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REVIEW

Venison production from farmed deer

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INTRODUCTION

Deer farming commenced in New Zealand (NZ) in 1969, and since then the number of farmed deer has progressively increased, to reach 1·3 million in 1993 (Game Industry Board (GIB), personal communication). These comprise 85% European red deer (*Cervus elaphus*), with the remainder being composed of elk (*Cervus elaphus canadensis*), elk/red deer crossbreds, fallow deer (*Dama dama*) and small numbers of other species. Initially, deer were obtained from the capture of feral animals, introduced to NZ over 100 years ago, but in the last 10 years the increase has come from breeding on deer farms. The industry has a strategic marketing plan to coordinate all sectors in order to maintain profitability. This plan has been implemented and financed by the GIB, through the collection of compulsory levies on venison and velvet sales. With the formation of the GIB in 1984, the NZ Deer industry has been strongly export market-led, and thus differs from the NZ sheep and cattle industries, which developed with a production-driven philosophy. Key aspects of the market-led approach have been to produce and market venison which is consistently tender and of low fat content, and at the carcass weight range and times required by the markets.

This study will review factors influencing the voluntary food intake (VFI), growth and health of deer, and how these can be maximized under pastoral farming systems for efficient venison production. The NZ system, based upon breeding from red deer hinds, will be described as a venison production system from temperate deer. Possible systems for tropical deer will be discussed, based upon rusa (*Cervus timorensis*) and sambar (*Cervus unicolor*) deer, as some countries in South East Asia and Oceania are beginning to develop deer industries based upon these species.

Animal health issues

Health and wellbeing are essential components of efficient deer farming systems (Wilson 1991*a*). The pastoral farming environment and feeding and management systems studied at Massey University (Ataja *et al.* 1992; Niezen *et al.* 1993; Semiadi *et al.* 1993; Soetrisno *et al.* 1994) optimized the wellbeing of deer, improving their disease resistance and minimizing exposure to factors predisposing to disease. However, management must be supplemented by a strategic animal health plan to prevent internal parasites, yersiniosis, tuberculosis and other important diseases in venison production systems (Wilson 1991*a*). There are currently no figures available on the cost of controlling animal health problems in the NZ deer industry, but the study of Audigé *et al.* (1993*a*) will yield some information upon which estimates can be made. Mortality rates are *c.* 3% per annum.

Lungworm (*Dictyocaulus viviparus*) is ubiquitous on NZ deer farms and if not controlled can cause reduced weight gains, respiratory disorders, coughing and death due to blockage of airways at the terminal stage (Wilson 1984). Deer 3–8 months of age are most susceptible, while older deer develop resistance, although they can succumb to clinical disease in the face of a high larval challenge. Prevention is by routine benzimidazole, ivermectin or albemycin anthelmintic treatment from weaning (3 months of age) at 3–4 week intervals throughout the first autumn of life, coupled with rotational grazing and standard pasture management practices to reduce larval contamination. Gastrointestinal parasites are also controlled by this programme (Wilson 1984).

Yersiniosis associated with *Yersinia pseudotuberculosis* serotypes I, II or III, is an acute enteritis, usually of deer 3–10 months of age, following a stress factor such as reduced feed intake, inclement weather, lack of shelter, transport or mixing with other stock (Mackintosh 1992). The condition is treatable using oral antibiotics and fluids if detected early, and prevention is by minimizing predisposing conditions, and by the use of a recently developed vaccine (Yersiniavax; MAF NZ) given in March (autumn) with a booster 4 weeks later.

Tuberculosis caused by *Mycobacterium bovis* is a potentially serious threat to the health of deer in NZ and many other countries (Clifton-Hadley & Wilesmith 1991). The disease primarily affects the lymph nodes and may progress from a clinically unapparent localized condition to a severe debilitating

53

generalized disease. Diagnosis of infection is by the use of a standard mid-cervical intradermal test (Corrin *et al.* 1987) with the use of ancillary tests including the comparative cervical test (Corrin *et al.* 1993) and the recently developed lymphocyte transformation and ELISA tests (Griffin *et al.* 1990). NZ has a very successful compulsory deer tuberculosis control programme based on annual herd testing, with slaughter of infected test-positive deer and movement control of infected herds (Wilson 1991*a*). Reactor incidence has fallen from 0·61% in 1986 to 0·12% in 1992 (Carter 1993).

Deer are especially susceptible to copper deficiency, which results in low growth rates and osteochondrosis in young deer and enzootic ataxia in deer 9 months and older (Killorn & Wilson 1990). The copper status of deer herds should be monitored and copper supplementation introduced where necessary. Selenium deficiency results in clinical white muscle disease.

