Nutritional Requirements and Management Strategies for Farmed Deer[a] - Review -

H. T. Shin*, R. J. Hudson[1], X. H. Gao[2] and J. M. Suttie[3]
College of Life Science and Natural Resources, Sung Kyun Kwan University, Suwon 440-746, Korea

ABSTRACT : Knowledge concerning the nutritional requirements and nutritional problems of farmed deer is limited. Nutritional recommendations must be based on data from domestic ruminants and farmed deer. An understanding of the biology and adaptative characteristics of wild deer is essential for sensible application of sheep and cattle nutritional principles. Nutritional requirements of deer are generally separated into five categories: energy, protein, minerals, vitamins and water. Research on deer nutrition has primarily focused on energy, protein and minerals (phosphorus and calcium). Changes in the nutritional requirements that occur with gestation, lactation, breeding and antler growth should be coordinated with seasonal changes in nutrient availability from forage plants. This paper describes aspects of current knowledge of energy, protein, minerals, vitamins and water requirements. Nutritional problems of farmed deer are described with recommendations for prevention or control. A comparison of production efficiency of deer, lamb, beef cattle and dairy cattle is included. *(Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 561-573)*

Key Words : Nutritional Requirements, Management Strategies, Farmed Deer

INTRODUCTION

The population dynamics and physical welfare of deer depend principally upon their nutritional status. Despite a good deal of field research, knowledge concerning the nutritional requirements and physiological processes of deer is still rather sparse. The necessary data can best be obtained by studying penned animals, since here some of the specific factors of their complex biology can be controlled and properly analyzed. But because deer are highly excitable, agile, and powerful, they are hardly an easy experimental animal to work with. Nevertheless, feeding of captive deer is now greatly simplified by the development of a pelleted ration which seemingly provides the essential nutrients for optimum growth and maintenance. In the future it could become expedient to supply complete pelleted rations for free roaming deer that are faced with acute browse shortages and severe environmental pressure.

As with any other livestock farming system, the aim of the deer farmer, as far as his farm management is concerned, should be to ensure that the relationship between the nutrient requirements of his deer and the feed supply available from the land, are matched in the most possible economic manner. To do this it is necessary to have some knowledge of the feed requirements of the various classes of stock at various times of the year, and of the capability of the land to supply it.

In view of the considerable literature dealing with various aspects of the nutrition of deer, the subject obviously cannot be completely covered in this paper. The following references will be of interest to readers desiring additional information or details : Kay and Staines (1981), Yerex (1982), Fennessy and Drew (1985), Reid (1987), Shin (1987), Wemmer (1987), Yerex and Spiers (1987), Hudson et al. (1989), Brown (1991), Haigh and Hudson (1993), Robbins (1993), and Alexander and Buxton (1994).

FEED INTAKE AND DIGESTION

Voluntary feed intake by deer shows a striking seasonal variation, being high in the summer and low in the winter, resulting in corresponding fluctuations in body weight and body weight gain. Calves and adults, both stags and hinds, all demonstrate this trait to a greater or lesser extent. Typical dry matter intakes (DMI) for farmed red deer are given in table 1.

Deer can eat and digest any of the range of feedstuffs used for more traditional domestic ruminants. In comparative digestibility trials deer have been found to digest poor quality roughage diets less completely but high quality concentrate diets more fully than do sheep (Milne et al., 1978). This may be partially explained by the shorter ruminal retention time and higher passage rate seen in the deer (Nagy and Regelin, 1975). The smaller species of deer which normally select low fiber diets do not have the omasal

* Address reprint request to H. T. Shin. Tel: 82-331-290-7804, E-mail: htshin@yurim.skku.ac.kr.
[1] Faculty of Agriculture, Forestry and Home Economics, University of Alberta, Edmonton, Canada
[2] Institute of Special Economic Animal and Plants, CAAS, Jilin 132109, P. R. China
[3] AgResearch, Invermay Agricultural Center, Private Bag 50034, Mosgiel, New Zealand
[a] This paper has been presented at Symposium IX entitled "Increasing Role of Secondary Animal Species in the 21st Century" of the 8th World Conference on Animal Production on June 30, 1998 at Seoul National University, Seoul, Korea.

Table 1. Daily dry matter intakes (DMI, kg) by red deer according to season and physiological status or age

Season	Hinds		Stags		Growing calves	
	Status	DMI (kg/d)	Status	DMI (kg/d)	Age (months)	DMI (kg/d)
Autumn	Dry/weaned	1.7	Rut/Live weight loss	0-3.0	3~ 5	1.4
Winter	Mid pregnancy	2.0	Maintenance	3.0	6~ 8	1.3
Spring	Late pregnancy	2.3	Increasing body condition	4.0	9~11	2.0
Summer	Lactation	3.0	Increasing body condition	4.0	12~15	2.2

(Adam, 1994)

capacity necessary for the further processing of coarse feed particles in low digestibility diets such as mature pastures and hays. Seasonal changes in feed intake are then associated with seasonal changes in rumen capacity without any seasonal alterations in apparent digestibility or retention time.

At digestibilities of less than 65%, deer are faced with the problem of needing more forage but being able to consume less (Haigh and Hudson, 1993). The protein content of forage is a good indicator of its digestibility. This is partly due to the correlation of protein content with stage of growth. But protein also can be a limiting factor for microbial growth and hence fermentative capacity. This opens the possibility of synergistic associative effects of feeds. Indeed, deer select diverse diets to capitalize on these nutrient balances and perhaps to avoid phytotoxicities (Haigh and Hudson, 1993).

