Nutritional Requirements

For pregnant and lactating red and fallow deer

A report for the Rural Industries Research and Development Corporation

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Foreword

Successful meat production systems require adequate care and maintenance of breeding females to ensure productivity and profitability are also maintained.

This report documents, for the first time, the daily feeding requirements of pregnant and lactating fallow and red deer, species that make up more than 90% of the farmed deer industry in Australia.

Daily nutritional requirements have been found to be higher than previously thought for fallow deer, with significant seasonal variations. In addition, adult does rapidly face competition from their fawns, which start to consume “hard” feed from seven weeks of age and have the same daily nutritional requirements from 16 weeks of age.

In terms of cost control, this report shows how precise strategic feeding of red and fallow deer can lead to improved fertility and higher quality carcases.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.

This report, a new addition to RIRDC’s diverse range of over 600 research publications, forms part of our Deer R&D program.

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- downloads at www.rirdc.gov.au/reports/Index.htm
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Peter Core
Managing Director
Rural Industries Research and Development Corporation

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Contents

Publications arising from this Study

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List of Abbreviations

ADL	acid detergent lignin
AI	artificial insemination
ANOVA	analysis of variance
BCS	body condition score
β-OHB	betahydroxybutyrate
BMF	bone marrow fat
BW	birthweight
CIDR	controlled internal drug release
CG	chest girth
cm	centimetres
CP	crude protein
CRL	crown-rump length
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIAA	Deer Industry Association of Australia
DE	digestible energy
DM	dry matter
d	days
E	European fallow deer (*Dama dama*)
eg	for example
et al.	et alia
etc	et cetera
DMD	dry matter digestibility
DMI	dry matter intake
DSE	dry sheep equivalent
FFA	free fatty acids
FCE	feed conversion efficiency
g	gram
H	hybrid fallow deer (¼ Mesopotamian, ¾ European)
Ha	hectares
Hd	head
HSCW	hot standard carcass weight
Iv	intravenous
IV	in-vitro
IR	infra red
IVDMD	in-vitro dry matter digestibility
KFI	kidney fat index
km	kilometres
LW	liveweight
LWC	liveweight change
L6	first 6 weeks of lactation
L12	first 12 weeks of lactation
M	molarity
M+	above maintenance
M-	sub maintenance
m	metres
ME	metabolisable energy
MJ	megajoules
mg	milligram
ml	millilitres
mm	millimetres
N	nitrogen
n	number

NDF	neutral detergent fibre
NDP	not diagnosed pregnant
NS	not significant
NSW	New South Wales
OM	organic matter
P	probability
PK	plasma ketones
ppm	parts per million
RIA	radioimmunoassay
rpm	revolutions per minute
SEM	standard error of the mean
sd	standard deviation
TBF	total body fat
TCM	total conceptus mass
T1	first trimester of pregnancy
T2	second trimester of pregnancy
T3	third trimester of pregnancy
UWS - H	University of Western Sydney - Hawkesbury
VFI	voluntary feed intake
VFA	volatile fatty acids
WHR	weight : height ratio
wt	weight
$W^{0.75}$	metabolic body weight
$<$	less than
$>$	greater than
=	equals
±	plus or minus
%	percent
^{o}C	degrees Celsius

List of Terminology

Term	Meaning
Doe	Adult female fallow deer
Buck	Adult male fallow deer
Castrate	Animal with gonads removed, usually male
Fawn	Juvenile fallow deer
Weaner	Weaned fawn
Hind	Adult female red deer
Stag	Adult male red deer
Calf	Juvenile red deer
Rut	Deer mating season
Trimester	One third of gestation
Lactation	Period of suckling by fawns

Executive Summary

This study describes a number of experiments undertaken to assess the nutritional requirements of pregnant and lactating fallow does with the aim of enhancing production and quality assurance in the Australian Deer Industry. Areas of study include determination of metabolisable energy intake of farmed fallow deer does of two genotypes throughout pregnancy and lactation, metabolisable energy intake of fallow deer fawns from 12 to 20 weeks of age and the effects of restricted maternal nutrition on foetal and placental development at different stages of gestation. In conjunction with nutritional adequacy, a body condition scoring system based on ante-mortem and post-mortem descriptors was developed for fallow deer.

Over the two consecutive breeding seasons of 1997-98 and 1998-99, multiparous European fallow does (n=12) and multiparous hybrid (¼ Mesopotamian, ¾ European) fallow does (n=12) were individually housed and fed *ad libitum* one of two concentrate rations throughout the second and third trimesters of pregnancy and 12 weeks into lactation. Daily energy intake, patterns of liveweight change and fawn birthweight were measured.

In parallel, patterns of liveweight gain and reproductive performance of pasture-fed fallow does (n=36) were monitored. Statistical analysis of the metabolisable energy intake for penned does over two years produced no significant differences between years and between genotypes (P=0.05) allowing data on energy intake requirements from the two genotypes over pregnancy and lactation to be combined. Individually housed does consumed on average 10.3 MJME/day (0.54 - 0.69 MJME/kg$^{0.75}$) during trimester 2 and 13.0 MJME/day during trimester 3 (0.72 - 0.90 MJME/kg $^{0.75}$). Average daily metabolisable energy intake over the first 12 weeks of lactation was shown to be double that of non-pregnant fallow does (Mulley et al 2000) at 20.4 MJME/day.

Compared with data for non-pregnant European and Hybrid fallow does (Mulley et al 2000) that consumed 3248 and 3697 MJME annually, pregnant European and Hybrid does in this study consumed on average 3666 and 3684 MJME over the 238 day period from week 11 of pregnancy through to the end of 12 weeks of lactation, with lactation accounting for 57% and 50% of annual ME intake for E and H does respectively. These data show that daily feed requirements effectively double following parturition, and farmers should feed budget, introduce supplements and or adjust stocking rates after trimester 2 through to the end of lactation to accommodate this increased feed demand.

Following the 1997-98 breeding season, individually housed does (n=12) were liberated, thus weaning them from their 12 week old fawns, which were fed the same concentrate ration they had been observed to consume with their mothers from 6 weeks of age onwards. Over the next 8 weeks, daily metabolisable energy intake and weekly liveweight change were monitored. It was found that both male and female fawns consumed in excess of 10.5MJME/day (0.95-1.1 MJME/kg $^{0.75}$), highlighting that weaner fawns have a similar, if not higher energy requirement than non-pregnant adult does. This high energy requirement suggests pre-rut weaning should be employed to offer adequate pasture availability for weaners to reach slaughter weight / joining weight.

The investigations into feeding behaviour of fallow deer consisted of the monitoring of individually housed concentrate-fed pregnant does (n=6), and pregnant pasture-fed fallow does (n=9). Feeding behaviour of individually housed pregnant fallow does was monitored 24 hours a day, 7 days a week from August 1997 to March 1998 when fawns were weaned. Pasture-fed does (n=9) were monitored at regular intervals for two 7-day periods during trimester 3 (1997) and mid lactation 1998.

All individually housed does conformed to 3 main periods of feeding activity over a 24-hour period, starting before sunrise and ending 2.5 (SEM±0.45) hours later. The second main period of feeding occurred just prior to sunset (P<0.01) also lasting for 1.7 (SEM±0.52) hours. The third and most prolonged period of feeding occurred around midnight (P<0.01) lasting for 2.3 (SEM±0.52) hours. Temperature had a significant effect on feed intake. It was shown that temperatures above 35^{o}C during a recognised period of feeding activity (sunrise and sunset) reduced the amount of time spent feeding (P=0.002). Reduced feeding time during periods of high temperature also suppressed average feed intake over a 24-hour period (P=0.02). Conversely, average ambient temperatures over a 24-hour period below 20^{o}C during recognised periods of feeding increased the average length of time by each doe spent at the feed trough (P=0.033). Does also spent on average greater time feeding at other times of the day when temperatures were below 15 ^{o}C. Temperatures in between these maximum and minimum thresholds had no significant effect on time spent at the feed trough, or on feed intake. The increase in MEI over the first 6 weeks of lactation (P=0.000) was reflected by the increased number of visits to the feed troughs, with individual visits being significantly higher (P<0.001). The increase in feeding activity during lactation was positively correlated with MEI, although there were statistical differences between timing or duration of feeding events between the high and low energy rations (P=0.506).

Observations of pasture-fed does suggest that morning feeding activity starts before daylight and steadily declines 1.5-2 hours after sunrise, while afternoon feeding activity commences approximately 1.5-2 hours before dusk and intensifies at sunset. Individually housed does also displayed a similar periodicity of feed intake, although there were much stronger feeding periods around midday and midnight.

A 5 point body condition score (BCS) system was developed from live and carcass measurements from over 350 fallow deer. Deer were assigned a BCS based on live animal palpation, with scores ranging from 1 (emaciated) to 5 (overfat). Alternative methods of estimating body condition were also evaluated, including bone marrow fat concentrations (BMF), the kidney fat index (KFI), circulating levels of betahydroxybutyrate (β-OHB), hot standard carcass weight (HSCW), chest girth and animal height. Measurements of fat depth on the rump, loin, brisket and shoulder on carcasses were used to confirm live animal palpation. There were significant differences in fat depth levels between all BCS's at the rump, loin and brisket (P<0.001). The correlation between BCS and depth of fat over the forequarter was not significant across all BCS grades (P=0.515). Fat depth at the rump, loin and brisket were all found to be correlated with BCS (P<0.001).

KFI and BMF were shown to be useful indicators of body condition. There was a linear relationship (r^2 = 0.847, df = 77, P<0.001) between BCS and KFI. This relationship is described by the equation y = 0.02243x + 1.292, where y = BCS and x = KFI. There were significant differences in levels of BMF between BCS grades 1 and 2 (P<0.001) and between BCS 2 and 3 (P<0.001). There was no significant difference in BMF% between BCS 3 and 4 (P=0.256). While some of the other methods of estimating BCS showed levels of significance between individual scores, they were largely inconsistent and of little practical value to the live animal and meat processing sectors of the deer industry.

The effects of restricted maternal nutrition on rates of liveweight gain, BCS and conceptus development were evaluated over two consecutive breeding seasons. Does over the first year of the study (n=12) were group-fed at the maintenance requirements for non-pregnant fallow does (Mulley et al 2000), produced no significant differences in placental mass, foetal weight, crown-rump length, circulating β-OHB concentrations and rates of doe liveweight gain at the end of the first, second and third trimesters of pregnancy when compared with group-fed *ad libitum* does. Feed restrictions in the second experiment were reduced to 70% of the daily metabolic bodyweight energy intake of *ad libitum* fed individually housed pregnant does, with all animals slaughtered at 12 weeks gestation.

While there was no significant treatment effect on conceptus development, *ad libitum* fed does had a higher mean liveweight than restricted intake does (P=0.043) and a higher mean BCS (P=0.001). It was concluded that while the level of maternal energy restriction had no significant effect on conceptus development over the first 12 weeks of gestation, the reductions in doe liveweight and BCS compared with *ad libitum*-fed does indicated that had the level of maternal restriction been taken to term, fawn viability may have been compromised.

Precise strategic feeding of red and fallow der breeding stock is now possible, which should lead to more consistent reproductive performance and higher quality slaughter animals. Furthermore, use of strategic feeding in conjunction with BCS systems for both species will lead to better resource management and profitability, as farmers consistently produce animals to specification.

1. Introduction

1.1 Background to the Project

In line with DIAA objectives, the deer industry must expand to achieve greater viability, and supply of animals for slaughter, with recent industry estimates (Tuckwell 1999) predicting deer numbers in Australia to increase to 320 000 by 2008. It is imperative that carcasses for the venison trade are of high quality if Australia is to compete for market share internationally. Precise feeding of breeding stock is fundamental to achieving this outcome, yet this information is not available to the Australian deer industry. At the commencement of this study there was no information available on the nutritional requirements of pregnant and lactating fallow deer that had been derived by thorough experimental appraisal. Estimates (Milligan 1984, Asher 1993) were interpolated from research performed on red deer stags in the South Island of New Zealand (Fennessy *et al* 1981*)* and limited work on 10 fallow deer does penned in 2 x groups of 5 (Mulley 1989).

Many of the findings on reproductive wastage in fallow deer (Mulley 1989) and red deer (Hansen 2000) and poor growth rate patterns to slaughter weight in fallow deer (Mulley *et al* 1996) relate to a lack of understanding of feed requirements of breeding stock, which is often indirectly manifest commercially by low weaning percentages, lower than expected growth rates of fawns/calves, and voluntary feed intake of growing fallow deer to slaughter weight (Mulley *et al* 2000). However, there are no clear guidelines for farmers to follow for the management of feeding of deer in mid to late pregnancy and during lactation. Red deer farmers are often advised by veterinarians to restrict feed intake to red deer hinds in the last three weeks of pregnancy to avoid dystocia problems, yet foetal growth in trimester 3 is the period of most rapid growth in the life of any animal. Whilst it is acknowledged that over feeding may lead to problems at parturition the impact of under feeding may be just as profound on long term production.

The consequences of such a strategy may well be reflected in the poor weaning performances being achieved by many red deer farmers (Hansen 2000). Low birthweight and associated poor survival rates of fallow deer fawns has long been recognised as a significant problem in Fallow Deer (Asher 1988, Mulley 1989, English & Mulley 1992), yet the affect of nutrition on placental growth and development, or on foetal growth at various stages of pregnancy has not been investigated for farmed deer. This study investigated the impact of different levels of energy intake on placental and foetal development at various stages of pregnancy and foetal growth in fallow deer, and development in trimester 3 for red deer. The work on red deer was completed as part of a collaborative project with AgResearch in New Zealand, and appears as a separate section in this report. Production of an easy to follow guide to feed management for fallow deer farmers, one of the objectives of this study, will lead to greater efficiency of resource utilisation, and should result in better nutrition for farmed fallow deer and a more consistent line of animals for slaughter or herd replacement. This aspect of quality assurance should enhance future market access for Australian farmed venison.

The relationship between body condition score (BCS) and production performance has been investigated and reported for red deer (Wilson & Audige 1996) but no work had been done on BCS for fallow deer prior to this study, to assist fallow deer farmers. Development of a common language grading system of body condition score is essential if comparisons of live animal, carcass and meat quality characteristics are to be used by various sectors of the industry in an integrated way to meet marketing objectives. Quality assurance is also vitally important to the future development of the Australian deer industry. At present approximately 40000 deer are slaughtered in Australia each year (Tuckwell 1999), and these are produced in a range of commercial enterprises that differ greatly from one another in terms of the quality, quantity and variety of feedstuffs on offer. Since over 90% of deer on Australian deer farms are either red or fallow deer (Tuckwell 1999), and almost all of the 1000 tonnes of venison produced annually is derived from these two species, then it is easy to determine that development of a BCS system for fallow deer and greater application of the BCS system already available for red deer is of vital importance to the approximately 1200 deer farmers in Australia (Tuckwell 1999).

It is recognised that education of farmers in the management and feeding of high quality feed to deer at critical times during their production cycle (particularly in late pregnancy and lactation) is a vital ingredient in the development of a production system that can consistently produce carcasses of high quality. The accomplishment of this necessitates the development of user friendly information on feeds and feeding of farmed deer at various times of the year, which will assist farmers in resource management to optimise their production systems and further strengthen the productivity of individual farmers. Such benefits would include :

i) an enhanced reputation for Australian produced venison due to greater product consistency

ii) increased profitability resulting from improved management strategies that will optimise reproductive performance and growth of progeny through to joining or slaughter age

iii) a greater awareness by farmers of the need to follow industry standard practices

iv) the potential to improve carcass quality Australia wide.

The results of this research will enhance the quality assurance program that has already been initiated and funded by the DIAA. In the past, many different feedstuffs, pasture species and what could loosely be described as deer "junkfood" (bread, surplus vegetable and fruit) have been fed to deer because of availability, price or the inquisitive nature of some farmers, without serious consideration of nutritive value or its effects on growth. In many cases, the production consequences are not known, but are likely to be sub-optimal. Farming objectives and philosophies also need to be more unified Australia wide for the outcomes of this research to be effectively implemented and the potential of the industry realised.

