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VENISON PRODUCTION
FROM WEANER RED DEER (*Cervus elaphus*)

EDI SOETRISNO

A thesis presented in partial fulfilment of the requirements for
the Degree of Master of Agricultural Science
in the Department of Animal Science,
Faculty of Agricultural and Horticultural Sciences,
Massey University, Palmerston North,

NEW ZEALAND

1993

to my wife ***Ratna****, my parents and my family*

"And livestock He (Allah) has created for you (human beings):
from them you derive warmth, And numerous benefits,
And of their (meat) you eat". **(Qur'an Surah Al- Nahl (16): 5)**

*"**Allah**! There is no god But He - the Living, The Self-subsisting, Eternal.*
No slumber can seize Him Nor sleep. His are all things in the heavens and on earth.
Who is there can intercede In His presence except As He permitteth?
He knoweth What (appareth to His creatures as) Before or After Or Behind them.
Nor shall they compass Aught of His knowledge Except as He willeth.
His throne doth extend Over the heavens And the earth, and He feeleth No fatigue
in guarding And preserving them For He is the Most High, The supreme (in glory)"
(Qur'an Surah Al-Baqarah (2): 255)

ABSTRACT

Forty four weaner red deer (*Cervus elaphus*) fawns (26 stags; 18 hinds) were used to investigate the effects of grazing pure red clover (*Trifolium pratense*) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pastures and immunisation against melatonin upon growth and venison production, with the objective of the stags attaining a minimum target slaughter liveweight (92 kg LW; >50 kg carcass) by 12 month of age. The experiment was conducted at the Deer Unit Massey University, NZ, during 1991.

The animals were randomly allocated into eight treatment groups (starting on 13 March 1991), with the combination of pasture types ((pure red clover (RC) or perennial ryegrass/white clover (PRG/WC)), sex (male or female) and immunisation (against melatonin or placebo only). The deer were rotationally grazed on either RC or PRG/WC pasture (feed allowances 6, 7 kg DM/h/day, respectively) during autumn and spring. During winter, all animals were combined and grazed together on PRG/WC pasture (6 kg DM/h/day feed allowance), at a pasture residual DM of 1100 kg DM/ha. The subcutaneous anti-melatonin injections were administered to the immunisation groups at birth and at weaning.

Pre-grazing herbage mass for RC or PRG/WC were respectively 3568, 3706 kg DM/ha in autumn; 2726, 2150 kg DM/ha in spring; 1736 kg DM/ha in winter. Post-grazing herbage mass for RC or PRG/WC averaged at 1822, 1882, in autumn; 1705, 1334, in spring; and 1170 kg DM/ha in winter, respectively. Total nitrogen (N) and organic matter digestibility (OMD) concentration of both feed on offer (FO) and diet selected (DS) were higher in RC than PRG/WC (FO total N: 3.4 vs 3.4% DM in autumn, 4.1 vs 2.6% DM in spring; FO OMD: 77.3 vs 78.6% OM in autumn, 84.5 vs 80.3% OM in spring; DS total N: 4.2 vs 3.9 % DM in autumn, 4.7 vs 3.3% DM in spring; DS OMD: 84.2 vs 83.2% OM in autumn, 87.7 vs 82.4% OM in spring).

Liveweight gain (LWG) of RC stags and hinds was significantly higher than PRG/WC animals in autumn (237 vs 207; 197 vs 159 g/d; $P<0.01$) and in spring (346 vs 281; and 260 vs 188 g/d; $P<0.001$), but not in winter (94 vs 95; 38 vs 40 g/d;

P>0.05). Weaner stags and hinds grazing RC forage had significantly higher voluntary feed intake (VFI) than the comparable animals grazing PRG/WC pasture in either autumn (P<0.05) or spring (P<0.001). By 12-month of age, stags grazing RC were 6 kg heavier and hinds 7 kg heavier than animals grazing PRG/WC forage. All (100%) RC stags attained the minimum target slaughter LW (>92 kg LW; 50 kg carcass) by 12-month of age at the end of November, compared to 90% of PRG/WC stags. Carcass weights (kg) and dressing percentage (%) of RC stags were significantly higher than PRG/WC stags (58.9 vs 53.3 kg, P<0.01; 56.2 vs 52.4%, P<0.001), but the carcass GR was not different (P>0.05) either after or before being adjusted to equal carcass weight.

The immunisation treatment did not provide any significant responses (P>0.05) in LWG and did not affect plasma prolactin concentrations. The immunisation against melatonin treatment did not give any significant effects (P>0.05) on all measurements of carcass production.

In conclusion, these studies show that early venison production from grazed PRG/WC pastures is possible, and that this can be further improved by inputs of RC. Weaner red deer grazing red clover forage during autumn and spring grew and produced venison better than animals grazing conventional PRG/WC pastures. The immunisation against melatonin did not provide any significant effects on growth and venison production from weaner red deer grazing either RC or PRG/WC forages. RC offers very good potential as a special purpose forage for venison production.

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EDI SOETRISNO

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GLOSSARY OF TERMS

DM	Dry matter
VFI	Voluntary feed intake
DMI	Dry matter intake
OM	Organic matter
FO	Faecal output
OMD	Organic matter digestibility
FO	Feed on offer
DS	Diet selected
LW	Liveweight
LWG	Liveweight gain
FOR	Rumen fractional outflow rate (% of rumen pool leaving to flow into abomasum/h)
Cr-EDTA	Chromium ethylene diamine tetra acetate
Ru-p	Ru- phenanthroline (particulate phase marker)
ME	Metabolisable Energy
MJ	Mega Joule
CT	Condensed Tannin
CP	Crude protein
MRT	Mean retention time
RC	Red clover
PRG	Perennial ryegrass
WC	White clover

MCF	Malignant Catarrhal Fever
RPM	Revolutions per minute
HSA	Human serum albumin
FCA	Freunds complete adjuvant
FIA	Freunds incomplete adjuvant
PRL	Prolactin
GLM	General Linear Model Procedure
LSM	Least Square Means
CRD	Intra ruminal chromium-slow-release capsule (sheep-size)
GR (carcass)	Soft tissue depth over the 12th rib 16 cm from the mid line (mm) (indirect measure of carcass fatness)
NZ	New Zealand
MAF	Ministry of Agriculture and Fisheries
GIB	Game Industry Board
NZDFA	New Zealand Deer Farmers Association
NZGCL	New Zealand Game Company Limited
	(now Cervena Company)
DSP	Deer slaughtering premises
GPH	Game packing houses
QA	Quality assurance

CHAPTER 1

LITERATURE REVIEW

1.1. INTRODUCTION.

This chapter will review the development of the New Zealand (NZ) Deer Industry, seasonality in temperate deer, and venison production. Reference will be made to the history of the NZ deer industry, the trend in deer numbers on NZ deer farms, the structure of the NZ deer industry, deer products and marketing issues. The seasonal cycles of voluntary feed intake (VFI), growth, plasma hormone concentration and reproduction, and factors affecting pre- and post-weaning growth, including nutrition, immunisation and breeding, will all be reviewed. Developments towards a more efficient venison production system will also be introduced.

1.2. THE NEW ZEALAND DEER INDUSTRY.

1.2.1. History of the New Zealand Deer Industry.

The very first deer herd in NZ was successfully imported and established in 1861. The importation of deer was continued by private individuals, Government and Acclimatization Societies until 1917. Deer numbers then increased at a remarkable rate through reproduction and gradually opened up forest canopies letting in more light to the forest floors, causing erosion and damage to the native flora. Since then, hunting the deer was legal to limit further damage problems. At least 80,000 deer were killed by private hunters in 1944 (Pearse, 1989). However, reducing the high density areas of deer herds was not as successful as had been hoped.

The NZ deer industry emerged in 1960's, since the establishment of an export market for venison to West Germany in the late 1950's. To meet the need for

processing of the product, processing plants for the packing of game for export were built. However, all of the exported venison was produced from the shooting of large numbers of feral deer, with venison production reaching a peak at about 4,000 tonnes in 1972. Thereafter, as a result of the high efficiency of helicopter shooting and recovery, the feral deer stocks became depleted and caused a rapid decline in venison production. The NZ deer industry realised that they had a limited future due to the reduction in a very lucrative form of game meat production, which formed the stimulus for the commencement of deer farming in NZ (Wilson and Barry, 1991), to produce a regular supply of deer products under controlled conditions.

1.2.2. Deer species in New Zealand.

Between 1861 and 1920, about ten species and sub-species of deer were introduced into NZ, mainly from Europe and North America, namely, red deer (*Cervus elaphus scoticus*), fallow deer (*Dama d. dama*), North American Wapiti (*Cervus elaphus nelsoni*), sambar deer (*Cervus u. unicolor*), sika deer (*Cervus nippon*), white tailed deer (*Odocileus virginanus borealis*), rusa deer (*Cervus timorensis rusa*), and moose (*Alces alces andersoni*). All survived in the wild except moose. The sambar and rusa deer originated from the tropics and the rest from temperate regions. Of these the red and fallow deer are the most successfully domesticated (Challies, 1985). Crossbreeding between the North American wapiti and the red deer occurred in the wild, and formed a high proportion of the feral Fiordland (South West of NZ) herd which is now named the NZ wapiti (Fennessy and Pearse, 1990). Table 1.1. shows the data of deer species farmed in NZ in 1992.

Table 1.1. Deer Species Farmed in New Zealand, 1992

Species	Male		Female	
	No.(x1000)	%	No.(x1000)	%
Red, Wapiti and Red x Wapiti	445,692	31.7	811,877	57.8
Fallow & others	39,179	2.7	109,021	7.8

Source : GIB (1993)

1.2.3. Deer Population and Growth of the NZ Deer Farming Industry.

Deer farming regulations were adopted and legalised in 1969, because previously deer farming was illegal with deer being classified as noxious animals (Wilson and Barry, 1991). The NZ deer farming industry has grown dramatically since the early 1980's (Fennessy et al., 1991). The prediction of the farmed deer population trend to 1996 is presented in Table 1.2. (GIB, 1993). There were 131,868 red and fallow deer in captivity on farms in 1982. In comparison, there are predicted to be 1,721,166 deer on farms in 1993, consisting of 1,607,827 (93.4%) red deer and 113,339 (6.6%) fallow deer. Of these, 176,866 (10.3%) are venison stags comprising 160,907 and 15,959, red deer stags and fallow deer bucks, respectively. The increasing population is also reflected in the increasing numbers of animals going for slaughter and also the volume and value of venison exported from NZ (GIB, 1993).

Table 1.2. New Zealand Farmed Deer Predictions to 1996.

Year	Red Deer Herd			Fallow Deer Herd			Total
		Stags			Stags		
	Hinds	Velvet	Venison	Hinds	Velvet	Venison	
1982	50421	57640	0	14339	6211	3257	131868
1983	96349	61884	7541	14052	6089	2428	188344
1984	139754	81629	7468	16620	6029	3084	254584
1985	181808	87591	32061	19579	6019	3455	330513
1986	228392	91697	44913	23735	6093	4113	398942
1987	287042	91794	61832	32197	6278	5039	484182
1988	361141	100901	69373	39676	6694	7113	584898
1989	457115	135277	65224	44443	7265	8541	717865
1990	568838	179543	83408	53342	7946	9716	902793
1991	711222	233985	102516	63627	8799	11515	1131664
1992	869332	302358	128692	74233	9880	13749	1398244
1993*	1067194	379726	160907	86230	11151	15959	1721166
1994*	1296228	473222	197942	98849	12591	18526	2097358
1995*	1546770	585490	239439	112191	13972	21162	2519023
1996*	1805660	718653	284410	124109	15569	23978	2972379

Source : NZ Game Industry Board (1993 forecast) *) estimates

1.2.4. Structure of the NZ Deer Industry.

The NZ deer industry consists of three main organisations. The farmers' point of view is put forward by the Deer Farmers Association. The processors are represented by the Game Industry Organisation. All facets of the deer industry work together within the framework of the Game Industry Board (GIB).

The New Zealand Deer Farmers Association (NZDFA), representing approximately 60% of the 5,500 deer farmers (Pearse, 1989), is the important organisation which was established to serve the interests of the deer farmers. It has been active in promoting regulations allowing deer farming, and encouraging

investment, political lobbying, assisting research and development, liaising with the veterinary profession on animal health issues, especially TB control and velvet harvesting (Wilson and Barry, 1991).

Exporters, owners of deer slaughtering premises (DSP), and game packing houses (GPH) established the Game Industry Association and Exporters Council. DSP's are by law responsible for slaughtering all farmed deer for sale for venison consumption. The carcasses are then transfer to GPH's for cutting and packaging for export.

The NZ Game Industry Board (GIB), established by the NZDFA in 1983, is the deer industry body charged with responsibility for promoting and assisting in the orderly development of the deer industry and products derived from deer (Fennessy et al., 1991). It consists of four processor/exporter representatives nominated by the New Zealand Deer Industry Association (NZDIA) and five producer representatives nominated by the NZDFA (GIB, 1992). It is thus weighted toward the producers (Wilson and Barry, 1991), three of whom have experience and qualification in areas such as marketing and commerce in addition to deer farming (Porter, 1986). The primary objective of the GIB is to co-ordinate the orderly export and marketing of venison and velvet to the best advantage for all the members (Wilson and Barry, 1991). Their function is to assist in the orderly development and in the orderly marketing of game and the products derived from game (restricted to deer) (Pearse, 1989). The Board is also actively involved in the collation and dissemination of statistical information relating to industry production and to export volumes and prices, distribution, strategy development and promotion in target markets on a planned basis (Porter, 1986), and the setting of quality standards via a "Quality Assurance" programme and market research (Fennessy et al., 1991). All activities are

funded from levies on venison collected from DSP's and from velvet purchasing companies (Pearse, 1989).

1.2.5. Products of the Deer Industry.

At present products of the deer industry consist of the sale venison stags for finishing and for slaughter, velvet, breeding stags, breeding hinds, and by products.

Venison, a highly desirable red meat for today's health conscious market, is high in protein and in iron but low in fat, energy and cholesterol, relative to lamb and beef (Drew et al., 1991).

Venison stags are purchased by finishing farms or by exporters for slaughter. The options for selling stags are in the paddock, by auction, or by schedule. Schedule prices quoted by buyers are usually gross returns per kilogram carcass, from which cartage, killing charges, GIB levies and meat inspection fees are deducted. Schedule prices are set weekly by exporters.

Venison exported from NZ is mostly from one- or two- year-old deer and is slaughtered in one of the regionally based DSP's. Modern DSP's have installed computerised inverted dressing systems for carcass processing. Ante- and post-mortem veterinary inspections are provided, to guarantee a sterile product for further processing, packaging, and marketing. Packed venison is shipped out in a variety of cuts in either frozen or chilled form, but the recent export trend is for fresh chilled vacuum packed product (Drew et al., 1991). Quality assurance and grading specifications are set by the GIB and monitored by MAF. Most of venison exports are handled by New Zealand Game Company LTD (NZGCL) members, such as Mair Venison Ltd., Fortex Group Ltd., Cavalier, Venison NZ Ltd., AFFCO NZ Ltd., Game Meats Ltd., and Duncan Deer Co. Ltd. (GIB, 1992).

Velvet, the antler of the male deer, is grown annually and is harvested at an early stage of growth (approximately 55 days from casting). In NZ, the velveting season is from October through to February. The velvet has to be immediately cooled and frozen as soon as it is removed from the stags, then packaged and sold. Velvet product is usually purchased by NZ exporters or overseas importers for further processing in NZ. Most velvet exported from NZ is processed in one of about 24 velvet drying plants, producing a consistent quality with the highest standards. The quality is determined by the age and breed type of the stags, the stage of growth at harvest time, and the care with which the velvet is removed and frozen. The schedule prices of average A grade velvet have fluctuated from $ 247.00/kg in 1989/90 down to $ 160.00/kg in 1991/92 (GIB, 1992). As the growth in the deer industry stabilises, velvet production is expected to come from sire animals and from farms specialising in velvet production.

Breeding stags and hinds also form output from deer farms, and are purchased by farmers building up herds, farmers buying hinds to contract graze or for live export. The sales are usually made either by auction or by private contract between buyer and seller.

Deer by-products consist of skins, tails, pizzles, sinews, entrails, blood, small goods and antler, and tusk (i.e. teeth) jewellery (Pearse, 1989). To indicate a more positive approach to this potential, as a strategic marketing perspective, the term 'by-products' has been replaced to the term 'co-products', hides, skins and leather (GIB, 1992). Most of them are taken by DSP's as payment for killing charges. The objective for co-products is likely be to bring more of the margin on shore in the fashion industry.

1.2.6. Markets for NZ deer products.

The future of the NZ deer industry is dependent upon the development of markets which will pay acceptable prices for high quality deer products. Europe is still the main market for NZ venison, half of which went to Germany, followed then by the growing markets such as the USA, Japan, Switzerland, Sweden and Denmark, as seen in Table 1.3.

Table 1.3. Major Venison Export Markets, Tonnages and Values 1990.

Country	Tonnes	Values $NZ m
West Germany	2110	17.3
United States	555	8.3
Sweden	488	3.9
Switzerland	404	4.6
Japan	237	5.0
Australia	216	1.3
Denmark	134	1.8
Netherlands	81	0.6
United Kingdom	78	0.6
France	58	0.6
Other	349	5.8
TOTAL	**4,709**	**49,7**

Source: GIB (1991).

Over the past six years, there has been a steady increase in both export volumes and values of venison, velvet and hides, as seen in Table 1.4. It shows that the future of the deer farming industry looks bright. Export receipts increased 39% in the year to December 1992 to $ NZ 182,983,209. Of this, venison contributed $ NZ 116,459,909, velvet $ NZ 59,697,171 and skins, hides and leathers $ NZ 6,826,129 (GIB, 1993). Venison exports have grown dramatically (Table 1.4),

however, the breakdown of volume and value by major regional markets is significant.

Table 1.4. Total NZ Deer Industry Export (Year ended December).