The major production-limiting diseases observed in farmed deer in NZ are similar to those reported in other deer farming countries (Haigh & Hudson 1993).

Seasonality

Deer that evolved in cold temperate regions have very strong patterns of seasonality (Barry *et al.* 1991), characterized by high VFI and growth in late spring and summer and low VFI and growth in winter, as shown for red deer stags in Fig. 1. Mating occurs over a concentrated period (8 weeks) in autumn, and consequently calving occurs over 8 weeks in late spring/early summer. These deer have thus evolved a system of timing their feed requirements and calving pattern in response to variations in available plant resources resulting from a long harsh winter and a short summer. Whilst this has ensured survival of red deer and elk at far northern latitudes, it has caused problems in the use of these species for deer farming in warmer environments, where forage production commences in early spring instead of early summer. The deer have evolved these endogenous cycles, which are cued or timed to photoperiod by the hormone melatonin. Hence, the timing of these cycles can be adjusted by changing photoperiod (Suttie *et al.* 1992) and by administration of melatonin (Asher *et al.* 1988).

Investigations into seasonality in tropical deer species are only just beginning. Young sambar deer stags have been shown to have endogenous cycles of VFI and growth (Fig. 1), which are of lower amplitude than for red deer, and with maximum and minimum values occurring in autumn and spring respectively (Semiadi 1993). Similar trends with time were apparent for hinds of both deer species. Reproductive activity commenced at an earlier age and at a lower bodyweight in sambar deer than in red deer, and took place over a longer period each year than for red deer. Peak calving was in autumn, but calves were born in all months of the year. Mylrea (1991) found that chital deer (*Axis axis*) and rusa deer in Australia also calved throughout the year, but with peaks in early spring and autumn respectively. Unmated chital females showed reproductive cyclicity for 12 months of the year, compared with 5 months for red deer. In one limited study to date (Loudon & Curlewis 1988), reproductive patterns in chital deer were not changed by melatonin treatment. Collectively, this rather limited evidence suggests that whilst tropical deer species may have evolved endogenous cycles of VFI and reproductive hormones, these may be only weakly and in some cases not at all entrained to photoperiod through melatonin. This is an area requiring further research, but for commercial deer farming it suggests that calving time in tropical deer can be more easily adjusted by time of introducing and removing stags than is the case with temperate deer.

Feeding value

Ulyatt (1973) defined feeding value (FV) as the animal production response to grazing a defined forage. It includes liveweight gain in growing animals and milk production in lactating animals. Ulyatt (1973) defined FV as a function of VFI, digestibility and the efficiency of utilization of absorbed nutrients. With most domesticated ruminants, FV is assumed to be a function of the feed only, but in the case of deer (and especially temperate deer) it follows that the growth performance achieved will be a function of the stage of the animal's seasonal cycle as well as the diet. Red deer have long been known to maintain digestibility as VFI increases from winter to summer (Milne *et al.* 1978), when a decrease might be expected. Recent studies have identified the mechanism as increased rumen mean retention time (MRT) and increased rumen ammonia production in summer compared to winter (Domingue *et al.* 1991; Freudenberger *et al.* 1994*a*), showing that at least in red deer there are also seasonal cycles in digestive function. Whilst there is information available on VFI in deer, more data are needed on the digestion, absorption and utilization of individual nutrients if we are to understand the FV of forages for deer production.

Venison production

An objective of any meat production system is the production of a desired carcass weight in the shortest possible period of time. Because of overseas market demand for chilled venison, this translates in NZ to attaining at least 50 kg carcass weight (92 kg liveweight) by September–November (spring). Given that red deer hinds are late calvers (November/December), the most efficient means of achieving this objective is