1.2 Project Objectives

Further expansion of the Australian deer industry, is dependent on production of carcasses of high quality, and resource efficient maintenance of breeding stock and velveting herds. The ability of farmers to meet the increasingly stringent demands of the market place for product will largely depend on the availability of accurate data on the annual feed demands of various classes of stock, in conjunction with a standardised means of identifying and communicating the condition of live animals and carcasses. This project concentrated on producing information to:

i) accurately establish the nutritional requirements of pregnant and lactating red and fallow deer

ii) to assess the impact of various feeding strategies on placental growth, foetal growth, fawn/calf survival and subsequent growth.

iii) development of a method of condition scoring of fallow deer, and

iv) to produce an annual "guide to feeding" chart for fallow deer farmers.

Whilst it is obvious that the research outcomes have industry application, there is no mechanism at present that will ensure the development of improved levels of husbandry in those herds that are performing below expectation. It would therefore follow that the outcomes of this research should be carefully integrated with the implementation of the quality assurance guidelines currently being developed for deer farmers, with the ultimate outcome being production of slaughter deer of consistently even quality.

2. Nutritional Requirements of Pregnant and Lactating Fallow Deer

2.1 Literature Review: Nutritional Requirements of Fallow Does

While the energy requirements for growth, pregnancy and lactation have been extensively studied for the majority of domestic ruminants, there is a lack of knowledge of the nutritional requirements of farmed fallow deer. Since the inception of deer farming in Australia over 20 years ago, farmers have had no experimentally derived data on the energy requirements for pregnant and lactating stock. Recently, Mulley *et al* (2000) outlined the daily energy intake requirements and growth to slaughter weight for entire fallow bucks, fallow deer haviers and non-pregnant fallow does from 10 to 21 months of age. The only other experimentally derived information on maternal nutrition for fallow does was derived from 2 small groups (n=10) of group-fed fallow does (Mulley 1989). Recently, energy intake data for red deer hinds over the third trimester of pregnancy (Asher e*t al* 2000), demonstrated effects of lower than optimal maternal nutrition on foetal and placental development and gestation length, and this may form the basis for between species comparisons with the fallow deer.

While there have been figures published for seasonal energy requirements for fallow deer (Milligan 1984, Asher 1992) based on interpolations from red deer data (Fennessy *et al* 1981), there has been no data published on the energy intake of fallow does through pregnancy and lactation. Furthermore, interpolations from data derived from red deer stags in the South Island of New Zealand may not be representative of the temperature ranges experienced by the majority of fallow deer farms in Australia, nor likely to be accurate for female stocks of a different species. Inter-species interpolations on nutritional requirements have also been known to lead to inconsistencies based on physiological and behavioural variants.

Recent statistics for the Australian Deer Industry indicate the need for increases in reproductive performance, with suggestions that 12 to 15% industry growth per annum, or an equivalent number of stock processed, could be achieved if weaning rates averaged 85% (RIRDC 1996). To support the objective of a rapid increase in the number of deer produced and to maintain carcass quality, (RIRDC in it's 5 year strategic plan, RIRDC 1996, Tuckwell 1999), accurate data on feeding requirements of pregnant and lactating does is essential.

Lower than optimal conception and weaning averages and poor growth to slaughter / joining weight in the Australian Deer Industry (Tuckwell 1999) are generally thought to be nutritionally related to some extent. Excessively high or low birth weights in deer, sheep and cattle are generally associated with an increase in neonatal mortality rates. Dams carrying large offspring are susceptible to dystocia, jeopardising both the offspring and dam (Cooper *et al* 1998), while neonates with low birthweights suffer from exposure and starvation (McCutcheon *et al* 1981). It is well established that mortality rates are high in fallow fawns with birth weights below the breed norm (Asher & Adam 1985, English & Mulley 1991), with this trend also well demonstrated with other species such as red deer (Blaxter & Hamilton 1980), and elk (Thorne *et al* 1976). Subsequent growth rates of surviving low birthweight neonates have also been demonstrated to be significantly slower with fallow deer (Mulley 1989) and red deer (Blaxter & Hamilton 1980).

Accordingly, the determinants of foetal growth rates and their influences on neonate viability and post-natal growth to slaughter or mating age are of considerable importance for increasing production. An increase of basic knowledge of seasonal nutritional requirements of breeding stock will assist fallow deer farmers to meet this objective.

Interpolations of fallow deer energy intake (Milligan 1984) from Fennessy *et al* 1981) suggest a figure of 0.85MJME/kg$^{0.75}$ / day for maintenance, thus a 45kg fallow doe would consume 15MJME/day. However, this estimate makes no allowances for the well-documented seasonal fluctuations in VFI and increased ME requirements during pregnancy and lactation. Calculations on seasonal energy intake requirements for fallow deer by Asher (1993), based on data for red deer (Fennessy *et al* 1981) have been the most useful figures produced to date, expressing daily energy intake requirements for 45 and 55kg fallow does in terms of MJ and pasture DM.

From these interpolations, feeding requirements for a 45kg fallow doe (weight at conception of a large European animal) was estimated to be 12.9 MJME/day in autumn, 13.9 MJME/day in winter, 15.8 MJME/day in spring and 21.6 MJME/day in summer (late pregnancy and lactation). This estimation results in an annual total of 5934 MJME consumed at pasture. Using the same data, feeding requirements for a 55kg fallow doe (weight at conception of a hybrid animal in the order of ½ to ¾ Mesopotamian) would be 15.0 MJME/day in autumn, 16.1 MJME/day in winter 17.5 MJME/day in spring and 23.4 MJME/day in summer (late pregnancy and lactation), with these figures totalling 6637 MJME annually.

Compared with recently produced ME intake data on non-pregnant European and hybrid does (Mulley *et al* 2000), autumn and winter figures submitted by Asher (1993) appear to be overestimated, although the relative increase in energy requirements over late pregnancy and lactation correlate with requirements for other ruminants. Several authors have provided DSE comparisons and seasonal dry matter intake data for fallow deer under Australian conditions (Mackay 1990 - data from Mulley 1989), but no industry-recognised guidelines for the feeding of pregnant and lactating stock are yet available.

2.2 Existing Farm Practice : Feeds and Feeding

Climatic conditions are conducive to a pasture-based feeding system for deer in most arable farming regions of Australia. However, the seasonality of reproduction of temperate species of deer such as red and fallow deer means the peak period of pasture production is misaligned with periods of peak nutritional demand in both Australia and New Zealand where large deer farming industries occur. In both countries, pasture growth exceeds the demands of deer over spring, but the reverse occurs over summer and autumn. This often requires conservation of feed (hay, silage etc) or supplementary feeding of concentrates to make up shortfalls in available pasture, and to meet specific targets for growth or condition score.

Anecdotal information and personal communication with many deer farmers has revealed a limited knowledge of the feed requirements of their stock, and exposed several misunderstandings emanating from what little advice technical publications from various government and industry agencies have provided.

Another problem that has been identified through discussions with many Australian deer farmers is a lack of understanding of basic terminology. For example, abbreviations such as MJME and relationships between documented feed requirements of different classes of stock and feed energy values are said to be difficult to interpret. This inability to match energy values of pasture and supplement with energy intake requirements of various classes of stock makes it extremely difficult to determine nutritional adequacy. Regardless of the degree of fractionalisation of ME requirements over seasons, trimesters of pregnancy or lactation, this information cannot be utilised effectively if feed quality cannot be estimated to match demand.

In the majority of farming situations it is quite simple for the farmer to determine whether a), there is sufficient feed in a paddock for the number of deer for a certain period of time, or b), there is insufficient feed in the paddock for the number of deer. If the latter, then a decision to either move the animals to another paddock or supplement their diet has to be made. Since it is often not practical or desirable to move does in late pregnancy or newly fawned animals, diet supplementation is the only option. Hence, there are some important points involved in the decision making process that will assist farmers in planning the nutritional intake of their deer.

Pasture management, including estimation of sward height, nutritive value of the sward, and particularly pasture budgeting are of paramount importance in matching feed supply to feed demands. The ability of farmers to accurately match grazing time and feed quality is particularly important in late pregnancy and lactation. Many does do not conceive until their 2nd or even 3rd oestrous cycles (an unfavourable hindrance to productivity), with the average spread of fawning dates in many fallow herds being 6 weeks and occasionally longer (Asher & Adam 1985). Add to this period sufficient time for fawn development, and it can be easily calculated that some mobs of deer will be difficult to move into fresh paddocks for up to 10 weeks. This requires either an adjustment in stocking rates or supplementary feeding, and this problem is compounded if the additional energy intake of lactating does is considered.

Whilst it is acknowledged that a large proportion of deer farms in Australia have less than 200 deer (Tuckwell 2000 pers. comm), and may be classed as hobby farms, or the deer are a secondary enterprise, it is clear that feeds and feeding in general are not conducive to the high levels of productivity required for continued investment and industry expansion.

One issue emanating from discussions with deer farmers and managers was the difficulty in matching feed supply to demand, with problems occurring with both understanding animal requirements and estimating the nutritive values of pastures. However, other studies have described methods by which post-grazing height of pastures or pasture DM/ha remaining after grazing are used as determinants of nutritional sufficiency. Barry *et al* (1993) demonstrated that weaner red deer stags grazing pasture that did not fall below a sward height of 10cm had a higher rate of liveweight gain than stags of the same age grazing pasture to a height of 5cm. Similarly, Hamilton *et al* (1995) grazed red deer stags on swards of various heights, and concluded that grazing to a sward height of 8cm will be close to optimising maximum output / ha whilst maintaining steady liveweight gains. In another study, Fennessy & Milligan (1987) demonstrated the same results based on residual pasture DM/Ha, identifying a threshold post-grazing mass of 1200kg/ha for adequate DMI and resultant nutritional sufficiency. A combination of these processes were used for the pasture-fed does in experiments in this study with the does moved to fresh pasture when average sward heights dropped to 10cm.

Body condition score may also be used as a determinant of nutritional sufficiency in isolation, or in conjunction with other methods. As outlined by Wilson & Audige (1996), farmers should be aware of seasonal bodyweight fluctuations, but set minimum body condition scores at strategic points of growth and reproduction in order to maximise overall productivity. Setting target or minimum body condition scores provides constant feedback on nutritional adequacy and also provides farmers with an insight of future feed requirements.

As has been widely documented with red and fallow deer, ME requirements are commensurate with growth rates (Drew 1996, Asher 1990), and given the seasonal variations in both DMI and ME requirements of these temperate species, different classes and ages of stock will have different seasonal ME requirements. As described by Nicol (1996), farmers have many options in relation to pasture supply and seasonal animal requirements, although recent statistics on performance of Australian farmed deer suggests that many farmers may not be utilising the options available.

With venison from farmed deer being promoted as a year round fresh product, it will become increasingly important for Australian deer farmers to be able to supply deer of adequate HSCW and condition for most of the year. This can only be achieved if farmers are aware of seasonal feed requirements of their stock and provide adequate nutrition to meet these production targets in conjunction with hybridisation and breeding strategies.

2.3 Metabolisable Energy Intake of Pregnant and Lactating Fallow Deer Does of Two Genotypes

This section describes an experiment designed to measure the metabolisable energy (ME) intake of pregnant European and hybrid fallow deer does from day 50 of pregnancy through to parturition, and 12 weeks into lactation.

2.4 Experiment 1 (1997-1998)

Methods

In April 1997, eighteen 3 year old European (E) fallow deer does with an average liveweight of 40kg, and eighteen 3 year old hybrid (H) fallow deer does (3/4 European and ¼ Mesopotamian fallow deer) with an average liveweight of 42.5 kg were obtained from a commercial deer farm at Bathurst. On the 14th of April, each doe received a single intra-vaginal progesterone-releasing device (CIDR-G®) containing 0.3g of progesterone for oestrus synchronisation. Fourteen days after insertion on the 28th of April, the CIDRs were removed (Day 0). Each genotype group was roughly split into two (7-8 per group) and randomly assigned a mature fallow buck (≥ 3 years) for natural mating. Five days after CIDR removal, the groups were merged and one buck remained with the does until Day 23. During the period of oestrous synchronisation and mating, does were given access to concentrate feed in preparation for pen feeding.

Ultrasonography was performed 30 days after CIDR removal. Does not identified pregnant on this date were re-tested on Day 50 and removed from all data collection if negative. Pregnancy was determined by observing fluid within the uterine horns, the presence of placentomes and or the presence of a foetus, as described by Mulley *et al* 1987. Fifty days after CIDR removal, each of the does were randomly assigned to a treatment group, to be fed either a formulated concentrate ration or to be pasture-fed for the remainder of pregnancy and for the first 12 weeks of lactation.

Pen Feeding

Twelve does, 6 of each genotype, were housed individually in pens 12 m^2. Each pen had coarse sawdust flooring, and provided shade, shelter from wind and rain, and ad libitum fresh water. Three deer in each genotype were fed ad libitum a ration containing 10.3 MJME / kg DM and 12% CP. This pelleted ration consisted primarily of oats and lucerne chaff with approximately 1% salt. Developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), one kilogram of this ration was formulated to equal 1 DSE (dry sheep equivalent, ie sufficient energy to keep one 45kg merino wether at maintenance).

The remaining 6 does were fed a modified dairy ration which contained on average 14 MJME / kg DM and 16% CP (formulated and manufactured by Premier Stockfeeds Australia, Pty Ltd). Also fed in pellet form, this ration consisted of a variety of grains and molasses, with the majority of the protein and energy delivered through soya bean meal and lupins. This ration is referred to as M+ and the CSIRO ration as M in both the results and discussion. Both concentrate feeds were bought in bulk and stored in silos to prevent contamination and spoilage from insects and rodents. New batches of feed were randomly sampled and ME determined as per the methods described by Odoly *et al* (1983). *In-vitro* dry matter digestibility was also calculated as a secondary measure of digestibility of both concentrate feeds, as described in by Clarke *et al* (1982). Discrepancies between DMD and subsequent ME values of feeds (ruminant equation, Oddy 1978) and *in-vitro* determination of feed digestibility with deer have been noted in other studies (Flesch & Mulley 1998, Hmeidan *et al* 2000), and are possibly due to differences in digestive morphology between deer and other species of domestic ruminants (Hoffman 1985). Since *in-vivo* digestibility equations were modelled on the latter, it may be expected that variations in digestive physiology and function between domestic ruminants such as sheep and cattle may lead to inconsistencies when such models are applied to cervids.

Deer were fed at approximately 4pm each day and the feed residues from the previous 24 hours recorded. Feed offered to each penned animal increased or decreased in 100-gram increments on a daily basis. Genotype and ration treatment were randomised across pen allocation in an attempt to negate any affects of pen location on feed intake and animal stress. Metabolisable energy intake (MEI) was calculated from the weight of feed consumed by each penned animal on a daily basis multiplied by the ME value of the respective feeds on a dry matter (DM) basis.

Infrared beams were placed above the feeding troughs in 6 of the pens (3 deer of each genotype) and connected to a data logger to determine 24-hour patterns of feeding (as discussed later). Does were weighed weekly up to two weeks before parturition, and allowed to fawn in their pens. Straw bedding (largely inedible) was provided for does to fawn on, keeping fawns off the sawdust to prevent infection from soiled bedding material. Iodine was daubed on the umbilical cord of each fawn when day old weights were recorded. Fawns were also weighed at 6 and 12 weeks of age.

Pasture Feeding

Eighteen does (9 of each genotype) were grazed on Kikuyu dominant pasture over the period of pregnancy and lactation. Ryegrass and oats were sown as winter pasture, with white clover also present in several paddocks. Pasture quality was monitored fortnightly for the duration of the experiment. Fawns were weighed and tagged at birth, 6 and 12 weeks of age. Although fawns were not matched to their mothers, grazing and suckling behaviours were monitored at various times throughout the trial.

