Effects of fresh forage quality on feed intake and live weight gain of red deer in spring

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Abstract
Changes in voluntary feed intake (VFI) and average daily gain (ADG) of 10- to 12-month-old male red deer (*Cervus elaphus*) in response to a range of pasture morphological development stages of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture in spring were investigated. An intake study in November 2000 tested responses to pastures spelled for 6, 8 or 10 weeks in a combined indoor/outdoor comparison over two weeks. This was followed by a 5 week grazing study which compared 3, 5 or 7 week spelling periods during November and December in 2001. Pasture spelled for 6, 8 or 10 weeks had acid detergent fibre concentrations of 216, 229 and 252 g/kg DM (P<0.001) and seed head proportions of 145, 364 and 539 g/kg DM (P<0.001) respectively. As spelling interval increased from 6 to 10 weeks ADG declined (P=0.003) from 394 g/day to 361 g/day and 221 g/day. VFI also declined from 2.40, to 2.23 and 1.64 kg DM/day (P=0.016), and digestibility declined from 786 to 764 and 734 g/kg DM (P=0.002). The grazing study comparing 3, 5 or 7 week spelling provided a different response to spelling interval as seed head production was similar regardless of spelling interval. During the course of the grazing study voluntary feed intake increased from 1.93 kg DM/day to 2.69 kg DM/day (P=0.004), while the digestibility of the forage declined from 719 to 687 g/kg DM (P=0.013). The energy lost during digestion increased by 4.9% for every 10% increase in seed head offered (P=0.011). The coefficient of conversion of digestible energy to metabolisable energy declined from 0.86 to 0.56 as the diet offered increased from 0% to 60% seed head.

Keywords: feed intake, forage quality, growth, digestible energy, red deer, spring.

Introduction
Average daily gain (ADG) during spring is a key element of venison production systems in New Zealand. Maximum ADG of deer is achieved during the late spring (Stevens *et al.* 2003), coinciding with maximum pasture growth. Late spring also coincides with the reproductive growth in pastures producing significant amounts of seed head (Litherland *et al.* 2002). Grass quality also declines during November and December (Litherland *et al.* 2002) with the shift from leaf to stem production. A key component that reflects the change in these factors is the acid detergent fibre (ADF) concentration, which has a significant influence on feed intake (van Soest 1994).

Feeding information for farmed red deer (*Cervus elaphus*) has concentrated around winter (Webster *et al.* 1997a, 2001), specialist pastures (Barry *et al.* 1998) and pasture mass and heights (Barry *et al.* 1998; Judson & Nicol 1997). Forage quality information has generally been restricted to a comparison of grass with legumes and herbs (Barry *et al.* 2000).

Information on the seasonal nature of red deer growth has concentrated on the amount of feed required and the response to day length, especially during winter (Judson & Nicol 1997; Webster *et al.* 1997b, 1998). Relatively little information is available on how the voluntary feed intake of red deer varies when pastures change in nutritional value, independently of any changes in botanical composition.

The effects of this morphological development on forage intake and liveweight gain, at a time when potential ADG is at a maximum, are unknown. This study aimed to define how the voluntary feed intake and ADG of rising 1-year-old red deer change as nutritional value and morphological composition of ryegrass, and the proportion of white clover in pasture changes during spring.

Materials and methods
The changes in voluntary feed intake and ADG of 10- to 12-month-old male red deer (*Cervus elaphus*) in response to a range of morphological development stages of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture in spring were investigated over 2 years at the Invermay Agricultural Research Centre, Mosgiel, New Zealand (45° 58' S; 170° 04' E). The first experiment studied the response to pastures spelled for 6, 8 and 10 weeks in a combined indoor/outdoor comparison over a short period to test the alkane dilution methodology and the experimental technique using a 7 day adjustment to the diet and a 7 day intake measurement period during late October and early November (spring) 2000. The second experiment applied the grazing methodology over a 5 week time period using 3, 5 and 7 week spelling periods during November and December in 2001.