Year	Venison		Velvet		Hide	T o t a l
	Volume (tonne)	Value ($NZ)	Tonnes Frozen	Value ($NZ)	Value ($NZ)	Value ($NZ)
1986	2472	24,636,834	65	8,410,434	1,225,240	34,275,508
1987	3418	27,353,127	75	11,364,722	1,587,872	40,305,721
1988	3550	32,558,030	87	13,763,989	1,338,469	47,660,488
1989	3770	40,718,984	120	32,649,813	2,023,599	75,392,396
1990	4710	49,684,982	160	48,859,297	2,541,928	101,086,207
1991	7770	61,661,969	220	52,292,025	4,728,481	118,983,209
1992	12739	116,459,909	268	59,697,171	6,826,129	182,983,209

Source : GIB (1993)

It shows that not only the higher returns per kg venison are achieved from smaller volume markets like Asia, but also that the larger volume markets form the essential base for sustained growth with their ability to absorb volume of product (GIB, 1992). Thus, a wide opportunity to extent new markets such as in Asia and the USA still remains a challenge to the NZ GIB in the future.

1.2.7. Marketing and Appellation Strategy.

For the time being, the focus of the GIB marketing implementation plan will be on venison, and this is the focus of the Board's 1992 strategic plan. It is anticipated that similar strategic plans will be later formulated for velvet, hides and skins, and other deer products (GIB, 1992). The GIB has invested a substantial amount of money in marketing of venison and is currently launching an appellation strategy for venison. Most marketing research is done in overseas markets or potential markets to investigate the scope for venison sales and to establish the most appropriate means of achieving the best financial returns (Wilson and Barry, 1991).

Markets in the GIB strategy will be segmented and prioritised according to their potential for growth and future returns, into "established markets" (mainly European) and "emmerging markets" (American, Asian and New Zealand). Recommended strategy for "established markets" is the certification trade mark strategy, while for "emerging markets" is the appellation strategy (Bryan, 1992).

The market objectives for the appellation strategy are to: differentiate the product and expand the markets, create a trade and consumer preference and loyalty, create market leadership position,"own" the market, and develop long-term security in the markets for the appellation strategy (GIB, 1992). Product positioning must be excellent in nutritional value, mild, tender, quality assured (QA), convenient preparation, and year round availability. Certification Trademark in trading strategy is launched to differentiate NZ farmed venison from other forms of venison and to increase price returns as well. The newly developed mark for quality, "ZEAL" quality assurance of NZ, will appear on licensees's product packaging from 1993 market launch of the new marketing strategy to certify and warranty the quality standards of the industry products (GIB, 1992). The 'pasture to plate' concept is also launched

as a major competitive marketing edge for the industry by seeking to develop the 'quality chain' from livestock on farms to the consumers, and the Board is committed to it. **Cervena**, the Natural Tender Venison, is chosen as a brand appellation for venison products (GIB, 1992). The GIB set up a Cervena company to license exporters to use the name on their venison, which will become known as the word that intrinsically means NZ farm-raised venison, that is, a light, lean and tender meat for fine cuisine in the future modern markets.

1.3. SEASONALITY IN TEMPERATE DEER.

Farmed deer can be classified by origin as temperate or tropical species. Red deer, Fallow deer and Wapiti, which comprise the considerable majority of farmed deer worldwide, are temperate deer which originated from high latitude regions of the Northern Hemisphere and all exhibit strong patterns of seasonality. Tropical deer species, such as Sambar, Rusa and Axis deer show less seasonality. The seasonality in temperate deer species is manifest by pronounced feed intake, growth, antler, pelage and reproductive cycles.

1.3.1. Voluntary feed intake and growth.

Regulation of voluntary feed intake (VFI) in farmed animals is governed by various factors located inside or outside the animal body (Forbes, 1986), namely genetic and environmental factors. Farmed deer have a rather different intake/digestion pattern than other farmed ruminant animals (Reinken, 1990). VFI by red deer shows marked seasonal variations, being high over spring-summer and low during autumn-winter periods, corresponding to fluctuations in body weight and liveweight gain (Pollock, 1975; Fennessy, 1981; Kay and Staines, 1981; Suttie and

Kay, 1985; Blaxter et al., 1988; Suttie et al., 1989; Adam, 1991). These seasonal cycles are most evident in intact adult stags and less pronounced in young stags (Fennessy and Milligan, 1987). Calves, adult stags, castrates, and hinds all demonstrate this trait to a greater or a lesser extent (Blaxter et al., 1974; Kay, 1979), with intermediate growth rates occur during the calves'first autumn (Moore et al., 1988). Figure 1.1. shows the seasonal cycle of VFI from red deer hinds and stags in Southern Hemisphere (NZ).

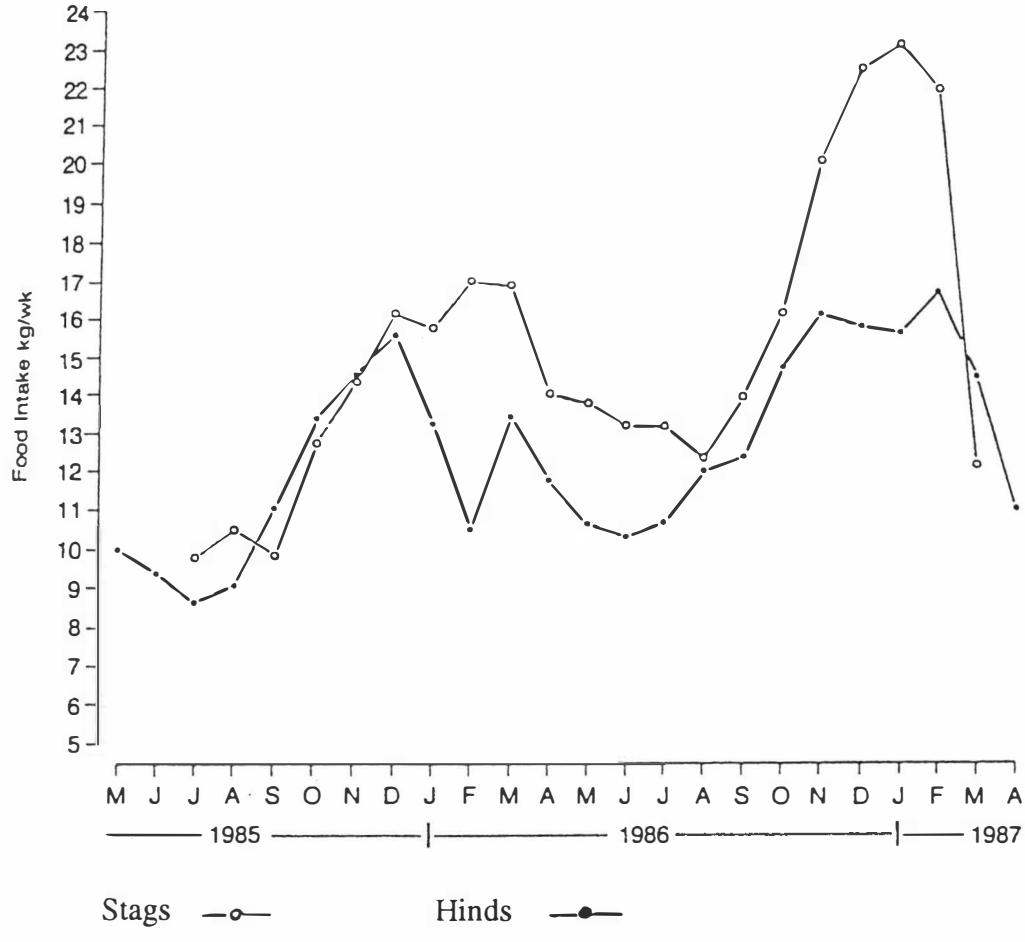

Figure 1.1. The seasonal cycle of voluntary feed intake (VFI) from red deer hinds and stags in Southern Hemisphere (NZ). (Suttie et al., 1987)

A seasonal cycle in VFI and growth in red deer is associated with a seasonal cycle in basal metabolic rate, ambient temperature, activity, the quality and availability of forage under outdoors conditions (Kay, 1985), and is under photoperiodic control (Suttie and Simpson, 1985). The pronounced seasonal changes in metabolic rates are associated with annual changes in appetite cycle or the VFI differing seasonally nutrient demands due to seasonal reproductive activities and photoperiodic cycles. The changing of the daylength is the environmental stimulus that entrains the physiological cycle to season of the year (Barry et al., 1991), with plasma melatonin concentration believed to synchronise the cycles of VFI and body growth to changes of photoperiod. Some hormones mediating these changes are melatonin, hypothalamic releasing hormones, pituitary hormones like prolactin, gonadotropin, and gonadal and thyroid hormones.

The intake pattern of stags is similar to hinds until September (in NZ), then the VFI of stags increases, reaching its peak in February and markedly reduced during March and April. With the onset of breeding season (March-May), stags loose their weight markedly, while hinds maintain their body weights (Suttie et al., 1987).

1.3.2. Digestion in deer and other species.

Capacities of four different stomach compartments of the digestive tract in ruminants have important implications in the process of digestion and absorption. Rumen capacity in relation to body weight influences the potential feed retention time in the rumen. Animals with big rumen, thus, can retain ingesta for a longer period and digest fibre better than the smaller ones. Due to this reason, animals with relatively small rumen must select forages lower in fibre but higher in fermentable carbohydrates. In addition, they have a greater basal metabolic rate per unit of body

weight than do larger animals (Chaplin, 1977), resulting in the energy requirements per unit body weight being higher in these animals. Table 1.5. shows the differences of rumen/reticulum capacities in deer and domestic livestock.

Table 1.5. Absolute and relative size and capacity of the rumen/reticulum (R/R) in deer and domestic livestock.

Species	Adult body weight (kg)	R/R volume as percentage of body weight	Weight of R/R contents as percentage of body weight	Weight of R/R dry matter as percentage of body weight
Roe deer	14	8	7	1.7
White Tailed deer	39	10	8	1.4
Fallow deer	40	14	9 - 12	1.6
Mule deer	57	10.3	7.4	1.07
Red deer	95	23	10 - 14.9	1.5
Sheep	45	25	13	0.64 - 1.15
Cow	450	26.4	14.1	0.96 - 1.88

Adapted from : Chaplin (1977).

Rumen water fractional outflow rate (FOR) as marked by Cr-EDTA, is especially fast for deer, and the rate at which water leaves the rumen in relation to particulate matter is faster for deer than for sheep or goats and increases in summer compared to winter (Barry et al., 1991; Domingue et al., 1991). The changes such as decreases in rumen particulate fractional outflow rate (FOR), increases in rumen pool size, rumen ammonia concentration and rumen acetate:propionate ratio in

summer compared to winter were remarkable in deer, which means that deer are capable of increasing their VFI without any decrease in apparent digestibility. The process is also enhanced due to rumen outflow rate and possibly by the hypertrophy of the rumen (Barry et al., 1991). The rumen FOR and VFI are greater in deer than sheep fed low quality roughage and lower when fed with high quality forages. Red deer, for instance, have variously been found to digest fibrous grasses less completely, but heather or hay and concentrate diets more fully than sheep (Kay and Goodall, 1976; Milne et al., 1978; Fennessy et al., 1980). Table 1.6. explains the phenomena above. The combination effects of a greater rumen pool size, a decrease in rumen FOR of a particulate DM (i.e. longer MRT), could explain the mechanism of how the deer were able to increase their VFI in summer without decreasing the apparent digestibility of DM or fibre. Deer have evolved a digestive system in which rate of passage of digesta through the rumen is much faster than that for sheep and accommodated summer increase in VFI by stimulating rumen digestion through necessary changes in digestive characteristics (Katoh et al., 1991).

1.3.3. Seasonal breeding and reproduction.

Deer of the world live in a wide range of habitats in cold, temperate and tropical climates (Whitehead, 1972). Most of them are seasonal breeders and produce their progeny at a particular time of the year related to seasonal variations in feed supply. Seasonal changes in temperature, rainfall and daylength, all contribute to dictating this change in feed supply which is the ultimate cause of the breeding season (Lincoln, 1985). Red deer adapted to temperate climates are entrained to cold

Table 1.6. Seasonal changes in voluntary feed intake, apparent digestibility, rumen pool size and rumen fractional outflow rate in castrated male sheep, goats and red deer[a].

Parameter	Season	Goats	Sheep	Red deer	SEM
Voluntary DM intake	S[b]	68.7	52.2	62.5	3.20
(g.kg $W^{0.75}$ day)	W	57.4	54.8	46.7	4.24
DM digestibility	S	0.56	0.54	0.57	0.004
	W	0.62	0.56	0.55	0.008
Rumen pool					
(DM = liquid)	S	340	275	289	17.5
(g/kg $W^{0.75}$)	W	268	307	191	13.4
Fractional outflow rate (FOR)/hr					
Cr-EDTA	S	0.108	0.104	0.158	0.0054
	W	0.096	0.103	0.163	0.0056
Ru-P	S	0.076	0.069	0.070	0.0038
	W	0.068	0.069	0.076	0.0034
Lignin	S	0.037	0.033	0.028	0.0016
	W	0.035	0.033	0.035	0.0014
Particle retain on sieve					
1.0 mm		0.001	0.001	0.003	0.0004
0.5 mm		0.017	0.019	0.025	0.0014
0.25 mm		0.049	0.053	0.073	0.0027
passing 0.25 mm		0.028	0.034	0.041	0.0029
passing 1.0 mm		0.033	0.036	0.044	0.0020
Ratio FOR					
Cr-EDTA/particle < 1 mm	S[c]	3.34	3.08	4.63	0.286
	W	3.01	2,98	3.58	0.139
Cr-EDTA/lignin	S	3.07	3.24	5.97	0.308
	W	2.82	3.12	4.77	0.110

Adapted from Barry et al. (1991).

[a] Fed a lucerne chaff diet.
[b] S, summer; W, winter. From Domingue (1989).
[c] Particle FOR (S) calculated as

$$\text{lignin FOR (S)} \times \frac{\text{Particle FOR (W)}}{\text{lignin FOR (W)}}$$

Northern Hemisphere conditions like Scotland or Norway/Sweden. When transported to NZ they retain this pattern and calve late (in late spring/early summer) in NZ. Table 1.7. summarises the reproductive characteristics of red deer recorded at Invermay, NZ (Kelly and Moore, 1978). Similar results were also found on the Isle of Rhum, Scotland (Guiness et al., 1971).

Table 1.7. Reproductive characteristics of red deer.

Characteristic	Value (mean ± SE)
1. Hind	
a. Puberty	16 months
b. Length of oestrus cycle	18.2 ± 0.4 days (n = 17)
c. Length of oestrus	12 hours
d. Onset of breeding season	April 13 (range 7/4 to 16/4)
e. Duration of breeding season	> 2 oestrus cycle
f. Gestation length	231.1 ± 0.6 days (n = 38) (Fallow 266 days) (Virginian 199 days)
g. Onset of calving	December 2 (range 29/11 5/12)
h. Period of calving	23 days (range 18 to 26 days)
i. Calf weight	6 - 7.5 kg at birth
2. Stag	
a. Puberty	Motile sperm first detected 14 months
b. Onset of breeding season	March

Adapted from : Kelly and Moore (1978); Wilson (1984)

The reproductive cycle, the probability of having a calf and the time of calving are influenced by nutrition (Milne, 1988), and related to the adult hind liveweight (Blaxter and Hamilton, 1980) and the age of the hind (Bray and Kelly,

1979). For each 4 kg heavier a hind is at mating, calving will take place one day earlier. The calving percentage were lower (74% vs 93%) and the mean calving dates were 6 to 12 days later in young hinds (2-year-old) than in mature hinds. Pre-mating nutrition requirements to ensure hinds reaching minimum 70 kg liveweight at mating should be included in the preferential treatments (Kelly and Moore, 1977; Fennessy et al., 1986). A continued lactation has been shown to delay the onset of the breeding season by 8 days (Milne et al., 1987) due to the effect of the suckling stimulus on plasma prolactin concentration (Loudon et al., 1983).

Red deer hinds produce only one fawn per year, and natural twinning is very rare. Attempts to induce twinning by exogenous hormonal have been relatively unsuccessful to date (Milne, 1988). Manipulation of time of calving to advance (up to 36 days) mean calving date to better fit typical NZ improved pasture production (feed supply and demand) patterns has been investigated and become a successful, by using the melatonin treatment regimes on pre-pubertal breeding hinds (Fisher et al., 1988; Asher et al., 1988; Wilson et al., 1991; Milne et al., 1990). Red stag progeny of melatonin-treated yearling hinds at weaning weigh (on average) 312 g heavier for each day earlier birth (Wilson, 1989), however, this liveweight difference at weaning declines as the deer approaches its ultimate bodyweight, i.e. as it ages towards maturity. Early fawns showed less effect of weaning and separation stress than the normal control, and under good winter feeding (quality pasture and supplementation) to encourage growth continue to show appreciable weight gains (Pearse, 1988). The effect of advanced calving, thus, is more critical for 12-month-slaughter venison production system than for 15- or 24-month slaughter system.

1.3.4. Seasonal pattern of prolactin (PRL) secretion in deer.

As recorded in red deer (Brown et al., 1979; Suttie et al.,1984; Barrell et al., 1985), roe deer (Schams and Barth, 1982), white-tail deer (Mirarchi et al., 1978; Bubenik et al., 1985) and rams (Brown et al., 1979; Simpson et al., 1984), blood plasma PRL concentration in those species is seasonal, being high and reaching the peak levels in spring and summer. In red deer stags, peak values of PRL concentration (100 ng/ml) occurred at maximum daylength and lowest values (5 ng/ml) at minimum daylength (Brown et al., 1979). Rams showed a similar pattern as deer, but with higher PRL concentration (150 and 20 ng/ml) during the respective seasons. It was considered that the increased PRL secretion during summer is controlled by daylength, as reported that it may play a role in influencing the seasonal cycle in growth of the summer coat (Allain et al., 1981), antler growth (West and Nordan 1976), and changes in appetite (Suttie 1979; Ryg and Jacobsen, 1982). High PRL concentration is associated with long daylength, high food intake and rapid weight gain in red deer (Suttie and Kay, 1985), reindeer (*Rangifer tarandus tarandus*) (Ryg and Jacobsen, 1982), and in sheep (Forbes et al., 1979). Administration of exogenous melatonin during long daylength depressed plasma PRL concentration to base-line levels in red deer (Webster and Barrell, 1985). Melatonin feeding in red deer and sheep significantly depressed the serum level of PRL concentration (Kennaway et al., 1982, Milne et al., 1990). In white-tail deer, the levels of PRL concentration was altered by pinealectomy (Schulte et al., 1981) Snyder et al., 1983). PRL, then, may be a hormone mediating the effects of photoperiod in some circumstances.

