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The efficiency of utilization of energy and nitrogen in young sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*)

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SUMMARY

Two experiments each with two rates of feeding (maintenance and twice maintenance) were conducted during summer 1993/94 (Expt 1) and summer 1994/95 (Expt 2), at Massey University, New Zealand. Four sambar and four red deer, including stags and hinds aged 10–14 months, were used in each year. Animals were fed a pelleted diet (total N 30 g/kg DM; NDF 247 g/kg DM). Digestibility and nitrogen (N) balances were determined using deer metabolism cages, whilst methane production and heat production were determined using open circuit respiration calorimetry, with measurements made on each deer at both rates of feeding. Digestibility and metabolizability of energy were greater for sambar than for red deer in Expt 1 but not in Expt 2. Nitrogen retention, expressed as a proportion of N intake, was similar for sambar and red deer. Metabolizable energy required for maintenance (ME_m) was 474 kJ kg $W^{-0.75}$ d^{-1} for sambar deer and 567 kJ kg $W^{-0.75}$ d^{-1} for red deer, whilst the efficiency of utilization of ME above maintenance (k_g) was similar for sambar deer and red deer. These studies indicated that the sambar deer had lower rates of maintenance heat production than the red deer, which may explain the sambar's superior feed conversion measured in previous experiments. However, the two species utilized nitrogen with similar efficiency, when fed a high quality ration.

INTRODUCTION

Red deer (*Cervus elaphus*) have strong seasonal cycles of growth and voluntary feed intake (VFI), with maximum values in summer and minimum values in winter (Suttie *et al.* 1987; Barry *et al.* 1991). The energy requirements for both maintenance and body gain in young growing red stags and hinds have also been studied by Simpson *et al.* (1978), Fennessy *et al.* (1981) and Suttie *et al.* (1987). A study with North American wapiti calves (*Cervus elaphus*) indicated lower energy requirements in summer and higher energy requirements in winter for both maintenance and growth (Jiang & Hudson 1994).

Interest in domesticating tropical deer is increasing, but there is limited information available on their nutritional requirements. Semiadi *et al.* (1995) showed that growing tropical sambar deer (*Cervus unicolor*) had less pronounced seasonal cycles in voluntary feed intake (VFI) and body growth, and better feed conversion efficiency (FCE) than growing red deer (*Cervus elaphus*).

The objectives of this study were to determine ration metabolizability (metabolizable energy (ME)/gross energy (GE)), ME requirements for maintenance (ME_m) and the efficiency of utilization of ME for growth (k_g) in young sambar and red deer, using a combination of nutrient balance and calorimetry techniques. Efficiency of nitrogen (N) retention was also measured.

MATERIALS AND METHODS

Experimental design

Two experiments, each with two rates of feeding, were conducted at Massey University, New Zealand (42° S) during the 1993/94 summer (Expt 1) and the 1994/95 summer (Expt 2), using four young sambar and four young red deer in each year. Animals were fed a pelleted concentrate diet at approximately maintenance (low intake) and twice maintenance (high

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intake) rates of ME intake in both metabolism cages and respiration chambers.

In Expt 1, pairs of animals were initially fed at maintenance for 4 weeks followed by twice maintenance for another 4 weeks. In Expt 2, one pair of animals was initially fed at maintenance and the other pair was initially fed at twice maintenance for 4 weeks; the reverse sequence was then followed for the next 4 weeks. Heat production and methane production were measured using indirect calorimetry, followed by measurement of faeces and urine excretion of both energy and N whilst the deer were confined in metabolism cages.

Animals

All deer calves were artificially reared from birth, using the procedures described by Semiadi *et al.* (1993). Four sambar and four red deer were selected for quiet temperament from larger groups of hand-reared animals (Table 1). Sambar deer give birth to their calves *c.* 6 months later in the season than red deer in NZ (Semiadi *et al.* 1994*a*), and peak voluntary feed intake (VFI, March) occurs *c.* 3 months later than for red deer (December; Semiadi *et al.* 1995). As a result, all measurements were made first with red deer during November/December, followed by sambar deer (January/February), when both species were undergoing their first period of maximum growth and were as similar in age and in weight as possible. Due to the small numbers of deer available, there were some differences in weight and age between the two species, which were larger in Expt 2. Animals were weighed at the beginning and end of each period. Due to behavioural problems, one sambar deer had to be removed from the data calculation in Expt 1.

Diets

All animals were fed a pelleted diet (Table 2), comprising (on a dry weight basis) barley (39·8%), bran (23·0%), brewer's grain (5·0%), soyabean (10·0%), lucerne (15·0%), molasses (4·0%), salt (1·0%), lime (1·5%), dicalcium phosphate (0·5%) and a vitamin mix (0·2%). The lower rate of feeding was intended to be equivalent to maintenance, and was assumed to be 0·52 MJ.kJ kg $W^{-0.75}$ d^{-1} for red deer (Fennessy *et al.* 1981) and 15% less for sambar deer. Feed intakes for the high groups were set at twice those of the maintenance groups.