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Experiment one

Experiment one was a randomised block design with three treatments consisting of 6, 8 and 10 week spelling intervals before feeding. Treatments were blocked by location with four deer per treatment housed indoors and four deer per treatment grazing freely outdoors. Individual deer intakes and liveweight changes were used as replicates. Weaners with starting weight of 82.3 kg, (SE 2.6 kg) were weighed twice weekly throughout the experiment.

Daily feed intake was measured indoors by difference between offered and residual feed from individual feeders and by alkane dilution, and outdoors by alkane dilution. Deer were allocated to treatments on 24 October 2000. Indoors they were trained to an operant feeding system that used electronic ear tags to open gates, until 6 November 2000 when all deer were dosed with *n*-alkane controlled release capsules (Captec™, NuFarm Ltd, Auckland, New Zealand) that contained 1000 mg each of n-Dotriacontane (C_{32}) and n-Hexatriacontane (C_{36}). Faecal collections were made on 13, 15, 20 and 22 of November for intake and digestibility determination and endpoint collections were made on the 24, 27, and 29 November and 1 December. The *n*-alkane release rates were determined based on assuming the capsule release expired the day before alkane concentration in the faeces dropped to 50% of the previous day's concentration. The final release rates were 58.8, 62.5 and 55.6 mg/day for 6, 8 and 10 week spelling treatments respectively. Deer on the 10 week spelling treatment were put outdoors on 22 November due to behavioural issues as they attempted to access food from other treatments. The results from four animals were omitted from the data set due to significant variations in feed intake caused by interference from other animals.

Pastures of endophyte-free perennial ryegrass and white clover were prepared in advance by grazing at weekly intervals to between 1000 and 1200 kg DM/ha from 7 August and then spelled for appropriate intervals to provide pasture that had been spelled for 6, 8 and 10 weeks. Pastures were cut fresh each morning and fed twice a day. Pasture not fed directly in the morning was stored at 4°C until the afternoon. Dry matter concentrations of the feed as fed each day were measured at harvest, and were also determined in refusal samples from both morning and evening. The pastures were harvested with a reciprocating mower and fed without further chopping. Outdoor deer were restricted to similar, uncut areas of pasture using a four-wire electric fence.

Daily forage samples and faecal samples were immediately deep frozen and freeze dried before analysis. The chemical composition, including ADF, neutral detergent fibre (NDF), soluble carbohydrate and crude protein (CP), was determined on the freeze-dried pasture by near-infrared spectroscopy (Model 6500, NIRSystems Inc., Silver spring, MD, USA) calibrated from wet chemistry (Corson et al. 1999).

Botanical and morphological composition of the diets was determined by separation of approximately 400-piece samples into white clover, dead material, and ryegrass leaf, pseudostem and true stem at each of the faecal collection dates which were treated as replication.

Analysis for n-alkane concentration followed the methodology described by Mayes *et al.* (1986) with an adjustment made for recovery of the n-alkanes of 0.826, 0.861, 0.838 and 0.882 for C_{31}, C_{32}, C_{33} and C_{35} respectively (Dillon 1993). Voluntary food intakes and dry matter digestibility were calculated from alkane dilution in faeces based on Dove & Mayes (1991), being the mean of that calculated from C31:C32 and C32:C33 ratios.

Regression analysis compared intakes measured indoors, over a 9 day period from 13 to the 22 November, with mean intake estimates derived from alkane dilution on the 4 days of faecal sampling. Liveweight gain was calculated using regression analysis of liveweights recorded from 10 November to 27 November. Analysis of variance was used to compare treatment effects on intake and liveweight gain, botanical and morphological components and feed chemical composition estimates. Simple linear regression analysis was used to investigate relationships between intake and diet digestibility, and intake and liveweight gain. Metabolisable energy concentration was calculated from alkane derived digestibility using equation 1 assuming $\alpha = 0.81$

Equation 1: $ME(MJ) = 18.4 \times digestibility\% \times \alpha$ (ARC 1980).

