endogenous urinary N and maintenance requirement for N in lactating goats were estimated to be 244, 218 mg N/kg body-weight $(W)^{0.75}$ per d and 478 mg total N/kg $W^{0.75}$ per d respectively from regression equations. A constant efficiency of use of dietary N for milk N plus retained N of 51·0% was found. By regressing milk energy plus apparent body energy retention or loss on metabolizable energy (ME) intake, the maintenance energy requirement was estimated to be 401 kJ ME/kg $W^{0.75}$ per d. When estimating the corrected milk yield as milk energy + (0·84 × negative energy retention) + (1·05 × positive energy retention), regression analysis indicated that the overall efficiency of use of ME for lactation was 66·7%. Also, from a plot of apparent body energy retention *v*. milk energy yield, both expressed as a percentage of ME intake above maintenance, the efficiency with which ME was used to promote energy retention in the body during lactation was calculated to be 0·907 times that for milk secretion.

Energy metabolism: Protein metabolism: Goats

Although nutrient requirements are now relatively well-defined in sheep and cattle, there is still a lack of reliable information in the literature about the nutritional needs of lactating goats. Most available information has relied on extrapolations of values derived from cattle and sheep experiments. Nevertheless, because of the specific physiological features of the goat, this approach needs further validation. Previous reports on protein and energy requirements of lactating goats have been derived mainly from feeding trials and only a limited number of studies have published results on nitrogen and energy balance trials. N requirements for maintenance and milk production in lactating goats have been obtained by N balance studies by Khouri (1974), Sengar (1980), Rajpoot *et al.* (1981), Brun-Bellut *et al.* (1984) and Ciszuk & Lindberg (1985). These studies indicate that, in goats, the N requirements for maintenance might be in agreement with reported findings for dairy cattle and sheep and also that the efficiency of use of dietary N for milk-protein synthesis appears to be somewhat lower than values given for dairy cattle. To our knowledge, the work of Armstrong & Blaxter (1965), in which energy requirements for maintenance were estimated from measurements of fasting heat production, is the only study which examines the energy requirements for maintenance or production in the lactating goat. Due to the scarcity of original studies directly concerned with the assessment of nutrient requirements of the goat, the present work aims to provide additional information on this subject and to define specifically the energy and protein requirements of the lactating Granadina goat.

Table 1. *Chemical composition (g/kg dry matter) and energy content (MJ/kg dry matter) of the experimental feed ingredients*

	Pelleted lucerne (*Medicago sativa*) hay		Barley	
Lactation no ...	1	2	1	2
Organic matter	895	863	980	976
Crude protein (nitrogen × 6·25)	162	212	107	109
Apparent digestible N	15·8	21·0	11·5	12·4
Gross energy	18·73	17·53	18·31	18·50
Digestible energy	8·90	8·38	14·64	15·33
Metabolizable energy	7·34	7·02	12·33	13·62
Dry matter (g/kg)	883	906	891	894

MATERIALS AND METHODS

Animals, diets and feeding

Twelve goats of the Granadina breed in mid- and late lactation were used in two consecutive years. All animals had previously completed one lactation. During the last 6 weeks of pregnancy and also over the course of lactation they were allowed a diet based on pelleted lucerne (*Medicago sativa*) hay and barley. These feed ingredients had been evaluated in a previous experiment with adult castrated male goats (Prieto *et al.* 1990). The composition and nutritive value of these ingredients appear in Table 1. The diets also included, on a daily basis, 6 g sodium chloride and 4 g mineral plus vitamin premix containing (g/kg): zinc 11·3, magnesium 45·0, manganese 7·9, iron 5·5, copper 2·2, cobalt 0·11, iodine 0·11, selenium 0·023, retinol 600 mg, cholecalciferol 10 mg. Water was always available. Individual animal feed intake was re-adjusted every 7 d to provide sufficient energy for maintenance plus milk yield based on the body-weight and milk yield observed in the preceding week, except during the balance periods when intake remained fixed. Maintenance was taken as 0·548 MJ metabolizable energy (ME)/kg body-weight $(W)^{0·75}$ per d and the requirement for milk production as 4·9 MJ ME/kg 4% fat-corrected milk (Aguilera *et al.* 1984). The diets were also formulated theoretically to provide sufficient rumen-degradable N (RDN) and undegradable N (UDN) to meet the requirements for maintenance plus milk production, as stated by the Agricultural Research Council (1980). The diets provided, on average, 1·30 g RDN/MJ ME and 0·32 g UDN/MJ ME.

