Consumption and Digestion of Forages by Male Rusa (*Cervus timorensis russa*) Deer-the Effects of Castration and Season

R. Sookhareea[1] and G. McL. Dryden*

School of Animal Studies. The University of Queensland. Gatton. Queensland 4343. Australia

ABSTRACT : In a split-unit design, 12 Javan rusa (*Cervus timorensis russa*) stags (6 castrated and 6 entire) were used to investigate seasonal (winter, spring and summer) effects on intake, digestibility of food constituents, volatile fatty acid profile, and nitrogen retention, when given lucerne (*Medicago sativa*) or rhodes grass (*Chloris gayana*) hays. Entire stags ate 9% more dry matter (DM) than castrates ($p<0.05$). Both castrated and entire stags exhibited seasonal changes in DM intake, these being higher ($p<0.05$) in winter (62.3 g/kg $W^{0.75}$) than spring (56.9 g/kg $W^{0.75}$) or summer (55.3 g/kg $W^{0.75}$). Intakes of lucerne hay (211 g protein/kg DM) were significantly higher than of rhodes grass hay (49 g protein/kg DM) in all seasons ($p<0.05$). Digestibilities of DM (0.58), neutral detergent fibre (0.59) and acid detergent fibre (0.47) were similar between castrates and entires. DM digestibility was higher ($p<0.0001$) for lucerne (0.66) than rhodes grass (0.55), and was higher ($p<0.05$) in winter (0.60) than spring (0.58) or summer (0.57). The ruminal acetate concentrations were higher ($p<0.001$) in spring than summer (78 and 73 molar % respectively). Apparent digestibility of protein was significantly less ($p<0.0001$) for rhodes grass (0.37) than lucerne (0.75). N retention was positive for lucerne (15.2 g/d) but negative for rhodes grass (-2.8 g/d) ($p<0.0001$), and was higher ($p<0.001$) in summer (12.0 g/d) than spring (4.3 g/d) or winter (2.4 g/d). The tropical rusa deer exhibits seasonal variations in feed intake, food constituent digestibilities, VFA profile and N retention. Castration did not alter these traits. The results do not support the view that rusa deer can thrive on low-quality pastures. The productivity and commercial exploitation of rusa deer could be optimised if they are given high-protein feed during spring and summer. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 8 : 1098-1106)***

Key Words : Rusa Deer, Forage, Food Intake, Digestibility

INTRODUCTION

The rusa is the most commercially important of the deer species farmed in the tropics and subtropics. Although their basal food is almost always forage, their abilities to consume and digest different forages, and the effects of season on these, are not well known. It has been suggested that they thrive in a wide range of nutritional environments and perform quite well on poor quality feeds (Woodford and Dunning, 1992). On the other hand, Hoffman (1985) classified the rusa deer as an "intermediate feeder". The acceptable growth, and lack of feeding disorders, of rusa weaners given concentrate-rich diets (Puttoo et al., 1998) supports this classification.

Dryden (1999) summarised data which indicates that daily voluntary dry matter (DM) consumption by rusa deer varies between 52 and 160 g per kg metabolic liveweight ($W_{kg}^{0.75}$) with most values between 55 and 75 g/kg $^{0.75}$. This range encompasses measurements made with mixed roughage/concentrate, and roughage-only, diets. Feed intake and retention of N by temperate deer species vary with season (Domingue et al., 1990, 1991a,b; Freudenberger et al., 1994b) and sex (Putman et al., 1993; Matiello et al., 1997; Mulley et al., 2000), but there are no comparable data for rusa deer.

Castration may be a useful management practice if male deer are intended for venison production (Sookhareea et al., 2001a). It may be particularly appropriate for stags which will be slaughtered in the rut (breeding season) or shortly afterwards. Castration reduces the behavioural problems associated with managing entire stags during the rut, and carcases from entire rusa stags slaughtered during the rut may have lower proportions of the more valuable joints than carcases from castrates (Sookhareea et al., 2001b).

We report the effects of castration and season on food intake, the apparent digestibilities of food constituents, N balance, and the rumen VFA profiles of rusa stags. These were given two hays (lucerne and rhodes grass) which are representative of the range of forages used by rusa deer in northern Australia.