There are also considerable differences in the rumen microbial populations and their *in vitro* activities between different species of deer (table 2). The larger species of deer have greater numbers and a more diverse range of ciliate protozoa than the smaller species which indicates a greater cellulolytic potential. Prins and Geleen (1971) found that red deer had 7 genera of ciliate protozoa in their rumen liquor, whereas fallow deer had only three genera and the roe deer had only one species. Increasing rumen turnover rate decreases the number and diversity of rumen ciliate protozoa (Prins and Geleen, 1971). The *in vitro* cellulolytic activity of the rumen fluid increases with increasing size of the species of deer, whereas amylolytic activity decreases (Prins and Geleen, 1971).

Table 2. Cellulolytic activity and amylolytic activity of rumen fluid from cattle and 3 species of Cervidae

Ruminant	Body wt. (kg)	Cellulolytic activity[a]	Amylolytic activity[b]
Cow	540	12.0	3.6
Red deer	95	9.0	5.2
Fallow deer	40	5.8	6.1
Roe deer	14	4.4	6.9

[a] Grams of cellulose hydrolyzed per liter of rumen fluid per 24 hours.
[b] Grams of soluble starch hydrolyzed per liter of rumen fluid per hour. (Prins and Geleen, 1971)

NUTRIENT REQUIREMENTS

The deer farm manager should consider deer nutrition on a seasonal reproductive cycle of the male (stags) and female (hinds) in table 3, figure 1 and figure 2.

Table 3. A summary of events in the life of red deer stags and hinds living in the Northern and Southern Hemispheres

Male	Northern Hemisphere	Season	Southern Hemisphere	Female
	January		July	│
	February		August	231 days
Casting antler	March	— Spring —	September	gestation
│	April		October	│
Velvet	May		November	↓
│	June	— Summer —	December	Calving
↓	July		January	
Cleaning antler	August		February	
Rut begins	September	— Autumn —	March	
Copulation	October		April	Conception
	November	— Winter —	May	│
	December		June	│

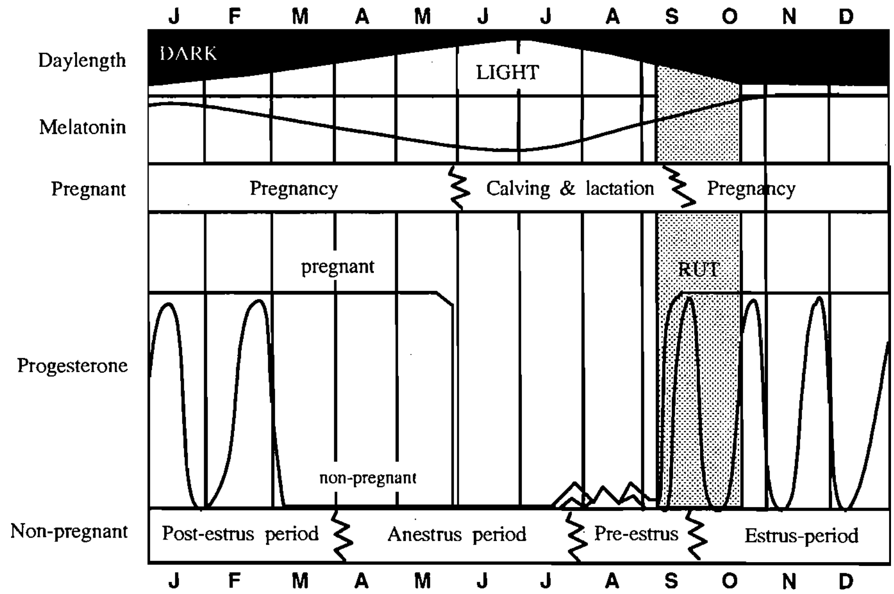

Figure 1. Seasonal reproductive changes in the hind (Haigh and Hudson, 1993)