The goats were in lactation for 6–10 weeks, were then dosed with Tetramisol (Sobrino, S.A.) against internal parasites and allocated at random to metabolism cages in a temperature-controlled room (24°) on a 12 h light–12 h dark cycle. A total of six balance experiments were carried out, two in the first lactation and four during the second lactation. Each balance experiment consisted of a 20 d preliminary period followed by a 12 d collection period. After the second balance of the second lactation, the goats were removed from the metabolic cages and fed, as previously described, for 4 months before completing the remaining two balances. The 12 d collection periods were initiated when, on average, the goats were at weeks 9 and 14 of lactation in the first lactation and weeks 13, 18, 35 and 40 of the second lactation. The animals were fed once daily at 09.00 hours. The pelleted lucerne hay:barley ratio in the rations, on a dry matter basis, ranged from 35:65 to 46:54. Dry matter intakes of feed ingredients over the course of lactations appear in Table 2. Refusals of lucerne hay and barley were collected and recorded separately. Samples of feed and refusals were taken daily and samples for each collection period were pooled for

Table 2. *Mean values of live weight (kg), intake (g/d), milk yield (g/d) and milk composition (g/kg) of lactating goats in mid- and late stages of two consecutive lactations*

(Values presented are means with their standard errors for twelve observations)

Lactation no....	1		2			
Period of lactation (weeks)	9	14	13	18	35	40*
Live wt (kg)						
Mean	34·5	34·1	40·6	40·1	40·6	41·4
SE	1·14	1·38	1·58	1·44	1·49	1·69
Dry matter intake						
Lucerne (*Medicago sativa*) hay						
Mean	416	394	646	512	453	453
SE	29·4	41·4	37·5	26·3	0·1	0
Barley						
Mean	749	734	970	908	536	536
SE	32·3	44·5	37·6	34·9	0·2	0
Milk yield						
Mean	1240	1094	1506	1344	483	381
SE	76·6	66·2	112·6	109·6	58·9	52·0
Total solids						
Mean	146·5	149·2	151·2	151·7	203·0	193·2
SE	2·74	2·53	2·32	2·93	8·88	4·69
Total nitrogen						
Mean	5·09	5·46	5·59	5·43	7·72	7·44
SE	0·078	0·137	0·125	0·128	0·650	0·421
Fat						
Mean	59·4	58·8	57·1	59·7	ND	ND
SE	1·850	3·180	1·425	2·876	ND	ND
Gross energy (MJ/kg)						
Mean	3·63	3·60	3·49	3·65	5·36	5·13
SE	0·106	0·089	0·081	0·091	0·292	0·150

ND, not determined.
* Means of ten observations.

analysis. Faeces and urine were collected daily and representative samples were taken and stored at −25° until required for analysis. No preservative for urine was used. The animals were weighed at the beginning and end of each balance period.

Respiration measurements

Measurements of heat production (HP) were staggered as only two chambers were available. Throughout each balance experiment, on days 2, 4, 6, 8, 10 or 12 of each 12 d collecting period, after a 24 h adaptation period, oxygen consumption and carbon dioxide and methane productions of each goat were measured for 24 h in open-circuit respiration chambers described elsewhere (Aguilera & Prieto, 1986). HP was calculated from the respiratory exchange using the factors of Brouwer (1965). All animals had been previously trained to confinement and to the routine procedures of the chamber operations by feeding them in the chambers for at least three separate 24 h periods before respiration measurements. 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.

Milk recording and analysis

The goats were hand-milked once daily at 08.00 hours and milk yield was recorded throughout the lactation. Collection of milk was made over two consecutive 5 d periods over the course of each balance experiment. Daily milk samples were preserved with potassium dichromate and kept at 4°. Pooled samples (from each milking) were analysed for total solids, fat, N and gross energy contents.