Results of Feed Intake Study

The results for liveweight change (LWC), metabolisable energy intake (MEI), metabolic bodyweight energy intake ($W^{0.75}$) and fawn birthweights are presented over the following pages for individually housed concentrate-fed animals from both genotype groups for the 1997-98 breeding season. Average fawn birthweight, LWC and pasture ME profiles are shown for pasture-fed deer.

One H doe was either misdiagnosed pregnant via ultrasonography at the time of treatment allocation, or resorbed the foetus. The temperament of penned H animals and responses to yarding and handling indicated higher levels of stress, with H animals in general taking longer to acclimatise to isolation than E does. Normal residues of feed ranged from 0 to 200 grams per day on average and up to 600 grams after a ‘stress incident’ such as weekly weighing, pen maintenance or sawdust replacement. A high residue such as this would normally occur for one day, with feeding patterns being normal, or even compensatory the following day. Over the course of the feeding experiments, several of the does ‘went off their feed’ at different periods of the study, with high residues over consecutive days. Freshly made batches of the M+ feed also reduced DM intake of three does for several days before returning to normal patterns of feed intake. Availability of raw products sometimes saw substitution of one grain for another in the formulation of the ration, which although contained identical CP values and ME, may have varied slightly in taste and smell.

One H doe failed to adjust to pen conditions, refusing to consume either ration. Following two weeks of limited feed intake, another H doe from the pasture fed group replaced her. Two other does, one E and one H, went off their feed later in the experiment. In each case, dietary substitutions over a two week period with a commercially produced Stud Mix (horse feed) analysed at 11.2MJME and 12% CP returned the does to their normal patterns of feed consumption. This incident was largely attributable to the temperament of the does, and was not confined to either ration. Both does that refused to consume their allocated rations in pens, readily consumed the identical rations in the paddock.

ME values of both concentrate rations were stable over the duration of the trial. Three batches of the M ration were produced, and two of the M+ ration. Two bags of the substitution feed (Stud mix) were purchased, with samples from each analysed. ME content of M and M+ rations ranged between 9.9-10.5 and 13.8-14.2 MJME/kg DM respectively. Despite the lower *in-vitro* DMD results of both rations comparative to *in-vivo* results (Figure 13), the previously determined ME averages of 14 and 10.3 MJME/kg DM for each ration were used in calculations of MEI over pregnancy to assist with both repeatability and inter-species comparisons.

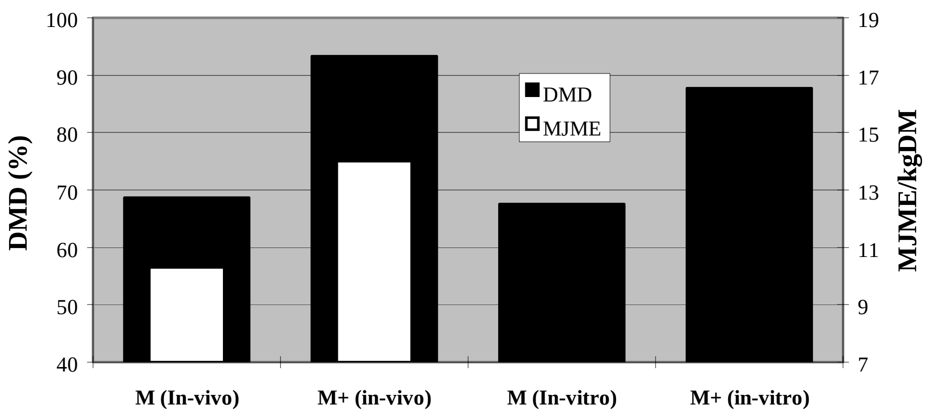

Figure 1 : In-vivo and in-vitro DMD and ME comparisons for M and M+ rations

Whilst *in-vitro* DMD for the M ration was similar to *in-vivo* DMD (67.6 and 64.5% respectively), these values differed for the M+ ration, with respective *in-vitro* and *in-vivo* DMD figures of 85.5 and 93.5%. Lower *in-vitro* DMD of the M+ feed may be explained by the small particle size of the pelleted ration, when compared with the coarsely ground M ration.

Figure 2 presents pasture values from April 1997 when does conceive, through until March 1998 when fawns were weaned at approximately 12 weeks of age. The white bars represent kikuyu, which is clearly of lower energy value and less palatable than the ryegrass / oats pasture, seen in grey. The black bars represent pasture grazed that consisted largely of oats and ryegrass of decreasing nutritive value (tall stalky and 'headed') with kikuyu, (winter dormant) beginning to dominate the lower sward.

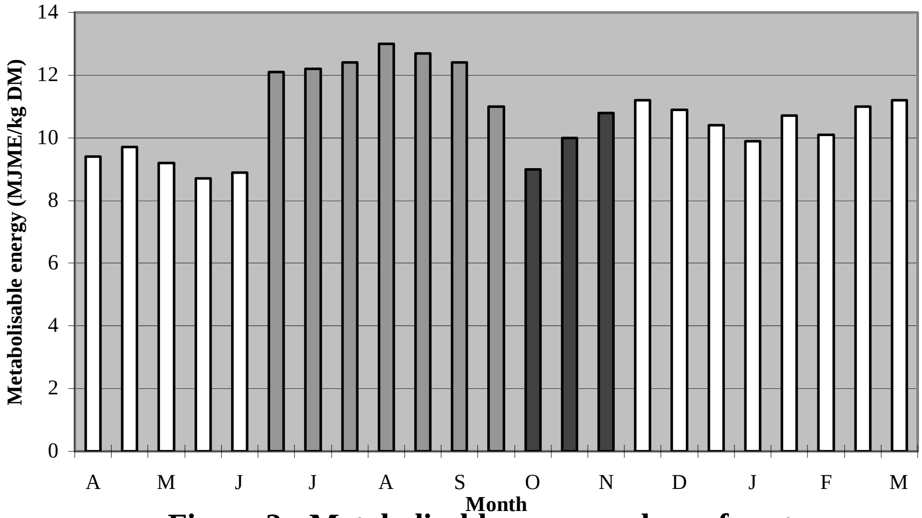

Figure 2 : Metabolisable energy values of pasture grazed by pregnant European and Hybrid does, 1997-98.

As outlined by Waghorn & Barry (1987) ryegrass pastures rapidly decrease in DMD during seed setting, and should be maximised during early stages of leaf growth when DMD is higher. Energy values ranged from as low as 8.6 MJME / kg DM for kikuyu and 12.7 MJME / kg DM for oats / ryegrass pastures.

Liveweight Changes

Weight increases and growth rates by trimester are shown in Table 1. Growth rates over trimesters one and two were calculated on eleven-week (77 day) averages. Both E and H does from all treatment groups lost between 15 and 43 g/hd/day over trimester one (trimester 1), and regained between 21 and 29 g/hd/day over trimester 2. Growth rates for trimester 3 were calculated for a period of 56 days, as does were not weighed for the three weeks prior to the calculated fawning date.

Table 1 : Mean liveweight change (kg) and mean daily weight gain (g/hd/day) of concentrate and pasture-fed European and Hybrid does over each trimester of pregnancy, 1997-98.

	Concentrate-Fed				Pasture-Fed			
	E		H		E		H	
Trimester 1	-2.0kg	-26g/day	-3.3kg	-43g/day	-1.2kg	-15g/day	-2.2kg	-29g/day
Trimester 2	1.8kg	23g/day	2.2kg	29g/day	1.6kg	21g/day	2.0kg	26g/day
Trimester 3	6.4kg	83g/day	6.9kg	90g/day	7.4kg	96g/day	6.8kg	88g/day

Concentrate-fed E and H does had average conception liveweights of 42.2 (SEM±2.2) and 45.1 (SEM±2.1) kg respectively. Concentrate-fed E does lost on average 4.8% of their mating liveweight by the end of the first trimester of pregnancy, with their H counterparts losing on average 7.4% of their mating liveweight over the same period. However, during T2 there was an increase in liveweight across both genotypes and feeding treatments, with the majority of animals re-attaining their weight at joining during this period. During T3, liveweight gain across all genotypes and feeding treatments accelerated, corresponding with a significant increase in VFI and the period of greatest foetal growth (Asher *et al* 2000). Overall, concentrate-fed E and H does had respective liveweight gains of 6.5 (SEM±1.9) and 4.9kg (SEM±1.8) from conception to 3 weeks from parturition.

There were no significant differences in rates of liveweight change (LWC) with E and H does across feeding treatments. Pasture-fed E and H does had average conception liveweights of 41.1 (SEM ± 2.3) and 45.3 (SEM ± 2.1) kg respectively, losing between 3.9 and 5.8% of their average conception liveweight by the end of the first trimester of pregnancy. As with the individually housed does, the pasture-fed does also had a period of liveweight recovery over the second trimester before a rapid period of liveweight gain to parturition. Pasture-fed E and H does had average liveweight gains of 7.6kg (SEM ± 1.7) and 7.7kg (SEM ± 1.7) respectively from conception to three weeks prior to parturition. As shown in Table 1, the net liveweight changes between conception and parturition are similar to the liveweight gains made by does of both genotypes in both feeding treatments in the third trimester of pregnancy. It is however notable, that despite the variances in liveweight gain over pregnancy, average fawn birthweights across both genotypes and feeding treatments were not significantly different ($P>0.4$).

Average liveweight changes for does of both genotypes are depicted in Figures 3-6, all of which illustrate the rapid growth rates of both pasture and concentrate-fed does of both genotypes in T3. Most does (27 out of 30) lost weight between conception and week 10 of pregnancy, with weight losses characteristic of deer over this period of time in line with reductions in VFI (Asher 1993).

Metabolisable Energy Intake (MEI)

Figure 7 illustrates average MEI from week 10 of pregnancy through to 12 weeks of lactation. Aberrant data points were corrected with a series of 3 day rolling means. Oscillations in daily MEI were similar for animals of both genotypes, although E does increased slightly above that of H does over the last 9 weeks of pregnancy and over lactation. E does consumed on average 10.1 MJME / day (SEM ± 1.1) in T2, 13.2 MJME / day (SEM ± 1.3) in T3, and 20.7 MJME / day (SEM ± 2.6) over the first 12 weeks of lactation. H does consumed 9.9 (SEM ± 1.0), 12.2 (SEM ± 1.2) and 19.6 (SEM ± 2.9) MJME/day over T2, T3 and lactation respectively.

The average DM intake for both genotypes increased gradually from approximately 800g/day at week 10 of pregnancy to1800g/day 2 weeks into lactation. Feed offerings were usually increased in 100gram increments with zero residue, although over this period, increases in VFI were rapid enough to increase feed offered to 200grams / day. The net energy consumption of both E and H does over the latter stages of pregnancy are particularly notable. E does consumed on average 787 MJME (SEM ± 91) in T2, 1019 MJME (SEM ± 84) in T3, and 1741 MJME (SEM ± 109) over the first 12 weeks of lactation. This gives a total of 3547 MJME over a 238 day period.

Fawns were witnessed to begin consumption of concentrate feed at 6 weeks of age, thus the MEI of the first 6 weeks of lactation (L6) is solely attributable to the does. Over L6, 817 MJME was consumed on average by E does, a figure comparable with the entire energy intake for T2.

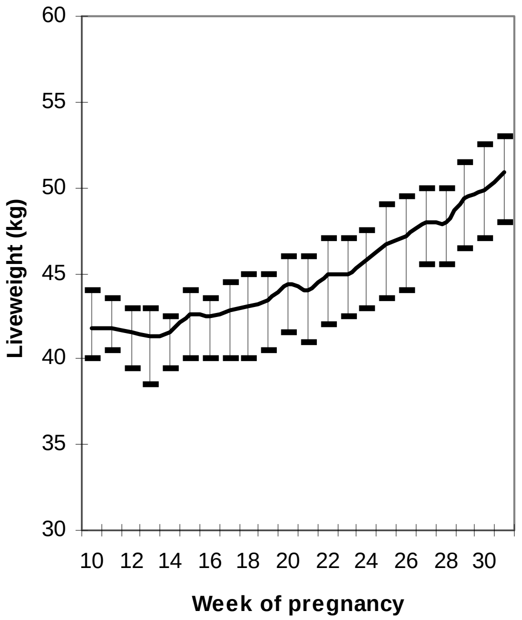

Fig. 3 : LWC of concentrate-fed H does 1997-98.

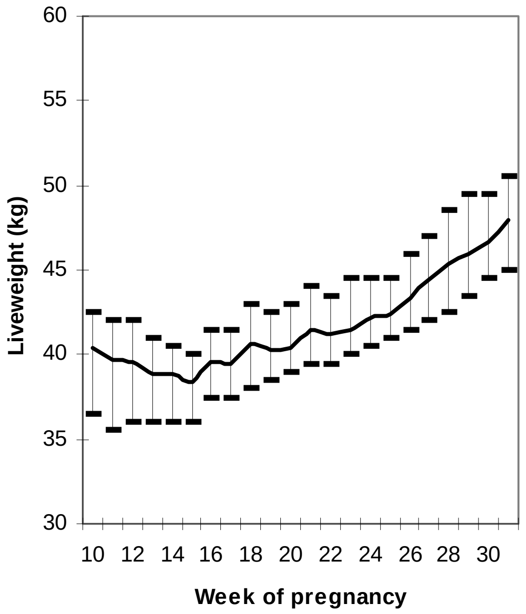

Fig. 4 : LWC of concentrate-fed E does 1997-98.

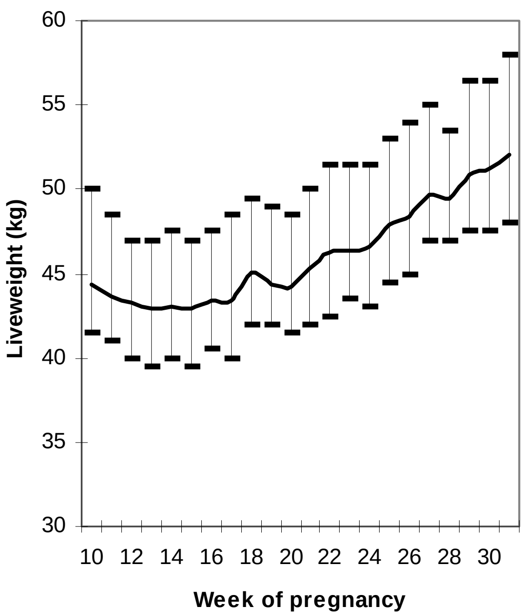

Fig 5 : LWC of pasture-fed H does 1997-98.

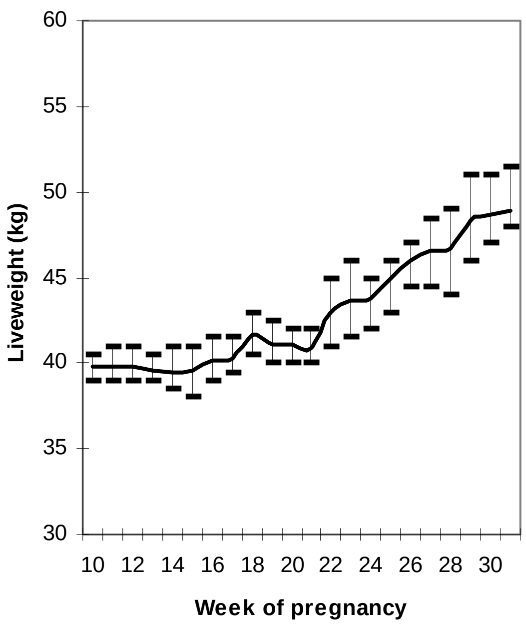

Fig. 6 : LWC of pasture-fed E does 1997-98.