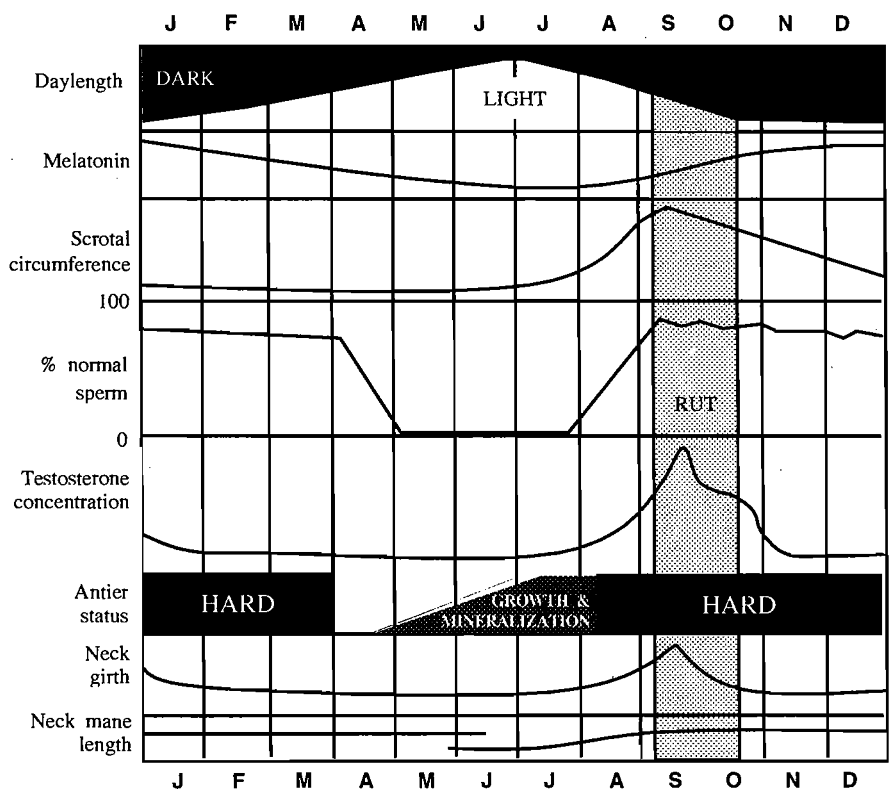

Figure 2. Seasonal reproductive changes in the stag (Haigh and Hudson, 1993)

Changes in the nutritional requirements of deer that occur with gestation, lactation, breeding and antler growth should be coordinated with seasonal changes in nutrient availability from forage plants. Feeding periods (seasons) are defined as follows in Canada by Haigh and Hudson(1993) : Autumn (Sept. 1- Nov. 1) runs from the onset of the rut to the start of winter feeding. Winter (Nov. 1-April 1) is the period of snow cover in western Canada and the midwestern states. Spring (April 1-May 15) is signaled by snow

Table 4. Energy, TDN, protein and ADF requirements for elk (dry matter basis)

Item	Maintenance	Growth				Gestation		Lactation	
		Velvet	3-6 mo	6-9 mo	9-18 mo	12-24 wk	24-36 wk	0-6 wk	6-12 wk
DE (MJ/kg)	9.6	10.1	12.6	11.7	10.9	10.5	10.9	11.7	11.3
TDN (%)	64	70	76	72	68	64	67	76	74
Crude protein (%)	7-10	10-12	18-20	16-18	12-14	12-14	14-15	14-16	12-14
Fat (%) min.	3	3	3	3	3	3	3	3	3
ADF (%) min-max	25-45	25-45	16-35	20-40	20-45	20-45	20-45	20-40	20-40

DE=Digestible energy; TDN=Total digestible nutrients; ADF=Acid detergent fiber. (Puntenney, 1995)

melt and the flush of green vegetation that occurs during the latter part of gestation. Summer (May 15-Sept. 1) begins with the calving season and extends through lactation to the rut. Fennessy (1982) divided the year into four periods for application of the seasonal nutrients requirements in New Zealand : Autumn (March-May; 65 days, the rut), Winter (May-August; 100 days), Spring (Sept.-December; 100 days, velvet antler growth and late pregnancy) and Summer (December-March; 100 days, lactation).

Energy requirements

Seasonal target weights and metabolizable energy (ME) requirements for elk in Canada are shown in table 4, and for New Zealand red deer and wapiti are summarized in table 5. These are based on summation of estimated requirements for maintenance, target gain, and reproduction. Deer should be fed to attain seasonal target weights. Such targets are specific to each genotype; the numbers in table 5 are indicative of the most commonly farmed races, the Rocky Mountain wapiti and New Zealand red deer.

Seasonal target weights of calves are selected primarily to ensure puberty and maximize conception rates at 15 months of age. Target weights for hinds are selected to minimize calving difficulties due to overfeeding during gestation and to ensure recovery of body condition during lactation to conceive in the ensuing rut. Targets for stags are selected mainly to ensure post-rut recovery, velvet growth, and regain of rutting condition. Since wapiti stags mature late in life, sometimes achieving weights up to 500 kg, it is difficult to summarize seasonal weight targets for all stags older than 3 years of age.

Seasonal energy requirements of red deer and wapiti differ mainly in scale. However, despite a 3-fold difference in weight, total daily requirements of wapiti hinds are only twice that of red deer. The weight difference of stags is about 2.5-fold, but requirements differ by only about 1.8-fold. This scaling (proportional to $W^{0.75}$) has been attributed to such geometrical factors as surface area-to-volume ratios, relative cross-sectional areas, or body composition.

The metabolizable energy requirement for maintenance for calves (three to 11 months of age) is approximately 0.45 megajoules per kg metabolic body weight (Milne et al., 1987) and for adults is about 0.57 $MJ/kg^{0.75}$ (Fennessy et al., 1981).

1) Growing deer

There is no substantial evidence for seasonal changes in the maintenance ME requirement for grazing calves, but some evidence for changes in the efficiency of utilization of ME for growth (table 4). Estimated values from United Kingdom studies are approximately 53-57 MJ ME per kg body weight gain in November to December at five to six months of age, 87 MJ in January to February at seven to eight months, and 41-56 MJ in March to April at nine to 10 months (Milne et al., 1987).

However, New Zealand researchers have estimated an overall constant figure of 37 MJ per kg body weight gain from six to 18 months of age (Fennessy et al., 1981). Calculated estimates of ME requirement for growing deer are given in table 6.