Analytical methods

N in feeds, wet faeces, urine and milk was measured by a Kjeldahl procedure using mineralization (Block Digestor Selecta S-509) distillation units (Büchi Laboratoriums Technik AG. Flawil, Switzerland; working capacity from 100 to 500 ml) and titration units from Metron 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 factor 6·38 was used for milk samples. Feeds were analysed for dry matter by oven drying at 103° for 24 h and for organic matter by ashing at 550°. Total solids in milk were determined by freeze-drying 5 ml of a well-mixed sample. Gross energy in feeds and in freeze-dried faeces, urine and milk was determined in an automated adiabatic calorimeter (Gallenkamp & Co. Ltd, London). Samples of faeces, urine and milk were freeze-dried on a polyethylene sheet of known energy value and their gross energy values were obtained by difference. Other analyses were carried out by standard procedures (Association of Official Analytical Chemists, 1975).

RESULTS

Milk yield and composition

Two goats were withdrawn from the experiments in the fourth balance period of the second lactation due to their extremely low milk yield (< 0·050 kg/d). The mean daily milk production of goats in mid- and late lactation on two consecutive years is shown in Table 2. Milk yield ranged widely from 0·649 to 1·742 kg/d in the first lactation and from 0·222 to 1·989 kg/d in the second lactation. Within lactation, milk yield declined progressively between consecutive periods, this effect being particularly noticeable in the second lactation. Milk composition remained rather constant during the midstage of lactation (weeks 9–18 of lactation), the average content (/kg milk) for total solids, total N, fat and gross energy being 149·7 g, 5·39 g, 58·8 g and 3·59 MJ respectively. These variables increased during the late state of lactation (weeks 35 and 40 of the second lactation) and this change in composition moved in the opposite direction to the changes in milk yield.

N balance

Table 3 shows the daily N balance of lactating goats over the course of the balance experiments. N intake (NI) ranged from 1·17 to 2·24 and from 1·24 to 2·75 g/kg $W^{0.75}$ per d and values for N balance (milk N plus retained N, NB) from 0·29 to 1·02 and from 0·29 to 1·26 g/kg $W^{0.75}$ per d in the first and second lactation experiments respectively.

When NB was regressed *v*. NI, a linear regression was obtained in each experiment. As these separate regressions did not differ significantly one from the other, a composite regression (Fig. 1(*a*)) was established on pooled data:

$$\mathrm{NB} = 0{\cdot}510\ (\mathrm{SE}\ 0{\cdot}038)\ \mathrm{NI} - 0{\cdot}244\ (\mathrm{SE}\ 0{\cdot}016),\quad r\ 0{\cdot}855,\quad \mathrm{RSD}\ 0{\cdot}132, \tag{1}$$

where NB and NI are expressed as g/kg $W^{0.75}$ per d and RSD is the residual standard deviation. The overall efficiency of use of dietary N for NB was 51·0%. At N equilibrium a daily intake of 478 mg N/kg $W^{0.75}$ per d is required. From equation 1 a value for total endogenous N (endogenous urinary N plus metabolic faecal N, TEN) of 244 mg/kg $W^{0.75}$ per d is obtained.

Endogenous urinary N (EUN) was estimated from a plot of urinary N (UN) against NI.

Table 3. *The daily nitrogen balance (g/kg body-weight$^{0.75}$) of goats over the course of two consecutive lactations, each period consisting of 12 d*

(Values presented are means with their standard errors for twelve observations)

Lactation no....	1		2			
Period of lactation (weeks)	9	14	13	18	35	40*
N intake						
Mean	1·72	1·56	2·37	2·04	1·56	1·53
SE	0·073	0·095	0·111	0·107	0·041	0·044
Faecal N						
Mean	0·59	0·56	0·81	0·68	0·50	0·53
SE	0·028	0·036	0·039	0·037	0·031	0·015
Apparent digestible N						
Mean	1·13	1·00	1·56	1·36	1·06	1·00
SE	0·046	0·059	0·072	0·072	0·032	0·028
Urine N						
Mean	0·36	0·40	0·55	0·68	0·55	0·52
SE	0·018	0·035	0·035	0·035	0·037	0·029
N balance (milk N + body N retention)						
Mean	0·77	0·60	1·01	0·68	0·51	0·48
SE	0·041	0·049	0·068	0·066	0·041	0·035
Milk N output						
Mean	0·45	0·43	0·53	0·46	0·17	0·16
SE	0·033	0·036	0·037	0·036	0·023	0·017
Apparent body N retention						
Mean	0·32	0·17	0·48	0·22	0·34	0·32
SE	0·030	0·044	0·042	0·037	0·035	0·034

* Means of ten observations.