Experiment two

Experiment two was a completely randomised design with three treatments which were 3, 5 and 7 week spelling periods after pastures were grazed to approximately 1500 kg DM/ha. Five paddocks of 0.64 ha were randomly allocated for use during the 5 weeks of the experiment, with one paddocks used each week. These paddocks were then divided into three equal plots by permanent fences and these plots were randomly allocated to each treatment.

Twelve deer (mean liveweight 89.5 kg, SE 2.7 kg) were allocated to each treatment on 23 October 2001. A put-and-take system was used to add or subtract extra deer in each plot weekly to offer similar daily allowances on each treatment. Pastures were perennial ryegrass/white clover.

Measurements began on 5 November and continued until 10 December 2001 (five weeks). Pasture mass was estimated weekly using a rising plate meter calibrated for each pasture. Samples for botanical and morphological component analysis (as per experiment one) were cut to ground level on each weekly allocation prior to grazing. The deer were weighed twice weekly. Faecal and pasture samples were collected for intake assessment twice weekly.

The deer were randomly assigned to treatment and to the alkane dosing schedule. Alkane methods were the same as in experiment one. Intakes were calculated from alkane dilution each week from four deer within each treatment group. The first group of four deer were dosed with controlled release alkane capsules on 23 October and samples were collected 16 and 18 days post-treatment. The second group of four deer were dosed on 7 November 2001 and sampled during the weeks of 12 and 19 November. The final group of four were dosed on 21 November and sampled during the weeks of 26 November and 3 December. Endpoint samples were taken 19, 21 and 23 days after capsule administration to determine the release rates of the controlled release capsules. Release rates were 58.8 mg/day for all treatments.

ADG was estimated using linear regression analysis before being analysed for treatment differences.

Repeated measures analysis of variance was used to separate effects of treatment from that of time and used to analyse any interactions between the two. The effects of time were much greater than the effects of treatment and so were explored using the general linear model to examine trends associated with daylength. Energy intake was calculated from feed intake and predicted energy concentration of the diet and energy intake per unit of metabolic liveweight ($BW^{0.75}$) calculated to standardise the influence of liveweight on intake. The energy requirements for maintenance and growth, calculated from Experiment 1, were used to calculate the metabolisable energy requirement of the deer and these were then used to estimate the efficiency of use of digestible energy as metabolisable energy (by rearranging equation 1 and solving for α for each data point. This was then compared to seed head concentrations of the diet using simple linear regression.

The experiments were conducted under the supervision of the AgResearch Invermay Animal Ethics committee in accordance to New Zealand Animal Welfare regulations as projects P481 and P529.

Results

Experiment one

Pastures spelled for 10 weeks generally had higher DM, ADF and NDF and lower CP than pastures spelled for 6 weeks, with the 8 week pastures being intermediate (Table 1). The proportions of grass leaf declined and the proportions of grass seed head increased as spelling interval increased from 6 to 10 weeks (Table 1).

The alkane-based estimates of voluntary feed intake of deer fed indoors were compared to the measured intakes (Figure 1). These were significantly correlated (R^2=0.845), but under-predicted intake at low values and over-predicted intake at high values (Alkane Intake = 1.19 × Measured Intake – 0.55).

The average liveweight of the red deer during the study was 84.6 kg. ADG was highest in deer fed pastures spelled for 6 weeks, intermediate in deer fed pastures spelled for 8 weeks and lowest in deer fed pastures spelled for 10 weeks (Table 2). Apparent dry matter digestibility and voluntary feed intake declined linearly ($P<0.001$; $P=0.04$) as spelling interval increased (Table 2). The calculated metabolisable energy intake also declined linearly ($P=0.002$) as spelling interval increased when

Table 1 The influence of spelling interval on the feed quality parameters and morphological composition of a perennial ryegrass-based pasture during November in 2000 (Experiment 1).