2) Pregnancy and lactation

The additional daily ME requirement above maintenance for pregnancy in the red deer increases from 1.7 to 5.0 MJ in the last three months of gestation (Adam et al., 1988). However, by far the greatest increase in energy requirement occurs in lactation (table 6). Peak daily lactation yield, seen at about 40 days in well nourished hinds, is about 2 kg, containing about 10.5 MJ of energy (Arman et al., 1974). This requires an increase above maintenance of 17.2 MJ ME in the diet if no weight loss is incurred, that is approximately double the daily ME requirement for a dry hind. As in more traditional farm livestock it is important to achieve and sustain a high peak yield early in lactation in order to maximize total lactation yield and milk consumption by suckled calves. Yield may be reduced by 30 to 60 percent by inadequate energy intake and there is indeed a strong positive correlation between suckled calf body weight gain and milk throughout the three to four months from birth to weaning in the autumn.

Protein requirements

Protein is very important for body growth in deer, especially for fawn and yearlings. Inadequate protein intake in a given year will also reduce antler development. In fact, a period of inadequate nutrition (low protein) for buck fawns may adversely influence antler development for several succeeding years. A deer must obtain at least a 6% to 7% crude protein

Table 5. Seasonal target weights and metabolizable energy requirements of Canadian wapiti and New Zealand red deer

Item	Hinds			Stags		
	3-15 mo	15-27 mo	Adult	3-15 mo	15-27 mo	Adult
Wapiti						
Autumn (Sept. 1-Nov. 1)						
Seasonal target weights[a]	120	220	290	140	280	365
Metabolizable energy[b]	27	35	39	32	33	40
Winter (Nov. 1-April 1)						
Seasonal target weights	130	225	290	150	260	340
Metabolizable energy	28	32	35	32	39	48
Spring (April 1-May 15)						
Seasonal target weights	150	225	270	168	260	349
Metabolizable energy	41	50	51	54	59	53
Summer (May 15-Sept. 1)						
Seasonal target weights	168	230	275	195	266	350
Metabolizable energy	49	80	84	68	58	50
Red deer						
Autumn (Sept. 1-Nov. 1)						
Seasonal target weights	43	85	95	48	105	190
Metabolizable energy	15	23	23	16	24	19
Winter (Nov. 1-April 1)						
Seasonal target weights	50	85	95	48	105	190
Metabolizable energy	18	22	22	19	28	35
Spring (April 1-May 15)						
Seasonal target weights	60	86	86	70	93	150
Metabolizable energy	22	24	24	27	31	42
Summer (May 15-Sept. 1)						
Seasonal target weights	68	88	88	80	96	152
Metabolizable energy	21	47	47	26	30	38

[a] Weights at beginning of each period(kg); [b] Megajoules (MJ) per day. (Haigh and Hudson, 1993)

Table 6. Caculated daily ME requirements by red deer for maintenance and additional requirements for growth, pregnancy and lactation

Item	Body weight (kg)	ME requirement (MJ) for					
		Maintenance	Season	Growth at (g/d)			
				50	100	150	200
Calves (3-16 months)	40	7.2	Autumn	2.8	5.5	8.3	11.0
	50	8.5	Winter	4.4	8.7	13.1	17.4
	60	9.7	Spr./Summ.	2.4	4.9	7.3	9.7
		Maintenance	Late pregnancy	Peak lactation			
Hinds	80	15.2	1.7-5.0	17.2			
	100	18.0					
		Maintenance					
Stags	150	24.4					
	250	35.8					

(Adam, 1994; Adam and Fletcher, 1994)

diet to maintain rumen function, but a protein diet in the 13% to 16% range is required for successful growth, antler development and reproduction (Verme and Ullrey, 1972).

Protein requirements are less well defined than energy requirements. The objective is to just meet the animal's needs for amino acids, since above this level, feed protein is used as an energy source. Excessive protein consumption by stags can result in prenuptial ulceration and prolapse from ammonia burns on the penis sheath.

For their first year of life, deer benefit from levels of 16-18% dietary protein for elk and red deer (tables 4 and 7), and 18.5% for sika deer during antler growth period (Gao et al., 1993). Other classes of stock should receive these levels only in spring and early summer when their demands are high (table 8). Winter maintenance requirements of adult are fully covered with protein levels of 8% to 10%, although attention to palatability is necessary (Fennessy and Drew, 1985).

Table 7. Crude protein (CP) concentrations in diets for farmed red deer

Item	Age/Status	Season	CP (% DM)
Calves	3~ 5 months	Autumn	17.0
	6~ 8 months	Winter	10.0
	9~15 months	Spring/Summer	12.0-17.0
Hinds	Dry	Autumn/Winter	10.0
	Pregnant	Spring	14.0
	Lactating	Summer	17.0
Stags	Weight loss	Autumn/Winter	10.0
	Weight gain	Spring/Summer	12.0

(Adam, 1994)

Mineral requirements

Mineral nutrition is important for deer, as indeed it is for any livestock enterprise, particularly when high levels of production are expected, however it must be stressed that levels of energy and protein nutrition are of primary importance. Whereas wild deer in their natural habitat can select a varied diet which usually sustains adequate mineral status, farmed deer generally have less variety in their diet and higher levels of performance, so that attention should be paid to the mineral content of their grazings and supplementary feeds. It is important to realize that the relationships between mineral components of the diet are complex, and no element can be adequately considered in isolation. Precise mineral requirements for deer are not well documented but the information available implies that extrapolation may be made from the better known requirements and dietary availabilities of minerals to other domestic ruminants (table 9).