The composite regression was:

$$UN = 0{\cdot}154\ (\text{SE}\ 0{\cdot}027)\ NI + 0{\cdot}218\ (\text{SE}\ 0{\cdot}025), \quad r\ 0{\cdot}678, \quad \text{RSD}\ 0{\cdot}077, \qquad (2)$$

where UN and NI are expressed as g/kg $W^{0.75}$ per d.

From equation 2 a value of 218 mg/kg $W^{0.75}$ per d for EUN is obtained.

Two significant separate relationships between milk N output (MN) and dietary N intake (NI) for the two lactations were found (Fig. 1(*b*)):

$$MN = 0{\cdot}297\ (\text{SE}\ 0{\cdot}041)\ NI - 0{\cdot}068\ (\text{SE}\ 0{\cdot}103), \quad r\ 0{\cdot}737, \quad \text{RSD}\ 0{\cdot}080; \quad n\ 24\ \text{(1st lactation)}, \qquad (3)$$

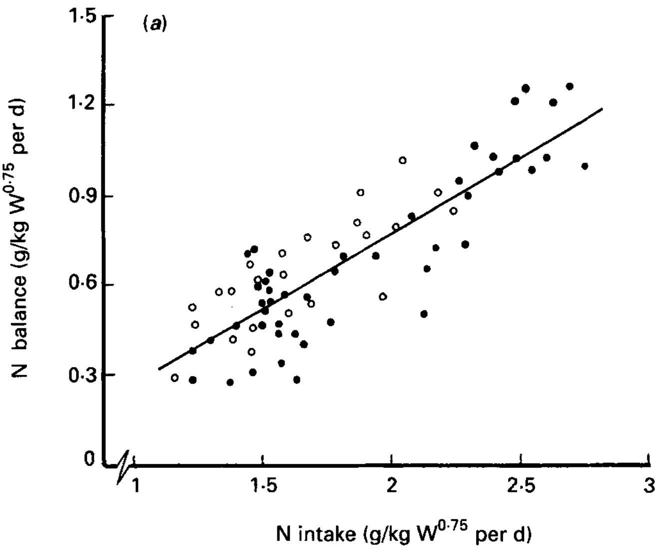
$$MN = 0{\cdot}388\ (\text{SE}\ 0{\cdot}028)\ NI - 0{\cdot}397\ (\text{SE}\ 0{\cdot}055), \quad r\ 0{\cdot}890, \quad \text{RSD}\ 0{\cdot}086; \quad n\ 46\ \text{(2nd lactation)}, \qquad (4)$$

where MN and NI are expressed as g/kg $W^{0.75}$ per d.

Energy metabolism

The daily energy balance of goats over the course of two consecutive lactations appears in Table 4. Apparent body energy retention was calculated by subtracting the energy output in faeces, urine, methane, HP and milk from the gross energy intake.

As had been planned, a considerable variation in milk production within animals was observed, as well as large changes in apparent body energy retention, which ranged from −324 to 353 kJ/kg $W^{0.75}$ per d. The overall apparent body energy balance was negative in the first lactation and positive in the second lactation.



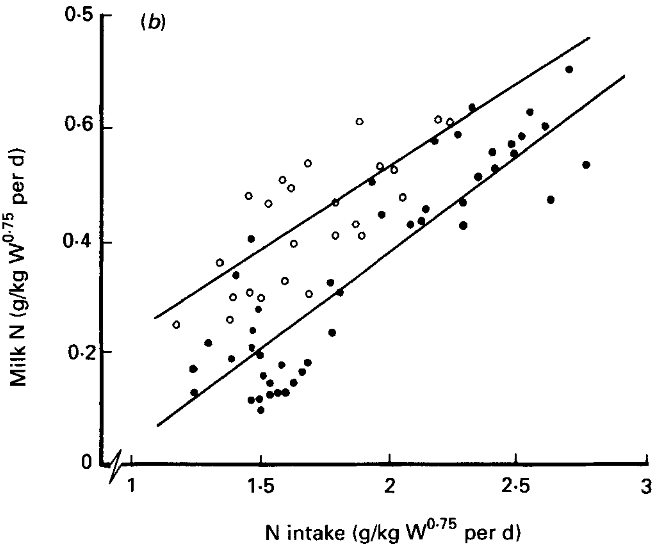


Fig. 1. Nitrogen balance (milk N+retained N) (*a*) or milk N (*b*) *v*. N intake, all expressed as g/kg body-weight $(W)^{0.75}$ per d, in lactating goats during two consecutive lactations (no. 1 (○), no. 2 (●)).

