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Small Ruminant Research 16 (1995) 13–20

Small Ruminant Research

Energy and protein utilisation for maintenance and growth of Thai native and Anglo-Nubian × Thai native male weaner goats

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Accepted 25 April 1994

Abstract

Twenty-four Thai native (TN), 25% Anglo-Nubian (AN), 50% (AN) entire male weaner kids (each eight) (15.7 ± 0.45 kg BW) were used to compare growth and feed utilisation of these three goat genotypes at four levels of intake (maintenance (M), 1.2 M, 1.4 M and ad libitum). TN kids had lower ($P < 0.05$) DM and OM digestibility coefficients than did 25 and 50% AN kids. Kids fed ad libitum had higher ($P < 0.05$) DM, OM, NDF and ADF digestibility coefficients than did kids fed 1.2 M and M intakes. There was no significant main effect of genotype on goat growth rates (g/d and g/kg$^{0.75}$/d), although 50% AN goats fed ad libitum had higher ($P < 0.05$) growth rates (g/d) than did 25% AN and TN goats given the same level of intake. As expected, growth rates increased as feed intakes increased from maintenance (1.3 g/kg$^{0.75}$/d) to ad libitum (10.0 g/kg$^{0.75}$/d). Linear regression equations combined across genotypes were used to calculate maintenance and growth requirements for energy and protein for these goats. Maintenance energy requirement was 376 ± 18.5 kJ ME/kg$^{0.75}$/d and the ME requirement for BW gain was 25.9 ± 2.4 kJ ME/g. Minimum N requirements for maintenance of BW was 4.4 ± 0.24 g DCP/kg$^{0.75}$/d and requirements for BW gain was 0.204 ± 0.033 g DCP/ g gain. Results from the present experiment suggest that Thai native and AN × Thai native goats have similar protein and energy requirements for growth, and that these values are similar to those reported for other breeds of goats. It is also suggested that the comparatively poor growth of all goats at the highest intake was related to low voluntary feed intakes and probably associated with high environmental temperatures and humidity.

Keywords: Thai native goat; Energy requirement; Protein utilisation; Maintenance; Growth

1. Introduction

Genotype plays an important role in growth and productivity of ruminants. Studies with cattle have shown significant interactions between nutrition and genotype (Vercoe and Frisch, 1982), temperature and genotype (Johnson et al., 1959) and parasite tolerance and genotype (Frisch, 1975; Frisch and Vercoe, 1984). These findings indicate that crossbreeding schemes aimed at improving the productivity of local or indigenous ruminants may only be successful when accompanied by high levels of management. In many tropical areas, goats are a major source of income for farmers, and there have been many reports of crossbreeding schemes aimed at improving the low productivity of goats in these systems (Devendra, 1966; Wilson et al., 1980; Das et al., 1982). Whilst the performance of crossbred goats is generally superior to that of indigenous goats under optimum management conditions, few studies

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SSDI 0921-4488(94)00041-5

have evaluated their performance in the low input village systems for which they were bred.

At Prince of Songkla University (PSU) in Thailand, a crossbreeding scheme between Thai native (TN) and introduced Anglo-Nubian (AN) goats is being undertaken. The aim of this program is to evaluate the potential of crossbreeding for increasing goat production at the village level. The program has two thrusts, firstly the creation and evaluation of different genotypes (0–75% AN) under optimum management conditions and secondly the evaluation of these genotypes for their suitability to village systems with lower levels of management.

The aim of the present study was to investigate the growth and feed utilisation of three types of goats (TN, 25% AN and 50% AN) given concentrate diets formulated from local feedstuffs and fed at four different levels of intake. This information on the performance of goat genotypes during feed restriction is required to determine whether crossbred goats will maintain their superior productivity under the poor nutritional regimes often found in village management systems.

2. Materials and methods

Location and climate

The study was conducted at Small Ruminant Research and Development Centre, Faculty of Natural Resources, PSU, Thailand. The facility was established as part of the Thai-Australian PSU project and is situated 7° N, 100° 30' E. The region has an annual rainfall of 1120–2800 mm with a dry period extending from mid-January to March/May with marked increases in rainfall in May/June and October/November. The area is 20 m above sea level with temperatures of 20–35°C, relative humidity of 63–88% and has 50 min difference in daylength between solstices (Milton et al., 1987). During the period of the experiment (September–December), average maximum and minimum temperatures and relative humidities in the shed were 25°, 35° and 92–57%, respectively.