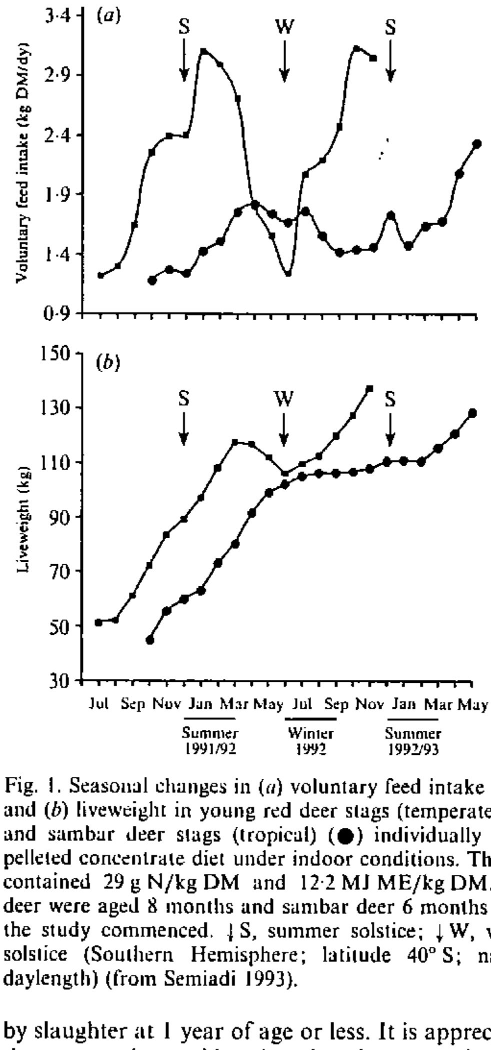

Fig. 1. Seasonal changes in (*a*) voluntary feed intake (VFI) and (*b*) liveweight in young red deer stags (temperate) (■) and sambar deer stags (tropical) (●) individually fed a pelleted concentrate diet under indoor conditions. The diet contained 29 g N/kg DM and 12·2 MJ ME/kg DM. Red deer were aged 8 months and sambar deer 6 months when the study commenced. ↓S, summer solstice; ↓W, winter solstice (Southern Hemisphere; latitude 40° S; natural daylength) (from Semiadi 1993).

by slaughter at 1 year of age or less. It is appreciated that economic considerations in other countries may dictate the development of different slaughter policies.

As spring pasture production commences about 8 weeks earlier than deer calving, one means of improving the efficiency of venison production is by manipulation of calving date. Manipulation of this by hormonal means is discussed later under chemical inputs, whilst hybridization of different deer species to achieve this objective is discussed later in the present section.

Nutrition

Research in NZ has aimed at achieving the above production target using normal perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pastures (PRG/WC; 0·80:0·20), which are grazed on a year-round basis. Early research (Ataja *et al.* 1992) showed that 42% of young red deer stags grazing 10 cm pastures during winter and spring (6–12 months of age) could achieve the target liveweight compared with none of the stags grazing 5 cm pastures. Well managed 10 cm pastures contained 25–44 g N and 10·5–11·6 MJ ME/kg DM in that study, and pasture of this height and composition has been used in our studies ever since.

When studies of post-weaning growth were extended to include autumn (Table 1), grazing pastures of this type increased the proportion of red deer stags attaining the target liveweight to 75% in 1990 and 90% in 1991. Grazing on pure red clover (*Trifolium pratense*) increased growth rates, and 100% of the stags on red clover pastures attained the target in both years (Semiadi *et al.* 1993; Soetrisno *et al.* 1994).

Separate studies have also examined production during lactation. Because of calving dates, lactation takes place during the summer, when normal PRG/WC pastures suffer from moisture stress. With its deep tap root, red clover grows well under these conditions, and it is during lactation that the biggest response in calf growth to inputs of this feed has been seen (Table 1). These studies demonstrate the feasibility of early venison production, and show that substantial responses can be obtained from the use of special purpose forages. More recent results indicate similar responses in deer production from grazing chicory (*Cichorium intybus*) pasture (Niezen *et al.* 1993; K. Kusmartono, personal communication). A major reason for superior deer production on red clover is increased VFI (Niezen *et al.* 1993; Semiadi *et al.* 1993).

Over a 3-year period, we have never encountered frothy bloat in deer grazing red clover. Bloat is caused by a build-up of soluble protein foam in the rumen (Mangan 1959). As fractional outflow rate (FOR) of solutes from the rumen is much faster for deer (16%/h) than for sheep and goats (10%/h) (Domingue *et al.* 1991; Freudenberger *et al.* 1994*b*), it seems that soluble protein is rapidly removed from the rumen in deer before a stable foam can develop.

Comparing growth over the four seasons of the year (Table 1), a strong seasonal pattern still persists under improved nutrition in the red deer, with maximum growth in summer and minimum growth in winter.