Milk energy yield (YE) plus apparent body energy retention or loss (RE) was regressed *v*. ME intake. The best fitting line gave a linear relationship. As there were no statistical differences between separate regressions established within lactation experiments, an overall regression on pooled values was obtained:

$$YE+RE = 0{\cdot}669 \ (\text{SE } 0{\cdot}037)\ ME - 268\ (\text{SE } 7{\cdot}1), \quad r\ 0{\cdot}909, \quad \text{RSD } 59{\cdot}5, \qquad (5)$$

where YE, RE and ME are all expressed as kJ/kg $W^{0.75}$ per d. This equation provides an estimate of the efficiency of use of ME for productive purposes (66·9%) and also predicts the maintenance energy requirement (ME_m), when YE+RE = 0, as 401 kJ/kg $W^{0.75}$ per d.

Table 4. *The daily energy balance (kJ/kg body-weight$^{0.75}$) of goats over the course of two consecutive lactations, each period consisting of 12 d*

(Values presented are means with their standard errors for twelve observations)

Lactation no....	1		2			
Period of lactation (weeks)	9	14	13	18	35	40*
Gross energy intake						
Mean	1564	1422	1792	1596	1119	1103
SE	58·7	77·0	79·6	81·7	28·6	31·3
Energy in faeces						
Mean	500	450	546	463	366	361
SE	25·5	33·6	26·4	25·6	9·3	10·2
Energy in urine						
Mean	80	87	79	50	38	17
SE	7·8	10·1	8·8	9·9	3·0	3·4
Energy in methane						
Mean	89	83	117	111	97	97
SE	8·0	6·9	6·7	8·0	2·4	2·4
Metabolizable energy intake						
Mean	895	802	1050	972	618	628
SE	26·8	36·1	44·7	47·1	16·0	17·0
Heat production						
Mean	594	562	611	544	465	464
SE	20·2	21·5	15·7	30·9	11·3	8·1
Total energy retained (YE+RE)						
Mean	301	240	439	428	153	164
SE	16·0	33·6	38·7	33·3	15·1	13·7
Milk energy (YE)						
Mean	326	286	329	308	130	118
SE	30·2	23·5	23·1	23·3	21·4	15·2
Body energy retention (+) or loss (−) (RE)						
Mean	−25	−46	110	120	23	46
SE	25·8	39·3	20·4	25·0	26·7	19·8

* Means of ten observations.

The efficiency of use of ME for lactation when there is no change in body-energy stores (k_1) was calculated according to the Agricultural Research Council (1980). Energy lost from the body, indicating a mobilization of body fat reserves in support of milk secretion, was assumed to be used for milk synthesis with an efficiency of 0·84 and the concomitant energy storage during lactation was taken to be 0·95 times as efficient as milk secretion. Consequently, the corrected milk energy yield (YE_c) was estimated as milk energy (milk E)+(0·84 × negative energy retention)+(1·05 × positive energy retention).

When regressing YE_c *v*. ME intake (Fig. 2), the following equation was obtained with values from both positive and negative energy retentions:

$$YE_c = 0{\cdot}667 \text{ (SE } 0{\cdot}036) \text{ ME } - 258 \text{ (SE } 6{\cdot}8), \quad r\ 0{\cdot}914, \quad \text{RSD } 57{\cdot}3, \qquad (6)$$

where YE_c and ME are expressed as kJ/kg $W^{0.75}$ per d. This equation, giving the best fitting line, indicates an efficiency of use of ME for lactation of 66·7%.

In case of concomitant energy deposition the equation found was:

$$YE_c = 0{\cdot}657 \text{ (SE } 0{\cdot}038) \text{ ME } - 237 \text{ (SE } 7{\cdot}3), \quad r\ 0{\cdot}935, \quad \text{RSD } 49{\cdot}4; \quad n\ 46, \qquad (7)$$

where YE_c and ME are both expressed as kJ/kg $W^{0.75}$ per d. In this case, when milk energy yield (YE) and apparent body energy retention (RE) were both expressed as a percentage