Ullrey et al. (1973) concluded that a dietary level of 0.4% calcium was adequate for normal development, bone strength and antler growth of young white-tailed deer fawns on a ration containing 0.25% phosphorus. Ullrey et al. (1975) later determined that 0.28% phosphorus was adequate for fawns on a 0.5% calcium diet of 18% crude protein. High energy diets require higher levels of Ca and P. Magruder et al. (1957) obtained best antler growth on a diet of 0.64% Ca and 0.56% P. The dietary Ca:P ratio should be from 1:1 to 3:1.

Clearly, productive deer require adequate quantities in their diet of the major minerals and trace minerals (table 10) ; deer, like cattle and sheep, may succumb to clinical or sub-clinical trace mineral deficiencies. Antler size may not be increased simply by feeding increased amounts of minerals. Imbalances of minerals can lead to toxicities that might not otherwise occur. Copper deficiency (enzootic ataxia) is recognized in wapiti in North America (Haigh and Hudson, 1993), and deficiencies of cobalt, selenium, and/or vitamin E and iodine have been documented in red deer in both the United Kingdom (Jones, 1994) and New Zealand

Table 8. Dietary energy (MJ/day) and crude protein (g/day) requirements for wapiti, red deer and sika deer

Item	Autumn (Sept. 1 ~ Nov. 15)		Winter (Nov. 15 ~ April 1)		Spring (April 1 ~ May 15)		Summer (May 15 ~ Sept. 1)	
	MJ/day	g/day	MJ/day	g/day	MJ/day	g/day	MJ/day	g/day
Wapiti								
Hinds	48	629	51	650	59	763	81	1430
Stags	57	733	58	798	62	953	60	803
Red deer								
Hinds	23	336	22	244	29	364	46	858
Stags	34	456	33	421	38	530	35	419
Sika deer								
Hinds	18	265	18	203	19	213	32	568
Stags	25	337	24	365	27	455	26	377

(Friedel and Hudson, 1994)

Table 9. Mineral requirements for cattle, sheep, and deer (dry matter basis)

Item	Cattle[a]	Sheep[b]	Deer			
			Haigh[c]	Adam[d]	Doshier[e]	Smits[f]
Major minerals (%)						
Sodium chloride	0.10	0.18	0.18-0.50	-	0.2	-
Calcium	0.37-0.60	0.20-0.82	0.5	0.3-0.6	1.6	0.8-1.0
Phosphorus	0.26-0.43	0.16-0.38	0.3	0.2-0.4	0.6	0.65-0.8
Magnesium	0.10	0.12-0.18	0.15	0.1-0.2	0.4	-
Potassium	0.65	0.50-0.80	0.65	0.30	1.0	-
Sulphur	0.10	0.14-0.26	0.15	0.1-0.3	0.3	-
Trace minerals (ppm)	0.50	0.10-0.80	0.50	0.1-1.0	1.0	0.7-0.9
Iodine						
Iron	50	30-50	50	40	75	50-250
Copper	8	7-11	15	10	30	20-30
Selenium	0.20	0.1-0.2	0.30	0.1	0.4	0.3-0.5
Zinc	30	20-33	35	30	95	120
Manganese	40	20-40	35	20-25	85	50-100
Cobalt	0.10	0.10-0.20	0.15	0.1	0.3	0.2-0.4

Source: [a]NRC(1984); [b]NRC(1985), [c]Haigh and Hudson (1993); [d]Adam (1994); [e]Doshier (1991); [f]Smits and Haigh (1990).

Table 10. Mineral requirements for elk (dry matter basis)

Item	Maintenance	Growth				Gestation		Lactation	
		Velvet	3-6 mo	6-9 mo	9-18 mo	12-24 wk	24-36 wk	0-6 wk	6-12 wk
Major minerals (%)									
Ca	0.35	1.40	0.60	0.55	0.50	0.50	0.60	0.70	0.60
P	0.25	0.70	0.30	0.30	0.30	0.40	0.40	0.40	0.40
K	0.65	1.00	0.65	0.65	0.65	0.65	0.65	1.00	1.00
Mg	0.20	0.40	0.20	0.20	0.20	0.20	0.20	0.25	0.20
NaCl	0.15	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Trace minerals (ppm)									
Copper	15	15	15	15	15	15	15	15	15
Manganese	40	40	40	40	40	40	40	40	40
Zinc	50	50	50	50	50	50	50	50	50
Iron	50	50	50	50	50	50	50	50	50
Iodine	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.60	0.60
Cobalt	0.10	0.20	0.10	0.10	0.10	0.10	0.10	0.20	0.20
Selenium	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

(Puntenney, 1995)

(Wilson, 1984). In Australia, investigators have concluded that iron, manganese, and zinc nutrition in red deer is similar to other ruminants and that liver concentrations are in the same ranges as those for cattle and sheep (Paynter et al., 1984).

Vitamin requirements

Very little research has been conducted on vitamin requirements of deer. In the natural state deer obtain most of the fat soluble vitamins from growing plants. Vitamins A, D and E are among the more important vitamins for proper growth, gestation and lactation for elk (table 11). The B-complex vitamins are normally synthesized by the adult deer rumen bacterial flora, but newborn deer need B-complex vitamins (table 12).