Weeks 6-12 of lactation (a period where both the doe and fawn consumed the concentrate feed offered) accounted for an average of 924 MJME, also greater than the T2 energy consumption for E does. H does consumed on average 770 MJME (SEM ± 73) in T2, 940 MJME (SEM ± 42) in T3, and 1778 MJME (SEM ± 79) over the first 12 weeks of lactation. This gives a total of 3488 MJME over a 238-day period. H does consumed on average 822 MJME over L6, which as with their E counterparts, is similar to the entire second trimester energy intake. Weeks 6-12 of lactation accounted for an average of 956 MJME, also comparable with T2 energy consumption for H does.

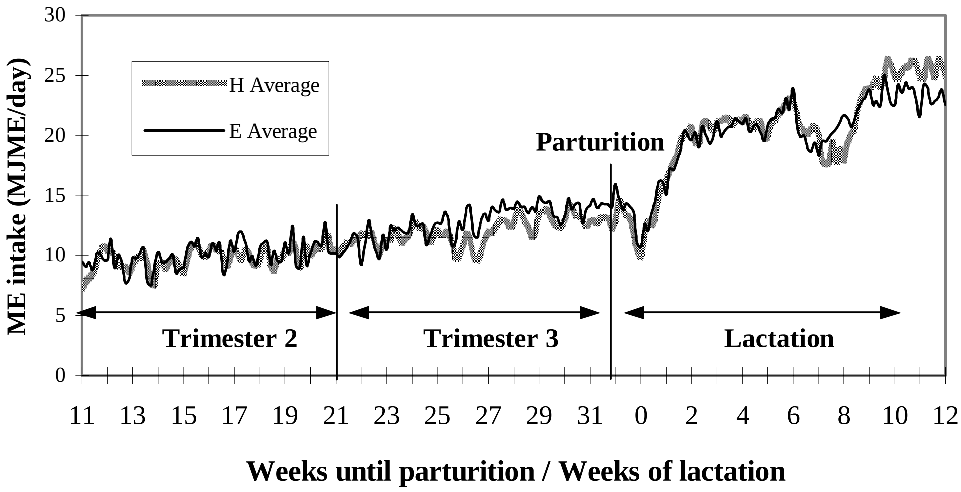

Figure 7 : ME intake of concentrate-fed E and H does throughout pregnancy and lactation ; 1997-98.

Metabolic Bodyweight Energy Intake

Energy intake for E does ranged from 0.47 to 0.69 MJME/kg$^{0.75}$/day and 0.55 to 0.71 MJME/kg$^{0.75}$/day for H does between weeks 14 and 31 of pregnancy. H does had a higher metabolic bodyweight energy intake over T2 (Figure 8), with intake levels between the two genotypes levelling throughout the remainder of pregnancy.

Fawn Birthweight

Nine fawns, (4 male and 5 female) were born in the pens over 13 days starting from the 14th of December 1998, although all does in individual pens were diagnosed pregnant on days 30 and 50. It appears three does may have suffered late embryonic mortality, the causes of which remain undiagnosed. Average gestation length for individually housed E and H does was 234.2 (SEM ± 4.8), and 233.8 (SEM ± 1.5) respectively, with no significant difference between feeding treatments ($P<0.05$). One doe gave birth to a dead fawn weighing 900 grams, 233 days after conception (at term) although from the size of the foetus, it may have died early in T3. Whilst there was no post-parturient mortality amongst fawns from the individually housed does, several fawns from the pasture-fed group were predated by foxes.

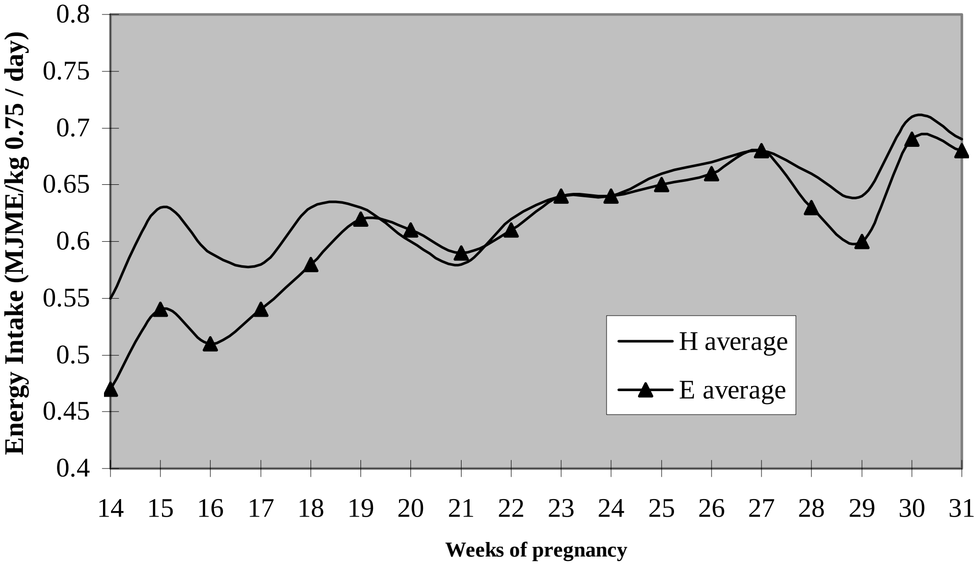

Figure 8 : Metabolic bodyweight energy intake of E and H does from weeks 12 to 31 of pregnancy ; 1997-98

Penned E fawns had average birth, 6 and 12-week weights of 5.1 (SEM ± 0.55), 14.3 (SEM ± 1.0), and 21.7 (SEM ± 1.75) kg respectively (Figure 9). Penned H fawns had an average birthweight of 4.9 kg (SEM ± 0.22), 6-week weight of 14.1 kg (SEM ± 1.0) and 12-week weight of 21.8 kg (SEM ± 1.8) (Figure 10). There were no significant differences in the weights of fawns at birth, 6 and 12 weeks of age between the feeding treatments ($P<0.05$). There was also no significant sexual dimorphism among fawns, with average birthweights for males and females being 4.9 (SEM ± 0.56) and 5.0 kg (SEM ± 0.36) respectively. The fawning period for the pasture-fed does was not as condensed as the penned animals, with fawns born between the 8th of December and the 3rd of January (26 days), although the majority of fawns were born in mid December. Three does not diagnosed pregnant (NDP) at day 50 via ultrasonography formed part of the pasture fed group. From the spread of fawning dates, two does may have conceived on the second oestrus cycle following synchronisation.

Given the conditions over which the pasture-fed group of does were managed (E and H does in one mob), and the variance in gestation length, it was extremely difficult and time consuming to accurately match fawns to does, thus fawn birthweight data was not analysed by genotype. However, fawns from the pasture-fed does of both genotypes had birth, 6 and 12 week weight averages of 5.2 (SEM ± 0.9), 14.0 (SEM ± 1.2), and 22.0 (SEM ± 1.9) kg respectively, mirroring growth of fawns from concentrate-fed penned does. There was also no sexual dimorphism among fawns from the pasture fed does, with average birthweights for males and females being 4.5 (SEM ± 0.5) and 5.1 (SEM ± 0.4) kg respectively. As the data for penned and pasture-fed does suggests, there were no significant differences in fawn weights between genotypes or feeding treatments. Figures 11 and 12 represent average fawn birthweight (by genotype) as a percentage of doe liveweight at conception, the start of T2 and 3 weeks prior to parturition. With the exception of H does at conception, birthweights of E fawns represented a higher proportion of doe bodyweight at conception, T2 and parturition, reflecting the higher average bodyweight of H does.

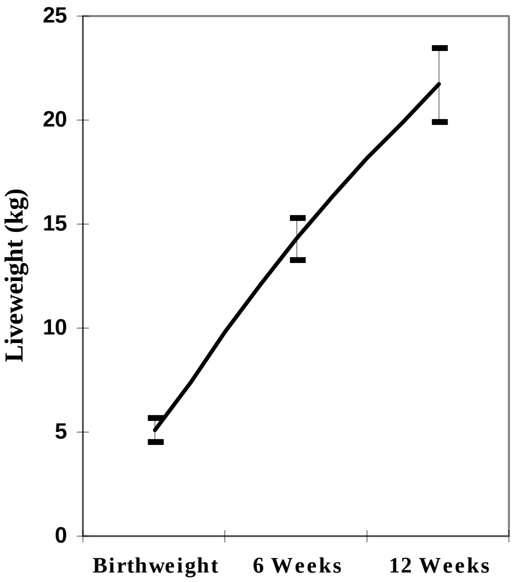

Figure 9 : Mean LWC (±SEM) of fawns from concentrate-fed E does

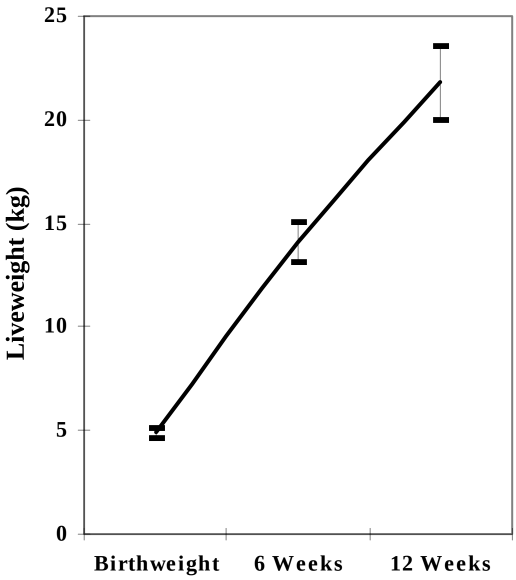

Figure 10 : Mean LWC (±SEM) of fawns from concentrate-fed H does

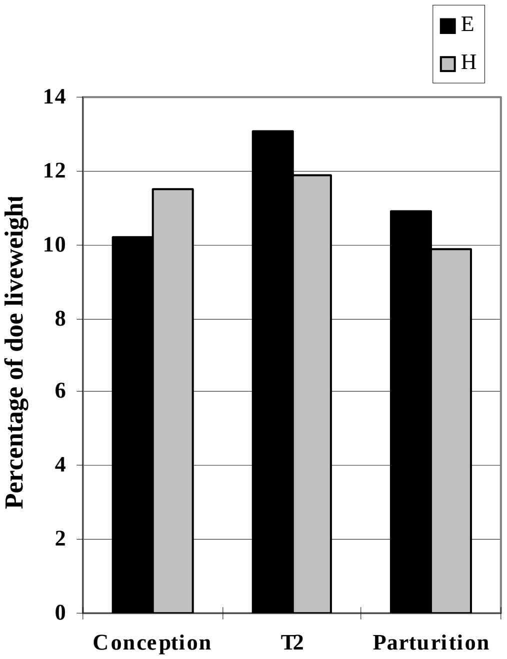

Fig 11 : Fawn birthweight as a percentage of pasture-fed doe liveweight at conception, T2 and parturition

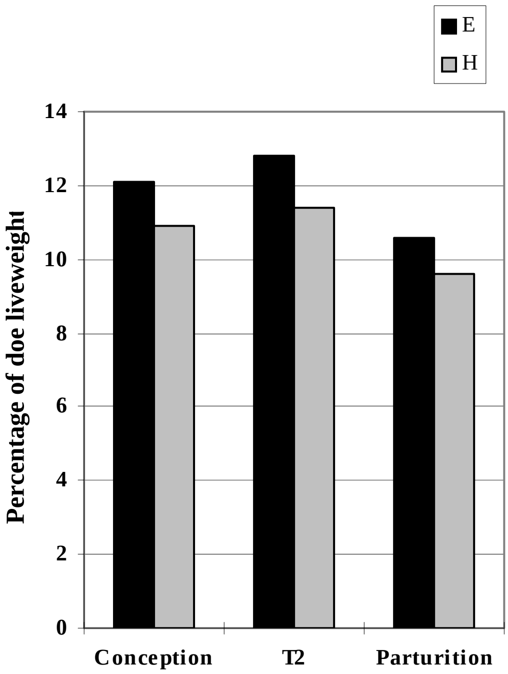

Fig 12 : Fawn birthweight as a percentage of concentrate-fed doe liveweight at conception, T2 and parturition

Discussion

A decrease in dry matter intake of does of both genotypes lead to a moderate loss in liveweight during the breeding season and into T1. Usually associated with entire males and the rut, reductions in VFI and a concomitant reduction in liveweight has been reported elsewhere with pregnant does (Asher 1986, Mulley 1989), and non-pregnant does (Mulley *et al* 2000). Handling procedures were minimised from CIDR removal to pregnancy testing at day 30 so as not to jeopardise embryo implantation. Although does did not enter individual pens until after day 50 of pregnancy, they were segregated into their individual feeding treatments after pregnancy testing at day 30, and thus new social hierarchies would have been formed. This process may have induced stress and perhaps reduced the VFI of certain individuals, as has been observed with red deer (Appleby 1980, Pollard u 1993, Hanlon *et al* 1994).

Whilst in individual pens, does had little or no contact with other deer. There appeared to be no long term effect of isolation on VFI or LWG, as has been reported with red deer calves (Hanlon *et al* 1997). While initial levels of energy intake were low (0.2 - 0.3 MJME/kg $^{0.75}$/day), feed intake rose to maintenance levels for other ruminants of similar size (eg, sheep), around 0.45 MJME/kg$^{0.75}$/day within 7-10 days of feeding. By the beginning of the second trimester of pregnancy (following 3 weeks of individual feeding), all does appeared to have adapted to pen conditions, with ME consumption settling to around 10.5 MJME/day and stress behaviours such as pacing and leaping minimal. There was no significant difference in LWC between concentrate-fed and pasture-fed does of both genotypes over this acclimatisation period. VFI steadily increased over the third trimester of pregnancy, dipping slightly around three days prior to parturition, an occurrence also noted with individually penned white-tailed deer (Langenau & Lerg 1976).

The process of adaptation to the experimental conditions may be regarded as having two components ; (1) adaptation to isolation and a concentrate-only diet and (2) adaptation to being handled during management procedures, weekly weighing and ultrasound pregnancy testing. Analysis of heart rate and cortisol levels in sheep and goats engaged in intensive and prolonged experimental procedures suggests that animals will satisfactorily adjust to laboratory conditions over a period of 2 weeks with daily contact, such as feeding, yarding and handling procedures (Pearson & Mellor 1976), although animals will still remain sensitive to small changes in routine and conditions (Meschia *et al* 1965).

Habituation was apparent in the current study, with does becoming so used to daily routines that changes in yarding and handling procedures, early or late feeding or manipulation of does in the crush, would result in a drop in VFI for the following day. The sudden decline in $W^{0.75}$ starting at week 27 of pregnancy is thought to be associated with the change in handling practices when does were fitted with individual collars as an identification safeguard and pen bedding material was changed and straw added for fawning. A large decline in feed intake mid-way through lactation (Figure 7) was also thought to be attributable to the disturbances caused to each doe and fawn during the attainment of 6-week weights for the fawns. It appears the decrease in VFI was compounded at this stage with fawns also observed consuming concentrate feed. There was a more dramatic and sustained reduction in VFI with H does due to this disturbance, although there appeared to be a period of compensatory feed intake over weeks 9-12 of lactation. Irrespective, compensatory feed intake would normally occur on the following day or days, with low intake days consequently being of little significance to the overall level of energy intake over any measured period of time.

The daily ME intake of E and H does over pregnancy was lower than estimates for fallow deer (Milligan 1984, Asher 1993) derived from work on red deer (Fennessy *et al* 1981), but higher than other estimates based on group-fed fallow does (Mulley 1989). However, data from the former study on red deer produced similar parallels over the period of lactation, accounting for 43% of the annual ME intake for red hinds (Fennessy *et al* 1981). Compared with annual ME intake for non-pregnant fallow does (Mulley *et al* 2000), the first 12 weeks of lactation for E and H does accounted for 53 and 48% of annual ME intake respectively. However, with the aid of video surveillance in several of the pens, fawns were observed to begin feeding from troughs at 6 weeks of age, and as such, only the first 6 weeks of lactation can truly be a measure of energy intake of the does for lactation. Given this, the first 6 weeks of lactation still account for 25% for E and 22 % for H animals, of annual ME intake - a figure which under a farming situation, equates to a very large volume of feed consumed over a short period of time. Careful feed budgeting is therefore required on farms to maintain optimal lactation in does.

