Seasonal effects of two forage-based nutrition regimens on intake and average daily gain of three genotypes of young red deer (*Cervus elaphus*)

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Abstract

The red deer genotypes currently being farmed in New Zealand have different forage-use habits and exhibit different growth profiles in different seasons. Three genotypes (NZ red, eastern European and elk-cross) were subjected to low and high nutritional regimens during autumn, winter and spring. Few differences among genotypes were found in autumn, but in winter the elk-cross genotype grew faster than did the NZ red and eastern European genotypes. NZ red deer consumed approximately 9% of their diet as hay in both autumn and winter, while eastern European and elk-cross deer had much higher intakes of hay (up to 44%). Divergence in response to the high- or low-nutrition regimens imposed developed in winter. Liveweight gain averaged 84 g/d on the low nutrition regimen and ranged from 132 to 199 g/d for NZ red and elk-cross genotypes respectively on the high-nutrition regimen. Eastern European deer were immediate. In spring as the NZ red genotype did not respond to increasing feed availability, while the eastern European and elk-cross deer increased growth rate by approximately 50 g/d and 100 g/d, respectively, in response to increased feed availability. This was matched by increases in forage and metabolisable energy intake. Understanding these interactions provides information that will enable feeding systems to be tailored to deer genotype to improve on-farm resource-use efficiency.

Keywords: diet selection; energy; forage intake; genotype; liveweight gain; red deer; seasonality.

Introduction

Recent developments in the New Zealand deer industry have seen the inclusion of a range of genotypes from different regions of the world (Rowe et al. 2015). Main red deer types include the original imported Scottish red deer (*Cervus elaphus* ssp. *scoticus*), North American elk (*C. e.* ssp. *nelsoni*), and Eastern European genotypes (*C. e.* ssp. *hippelaphus*). There is potential for each of these genotypes to respond differently to seasonal signals of day-length and temperature, and to nutrition regimen, based on their evolutionary circumstance (Rhind et al. 2002).

Previous research has indicated that red and elk × red deer may grow at different rates throughout the year (Judson & Nicol 1997; Nicol & Barry 2003), though variation among herds can be great, as reported by Stevens et al. (2003). The different dry matter intakes (DMI) of NZ red deer (*C.E. scoticus*) and red x elk (*C.E. nelsoni*) were explained by live weight differences rather than genotype as DMI were similar when expressed in terms of metabolic body weight.

This experiment aimed to define the autumn, winter and spring dry matter intakes of the three major red deer sub-species in New Zealand and investigate how the genotypes responded to different amounts of feed offered, to aid farmers in using this variation to develop profitable farming systems.

Materials and methods

One hundred and twenty-six five-month-old red deer were assigned to one of two nutrition regimens in early autumn 2003 at the Winchmore Research Station (43 80S; 171 78E). High- and low-nutrition regimens, represented by a single mob for each, were imposed using a leader (High) - follower (Low) rotational-grazing system, with the High treatment being allocated 1 kg barley/head/d plus approximately 0.4 kg DM as lucerne hay during autumn and winter, while the Low treatment was allocated 0.5 kg barley/head/d plus *ad libitum* meadow hay during autumn and winter. During spring, the leader-follower grazing system was used without supplement. Within each mob were 21 deer of three genotypes – NZ red (*Cervus elaphus scoticus*), eastern European (*C. e. hippelaphus*) and elk-cross (2/3 NZ red x 1/3 elk *C. e. nelsoni*).

In each season seven animals of each genotype were used to determine the forage intake and digestibility for each nutrition regimen using the alkane dilution technique as described by Dove and Mayes (1991) using controlled-release alkane capsules as described by Stevens and Corson (2006). Animals were dosed with a controlled-release capsule, delivering an assumed constant supply of C_{32} and C_{34} on April 24, June 19 and October 17. Faecal collections were taken on days 14 and 15 following dosing to assess fecal concentrations of both dosed and natural alkanes. Endpoint samples to determine release rate of dosed alkanes were taken between days 18 and 22. Digestibility estimates were then used to calculate the metabolisable energy concentration of individual intakes using the following equation (AFRC 1990)

$$ME\ (MJ/kg\ DM) = 0.81*(18.4*Digestibility(\%)/100).$$

Samples of diet were determined from plucked pasture samples representative of the diet selected, and grab samples of supplements. Both diet and faecal samples were snap frozen and freeze dried before analysis. Live weights were measured every two weeks and average daily gain assigned to each season based on the calendar months

March to May (autumn), June to August (winter) and September to November (spring). Herbage mass before and after grazing was determined by taking 40 readings within the grazing area using a rising-plate meter and published equations (L'Huillier & Thomson 1988). Pre- and post-grazing pasture composition was determined by dissection of approximately 40-g samples into grass leaf, grass stem, legume, weed and dead material from 20 random grab samples taken to ground level.