Vitamin A is undoubtedly important for antler growth as hardening (ossification) occurs. Deer can convert β-carotene in green leaves into vitamin A, which then becomes available for a variety of functions. During most of the year, β-carotene intake should be more than adequate, but slight vitamin A deficiencies may occur during harsh, dry winters. Vitamin A is required for the maintenance of epithelial surfaces and fertility. Recommended levels are 22-44,000 IU/kg of concentrate feed with the higher levels being fed to the smaller species

Table 11. Vitamin requirements for elk (dry matter basis)

Item	Maintenance	Growth				Gestation		Lactation	
		Velvet	3-6 mo	6-9 mo	9-18 mo	12-24 wk	24-36 wk	0-6 wk	6-12 wk
A (IU/kg)	3000	5,000	4,000	4,000	3,000	5,000	5,000	5,000	5,000
D (IU/kg)	600	1,000	800	800	600	1,000	1,000	1,000	1,000
E (IU/kg)	30	40	30	30	30	40	40	40	40

(Puntenney, 1995)

Table 12. Vitamin requirements of milk replacer, growing and adult deer (dry matter basis)

Item	Wohlbier (1974)			Doshier (1991)	Smits & Haigh(1990)
	Milk replacer	Weaner/grower	Winter supplement	Elk	Fallow deer
Vitamin A (IU/kg)	20,000	8,000	10,000	5,600	5,000
Vitamin D_3 (IU/kg)	4,000	1,000	1,500	750	400
Vitamin E (IU/kg)	100	20	50	100	200
Vitamin K (mg/kg)	3	-	-	-	-
Thiamin (mg/kg)	5	10	-	-	-
Riboflavin (mg/kg)	5	-	-	-	-
Vitamin B_6 (mg/kg)	5	-	-	-	-
Niacin (mg/kg)	20	-	-	-	-
Pantothenic acid (mg/kg)	15	-	-	-	-
Biotin (μg/kg)	100	-	-	-	-
Folic acid (μg/kg)	2	-	-	-	-
Vitamin B_{12} (μg/kg)	25	-	-	-	-

(Wallach, 1972). High nitrate levels in the diet will interfere with the conversion of β-carotene into vitamin A. Excesses of dietary vitamin A have not been reported in zoo ruminants, but deficiencies appear as the classical emaciation, poor growth, anasarca, dull hair, excessive lachrymation, infertility, and weak or deformed off-spring. Birth defects associated with vitamin A deficiencies include diaphragmatic hernias and cleft palates (Wallach, 1972).

Vitamin D is probably important in promoting calcium absorption and the mineralization of bone as it is in other species. Vitamin D requirements are probably met by exposure to sunlight (ultraviolet light) and by the consumption of ultraviolet irradiated plant tissues. Recommended levels are 5.5 to 6.6 IU/kg body weight for small ruminants and 4.0 to 5.0 IU/kg body weight in larger species. Severe excesses from over zealous use of vitamin-mineral mixes resulted in fibrous osteodystrophy in conjunction with low Ca diets and fibrous interstitial nephritis of adults and newborn (Wallach, 1972).

Vitamin E functions as a biological antioxidant is physiologically interrelated with selenium. Recommended levels are 55-175 IU/kg of diet with the higher level being used for the smaller species (Wallach, 1992). Deficiency produces white muscle disease which is the most frequently reported nutritional disease in white-tailed deer (Brady et al., 1978).

Water requirements

Water requirements for deer vary with type and amount of feed consumed, physiological state, amount of activity and environmental conditions such as varying ambient temperatures and the presence or absence of snow. The amount of drinking water consumed is inversely proportional to the concentration of water in feed. Although it has not been experimentally established, deer can probably survive without drinking water if green forage is abundant. Forage plants often contain significant amounts of water (45 to 65% in browse and 70 to 90% in forbs). Water availability can be critical during drought situations when forbs and other succulent vegetation are scarce (Reid, 1987; Wemmer, 1987).

For red deer, water intake varied from 0.27 L/kg dry matter intake for a grass diet to 3.82 L/kg dry matter on concentrated pellets. As with sheep, water restriction will reduce dry matter and cellulose digestibility in deer (Maloiy et al., 1970). Water restriction will greatly reduce the intake of low digestibility feeds such as mature pastures.

Red deer have a voluntary water intake of at least

50% more per kilogram of feed consumed than is normal for sheep. Their appetites are affected at an earlier stage of water restriction, fecal moisture content remains high and urine concentration does not increase to the levels observed for sheep (Blaxter et al., 1974). Fallow deer, which have evolved in a more arid region than red deer, appear to require less water per unit feed intake. Red deer on water restriction took 90 minutes to consume a meal normally eaten in ten minutes (Maloiy et al., 1970). Fecal and urine water losses when intake is restricted indicate that red deer are not as well adapted to water deprivation as sheep, in a similar fashion to the differences between *Bos taurus* and *Bos indicus*.

When amounts of the diet just described were varied and ambient temperatures were 10℃, there was a significant correlation between feed and water intake of 0.86. Water was consumed in the ratio of 2.9 kg/kg of feed (Ullrey et al., 1970). When deer were offered fresh browse such as white cedar fronds (containing about 54% moisture) at ambient temperatures from -14 to 25℃, and liquid water was offered 2 hours per day, only 0.5 kg of water was consumed/kg of diet.

MANAGEMENT STRATEGIES FOR PREVENTING NUTRITIONAL PROBLEMS OF FARMED DEER

The etiological bases for the nutritional problems of farmed deer are similar to those for sheep and cattle. However, the production-limiting effects of nutrition are likely to be more extreme for farmed deer than for sheep or cattle due to the wider seasonal variation of nutritional requirements for deer, the complete inability of the deer farmer to manipulate the timing of the rut to achieve a calving date suitable to the local pasture growth cycle and the low metabolic priority for reproduction in deer. Nutritional stress may also be involved in the appearance of clinical signs of endemic diseases such as yersiniosis and malignant catarrhal fever. Farmed deer are unable to invoke many of their evolutionary adaptations to seasonal nutritional deprivation. Migration to areas of better shelter and feed availability is prevented by fences. Recognition of new problems and an increase in the severity of currently recognised problems are likely with increasing intensification of deer farming (Haigh and Hudson, 1993).