There was no association between the short-term increases in plasma PRL concentration and the changes in VFI in red deer hinds (Milne et al., 1990), but the

peak in VFI was advanced by 2 week ($P<0.05$) in melatonin treated animals than controls. In contrast, Ryg and Jacobsen (1982) reported that the injection of PRL to yearling reindeer stags during winter were associated with the increased in VFI and weight gain. There is thus conflicting evidence that PRL mediates the increased VFI during spring/summer in deer, eventhough PRL secretion and seasonal variations in appetite follow similar patterns related to photoperiod. There is a need to do further studies to evaluate and explain this phenomena.

1.4. VENISON PRODUCTION.

Research on farmed red deer in NZ was initiated in 1968 at Lincoln University, Canterbury and in 1973 at Invermay Agricultural Research Centre (Drew, 1976), starting with feasibility studies of the intensive husbandry of red deer. Then, some experiments in various aspects of farmed deer were conducted in NZ and elsewhere, such as in nutrition (Blaxter et al., 1974; Fennessy et al., 1981; Kay and Staines, 1981; Domingue et al., 1991; Ataja et al., 1992[a]; Niezen et al., 1993; Semiadi et al., 1993; Freudenberger et al., 1993), reproduction (Lincoln, 1971; Flecher 1974; Asher and Adam, 1985), and immunisation (Duckworth and Barrel, 1989; Ataja et al., 1992[b]). However, there is still little literature information available on deer nutrition under grazing conditions, particularly for growing deer, since the energy requirement estimates were converted from nutritional work done indoors (Fennessy et al., 1981). Thus, to develop a more efficient venison production system in NZ, it is very important to do research on aspects of nutrition by introducing new forages such as red clover and chicory and improving growth rates of weaner red deer.

Since the legalisation of deer farming in 1969 (Challies, 1985), all captive deer in NZ have been managed under pastoral conditions for the entire 12 month production cycle, with largely grazing on the conventional perennial ryegrass (*Lolium perenne*; 85%) -white clover (*Trifolium repens*; 15%) pastures. There is almost no indoor housing during winter in NZ.

Venison production is a new and rapidly growing form of animal production in NZ (Ataja et al., 1992[a]) with specialised venison production farmers produce stags for slaughter at age 12 - 24 months (Wilson and Barry, 1991). Highest prices are paid for carcasses of 50-70 kg. The venison carcass price schedule, however, also fluctuates seasonally, showing high values at all times, but highest in spring. Figure 1.2. demonstrates obviously the seasonal nature of venison price schedule fluctuations since 1987.

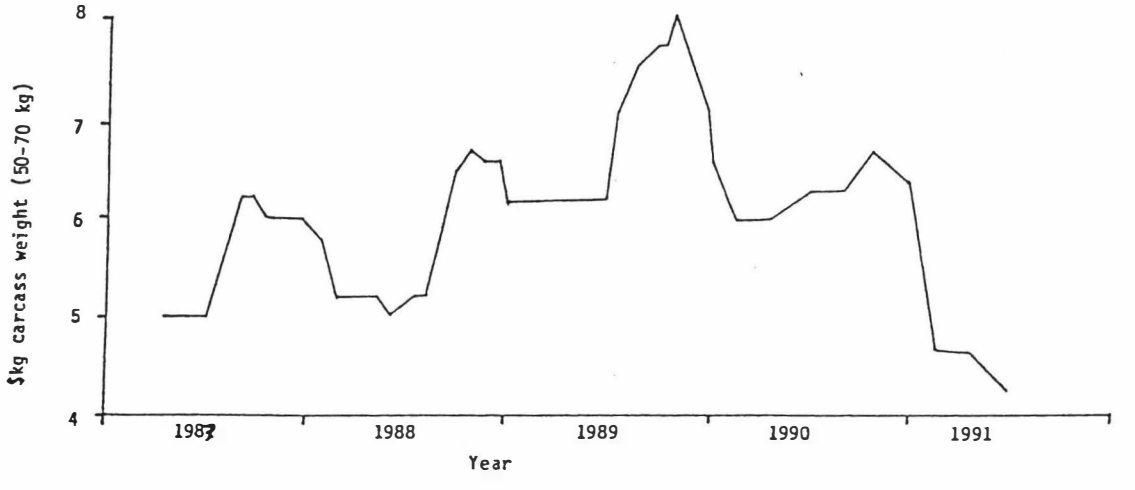

Figure 1.2. The seasonal venison price schedule fluctuations, 1987-1991. (Adapted from: Wilson, 1991)

Although the absolute figures have varied somewhat from year to year, the cyclical pattern has been consistent. In response to the Northern Hemisphere export market demand for chilled product during their autumn and winter, venison prices in NZ are invariably lowest from January to August and then increase substantially from September to reach a peak normally in late September/October. By Christmas the venison price falls substantially. To achieve maximum returns per kg venison from stags, the producers (farmers) must produce venison at this peak price time. Currently, the most efficient and economical venison production system is to slaughter stags under 12 month of age (Ataja et al., 1992[a]; Semiadi et al., 1993), with carcasses weighing 50 - 70 kg available in September-December to meet the Northern Hemisphere market demands. This contrasts with the usual practice of slaughtering farmed deer stags at 15 or 27 months of age (February-March), when they stop growing for 5 months due to the onset of the rutting season. Options for accelerating fawn growth as rapidly as possible to reach the target of 50 kg carcass by 12 months of age should thus be researched. Pre- and post-weaning growth of young deer are both critical phases.

1.4.1. Pre- weaning growth.

A number of factors influence fawns' growth during this phase. The ability of hinds to lactate, depending upon feed nutritional quality and quantity available and genetic factors, all influence fawn growth.

1.4.1.1. Nutritional aspects.

Lactation and calf growth in red deer has been reviewed by Loudon and Kay (1984), who mentioned that suckled calves are always wholly dependent upon milk for the first month of life, but by 3 months they probably receive only 10-20% their energy requirements from their dam. The red deer hinds produce a rich milk (Table 1.8.), which contains about three times as much fat, twice as much protein, but the same concentration of lactose as cow's milk and is also rather more rich than ewe's milk (Kay and Staines, 1981).

Table 1.8. The organic and mineral constituents of red deer milk (g/kg milk) at different stages of lactation.

Stage of Lactation (days)	Total Solids	Fat	Crude Protein (N x 6.38)	Lactose	Gross Energy
3 - 30	211	85	71	44	5440
31 - 100	235	103	76	44	6630
over 100	271	131	86	45	7740
	Calcium	**Phosphorus**	**Magnesium**	**Sodium**	**Potassium**
3 - 30	2.2	2.2	0.18	0.33	1.2
31 - 100	2.2	1.8	0.18	0.37	1.3
over 100	2.5	1.9	0.22	0.35	1.2

Adapted from : Kay and Staines (1981).

Fawns given a simulated deer milk obtained growth rates of 251 and 237 g/day for hinds and stags, respectively (Fennessy et al. (1981).

To achieve a better milk production, hinds require a high quality feed (about 47.5 MJ ME/day) to meet the energy-demanding physiological process, both for their maintenance and lactation (Fennessy and Milligan, 1987), resulting in a greater weaning weight.

The seasonal VFI in temperate deer peaks in summer (Barry et al., 1991), however, due to the moisture stress, the seasonal growth of conventional pastures in NZ and their nutrient quality is decreased in summer (Korte et al., 1987). This condition can result in a serious feed deficit especially for lactating hinds, since red deer are late calvers, fawning in late spring/early summer (November-December in NZ).

Pastures available for lactating hinds must be palatable, of sufficient bulk on offer and of high energy content (Wilson et al., 1991). The improvement in pasture quality could raise growth rates to 369 g/day in fawns suckled by hinds grazing lightly stocked grass pasture at Gleansaugh, UK (Loudon et al., 1984).

Lactating hinds grazing on red clover forage during summer improved their fawn growth rates and weaning weight, compared to control animals grazing a medium allowance of ryegrass/white clover pasture as indicated in Table 1.9. (Niezen et al., 1993).

Table 1.9. Fawn average daily gain (ADG), fawn weaning weight and hind weight change on a medium allowance of ryegrass/white clover (CON) or a high (HC), medium (MC) or low (LC) allowance of red clover.

	HC	MC	LC	CON	SEM
Fawn ADG (g/day)	461	433	380	333	45.2
Fawn Weaning Weight (kg)	51.3	49.5	46.7	42.8	2.76
Hind Weight Change (g/day)	53.3	58.3	5.3	-52.2	42.0

Adapted from : Niezen et al. (1993)

1.4.1.2. The advancement of calving time in red deer.

Calving in red deer normally occurs in late summer, from mid-November to late December in NZ. Birth weight and growth rate of fawns are positively related to the weight of the hinds, with a 0.33 kg increase in birth weight corresponding to a 10 kg increase in dam weight, and males increase in weight at a greater rate (10%) than females (Blaxter and Hamilton, 1980; Moore et al., 1988). Techniques to advance date of calving have been evaluated using melatonin implants to both stags and hinds, and cross-breeding with the earlier calving Pere David's deer or the aseasonal calving Sambar deer.

Implantation of both hinds and stags with melatonin in summer has been successfully used to advance the mean date of the onset of the breeding season by up to 22 days (range 12-36 days) in both red deer and fallow deer (Asher et al., 1988; Fisher et al., 1988; Milne et al., 1990; Wilson et al., 1991) with no signs of depression in their lactation performance. Cross-breeding work with the Pere David's deer has been limited and being produced only in small numbers, due to the susceptibility of the breed to Malignant Catarrhal Fever (MCF) in NZ. The objective of hybridisation studies between red deer hinds and sambar stags is to improve carcass meat conformation and extend the calving period of the progeny (Muir, 1992).

1.4.2. Post- weaning growth.

A number of systems to improve the early growth rates and to increase liveweights of red deer for successful venison production are being researched and developed. These include the option to slaughter stags by 12 month of age, early calving, developing new pasture species which provide a better match between feed supply and demand, using immunisation treatments, and selection of genetically superior animals in terms of growth rate and early maturity (hybridization of red deer hinds with wapiti/wapiti cross stags).

1.4.2.1. Growth pattern and nutritional requirements.

The growth pattern of weaner red deer (*Cervus elaphus*) stags from weaning to one year of age is illustrated in Figure 1.3.

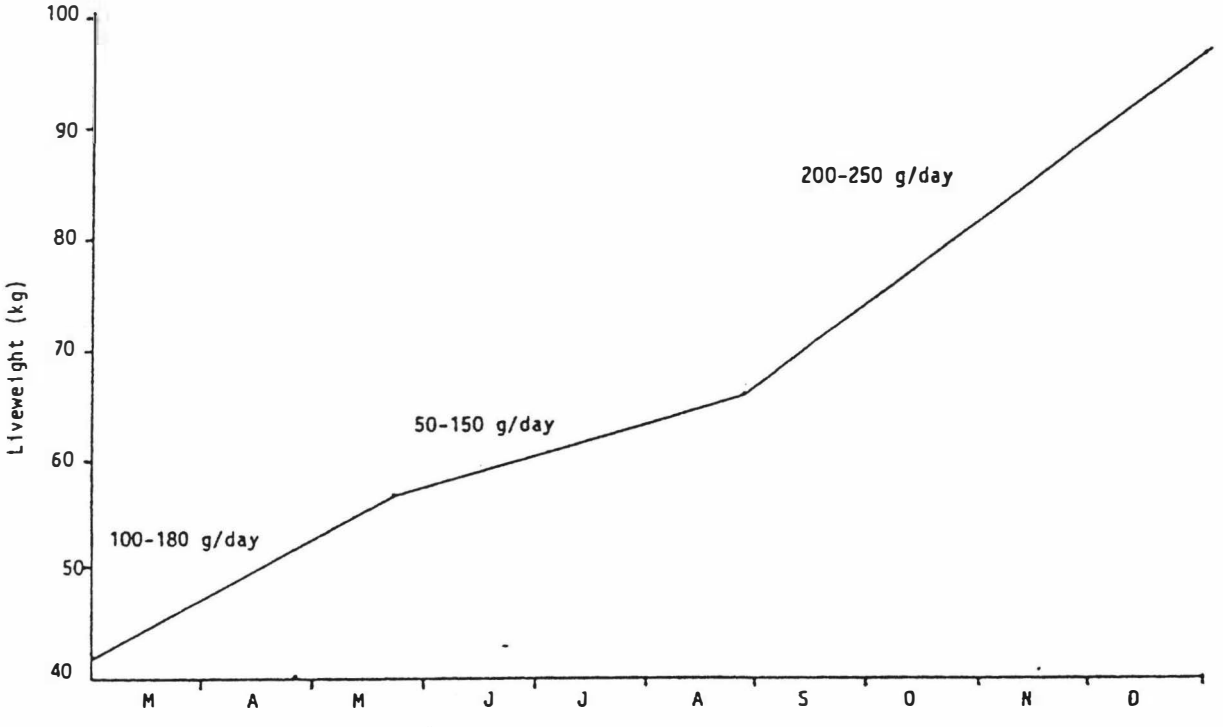

Figure 1.3. Typical growth pattern of red deer stags from weaning (early March) to 1 year of age (Adapted from Wilson. 1991). (Massey University Deer Unit Data)

The main purpose of venison production from weaner red deer stags under one year of age is to achieve a liveweight of 92 kg or greater by slaughter at the end of November. A deer needs to be at least 92 kg liveweight (55% killing out) to produce a carcass weight of 50 kg (Wilson, 1991). Thus, accelerating the weaner growth at all times (autumn, winter and spring) is crucial for a 12 month slaughter system.

Both the growth rate and the appetite of red deer calves decline during winter months (Drew, 1976), while some calves given a concentrate diet to appetite indoors may maintain slow growth rate of up to 100 g/day throughout winter, others may cease growing altogether for some weeks. Rates of growth in winter could be related both to weight at weaning and to the amount of herbage mass and supplementary

feed provided (Hamilton and Blaxter, 1981; Kay, 1985; Milne et al., 1987; Moore et al., 1988). Differences of diet and management after weaning, as well as species characteristics, influence the rate at which digestive functions mature (Kay and Staines, 1981). For instance, if a ruminant animal is to grow well and make efficient use of the feed provided, amino acids and metabolisable energy must be absorbed in the proportion that meets the requirements for lean tissue growth plus endogenous nitrogen metabolism and for deposition of fat plus heat losses. The nutritional requirements of red deer calves can be estimated as seen in Table 1.10.

The seasonal metabolisable energy (ME) requirement and target liveweight of red deer (growing animals, adult stags and non-lactating hinds) is seen in Table 1.11.

Young red deer are very lean animals compared to lambs, depositing little fat during first year of life. Whilst, the protein:energy ratio required and the conversion of dietary N to carcass N is equally efficient for both animals (Kay and Staines, 1981). This is, indeed, one of the attracted features of venison to the consumer.

Table 1.10. Estimated nutritional requirements of red deer calves with artificially-increased VFI in winter.

Age (months)	DMI (kg/d)	ME requirement (MJ/d) above maintenance[a)] for growth at 100 g/d	ME requirement (MJ/d) above maintenance[a)] for growth at 200 g/d	Dietary CP (g/kg DM)
3 - 5	1.4	5.5	11.0	170
6 - 11	2.0	4.9	9.7	170

Adapted from Adam (1991).

[a)]Maintenance = 0.45 MJ/kg$^{0.75}$

1.4.2.2. Factors influencing growth rates on young deer for 12-month-slaughter venison production system.

1.4.2.2.1. Seasonal pasture production and quality.

Patterns of pasture production in New Zealand fall into four major environmental categories; warm humid (Northland), summer dry (Canterbury, Manawatu, Hawke's Bay and Wairarapa), cold humid (Southland) and cold dry (Central Otago) (Korte et al., 1987). Peak production mostly occurs in November as a result of the hot and dry conditions. The least pasture production occurs during winter and summer (Radcilffe, 1975).

The seasonal changes in pasture composition, plant maturity and grazing management influence pasture quality, feed intake and animal performance. As the grass matures, the highly digestible leaves become a smaller and less digestible fraction of the whole plant. Waghorn and Barry (1987) revealed that legumes differ from grasses in the effects of maturity on their structural and chemical composition and digestibility. Most legumes maintain a higher proportion of leaf/stem with advancing maturity and the leaf retains a higher digestibility than grass leaf of comparable maturity. It is thus very important to apply a good grazing management for young deer in farming practices by keeping pasture swards in the leafy vegetative stage as long as possible, hence maximising their nutritive value and the animal performance.

Table 1.11. Seasonal metabolisable energy requirement and target liveweight of red deer.

	Target live weight (kg)	Daily ME requirement (MJ ME/head/day) autumn 65 d	winter 100 d	spring 100 d	summer 100 d	Annual total ME requirement (MJ ME/head) 365 d
			STAGS			
(Age-years)						
0.25-1.25	48	16.5	20.9	27.0	26.5	8300
1.25-2.25	105	24.5	28.0	31.5	30.0	10500
2.25-3.25	140	23.5	33.0	38.0	36.2	12200
3.25-4.25	175	19.5	33.0	38.5	38.2	12200
4.25-5.25	190	18.5	34.5	43.5	39.0	12900
> 5.25	200	19.0	36.0	42.5	38.0	12900
			HINDS			
(Age-year						
0.25-1.25	44	15.0	17.5	22.0	21.0	7000
1.25-2.25	83	20.5	23.5	23.5	45.0	10500
2.25-3.25	94	22.5	24.0	24.5	47.5	11000
> 3.25	100	23.5	22.5	24.5	47.5	10900

Adapted from : Fennessy and Milligan (1987).

Note: ME requirement have been calculated from the equations below.

(i) For growing animals, adult stags and non-lactating hinds: ME = S(0.57 $LW^{0.75}$) + 37 DLWG where, ME is metabolisable energy requirement in MJ ME/day; S is the 'seasonal coefficient'(11);1.30 for autumn (65 d), 1.50 for winter (100 d), 1.20 for spring (100d) and 1.10 for summer (100 d); LW is liveweight in kg; DLWG is daily liveweight gain in kg/d.