MATERIALS AND METHODS

Animals, housing and management

Twenty four male Javan rusa (*Cervus timorensis russa*) calves born in March/April 1993 were weaned on 6 September 1993. Twelve were surgically castrated in October 1993, at the time of pedicle development. All animals were depastured on a mixed kikuyu (*Pennisetum clandestinum*)/couch grass (*Cynodon dactylon*)/rhodes grass (*Chloris gayana*) pasture in a single herd until late December 1993.

* Corresponding Author: G. McL. Dryden. Tel: +61-7-5460-1255, Fax: +61-7-5460-1444, E-mail: g.dryden@uq.edu.au

[1] Ministry of Agriculture, Food Technology and Natural Resources, Reduit, Mauritius, Australia.

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Table 1. Chemical composition of lucerne and rhodes grass hays fed *ad libitum* to castrated and entire Javan rusa males

Attribute	Experiment 1 and Experiment 2 (winter and spring)		Experiment 2 (summer)	
	Rhodes grass	Lucerne	Rhodes grass	Lucerne
Dry matter (g/kg)	902	891	908	887
Crude protein (g/kg DM)	54	207	49	211
Ash (g/kg DM)	79	104	82	94
Ether extract (g/kg DM)	14	22	15	22
NDF (g/kg DM)	837	541	808	532
ADF (g/kg DM)	706	377	622	394
Gross energy (MJ/kg DM)	17.6	18.5	17.6	18.3

The 24 deer were confined in a holding pen (15×10 m, enclosed to a height of 2.5 m and provided with shade and water) from 20 December 1993 until 17 March 1994. During this period they were fed lucerne (*Medicago sativa*) hay, and became accustomed to the presence of humans, the feeding methods used, and other routine procedures. The deer were introduced to metabolism pens in March 1994, and in May 1994 the six most tractable animals in each treatment (castration) group were selected and used in both experiments. During the adaptation and collection periods of each experiment the deer were confined individually in metabolism pens. They were allocated to the pens at random, and the randomisation was repeated for each new measurement period. Mean liveweights, calculated from measurements on day 1 of adaptation and day 7 of the collection period in each experimental period, varied by less than 2.5 kg over the course of the two experiments. For the entires and castrates respectively, liveweights were (mean±SD) in Experiment 1, 64±4.9 and 61±5.0 kg, and in Experiment 2, 65±4.5 and 61±3.2 kg.

Experiment 1

Measurements of the intake and digestibility of lucerne hay were carried out in a preliminary study in early winter (14 to 28 June 1994). Stags were given chopped lucerne hay (Table 1), offered twice daily at 8.00 and 16.00 h. Forage refusals were weighed each day. Water and a multi-mineralised salt block were available *ad libitum*.

Experiment 2

The effects of season and castration on the consumption and digestibilities of lucerne and rhodes grass hays (Table 1) were investigated in winter (from 28 June to 23 August), spring (23 August to 11 October) and summer (12 October to 30 November). The treatments (castration, season, and diet (hay type)) were administered in a split-units experimental design in which individual deer were the main units, seasons the subunits, and diets within seasons the sub-subunits.

Each measurement period included 2 weeks adaptation and 1 week sample collection. The diet was changed over 4 days at the beginning of each adaptation period. Both forages were chopped, and given *ad libitum* with feed offered twice daily (09:00 and 17:00 h). The amount of hay first given was equivalent to 30 g/kg body weight daily (as-fed basis), and the amounts offered were subsequently adjusted to allow refusals equivalent to either 10% (lucerne) or 20% (rhodes grass) of the amounts offered. Water and a multi-mineralised salt block were provided *ad libitum*.

Measurements and sample collection

During the collection periods, samples of feed (about 200 g), feed refusals (20%, after thorough mixing), and faeces (a 10% sub-sample stored at -20°C) were collected each day. Urine was collected into H_2SO_4 (30 to 50 ml of a solution of 50 ml conc. H_2SO_4/l), and depending on the urine output an aliquot of 5 to 40% was collected, the pH adjusted to ≤3, and stored at 4°C. On day 7 of each collection period, the daily samples of feed, refusals, faeces, and urine were bulked within animals and mixed, and sub-samples were taken and frozen (-20°C) for later analysis.

Samples of rumen contents (100 to 200 ml) were obtained by stomach tube on day 7 of the collection period, usually between 13:00 to 15:00 h. The samples were acidified with conc. H_2SO_4 (3 ml/l) and frozen until subsequent volatile fatty acid (VFA) analysis.