Diet composition (hay and pasture) were determined using the procedure of Mayes et al. (1995), adjusted for recovery by the method of Dillon (1993). Diet alkane proportions were then allocated on this basis and forage intake calculated using the C_{31}:C_{32} ratios. Analysis of the data recognised a potential bias due to high dead-material intakes of deer on the Low-nutrition regimen in autumn. This was not apparent in winter or spring. Plucked samples represent the diet as predominantly green leaf. Much of the dead material was seedhead left from summer. Based on the much higher alkane concentrations measured in the inflorescence of grasses (Dove et al. 1996), secondary calculations were done on the autumn Low samples. This assumed that the hay samples were representative of the dead material in the pastures and diet alkane proportions were adjusted to reflect the 30% of the intake from dead material. These were re-analysed and are presented in the results.

Animal data for each season were analysed separately by ANOVA (GenStat 2015) as a 2 x 3 factorial randomised-plot design with individual animals being used as replicates. The ability to determine both intake and the energy concentration of the diet of individuals provided the means to define the diet of those individuals. Thus the comparison of the relative treatments can be refined and described by those differences, enabling the use of the individual as replication of the nutritional treatments. Pasture samples were taken three times within each season. These samplings were used as replication of the pre- and post-grazing herbage. Different paddocks were used in each season and, therefore, the paddocks become independent of the nutritional treatments. The experiment was approved by the AgResearch Invermay Animal Ethics Committee in accordance with New Zealand animal-welfare regulations.

Results

The amount of pasture on offer (kg DM/ha) differed significantly between the nutrition treatments and between seasons (Table 1; $P<0.05$). However, when expressed as the amount offered per head, the difference only occurred between nutrition regimens (Table 1). Botanical composition of the offered and residual pasture, when measured as the proportion as grass leaf, clover and dead material, did not differ significantly between nutrition regimes or among seasons (Table 1). The residual pasture cover was 2060 and 1290 kg DM/ha after the High and Low treatments had grazed the pastures (Table 1; $P<0.01$).

During autumn, data were analysed as recorded, and then recalculated to reflect the high dead-material intake of the Low regimen. No significant differences were found in deer growth rate (Table 2; mean=142 g/d), though estimated dry matter intake was significantly lower (Table 2; $P<0.001$) for the High treatment compared with the Low treatment. The digestibility of the Low diet was also higher than that of the High diet (Table 2; $P<0.001$). The proportion of hay in the diet was greater in the Low regimen compared with the High regimen. The addition of barley to the diet substituted for the forage, leading to similar metabolisable energy intakes on both treatments. No differences were found between the liveweight gains of the genotypes in autumn. The NZ red and eastern European deer were similar weights (60.6 and 57.2 kg respectively) while the elk-cross were heavier at 72.5 kg (Table 2). Intake of hay was low for the NZ red, intermediate for the elk-cross and greatest for the eastern European deer.

Recalculation of the intakes to reflect high dead-material intakes (approximately 30% of the forage diet, Table 2) reduced the estimated forage intake of the Low regimen by approximately 0.3 kg DM/d (Table 2) compared

Table 1 Herbage mass and botanical composition of the offered and residual pasture fed in two differing nutrition regimens to three red deer genotypes over three seasons.

		Nutrition			Season			
		Low	High	LSD (0.05)	Autumn	Winter	Spring	LSD (0.05)
Pasture on offer	kg DM/ha	1760	2850	545	2300 ab[1]	1840 b	3020 a	950
	kg DM/head	5.1	8.0	2.8	7.2	5.3	7.8	3.7
Pasture residual	kg DM/ha	1290	2060	540	1530 b	1370 b	2310 a	665
Botanical composition (on offer)								
Grass	%	74.4	81.1	11.6	72.8	79.6	81.2	14.3
Clover	%	6.2	10.2	7.8	9.8	3.6	12.8	9.6
Dead	%	19.4	8.7	12.1	17.4	16.8	5.6	14.9
Botanical composition (residual)								
Grass	%	64.5	77.2	14.9	74.8	65.1	75.0	18.4
Clover	%	5.8	4.8	5.1	7.7	3.6	4.6	6.3
Dead	%	29.7	18.0	16.7	17.5	31.3	20.5	20.6

[1]Values within rows with different letters are significantly different

Table 2 Forage intake, digestibility, and energy intake of three strains of red deer fed two differing nutrition regimens during autumn before and after adjustment for dead material intake determined by pre- and post-grazing pasture composition.