		Spelling interval (n=9)				
		6 weeks	8 weeks	10 weeks	s.e.d.	P value
Feed quality parameter (g/kg DM)	DM (%)	180	204	201	3.0	<0.001
	ADF	216	229	252	6.4	<0.001
	NDF	381	405	435	7.8	<0.001
	Soluble carbohydrate	131	138	136	3.4	0.083
	Crude protein	203	163	145	6.6	<0.001
Morphological composition (g/kg DM)						
	White clover	62	44	13	37.0	0.49
	Grass leaf	578	433	338	35.5	<.001
	Grass pseudostem	204	146	100	39.5	0.091
	Grass seedhead	145	364	539	57.5	<.001
	Dead matter	11	13	10	10.1	0.913

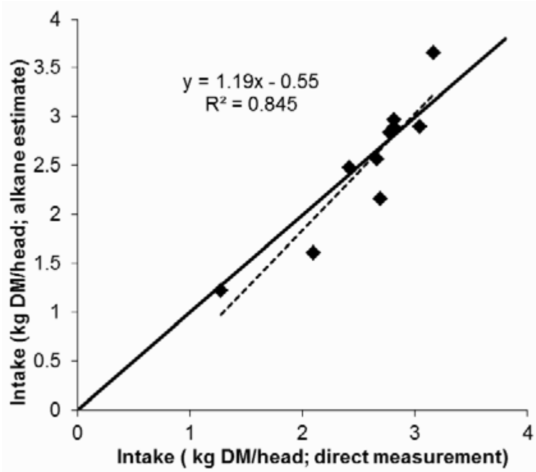

Figure 1 The relationship between fresh pasture intake measured directly in-stall or estimated by alkane dilution during November 2000 (solid line is the 1:1 relationship).

expressed as both MJME/day and MJME/kg $BW^{0.75}$/day (Table 2). Maintenance requirements were 0.376 MJME/kg $BW^{0.75}$ (R^2 = 0.9426) when calculated from regression fitting. Energy required for gain was calculated as 38.3 MJME/kg gain (R^2 = 0.8275).

Experiment two

The concentration of ADF, NDF, soluble carbohydrate and CP of pastures spelled for 3, 5 or 7 weeks were not significantly different (Table 3). When compared over the 5 weeks of the experiment, both ADF and NDF increased with time (Table 4). Crude protein declined significantly over the 5 weeks (Table 4). Significant variations in soluble carbohydrate were also recorded (Table 4), with a downward trend evident.

The total amount of pasture on offer (kg DM/ha) increased as spelling interval increased (Table 5). Pasture growth rate in all treatments was approximately 100 kg DM/ha/day. Stocking rate (deer/ha) was increased as spelling interval and pasture yield increased (Table 5) and this ensured that the amount of feed offered to

Table 2 Live weight, apparent digestibility, voluntary intake and average daily gain of rising 1-year-old red deer when fed ryegrass-based pastures after different spelling intervals in November 2000 (Experiment one).

		Spelling interval (n=8)				
		6 weeks	8 weeks	10 weeks	s.e.d.	P value
Live weight	kg	84.7	83.5	85.6	2.58	0.719
Apparent dry matter digestibility	g/kg DM	786	764	734	11.9	0.002
Voluntary intake	kg DM/day	2.40	2.03	1.64	0.234	0.016
	MJME/day	28.1	23.1	18.1	2.83	0.008
	MJME/kg $BW^{0.75}$	1.001	0.833	0.641	0.0876	0.002
Average daily gain	g/day	394	361	221	50.4	0.006

Table 3 The influence of spelling interval on the feed quality parameters and morphological composition of a perennial ryegrass-based pasture during November 2001 (Experiment two).