Calorimetry

The calorimetric measurements were carried out in two open circuit chambers, generally as described by Holmes (1973). The average temperature at the maintenance rate of feeding was 17–20 °C and at twice maintenance was 14–16 °C. The composition of air samples drawn from the ingoing and exhaust airstreams were measured by paramagnetic and infrared (Servomex, United Kingdom; Beckman, USA) gas analysers. These analyses were carried out on aliquot representative samples (*c.* 7000 ml) collected at a constant rate during each 24 h period.

Heat production was calculated from oxygen consumption, carbon dioxide production, methane production and urinary nitrogen excretion using the equation of Brouwer (1965).

Faeces and urine losses

Faeces and urine were collected for 7 days, following an adjustment period of 6–8 days to the metabolism cages. Feed refusals, faeces and urine from individual animals were weighed daily. Urine was collected in buckets containing sufficient H_2SO_4 (25% v/v; 250 ml/l) to maintain pH at < 3·5. Animals were fed once daily and drinking water was freely available. Metabolism cages were similar to those described by Milne *et al.* (1978).

For each digestion period, samples of feed on offer were collected daily and pooled at the end of each trial. Samples of feed refusals, faeces and urine (10% of the daily total) for each animal were collected daily and stored at −20 °C. At the end of each trial, samples were thawed and pooled for each animal, mixed thoroughly and subsampled.

Laboratory methods

Samples of feed on offer, feed refusals and faeces were freeze-dried, ground to pass through a 1 mm sieve (Willey Mill, USA) and analysed for organic matter (OM), total N and energy contents. Dry matter (DM) content was determined by drying at 105 °C to constant weight (48 h for faeces). Organic matter was determined by ashing overnight at 550 °C, total N was determined by the Kjeldahl method and gross energy was determined using an adiabatic bomb calorimeter (Gallenkamp Autobomb; Loughborough, Leics, UK). Samples of feed and faeces were pelletted (0·5–0·8 g DM, 12 mm diam) prior to combustion. Total N and energy contents of urine were determined by the Kjeldahl method and bomb calorimetry, respectively.

Data calculation and statistical analysis

Because of the significant interaction between years and deer species, data were analysed separately for each year as a separate experiment. Effects of rate of feeding, deer species and their interactions on apparent digestibility, energy losses, metabolizability, nitrogen excretion and nitrogen retention were analysed using the Statistical Analysis System package (SAS 1987). In order to estimate ME_m and k_g, relationships between energy retained and ME intake were studied by linear regression analysis for each deer species.

Table 1. *Duration of the experiments, mean initial age (days, S.E.) and initial body weight (kg, S.E.) of sambar and red deer used in the calorimetry and digestion trials during 1993/94 (Expt 1) and 1994/95 (Expt 2)*

Experiment	Species	Duration	Number of animals: Stags	Hinds	Initial age (days)	Initial body weight (kg)
1	Red deer	01.11.93–01.12.93	1	3	335 (2)	58·6 (3·1)
	Sambar	19.01.94–21.02.94	1	2	323 (35)	77·5 (1·4)
2	Red deer	24.11.94–24.01.95	1	3	342 (2)	72·1 (1·5)
	Sambar	01.02.95–23.03.95	2	2	425 (60)	94·0 (4·6)

Table 2. *Chemical composition (g/kg DM) of the pelleted diet used during the 1993/94 (Expt 1) and 1994/95 (Expt 2) studies*

	Expt 1	Expt 2
Total nitrogen (N)	29·0	30·7
NDF	256	238
ADF	92	86
Lignin	20	17
Heat of combustion (MJ/kg DM)	18·3	17·2

Table 3. *Mean apparent digestibility of the pelleted ration fed to growing sambar and red deer at two feeding rates*

Experiment 1	Red deer (*n* = 4)	Sambar deer (*n* = 3)	S.E.
Low rate			
Dry matter	0·71	0·78	0·019
Organic matter	0·72	0·80	0·018
Energy	0·70	0·77	0·018
High rate			
Dry matter	0·70	0·79	0·019
Organic matter	0·73	0·81	0·017
Energy	0·70	0·79	0·019

Experiment 2	Red deer (*n* = 4)	Sambar deer (*n* = 4)	S.E.
Low rate			
Dry matter	0·72	0·74	0·018
Organic matter	0·76	0·78	0·016
Energy	0·74	0·76	0·017
High rate			
Dry matter	0·74	0·74	0·021
Organic matter	0·78	0·78	0·018
Energy	0·77	0·77	0·021