Animals and their management

In October 1990, TN, 25% and 50% AN does were joined to TN, 25% AN (F_1) and 50% AN (F_1) bucks to produce TN, 25% AN (F_2) and 50% AN (F_2), respectively. The does kidded over 7 wk period from mid-February to early April 1991.

Kids were weaned at 83 to 87 d of age and treated with a coccidiostat within 7 d of weaning (Baycox 2.5%, Bayer Laboratories Ltd., Thailand, active ingredient 20 mg toltrazuril/kid). All kids were vaccinated against foot and mouth disease (type A, O and Asia 1, Department of Livestock Development) and haemorrhagic septicemia (Veterinary Biologics Center, Pakchong, Thailand). Weaned kids were drenched to control *Monezia* sp. (Mansonil-M, active ingredient 790 g/kg niclosamide monohydrate, Bayer Australia Ltd., 100 mg/kg BW/d) and to control helminths (Panacur, 125 mg fenbendazole/kg BW/d, Hoechst Veterinär GmbH, Germany).

Selected male weaner kids ($n=24$) (mean body weight (BW) 15.7 ± 0.45 kg) were held in individual pens and drenched again with Mansonil-M and also injected with Ivomec (1 ml, 1% w/v ivermectin) to control internal and external parasites. All kids were offered the concentrate ad libitum and also 50 g *Paspalum plicatulum* hay per day for 7 d adaptation period. Eight goats of each genotype (TN, 25% AN and 50% AN) were used, two goats were randomly allocated to concentrate intake which varied from maintenance to ad libitum.

The experiment lasted approx. 3 months, commencing on September 15, 1991.

Experimental design

The design was a 3×4 factorial in a completely randomised design. Factors were genotype (TN, 25% AN and 50% AN) and level of feed intake (maintenance (M), 1.2 M, 1.4 M and ad libitum), with two replicates per treatment. Maintenance energy requirements were estimated as 376 kJ ME/$kg^{0.75}$/d (Ash and Norton, 1987) or 34 g dry matter/$kg^{0.75}$/d assuming that the feed contained 11 MJ/ME kg DM. Feed allocations for goats offered restricted intakes were adjusted fortnightly for BW change. Ad libitum intakes were ensured by providing 120% of previously recorded intake by these goats.

Diet and feeding methods

Table 1 shows the chemical and ingredient composition of the concentrate diet. All ingredients were ground through 23 mesh sieves. Vitamin A and D 5000 IU/kg and 100 IU/kg, respectively, were mixed with

Table 1
Composition (%) of ingredients and concentrate mixes offered to kids

Ingredient	Composition (g/kg dry matter)						
	Ration	DM	CP	Ether extract	Cruce fiber	Ca	P
Palm kernel cake	300	900	130	135	151	2.8	6.0
Corn	440	874	100	47	19	1.0	2.0
Soybean meal	170	900	460	10	75	3.0	7.0
Fish meal	50	920	550	114	15	83.0	36.0
Crude salt	20	900	–	–	–	–	–
Oyster shell	10	1000	–	–	–	–	–
Molasses	10	700	30	–	–		
Composition[b]		879	181	61	60[c]	12.2	6.1

[a]Vitamins A (5000 IU/kg) and D (100 IU/kg) mixed in molasses.
[b]NDF and ADF = 395 and 198 g/kg DM, respectively.

the feed, and feed was mixed with 10% of molasses each week before feeding. Feed refusals for each goat were collected weekly throughout the experimental period. All goats were weighed fortnightly and feed allocations adjusted for BW change.

All goats were also provided with 50 g/d *Paspalum plicatulum* hay harvested from a mature stand (14 wks regrowth). The chemical composition (g/kg DM) of the grass was as follows: 943 organic matter (OM), 37 crude protein, and 17.2 MJ/kg DM and for the concentrate mixture 18.7 MJ/kg DM.

Measurements and sampling methods

The kids were held in individual pens for 13 wks. During weeks 3 to 9 of the experiment, metabolism trials (7 d adaptation then 7 d measurement) were conducted on all kids (random genotypes and replicates of feed intake level) to determine nutrient digestibilities and balances. Three sequential metabolism trials with eight goats were conducted. Liveweight change for each goat over the whole experimental period (14 wks) was calculated from the linear regression of BW and time (d).