(ii) For lactating hinds and their calves at foot: ME = S(0.57 $LW^{0.75}$ hind) + 37 DLWG hind + 65 DLWG calf where, DLWG is daily liveweight gain in kg/day for the hind or the calf as indicated

1.4.2.2.2. Matching pasture supply and demand.

Different farms could have differing seasonal requirements for their deer. In NZ, normally, there is a feed surplus in the early and mid spring, whereas a feed deficit occurs in January, February and March, which continues through into winter. In terms of venison production of young stags, early weaning would give an advantage to match feed supply and demand. It could lower the overall feed requirement during the drought summer period, as indicated in Figure 1.4.

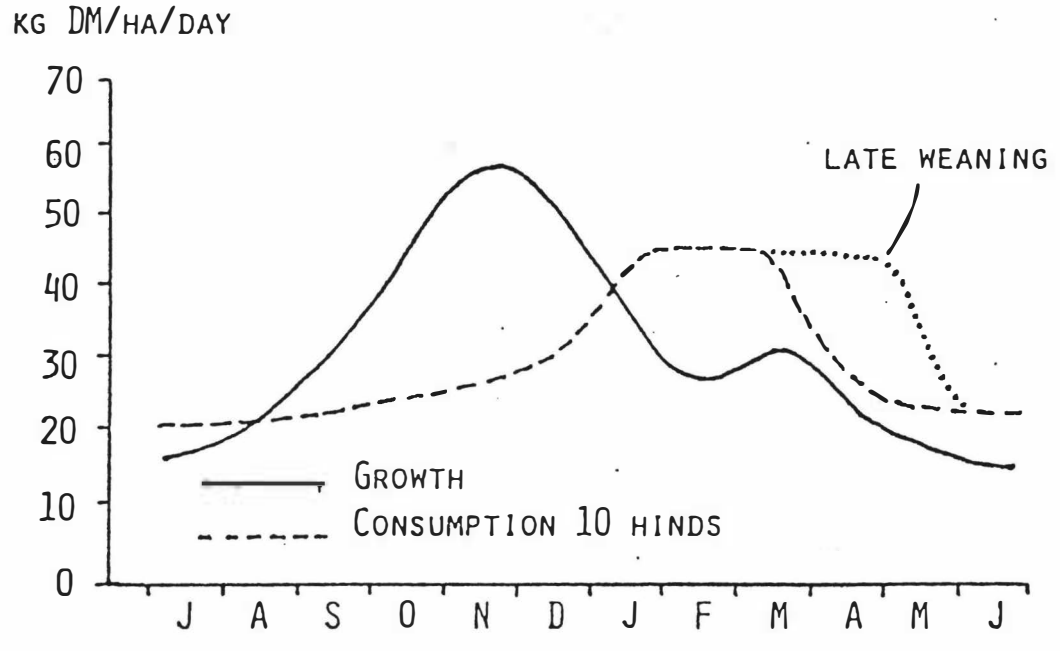

Figure 1.4. Average pasture growth rates in the Manawatu Downland. (Adapted from: Wilson, 1991)

The other alternative is by managing a combination between venison stags and breeding hinds. For the Manawatu feed supply and demand pattern, Figure 1.5. illustrates that there is still a winter deficit, the spring surplus is less, but the summer deficit disappears. Venison stags should be slaughtered before the summer deficit.

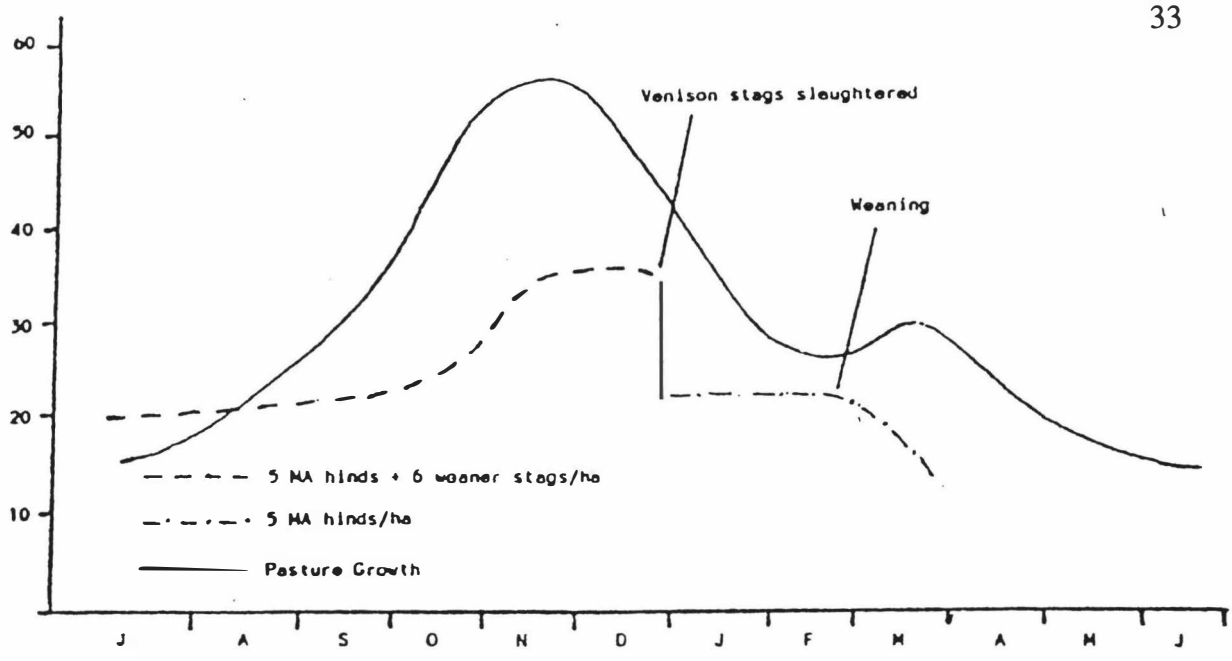

Figure 1.5. The seasonal feed supply and demand pattern for the Manawatu Downland, with a venison stags and breeding hinds operation. (Adapted from: Wilson, 1991)

1.4.2.2.3. Stocking rates.

Higher stocking rates reduce daily gains of newly weaned stags over autumn (Adam, 1988), and influence carcass production of red and fallow deer stags (Adam and Asher, 1986), as seen in Table 1.12. and Table 1.13., respectively.

Table 1.12. Effect of stocking rate on weight gains of newly weaned red deer stags during autumn.

	Year			Stocking rates (stags/ha)		
	1	2	SED	16	20	24
Daily gain (g/day)	143	110	13.7	158	135	97

Adapted from: Asher (1988).

Table 1.13. Effects of stocking rate on per animal and per production with male red and fallow deer.

Species	Stocking Rate/ha	Hot carcass weight (kg) Per animal	Gross/ha	Net/kg
Red	16	56.5	904	498
	24	51.6	1236	625
Fallow	32	25.5	816	430
	48	24.7	1185	608

Adapted from: Asher and Adam (1986).

1.4.2.2.4. Pre- and post- grazing herbage mass and pasture allowances.

Liveweight gains (LWG) in grazing young red deer were positively related to surface height and pre- grazing herbage mass (Milne et al., 1987), and influenced by post- grazing (residual) dry matter. Weaner deer grazing 6 cm sward (2860 ± 24.2 kg DM/ha) showed significantly higher LWG than those grazing 2.54 cm sward (1600 ± 50.2 kg DM/ha). Whilst, to achieve a maximum growth rate weaner need a minimum of 1500 kg DM/ha post-grazing herbage mass. In addition, to achieve daily liveweight gain of 200 g over autumn requires a pasture allowance equivalent to 5 kg DM/day (Adam, 1988), because herbage allowance, according to Hodgson (1989), is more appropriate for predicting animal performance and is best qualified for variations in pasture cover either before or after grazing.

1.4.2.2.5. Nutrition factors.

Nutrition is very important for deer production. Nutrition of red deer has been well reviewed by Kay and Staines (1981). Nutritional requirements for farmed red deer in NZ had also been reported in detail (Fennessy et al., 1981; Milligan, 1984; Fennessy and Milligan, 1987). Seasonal feed requirements vary depending mainly upon the level of production desired and the animal maintenance requirements. For instance, stags need a relatively high requirement over winter due to their lack of body energy reserves and subcutaneous fat, whereas hinds need it during summer when they are lactating.

Weaner red deer grazing perennial ryegrass during winter and spring grew more rapidly at 10 cm compared with 5 cm sward height, and increased the proportion of animals attaining the target slaughter weight (92 kg) by 30 November from 0 to 40% (Ataja et al., 1992[a]). The inclusion of improved pasture with moata annual ryegrass increased winter carrying capacity and the proportion of animals attaining target slaughter weight to 60%.

Despite these studies, which demonstrate the feasibility of one year venison production system from grazed pastures at a very efficient cost to the farmers, the development of specialist forages for deer production, such as red clover, which increased hind lactation performance and fawn weaning weight (Niezen et al., 1993), needs further study to evaluate its effects upon post-weaning growth. Red deer have a preference for pasture species other than ryegrass, with red clover, lotus and chicory being amongst the preferred species of 16 tested, whilst ryegrass was the least preferred (Hunt and Hay, 1990). Under indoor feeding trials, red clover also provided greater energy and fibre digestibility and hence greater energy absorption than perennial ryegrass (Freudenberger et al., 1993).

1.4.2.2.6. Immunisation.

The seasonal change in daylength acts as the main environmental cue which controls the annual cycle of voluntary feed intake (VFI), reproduction and growth (Adam, 1991). Hormonal control of seasonal changes in VFI is substantially unknown at present (Barry et al., 1991), however, it is recognised that the pineal hormone, melatonin, which is secreted during the hours of darkness, is the primary mediator of photoperiodic information within the animal's body (Adam, 1991). Strategic administration of exogenous melatonin, thus, elicits the same physiological responses as an artificial reduction in daylength, namely reproductive activity and reduced VFI (Domingue et al., 1992).

Hormonal manipulation such as active immunisation against melatonin which may reduce the reduction of feed intake during winter and hence accelerate growth rates has been investigated. Melatonin does not have direct stimulatory or inhibitory effects on growth (by inference VFI) and reproduction, yet the entire rhythm is entrained by it (Barry et al., 1991). When animals were treated with melatonin, there was a decline in plasma prolactin concentration to baseline level of 20 mg/ml within 30 days of treatment, and VFI by 10 to 15% and heart rate by 22% during 180 days after treatment. After which, the values for implanted deer rose and surpassed control animals, hence supporting the concept of melatonin's entraining circannual rhythms and probably mediates the effect of daylength on digestive function in red deer (Domingue et al., 1992). Melatonin administration depressed the VFI, rumen pool size and heart rate values in late spring and summer and increased all the values in autumn and winter, relative to control animals (Domingue et al., 1992)

Immunisation of red deer fawns at birth against melatonin increased stags'liveweight at the end of the next two winters (9-11 and 16-20 months) by 7 to 10% (Duckworth and Barrell, 1989). The effect of immunisation did not appear until the first winter. Active immunisation against melatonin given either at birth or at weaning did not obtain such response in liveweight gain, but tended to result in higher plasma prolactin concentrations during winter and an earlier onset of the spring rise in prolactin (Ataja et al., 1992[a]).

1.4.2.2.7. Cross-breeding options.

The deer industry in NZ seeks to gain a strategy to improve the size of deer and to grow faster than the base red deer. Cross-breeding with North American Elk (Wapiti) as terminal sire over red deer hinds as the dam has a promising result. The preferred option is to use a 0.5 elk : 0.5 red stag, giving 25% of wapiti in the offspring. This is sufficient to boost growth rate of the progeny, without causing undue calving difficulties, calving rate, the survival of the progeny, or temperament problems often associated with wapiti (Pearse, 1992). NZ red deer hinds mated to wapiti stags have successfully reared their hybrid calves (Moore and Littlejohn, 1989), and increased carcass production and quality (Drew and Hogg, 1990). Table 1.14. shows the superior growth of wapiti x red deer calves, compared to red deer.

Table 1.14. Liveweight measurements in 3 "breed" types of young male deer from weaning to 14 month of age (mean of 4 season ± sd).

	Red x Red	Wapiti-type bull x red hind	Wapiti-type x Wapiti-type
Liveweight (kg)			
Weaning (March)	47 ± 6	55 ± 7	67 ± 14
14 months	99 ± 8	115 ± 11	140 ± 15
Liveweight gain (October - February)			
g/day	234	297	362
relative gain	100	127	155

Adapted from : Suttie (1987)

1.5. VENISON, COMPARED TO OTHER ANIMAL MEATS.

Deer have a superior carcass weight to LW ratio compared to other farmed ruminants. Mature pasture-fed stags at Invermay dressed out at 59%, compared to 40-50% for young sheep and cattle (Drew, 1985). Deer carcasses comprise 52-54% of high priced cuts, 39-42% of second class cuts, and about 6 % of discarded bone. Deer carcasses contain a much lower fat than ram lamb or bull carcasses, as indicated in Table 1.15.

Table 1.15. Carcass weight (CW) and fatness in lambs, bulls and stags.

	CW range (kg)	Carcass fat (% CW)
Ram lambs	15 - 20	22 - 27
Bulls	200 - 240	18 - 22
Stags	55 - 70	8 - 12

(Adapted from: Drew, 1985)

The yield of lean meat from red deer and wapiti/red deer is 73-76% which is much greater than from beef, lamb, pork and chicken (48% to 59%). The detail is seen in Table 1.16.

Table 1.16. Separable lean, fat and bone from the carcass of different animal species.

Species	Carcass Weight (kg)	Percent yield			
		lean	fat	bone	lean/bone
Beef	239	59.0	23.0	18.0	3.3
Pork	52.0	48.0	25.0	27.0	1.8
Chicken	1.2	59.0	15.0	24.0	2.5
Red deer	62.5	72.7	7.0	20.3	3.6
Wapiti/red deer	67.6	76.0	4.7	19.3	3.9

(Adapted from: Drew et al., 1991)

One kg of carcass gain in young stags comprises 0.23 kg fat compared to 0.41 kg fat/kg gain in ram lambs (Fennessy et al., 1982). Deer, thus, has a higher efficiency converting feed into lean tissue and a greater producer of lean meat than sheep or cattle (Table 1.17.).

Table 1.17. Comparative efficiency of feed conversion of ruminants.

	Dry matter intake (kg)	Meat produced (kg)
Deer	30	3.0
Cattle	30	1.0
Lambs	30	1.0
Dairy cows (Butter fat)	30	1.5

(Adapted from: Yerex and Spiers, 1990)

The nutrient composition of venison product is extremely high in protein and iron while being very low in fat, energy and cholesterol. The comparative nutritive value of some animal meats is presented in Table 1.18.

Table 1.18. Comparative nutritive value of some animal meats. (Based on 100 g cooked portion).

	Calories	Fat (g)	Cholesterol (mg)	Protein (g)
Venison, loin cut[1)]	159	3.3	66	25
Venison, leg cut[2)]	163	6	73	26
Beef bottom round-lean	222	9	95	32
Beef tenderloin	205	9	85	28
Beef brisket	262	15	91	28
Ground beef 85%-lean	250	14	99	29
Lamb leg roast-lean	180	7	87	28
Lamb loin chop	215	9	94	29
Veal cutlet	182	5	132	33
Pork shoulder-lean	243	15	96	26
Pork top loin	258	15	94	28
Chicken breast (with skin)	196	8	85	29
Chicken breast (no skin)	165	4	85	31
Salmon-broiled	165	6	71	25
Scallops (breaded)	215	11	77	17

Adapted from: Mair Venison Ltd. & Venison New Zealand Booklet (1993).

Source: US Department of Agriculture and Esha Research.

[1)] Analysis of venison done by Invermay Research Centre, NZ.

[2)] Analysis of venison done by The National Food Laboratory Inc.

1.6. CONCLUSIONS.

The future of the NZ Deer Industry is dependent upon further development of markets for its products. Farmers, processors and exporters represented with NZDFA, NZDIA, NZGIB, and NZGCL should work together for the future marketing of high quality deer products from NZ, in terms of venison production. A well developed marketing strategy and structure for NZ farmed-raised venison has been co-ordinated by the GIB, with the use of Appellation Markets (i.e. to use **Cervena** brand to differentiate NZ products) and the Certification Trademark Markets (i.e. to use **'Zeal'** quality mark to emphasise and differentiate quality standard of NZ products). The prospect of venison demand is very optimistic, because of the excellent nutritional quality of venison, with the best attributes of red meat without any perceived bad features. A quality venison product depends on a quality management of deer on the farm, skilled and careful transport operators, and a high standard of performance in DSP's, packaging and marketing process. Therefore, it is likely to be able to sell NZ farm-raised venison in the future and the return to NZ deer producers is likely to remain high.

Obviously, the VFI and LWG in red deer are seasonal. Venison production from stags under one year of age is feasible. To meet the target for 12 month venison production system (92 kg LW; 50 kg carcass) by the end of November, the growth rate of red deer weaner stags in all seasons needs to be high, and integrated into a farming operations.

Red clover has given a substantial increase in weaning weight when grazed by lactating hinds and fawns (Niezen et al., 1993). There is a need to evaluate this system for increasing post-weaning growth and venison production by one year of age. The combination of this system with the immunisation against melatonin treatment for weaner red deer needs also to be researched. How to produce venison as efficient and economical as possible is still a challenge to farmers and animal scientists.

CHAPTER 2

Effects of grazing red clover (*Trifolium pratense*) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pastures and immunisation against melatonin upon growth and venison production from weaner red deer (*Cervus elaphus*)

2.1. INTRODUCTION.

Deer farming in New Zealand (NZ) is now established as a recognised livestock alternative because of its profitability. The deer is considered as a meat producing animal grazing mainly on traditional perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture.

Under current pasture conditions and management, young red deer (*Cervus elaphus*) stags normally will be reaching the target slaughter liveweight (92 kg; 50 kg carcass) at 15 months of age (Drew, 1989), but venison schedule prices have declined by that time (March). In order to meet the Northern Hemisphere venison market demand, the price is normally highest between August -December (Ataja et al., 1992[a]), and it is most profitable to produce venison from red deer in NZ with carcasses weighing more than 50 kg by just under one year of age. By offering high allowances (6.3 kg DM/ha/day) to weaner red deer stags grazing annual ryegrass pasture during both winter and spring, Ataja et al. (1992[a]) showed that 60% of animals could attain this target.

Young red deer (*Cervus elaphus*) exhibit a seasonal pattern of growth and voluntary feed intake (VFI), with high values in spring and summer, and low values in winter (Barry et al., 1991). This is a major constraint to increasing growth during winter and hence to increasing venison production.