		Nutrition			Genotype			
		Low	High	LSD (0.05)	NZ Red	Eastern European	Elk cross	LSD (0.05)
Unadjusted								
Forage intake	kg DM/d	2.27	1.65	0.29	2.03[1]	1.97	1.90	0.36
Digestibility	g/kg DM	777	715	27	753	730	755	33
Proportion of hay	%	36.1	15.3	12.1	9.1 c	43.3 a	23.9 b	14.9
Barley intake	kg DM/d	0.5	1	na	0.75	0.75	0.75	na
Metabolisable energy intake								
	MJME/d	32.9	30.7	3.8	32.7	31.3	31.3	4.6
	MJME/kg $BW^{0.75}$	1.49	1.37	0.16	1.51	1.50	1.27	0.21
Adjusted for dead intake								
Dead intake	kg DM/d	31	1	na				
Forage intake	kg DM/d	1.96	1.65	0.29	1.70	1.95	1.79	0.36
Digestibility	g/kg DM	732	715	31	717	716	740	38
Proportion of hay	%	23.1	15.3	13.4	5.9 b	36.5 a	14.4 b	16.5
Metabolisable energy intake								
	MJME/d	28.1	30.7	3.9	28.1	30.5	29.6	4.7
	MJME/kg $BW^{0.75}$	1.27	1.37	0.17	1.29	1.46	1.20	0.21
Average live weight	kg	62.4	63.6	3.0	60.6 b	57.2 b	72.5 a	3.7
Live weight gain	g/d	133	151	41	119	161	146	51

[1] Values with different letters are significantly different

Table 3 Forage intake, digestibility, and energy intake of three strains of red deer fed two differing nutrition regimens during winter.

		Nutrition			Genotype			
		Low	High	LSD (0.05)	NZ Red	Eastern European	Elk cross	LSD (0.05)
Forage intake	kg DM/d	1.9	1.3	0.27	1.37 b[1]	1.40 b	2.10 a	0.32
Digestibility	g/kg DM	619	617	37	598 b	603 b	653 a	45
Proportion of hay	%	26.9	4.4	7.9	8.6 b	16.4 ab	22.0 a	9.7
Barley intake	kg DM/d	0.5	1	na	0.75	0.75	0.75	na
Metabolisable energy intake								
	MJME/d	24.6	25.4	3	22.2 b	22.6 b	30.5 a	3.7
	MJME/kg $BW^{0.75}$	1.01	0.99	0.12	0.95	0.97	1.1	0.15
Average live weight	kg	69.5	74.9	2.6	67.7 b	64.9 b	84.0 a	3.2
Live weight gain	g/d	84	159	16	112 b	112 b	140 a	20

[1]Values with different letters are significantly different

Table 4 Forage intake, digestibility, and energy intake of three strains of red deer fed two differing nutrition regimens during spring.

		Nutrition			Genotype			
		Low	High	LSD (0.05)	NZ Red	Eastern European	Elk cross	LSD (0.05)
Forage intake	kg DM/d	2.61	2.86	0.36	2.52 b[1]	2.64 b	3.10 a	0.45
Digestibility	g/kg DM	617	736	26	688	654	691	32
Metabolisable energy intake								
	MJME/d	24.2	31.6	3.7	25.8 b	25.4 b	32.5 a	4.6
	MJME/kg $BW^{0.75}$	0.85	0.99	0.12	0.92	0.88	0.96	0.15
Average live weight	kg	81.9	93.1	3.7	80.2 b	81.8 b	102.6 a	4.56
Live weight gain	g/d	257	308	37	250 b	297 a	300 a	45

[1]Values with different letters are significantly different

to the original data, though this remained significantly greater than forage intake on the High regimen. Forage digestibility was also reduced by the recalculation and values were not significantly different between the nutrition regimens. The proportion of hay in the diets of the Low-nutrition regimen was reduced under this methodology, with similar reductions in the amount of hay eaten by the different genotypes (Table 2). The energy intake, once recalculated to reflect dead material content, of the Low regimen was numerically lower than that of the High regimen. Energy intakes of the three genotypes reflected their relative liveweight gains, with the eastern European deer having both the highest energy intake and highest liveweight gain, the elk-cross being intermediate and the NZ red deer having the lowest intake and liveweight gain (Table 2).