Chemical analyses

Feed, refusals, and faeces were prepared by drying in a forced draft oven at 65°C for 48 h and were then ground to pass a 1 mm screen. Urine samples were first strained free of extraneous matter, any uric acid crystals were dissolved, and the urine was filtered a second time through cotton wool.

Feed, refusals, and faeces samples were analysed for dry matter (DM; 105°C for 24 h), organic matter (OM; by ashing overnight at 550°C), and neutral and acid detergent fibres (NDF, ADF; by the methods of Goering and Van Soest, 1970 and Van Soest and Robertson, 1980). Nitrogen was determined by a semi-micro Kjeldahl procedure, using Na_2SO_4 and Se in the digestion mixture, and estimating N in the distillate by an automated colorimetric method using the indophenol reaction with salicylate and sodium dichloro-isocyanurate. Neutral detergent-soluble N in faeces was measured by determining the N content of faecal NDF, and was assumed to be equivalent to the metabolic faecal nitrogen (MFN) (Van Soest, 1982). VFA in rumen liquor

Table 2. Experiment 1: Intake, digestibility, N retention and rumen volatile fatty acid profile of castrated and entire Javan rusa stags given chopped lucerne hay in early winter

Attribute	Castrates	Entires	Residual SD	Significance (p=)[1]
Intake:				
Dry matter (kg/d)	1.6	1.7	0.08	0.12
Dry matter (g/kg $W^{0.75}$·d^{-1})	72.9	73.6	4.16	0.77
Organic matter (g/kg $W^{0.75}$·d^{-1})	65.5	66.1	3.80	0.13
Crude protein (g/kg $W^{0.75}$·d^{-1})	15.6	15.8	0.83	0.88
Digestibilities:				
Dry matter	0.67	0.67	0.0093	0.79
Organic matter	0.69	0.69	0.0085	0.55
Gross energy	0.87	0.89	2.0010	0.78
Crude protein (apparent)	0.75	0.74	1.0041	0.21
Crude protein (true)	0.92	0.92	0.0058	0.09
Ether extract	0.40	0.40	3.0037	0.99
Neutral detergent fibre (NDF)	0.64	0.63	1.0066	0.78
Acid detergent fibre (ADF)	0.52	0.50	3.0051	0.67
N balance (g/d):				
Intake	54.2	56.8	2.33	0.09
Faecal excretion	13.3	14.5	0.77	0.02
Urinary excretion	27.3	25.8	2.94	0.39
MFN excretion	8.8	10.2	0.82	0.02
Retention				
(g N/d)	13.6	16.5	2.91	0.12
(g/kg N intake)	250	291	492	0.24
Volatile fatty acids (molar %):				
Acetate	73.2	72.7	2.52	0.79
Propionate	16.8	15.6	1.31	0.17
Iso-butyrate	2.9	2.9	0.70	0.95
n-butyrate	5.5	6.2	1.05	0.34
Iso-valerate	1.5	2.6	0.83	0.09
Acetate:propionate ratio	4.4	4.7	0.50	0.31

[1] Significance of difference between castrates and entires.

were analysed using a Hewlett Packard 8530A gas chromatograph. Gross energy was determined by bomb calorimetry.

Statistical analysis

Analyses of variance were carried out using the general linear model procedure of Statistical Analysis Systems (1989). The main effects (castration treatment, season and diet) were tested with specific error terms. The model statements were:

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Variables=treatment deer (treatment) season treatment×
        season deer×season (treatment) diet treatment×
        diet season×diet deer×season×diet (treatment);
Test hypothesis=treatment; error=deer (treatment);
Test hypothesis=season treatment×season;
error=deer×season(treatment);
Test hypothesis=diet treatment×diet season×diet;
error=deer×season×diet(treatment);
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Treatment was the effect of castration. Statistical significance was declared at $p<0.05$.

RESULTS

Experiment 1

Intakes, digestibilities of DM, OM and protein, and N balances of stags eating lucerne hay in this experiment are in Table 2. Castrates and entires ate similar amounts of food (approximately 26 g DM/kg liveweight·d^{-1}) and digested it with similar efficiencies ($p>0.05$). Entires excreted significantly more total N and MFN than did castrates ($p=0.02$), but there were no significant differences in the apparent and true digestibilities of N. The N balances were positive and there were no significant differences in N retention, either as g/d, or g/kg N intake ($p>0.05$).