Irrespective of the distribution of feed consumption between the doe and fawn, the doe / fawn units of both E and H animals still consumed averages of 20.7 and 21.2 MJME /day, which in a farm situation, still equates to increased grazing pressure and greater feed demand for the herd. As noted by Clutton-Brock *et al* (1982), lactating red deer hinds will graze for up to 2 hours longer per day than dry hinds, indicating greater energy requirements over this period in conjunction with the pasture consumed by fawns. Compared with data for non-pregnant E and H fallow does consuming 3248 and 3697 MJME annually (Mulley *et al* 2000), pregnant E and H does in the present study consumed 3547 and 3488 MJME over the 238 day period from week 11 of pregnancy through to the end of 12 weeks of lactation. The high energy costs of lactation have been similarly observed with red hinds, with lactating hinds reported to consume up to 2.6 times the maintenance requirements of non-breeding hinds of the same weight (Arman *et al* 1974). These data indicate that strategic feeding of fallow does, as suggested by Suttie *et al* (1996), should be implemented in the third trimester of pregnancy and during lactation.

The energy requirements for the slightly heavier H does in this study were marginally lower than for their E counterparts during T2 and T3, and although H does produced fawns of equivalent birthweights to E does with similar growth rates to weaning, they consumed 5% less feed energy to parturition. Other controlled feed intake studies that compared ¼ Mesopotamian with European fallow deer also demonstrated H animals to be more efficient in feed conversion than their E counterparts (Mulley *et al* 1996). Based on these observations, the larger framed H fallow doe should be viewed favourable by farmers, where feed utilisation and efficiency and ease of fawning are major considerations for successful reproductive performance.

While demonstrating favourable performance qualities, the temperament of the H animals was not conducive to prolonged individual housing and weekly weighing. Depressions in VFI for H animals following handling procedures were usually more severe in the current study, and it is possible that poor temperament of one of the H does led to foetal resorption. Whilst stress behaviours such as pen pacing and rearing ceased even with the flightiest of does over the latter stages of pregnancy, feed intake data for the dry does suggested that foetal resorption may have occurred sometime in T2 when flight and evasive behaviours often resulted in physical contact or collisions with handling shed infrastructure. However, pasture-fed H does showed no such signs of stress, and displayed similar patterns and rates of growth when compared to their concentrate-fed counterparts.

The metabolic bodyweight energy intake ($W^{0.75}$) requirements for domestic ungulates (sheep, cattle and goats) and for wild ungulates such as deer, lie between 0.42 and 0.58 MJME/kg$^{0.75}$/day and rise to between 0.58 and 0.71 MJME/kg$^{0.75}$/day in late pregnancy (Anon 1975, 1976, 1978, 1981; Simpson *et al* 1978, Loudon 1985), although this requirement has been shown to rise to higher levels in white-tailed deer (Holter *et al* 1976). Data from this study indicate that the $W^{0.75}$/day requirements for E and H fallow deer are higher than that of other domesticated ruminants, particularly in late pregnancy. However, Oftedal (1984) suggested extrapolations from domestic species would place energy requirements of wild herbivores to above 1.0 MJME/kg$^{0.75}$/day over lactation. In the current study, both E and H concentrate-fed does reached a metabolic bodyweight energy intake of 0.75 MJME$^{0.75}$/day just prior to parturition, and clearly rose above a $W^{0.75}$ of 1.0 as suggested by Oftedal (1984), given the increase in VFI seen over the first 6 weeks of lactation.

There was no significant difference in fawn birthweight between pasture-fed and concentrate-fed animals, nor was there a significant difference between birthweights of fawns from concentrate-fed does of both genotypes. Differences in the conception to parturition LWC between genotypes were also insignificant as seen in average fawn birthweights across both feeding treatments. Russel *et al* (1981) suggested that condition score and liveweight at conception in British blackfaced sheep has an influence on foetal development and subsequent birthweight. Liveweight variances between does were not significant in this study, and fawn birthweights were consistently between 10-12% of doe liveweight at joining. With 10% of doe liveweight at joining used as a prediction of fawn birthweight, assuming a rising plane of maternal nutrition (Asher & Adam 1985, Mulley 1989,), average fawn birthweights for E and H concentrate-fed does would have approximated 4.2 and 4.5kg respectively. However, as previously stated, actual average birthweights for fawns from both doe genotypes were significantly higher, even though does lost weight between conception and the start of the second trimester of pregnancy. Similarly, pasture-fed E and H does would have had estimated average fawn birthweights of 4.1 and 4.5kg respectively, with the actual (E and H combined average) birthweight being 5.2kg.

Liveweight changes over the duration of pregnancy provide some indication of when foetal growth accelerates, leading to higher energy demands on the doe. The overall LWC and patterns of growth from conception to the end of T1 were not reflective of a large metabolic impost on the does, and liveweight profiles of pregnant and non-pregnant does remained alike for both concentrate and pasture-fed does of both genotypes until week 14 of pregnancy. Weber & Thompson (1993) reported no differences in body condition in fallow does at week 8 of pregnancy via computer-aided tomography compared with non-pregnant animals, suggesting that conceptus development poses little nutritional challenge to the doe over early pregnancy.

Relating morphological measurements to feed availability and pasture quality places an increasing amount of emphasis on T3. Unlike sheep where placental development ceases between days 75 and 80 of pregnancy, ie, approximately 0.6 of gestation length (Ehrhardt & Bell 1995), placentomes in deer continue to grow throughout gestation, which combined with the most rapid period of foetal development in deer (Asher *et al* 2000), places a great deal of importance on nutritive supply over this period.

Data from this study shows that does shed liveweight (presumably fat depots) over the first trimester of pregnancy, commensurate with reductions in VFI, whilst nourishing a developing foetus and placenta, at the time of year when pasture quality and availability are diminishing. As illustrated in Figure 7, MEI elevations over T2 were only slight, and the majority of feed intake occurred in the 8 weeks immediately prior to parturition. E and H does consumed 782 and 708 MJME respectively over this 8 week period - a figure comparable with the entire second trimester of pregnancy. Once again, this reinforces the importance of strategic feeding of does over T3 and lactation.

2.5 Metabolisable Energy Intake (MEI) of Pregnant and Lactating Fallow Does of Two Genotypes

Experiment 2 (1998-1999)

Experiment I was repeated in 1998-99 to enhance the statistical value of the data collected. There were few variations in the materials and methods with the same does used over the two consecutive breeding seasons, ie, does were 4 years old. With the exception of one ¼ Mesopotamian doe, animals from the pasture-fed group of does in Experiment I formed the individually housed concentrate fed group in Experiment II and vice-versa.

Methods

In April 1998, eighteen 4 year old European fallow deer does with an average liveweight of 40kg, and eighteen 4 year old hybrid fallow deer does (3/4 European and ¼ Mesopotamian fallow deer) with an average liveweight of 42.5 kg received a single intravaginal progesterone releasing device (CIDR-G®) containing 0.3g of progesterone for oestrus synchronisation. Fourteen days after insertion, the CIDRs were removed (Day 0). Each genotype group was roughly split into two (7-8 per group) and randomly assigned a mature fallow buck (≥ 4 years old) for natural mating. Five days after CIDR removal, the groups were merged and one clean-up buck remained with the does until day 23. During synchronisation of oestrus and mating, does were given access to concentrate feed in preparation for pen feeding. Ultrasonography was performed on day 30 post CIDR removal. Does not diagnosed pregnant on this date were re-tested on day 50 and removed from all data collection if again negative. Pregnancy was determined by observing fluid within the uterine horns, the presence of placentomes and or the presence of a foetus. On Day 50, each of the does were randomly assigned to a treatment group, to be fed either a formulated concentrate ration or to be pasture fed for the remainder of pregnancy and lactation.

Pen Feeding

Twelve does, 6 of each genotype, were housed individually in pens 12 m^2. Each pen had coarse sawdust flooring, and provided shade, shelter from wind and rain, and ad libitum fresh water. Three deer in each genotype were fed ad libitum a maintenance ration containing 10.3 MJME / kg DM and 12% CP. This pelleted ration consisted primarily of oats and lucerne chaff with approximately 1% salt. Developed by CSIRO, one kilogram of this ration was formulated to equal 1 DSE. The remaining 6 does (3 of each genotype) were fed a modified dairy ration formulated and produced by Premier Stockfeeds Australia Pty Ltd, which provided 14 MJME / kg DM and 16% CP. Also fed in pellet form, this ration consisted of a variety of grains and molasses, with the majority of its protein and energy delivered through soya bean meal and lupins. Repeated analysis of both concentrate-feeds used in Experiment 1 saw average ME contents of 10.3 and 14MJME/kg DM of the CSIRO and M+ rations respectively, and consequently, these rations were not re-analysed for the second year of the feed intake study.

Genotype and ration type were randomised across pen allocation in an attempt to negate any affects of pen location on feed intake and animal stress (Table 3). Deer were fed at approximately 4pm each day and the feed residues from the previous 24 hours recorded. Dependant on residue levels and daily activity (eg, weighing) feed offered per day increased or decreased in 100-gram increments. MEI was calculated from the weight of feed on a dry matter basis, multiplied by the respective ME value of the respective feed.

Infrared beams were located above the feeding troughs in 6 of the pens (3 deer of each genotype) and connected to a data logger to determine 24-hour patterns of feeding. Does were weighed weekly up to three weeks before parturition, and allowed to fawn in the pens. Ample straw bedding (largely inedible) was provided for does to fawn in, keeping fawns off the sawdust to prevent infection, although iodine was daubed on the umbilical cord of each fawn when day old weights were recorded. Fawns were also re-weighed at 6 and 12 weeks of age.

Pasture Feeding

Sixteen does (8 of each genotype) were grazed on kikuyu dominant pasture over the period of pregnancy and lactation. Ryegrass and oats were sown as winter pasture, with white clover also found in several paddocks. Pasture quality was monitored fortnightly for the duration of the experiment. Fawns were weighed and tagged at birth, 6 and 12 weeks of age. Although fawns were not matched to their mothers, grazing and suckling behaviours were monitored at various times throughout the trial.

Results of 2nd Year of Feed Intake Study

The results for liveweight change (LWC), metabolisable energy intake (MEI), metabolic bodyweight energy intake ($W^{0.75}$) and fawn birthweights are presented over the following pages for individually housed concentrate-fed animals from both genotype groups for the 1998-99 breeding season. Average fawn birthweight, LWC and pasture ME profiles are shown for pasture-fed deer. One concentrate-fed H doe failed to conceive, or resorbed the foetus, with the remainder of the individually housed does successfully rearing fawns to 12 weeks of age. As with Experiment 1, several concentrate-fed does had periods of low VFI in the initial stages of the trial, although these animals resumed normal patterns of feed intake after several days of remedial feeding, as described previously in this Chapter.

Figure 13 presents pasture values from April 1997 when does conceived, through until march 1998 when fawns were weaned at approximately 12 weeks of age. The white bars represent kikuyu, which is clearly of lower energy value and less palatable than the ryegrass / oats pasture, seen in black.

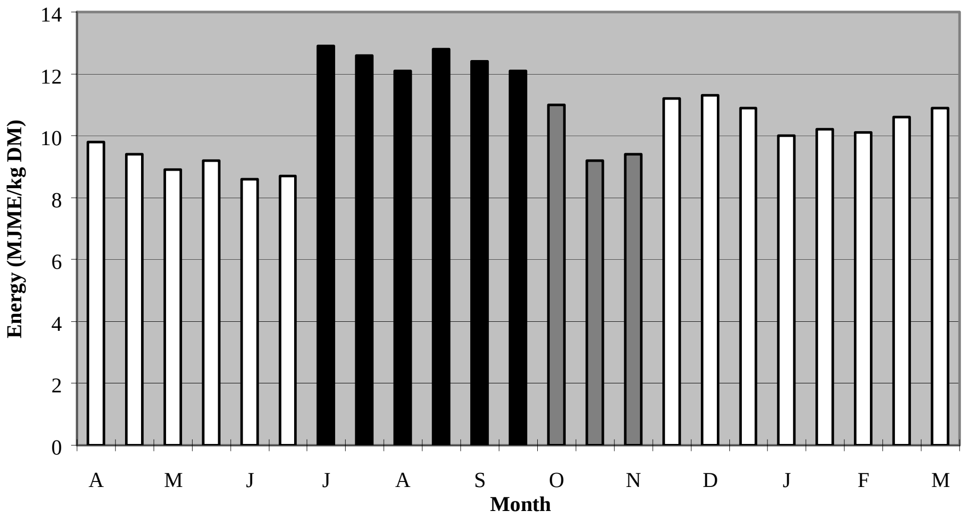

Figure 13 : Metabolisable energy values of pasture grazed by pregnant European and Hybrid does, 1998-99.

The grey bars represent pasture grazed that consisted largely of oats and ryegrass of decreasing nutritive value with kikuyu beginning to dominate the lower sward. Pasture values for the 1998-99 breeding season were similar to that of the previous year, although excessive rainfall during sowing prevented several paddocks from being sown, with ryegrass and oats not attaining grazing height until early July. Energy values ranged from 8.8 MJME / kg DM for kikuyu to 12.9 MJME / kg DM for oats / ryegrass pastures. While energy values are comparable to the 1997-98 breeding season, there were some minor variations in pasture growth.

Liveweight Changes

Unlike the 1997-98 breeding season, does were joined this year at a slightly lower average liveweight and showed markedly slower LWG over T1 than the previous year. One H doe refused to accept a variety of rations offered under pen conditions, and was replaced with another pasture-fed H doe after 7 days.

Weight increases and growth rates by trimester are shown in Table 2. T1 and T2 were calculated on 77-day averages. T3 was calculated as 56 days, as does were not weighed later than 3 weeks before the calculated date of parturition. Unlike in the 1997-98 breeding season, liveweight of does remained static or slightly increased between conception and week 10 of pregnancy, possibly compensatory from the metabolic toll of lactation. Within genotype groups, there was no significant difference in average daily weight gain (P<0.02). Concentrate-fed does of both genotypes had higher LWG over the last trimester of pregnancy, although overall changes in liveweight between feeding treatments and genotypes were not dissimilar.

Table 2 : Average liveweight change (kg) and average daily weight gain (g/hd/day) of concentrate and pasture-fed European and Hybrid does over each trimester of pregnancy, 1998-99.

	Concentrate-Fed				Pasture-Fed			
	E		H		E		H	
Trimester 1	1.0kg	13g/day	0.9kg	12g/day	0.6kg	8g/day	0.8kg	10g/day
Trimester 2	3.7kg	48g/day	3.7kg	48g/day	2.4kg	31g/day	3.9kg	51g/day
Trimester 3	4.9kg	88g/day	5.5kg	98g/day	4.4kg	79g/day	4.6kg	82g/day

Overall LWC between conception and parturition was higher with concentrate fed does, and marginally higher with H does within each feeding treatment, although this trend was not reflected in fawn birthweights. Concentrate-fed E and H does had respective liveweight gains of 9.6 and 10.1 kg from conception to 3 weeks before parturition. Pasture-fed E and H does had marginally lower liveweight increases of 7.4 and 9.3 kg over the same period.

Concentrate-fed E and H does had average conception liveweights of 39.1 (SEM ± 1.9) and 40.9 (SEM ± 2.8) kg respectively. Unlike the T1 weight decreases seen across does in both feeding treatments in the 1997-98 breeding season, liveweight was maintained or increased over T1 in Experiment II. This discrepancy with 1997-98 breeding season data is thought to be attributable to the lower mean bodyweights (and condition scores) of does at conception. This feature is also illustrated in differences between average liveweight at conception and average liveweight 3 weeks from parturition between Experiments I and II. Figures 11 & 12 and 22 & 23 compare fawn birthweight with doe bodyweight at the start of T2 for each breeding season for this reason.