		Spelling interval (n=5)				
		3 weeks	5 weeks	7 weeks	s.e.d.	P value
Feed quality parameter	DM (%)	155	151	161	12.6	0.354
	ADF (g/kg DM)	237	255	265	21.4	0.477
	NDF (g/kg DM)	398	427	446	28.9	0.322
	Soluble carbohydrate (g/kg DM)	115	116	119	8.2	0.857
	Crude protein (g/kg DM)	214	187	165	19.3	0.109
Morphological composition (g/kg DM)						
	White clover	139	139	112	55.3	0.852
	Grass leaf	522	517	400	48.3	0.059
	Grass pseudostem	77	73	106	43.0	0.714
	Grass seedhead	199	219	339	48.2	0.04
	Dead matter	49	40	40	16.2	0.775

the deer did not significantly differ among treatments (Table 5), averaging 8.39 kg DM/deer/day.

The amount of white clover in the pasture ranged from 11 to 14% and did not differ significantly among spelling intervals (Table 3) or over the duration of the experiment (Table 4). The amount of grass leaf ranged from 522 to 400 g/kg DM as spelling interval increased from 3 to 7 weeks (P=0.059). Grass seed head increased significantly from 199 to 339 g/kg DM as spelling interval increased (Table 3), and also increased over the duration of the experiment (Table 4). Neither grass pseudo-stem nor dead matter varied significantly with spelling interval (Table 3) or over the duration of the experiment (Table 4).

Liveweight of the weaner deer (Table 5) averaged approximately 94.4 kg. ADG was not significantly affected by spelling interval (Table 5). Apparent dry matter digestibility ranged from 688 to 719 g/kg as spelling interval increased from 3 to 7 weeks (P=0.087; Table 5) and declined slowly over the duration of the experiment (Table 4). Voluntary feed intake was not significantly affected by spelling interval before grazing (Table 5), averaging 2.36 kg DM/day. Voluntary feed intake and seed head increased during the duration of

Table 4 Feed quality parameters, botanical and morphological composition and intake measures of rising 1-year-old red deer grazing ryegrass-based pastures over 5 weeks during November and early December 2001 (Experiment 2).

		Time						
		Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**s.e.d.**	**P value**
Feed quality parameter (g/kg DM)								
	ADF	205	235	255	276	291	8.3	<.001
	NDF	367	406	424	457	465	10.8	<.001
	Soluble carbohydrate	141	117	125	107	94	8.3	0.003
	Crude protein	219	213	180	169	162	11.9	<.001
Botanical parameter (g/kg DM)								
	White clover	185	177	112	104	71	71.3	0.481
	Grass leaf	631	578	497	360	334	62.4	0.005
	Grass pseudostem	119	67	148	28	63	55.5	0.295
	Grass seedhead	34	144	200	434	451	62.2	<.001
	Dead matter	28	34	37	52	81	21.0	0.18
Liveweight	kg	89.52	92.7	94.85	96.58	98.35	2.723	0.076
Apparent dry matter digestibility	g/kgDM	719	702	723	696	687	9.1	0.013
Voluntary intake	kg DM/day	1.93	2.27	2.45	2.43	2.69	0.132	0.004
	MJME/day	20.8	23.9	26.6	25.4	28.1	1.47	0.012
	MJME/kg $BW^{0.75}$	0.71	0.799	0.852	0.818	0.893	0.0429	0.031
Average daily gain	g/day	306	363	285	335	215	33.7	0.006

Table 5 Liveweight, apparent dry matter digestibility, feed intake, average daily gain, pasture yield, amount offered and stocking rate of rising 1-year-old red deer grazing ryegrass-based pastures after differing spelling intervals in 2001.