Unlike temperate deer, time of calving in tropical rusa deer can be adjusted by changing the time of introduction and withdrawal of the breeding stag. Using this strategy, separate groups of autumn-calving and spring-calving rusa hinds have been developed in Queensland, Australia (Woodford & Dunning 1992). These authors recommended a system of venison production with slaughter of rusa stags at 13–15 months of age, just before the first rut, giving mean carcass weights of 50 and 47 kg in the two years. Carcass dressing percentage (60–62%) was higher than for comparable red deer (52–56%; Table 1). On the same deer unit in that sub-tropical environment,

Table 1. *Growth of young red deer* (Cervus elaphus) *stags grazing perennial ryegrass/white clover pasture (PRG/WC) or red clover (RC) at Massey University Deer Unit during 1990 and 1991. Both forages were compared at the same DM allowance/deer; 12 kg/day for lactation and 6–8 kg/day for post-weaning growth*

	1990		1991	
	PRG/WC	RC	PRG/WC	RC
	Lactation*			
Summer				
Calf growth (g/day)	333	433	331	410
Calf weaning weight (kg)	42·8	49·5	46·7	50·5
Hind weight change (g/day)	−52	58	27	70
	Post-weaning growth†‡			
Liveweight gain (g/day)				
Autumn	197	263	207	237
Winter§	110	103	95	94
Spring	343	366	281	346
Mean liveweight (kg) at end of November‖	101	108	99	105
Carcass dressing out percentage	53·2	55·3	52·4	56·2
Carcass weight (kg)	54·5	59·9	53·3	58·9

* Niezen *et al.* (1993).
† Semiadi *et al.* (1993).
‡ Soetrisno *et al.* (1994).
§ Both groups grazed on PRG/WC during winter, when RC was dormant.
‖ Approximately 1 year of age.

autumn-born rusa stags showed relatively linear growth from 4 to 19 months of age, whereas spring-born red deer stags run from 4 to 19 months of age showed reductions in growth associated with winter and with the rut (Suttie *et al.* 1992). At this latitude (27° S) both the temperate and tropical deer species showed less seasonal fluctuation in growth than observed in NZ (40° S; Fig. 1), but the tropical species showed less change with season in both environments.

Hybridization

Because 85% of NZ's commercial deer population comprises red deer, hybridization studies have been conducted using stags of other species with red deer hinds. In all cases the objective has been to produce an F_1 generation hybrid, and then mate the F_1 hybrid stags with commercial red deer, to get a wide spread of the desired trait. This was first done using Canadian elk bulls and natural mating to increase body size and growth rate, with red deer stags, F_1 hybrid stags and elk bulls aged 16 months weighing 100, 155 and 155 kg respectively (Pearse 1992), showing clear evidence of hybrid vigour. In the next generation, growth during autumn (3–6 months of age) was 179 and 203 g/day for red deer and 0·25 elk:0·75 red deer stags grazing PRG/WC pasture, and 247 and 317 g/day for comparable animals grazing chicory (K. Kusmartono, personal communication). This indicates that the high growth potential of the quarter-breds can best be expressed with high nutritive value forages, and that the place of elk in the NZ deer industry lies in using F_1 hybrids as terminal sires on red deer hinds.

Père David's (PD) deer (*Elaphurus davidianus*) are also bigger than red deer and their seasonal cycles of reproduction (and hence calving), VFI and growth occur *c.* 8 weeks earlier than for red deer (Louden *et al.* 1989). F_1 PD:red deer hybrids have been produced by artificial breeding (AB) using frozen semen, but the success rate was only 8% (Fennessy & Mackintosh 1992). In the same study, calving percentage of red deer hinds to fresh semen from F_1 stags was 43–58%, and at 15 months of age red deer and 0·25 PD:0·75 red deer stags weighed 105 and 131 kg respectively. The authors commented that the earlier and more rapid growth of the quarter-breds may be their main asset, that their earlier oestrus may be offset by a longer gestation period, and that use of PD deer may be hampered by their high susceptibility to Malignant Catarrhal Fever and the difficulty in producing F_1 hybrids.

Studies are currently being done on the feasibility of producing hybrid sambar/red deer, using AB techniques (P. D. Muir, G. W. Asher & G. Semiadi, personal communication), with the objective of introducing earlier calving and less winter decline in VFI and growth into populations based upon red deer.

In the tropics, sambar deer and rusa deer are well known to hybridize, using natural mating. On a rusa deer unit, a reasonable objective would seem to be using the larger sambar deer, or perhaps F_1 sambar/rusa hybrid stags, as terminal sires in a venison production system.

Production profiling

Management strategies to maximize deer farm production have evolved by the adaptation of methods used in sheep and cattle farming, but there have been few investigations of the efficiency of various management systems on commercial deer farms. An innovative 'holistic' approach to the evaluation of deer herd productivity known as 'deer herd health and production profiling' is being developed at Massey University using advanced epidemiological techniques (Audigé *et al.* 1993*a*). In addition, this study is enabling the establishment of a range of baseline data such as reproductive performance, growth rates, blood parameters, disease control and efficiency from commercial deer herds. The objectives are to investigate associations between various management practices, disease treatment and prevention regimes, and outcomes such as deer performance and health; to identify major animal and farm factors associated with various performance levels; to identify areas where lack of knowledge may be impairing management; to identify priority areas for future research and, ultimately, to provide data and information to enable the establishment of a computer model for deer production systems.