Pasture-fed E and H does had average conception liveweights of 41.1 (SEM ± 2.2) and 45.3 (SEM ± 1.8) kg respectively, and maintained liveweight through to the end of T1. Figures 14-17 illustrate that, unlike the concentrate-fed does, the patterns of growth of pasture-fed animals over the second trimester of pregnancy were not as rapid, with E animals actually having an average depression in liveweight between weeks 13 and 16 before a period of accelerated LWG. As is shown in Table 2, these net liveweight gains made by does of both genotypes in both feeding treatments over T3 are close to half of the entire LWG from conception to parturition.

Average liveweight changes for does of both genotypes is depicted in Figures 14-17, all of which illustrate the rapid growth rates of both pasture and concentrate fed does of both genotypes in T3. Concentrate-fed does show a more linear rate of LWG, with growth rates for pasture-fed does of both genotypes appearing to be marginally affected by pasture quality.

Metabolisable Energy Intake (MEI)

Figure 18 illustrates average MEI from week 11 of pregnancy through to parturition and 12 weeks into lactation. Data points were established with a series of 3 day rolling means. Oscillations in daily MEI were similar for animals of both genotypes through trimester one. European does had a slightly higher energy intake over the three weeks prior to parturition than their Hybrid counterparts, with hybrid animals tapering off in their DM intake from week 30. However there was a concomitant increase in MEI by Hybrid animals over the first 6 weeks of lactation. Energy intake of both genotype groups was almost identical from weeks 6 to 12 of lactation, with intakes peaking at 25MJME/day. Given the difference in ME between the two concentrate feeding treatments, DMI varied significantly (P<0.03). DM intake for both genotypes increased gradually from approximately 800g/day at week 10 of pregnancy, 1800g/day 2 weeks into lactation and 2400g at week 10 of lactation. Concentrate-fed E does consumed on average 10.6 MJME / day (SEM ± 0.8) in T2, 13.14 MJME / day (SEM ± 1.4) in T3, and 20.54 MJME / day (SEM ± 2.9) over the first 12 weeks of lactation. Concentrate-fed H does consumed 10.35 (SEM ± 1.1), 13.35 (SEM ± 1.4) and 20.77 (SEM ± 2.7) MJME/day respectively over T2 and T3 and the first 12 weeks of lactation.

The increases in average energy consumption of both E and H does over the latter stages of pregnancy are particularly notable. E does consumed on average 828 MJME (SEM ± 134) in T2, 1102 MJME (SEM ± 96) in T3, and 1736 MJME (SEM ± 73) over the first 12 weeks of lactation. This adds to a total of 3666 MJME over a 238-day period. As does are believed to consume the vast majority of the concentrate offered for the first 6 weeks of lactation (fawns began consumption of concentrate feed at 6 weeks of age), 775 MJME was consumed on average by E does during this 6 week period, a figure comparable with the entire energy intake for T2. Weeks 6-12 of lactation accounted for an average of 961 MJME, also greater than total average T2 ME intake by concentrate-fed E does. Concentrate-fed H does consumed on average 810 MJME (SEM ± 53) in T2, 1117 MJME (SEM ± 118) in T3, and 1756 MJME (SEM ± 88) over the first 12 weeks of lactation.

This gives an average total of 3684 MJME over a 238-day period. E does consumed on average 818 MJME over the first 6 weeks of lactation, which as with their H counterparts, is similar to the entire ME consumption during T2. Weeks 6-12 of lactation accounted for an average of 938 MJME, also greater than T2 MEI for H does.

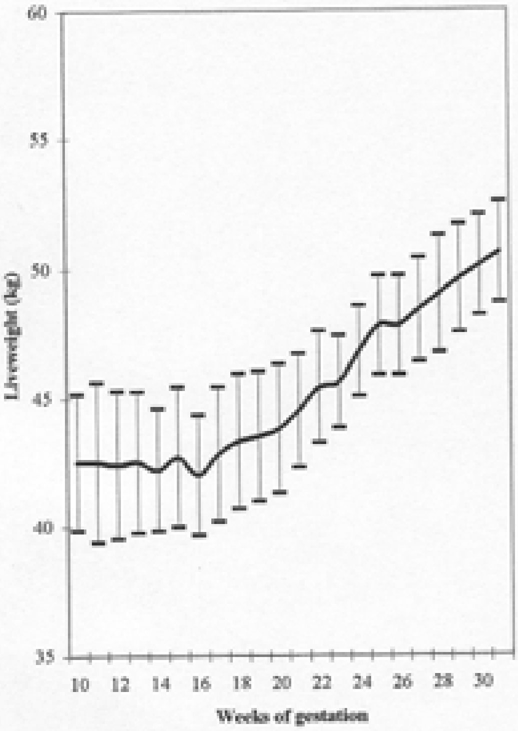

Fig. 14 : Liveweight change (±SEM) of pasture-fed European does from week 10 to 31 of gestation

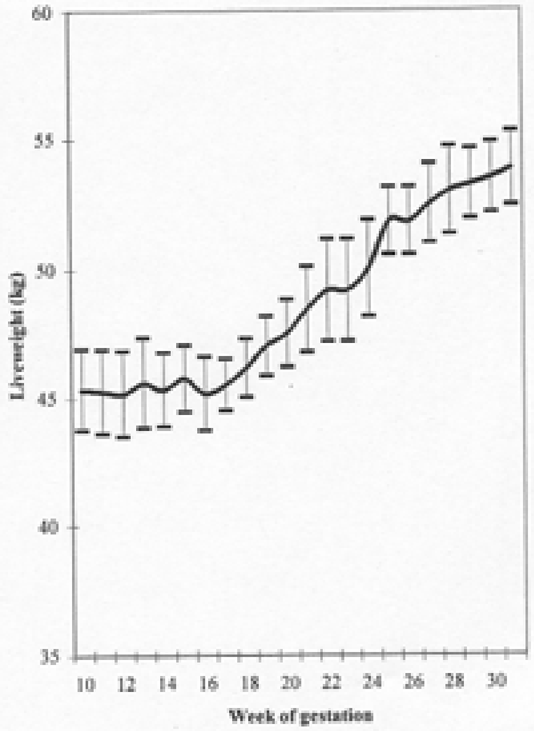

Fig. 15 : Liveweight change (±SEM) of pasture-fed Hybrid does from week 10 to 31 of gestation

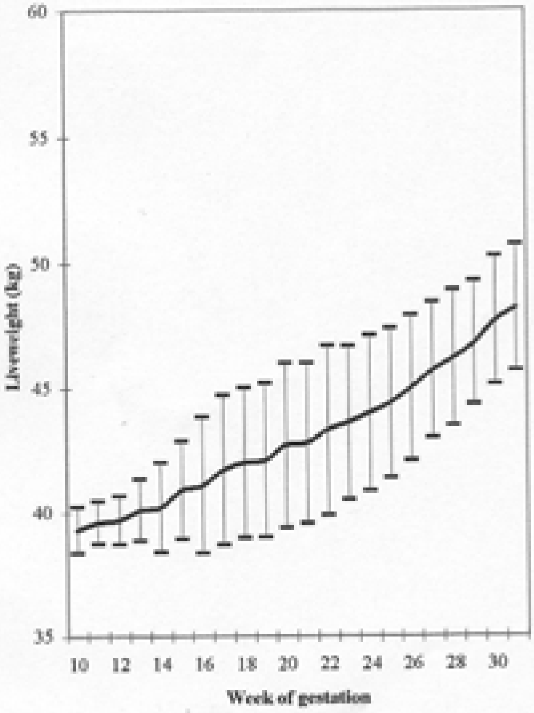

Fig. 16 : Liveweight change (±SEM) of concentrate-fed European does from week 10 to 31 of gestation

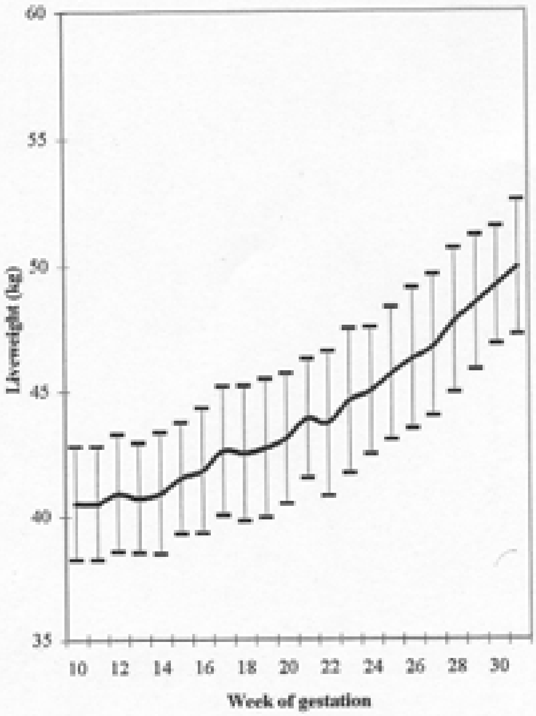

Fig. 17 : Liveweight gain (±SEM) of concentrate-fed Hybrid does from week 10 to 31 of gestation

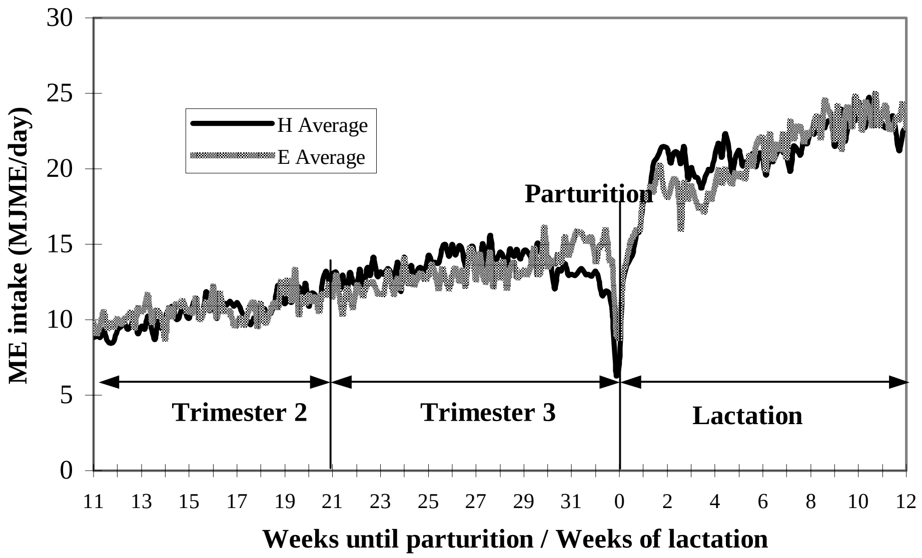

Figure 18 : ME intake (MJME/day) of concentrate E and H does over T2, T3 and first 12 weeks of lactation, 1998/99

Metabolic Bodyweight Energy Intake

Energy intake for E does ranged from 0.58 to 0.81 MJME/kg$^{0.75}$/day and 0.55 to 0.80 MJME/kg$^{0.75}$/day for H does between weeks 12 and 31 of pregnancy. As illustrated in Figure 31, ($W^{0.75}$) was similar for both genotypes in T2, with H does having a higher metabolic bodyweight energy intake over T3, although a similar trend to energy intake (MJME) is seen in the four weeks leading to parturition.

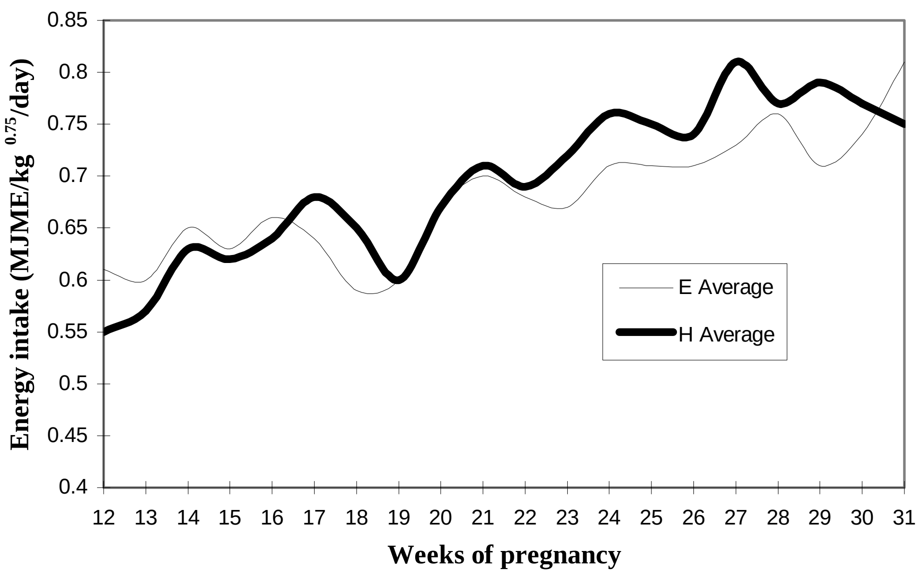

Figure 19 : Metabolic bodyweight energy intake (MJME/kg $^{0.75}$/day) for H and E does from weeks 12 to 31 of pregnancy ; 1998-99.

Fawn Birthweight

Fawns were weighed at birth, 6 weeks and 12 weeks of age. Ten fawns, (4 male and 6 female) were born in the pens over 10 days starting from the 12th of December 1998, although all does in individual pens were diagnosed pregnant on days 30 and 50. It appears one doe was mis-diagnosed pregnant, with her individual feeding records never increasing in trimester 2. Another doe appeared to suffer late embryonic mortality, the cause of which remains undiagnosed. Average gestational length for individually housed E and H does was 232.8 (SEM ± 2.2), and 232.4 (SEM ± 3.5) days respectively, with no significant difference between feeding treatments (P=0.242).

Penned H fawns had an average birthweight of 4.7 kg (SEM ± 0.28), 6-week weight of 14.0 kg (SEM ± 1.6) and 12-week weight of 21.7 kg (SEM ± 1.9), as seen in Figure 20. Penned E fawns displayed similar average weights and patterns of growth, with birth, 6 and 12-week weights being 4.6 (SEM ± 0.15), 13.9 (SEM ± 1.6), and 21.5 (SEM ± 1.1) kg respectively (Figure 21). There were no significant differences in the weights of fawns at birth, 6 and 12 weeks of age between the feeding treatments (P>0.05). There was also no significant sexual dimorphism among fawns, with average birthweights for males and females being 4.6 (SEM ± 0.1) and 4.7 (SEM ± 0.28) kg respectively.

The fawning period for the pasture-fed does occurred over a similar period to their penned counterparts, with fawns born between the 18th of December and the 27th of January (10 days). Two does not diagnosed pregnant (NDP) at day 50 via ultrasonography formed part of the pasture fed group, and fawned in January, having conceived on the second oestrus cycle following synchronisation. The H doe expelled from the pen feeding trial gave birth to a healthy male fawn (5.0kg) despite enduring a period of 10 days of virtually zero feed intake late in the first trimester of pregnancy.

Given the conditions over which the pasture-fed group of does were managed (E and H does in one mob), and the variance in gestation length, it was impossible to accurately match fawns to does, thus fawn birthweight data was not analysed by genotype. There was also no sexual dimorphism among fawns from the pasture fed does, with average birthweights for males and females being 5.1 and 4.9kg respectively. As Figures 20 and 21 illustrate, there were no significant differences in fawn weights between genotypes or feeding treatments. Figures 22 and 23 represent average fawn birthweight (by genotype) as a percentage of doe liveweight at conception, the start of the second trimester of pregnancy and 3 weeks prior to parturition. These relationships were totally dissimilar to the proportions of fawn / doe bodyweight seen in 1997-98. Birthweights for E and H concentrate-fed does would have approximated 3.9 and 4.1kg respectively. Unlike the previous breeding season, does displayed a linear rate of LWG - a visible trend with doe: fawn proportions.