Analytical methods

The concentrate, grass hay, feed refusals and faeces were analysed for DM by oven drying to constant weight (75°C for 48 h), while OM in these fractions was determined by ashing in a muffle furnace at 550°C for 4 h. Samples were analysed for NDF (Van Soest and Wine, 1967) and ADF by the methods of Van Soest (1963). Feed, refusal, faecal and urine samples were analysed for total nitrogen by a rapid flow analyser (Chemlab, England) after digestion by the Kjeldahl method (AOAC, 1960).

Statistical methods

The significance of differences between treatments was calculated by a least squares analysis of variance and where appropriate, analysis of covariance (Steel and Torrie, 1960) using General Linear Models Procedure of Statistical Analysis System (SAS, 1987).

3. Results

3.1. Effect of genotype and feeding level on kid growth rates

Table 2 shows means for the main effects of genotype and feeding level on final BW, dry matter intakes (DMI) and growth rates. There were no significant differences between genotypes for final BW, DMI,

Table 2
Means with SEM for main effects of genotype and level of feeding on initial BW, DMI, growth rate and feed/gain of Thai native (TN) and TN × Anglo-nubian (AN) goats given a concentrate ration

Treatment	Final BW (kg)	Dry matter intake ($g/kg^{0.75}/d$)	Body weight change		Feed per gain
			g/d	$g/kg^{0.75}/d$	
Genotype					
TN	21.4	45.6	61	6.6	7.2
25% AN	22.1	44.2	62	6.6	8.1
50% AN	22.2	47.0	69	7.4	8.1
Feeding level					
Ad libitum	26.4a	54.2a	100a	10.0a	5.2a
1.4 M	22.7b	48.2b	76b	8.4ab	5.2a
1.2 M	22.2b	44.3c	67b	7.4b	5.4a
Maintenance (M)	16.5c	35.8d	13c	1.6c	15.5b
SEM[a]	0.52	0.45	2.7	0.27	0.36
Genotype (G)	NS	NS	NS	NS	NS
Feeding level (F)	**	**	**	**	**
G × F	NS	NS	NS	NS	NS

Values within columns between treatments with differing scripts differ significantly; $^{**}P < 0.01$, NS = not significant.
[a]SEM = standard error of mean.

Table 3
Means with SEM for main effects of genotype, level of feeding on BW, voluntary feed intake and apparent digestibility coefficient of nutrients by Thai native (TN) and TN crossbred kids

Treatment	Mean BW (kg)	DMI ($g/kg^{0.75}/d$)	Apparent digestibility (%)			
			DM	OM	NDF	ADF
Genotype						
TN	18.0	46.5	74.7	75.6a	60.8a	39.8
25% AN	18.0	45.4	77.5	77.9b	64.8b	45.4
50% AN	17.4	48.4	77.0	77.5b	63.9ab	45.9
Feeding level						
Ad libitum	20.2a	50.3a	78.7a	79.3a	66.7	47.9
1.4 M	17.6b	51.5a	76.7b	77.5ab	64.0	43.6
1.2 M	17.5b	46.1ab	74.5c	75.2c	60.0	38.5
Maintenance (M)	15.9c	39.2b	75.7c	76.0b	62.0	42.9
SEM*	0.55	1.20	0.32	0.34	0.66	1.14
Genotype (G)	NS	NS	**	*	NS	NS
Feeding level (F)	*	*	**	**	*	*
G × F	NS	NS	NS	NS	NS	NS

Values within columns between treatments with differing scripts differ significantly; *$P < 0.05$, **$P < 0.01$, NS = not significant, *SEM = standard error of mean.

growth rate (g/d or $g/kg^{0.75}/d$) and feed conversion ratio (feed: gain) over the experimental period. However, the kids fed ad libitum and 1.4 M had higher ($P < 0.01$) growth rates ($g/kg^{0.75}/d$) than did kids given M level of intake. Goats given M had higher ($P < 0.01$) feed: gain than did other treatments. There was a significant interaction between genotype and feeding level for growth rates expressed in g/d, AN (50%) kids fed ad libitum had higher ($P < 0.05$) growth rates (g/d) than did 25% AN and TN kids given at the same level of intake. However, this difference was not significant when growth rates were expressed as $g/kg^{0.75}$/d.