Table 4. *Gross energy intake (MJ/day) and energy losses (% gross energy intake) in sambar and red deer fed a pelleted diet at two feeding rates*

Experiment 1	Red deer (*n* = 4)	Sambar deer (*n* = 3)	S.E.
Low rate			
Gross energy intake (MJ)	17·9	17·2	0·25
Energy losses (%)			
Faeces	29·9	23·0	1·84
Methane	4·9	6·1	0·24
Urine	5·0	4·6	0·18
Metabolizable energy (%)	60·2	66·3	1·77
High rate			
Gross energy intake (MJ)	35·2	30·0	1·47
Energy losses (%)			
Faeces	30·1	21·5	1·88
Methane	4·7	6·8	0·41
Urine	2·9	3·6	0·41
Metabolizable energy (%)	62·3	68·1	1·46

Experiment 2	Red deer (*n* = 4)	Sambar deer (*n* = 4)	S.E.
Low rate			
Gross energy intake (MJ)	18·4	18·8	0·59
Energy losses (%)			
Faeces	25·7	23·7	1·70
Methane	4·9	6·1	0·46
Urine	4·4	5·0	0·23
Metabolizable energy (%)	65·0	65·2	1·75
High rate			
Gross energy intake (MJ)	36·0	24·7	2·44
Energy losses (%)			
Faeces	23·2	23·3	2·07
Methane	4·7	6·8	0·48
Urine	2·8	4·0	0·43
Metabolizable energy (%)	69·3	65·9	1·84

RESULTS

The chemical composition (g/kg) of the pelleted concentrate diet used during the experiments was similar in both years (Table 2). There was no interaction between rates of feeding and deer species for digestibility in either experiment (Table 3). Sambar

Table 5. *Nitrogen (N) intake, excretion and retention in sambar and red deer fed a pelleted diet at two feeding rates*

Experiment 1	Red deer ($n = 4$)	Sambar deer ($n = 3$)	S.E.
Low rate			
N intake (g/d)	28·0	26·6	0·30
Faeces N (% intake)	32·4	27·3	1·86
Urine N (% intake)	57·0	57·6	1·39
N retention (% intake)	10·6	15·1	2·20
High rate			
N intake (g/d)	56·9	47·3	2·54
Faeces N (% intake)	34·0	26·1	1·82
Urine N (% intake)	38·0	42·2	3·95
N retention (% intake)	28·0	31·7	5·30

Experiment 2	Red deer ($n = 4$)	Sambar deer ($n = 4$)	S.E.
Low rate			
N intake (g/d)	32·6	33·7	1·06
Faeces N (% intake)	28·0	22·6	1·85
Urine N (% intake)	55·8	62·1	1·69
N retention (% intake)	16·2	15·3	1·69
High rate			
N intake (g/d)	63·7	44·4	4·26
Faeces N (% intake)	26·8	23·4	2·48
Urine N (% intake)	41·5	47·2	2·68
N retention (% intake)	31·7	29·4	1·62

Table 6. *Energy balance values (MJ kg $W^{0.75}$ d^{-1}) in sambar and red deer fed a pelleted diet at two feeding rates*

Experiment 1	Red deer ($n = 4$)	Sambar deer ($n = 3$)	S.E.
Low rate			
Liveweight (kg)	59·5	77·6	3·96
GE intake	0·84	0·66	0·037
ME intake	0·50	0·44	0·022
Heat production	0·55	0·48	0·025
Energy retained	−0·05	−0·04	0·009
High rate			
Liveweight (kg)	61·2	81·3	4·39
GE intake	1·61	1·10	0·109
ME intake	1·00	0·76	0·059
Heat production	0·70	0·53	0·037
Energy retained	0·30	0·23	0·041

Experiment 2	Red deer ($n = 4$)	Sambar deer ($n = 4$)	S.E.
Low rate			
Liveweight (kg)	72·3	93·2	5·45
GE intake	0·75	0·63	0·023
ME intake	0·47	0·41	0·019
Heat production	0·54	0·44	0·020
Energy retained	−0·06	−0·03	0·013
Heat rate			
Liveweight (kg)	72·9	93·5	5·35
GE intake	1·33	0·97	0·086
ME intake	0·92	0·63	0·062
Heat production	0·69	0·54	0·033
Energy retained	0·23	0·09	0·032

deer digested DM, OM and GE intake more efficiently ($P < 0·01$) than red deer in Expt 1, but in Expt 2 there was no significant difference in digestibility between the deer species.