Red clover (*Trifolium pratense*) is of a high nutritive value and is highly preferred by red deer (Hunt and Hay, 1990). It is considered as a summer-autumn alternative crop for deer farming, because both the growth rate and nutritive value of perennial ryegrass decline during summer. Offering a high allowance to hinds grazing on red clover forage during lactation significantly improved fawn growth

rates (433 vs 333 g/day) and weaning weights (49.5 vs 42.8 kg), compared to those grazing perennial ryegrass/white clover pasture (Niezen et al., 1993).

Growth manipulation in young red deer using immunisation techniques is still inconclusive. Immunization of red deer calves against melatonin from birth was found to modify their seasonal pattern of liveweight gain (LWG) during their first two years of life, increasing stags'liveweight by 7-10% between 9-11 and 16-20 months of age (Duckworth and Barrell, 1989), whereas no such significant response was obtained by Ataja et al. (1992[b]) in animals immunised at birth. However, active immunisation against melatonin tended to result in higher plasma prolactin concentrations during winter and an earlier onset of the spring rise in prolactin concentration (Ataja et al., 1992[a]). In other experiments, raising prolactin concentration during winter through sub-cutaneous injections of prolactin has increased LWG in growing reindeer (Ryg and Jacobsen, 1982) and in growing red deer (Suttie and Corson, 1991). In both instances, LWG was increased during winter.

The present study was designed to investigate feeding red clover and immunisation against melatonin for increasing venison production from young red deer by one year of age. Measurements made included diet composition, growth, voluntary feed intake (VFI), carcass weight and fatness, and plasma prolactin concentration.

2.2. MATERIALS AND METHODS.

2.2.1. Experimental Design.

Forty four weaner red deer (*Cervus elaphus*), consisting of 26 stags and 18 hinds, were randomly allocated to two types of forage (pure red clover and perennial ryegrass/white clover pasture) and two kinds of immunisation (anti-melatonin vaccine and placebo/adjuvant only), with treatment groups balanced for sex. Equal numbers of animals were allocated to each forage. The groups were rotationally grazed on either pure red clover or perennial ryegrass/white clover pasture. The present experiment was therefore of 2 x 2 x 2 factorial design.

The trial was conducted at Massey University Deer Research Unit, New Zealand, from 13 March 1991 to 6 December 1991, and was divided into autumn, winter and spring periods.

2.2.2. Animals.

The forty four weaner red deer (*Cervus elaphus*) fawns, aged approximately 3.5 months (mean fawning date end of November 1990), were allocated randomly into eight groups, with equal initial body weight. The combination of treatments were:

Pasture types	**Sex**	**Immunisation**
Red Clover	Male	Placebo
Red Clover	Male	Melatonin
Red Clover	Female	Placebo
Red Clover	Female	Melatonin
PRG/WC	Male	Placebo
PRG/WC	Male	Melatonin
PRG/WC	Female	Placebo
PRG/WC	Female	Melatonin

All twenty two deer allocated to each forage were grazed together as a single group. During the experiment, one hind and one stag from the red clover group died, due to yersiniosis, on 31 May 1991 and 1 June 1991, respectively. Both had the lowest body weight within their group. One stag from the PRG/WC group was euthanised because of misadministering a chromium slow release capsule, which caused an abscess in the neck. Also, two sick animals showed very low performance. Data from these animals were excluded from the statistical analyses.

All animals were eartagged and vaccinated against clostridial infections (Coopers, Animal Health Ltd., NZ) at weaning (11 March 1991). Drenching the animals to prevent lungworm and internal parasites was given orally with invermectin (IVOMEC - 0.4 % m/v at 200 µg/kg live weight; Merck, Sharp and Dohme, NZ) at three week intervals until end of June, then six weekly until slaughter in December. Checking for copper deficiency using blood samples was conducted, and the laboratory analysis result showed that there was no sign of copper deficiency. Therefore, copper supplementation was not given.

2.2.3. Pasture Management.

Areas for the trial comprised 2.4 ha (8 paddocks) of red clover (RC), and 2 ha (4 paddocks) of perennial ryegrass/white clover (PRG/WC) pasture. Pasture areas received urea fertilization in April and mid July 1991 at the level of 50 kg and 100 kg of urea/ha, corresponding to 23 and 46 kg N/Ha, respectively. The herbicide (KERB-FLO, RHOM and HAAS Ltd., NZ) treatment was also applied to part of the red clover area to control grasses during winter. The RC forage was in the second year, while the PRG/WC pasture was several years old.

Animals allocated to the two forage treatments were rotationally grazed during autumn and spring, 13 March 1991 to 15 May 1991 and 9 September to 6 December 1991, respectively. All animals in both groups were combined and grazed together on PRG/WC pasture (4 ha; 8 paddocks) over the winter period (15 May - 9 September 1991), because RC is dormant over this time. Pasture hay supplementation (0.5 kg DM/head/day) was also provided over winter to meet the nutritional requirements. Pasture residual dry matter was maintained at about 1100 kg DM/ha during the winter. Feed allowances offered to the animals were 6, 7 kg DM/deer/day during autumn, winter and spring, respectively.

2.2.4. Immunisation Treatments.

Animals allocated to the anti-melatonin immunisation treatment had first been vaccinated against melatonin at birth (primary immunisation). The first booster vaccination was given to the calves at weaning (25 February 1991). Booster anti-melatonin vaccination was also administered on 17 April 1991 to the immunisation treatment and placebo (adjuvant only) to the control group. A single dose of anti-melatonin vaccine comprised: 1 mg antigen ARH-291 ((5-methoxy-tryptamine hemisucciamide conjugated to human serum albumin (HSA)), 1 ml physiological saline (9 g NaCl/l), 1 ml Freund's adjuvant. Freunds complete adjuvant (FCA) was used for the primary immunisation and Freunds incomplete adjuvant (FIA) for all booster immunisations. A single dose of the placebo was composed of : 1 ml physiological saline (9 g NaCl/l), and 1 ml Freund's adjuvant.

2.2.5. Blood Sampling.

Jugular vein blood sampling was taken from individual animals for hormone analysis. The blood samples were collected in 10 ml vacutainers (Nipro Medical Industries Ltd., Japan) using Na heparin as anti-coagulant and put on ice cubes. To harvest blood plasma used for hormone analysis (prolactin), blood samples were centrifuged at 4^0 C, at 3000 RPM (1851 g) for 30 minutes. Plasma samples were separated from blood serum, and stored in five 1 ml lots at -20^0 until required for analysis.

2.2.6. Scrotal Circumference Measurement.

Scrotal circumference for stags was measured by using millimetre grade tape from June onwards at three week intervals.

2.2.7. Velvet Antler Removal.

Velvet antler was harvested when it attained approximately 20 cm of length. The precise length, weight and velveting dates were recorded. The animals were treated either by sedating with 10 % xylazine (Rompun, Bayer Ltd., NZ) at a dosage rate of 0.5 mg/kg body weight, intramuscularly or by restraining the animals in a pneumatic deer crush. After the animals had been mildly sedated or crushed, local anaesthetic was given by injecting 15 ml lignocaine hydrochloride (Xylotox, A.H. Robins Co. Ltd., England) in a ring block around each antler, then tied up with tape to form a tourniquet. About five minutes later the velvet was cut using a sterilized saw. To the sedated animals, xylazine was reversed with 1.5 - 2.0 ml yohimbine hydrochloride (Reservyl, Aspiring Veterinary Service, NZ) to counteract the xylazine effect. Lastly, the tapes were removed and the animals released.

2.2.8. Pasture Sampling.

Herbage mass measurement (kg DM/ha) were done as pre-grazing herbage mass, prior to the animals being introduced into each paddock, and post-grazing herbage mass, to determine the residual dry matter, as soon as the animals were shifted from the paddock. Forage samples were cut to ground level with 8 quadrates per plot of 0.10 m^2 size. A portable shearing hand piece (Clipmaster, Sunbeam, Australia) powered by a portable generator (Kawasaki, Japan) was used to cut the herbage samples. The herbage samples taken were then washed, oven-dried at 90^0 C for 18 hours, and weighed. Then, data was calculated as :

$$\text{Herbage mass (kg DM/ha)} = \frac{\text{dry weight (g)} \times 1 \times 10}{\text{fresh weight (g)} \times \text{area cut (0.8 } m^2\text{)}}$$

The length of time for the animals grazing each paddock based on the allowances offered was calculated as follows :

$$\text{Total days} = \frac{\text{herbage mass (kg DM/ha)} \times \text{total area of paddock}}{\text{(total animals/group)x(pasture allowance/deer/day)}}$$

For laboratory analysis, 8 quadrat (0.1 m^2) of fresh herbage/feed on offer were cut to ground level from each paddock when the deer were introduced. Samples were then combined, mixed, and divided into two parts. The first part was to determine botanical composition, and the second part was to be stored at -20^0 C to determine nutritive value.

Whilst the deer were grazing on each allocated paddock, diet selection samples were collected by hand-plucking plants in that particular area. The samples

were harvested daily by imitating the animal's selection of plants. Collected daily samples were then pooled for each paddock, combined, mixed, and stored at -20^0 C for total N and in-vitro digestibility analysis.

2.2.9. Estimation of Faeces Output and Voluntary Feed Intake.

To estimate the faecal organic matter output, 24 stags and 16 hinds were dosed with sheep-size intra ruminal chromium-slow-release capsules (CRD, Cr_2O_3 matrix, Captec Ltd., Auckland, NZ) during autumn and with calf-size during spring. Faeces were sampled from the rectum of individual animals from day 7 to day 21 after CRD administration, at 3 day intervals. The faecal samples were collected in plastic bottles, oven dried at 90^0 C for 24 hours, and stored until the laboratory analysis was done. Chromium release rate from the capsules was measured at the same time by putting the capsules into the rumen fistulated red deer and measuring the rate of plunger travel.

2.2.10. Carcass Data.

All stags attaining 92 kg liveweight or greater by 30 November were weighed about 24 hours prior to the slaughter time. Stags with velvet antler were de-velveted before being transported to the DSP in Fielding.

Hot carcasses (kg) were weighed, rump fat width (mm) (Ataja et al., 1992[a]), and the carcass GR (mm) (soft tissue depth over the 12th rib 16 cm from the mid line) as an indirect measure of fatness (Kirton, 1989) were measured and recorded immediately after slaughter.

The fore-legs distal to the carpal bones were collected at slaughter and the cannon bones (metacarpal) were dissected out and were weighed (g), and the maximum length and circumference (mm) were measured. Testes from individual animals were also collected and weighed (g).

2.2.11. Laboratory Analysis.

All herbage samples were stored at -20^0 C, freeze dried and ground to pass a 1 mm mesh diameter sieve (Willey mill, USA) prior to laboratory analysis. Dry matter (DM) was determined by oven heating at 100^0 C for 16 h. Total nitrogen (N) was determined by the Kjeldahl procedure, using a selenium catalyst with sulphuric acid digestion, and with the ammonia being determined by automatic titration against 0.1 M HCl in a Kjeltec Auto 1030 Analyzer (Tecator A.B.,Sweden). In-vitro digestibility was determined following the method of Roughan and Holland (1977), using six standards derived from in-vivo digestion trials with sheep.

For botanical composition, samples of fresh herbage were dissected into grasses, clover (red or white clover), dead material and others. The components were separately oven dried at 90^0 C for 17 h, and weighed. The proportion (%) of the components were calculated as :

$$\frac{\text{dry weight of individual components (g) x 100}}{\text{total dry weight of sample (g)}}$$

Chromium analysis of faeces output was done according to the method of Parker et al.(1989). Crushed 0.5 g samples taken from individual daily faecal sampling were pooled per animal, oven dried at 110^0 C for 17 h, re-weighed after being cooled, ashed for 17 h, and Cr then determined by atomic absorption.

Plasma prolactin concentration was determined as the method of van Landeghem and van de Weil (1978) modified by Ruminant Endocrinology and Metabolism Laboratory , Department of Animal Science Massey University. The specifications of Radio Immunoassay for Prolactin analysis (PRL) were described as follows :

Standards were based on biological grade ovine prolactin, NIADDK-oPRL-18(AFP-8277E, 30 IU/mg) from National Institute of Arthritis, Diabetes, Digestive and Kidney Diseases, National Institute of Health, Bethesda, U.S.A., and, supplied through National Hormone and Pituitary Program, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A. Standards used were 1, 10, 25, 50, 100, 150, 200, 400, 600, 800 and 1200 ng/ml. Linear range was approximately 10-800 ng/ml.

First antibody being used was NIADDK-anti-oPRL-2(AFP-C358069 II) by the National Hormone and Pituitary Programme, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A.

^{125} I-labelled Prolactin being used was lyophilized ovine prolactin, NIADDK-oPRL-I-2(AFP-7150B) from NIADDK,NIH, Bethesda, MD.,U.S.A. and supplied through NHPP University of Maryland School of Medicine, Baltimore, MD., U.S.A. Iodination was based on procedure of Greenwood et al., Biochem. J. 89:114 (1963) but using borate instead of phosphate buffers. Separation of bound and free iodine using Sephadex G50 (coarse) gel column (Pharmacia Fine Chemicals, Uppsala, Sweden, Lot No. 0870).

Second antibody being used was Donkey anti-rabbit serum (IDS, Washington, Tyne and Wear, England, Code APPT 1, Lot 11656).

Coefficients of variation were Intra-assay CV 9.7 % and Inter-assay CV 16.6% and the least amount discernable from zero was 0.417 ng/ml.

2.2.12. Data Calculation and Statistical Analysis.

The experimental data, live weight gain (LWG), carcass weight, GR measurement, Scrotal circumference, velvet weight, prolactin concentration, and voluntary feed intake were analyzed using General Linear Model Procedure (GLM), as a 2 x 2 x 2 factorial design, with two types of forages (RC and PRG/WC), two level of sex (Male and Female), and two kinds of immunisation (Anti-Melatonin and Placebo/Adjuvant only). Initial body weight was fitted as a covariate except for scrotal circumference, velvet weight and VFI values. To test the differences between treatments, Least Square Means (LSM) analysis was used.

The autumn LWG (g/day) was calculated as :

$$\frac{\text{Liveweight (kg) on 15 May - Liveweight (kg) on 13 March}}{\text{63 days}} \times 1000$$

using the initial LW (13 March) as a co-variate.

The winter LWG (g/day) was calculated as :

$$\frac{\text{Liveweight (6kg) on 9 Sept - Liveweight (kg) on 17 May}}{\text{115 days}} \times 1000$$

using the initial LW (13 March) as a co-variate.

The spring LWG (g/day) was calculated as :

$$\frac{\text{Liveweight (kg) on 26 Nov - Liveweight (kg) on 12 Sept}}{\text{75 days}} \times 1000$$

using the initial LW (13 March) as a co-variate.

Faeces output (FO) was calculated as :

$$\text{FO (g OM/day)} = \frac{\text{Chromium release rate (mg/day)}}{\text{Faecal chromium concentration (mg/g OM)}}$$

The chromium release rates of sheep-size and calf-size CRD used in autumn and in spring were assumed to be 121 mg/day (A.M. Ataja, personal communication) and 344 mg/day (J. Niezen, personal communication), respectively. The values obtained were based on the release rate measurement of CRD in rumen fistulated red deer.

Voluntary feed intake (VFI) was then calculated as :

$$\text{VFI (g OM/day)} = \frac{\text{Faecal Output (g OM/day)}}{1 - \text{Digestibility of OM}}$$

where the organic matter digestibility (OMD) value was taken from the hand-plucked sampling value.

2.3. RESULTS.

2.3.1. Pre- and post-grazing herbage mass.

Mean pre- and post-grazing herbage mass (kg DM/ha) of RC and PRG/WC pastures at Massey University Deer Unit, during autumn, winter and spring 1991 are shown in Table 2.1. Values of pre-grazing herbage mass for both forages were highest in autumn (3568 kg DM/ha for RC; 3706 kg DM/ha for PRG/WC), followed by spring (2726 kg DM/ha for RC; 2150 kg DM/ha for PRG/WC), and winter (1736 kg DM/ha for PRG/WC). Post-grazing herbage mass averaged 1822, 1882, 1704, 1334, 1170, kg DM/ha for autumn (RC), autumn (PRG/WC), spring (RC), spring (PRG/WC), and winter (PRG/WC), respectively.

2.3.2. Botanical composition of pastures.

The percentage of various sward components in the RC and PRG/WC pastures are shown in Table 2.2. Red clover (*Trifolium pratense*) dominated 72% and 63% of the RC sward DM during autumn and spring, respectively, with the proportion of white clover (*Trifolium repens*) increasing from 5% in autumn to 26% in spring. PRG/WC swards were predominantly composed of perennial ryegrass (*Lolium perenne*) (62% in autumn; and > 80% in winter and spring), with 7 - 10% of white clover. Following the dry summer, the RC and PRG/WC swards comprised of 21% and 26% dead material in autumn, respectively. Both white clover and dead matter proportions declined in winter and in spring.

Table 2.1. Pre- and post-grazing herbage mass (kg DM/ha ± SE) of red clover (RC) and perennial ryegrass/white clover (PRG/WC) forages grazed by weaner red deer (*Cervus elaphus*) at Massey University Deer Unit, during autumn, winter and spring of 1991.

	PRG/WC					RC				
	Pre-grazing	SE	Post-grazing	SE	(n)	Pre-grazing	SE	Post-grazing	SE	(n)
AUTUMN	3706	219.7	1886	256.6	7	3569	215.1	1823	132.1	9
WINTER [1)]	1736	83.1	1170	41.4	40					
SPRING	2150	63.9	1335	21.8	13	2726	43.2	1705	41.4	19

(n) = Number of samples taken per season

[1)] During winter, all animals from both PRG/WC and RC groups were combined and grazed together on PRG/WC pasture

Table 2.2. Botanical composition (% DM ± SE) of red clover (RC) and perennial ryegrass/white clover (PRG/WC) forages on offer to weaner red deer (*Cervus elaphus*) during autumn, winter and spring of 1991.