The molar proportions of volatile fatty acids (VFA) in the rumen liquor are in Table 2. There were no significant differences between castrates and entires in the concentration of any VFA or in the acetate:propionate ratio (Ac:Pr; $p>0.05$).

Experiment 2

Daily intakes of DM were influenced by season ($p<0.001$) and diet ($p<0.0001$). Castrates ate less DM (g/d)

Table 3. Experiment 2: Effects of seasons and castration on feed intake and digestibility (least squares means) of lucerne and rhodes grass hays by Javan rusa male deer

Attribute	Intake			Digestibility			
	Dry matter (kg/day)	Dry matter ($g/kgW^{0.75}\cdot day^{-1}$)	Crude protein ($g/kgW^{0.75}\cdot day^{-1}$)	Dry matter	Organic matter	NDF	ADF
Season:							
Winter	1.38^{b}	62.3^{b}	10.1^{b}	0.60^{b}	0.61	0.61^{b}	0.54^{c}
Spring	1.27^{a}	56.9^{a}	8.9^{a}	0.58^{a}	0.59	0.61^{b}	0.37^{a}
Summer	1.25^{a}	55.3^{a}	8.8^{a}	0.57^{a}	0.59	0.55^{a}	0.47^{b}
SED [1]	0.035	1.68	0.51	0.0089	0.0098	0.0244	0.0269
Diet:							
Lucerne	1.62^{b}	72.6^{b}	16.0^{b}	0.66^{b}	0.68^{b}	0.63^{b}	0.51^{b}
Rhodes grass	0.98^{a}	43.7^{a}	2.6^{a}	0.50^{a}	0.51^{a}	0.55^{a}	0.42^{a}
SED	0.028	1.37	0.42	0.0073	0.0080	0.0200	0.0219
Castration:							
Entires	1.35^{b}	59.4	9.4	0.58	0.60	0.59	0.47
Castrates	1.24^{a}	56.9	9.2	0.58	0.59	0.59	0.46
SED	0.028	1.37	0.42	0.0073	0.0080	0.0200	0.0219
Significance of effects (p=):							
Castration	0.0002	0.0749	0.5271	0.8193	0.7140	0.7909	0.7759
Season	0.0007	0.0003	0.0299	0.0130	0.2000	0.0360	0.0001
Diet	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Season×diet	0.0299	0.0272	0.3607	0.0646	0.5675	0.7802	0.0213

[a, b] Within columns and attributes, means with different superscripts are significantly different ($p<0.05$). [1] Standard error of the difference between means.

Table 4. Experiment 2: Effects of seasons, diets and castration on intake, digestion and retention of nitrogen by Javan rusa stags

Attribute	N intake (g/day)	N excretion (g/day)			N retention (g/day)	N digestibility	
		Faecal N	Urine N	Metabolic faecal N		Apparent	True
Seasons:							
Winter	35.7^{b}	10.6^{c}	22.7^{c}	7.2^{b}	2.4^{a}	0.58	0.85^{b}
Spring	31.8^{a}	9.7^{b}	17.8^{b}	6.3^{a}	4.3^{a}	0.55	0.83^{a}
Summer	31.6^{a}	9.0^{a}	10.7^{a}	6.0^{a}	12.0^{b}	0.56	0.85^{b}
SED [1]	1.84	0.34	1.47	0.34	2.73	0.0172	0.0075
Diets:							
Lucerne	56.8^{b}	13.8^{b}	27.8^{b}	9.4^{b}	15.2^{b}	0.75^{b}	0.92^{b}
Rhodes grass	9.3^{a}	5.8^{a}	6.3^{a}	3.6^{a}	-2.8^{a}	0.37^{a}	0.76^{a}
SED	1.56	0.28	1.19	0.27	2.24	0.0141	0.0061
Castration:							
Entires	34.3	10.1^{b}	17.0	6.7	7.3	0.57	0.84
Castrates	31.8	9.5^{a}	17.2	6.4	5.1	0.56	0.84
SED	1.56	0.28	1.19	0.27	2.24	0.0141	0.0061
Significance of effects (p=):							
Castration	0.0986	0.0425	0.8764	0.1999	0.3341	0.5180	0.3048
Season	0.0523	0.0001	0.0001	0.0022	0.0018	0.4415	0.0018
Diet	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Season×diet	0.4621	0.0263	0.0001	0.4913	0.0184	0.4608	0.4004