3.2. Effect of genotype and feeding level on feed intake and digestibility

Table 3 shows mean values and standard error of means (SEM) for the main effects of genotype and level of feeding on live weight, feed intake (digestibility trial) and apparent digestibility of nutrients. There were no significant differences between either genotypes or feeding levels for mean BW. There was no significant difference between genotypes for feed intake. However, kids fed M had lower ($P < 0.05$) feed intakes than did ad libitum and 1.4 M kids.

Thai native kids had lower ($P < 0.05$) DM and OM digestibility coefficients than did 25 and 50% AN kids. There was no significant difference between 25 and 50% AN kids for DM, OM and NDF digestibility coefficients. There was no significant difference among the genotypes for ADF digestibility. Kids fed ad libitum had higher ($P < 0.05$) DM, OM, NDF and ADF digestibility coefficients than did kids fed 1.2 M and M intakes.

3.3. N utilisation and live weight gain of kids

Table 4 shows mean values with SEM for the main effects of genotype and feeding level on apparent N digestibility (ADN%), N balance and percentage of apparently digested N (ADN) retained by kids. TN kids had lower ($P < 0.05$) N digestibility coefficients than did 25 and 50% AN kids. Kids fed ad libitum had higher ($P < 0.05$) ADN (%) and nitrogen balances than did 1.2 M and M kids.

There were significant ($P < 0.05$) correlations between growth rate, ADN intake and N balance, and since covariance analysis showed no significant effect of genotype in any of these relationships, the combined

Table 4
Mean values with SEM for the main effects of genotype and feeding level on apparent digestibility of nitrogen (ADN), N balance and the percentage of ADN retained of kids

Treatment	Apparently digested N (ADN) (%)	N balance ($g/kg^{0.75}/d$)	% ADN retained
Genotype			
TN	76.8a	0.49	39.9
25% AN	79.2b	0.56	46.9
50% AN	80.0b	0.53	42.0
Feeding level			
Ad libitum	80.8a	0.61a	46.5ab
1.4 M	79.1ab	0.66a	48.2a
1.2 M	76.9b	0.47b	39.0bc
Maintenance (M)	77.8b	0.37b	37.2c
SEM*	0.39	0.02	1.28
Genotype (G)	*	NS	NS
Feeding level (F)	*	*	*
G×F	NS	NS	*

Values within columns between treatments with differing scripts differ significantly; *($P < 0.05$), **($P < 0.01$), NS = not significant. *SEM = standard error of mean.

regression equations with correlation coefficients (r) and residual standard deviations (RSD) were:

$$NB = 0.0199(\pm 0.0071)GR + 0.367(\pm 0.059);$$
$$r = 0.51^{**},\ RSD = \pm 0.1207 \quad (1)$$

$$NB = 0.5166(\pm 0.1710)ADN + 0.0256;$$
$$r = 0.54^{**},\ RSD = \pm 0.1182 \quad (2)$$

$$ADN = 0.0327(\pm 0.0052)GR + 0.702;$$
$$r = 0.80^{**},\ RSD = \pm 0.0882 \quad (3)$$

where NB = N balance (g $N/kg^{0.75}/d$), GR = growth rate (g $/kg^{0.75}/d$) and ADN = apparently digested N intake (g $N/kg^{0.75}/d$).

3.4. The relationship between energy intake and live weight gain

Analysis of covariance of the relationship between ME intake and growth rate indicated that when compared at the same intake there was no significant difference between genotypes in growth rate. ME intake was calculated as DOM intake (g $/kg^{0.75}/d$) × 15.6 (ARC, 1980). The relationship between ME intake and growth is described by the following equations which show with standard errors, correlation coefficients (r) and residual standard deviations (RSD).

$$GR = 0.03208(\pm 0.00309)ME - 10.90(\pm 1.72);$$
$$r^2 = 0.83^{**},\ RSD = \pm 1.483 \quad (4)$$

$$ME = 25.89(\pm 2.492)GR + 375.5(\pm 18.9);$$
$$r^2 = 0.83^{**},\ RSD = \pm 42.13 \quad (5)$$

where ME = metabolisable energy intake (kJ $/kg^{0.75}/d$), GR = growth rate (g $/kg^{0.75}/d$). Eq. 4 uses ME as the independant variable and assumes that ME is measured without error, and Eq. 5 assumes that ME (y) and GR (x) are samples from a bivariate distribution. This latter equation permits the direct presentation of standard errors on values of biological interest. ME requirement for gain (regression coefficient b) and the ME requirement for liveweight maintenance (intercept value where GR = 0).