During winter forage intake was higher on the Low-nutrition treatment, while liveweight gain and average live weight were lower than the High-nutrition treatment (Table 3). The elk-cross deer had higher forage intake and digestibility than did the NZ red and eastern European deer in winter (Table 3). The elk-cross were the heaviest (P<0.001), had higher energy intake per day (Table 3) and significantly higher liveweight gain than the other genotypes. Concurrently, the intake of hay as a percentage of the diet was greater in the elk-cross deer compared with NZ red, with eastern European deer being intermediate (Table 3).

In spring, significant differences again occurred between the nutrition regimens (Table 4) with the High treatment having a higher digestibility, greater energy intake and higher liveweight gain. The eastern European deer had a liveweight gain similar to that of the elk-cross, while both grew faster than the NZ red deer. However, the intake of the eastern European deer was similar to the NZ red deer, and both were lower than the elk-cross (Table 4).

Interactions among nutrition regimen and genotype for liveweight gain occurred in winter and a trend towards interactions occurred in spring (Table 5). During winter the liveweight gain of all genotypes on the Low nutrition regimen was uniformly low. However, on the High regimen, the elk-cross deer grew faster than did either the NZ red or eastern European deer, which grew faster than their Low-nutrition cohort. The interaction term provided no

Table 5 Interactions among liveweight gain, feed intake and feed digestibility for NZ Red, Eastern European and elk cross weaner deer fed two nutrition regimens in winter and spring.

		Genotype				
Season	Nutrition	NZ Red	Eastern European	Elk cross	P values	LSD
Winter		Liveweight gain (g/d)				
	Low	92 c[1]	77 c	84 c	0.002[3]	28
	High	132 b	148 b	199 a		
		Total feed intake (kg DM/d)				
	Low	2.19	2.1	3.05	0.306	0.46
	High	2.08	2.22	2.67		
		Forage digestibility (%)				
	Low	60.4	59.5	65.7	0.789	6.4
	High	59.2	61.1	64.9		
		Energy intake (MJME/d)				
	Low	21.8	20.6	31.6	0.293	5.2
	High	22.5	24.4	29.5		
		Average liveweight (kg)				
	Low	65.8	61	81.5	0.42	4.5
	High	69.5	68.8	86.5		
Spring		Liveweight gain (g/d)				
	Low	251	259	260	0.07	45
	High	250	311	368		
		Total feed intake (kg DM/d)				
	Low	2.44 b	2.79 b	2.67 b	0.04	0.63
	High	2.59 b	2.47 b	3.57 a		
		Forage digestibility (%)				
	Low	64.9	58.1	62.6	0.089	4.6
	High	72.7	72.7	75.7		
		Energy intake (MJME/d)				
	Low	23.6 b	23.7 b	25.3 b	0.036	6.6
	High	28.1 b	27.2 b	40.2 a		
		Average liveweight (kg)				
	Low	75.3	76.3	95.7	0.709	6.5
	High	85	87	109.1		

[1]Values with different letters are significantly different

more explanation of difference in total feed intake, forage digestibility and energy intake during winter. During spring there was a trend towards a significant interaction between the nutrition regimens and the genotypes for liveweight gain (Table 5). While the NZ reds did not respond to the increased availability and quality of the pasture of the High-nutrition regimen, both the eastern European and elk-cross deer had a higher liveweight gain on the High-nutrition regimen compared with the Low regimen. This was reflected in significant interactions between nutrition regimen and genotype for total and metabolisable energy intake.