		Spelling interval (n=12)				
		3 weeks	**5 weeks**	**7 weeks**	**s.e.d.**	**P value**
Liveweight	kg	93.54	95.63	94.02	2.109	0.603
Apparent dry matter digestibility	g/kgDM	688	710	719	11.8	0.074
Voluntary feed intake	kg DM/day	2.42	2.17	2.48	0.131	0.087
	MJME/day	25.3	23.0	26.6	1.64	0.135
	MJME/kg $BW^{0.75}$	0.830	0.748	0.866	0.0547	0.141
Average daily gain	g/day	300	327	275	23.4	0.135
Pasture yield	Kg DM/ha	3670	5210	6170	465	0.002
Amount offered	kg DM/head/day	9.33	8.13	7.72	0.611	0.071
Stocking rate	weaners/day	56	91	114	2.5	<.001

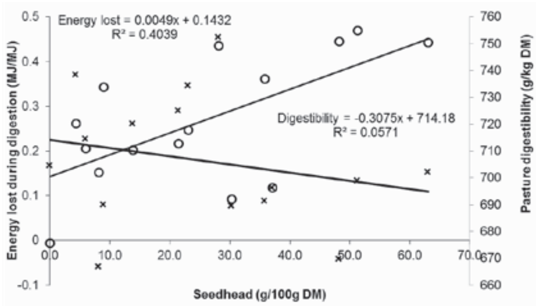

Figure 2 Relationships between the proportion of seed head in pasture on offer and the digestibility of pasture (x) and the energy lost during digestion (o) in rising 1-year-old red deer during November in 2001 (Experiment 2). Note the different scales and units of the Y-axes.

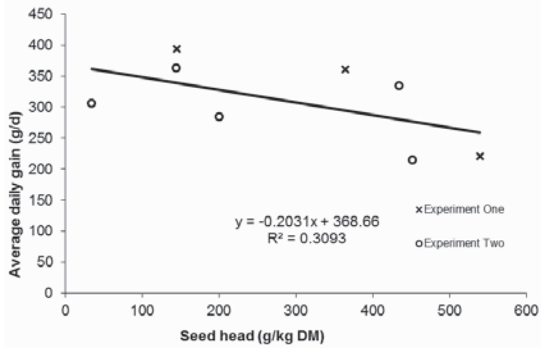

Figure 3 The relationship between the proportion of seed head offered to rising 1-year-old deer and average daily gain during November in 2000 (Experiment one) and 2001 (Experiment two).

the experiment (Table 4). The calculated metabolisable energy intake was not significantly affected by spelling intervals when expressed either as MJME/day or MJME/kg $BW^{0.75}$/day (Table 5).

When the parameter estimates of energy requirement for maintenance and growth calculated from experiment one were applied to the data from experiment two, the energy lost during digestion could be estimated. Energy loss during digestion increased significantly as the proportion of seed head offered increased (Figure 2; Energy loss = 0.0049x + 0.1432; R^2=0.404; P=0.011).

Discussion

The results from the two experiments differed from each other as experiment one produced a clear difference between spelling length while experiment two did not. Experiment one was set up in a classical feeding study design with a 7 day adjustment period and a 7 day feeding period. The confined nature of the feed supply, over a single week and the spelling treatments (6 to 10 weeks) allowed a wide range in the amounts of seed head presented to the deer. This resulted in classical relationships emerging with ADF and NDF increasing as seed head increased with a predicted decline in feed intake, and digestibility (van Soest *et al.* 1978), and an expected decline in ADG. The pastures which provided the feed for this experiment were all fed over one time period though they were closed for growth at different times. The range in feed quality was so wide that behavioural issues arose with the deer fed indoors and some data was lost as a consequence.

The short term nature of experiment one provided the opportunity to estimate the metabolisable energy concentration of spring grown perennial ryegrass pastures without allowing the deer to adjust to the changing concentrations of ADF. This provided estimates of energy intake and allowed the calculation of energy requirements for maintenance and growth. These estimates were within the range of previous estimates (Fennessy *et al.* 1981; Jiang & Hudson 1994; Webster *et al.* 2000).