4. Discussion

4.1. Effect of genotype and feed intake on the growth of kids

A previous study with Australian cashmere (AC) goats and their crosses with Anglo-Nubians (AN) offered lucerne pellets ad libitum showed that crossbred (AC × AN) kids had higher growth rates than AC kids (9.7 vs. 7.1 g $/kg^{0.75}/d$) despite similar voluntary ME intakes (800 kJ $/kg^{0.75}/d$) (Pralomkarn, 1990). These results suggest a genotype × nutrition interaction, and indicate that AC × AN kids used absorbed nutrients more efficiently for growth than did AC kids. In the present study, there were no significant differences between genotypes for either growth rates (range 9.1–14.1 g $/kg^{0.75}/d$) or voluntary feed intakes (mean 681, range 598–764 kJ ME $/kg^{0.75}/d$ or 1.9 M), and there was no significant interaction between genotype and nutrition observed. However, both growth rates and ad libitum intakes of goats in the present study were considerably lower than those observed for Australian cashmere kids (Ash and Norton, 1987) and for West African Dwarf goats of similar BW and given concentrate diets. Maximum intakes in these studies were 900 and 894 kJ ME $/kg^{0.75}/d$ respectively or approx. 2.4 M, and it would seem that either the diet used in the present experiment or the local tropical environment limited voluntary feed consumption and hence the growth of these TN and TN × AN goats.

It seems unlikely that low dietary fibre content was limiting intake, since the diets contained 19.8% ADF which meets the minimum requirement (15–20%) for fibre in concentrate rations for goats (Adebowale, 1983; McGregor, 1984). Palm kernel cake (PKC) was also included in the ration (30%) and may have been associated with lower feed intakes, although intensive studies with this by-product have shown that up to 40% may be included in the ration without effect on feed intake and growth (Rengsirikul and Sae Nai, 1991). It is possible that the low feed intakes, and therefore poor weight gains may have been related to high environmental temperatures and humidity. This aspect of intensive goat production in southern Thailand requires further study.

4.2. Energy requirements for maintenance and growth of kids

The estimated ME requirement for BW gain for kids in the present experiment (25.9 ± 2.5 kJ/g, 95% confidence interval 20.7 to 31.1) was similar to the value of 24.8 ± 5.0 reported for Australian cashmere goats (18.5 kg BW) by Ash and Norton (1987), and of 30.3 calculated by NRC. (1981). Since then, Zemmelink et al. (1985) and Zemmelink et al. (1991) have reported values of 44.4 and 38.1 kJ ME/g gain for West African Dwarf goats (mean BW 11.5–17.8 kg). This variability in the energy content of the gain between different experiments may reflect real differences between breeds, type of diet and environment. However, Zemmelink et al. (1991) have suggested from a review of this data, that this variability arises largely from differences in experimental design and methods of data analysis. They have proposed that ME content of gain should be calculated as the reciprocal of the regression coefficient ($1/b$) from the relationship between BW change (dependant variable) and ME intake (independent variable), and that maintenance requirement should be calculated by substituting BW change = 0 in this equation. They have re-analysed data from the literature in this way and found an average value ($n = 14$) of 40.8 kJ ME/g gain and 367 kJ ME/$kg^{0.75}$/d as the maintenance requirement. It may be calculated that the SE for ME content of gain in their study was ±4.84 (95% confidence interval 30.4 to 51.2 kJ/g gain). It should also be noted that these authors have combined heterogeneous and significantly different data sets in this calculation, and the high values obtained may be biassed. When similiar calculations were used for data from the present experiment (Eq. 4), a value of 31.2 ± 3.00 kJ ME/g gain (95% confidence interval 25.0 to 37.4) was found. Although both values calculated from our experiment were lower (Eq. 4: 31.2, Eq. 5: 25.9) than those calculated by Zemmelink et al. (1991) (40.8), none of these values are significantly different statistically.