[a, b] Within columns and attributes, means with different superscripts are significantly different ($p<0.05$). [1] Standard error of the difference between means.

than entires, but this difference was not apparent when intakes were corrected for differences in liveweight. Intakes peaked in winter and were lowest in summer (Table 3). There was little change in the consumption of rhodes grass hay DM with season (46.3, 41.4 and 43.5 g/kg $W^{0.75}\cdot d^{-1}$ in winter, spring and summer respectively), but less lucerne hay was eaten in summer (78.4, 72.5 and 67.1 g/kg $W^{0.75}\cdot d^{-1}$). These responses led to significant interactions ($p<0.05$) between season and hay type for DM intake (kg/d and $g/kgW^{0.75}\cdot d^{-1}$).

Digestibilities of all food constituents (Tables 3 and 4) were highest for lucerne hay ($p<0.0001$), and castration did not affect the stags' ability to digest these forages. Digestibilities of DM and cell wall constituents were significantly higher in winter than summer, while the true digestibility of N was lowest in spring. The digestibility of rhodes grass hay DM decreased ($p<0.05$) from winter (0.53) to summer (0.48) while that of lucerne hay was not affected

Table 5. Experiment 2: Effects of seasons, diets and castration on rumen volatile fatty acid profile in Javan rusa stags

Attribute	Volatile fatty acids (molar %)						
	Acetate	Propion-ate	Iso-butyrate	n-butyrate	Iso-valerate	n- valerate	Ac:Pr [1]
Season:							
Winter	75.0[a,b]	16.1[a,b]	1.2[a,b]	5.9[b]	1.5[b]	0.5[b]	4.9[b]
Spring	77.9[b]	15.8[a]	1.1[a]	4.8[a]	0.6[a]	0.1[a]	5.0[b]
Summer	72.9[a]	17.4[b]	1.6[b]	6.4[b]	1.1[b]	0.5[b]	4.3[a]
SED [2]	1.19	0.58	0.19	0.37	0.23	0.13	0.24
Diets:							
Lucerne	72.4[a]	17.5[b]	1.7[b]	6.5[b]	1.5[b]	0.6[b]	4.3[a]
Grass	78.0[b]	15.5[a]	1.0[a]	4.9[a]	0.6[a]	0.1[a]	5.2[b]
Sed	0.97	0.47	0.16	0.30	0.19	0.10	0.19
Entires	75.4	16.6	1.3	5.4	0.9	3.8	4.7
Castrates	75.0	16.3	1.3	6.0	1.0	0.3	4.7
SED	0.97	0.47	0.16	0.30	0.19	0.10	0.19
Significance of effects (p=):							
Castration	0.6021	0.7007	0.6536	0.0924	0.3861	0.5551	0.9601
Season	0.0010	0.0190	0.0165	0.0005	0.0061	0.0033	0.0101
Diet	0.0001	0.0002	0.0003	0.0001	0.0001	0.0008	0.0001

[a, b] Within columns and attributes, means with different superscripts are significantly different ($p<0.05$).
[1] Ac:Pr is the acetate: propionate ratio (molar%). [2] Standard error of the difference between means.

by season (0.67 in winter and 0.66 in summer), giving a season×diet interaction which approached significance ($p=0.0646$). Digestibility of ADF in rhodes grass hay declined significantly ($p<0.05$) from 0.61 in winter to 0.44 in spring and 0.47 in summer. Digestibilities of lucerne hay ADF were 0.47, 0.30 and 0.47 in winter, spring and summer, with the digestibility in spring being significantly ($p<0.05$) less than in the other seasons. These differences gave a significant season×diet interaction for ADF digestibility ($p<0.05$).

The effects of castration, season and feed type on N intake and retention are reported in Table 4. There was no effect of castration on the intake, excretion in urine, or retention of N. Castrates excreted slightly less total faecal N ($p<0.05$) than entires.

Compared to rhodes grass, when the deer were fed lucerne they had higher intakes of N, and higher total faecal, urinary and MFN excretions. The apparent and true digestibilities of N were significantly higher for lucerne than rhodes grass ($p<0.0001$). When the stags were fed lucerne hay they retained N, but when given rhodes grass hay they were in negative N balance ($p<0.0001$).