The ADGs achieved in experiment one were higher than those achieved in experiment two. However, an increase in seed head and stem in the pasture was correlated to the decline in ADG when the data from both years were combined (Figure 3), with ADG declining by 20 g/day for each 10% increase in seed head and stem. Reported growth rates on 10–12-month-old red deer stags on perennial ryegrass/white clover pasture in spring have ranged from 255 to 354 g/day (Hoskin *et al.* 1999; Kusmartono *et al.* 1996; Min *et al.* 1997; Semiadi *et al.* 1993; Soetrisno *et al.* 1994), though none have manipulated the quality of perennial pasture or recorded seed head production.

Experiment two was designed as a grazing study over the period when seed head proportion is changing most rapidly in response to daylength. The feed supply in experiment two changed significantly over the 5 week experimental period, with seed head being the predominant component in pasture in all treatments by the end of the trial. Seed heads extend into the grazed stratum over a relatively short time frame and this may be relatively unaffected by spelling interval. Average ryegrass heading date (14 November) was unaffected by closing dates of 30 September or 21 October regardless of significant differences in total dry matter production, feed quality and seed head production (Browse *et al.* 1981). Thus, as the experiment proceeded into late November, the drive to produce a seed head was able to be completed within the spelling intervals chosen. This provided a unique insight to the issues faced by graziers as feeding conditions change rapidly, regardless of grazing management. Grazing intensity needs to be particularly severe to control seed head production, leaving little or no leaf after grazing (Korte *et al.* 1984) and not generally practised at this time of year.

The outcomes from experiment two over the 5 week period did provide the opportunity to further investigate relationships between daylength, intake and seed head development which affect ADG of weaners. Grass seed head was the most significant factor when predicting intake and liveweight gain during these spring experiments.

During experiment two the deer increased voluntary feed intake over the course of the five measurement weeks even though forage quality was declining, as indicated by the ADF concentration. This increase in feed intake was linearly associated with increasing daylength and was expected (Suttie *et al.* 1983). Liveweight gain declined during this time, indicating that, although feed intake increased, energy available for growth declined. This is at odds with the forage digestibility which in red deer changes in response to seasonal variations in day length (Barry *et al.* 1991). This can result in high voluntary feed intake even though forage quality may decline (Milne *et al.* 1978). The increase in rumen capacity of red deer during summer while maintaining digestibility (Freudenberger *et al.* 1994a,b) appears to be a mechanism to meet seasonally and genetically determined growth potentials. This ability to modify gut fill to try to attain seasonally and genetically predetermined levels of intake and performance (Jiang & Hudson 1992) adds further to previous relationships (Webster *et al.* 2000) when voluntary intake increased as energy concentration declined. The result in this case, however, was that while intake increased, the proportion of energy lost during digestion increased as seed head increased. When seed head was not present, the coefficient of conversion of digestible energy to metabolisable energy was approximately 0.86, similar to other estimates (ARC 1980). This coefficient declined to 0.56 when the diet offered comprised of 60% seed head (Figure 2). There have been no other reported calculations of efficiency of use of DE for ME in pastures of differing seed head composition. This decline may be related to an increase in the heat increment associated with digestion and increased losses due to methane production. More energy may also be required for maintenance due to increased processing of the diet, as greater energy may be needed for prehension and mastication of a diet of seed heads, but this has not been accounted for in these calculations.

Conclusions

This study provided some insights into the dynamic of pasture production and its effects on red deer intake, digestion and average daily gain during the reproductive growth phase of ryegrass pastures. Graziers should aim to maximise green leaf intake with growing weaners during the seed-head production period. While seed-head may be eaten and digested by weaner deer, this can limit production by reducing intake (experiment one) and dry matter nutritive value (experiment two). Surplus seed head may be controlled by mechanical means but remains problematic when trying to use livestock. Losses of energy during digestion of pasture containing significant amounts of seed head should be investigated further.

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