Nutritional problems in farmed deer

Nutritional problems recognized in farmed deer in Korea or overseas include :

① Winter death syndrome
② Reproductive failure due to maternal under-nutrition
③ Weaner ill-thrift
④ Suboptimal velvet antler production
⑤ Nutritional allotriophagy

1) Winter death syndrome

This syndrome occurs in tropical and temperate species of deer. The annual incidence is related to the severity and duration of winter conditions. Most deaths occur in the late winter or early spring and are frequently associated with a period of particularly bad weather. To reduce winter deaths, it is essential that sufficient body fat reserves are laid down in autumn by all deer. High energy diets of high palatability may be useful during winter for tropical species. And it is difficult to increase the energy intake of wintering deer of the temperate species, and "supplementary" feeding may in fact be "substitution" feeding. The most useful managemental technique to reduce the negative energy balance of temperature species during winter is to reduce their energy requirements for body temperature maintenance by the provision of adequate shelter (McAllum, 1985).

2) Reproductive failure due to maternal under-nutrition

The forms of reproductive failure observed in temperate species are ① low conception rate (or embryo resorption) due to low autumn body weight of hinds, and ② perinatal mortality (low fawn birth weight, low brown fat reserves, maternal desertion) due to prolonged winter conditions during third trimester pregnancy, and poor maternal body condition at fawning (Alexander and Buxton, 1994).

Weaning rate of deer in years of nutritional deprivation has been as low as 60% compared to 85% in better years. For temperate deer species, high conception rates depend on good body condition during third trimester pregnancy. Maternal desertion is related to poor maternal body condition as well as disturbance. For temperate species, reproductive failure is primarily related to poor body condition in the previous autumn (Denholm, 1984).

3) Weaner ill-thrift

Poor growth of weaners is primarily a function of low digestibility pasture with an inadequate protein : energy ratio during summer and autumn. The problem is similar to nutritional weaner ill-thrift of sheep (Linderman, 1982). Irrigated summer pastures or high protein concentrate supplements (20% crude protein) will improve the growth rate of weaners (table 4). Weaners should be fed to maintain growth during late summer and autumn at a similar level to the spring growth rate. This is necessary to achieve a high conception rate in females at 16 months and to avoid "winter death syndrome" of juveniles (Giles, 1982).

4) Sub-optimal velvet antler production

Velvet antler production is closely related to body condition and to the increase of body weight during the phase of antlerogenesis (English, 1984; Suttie et al., 1996). It has been suggested that high energy : high protein diets fed during late winter and early spring will result in earlier hard antler casting and consequently a longer period for velvet antler growth.

Ad libitum supplementary feeding of velvet producing stags with high energy-high protein rations is recommended during the period from pasture maturation until velvet harvest (Suttie and Kay, 1983). Body condition is usually good at the time of antler casting. However, due to protein : energy imbalance and low digestibility of the pasture, supplementary feeding of high energy-high protein diets is probably necessary to maximize velvet antler yield.

5) Nutritional allotriophagy

Pica has been a persistent problem in hand-reared fawns and adults of the tropical deer species. Some weaned and mature deer have had a sufficient volume of completely indigestible plastic material in their reticulo-rumens at postmortem to cause noticeable inanition and wasting. This pica may be due to seasonal deficiencies of specific micronutrients or seasonal lack of dietary roughage (Denholm, 1984; Jones, 1994). Deer should not have access to any plastic or rubber material, or any other rubbish.

Supplementary feeding

Stocking rates on deer farms should be relatively high to achieve efficient utilization of expensive fencing. Supplementary feeding will assist efficient utilization of pasture as well as fencing and reduce changes in the botanical composition of pasture as a result of seasonal overgrazing (Fennessy, 1982).

The specific objective of supplementary feeding should be to match the seasonal variation of pasture production with supplements to the seasonal variation of voluntary feed intake by the deer. Supplementary feeding should be carefully planned to correct the energy : protein imbalance of available pasture and to avoid "substitution" feeding (Denholm, 1984; Robbins, 1993).

Deer show strong preferences for, or rejection, of many supplementary ingredients fed to traditional farm livestock (Koo, 1997). Wheat, barley, oats, sorghum, lupins and field peas are all acceptable to deer. Good quality alfalfa hay is acceptable, although stems are usually rejected unless the hay is chopped. Meadow hay is eaten in limited quantities only with clover selected from the mixture. Oak leaves, corn silage, beet pulp, turnips, chicory and kale have been fed in Korea and overseas. Compounded rations in pelleted form are highly acceptable (table 13).

Table 13. Chemical composition of typical pelleted compound rations

Item	Haigh and Hudson (1993)		Verme & Ullrey (1972)
	Ministik	Michigan State University	
Crude protein (%)	16.6	17	17.6
Crude fat (%)	-	3	2.0
Neutral detergent fiber (%)	27.2	18-20	40.5
Acid detergent fiber (%)	16.8	12-17	17.6
ME (kJ/g)	11.6	-	-

Consideration of the herd social structure is vital when planning a supplementary feeding programme. Where deer are fed *ad libitum* from a single trough most of the feed will be consumed by the dominant members of the herd which are often those least requiring supplementary feed. The dominant animals will feed and then move off from the feeding area.