	RC					PRG/WC				
Components	**RC**	**WC**	**Dead**	**Other Matter**	**(n)**	**PRG**	**WC**	**Dead**	**Other Matter**	**(n)**
AUTUMN	72.1	5.4	21.4	1.1	8	62.1	10.1	26.8	1.3	6
(SE)	(1.20)	(1.20)	(1.20)	(1.20)		(1.26)	(1.26)	(1.26)	(1.38)	
WINTER	.....					81.2	7.4	10.2	1.4	40
(SE)						(0.48)	(0.49)	(0.49)	(0.49)	
SPRING	63.7	26.0	10.3	0.04	19	81.5	8.6	9.3	0.03	13
(SE)	(0.78)	(0.78)	(0.78)	(0.78)		(0.89)	(0.86)	(0.86)	(0.86)	

RC = red clover
WC = white clover
PRG = perennial ryegrass
(n) = Number of samples taken per season

2.3.3. Chemical composition.

The chemical composition of "feed on offer" (FO) and "diet selected-hand pluck" (DS) of both RC and PRG/WC pastures are shown in Table 2.3. Total nitrogen (N) content and organic matter digestibility (OMD) values of both FO and DS were generally higher in RC than PRG/WC pasture, with the differences attaining significance for total N ($P<0.001$) and for OMD ($P<0.01$) of FO in spring, and for total N and OMD ($P< 0.001$) of DS in spring. The total N and OMD values of DS for both RC and PRG/WC pastures in autumn and in spring were consistently higher than of FO. Those were very significant ($P<0.001$) for RC and significant ($P<0.05$) for PRG/WC, except the OMD value for PRG/WC in spring.

2.3.4. Seasonal liveweight change.

The seasonal pattern of growth in the weaner red deer immunized against melatonin or placebo only (control) grazing either RC or PRG/WC forages can be seen in Figure 2.1 and 2.2. These show three phases in the growth curve; intermediate growth during the autumn, slow growth during the winter and faster growth during the spring period. Animals in all treatment groups showed similar growth patterns.

Table 2.3. Nutritive value of feed on offer and diet selected for weaner red deer (*Cervus elaphus*) grazing either red clover (RC) or perennial ryegrass (PRG/WC) forages during autumn, winter and spring of 1991.

	Total Nitrogen (N; % DM)				Organic matter digestibility (OMD; %OM)			
	RC	(n)	PRG/RG	(n)	RC	(n)	PRG/WC	(n)
				Feed on offer				
AUTUMN	3.4	9	3.4	7	77.3	9	78.6	7
(SE)	(0.14)		(0.17)		(0.72)		(0.88)	
WINTER	.....		3.9	11	.....		76.9	11
(SE)			(0.09)				(0.61)	
SPRING	4.1	9	2.6	6	84.5	9	80.3	6
(SE)	(0.14)		(0.17)		(0.72)		(0.88)	
				Diet selected				
AUTUMN	4.2	9	3.9	7	84.2	9	83.2	7
(SE)	(0.14)		(0.15)		(0.75)		(0.85)	
WINTER	.....		4.3	11	.....		79.7	11
(SE)			(0.09)		(0.61)			
SPRING	4.7	9	3.3	6	87.7	9	82.4	6
(SE)	(0.14)		(0.17)		(0.75)		(0.92)	

(n) = Number of pooled samples taken per season for laboratory analysis

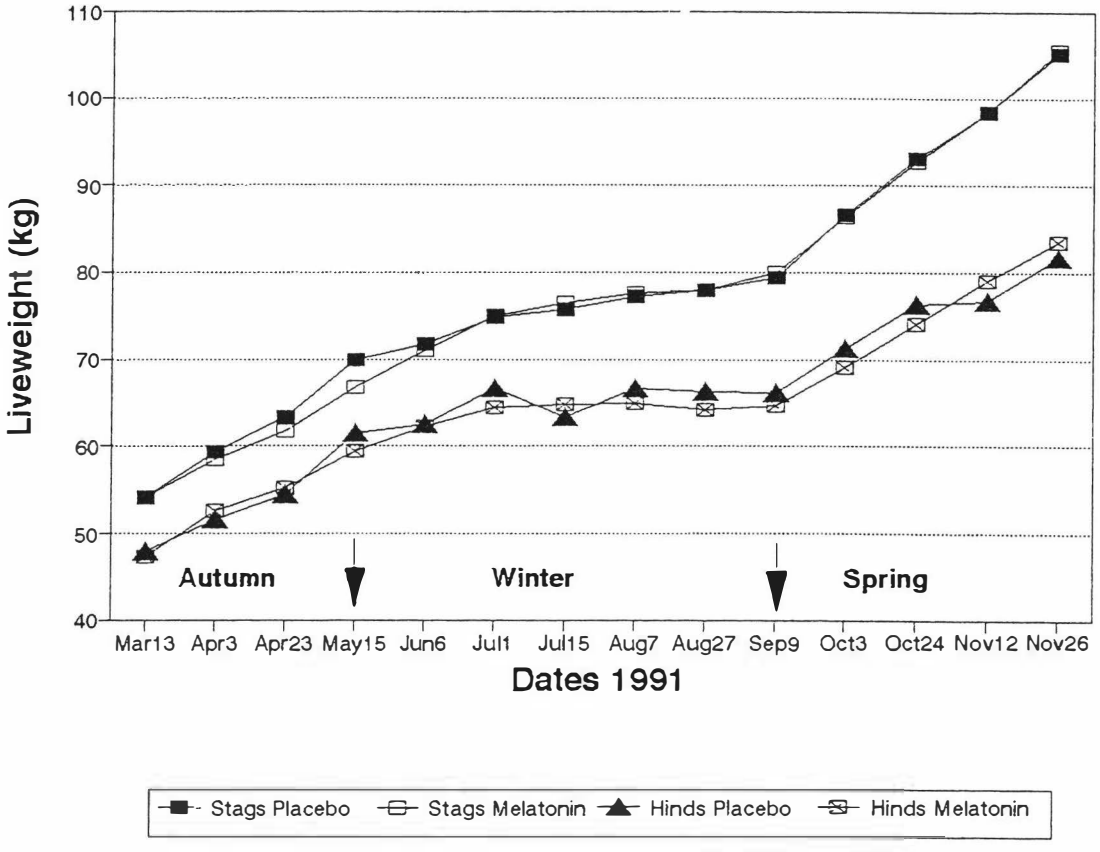

Figure 2.1. The seasonal liveweight change of weaner red deer (*Cervus elaphus*) stags and hinds immunized either against melatonin or placebo only (control) grazing red clover (RC) forage.

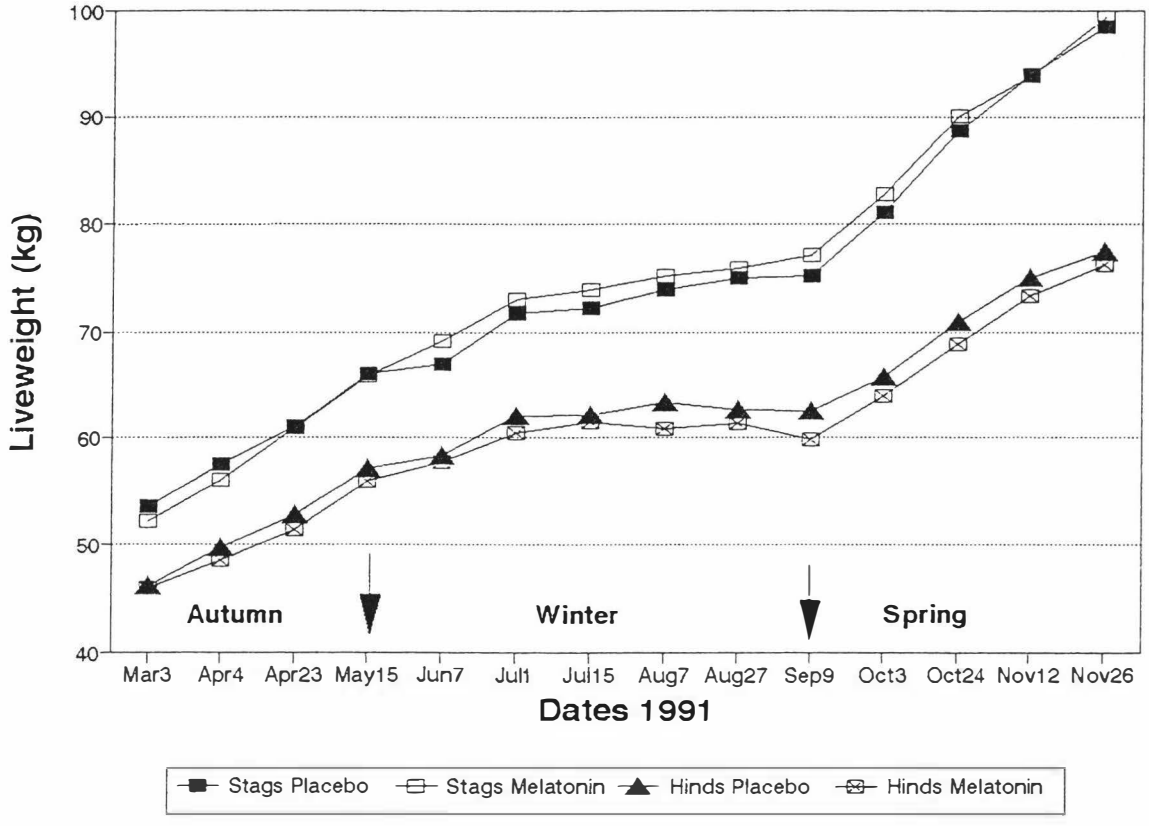

Figure 2.2. The seasonal liveweight change of weaner red deer (*Cervus elaphus*) stags and hinds immunized either against melatonin or placebo only (control) grazing perennial ryegrass/white clover (PRG/WC) pasture.

2.3.5. Voluntary feed intake (VFI).

Voluntary feed intake (VFI) of weaner red deer grazing either RC or PRG/WC pasture during autumn and spring is shown in Table 2.4. The interaction between forage groups, sex and immunisation treatments was not significantly different (P>0.05) in either autumn or spring.

Table 2.4. Organic matter intake (g OM/kg $W^{0.75}$/day ± SE) of weaner red deer (*Cervus elaphus*) grazing either red clover (RC) or perennial ryegrass/white clover (PRG/WC) forages during autumn and spring of 1991.

	STAGS		HINDS		SE
	RC (n=12)	**PRG/WC** (n=12)	**RC** (n=7)	**PRG/WC** (n=10)	
AUTUMN	124	109	116	71	4.56
SPRING	181	125	169	126	6.71

(n) = Number of animals dosed with chromium slow release capsules

The interaction between forage groups and sex was significantly different (P<0.001) in autumn, but not in spring (P>0.05). Weaner stags and hinds grazing red clover forage had significantly higher VFI than the comparable animals grazing PRG/WC in either autumn (P<0.05) or spring (P<0.001).

2.3.6. Forage effects on liveweight gain.

Liveweight gain (LWG) (g/day) of weaner red deer stags and hinds grazing either RC forage or PRG/WC pasture during autumn, winter, and spring is shown in Table 2.5. The mean initial liveweight of animals allocated to RC or PRG/WC was not significantly different ($P>0.05$) for both stags and hinds at the beginning of the trial. The interaction between forage groups and sex for LWG was not significantly different ($P>0.05$) in both autumn and spring.

LWG of stags and hinds grazing RC forage was higher than those grazing PRG/WC pasture, with the difference attaining significance ($P<0.01$) in autumn (averaged 237 vs 207 g/day for stags; 197 vs 159 g/day for hinds), and very significant ($P<0.001$) in spring (averaged 346 vs 281 g/day for stags; 260 vs 188 g/day for hinds). There was no significant difference ($P>0.05$) for both stags and hinds grazing PRG/WC pasture in winter. At the end of spring (by one year of age), stags and hinds grazing RC forage were respectively 7 and 6 kg liveweight heavier than those animals grazing PRG/WC pasture (Figure 2.3).

2.3.7. Immunisation effects on liveweight gain.

The liveweight gains (g/day) of weaner red deer stags and hinds either immunized against melatonin or placebo only (control) are seen in Table 2.6. The mean initial liveweight of both stags and hinds were not significantly different for animals allocated to immunisation and control groups. The LWG values of both stags and hinds for both immunisation and control groups did not show any significant differences ($P>0.05$) in all seasons. In addition, the interaction between forage groups and immunisation treatments, and sex and immunisation treatments did not attain significance ($P>0.05$).

Table 2.5. Liveweight gain (g/day ± SE) of weaner red deer (*Cervus elaphus*) grazing either RC or PRG/WC pasture, during autumn, winter and spring of 1991.

	STAGS		HINDS		SE
Liveweight gain (g/day)	PRG/WC[1)] (n=11)	RC[2)] (n=11)	PRG/WC[1)] (n=10)	RC[2)] (n=5)	
AUTUMN	207	237	159	197	13.67
WINTER	95	94	40	38	8.47
SPRING	281	346	188	260	13.22

[1)] Perennial Ryegrass/White Clover

[2)] Red Clover

(n) = Number of animals per group

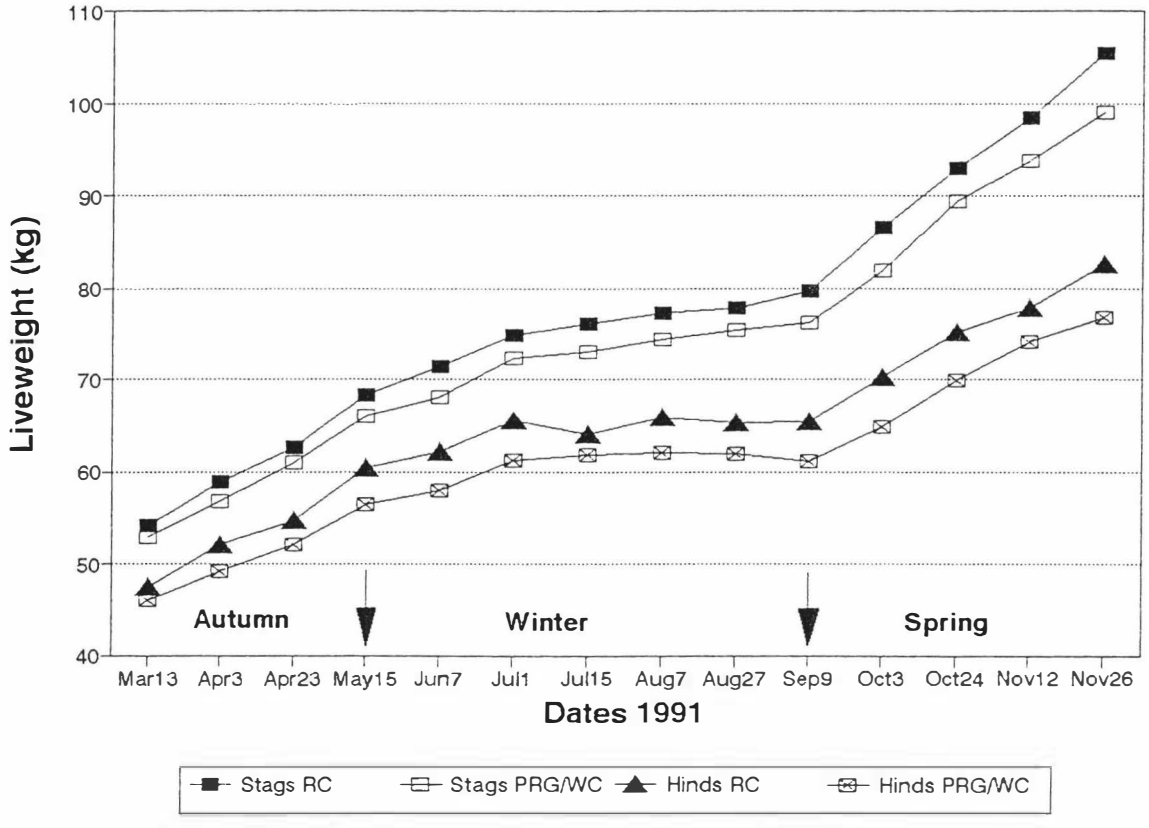

Figure 2.3. The overall liveweight change of weaner red deer (*Cervus elaphus*) stags and hinds grazing either red clover (RC) or perennial ryegrass/white clover (PRG/WC) forages.

Table 2.6. Effect of immunisation against melatonin on liveweight gain (g/day ± SE) and mean liveweight (kg ± SE) of weaner red deer (*Cervus elaphus*) grazing either RC or PRG/WC pasture, during autumn, winter and spring of 1991.

Liveweight gain (g/day)	STAGS		HINDS		SE
	control (n=14)	**immunisation** (n=9)	**control** (n=7)	**immunisation** (n=9)	
AUTUMN	224	220	182	175	18.43
WINTER	87	102	41	38	8.34
SPRING	312	316	219	229	14.42

(n) = Number of animals per group

2.3.8. Treatment effects on plasma prolactin (PRL) concentrations.

The patterns of plasma prolactin concentration from weaner red deer grazing either RC or PRG/WC forage, and either immunized against melatonin or placebo only are shown in Figure 2.4. and 2.5., respectively. The PRL concentrations were low (averaged 2.6 ng/ml) during autumn and winter and did not show any marked increased and any significant differences ($P>0.05$) in all treatment groups. Starting from the early spring (24 September onwards) the PRL concentrations were apparently increased, but there was no significant difference ($P>0.05$) in the interaction between forage groups, sex and immunisation treatments in all dates of sampling (Table 2.7). Forage treatment (RC vs PRG/WC) did not give any significant effects ($P>0.05$) on PRL concentrations. There was no significant effects ($P>0.05$) of the immunisation treatment (against melatonin vs placebo only) on plasma PRL concentrations.