N intakes were slightly higher in winter ($p<0.05$). Faecal and urinary N excretions were lowest in summer and highest in winter, with all seasons being significantly different ($p<0.0001$). MFN excretion was also highest in winter ($p<0.005$). N retention was higher in summer than in winter or spring ($p<0.005$).

There were significant interactions between diet and season for urinary ($p<0.0001$) and faecal ($p<0.05$) N excretions and for N retention ($p<0.05$), but not for MFN excretion (Table 4). When fed rhodes grass hay the stags excreted 6.4 g faecal N/d in winter, compared to the significantly lower ($p<0.05$) amounts of 5.4 and 5.6 g/d in spring and summer. Amounts of faecal N excreted by stags fed lucerne hay in winter and spring were 14.9 and 14.0 g/d, significantly more than in summer (12.4 g/d; $p<0.05$). Urinary N losses were similar in winter, spring and summer when rhodes grass was given (8.4, 5.8 and 4.8 g/d, respectively; $p>0.05$), but were different in all seasons when lucerne hay was fed (36.9, 29.9 and 16.7 g/d in winter, spring and summer, respectively; $p<0.05$). The diet×season interaction for N retention arose because there were similar retentions when rhodes grass was fed (-4.2, -2.7 and -1.6 g/d in winter, spring and summer, respectively; $p>0.05$) but more ($p<0.05$) lucerne N was retained in summer (25.5 g/d) than in winter or spring (8.9 and 11.1 g/d).

The effects of season, hay type and castration on ruminal VFA are reported in Table 5. All the VFA concentrations and the Ac:Pr ratio varied seasonally ($p<0.05$) and between diets ($p<0.001$), but were not affected by castration. The concentration of Ac peaked in winter and spring. Pr was highest in summer but was lowest in spring, while n-butyrate was lower in spring than summer or winter ($p<0.05$). The Ac:Pr ratio was higher in spring and winter than in summer.

DISCUSSION

The rusa deer adapted well to individual confinement, and intakes of lucerne hay in the metabolism cages were similar to those when the deer were held in a group in a yard. We suggest that the deer were not stressed while in the metabolism cages.

Food intake

The daily DM intakes (44 g rhodes grass hay, and 73 g lucerne hay/kg $W^{0.75}$) in this study are similar to values

reported for all-forage diets by Puttoo and Dryden (1998; 64 g lucerne hay DM and 61 g barley hay DM/kg $W^{0.75}$) and Hmeidan and Dryden (1998; 67 g lucerne hay DM and 73 g soybean hay DM/kg $W^{0.75}$). Consumption of mixed diets is similar to, or greater than, the intakes reported here. For example, Grimaud and Chardonnet (1989) fed young rusa deer fresh *Brachiaria* grass with a commercial concentrate and reported daily DM intakes (/kg $W^{0.75}$) of 120 to 160 g, and Tomkins and McMeniman (1996) reported DM intakes of 91 g to 101 g/kg $W^{0.75}$ when young rusa deer (32 kg liveweight) were fed pelleted foods containing 90 to 205 g protein/kg. The daily DM intakes of sambar deer (a species closely related to the rusa) fed a pelleted diet by Semiadi et al. (1995) varied between 42.3 and 63.4 g/kg $W^{0.75}$ depending on season.

Castration did not affect DM intake in our experiment, when this was corrected for differences in deer liveweight. Sookhareea et al. (2001a) reported a small difference in growth rate (21 g/d averaged over three years) between entire and castrated rusa stags. This may reflect differences in either nutrient intake, nutrient utilisation, or digestive tract fill. There is little information on the effect of sex on food intake in tropical deer. Differences between males and females in DM intake corrected for liveweight were reported by Puttoo et al. (1998) who fed weaners of about 35 kg liveweight diets between 0.75 to 0.88 concentrate and 0.12 to 0.25 chopped sorghum stubble. These authors obtained intakes of 60 to 76 g/kg $W^{0.75}$ (stags) and 68 to 70 g/kg $W^{0.75}$ (hinds).