Discussion

The alkane technique to predict forage intake and diet composition has been used successfully in many situations. However, the key issues of alkane recovery and collecting a representative sample of the animals' diet remain challenging. Miller and Thompson (2005) compared botanical composition of the diet of grazing sheep and found that the alkane technique was more accurate than faecal cuticle analysis in a mixed native-grass community. However, this still requires an accurate collection of the diet components. Alkane concentrations vary among pasture species and the age and development of those species (Dove & Mayes 1991). Adjusting alkane concentrations to reflect the balance of the diet in Autumn was done in retrospect after examination of the original data. The subsequent results appear to represent the actual feed requirements of the animal reflected in the liveweight gains. However, this calculation needs to be treated with caution as it highlights the problems with the techniques without providing a definitive solution. Results from the winter and spring appear to be consistent with the feed requirements predicted by live weights and liveweight gains

The red deer genotypes currently being farmed in New Zealand have different forage use habits and exhibited different growth profiles in different seasons. Few differences were found in autumn. Overall the deer on the high-nutrition regimen had a lower digestibility of the forage eaten. High levels of grain in the diet may compromise the digestibility of forage (Van Soest 1994), though increasing forage intake can also result in lower digestibility through faster passage rate (Mertens & Ely 1979).

In winter, divergence in growth of the genotypes under the two nutrition regimens started to emerge. While the elk-cross genotype grew faster than the NZ red and eastern European genotype overall, the eastern European deer also began to exhibit greater growth than the NZ red deer when offered the high regimen. Forage intake of the elk-cross was greater, in part due to the greater live weight. The extra intake and the slightly higher liveweight gain would reflect the greater live weight of the elk-cross deer at this time of the year, similar to that measured by Stevens et al. (2003). Differences in intake between low and high regimens were small and forage digestibility appeared relatively unaffected by nutrition regimen. The two mechanisms that may influence potential liveweight gain are the capture of digestible energy as metabolisable energy, or the conversion of metabolisable energy to net energy. Evidence suggests the capture of digestible energy as metabolisable energy, as the red deer has exhibited the ability to reduce gut passage rate of feed in winter (Sibbald & Milne 1993). If this was the case on the low regimen, then more of the digested energy may be lost as heat and methane, lowering the yield of metabolisable energy, as has been measured in low-quality feeds in white-tailed deer (Ullrey et al. 1972).

The data also demonstrate a divergence in the performance of the genotypes when exposed to different nutrition regimens. Again the opportunity of the larger elk-cross deer to utilise the greater energy intake due to their size may explain some of this. However, the eastern European deer appeared to be beginning to exhibit some divergence from the NZ red deer, even though they were of approximately the same size.

In spring, the energy intake of the High-nutrition regimen was greater than that of the Low regimen as a consequence of slightly higher dry matter intake and significantly higher digestibility. This led to greater liveweight gains on average for the High treatment. However, the NZ red genotype did not respond to increasing feed availability, while the eastern European and elk-cross deer increased liveweight gain by approximately 53 to 108 g/d in response to increased feed availability. This was matched by increases in forage and metabolisable energy intake in all three genotypes, but no significantly greater liveweight gain in the NZ Red deer. These results are consistent with those of Judson and Nicol (1997) who found that an allowance of 8 kg DM/100 kg live weight was required to maximise liveweight gain in elk-cross deer while only 6 kg DM/100 kg live weight was needed to maximise the gain of NZ red deer, with both genotypes growing at similar rates when pasture allowance was low. This data suggests that the eastern European deer require similar allowances to elk-cross during spring to maximise their growth potential.

The liveweight gain in spring was approximately 100 g/d higher than during the winter and spring despite the energy intake on the Low nutrition treatment being similar in both seasons. This may reflect the added maintenance cost of the deer in winter (Simpson et al. 1978), though the translation of digestible energy to metabolisable energy may have been altered, due to greater losses during the digestion process.

The outcome of higher liveweight gain during each season for the High-nutrition regimen was a greater live weight in spring of 11.2 kg. This is valuable in financial terms as well as biological terms, as a greater proportion of the deer in the High-nutrition regimen were ready for slaughter (76% compared with 29% in the High and Low treatments, respectively, had an estimated carcase weight of

50 kg or greater) by mid-November. The efficiency of gain is reflected in the comparison of the feed intake, expressed as the ratio in metabolic live weight to liveweight gain. This demonstrated that the elk-cross genotype appeared to be more efficient in the winter, while the eastern European genotype was more efficient during the spring. Interestingly, these genotypes both had live weights of approximately 85-87 kg at their most efficient stage of growth.

Understanding these interactions provide the researcher and farmer with information that will enable tailored feeding systems to be developed to improve the efficiency of on-farm resources.

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