In the present experiment, extrapolation of the relationship between BW gain and ME intake (Eq. 5) to zero gain would suggest a maintenance energy requirement for these goats of 376 ± 18.5 kJ ME/$kg^{0.75}$/d. This value is similar to those for Australian cashmere goats: 376 kJ/$kg^{0.75}$/d – Ash and Norton (1987); 393 kJ/$kg^{0.75}$/d – Alam et al. (1983), and for West African Dwarf goats, 384 kJ /$kg^{0.75}$/d – Zemmelink et al. (1991). Beetal (Kurar and Mudgal, 1981) and Alpine × Beetal (Kurar, 1983) goats have been reported to have substantially higher maintenance energy requirements (523 and 673 kJ ME/$kg^{0.75}$/d, respectively) than found in this study. The wide variation in some estimates of maintenance requirements of goats may be attributed to real breed and environmental differences and/or varying experimental and statistical methods for calculating maintenance requirements. In the present study we have used a bivariate model for relating body weight gain (x) to ME intake (y) since this permits the SE associated with both ME requirement of gain and the maintenance energy requirement to be directly presented (Eq. 5). This model appears to be no less valid statistically than one which sets ME intake as the independant variable (Neter and Wasserman, 1974) but the model chosen does affect the values obtained. In the present studies, the bivariate model produced lower values (17%) for ME requirements for gain and higher values (10%) for maintenance requirements than did the normal regression model (ME as independant variable). Similar conclusions can be drawn from the data presented by Zemmelink et al. (1991). The 'appropriate' model depends on the use to which the data are to be put. Where prediction of growth from ME intake is the objective (feed allocation tables), then ME intake should be used as the 'independent' variable. When prediction of energy requirements for growth is needed, as was the case in the present study, then growth rate should be used as the 'independent' variable. In neither case should correlation be confused with causation.

The present study has shown that Thai native goats, their various crosses with Anglo-Nubians, and Australian cashmere goats have similar energy requirements for maintenance and weight gain over a weight range of 15–25 kg. There is now a need to investigate the relationship between energy intakes and weight gains of these goats in the latter stages of their growth, so that meaningful values for maintenance requirements can be provided for all classes of animals.

4.3. Protein utilisation for kid growth

Ash and Norton (1987) found that increasing the protein content of the diet (11.3, 16.0 and 20.9% CP) resulted in significantly greater BW gains, largely pro-

moted by increased intake rather than by enhanced feed efficiency. In the present study, maintenance N requirements, expressed as digestible crude protein (DCP = ADN × 6.25), were 4.4 ± 0.24 g DCP/$kg^{0.75}$/d, and DCP requirement for BW gain was 0.205 ± 0.033 g DCP/g (Eq. 3). This latter value is close to that recommended for goats (0.195 g DCP per g BW gain) by NRC (1981). The DCP requirement for maintenance is similar to that reported by Sengar (1980) (4.3–4.7) but higher than that given by NRC (1981) (2.82 g DCP/$kg^{0.75}$/d (range 2.12–3.40, $n = 7$). Cheva-Isarakul et al. (1991) have reported that mean protein requirement for maintenance of adult Thai native goats (an average initial weight of 26.5 kg) was only 1.65 g DCP/$kg^{0.75}$/d. Although such values continue to be presented in the literature, their relevance to an understanding of protein requirements is doubtful, because each estimate represents a diet specific requirement. Because dietary N is degraded to variable extents in the rumen, DCP is characterised by both usable (amino acids) and non-usable (e.g., ammonia) absorbed N, and therefore the proportion actually available for tissue protein synthesis will vary. In the present study, DCP (ADN) was used for N storage in tissues (12.5% CP, Eq. 1) with a net efficiency of 51.6 17.1% (Eq. 2), and if a biological value of 70% is assumed for absorbed protein in ruminants (ARC, 1980), then some 25% of DCP in this ration was unavailable for tissue synthesis. Future studies of protein metabolism in goats must measure protein absorbed from the small intestines and efficiency of protein utilisation for tissue growth if meaningful information of protein requirements is to be obtained. Only then can some decisions be made about the effects of breed, environment, feed intake and physiological state on protein metabolism in goats.

Acknowledgements

The authors wish to thank the Australian International Development Bureau which funded the Thai-Australian PSU Project, and Thai Government for providing facilities and funds for the conduct of this study.

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