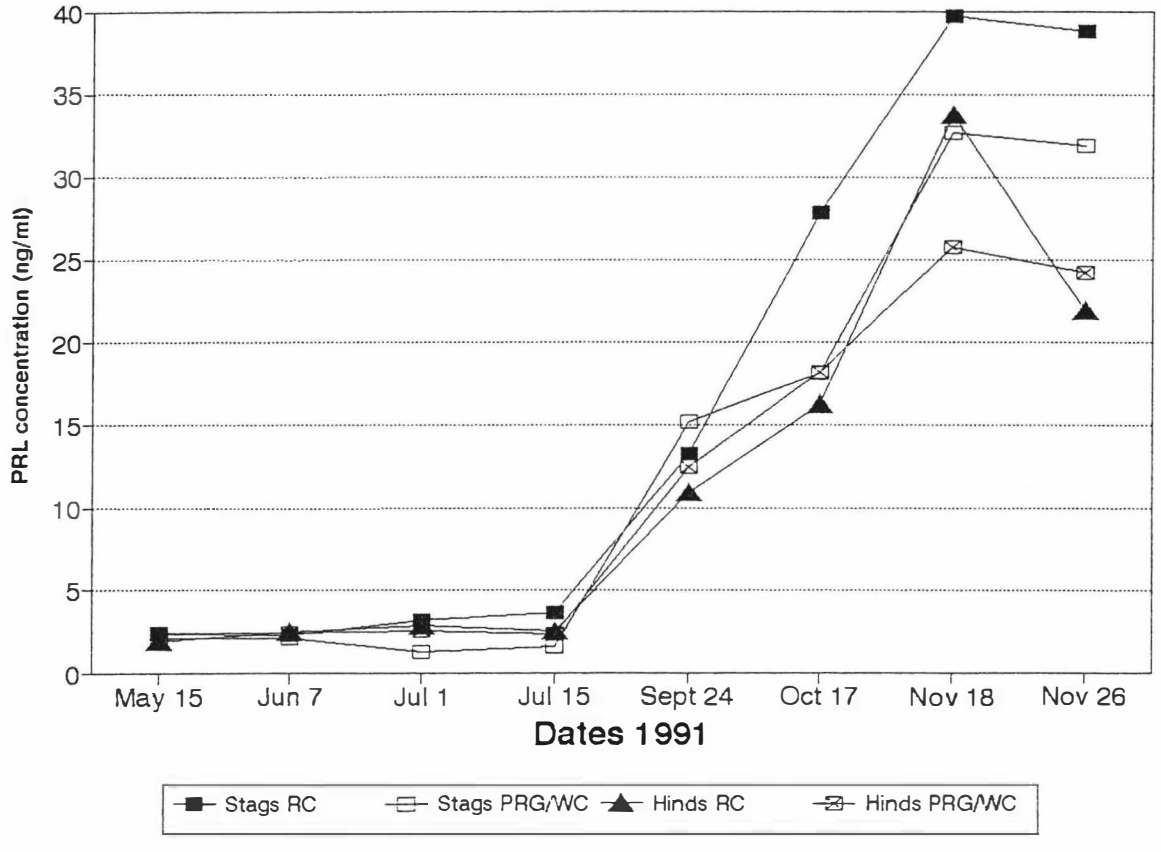

Figure 2.4. The overall prolactin (PRL) concentration (ng/ml) of weaner red deer (*Cervus elaphus*) stags and hinds grazing either red clover (RC) or perennial ryegrass/white clover (PRG/WC) forages.

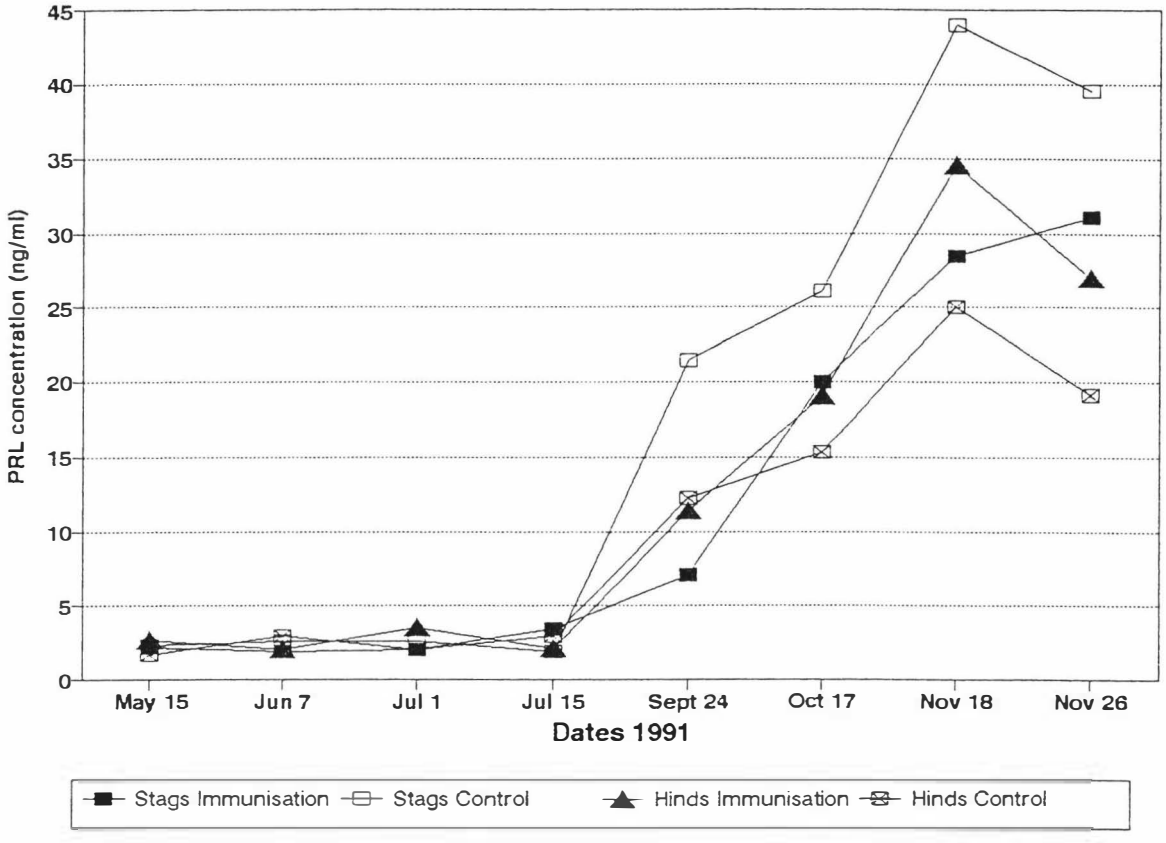

Figure 2.5. The overall prolactin (PRL) concentration (ng/ml) of weaner red deer (*Cervus elaphus*) immunized either against melatonin or placebo only (control) during 1991.

Table 2.7. Plasma prolactin concentrations (ng/ml ± SE) of weaner red deer (*Cervus elaphus*) immunized by against melatonin or placebo only (C = control) grazing either RC or PRG/WC forages during autumn, winter and spring of 1991.

	Plasma prolactin concentration (ng/ml)								
	PRG/WC				RC				
Dates	Stags		Hinds		Stags		Hinds		
	C	Immunized	C	Immunized	C	Immunized	C	Immunized	SE
15 Jul	1.6	1.6	2.9	1.9	2.0	5.8	3.0	2.3	2.24
24 Sept	19.0	6.5	11.9	13.3	19.0	8.2	12.4	9.6	8.19
17 Oct	20.3	13.7	14.7	21.6	28.5	29.9	15.9	16.6	9.21
18 Nov	37.8	23.4	24.1	27.6	51.6	27.8	26.0	41.5	16.96
26 Nov	37.93	20.93	23.84	24.74	42.8	34.8	14.5	29.4	14.46

2.3.9. Pasture effects on carcass production.

All (100%) stags grazing RC forage during autumn and spring, and 90% stags grazing PRG/WC pasture during autumn, winter, and spring attained the target slaughter weight (>92 kg; 50 kg carcass) by one year of age (at the end of November). Carcass weight (kg) ($P<0.01$) and dressing percentage (%) ($P<0.001$) were significantly higher for RC than PRG/WC stags (Table 2.8). There was no difference ($P>0.05$) in carcass GR either before or after being adjusted to equal carcass weight.

2.3.10. Immunisation effects on carcass production.

Immunisation against melatonin in weaner red deer stags did not give any significant effects ($P>0.05$) on all measurements of carcass production (liveweight at slaughter, carcass weight, dressing percentage and carcass GR), compared to control animals (Table 2.9).

Table 2.8. Carcass production from red deer (*Cervus elaphus*) stags grazing either RC or PRG/WC pasture and attaining slaughter liveweight (92 kg) by one year of age, during 1991. Mean values were adjusted to equal initial liveweight for carcass data.

	PRG/WC (n=11)	RC (n=11)	SE
Stags attaining target slaughter liveweight (%)	90	100	
Liveweight (kg)	101.8	104.7	1.76
Carcass weight (kg)	53.3	58.9	1.00
Dressing percentage (%)	52.4	56.2	0.52
GR (mm)	4.9	6.4	0.73
GR*) (mm)	5.7	5.7	0.76

*) Carcass weight as covariate

(n) = Numbers of stags per group

Table 2.9. Carcass production from red deer (*Cervus elaphus*) stags immunized by either melatonin or placebo only (control) and attaining slaughter liveweight (92 kg) by one year of age, during 1991. Mean values were adjusted to equal initial liveweight for carcass data.

	CONTROL (n = 13)	IMMUNISATION (n = 9)	SE
Stags attaining target slaughter liveweight (%)	92	100	
Liveweight (kg)	104	102	1.90
Carcass weight (kg)	56.0	55.9	1.11
Dressing percentage (%)	54.2	54.6	0.61
GR (mm)	5.7	5.6	0.84
GR*) (mm)	5.6	5.7	0.77

*) Carcass weight as covariate

(n) = Numbers of stags per group

2.3.11. Scrotal circumference development and testis weight.

The overall scrotal circumference development for weaner red deer stags recorded from June onwards did not differ between the treatment groups as seen in Figure 2.6. But, from October onwards the scrotal circumference of RC stags was larger ($P<0.01$) than that of PRG/WC stags. At slaughter, RC stags had significantly heavier ($P<0.01$) testes weights than PRG/WC stags, but there were no significant difference ($P>0.05$) between immunized stags and control stags (Table 2.10).

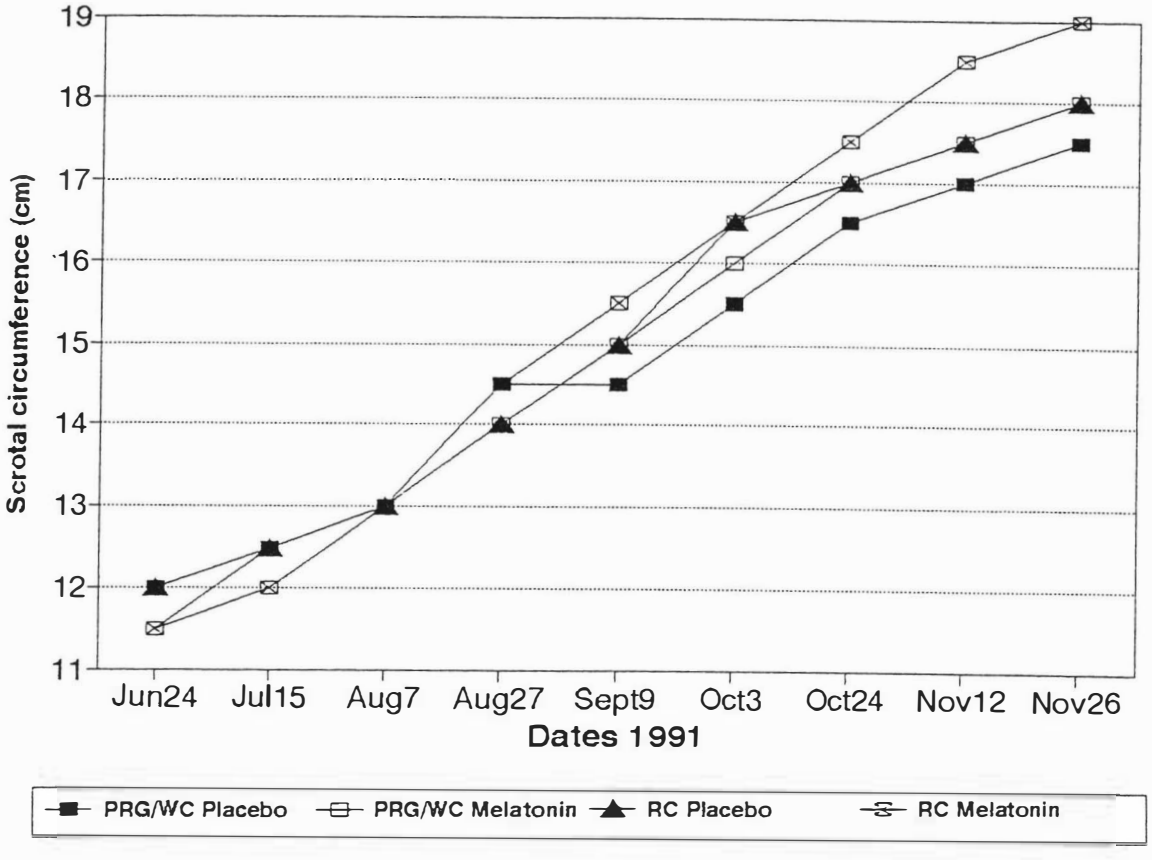

Figure 2.6. The overall scrotal circumference development (cm) for weaner red deer (*Cervus elaphus*) stags.

Table 2.10. Testis weights (g ± SE) at slaughter of weaner red deer (*Cervus elaphus*) stags either immunised by against melatonin or placebo only and grazing RC or PRG/WC forage during autumn, winter and spring of 1991.

Testis weight (g)				
PRG/WC		RC		SE
Immunisation	Control	Immunisation	Control	
43.1 (n= 5)	44.3 (n= 6)	55.6 (n= 6)	57.6 (n= 6)	2.86

n = number of stags

2.3.12. Velvet antler production.

The first-cut velvet antler weight from weaner red deer stags was variable between tretment groups, with no difference (P>0.05) either between RC stags and PRG/WC stags, or between immunized stags and control stags (Table 2.11). Approximately 65% of stags grazing either RC or PRG/WC produced harvestable velvet antler.

Table 2.11. First-cut velvet antler weight of weaner red deer (*Cervus elaphus*) stags either immunised by against melatonin or placebo only and grazing RC or PRG/WC forage during autumn, winter and spring of 1991.

First-cut velvet antler weight (g)				
PRG/WC		RC		SE
Immunisation	Control	Immunisation	Control	
218 (n= 4)	224 (n= 3)	245 (n= 3)	238 (n= 5)	45.7

n = number of stags

2.4. DISCUSSION.

The objective of the present study was how to improve liveweight gains of weaner red deer (*Cervus elaphus*), such that they attained at least 92 kg liveweight (50 kg carcass) by one year of age (30 November). Earlier studies (Ataja et al., 1992[a]) showed that by feeding high allowances of pastures based upon perennial ryegrass or annual ryegrass during winter and spring, respectively 41 and 60% of young red deer stags could attain this slaughter target, and that immunisation against melatonin, commencing at birth, could be successfully used to raise anti-melatonin antibodies. The present studies were designed to further extend this concept, by feeding high allowances of PRG/WC pasture in autumn as well as in winter and spring, and replacing annual ryegrass with red clover as a special purpose forage for deer production. The choice of red clover was based upon economics, as its establishment cost could be spread over several years versus only one year for annual ryegrass, and that it is highly preferred by red deer (Hunt and Hay, 1990).

2.4.1. Seasonal liveweight changes.

The growth pattern of weaner red deer showing intermediate growth during autumn, slow growth during winter, and high growth during spring in the present experiment, and is in agreement with the growth of farmed red deer being seasonal (Blaxter et al., 1974; Drew, 1976; Fennessy et al., 1981; Ataja et al., 1992[a]; Semiadi et al., 1993). Slow growth of the animals during winter is typical for young red deer, due to the seasonal loss of appetite (Kay, 1985; Barry et al., 1991) and acts as a major constraint to increasing venison production from young deer.

2.4.2. Growth on the PRG/WC pasture diet.

Stags (90%) of PRG/WC group attained the target slaughter weight (>92 kg liveweight; 50 kg carcass) by one year old age, because they consumed forage diets with a high feed allowance during autumn, winter and spring, with high values for total nitrogen (N) and organic matter digestibility (OMD) in the diet selected (Table 2.3). This resulted in high deer growth rates and the proportion of animals attaining target slaughter weight are an improvement on the findings of Ataja et al. (1992[a]) (41%) and Semiadi et al. (1993) (75%) for young red deer stags grazing PRG/WC pastures (Table 2.12).

2.4.3. Growth on RC diet.

Weaner red deer grazing RC grew better than those grazing PRG/WC, because RC contained a higher total N and OMD value in the diet on offer and in the diet selected (Table 2.3), and had a higher voluntary feed intake (VFI) (Table 2.4). Hence, RC has some advantages as an alternative forage for weaner red deer during autumn and spring, compared to PRG/WC-based pasture. Niezen et al. (1993) also reported that RC had a high nutritive value during summer, resulting in a higher fawn growth rate (433 vs 333 g/d) from the hinds grazing on RC forage than on PRG/WC pasture. This was also associated with higher VFI on red clover.

Deer fed RC had a faster rumen fractional outflow rate (FOR) of liquid relative to particulate matter than those fed PRG, resulting in a bloat resistance (Freudenberger et al., 1993). However, rumen pool size in deer fed RC was lower than PRG, because of the higher contents of protein and non-protein cell contents in RC, and their more rapid rate of disappearance from the rumen, compared with deer fed PRG (Freudenberger et al., 1993). This allows greater opportunity for increasing

VFI in deer consuming RC, as found in the present study. The VFI of lactating hinds (Niezen et al., 1993) and of growing weaner red deer (Semiadi et al., 1993) under grazing conditions on RC forage was also greater than those grazing PRG/WC pasture.

The present study has strongly proved that there are some advantages in terms of liveweight gain (LWG) and animals reaching slaughter target (Table 2.12) from using RC as a special purpose feed for deer production. The faster increase in scrotal circumference may also mean that stags grazed on RC forage reach sexual maturity than those stags grazed PRG/WC pasture, and this needs to be determined in future studies.

2.4.4. The immunisation effects.

Immunisation against melatonin did not give any significant responses in liveweight and LWG (Table 2.7) and in carcass production (Table 2.9). These results were supported by the plasma PRL concentration data (Table 2.6), which showed that there was no significant responses in the immunized deer. This explains the lack of growth response in the treated animals in the present study, in contrast to the results found by Duckworth and Barrell (1989), who showed that active immunisation against melatonin increased liveweight by 7-10% in red deer stags between 9 and 11 months of age and at 16 and 20 months of age. As the antibody used in the present study was successful in raising antibodies against melatonin and in increasing PRL concentrations during winter (Ataja et al., 1992 [a,b]), no reasons can be given for the different responses to immunisation between the study of Duckworth and Barrell (1989) and the present study.