Similarly, pasture-fed E and H does would have had estimated mean fawn birthweights of 4.1 and 4.5kg respectively, with the actual (E and H combined mean) birthweight being 4.9kg, although variations in pasture quality over the early stages of T2 could have possibly affected LWG and resultant liveweight comparisons. However, comparisons of fawn birthweight and doe liveweight over the different stages of gestation were similar across feeding treatments and genotypes.

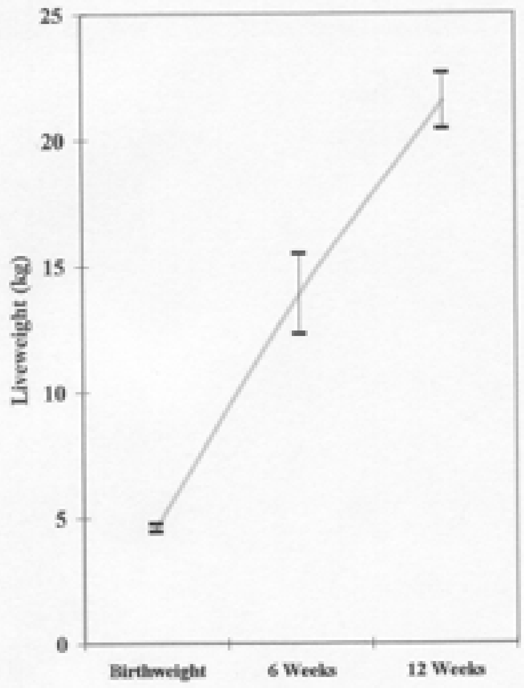

Figure 20 : Mean LWC (±SEM) of fawns from concentrate-fed E does, 1998-99.

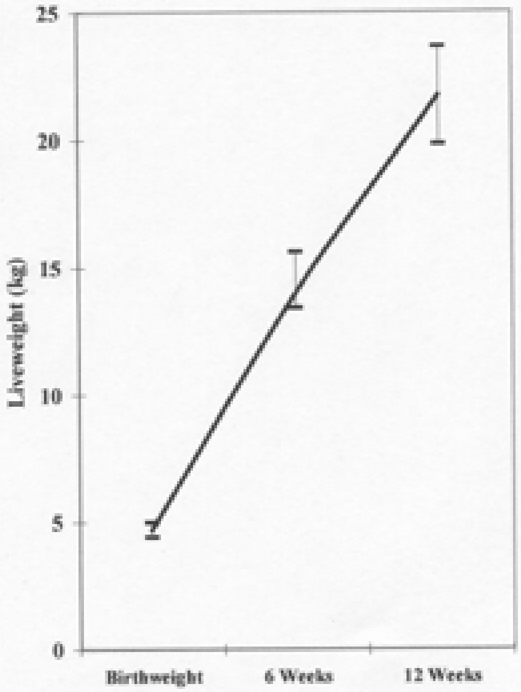

Figure 21 : Mean LWC (±SEM) of fawns from concentrate-fed H does, 1998-99.

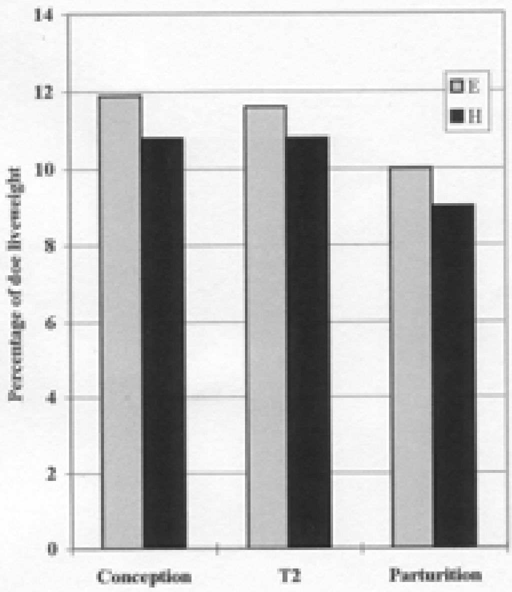

Fig. 22 : Fawn birthweight as a percentage of pasture-fed doe liveweight at conception, T2 and parturition, 1998-99.

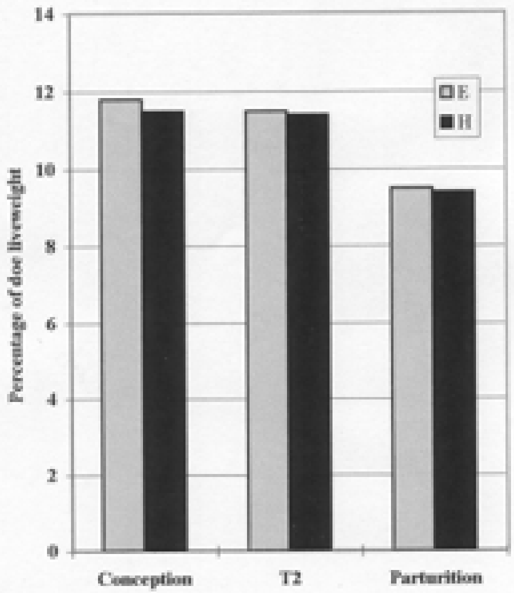

Fig. 23 : Fawn birthweight as a percentage of concentrate-fed doe liveweight at conception, T2 and parturition, 1998-99.

Discussion

As with the 1997-98 breeding season, there was not a 100% weaning rate with experimental does in both feeding treatments, despite synchronisation of oestrus and pregnancy diagnosis at days 30 and 50 post CIDR removal. Ten out of 12 of the concentrate-fed does successfully raised fawns, while there were 2 fawns unaccounted for with the pasture-fed animals, with no signs of predation. This gives respective fawning (and weaning) percentages of 83.3 and 87.5%. While these figures are approximately 8-10% higher than the Australian commercial average (Tuckwell 1999) it is still difficult to explain how up to 15% of does either fail to conceive (given the opportunity of a second oestrus cycle) in controlled conditions with *ad libitum* access to high quality feed.

Other authors have made similar observations on reproductive periodicity in deer. Mulley & English (1991) described such occurrences with farmed fallow does, as has Asher 2000 (pers.comm) involving nutritional experiments with red deer hinds. The occurrence of 'barren' adult females in wild populations of deer is also well documented. Failure to conceive and failure to take pregnancy to full term has been observed in red deer (Guinness *et al* 1978, Clutton-Brock *et al* 1982 and Albon *et al* 1986), and fallow deer (Chapman & Chapman 1975) and such occurrences appear to result from a combination of low body condition scores, age or sub-optimal nutrition.

Initial behavioural responses to isolation by the fallow does in the current experiment were similar to those reported over the previous breeding season. While initial levels of energy intake were low (0.2 - 0.3 MJME/kg $^{0.75}$ / day), feed intake rose to maintenance levels of other ruminants of similar size (0.45 MJME/kg$^{0.75}$/day) within 7-10 days of feeding with MEI rising to around 10.5 MJME/day. There was a more pronounced depression in MEI starting 3 days before parturition than in the 1997-98 breeding season, although energy intake during lactation was less affected by the weighing of fawns compared with the previous year.

The daily ME intake of E and H does over pregnancy was similar to that of Experiment I does. Compared with annual ME intake for non-pregnant fallow does (Mulley *et al* 2000), the first 12 weeks of lactation for E and H does accounted for 57% and 50% of annual ME intake respectively, with the first 6 weeks of lactation accounting for 30% for E and 26% for H animals, of annual MEI. These percentages of annual energy intake compared with non-pregnant fallow does, being marginally higher than those derived from Experiment I, further emphasise feed energy requirements of breeding stock over spring and summer.

Combined, the doe / fawn units of both E and H animals consumed averages of 20.7 and 20.9 MJME /day. Compared with data for non-pregnant E and H fallow does (Mulley *et al* (2000) that consumed 3248 and 3697 MJME annually, pregnant E and H does consumed on average 3666 and 3684 MJME over the 238 day period from week 11 of pregnancy through to the end of 12 weeks of lactation. Unlike Experiment I, there were no significant differences in MEI between concentrate-fed E and H does ($P>0.5$) between trimesters of pregnancy or lactation.

Both E and H concentrate-fed does reached a metabolic bodyweight energy intake in excess of 0.80 MJME/kg$^{0.75}$/day just prior to parturition, and would clearly eclipse the $W^{0.75}$ figure of 1.0 suggested by Oftedal (1984) given the increase in VFI seen over the first 6 weeks of lactation, as with does in Experiment 1. There was no significant difference in fawn birthweight between pasture and concentrate-fed animals ($P>0.05$), nor was there a significant difference between birthweights of fawns from concentrate-fed does of both genotypes ($P>0.05$). Differences in the conception to parturition LWC between genotypes were also insignificant ($P>0.05$), as seen in average fawn birthweights across both feeding treatments.

2.6 Conclusions From Feed Intake Study

Repeating the feed intake study over two consecutive breeding seasons has provided a better indication of doe energy requirements throughout pregnancy and increased the size of the data set for statistical analysis. Energy intake data and liveweight characteristics from 60 pregnant and lactating fallow does of 2 genotypes were collected. Over two seasons, 18 viable fawns were monitored from individually penned does, and 31 fawns from pasture fed does. Statistical analysis of the two years MEI data for penned does has allowed genotypes over the two breeding seasons to be merged because there were no significant differences between years and between genotypes providing a more robust data set on values for energy intake requirements over pregnancy and lactation.

Figure 24 represents the MEI of both genotypes of individually penned does over each breeding season, clearly indicating the consistent trends of energy intake over pregnancy and lactation. Figure 25 illustrates the merging of MEI data of the genotypes within each breeding season. As stated in the relevant discussion of each experiment, there were differences in conception weights over the two years (year 2 < year 1), affecting rates of liveweight change throughout pregnancy. Although no energy intake data were collected over T1, it would be assumed a period of compensatory feed intake and LWG would take place over this period, with body condition score at conception appearing to have no affect on VFI over mid to late pregnancy. However, liveweight characteristics and resultant growth rates per trimester were markedly different between the two experiments, as documented in Tables 1 and 2. Using average birthweight within genotype as a constant, these growth relationships are particularly apparent, as illustrated in Figures 11 and 12 for 1997-98 and 22 and 23 for the 1998-99 breeding season.

However, given the variances in liveweight characteristics, MEI over the two breeding seasons was not significantly different. This raises questions of digestive efficiency and energy utilisation, although this study provides no answers for the mechanisms of nutrient partitioning. Furthermore, there were no significant differences in average fawn birthweights between genotypes and years.

With offspring being the desired and measurable result of pregnancy, merging of data sets could be justified. This has allowed a series of comparisons to be made without differentiating between genotypes, and thus provides a complete set of data for energy consumption from T2 to weaning at 12 weeks of age.

Tables 3 and 4 summarise T2 and T3 data respectively over the two breeding seasons. Using a figure of 10.5MJME/kg DM as an average figure, estimations on dry matter intake (DMI) have been made, with does shown on average to consume close to double their own bodyweight in DM over T2. Due to the variations in LWC, feed conversion efficiency (FCE) values for does over different years varies significantly, although they are still considerably lower than the annual average E (603) and H (544) figures for non-pregnant fallow does (Mulley *et al* 2000).

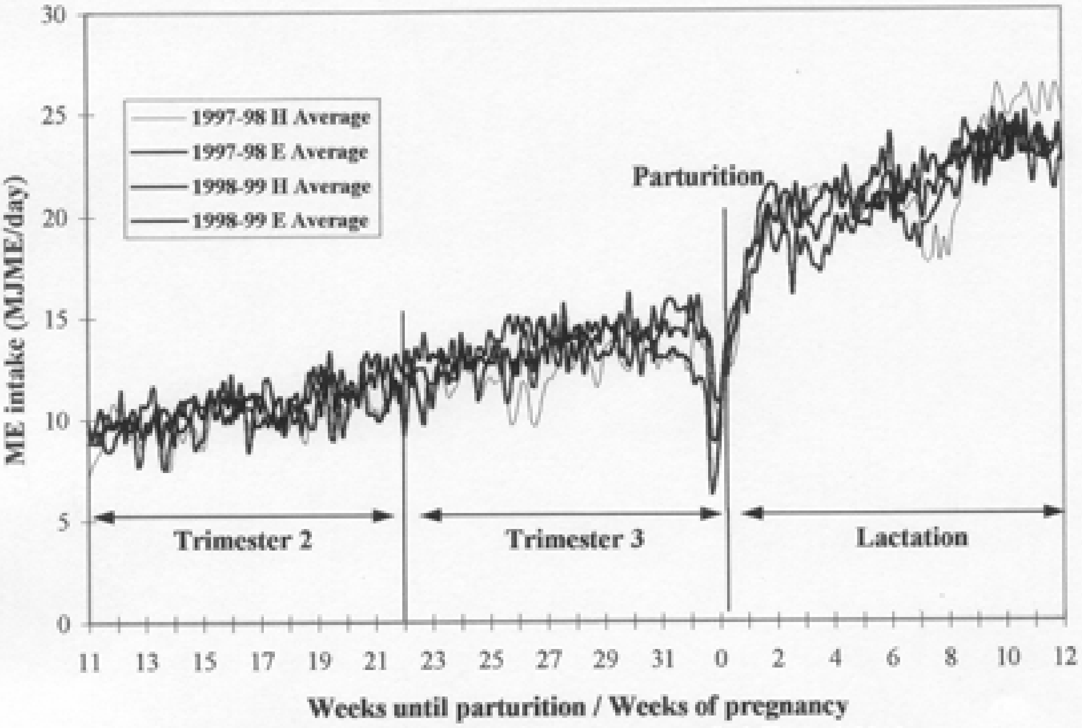

Figure 24 : ME intake of concentrate-fed E and H does throughout pregnancy and lactation over 2 consecutive breeding seasons

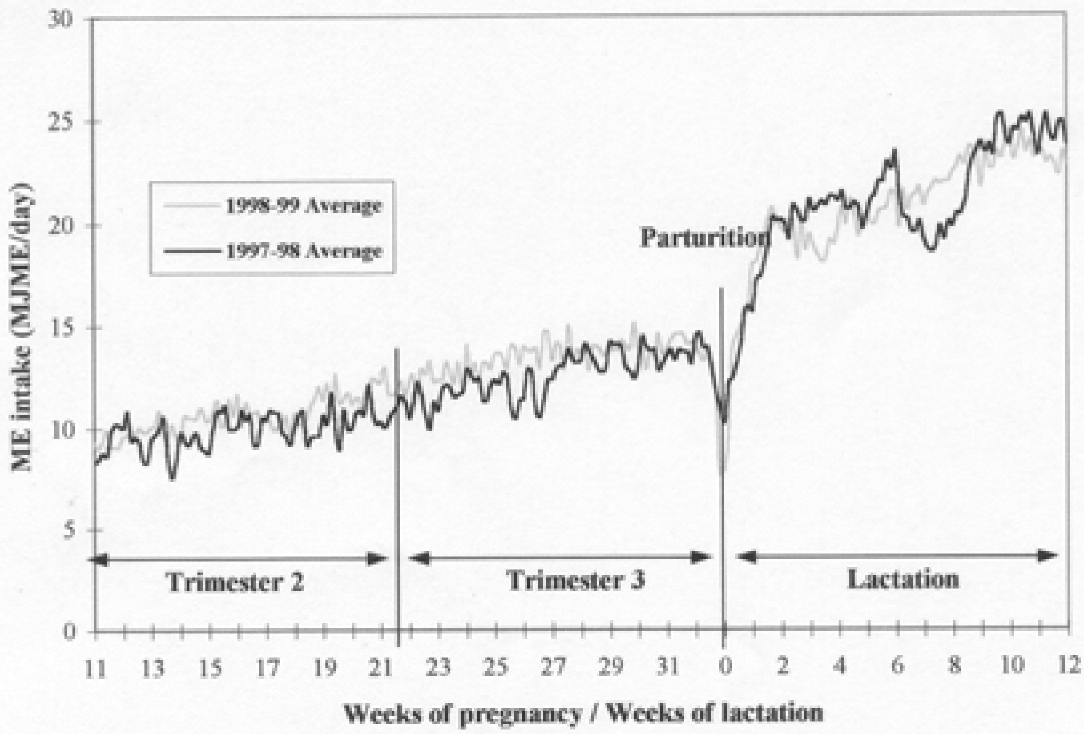

Figure 25 : Average ME intake of fallow does over two consecutive breeding seasons

Table 3 : Average and total MEI, DMI, LWC and FCE of fallow deer of 2 genotypes over the second trimester of pregnancy.