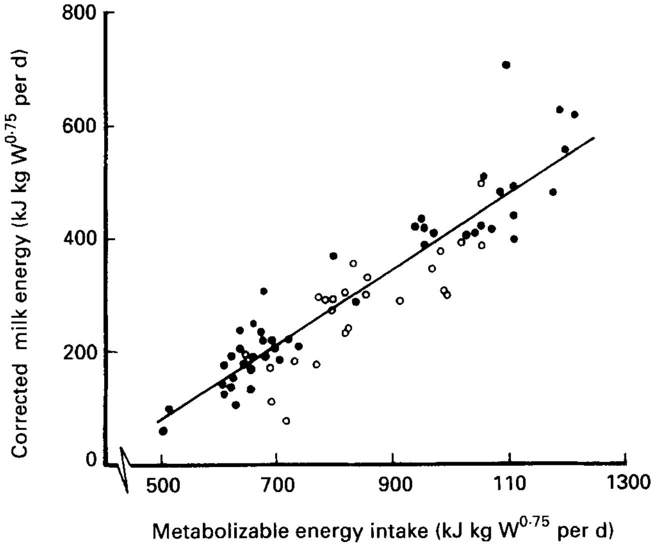


Fig. 2. Corrected milk energy yield *v.* metabolizable energy intake, all expressed as kJ/kg body-weight $(W)^{0.75}$ per d, in lactating goats during two consecutive lactations (no. 1 (○), no. 2 (●)).

of ME intake above maintenance (ME_p) using for ME_m the value of 401 kJ/kg $W^{0.75}$ per d (equation 5), and RE was regressed *v.* YE, according to the procedure described by Armstrong & Blaxter (1965) in experiments with lactating goats, the following equation was obtained:

$$RE/100\ kJ\ ME_p = -0.907\ (SE\ 0.088)\ YE/100\ kJ\ ME_p + 67.6\ (SE\ 1.62),$$

$$r\ 0.671,\quad RSD\ 12.47,\quad n\ 46. \qquad (8)$$

Equation 8 suggests that a fall in milk energy yield of 1 kJ was associated with an increase in body energy store of 0·907. In addition, the intercept of this equation indicates that a change in milk production to zero milk energy secretion/100 kJ ME given above maintenance would result in an increase of body energy retention of 67·6 kJ. Alternatively, at zero body energy retention/100 kJ ME_p, the output of milk energy would be 74·5 kJ/100 kJ ME_p.

DISCUSSION

N balance

In the present work values of TEN and EUN losses of 244 and 218 mg/kg $W^{0.75}$ per d were obtained. These results suggest that in lactating goats EUN is by far the main endogenous N loss, in agreement with our results for non-lactating goats (Prieto *et al.* 1990).

There are wide variations between the few literature values of daily EUN losses for non-lactating goats, ranging from 40 mg N/kg $W^{0.75}$ per d in dwarf goats (Akinsoyinu *et al.* 1976) to 240 mg N/kg $W^{0.75}$ per d in castrated male goats (Itoh *et al.* 1978), although most of them are in the vicinity of 125 mg N/kg $W^{0.75}$ per d (Majumdar, 1960; Rajpoot *et al.* 1980; Reynolds, 1981; Devendra, 1982; Guerrero, 1982). The value of 218 mg N/kg $W^{0.75}$ per d derived from equation 2 is at the top of the range of the values mentioned previously, but compares well with the estimate of 229 mg N/kg $W^{0.75}$ per d found in lactating goats by Ciszuk & Lindberg (1985). It is higher than that of 119 mg/kg $W^{0.75}$ per d, which was obtained for non-lactating goats fed on similar diets in our laboratory (Prieto *et al.* 1990).

The results suggest that the lactating goat has an increased endogenous loss of urinary N in comparison with the non-productive goat.

The maintenance requirement for N in lactating goats estimated in the present paper from equation 1 (478 mg total N/kg $W^{0.75}$ per d) is in agreement with those of 477, 457 and 503 mg total N/kg $W^{0.75}$ per d which can be calculated from the experiments in lactating goats of Khouri (1974), Brun-Bellut *et al.* (1984) and Ciszuk & Lindberg (1985) respectively, assuming an average apparent digestibility for total dietary N of 70%. On the other hand, our requirement is lower than the values for lactating goats reported by Sengar (1980), which are in the range of 716–876 mg total N/kg $W^{0.75}$ per d, and by Rajpoot *et al.* (1981) (1131 mg total N/kg $W^{0.75}$ per d). Also, our value of 478 is higher than that of 409 mg total N/kg $W^{0.75}$ per d, which was obtained for non-lactating goats given similar diets (Prieto *et al.* 1990). This latter observation is consistent with the higher endogenous N losses found in the lactating animal in comparison with those observed in the castrated male goat.