This is an observational approach involving a number of deer herds in which physical data on the farm, evaluation of the farmer, daily climatic events, daily management events such as paddock shifts, disease control and prevention, reproductive management and outcomes, disease events and mortalities, growth rates, feeding levels and a range of production outcomes such as carcass weights are all recorded. In addition, sentinel animals on each farm are sampled four times annually for a range of blood haematological, biochemical and serological analyses and physical characteristics. Pasture and soil analyses are also undertaken. A multivariate analytical approach is used to evaluate the major associations between events and outcomes along various pathways (path analysis). Preliminary results have highlighted considerable differences in outcomes such as reproductive performance and physical and blood parameters between herds (Audigé *et al.* 1993*b*). For example, the pregnancy rate of rising 2-year-old hinds has been as low as 50% in some herds while others achieved 100%, and winter growth rates ranged from 0 to 150 g/day between herds.

Chemical inputs

While NZ deer production is pastoral-based and is often extensive, chemicals are strategically used to optimize health, wellbeing and productivity. Anthelmintics are used to control internal parasites, occasionally insecticides and acaricides are used for external parasite control, a range of drugs is used for the treatment of clinical disease, and reproductive manipulations such as advanced calving, artificial insemination and embryo transfer require hormones such as melatonin, progesterone and gonadotropins. Chemical immobilizing agents and local anaesthetic are used for velvet antler harvest and trace element supplementation is used where deficiencies arise. Some herbicides and pesticides are occasionally used on pastures (Wilson 1991*b*). The GIB marketing strategy, presenting NZ deer products as from a clean green environment, focuses on natural production systems fulfilling requirements for animal production and wellbeing, and is requiring a re-evaluation of chemical usage on deer farms. A national 'pasture-to-plate' quality assurance scheme is being implemented (McKendry 1992) whereby farmers will need to record chemical usage and comply with standards for their use before venison products can be marketed under the quality-assured brand name. The producer is acutely aware of the need to minimize inputs of all chemicals with the exception of phosphorus-based fertilizers.

Most animal remedies used in NZ are under veterinary control and withholding times are strictly adhered to, with residues in venison detected by routine pre-export monitoring being 'extremely rare' (Marshall 1991). The industry has not adopted the commercial use of melatonin to advance the onset of the breeding season as reported by Wilson *et al.* (1991) largely because of concerns about hormonal usage and the risk to the marketing image.

There is growing research and commercial interest in developing low chemical input deer farming systems. There will be a greater emphasis on monitoring the need for and strategic use of anthelmintics and trace elements. Vaccines such as Yersiniavax and leptospiral vaccines should reduce the requirements for antibiotic usage in commercial herds. Development of alternative pasture species and grazing management systems for parasite control is under way. Further development of deer handling and restraint systems should reduce chemical usage for immobilization in procedures such as velvet harvesting. Development of dressing and processing techniques at deer slaughterhouses has resulted in a substantial reduction in carcass bacterial contamination, considerably extending the shelf-life of prime chilled product (Drew *et al.* 1991). Veterinary inspection at the slaughterhouse prevents diseased carcasses from entering the food chain. Thus venison from farmed NZ deer will be managed and processed under even more rigid control and monitoring than that undertaken at present, ensuring that the product will conform to even more rigorous quality standards.

Future developments

A major development in NZ will undoubtedly be the GIB's appellation marketing strategy, with its 'Cervena' and 'Zeal' branded products, differentiating NZ farm-reared venison from the very variable feral venison, and allowing quality chilled venison to be available at all times of the year. GIB predictions are that the NZ deer industry will continue to expand, and will attain 2·2 million animals by the year 2000, giving a similar number of animals to the NZ dairy industry. Hence, work on deer nutrition and hybridization is likely to continue, and will be focused on development of grazing systems and animal genotypes to produce venison on a year-round basis, at specified carcass weights and of low fat cover. The farming of temperate deer species for venison production is now spreading to many European and North American countries and to southern Australia; these deer industries may well develop along the NZ model.

Other groups in South East Asia, the Pacific Islands and North Australia are developing tropical deer industries based upon the rusa and sambar deer, but developments are about 20 years behind the temperate deer industries. In tropical countries, the capture and domestication of indigenous tropical deer is likely to prove more practical than importing red deer from NZ and other temperate countries. In many of these countries, deer industries may develop as a source of alternative animal protein for the local population, rather than as an export industry. Thus, many tropical deer industries, particularly in underdeveloped countries, may develop along different lines from the NZ deer industry.

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