Table 2.12. Comparison between liveweight gain, total animals attaining target slaughter weight (92 kg), and carcass production from red deer (*Cervus elaphus*) stags at Massey University Deer Unit during 1989, 1990 and 1991.
(RC, red clover; PRG/WC, perennial ryegrass/white clover pasture)

	STAGS		HINDS	
	RC	PRG/WC	RC	PRG/WC
Liveweight gain (g/day) :				
AUTUMN 1990	263	197	200	173
AUTUMN 1991	237	207	197	159
WINTER 1989[1)]	-	140 (165)[4]	-	-
WINTER 1990[2)]	103	110	55	54
WINTER 1991[3)]	94	95	38	40
SPRING 1989	-	226 (235)[4]	-	-
SPRING 1990	366	343	238	218
SPRING 1991	346	281	260	188
Liveweight and slaughter criteria :				
Animals over 92 kg (%):				
1989	-	41 (60)[4)]		
1990	100	75		
1991	100	90		
Mean liveweight (kg) end of November :				
1990	108	101	87	84
1991	105	99	83	77
Carcass production :				
Carcass weight (kg)				
1990	59.9	54.5		
1991	58.9	53.3		
Dressing out (%)				
1989	-	52.6 (53.8)[4)]		
1990	55.4	53.0		
1991	56.2	52.4		
GR (mm)				
1989	-	2.9 (3.6)[4)]		
1990	9.2	6.3		
1991	6.4	4.9		

[1)] Ataja et al. (1992 [a])
[2)] Semiadi et al.(1993)
[3)] Present investigation
[4)] Annual ryegrass pastures

2.4.5. Value of the findings to the NZ deer industry.

It has been shown that RC is of good value as a special purpose forage for deer production. As the stand red clover pasture lasted for 3 years under deer grazing, it seems plant breeders should select a RC variety having greater persistency, for use in deer farming. This is currently under way, with the evaluation in NZ of a RC cultivar selected for persistence under grazing in Australia, and which is stoloniferous (Challenge Seeds; personal communication). If a deer farmer only grew a limited area of RC, he should manage and feed it to the lactating hinds during summer in order to get a greater fawn weaning weight, then carry on grazing it to weaners in autumn and spring for in a 12-month venison production system. Use of special purpose crops like RC should be restricted to no more than 15-20% of the total area on deer farms, as these crops do not grow during winter. Hence, whilst feeds such as RC solve feeding problems on deer farms during summer, if too great an area is used, then they can cause problems of carrying capacity in winter.

RC has a very high protein solubility (Freudenberger et al., 1993), which means that N is used inefficiently. As protein supply may be deficient in ruminants fed fresh forages, there is a need to evaluate feeding RC along with a legume like sulla (*Hedysarum coronarium*) or chicory (*Chicorium intybus*) that contains condensed tannins (CT). CT are recognised as being antinutritional in the diet of monogastric animals, because high concentrations can reduced the absorption of protein from the small intestine (Wiseman and Cole, 1988), and binding more strongly to protein than to fibre (McLeod, 1974). However, in ruminant diets, low concentrations of CT (1-3%) are thought to be beneficial, because of their effect in reducing rumen degradation of forage proteins and increasing protein availability in the small intestine (Barry, 1989). Due to its higher ratio of readily

fermentable:structural CHO compared to perennial pasture, lambs grazing sulla demonstrated greater rate of body growth. In fact, very low dietary concentrations of CT may be nutritionally beneficial, hence forages should be investigated where CT concentration is 10-20 g/kg DM (Terrill et al., 1992). An ideal CT concentration for *Lotus* species, for instance, is suggested to be 10-20 g/kg DM (Barry, 1989). Together with the finding that deer have a higher rumen FOR than sheep (Domingue et al., 1991), they would have double benefits in utilising proteins when fed forages containing ideal level of CT. If it works, we should breed a RC that contains CT in future.

The immunisation data of the present study appears not to have worked. As a means of increasing the deer growth during winter, the immunisation against melatonin commenced at birth was be able to increase LW of stags at 9-11 and 16-20 months of age by 7-10% (Duckworth and Barrell, 1989). Using a similar immunisation sequence, however, resulted in insignificant differences in LWG (Ataja et al., 1992[a]), despite plasma PRL concentration being higher in winter. The reason for these differing results is still not clear. As NZ venison is marketed as a healthy product raised in a clean, green and unpolluted environment, for marketing reasons, NZ deer industry suggest that the use of hormonal product (such as melatonin) associated with a meat producing animals (deer) should be avoided and may be unacceptable to the consumers. However, NZ MAF Quality Assurance Service proposed that "The use of melatonin in deer to advance the breeding season in hinds and stags is not likely to create any immediate concern in the minds of consumers in Europe, as it is a natural cyclical hormone which is only given in physiological quantities to animals which are reproducing and not being sent directly for slaughter. The reality that melatonin will therefore not create residue problems in the carcass

meat as animals are slaughtered during the day when the natural levels are low, may, however, be offset by consumer perception of its 'hormone-like use'. The wide-spread use of this substance therefore needs to be carefully considered by the industry in terms of the overall marketing strategy and the image the industry wishes to portray" (Marshall, 1991). In addition, it is impossible to detect melatonin residues, because melatonin is a natural hormone used at close to physiological levels (Asher et al., 1988; Webster et al., 1991). For the scientific knowledge point of view, studies of melatonin in deer have contributed to explaining the basis of seasonality. In future the immunisation treatments in deer for maximising body growth is still needed to help provide a complete scientific understanding of its effects on the seasonality in deer, but its uptake for commercial deer production seems unlikely in a strongly market conscious NZ deer industry.

Cross breeding red deer hinds with elk stags is also a best option. The potential advantages of doing this are the very fast growth of the progeny. The quarter-bred wapiti hybrid produced carcass weights of 56-58 kg in October/November, or 66-68 kg at 15 months of age (i.e., about 25% heavier than red deer of the same age) and satisfies all the existing market requirements for weight, leanness and quality (Pearse, 1992). In future, we should thus be doing experiments with red deer calves (like the present experiment) compared with 0.25 elk: 0.75 red deer calves, fed RC versus PRG/WC, to evaluate if we can get even better results than those obtained in the present study. To fully express their superior genotype, it is probable that special feeding and management systems will also have to be developed for 0.25 elk: 0.75 red deer weaner calves.

CONCLUSIONS

In the future, the development of the NZ deer industry is dependent on the success of the marketing of deer products, and in particular the development of new markets. For the NZ deer industry members, working together to achieve the single objective of creating a brand new industry is very likely to be implemented.

The present studies demonstrated that early venison production from weaner red deer stags grazing conventional PRG/WC pasture is possible. 90% of weaner red deer stags grazing high allowances (6, 7 kg DM/head/day) on PRG/WC pasture during autumn, winter and spring attained the minimum target of slaughter weight (92 kg liveweight; >50 kg carcass) by 12 months of age, at the end of November.

Weaner red deer grazing pure RC pasture during autumn and spring grew and produced venison better than comparable animals grazing PRG/WC, with all (100%) stags attained the target slaughter criteria.

Immunisation against melatonin given at birth and at weaning did not provide any significant effects on growth and venison production from weaner red deer grazing either RC or PRG/WC forages.

Together with previous studies (Niezen et al., 1993; Semiadi et al., 1993), the present study strongly proved that RC offers very good potential as a special purpose forage for venison production, particularly from young red deer stags. With a limited area of RC, feeding RC to lactating hinds during summer and to weaners during autumn and spring is to be the first and the second priority on deer farms, to attain a greater weaning weights, and better growth and more venison production from young red deer. Due to the dormancy of RC during winter, a deer farm should limit area of RC to be a less than 20% of the total area.

Regarding to the N retention inefficiency in RC and legumes with reduced N solubility (Freudenberger et al., 1993), there is a need to evaluate and further improved deer production, such as feeding RC along with condensed tannin (CT) containing plants like sulla (*Hedysarum coronarium*) and chicory (*Chicorium intybus*) (Barry, 1989; Terrill, 1992), to develop other specialist pasture species for deer production in the future.

Based on the study of anti-melatonin immunisation in deer (Ataja et al., 1992[a,b] ; Duckworth and Barrell, 1989) and the present study, further research to understand manipulation of body growth and venison production in red deer using anti melatonin immunisation is needed.

As red deer, at present, are the most popular farmed deer, further studies in the seasonal cycles unique to deer species, in terms of feeding strategies for venison and velvet production, is absolutely needed. All factors proven to improve VFI, growth and venison production should be implemented in a single deer production system aimed at efficient venison production.

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Appendix 1. Calculation for the estimation of feed intake using Cr_2O_3 release rate from capsules as faecal marker. (Parker, 1990)

1. Faecal output is estimated indirectly from the concentration of Cr in the faecal sample by the following steps:

a) Correct the atomic absorption reading (AA) to the equivalent for 1 g faecal DM. Total sample weight range from 0.4 - 2.5 g (bulked across days). The dried weight of the sample should be used to calculate the adjusted aa:

Adj aa (mg Cr/g DM) = AA * 1/Wt

where Wt= dry weight of the sample (g)

e.g., AA = 4.5 and Wt = 0.5 then Adj aa = 4.5/0.5 = 9 mg Cr/g DM

b) Correct the Adj aa reading to the equivalent concentration for a 1 litre dilution by multiplying by 0.05 (Samples are made up to 50 cm^3 in the volumetric flasks).

Adj aa * 0.05 = Adj AA (mg Cr/g DM)

9.0 mg Cr/g DM (in 50 cm^3) * 0.05 = 0.45 mg Cr/g DM

or 450 μg Cr/g DM

or 450 ppm Cr

c) Divide the expected average daily Release Rate (RR) of Cr from the controlled release capsule (CRC) by the concentration of Cr in the dry matter to derive faecal dry matter output (FO):

$$\text{FO (g DM/d)} = \frac{\text{RR (mg Cr/d)}}{\text{(Adj AA (mg Cr/g DM) - BC)} * \text{CF}}$$

where BC = correction for background (or natural) Cr. Animal faeces will be include some Cr from the soil and plant material consumed. In practice BC values are very low (10-15 µg/g DM) and can be disregarded where the animals are on similar grazing treatments or if the standards are made up with faecal material from the animals grazing on treatment area without a chromium capsule.

CF = recovery correction factor for the Cr assay. (Recovery of Cr from spiked faecal samples is typically 95-98%. A recovery factor 1.042 is therefore used since the calculation of the faecal output assumes that 100% of the chromium administered to the animal is recovered).

For the example:

$$FO = \frac{139 \quad \text{(mg Cr/d)}}{(0.45 * 1.042) \quad \text{(mg Cr/g OM)}}$$

$$= 296 \text{ g OM/d}$$

RR for sheep CRC are normally between 135 and 145 mg Cr/d and for the cattle CRC are between 1150 and 1300 mg Cr/d.

RR vary according to the type of capsule and the animal species in which the capsule is used.

The Adj aa readings for sheep typically lie within the range 2.5-10.00 ppm, while those for cattle vary from 10.00 to 30.00 ppm. (The Adj aa concentrations will vary with the number of days samples are bulked across). Normally sheep samples are read with the AA set at a 359 nm wavelength and standards of 0, 2.5, 5.0, 10.0 and 20.0 ppm. For cattle standards of 0, 10.0, 25.0, 50.0 and 100.0 ppm at a 429 nm wavelength will often be more appropriate.

The RR values used in the present study are :

for autumn : 121 mg Cr/d (sheep-size capsules)

for spring : 344 mg Cr/d (calf-size capsules)

d) To estimate feed intake >>> divide FO by the indigestibility (1 - digestibility) of feed.

$$DMI = \frac{FO}{(1 - DMD)}$$

where DMI = dry matter intake (g DM/d)
DMD = dry matter digestibility (%)

For the example, if DMD = 75%;

$$DMI = \frac{296 \quad (g\ DM/d)}{(1.00 - 0.75)} = 1184\ g\ DM/d$$

The estimate of DMI is very sensitive to the DMD value. This can be seen if the same calculation was repeated with a feed DMD of 80% :

$$DMI = \frac{296}{(1.00 - 0.80)} = 1480\ g\ DM/d$$

(i.e., a 5% difference in DMD results in a 25% difference in DMI estimate)

The digestibility of feed is estimated in-vitro for most trials from samples collected from the treatment pastures either by hand plucking or by the collection of extrusa from the oesophageal fistulated (OF) animals. The opening in the throat of the OF allows feed consumed by the animal (which should be representative of that eaten by the experimental group) to be diverted into a plastic bag and deep frozen until analyzed by the Nutrition Laboratory.

2. Calculation of organic matter (OM) content.

Calculations described above for feed intake can also be done on the basis of organic matter. This is why the ash content of the sample is recorded.

$$\text{Organic matter (\%)} = \frac{\text{sample dry wgt - ash wgt}}{\text{sample dry wgt}} * \frac{100}{1}$$

for clean plant material OM = 90% but the OM content of faeces depends on how much soil is consumed by the animal while grazing. On short pasture during wet winter weather the OM content of faeces may be as low as 30-40% (i.e., 60-70% of the faeces are ash). Soil material usually has only 8-10% OM and is almost indigestible. Thus virtually all of the soil eaten passes through the animal and appears in the faeces. This means that the estimation of intake on a DM basis from the concentration of Cr in the faecal DM can be misleading.

eg., if the ash content of the faecal material was 30% then the OM content is 70% and the faecal content can be derived as follows for the example sheep :

$$\text{Faecal OM} = (196 \ 0.70)$$
$$= 207 \text{ g OM/d}$$

and the organic matter intake (OMI) equals the following if the organic matter digestibility (OMD) of the feed was 80%:

$$\text{OMI (g/d)} = \frac{207}{(1.00 - 0.80)}$$

$$= 1035 \text{ g OM/d}$$

3. Variation between duplicates and between batches (i.e., intra- and inter- assay variation.

A "good" biological assay has a coefficient of variation (CV) of < 5%. The CV is a measure of variability:

$$CV\ (\%) = \frac{\text{standard deviation of samples (duplicates)}}{\text{mean of samples (duplicates)}} * \frac{100}{1}$$

For the chromium assay variation within a batch can occur because of:

a) weighing errors
b) incomplete ashing
c) incomplete digestion
d) partial transfer to volumetric flasks
e) errors in AA readings

These effects can be additive and give the potential for quite large errors to occur. This is not helped by the fact that Cr is difficult to quantitatively recover from faecal material.

The error between duplicates 1 and 2 with corrected (Adj AA) readings of 10.50 and 9.50 mg Cr/g DM can be estimated as:

$$CV = \frac{0.71}{10.00} \times \frac{100}{1}$$

$$= 7.1\%$$

Whether this sample was repeated would depend on:

a) the overall variability in the assay - variation is normally greater between duplicates when samples of intact faeces are bulked across several days than when a single daily sample (or bulked ground sample) is analyzed.

b) the previous Adj AA readings for the animal concerned.In some cases duplicates with a CV >5% are repeated, in other cases a CV >10% may be appropriate.

99 readings:

To monitor variation due to the AA instrument within a batch a "within-run" standard is at regular interval (every 5-10 readings depending on overall machine stability). We refer to this as a "99" reading. Normally the standard curve should be re-entered (or restandardised) if there is more than a 10% "drift" between 99 readings. (Note that the Adj AA readings should include a correction for machine drift if this has occurred while the batch was being read).

Pool readings:

The stability of the assay method through time (inter-assay variation) is monitored by including common samples (pools) with each assay batch. The pool samples should preferably give Adj AA readings which lie within the range of the unknown samples being tested. The variation between batches can be estimated by deriving the CV between the mean values of the pool samples.

Sample calculation:

If : Dry weight (DRYWT) = beaker and dry weight - beaker weight

= 22.4729 - 20.1005

= 2.3724

Ash weight (ASHWT) = beaker and ash weight - beaker weight

= 21.0165 - 20.1005

= 0.9160

If : Atomic absorption reading (AA) = 18.48

then, Adj AA = AA * (1/DRYWT) * 0.05

= 18.48 * (1/2.3724) * 0.05

= 0.3895

If : Release Rate (RR) for autumn = 121 (mg Cr/d)

for spring = 344 (mg Cr/d)

then, Faecal Dry Matter Output (FDMO) = 344 / (Adj AA * 1.042)

= 344 / (0.3895 * 1.042)

= 344 / 0.405859

= 847.5849 DM/d

Organic matter percentage (PCTOM) = (DRYWT - ASHWT) / DRYWT

= (2.3724 - 0.9160) / 2.3724

= 0.6139%

Faecal Organic Matter Output (FOMO) = PCTOM * FDMO

= 847.5849 * 0.61

= 517.0268 OM/d

If : OMD for red clover in spring = 0.879

then, Organic Matter Intake (OMI) = FOMO / (1 - OMD)

= 517.0268 / (1 - 0.879)

= 517.0268 / 0.121

= 4272.9492 g OM/d

Metabolic bodyweight (METBW) = BW ** (0.75)

OMI per bodyweight (OMIBW) = OMI / BW

OMI per metabolic bodyweight (OMIMET) = OMI / METBW

If : bodyweight of the experimented animal = 85 kg

then, OMIBW = 4272.9492 / 85

= 50.2699 g/kg BW

METBW = 85 ** (0.75)

= 27.9939

OMI per Metabolic Bodyweight = 4272.9492 / 27.9939

= 152.6385

= **152.64 g OM/kg $W^{0.75}$**

Appendix 2. Calculation for the daily Release Rate (RR) of Cr from the controlled released capsule (CRD).

Release Rate = π * r^2 * linear density * rate of plunger travel * chromium concentration

where,

RR is in mg Cr/d

radius is in mm

linear density is in mg Cr_2O_3/mm travel

rate of plunger travel is in mm/d

chromium concentration is in a fraction (eg. % x 0.01)

Sample calculation:

If, active ingredient in capsules is Chromium Sesquioxide (Cr_2O_3)

π = 22/7

r = 8.95 mm

linear density = 220 mg Cr_2O_3/mm travel

rate of plunger travel = 0.35 mm/d

and concentration is Cr content of Cr_2O_3 = $\frac{104}{152}$ = 0.6843

then,

RR = 3.14 * 8.95^2 (mm) * 220 (mg/mm) * 0.35 (mm/d) * 0.6843 * 0.01

= 132.5 mg Cr active/day.