Division of the herd into age and sex class groups (e.g., weaners, maiden hinds, mature hinds, stags) is recommended to reduce this problem. Division of the herd is also useful to allow the individual nutritional requirements of each age or sex class to be provided. Weaners require a higher dietary protein and energy ration than adults. Excessive feeding of breeding hinds during spring may lead to dystocia whereas heavy feeding of stags for velvet antler production is indicated at this time. Animals in a group have adequate access to supplementary feeds, these should be placed in several troughs (spaced about 10 to 20 metres apart) or trailed out on the ground over a wide area.

COMPARISON OF BIOLOGICAL EFFICIENCY FOR MEAT PRODUCTION FROM VARIOUS RUMINANTS

Deer farming is probably the fastest-growing livestock industry in New Zealand and Australia today and, potentially, the most profitable (Anderson, 1984; Woodhouse, 1993). Deer farming bears some resemblances to livestock industries utilizing domesticated animals, but these are not as extensive as farmers and veterinarians sometimes assume. Deer never domesticate fully unless bottle-reared, which is not feasible under commercial conditions. Commercial

Table 14. Meat or butterfat production from same pasture dry matter by various ruminants[a]

Ruminant	Pasture DM (kg)	Products (kg)	Schedule price (NZ$)	Total price (NZ$)	Meat energy (joule/100 g)[b]
Deer (meat)	30	3	7.50	22.50	630
Cattle (meat)	30	1	2.00	2.00	1,460
Lambs (meat)	30	1	1.40	1.40	1,130
Dairy cows (butterfat)	30	1.5	3.00	4.50	-

Source: [a]Yerex and Spiers (1987); [b]Drew (1985).

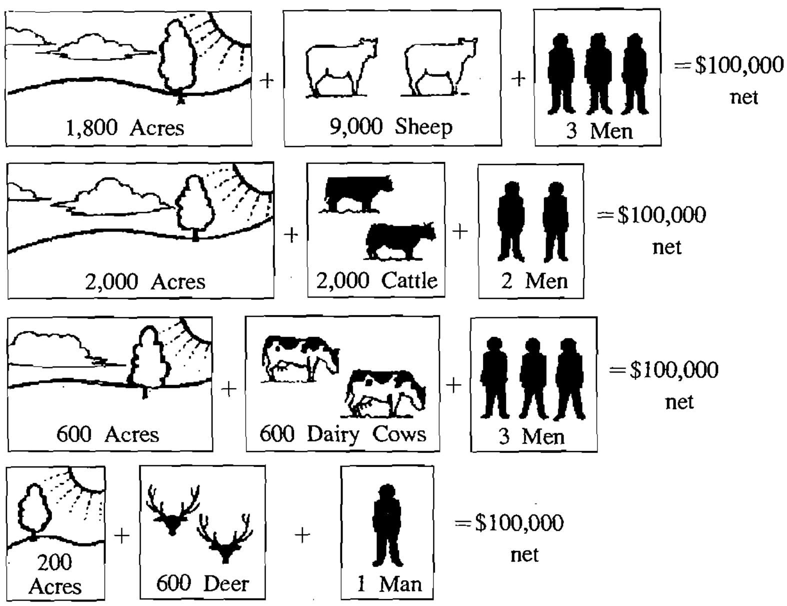

Figure 3. Resources required to generate NZ$ 100,000 net income (Yerex and Spiers, 1987)

deer farming offers a logical area of diversification for deer farmers; it offers excellent profit potential; it has open to it both domestic and export market opportunities, and it permits sensible and planned utilization of a presently wasted natural resource (Blaxter et al., 1974; Anderson, 1984; Hudson et al., 1989; Fennessy et al., 1993).

Apart from feedlot operations, research shows that deer farmed on high fertility soil produce meat in both quantity and feed conversion efficiency terms at levels which compare more than favourable with sheep and cattle (Simpson et al., 1978). In addition, deer have a very favourable dressing percentage of around 60% - significantly better than either sheep or cattle (Anderson, 1984; Drew, 1985).

New Zealand studies have shown that 9.5 kg of pasture dry matter is consumed for every kilogram of deer carcass gain, compared to 30 kg pasture dry matter (DM) for fat lambs (Drew and Greer, 1977). Those given in table 14 and figure 3, taken out in 1985-1987, do in fact use a venison schedule which, though current, is higher than should be anticipated as a year-round average, and wool from sheep and value of progeny are not included in any analysis.

The ultimate value of any meat production enterprise is the acceptability of the product on the consumer's plate. Table 14 shows that a 100 g portion of leg of venison has 44% less energy than a similar portion of lamb and 57% less than 100 g of rump steak. Venison can confidently be marked as a health food for those people who don't like fat, want to limit their energy intake, or want to lower their saturated fatty acid intake while still enjoying a good meal of red meat.

Another efficiency factor in favour of deer is the long breeding life of hinds. The industry has not been going long enough for anyone to produce conclusive figures as to the average breeding-life expectancy of hinds, but some farmers at least, believe it may prove to be 15 years or more. Fennessy (1982) has remarked on the fact that, in a dairy herd, 20 percent of female calves have to be reared as herd replacements annually, but he believes that in his deer herd the figure could be as low as 5 percent, and this has a marked influence on profitability.

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