Values for dairy cows from Wageningen (Boekholt, 1972) showed the relationship between the milk N output plus the N retained in tissues (NB) and the intake of apparently digested N (ND) of NB = 0·74 ND −22·26. The slope of this regression indicates an efficiency of use of ND for productive purposes which agrees well with that of 0·510 (equation 1) when an average apparent digestibility for total N of 0·70 is assumed.

Energy metabolism

The ME_m in the present paper was estimated to be 401 kJ/kg $W^{0.75}$ per d (equation 5), a value which is slightly lower than that observed in experiments (Prieto *et al.* 1990) with adult castrated male goats (443 kJ/kg $W^{0.75}$ per d). Consequently, no differences in metabolic rate at maintenance have been found between lactating and non-lactating goats in contrast to available results from dairy cows, suggesting that the lactating animal has a somewhat higher ME_m than the dry animal (Moe *et al.* 1970; Patle & Mudgal, 1977; Van Es & Van der Honing, 1979). No previous reports have been found based on calorimetric trials on energy requirements for maintenance or production in the lactating goat, with the exception of that of Armstrong & Blaxter (1965). Their experiment measured fasting HP (236 kJ/kg $W^{0.73}$ per d) and from this a maintenance requirement of 319 kJ/kg $W^{0.73}$ per d can be calculated assuming a constant efficiency for the use of ME for maintenance of 73·9%. Our estimate of ME_m is lower than those published for milking cows (510 kJ/kg $W^{0.75}$ per d, Moe *et al.* (1970); 523 kJ/kg $W^{0.75}$ per d, Van der Honing & Van Es (1974)) and higher than those reported for sheep of similar weight (318 kJ/kg $W^{0.75}$ per d, Agricultural Research Council (1980)).

The efficiency of use of ME for lactation of 66·7% obtained from equation 6 is slightly higher than the top value of the range of theoretical values based on biochemical considerations (0·60–0·65) and is about four percentage units higher than the value obtained from the equation $k_1 = 0{\cdot}35\, q_m + 0{\cdot}420$ (Agricultural Research Council, 1980) when the average metabolizability of the ration (q_m) of 0·58 found in the present experiments is taken. This increased efficiency may be attributed to the use of pelleted lucerne hay as a component of the experimental diets since pelleting has been proved to cause an increase in the efficiency of energy use for lactation (Van der Honing & Van Es, 1974). However, Armstrong & Blaxter (1965) reported a similar value of 69·1 for the efficiency of use of ME for milk synthesis. Therefore there appears to be very little difference in the efficiency of use of ME for lactation between goats, cattle or sheep. Also, from equation 6 it can be calculated that 5·38 MJ ME are required for the production of 1 kg goat milk with an average energy content of 3·59 MJ/kg or 4·20 MJ ME/kg 4% fat-corrected milk. The National Research Council (1981) gives a value of 5·21 MJ ME/kg 4%

fat-corrected milk based on a mean of four feeding trials. This value is similar to that of 5·1 MJ ME/kg 4% fat-corrected milk (Agricultural Research Council, 1980) for dairy cattle. French recommended allowances for dairy cattle are 4·35 MJ ME/kg 3·5% standard milk (Morand-Fehr *et al.* 1987).

Equation 8 predicts that the efficiency of concomitant energy storage during lactation is 0·91 times that for milk secretion. This value compares well with the value of 0·96 obtained by Armstrong & Blaxter (1965) in goats. Although the difficulty of estimating the efficiency with which ME is used to promote energy retention in the body during lactation has been widely recognized, most authors agree that this efficiency is higher than that in the non-lactating animal. Literature values range from 0·78 to 1·13 (Mollgaard, 1929; Armstrong & Blaxter, 1965; Moe *et al.* 1970; Van Es *et al.* 1970; Patle & Mudgal, 1977) and the Agricultural Research Council (1980) has assumed an efficiency of 0·95 times that for milk energy yield.

At present insufficient information is available to prove conclusively whether or not protein and energy requirements derived from other ruminants can be applied to the goat. On the basis of the results reported in the present paper it is proposed that the use of feeding systems based on values in cattle and sheep are likely to be suitable for lactating goats.

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