The average consumption of lucerne hay across all seasons and treatments was 1.40 times higher than for rhodes grass. Tomkins and McMeniman (1996) showed that young rusa ate more food as the protein content increased and that greatest DM intake was at 160 g protein/kg. Therefore it is possible that its low protein content may have limited the intake of rhodes grass hay. Further, the digestibilities of these two forages were significantly different, and this may have been associated with differences in digesta passage rate as low rumen passage rates are associated with low food intakes (Manyuchi et al., 1997). Alternatively, rusa deer may find rhodes grass hay unpalatable, as suggested by Hmeidan and Dryden (1998) in an experiment in which the DM digestibilities of rhodes grass and lucerne hays were similar but DM intakes were very different.

Seasonal variation in DM intake is found in both tropical and temperate deer species. In New Zealand the tropical sambar deer ate most DM in autumn and least in spring (Semiadi et al., 1994), but the cycle was of much reduced amplitude compared to that observed with temperate deer species which show a marked seasonal variation in DM intake irrespective of food availability (Suttie et al., 1984; Domingue et al., 1990). Javan rusa males are sexually active in Queensland during winter/spring, but we found no effect of castration on DM intake, or any season×castration interaction. This may be because the changes in DM intake, although statistically significant, were of small magnitude. The size of food intake changes in stags may be influenced by latitude, possibly mediated through different changes in day length. In comparison to Semiadi et al. (1995) who reported a 33% change in DM intake between autumn and spring, our stags had only a small (<10%) increase in DM intake in winter, and Grimaud and Chardonnet (1989) reported a relatively constant DM intake by young rusa deer throughout the year in New Caledonia. However, all of the reported observations on DM consumption by tropical deer have been made with young animals, and the DM intake of more mature entire males could exhibit greater seasonal variation.

Efficiency of digestion

The digestibility of lucerne hay DM (0.61 to 0.69) was similar to other values reported with rusa deer (Hmeidan and Dryden, 1998; Puttoo and Dryden, 1998), but higher than in other studies, e.g. red deer (0.55 and 0.57, Domingue et al., 1991a; and 0.60, Freudenberger et al., 1994b); sika deer (0.60, Katoh et al., 1991); and wapiti (0.52 and 0.58, Renecker and Hudson, 1990). Rusa deer digest low-quality forages with variable efficiencies. Values for rhodes grass hay vary from 0.55 organic matter digestibility (Hmeidan et al., 2000) and 0.53 DM digestibility in this experiment, to 0.64 DM digestibility (similar to lucerne hay; Hmeidan and Dryden, 1998). Puttoo and Dryden (1998) observed similar DM digestibilities (0.66) for barley and lucerne hays. The differences between experiments in the digestion of these forages are probably the result of differing physico-chemical characteristics of plants at different stages of maturity.

Neither Domingue et al. (1991a) nor Freudenberger et al. (1994b) found any seasonal changes in DM digestibility by red deer. DM digestibility is apparently unaffected by the pronounced increase in the DM intake by red deer in summer, because of an increase in rumen volume and a reduction in particulate outflow rate in summer (Domingue et al., 1991a). However, there are conflicting reports. A seasonal change in the DM fermentation rate of lucerne (but not of timothy-brome grass) was demonstrated for wapiti by Renecker and Hudson (1990), while the sika deer studied by Kim et al. (1995) had slightly increased DM, protein and NDF digestibilities in summer but no change in the ruminal passage rates of Cr-mordanted fibre. In our study, DM, ADF and NDF were digested more efficiently in winter than summer, even though summer DM intakes were lower. Although we found season×forage interactions for the digestibilities of DM and ADF, the general patterns of DM and cell wall digestion were consistent, being higher in

winter and lower in spring and/or summer. Domingue et al. (1991a) reported generally lower digestion of cell wall constituents in winter than in summer, again when DM intakes were less. It is clear, from these conflicting data, that the physiological factors which influence seasonal changes in forage digestibility by cervids are not fully understood and need further investigation.

Volatile fatty acids

Our deer had a high proportion (0.75) of Ac, with less Pr and small concentrations of butyrate and valerate. These proportions are expected when ruminants eat fibrous forages, and Domingue et al. (1991b) and Puttoo and Dryden (1998) have reported similar VFA proportions for red and rusa deer, respectively, given forage-rich diets.