In Expts 1 and 2, there were interactions ($P < 0·10$; Table 4) between rates of feeding and deer species for gross energy intake, due to the lower intakes of sambar deer at the high rate of feeding in Expt 2. In Expt 1, sambar deer had smaller ($P < 0·01$) energy losses in faeces and had higher ration metabolizability (ME/GE) ($P < 0·01$) than red deer. Faecal energy losses and ration metabolizability were similar for sambar and red deer in Expt 2.

The interaction between deer species and rate of feeding for nitrogen intake (NI) in Expts 1 and 2 was significant ($P < 0·10$; Table 5), but not in other variables. Sambar deer excreted less N in faeces ($P < 0·05$) but more N in urine than red deer, consequently N retention was similar for both species.

The numbers of males and females were unbalanced; however there was no obvious difference between the sexes.

Sambar deer were significantly heavier ($P < 0·01$; Table 6) than red deer. Energy retention at the low feeding rate was close to zero, as planned in the experimental design. Energy retention was considerably higher at the high rate of intake in all instances, except for the sambar deer in Expt 2, which had a low intake (Table 4).

When energy retention (ER; MJ $W^{-0·75}$ d^{-1}) was regressed on ME intake (MEI; MJ $W^{-0·75}$ d^{-1}), significant linear relationships ($P < 0·001$) were obtained for each deer species in each year. The equations were similar between years for each deer species, and the pooled equations shown below were then calculated for each species. The metabolizable energy requirement for maintenance of energy balance was considerably lower for sambar deer than for red deer (474 *v.* 567 kJ $kg^{-0·75}$ d^{-1}) for red deer and sambar, respectively) but k_g values were similar for both species (0·68 and 0·73 for red deer and sambar, respectively).

In Expts 1 and 2, for red deer, ER = −385 (S.E. 32·5) + 0·68 MEI (S.E. 0·042) ($r = 0·95$, $P < 0·001$), while for sambar deer, ER = −346 (S.E. 40·5) + 0·73 MEI (S.E. 0·071) ($r = 0·90$, $P < 0·001$).

DISCUSSION

The present results are based on measurements with small numbers of deer, made at ages and weights which differed slightly between species. The actual weights should be compared with estimated mature weights of 100 and 250 kg for red deer hinds and stags respectively and with values *c.* 1·5 times heavier for sambar. Despite these limitations, the results do provide some valuable comparative data for the two species of deer.

The most important finding from this study was that ME_m was lower for sambar deer than for red deer, and that k_g values were similar for the two deer species. This shows that maintenance heat production was lower for the tropical sambar than for the temperate red deer and provides a logical explanation for the sambar's superior feed conversion efficiency measured in previous experiments (Semiadi *et al.* 1995). Frisch & Vercoe (1969) also found better feed conversion in tropical (*Bos indicus*) than in temperate (*Bos taurus*) cattle, due mainly to the lower fasting heat production of the tropical cattle associated with lower *ad libitum* feed intake. On the basis of this limited evidence, it seems that deer and cattle which evolved in the tropics have adapted by reducing their heat production and thereby increasing the efficiency with which they utilize dietary energy.

Averaged over both experiments, ration metabolizability (ME/GE) was 66% for sambar deer and 64% for red deer, whilst digestibility of energy was 77 and 73%, respectively, for the two deer species. These differences are small relative to the difference between deer species in ME_m, and were due entirely to the significant differences in Expt 1. Semiadi *et al.* (1994*b*) found no difference in digestive efficiency between sambar and red deer when fed a medium quality roughage (60% OMD), whilst Howse *et al.* (1995) found no difference when the two deer species were fed a low quality roughage diet (42% OMD). The present results with a high quality diet (77% OMD) confirm the general finding that differences in digestive efficiency between sambar deer and red deer are either zero or small. Whilst differences between deer species were detected in energy metabolism, no differences were detected in N retention when fed a high quality diet. This differs from the results of Howse *et al.* (1995), who found less negative N balance in sambar than in red deer when both were fed a low quality roughage. It therefore seems that sambar deer could conserve N better than red deer when both are losing N (i.e. in negative N balance), but when both are growing and retaining N then there appears to be no difference in N retention between the two species.

A notable feature of the present results was that sambar deer did not consume all the feed that was offered at the high rate of feeding, resulting in a lower feed intake in sambar than in red deer. This occurred in both experiments, but was more marked in Expt 2, and supports the earlier results of Semiadi *et al.* (1995). It may be associated with the lower ME_m required by the sambar deer and is similar to results for *Bos indicus* cattle (Frisch & Vercoe 1969). The effects of differences in feed intake were reduced in the data analyses by expressing all energy losses relative to the amount of energy consumed.

Overall, it can be concluded that sambar deer have lower rates of maintenance heat production than red deer and therefore, at a particular rate of ME intake, sambar deer retain more energy than red deer. This may be the result of an evolutionary adaptation to high tropical environmental temperatures.

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