In red deer, lower Ac:Pr ratios in winter than in summer were reported by Domingue et al. (1991b) but no differences were found in the study of Freudenberger et al. (1994b). In our study, Ac concentration was higher in winter and spring; Pr higher in summer, and the Ac:Pr ratio was greater in winter and spring. We observed similar trends in both castrates and entires. High Ac concentrations coincided with high DM and NDF, but low ADF, digestibilities. In both the study of Domingue et al. (1991b) and the present study, lower Ac:Pr ratios were associated with lower DM intakes. As fibrolytic bacteria are important (although not the only) producers of Ac (Stewart et al., 1997), and as the rate of clearance of fibre from the reticulorumen is an important factor in DM intake, these observations are consistent and suggest that there are seasonal changes in the microbial population of the deer reticulorumen.

Nitrogen digestion and retention

The apparent digestibility of N in lucerne in our study was similar to those reported in red deer fed lucerne, e.g. 0.63 to 0.68 (Domingue et al., 1991b) and 0.71 to 0.75 (Freudenberger et al., 1994b). When given rhodes grass, our rusa had a similar N digestibility to that of pangola grass by red deer (0.37, Tomkins et al., 1991), but a lower digestibility than those reported for sika deer fed fresh tropical forages (e.g. napier grass 0.70, pangola grass 0.78, and guinea grass 0.65; Lin et al., 1988). The apparent N digestibilities in our experiment and that of Tomkins et al. (1991) were low because of the low protein contents of the forages used (5 and 6%, respectively). Apparent N digestibility is reduced at low diet protein contents because the amount of endogenous faecal N excreted is more influenced by DM intake than diet protein content (Merchen, 1993).

In the present study, urinary N excretion was high on both lucerne and grass hays, and depending on seasons, ranged from 35 to 62% of total N intake. This is consistent with reports that red deer excrete more N in urine than faeces (Freudenberger et al., 1994a). N balances were positive when we fed lucerne hay, with an average retention of 27 g N/100 g N consumed (over both experiments), but were negative when rhodes grass hay was given, with losses of up to 30 g N/100g N consumed. Red deer given pangola grass hay (62 g protein/kg) were also in negative N balance (Tomkins et al., 1991). The similarity between our results and those reported for red deer support the observations of Semiadi et al. (1998) that sambar and red deer retain N with similar efficiencies. The changes in N retention which we observed when our stags were fed rhodes grass and lucerne hays are consistent with present knowledge of the protein requirements of rusa deer. Data from Tomkins and McMeniman (1996) and Puttoo et al. (1998) show that the protein requirement of rusa stags is approximately 15% of the diet DM. This was easily supplied by the lucerne hay (21% protein in the DM) but our data show that the rhodes grass hay protein content (5%) was insufficient to meet even the maintenance requirement.

Seasonality in N excretion has been reported in red deer (Domingue et al., 1991b; Freudenberger et al., 1994b) and white tailed deer (Holter et al., 1977). Increases in N retention in red deer were the result of a decreased urinary N excretion. In our experiment, urinary N excretion decreased (by 44%) from 23 g/d in winter to 11 g/d in summer. Faecal N excretion was also lower in summer than winter. Both castrated and entire rusa stags had similar seasonal patterns of N retention. It should be noted that we observed these seasonal changes in N retention only when lucerne hay was fed, and this effect was responsible for the overall "season" main effect. The difference in forage N contents may explain why N retention from the two forages varied-the deer were always in N deficit when eating rhodes grass, but there was always enough N provided from lucerne to allow the expression of seasonal changes in N retention. The reasons for this seasonal change in N economy have not been explained, but the increase in N retention which we observed in summer is consistent with the increased liveweight gains usually observed with rusa deer on pasture at this time of the year (Sookhareea et al., 2001a).

This study indicates that rusa stags in subtropical latitudes have seasonal patterns of food intake, digestibilities of DM and cell wall constituents, and N retention. The seasonal change in DM intake is small, at least in young stags. Performance on low-quality food is poor: the stags were in negative N balance, and lost weight, when given rhodes grass hay. The seasonal variation in N retention indicates that using protein-rich food during winter may be wasteful. More efficient use of food might be achieved if diets of varying energy and protein content are fed according to seasons. We suggest that the productivity

and commercial exploitation of rusa deer could be optimised if they are kept on high-quality food during spring and summer. There were no biologically significant effects of castration on nutrient intake or use. We conclude that deer farmers could use castration as a management tool with no adverse effects on their stags' nutritional performance.

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