Year and Genotype	Av. T2 ME (MJ)	Total MEI (MJ)	LWC (kg)	FCE (MJ/kg)	DMI (kg)
1997-98 E	10.1	787	1.8	437	75
1997-98 H	9.9	770	2.2	350	73
1998-99 E	10.6	828	3.7	224	79
1998-99 H	10.4	810	3.7	219	77
Average	10.3	799	2.9	307	76

Table 4 : Average and total MEI, DMI, LWC and FCE of fallow deer of 2 genotypes over the third trimester of pregnancy.

Year and Genotype	Av. T3 ME (MJ)	Total MEI (MJ)	LWC (kg)	FCE (MJ/kg)	DMI (kg)
1997-98 E	13.2	1019	6.4	159	97
1997-98 H	12.2	940	6.9	136	90
1998-99 E	13.1	1102	4.9	225	105
1998-99 H	13.4	1117	5.5	203	106
Averages	13.0	1045	5.9	181	99

There were significant changes in MEI characteristics over T3. A more efficient FCE was seen, even with DMI levels averaging close to 100kg over the trimester. LWG over this period was at minimum, the average of fawn birthweight, illustrating the importance of maternal nutrition over T3.

Data averages over the first 6 weeks of lactation (L6) show very little difference between genotypes over the 2 years of the feed intake study (Table 5). Once again, dry matter intake over this period is comparable with the entire T2 intake. There was also no significant difference in average energy intake over the first 12 weeks of lactation (L12) between genotypes or years, as shown below in Table 6. This table clearly shows how feed demand in terms of DMI has doubled since T2.

Table 5 : Average and total MEI and DMI of fallow deer of 2 genotypes over the first 6 weeks of lactation.

Year and Genotype	Av. L6 ME (MJ)	Total L6 MEI (MJ)	DMI (kg)
1997-98 E	19.4	817	78
1997-98 H	19.4	822	78
1998-99 E	18.4	775	74
1998-99 H	19.5	818	78
Average	19.2	808	77

Table 6 : Average and total MEI and DMI of fallow deer of 2 genotypes over the first 12 weeks of lactation.

Year / Geno.	Av. L12 ME (MJ)	Total L12 MEI (MJ)	DMI (kg)
1997-98 E	20.7	1741	166
1997-98 H	19.6	1778	169
1998-99 E	20.5	1736	165
1998-99 H	20.8	1756	167
Average	20.4	1753	167

Tables of trimester and lactation data provide a total energy intake of 3597MJME over the 238-day period of data collection. Combining the two years of data has allowed the following averages to be developed (Figure 26).

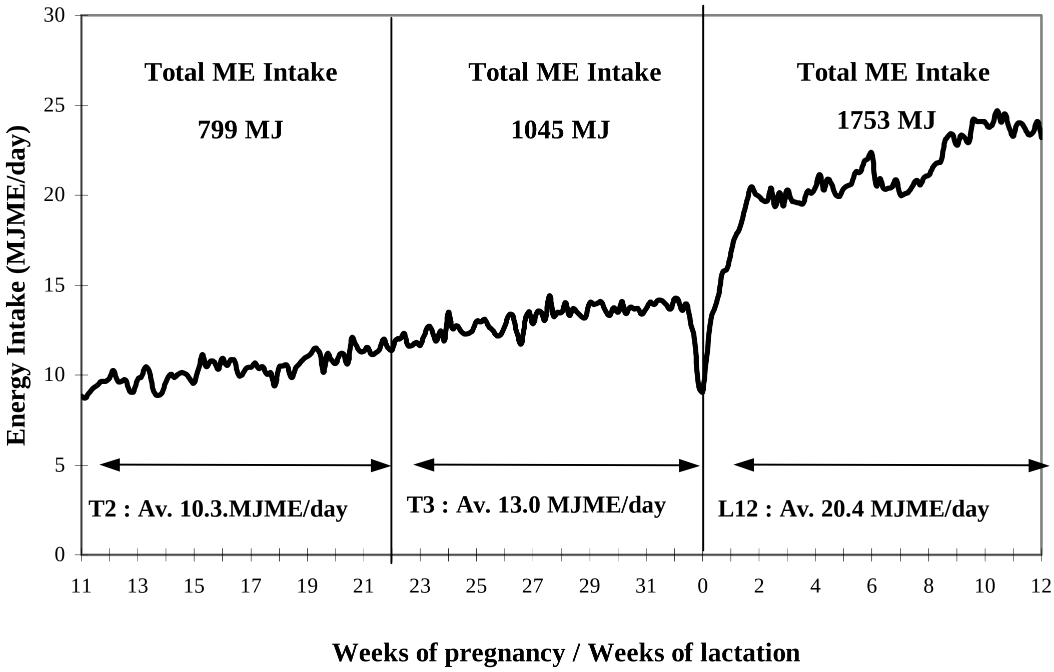

Figure 26 : Metabolisable energy intake of fallow does over the second and third trimesters of pregnancy and first 12 weeks of lactation

Figure 26 summarises the feed intake data for the two years of the study and indicates clearly the energy intake demands of trimesters 2 and 3 of pregnancy, and 12 weeks of lactation, for European fallow deer and hybrids (¼ and ¾ European).

3. Diurnal Feeding Behaviour of Pregnant Fallow Does.

3.1 Literature Review : Feeding Behaviour

Whilst the seasonal fluctuations in feed intake of farmed deer have been well defined, there has been little quantitative data produced on the diurnal patterns of feed intake and changes thereof, during different periods of the production cycle. The seasonal patterns in VFI of farmed red stags and fallow bucks in particular have been well documented in relation to ME requirements, body weight, condition and rutting activity due to the obvious and visual metabolic impost of reproductive behaviour (Suttie *et al* 1983, Mulley 1989, Asher 1993), however, the diurnal patterns of feeding activity of farmed deer, particularly breeding stock, have not been as extensively studied.

The aforementioned studies were mainly concerned with the effects of photoperiod on VFI. The influence of photoperiod could be considered to operate at two levels, i) through its effect on the pattern of melatonin secretion providing a seasonal cue for increased or decreased levels of feed intake and ii) through the direct stimulus of daylight to feeding behaviour (Sibbald 1994). Thus, while is has been shown that photoperiod has a definite affect on VFI with temperate species of deer, there is evidence to suggest that photoperiodic changes also affect diurnal patterns of grazing activity, autonomous of feed supply, as has been documented with penned red deer stags (Sibbald 1994).

Patterns of feeding behaviour of free-ranging red and fallow deer have been extensively studied in relation to seasonal variations in feed availability and forage preferences (Jackson 1977, Chapman & Chapman 1975, Thirgood 1995) and lactation (Clutton-Brock *et al* 1982a), and it is apparent from these studies that the temperate species of deer show distinct diurnal rhythms of feeding behaviour, with peaks of feeding or grazing activity around sunrise and sunset. Similar patterns of feed intake have also been observed with housed red deer (Sibbald 1994, Sibbald & Milne 1997).

There have been few studies on feeding behaviour of fallow deer, although a study by Mattiello *et al* (1997) on a population of confined mixed sex fallow deer also showed this species to conform to a mainly crepuscular pattern of feeding activity, with evening being the preferred time for grazing pastures; an observation shared by Thirgood (1995) during studies on seasonal foraging behaviour of free-ranging fallow deer, with both authors linking social and herding behaviours of fallow deer to the proclivity to graze in open areas nocturnally.

In relation to the current study, Clutton-Brock *et al* (1982) showed that pregnant and lactating free ranging red deer hinds spent significantly longer grazing than dry hinds, both in terms of the number and duration of individual feeding sessions. Although the amount of time spent grazing by lactating hinds over dry hinds during a 24 hour period was not commensurate with the large differences in energy requirements between the two, these data demonstrate that diurnal patterns of feeding activity are also affected by reproductive status and resultant energy requirements, as well as photoperiod / daylight cues.

Relevance of Feeding Knowledge to Industry

Knowledge of diurnal patterns of feeding behaviour may be of importance in several production and research applications. In relation to commercial deer production, management of stock and pastures to accommodate diurnal patterns of feeding activity may benefit both pasture-fed and concentrate-fed (and concentrate-supplemented pasture-based deer) and may have implications for efficiency of pasture utilisation, and ultimately patterns of growth. Although other aspects of the behavioural plasticity of fallow deer to production situations have been well noted, the ability of farmers to accommodate feeding behaviour of their stock may have possible productive advantages.

As well as allocation of pasture availability to grazing stock, farmers also have direct control over the feed intake patterns of their stock at certain times of the year, particularly over the Winter months in Australia and New Zealand where the diet of most deer in whole or part, comes from concentrate sources. Furthermore, allocation of feed on a daily basis either as pasture or concentrate, can be carefully controlled in the same way that feed is allocated to intensively farmed dairy cattle. The concept of strategic feeding as prescribed by Suttie *et al* (1996) may be implemented to embrace known diurnal patterns of feeding by farmed deer. With the relationship between VFI and liveweight gain well documented in growing deer, farmers would do well to ensure VFI is maintained at its maximum level.

3.2 Methods

The investigations into feeding behaviour of fallow deer consisted of 2 main components, i) the monitoring of individually housed concentrate-fed pregnant does, and ii) pregnant pasture-fed fallow does. Feeding behaviour of individually housed pregnant fallow does was monitored 24 hours a day, 7 days a week from August 1997 to March 1998 when fawns were weaned. Pasture-fed does were monitored at regular intervals for two 7-day periods during T3 (1997) and mid lactation 1998.

Pen Fed Does

Patterns of feed intake and times of feeding were monitored for individually housed concentrate-fed fallow deer (n=6) from August 1997 to March 1998. Diets and handling of the animals were discussed previously. The monitoring unit used in the trial consisted of a purpose built microprocessor based data acquisition unit located adjacent to the six trial pens and linked via a serial cable to a 286 desktop computer located approximately 45 metres away in the deer research unit office. Temperature, light and proximity sensors located in the pens were wired into the data acquisition unit.

The data acquisition unit was based on a MICROCHIP P1C16C84 RISC microprocessor coupled to a MAXIM 186 eight channel 12 bit analogue to digital converter. This configuration provided 8 analogue input channels for temperature and ambient light measurement and utilised unused digital I/0 pins on the microprocessor to be used as digital inputs for sensing the presence of the deer at the feeders. The microprocessor acted as a slave device and was programmed to reply to single character commands issued from the desktop computer. An AD 590 temperature sensor was placed in each pen to measure the temperature and was located on the northern wall approximately one metre above ground level (adult deer height). A single light dependent resistor (LDR) was located in the pen area to give a reading of the light intensity representative of the ambient light in the pens. The six temperature sensors and the light sensor were connected to the first seven analogue channels on the data acquisition unit.

Off the shelf infra red (IR) intruder detectors were modified to detect the presence of the deer at the feeders. The IR detectors were placed in a rectangular tube to restrict the detection zone to a similar shape and size to that of the feeders and were placed directly above the feeders just above door height. The outputs of the detectors were each connected to a separate digital input on the data acquisition unit.

A relatively simple program was written in VISUAL BASIC for dos which ran on the desktop PC. This program simply polled the data acquisition unit when required for the current value or status of any of the inputs it required and formatted and stored the data received in a file on the hard drive of the PC. A separate unique data file was created for each day and for easy recognition the file name reflected the date eg 0511 1997.txt was the data file for the 5th of November 1997. The logging was set at 5 minute intervals. Each of these 5 minute intervals were subdivided into 100 sub periods each of 3 seconds duration. Each 3 seconds all the IR detectors were scanned for the presence of deer at the feeders. A separate counter for each pen was incremented if the result for that pen was true. At the end of each logging period (ie 100 scans) the temperature for each pen, the ambient light level and the occupancy count for each pen was written to the hard disk and the counters for each pen reset to zero. As a result of this procedure each five minutes the temperatures and light level were recorded along with the percentage of time each animal had spent at the feeder.

As shown in results for individually penned deer, a program was written to display a graph of temperature or light and total visits to the feed trough (vertical black bars) for each day of the feeding trial. Graphs are presented in minutes from midnight, with the thickness of vertical bars over time indicating the duration of feeding. Each ‘print window’ indicates the date, maximum and average temperatures, the pen selected and total time at the feed trough for the pen selected. A total number of visits for each deer in the other pens are also visible on the screen, allowing the researcher to compare with other pens. Data for feeding activity could be viewed for individual deer or concurrently, with a threshold number of deer (between 2 and 6) able to be selected to correlate feeding events between different pens.

Pasture-fed Fallow Does

Grazing activity and behaviour of a selected number of pasture-fed does (n=9 out of 18 does) from Experiment 1 were monitored over two 7-day periods from the 27th of September to the 3rd of October (T3) and from the 9th to 14th of February 1998 (during mid-lactation). Does were fitted with numbered collars for identification. Does were monitored from a loft situated in the deer handling shed, approximately 120m from the paddocks in which the deer were located. The loft was elevated approximately 4m above ground level and provided a clear view of the paddocks, with the deer being unaware of the presence of the researcher. Collar numbers of individual does were identified by a 20-60X telescope with ear-tag numbers and colours also used as secondary means of identification. The pastures grazed by these animals were described earlier.

Observations by other authors (Chapman & Chapman 1975, Kilgour 1988) and initial observations on feeding behaviour of individually housed fallow deer suggested that fallow deer follow a crepuscular pattern of grazing activity, grazing for several hours after dawn followed by a period of ruminating and sleeping, before resuming grazing activity before dusk. Accordingly, does were monitored for the first 3 and a half hours after sunrise (5:00 to 8:30am), during the middle of the day from 12:00 to 2:00pm, and during the 3 hours before sunset (4:30 to 7:30pm). Activity was monitored 6 times per hour (every 10 minutes) with feeding status classified as either grazing or non-grazing. Animals non-grazing were classified as sitting, ruminating or other, such as grooming, playing or reacting to disturbances.

3.3 Results

The results of individually housed does and pasture-fed does are documented separately. The methods for observing patterns of feed behaviour with individually penned does provided continuous 24 hour information on patterns of feed activity, with video footage also available from certain pens, providing additional information and conformation of feeding and other activity. Data on doe presence at feeding troughs was segmented into 1-hour blocks and analysed. Preliminary data on timing and periodicity of feeding events from individually housed animals was used to inform the observations on the pasture-fed does, allowing basic trends on feeding activity to be seen.

Individually Housed Fallow Does

There were several measures of feeding activity thought to be reflective of changing nutritional requirements over the duration of the individually housed doe experiments. Firstly, the elevated levels of VFI and subsequent ME intake over lactation were thought to be correlated with the number of visits to the feed trough. Temperature was also a limiting factor to feed intake along with the temperament of certain H does in relation to the proximity of the pens to the road and noise associated with deer handling, road traffic and people.

All individually housed does conformed to 3 main periods of feeding activity over a 24-hour period. The first main period of feed intake took place during early morning, starting before sunrise and ending 2.5 (SEM±0.45) hours later, with all does being present at the feed trough at some point during this period ($P<0.01$). The second main period of feeding occurred just prior to sunset ($P<0.01$) and lasted for 1.7 (SEM±0.52) hours. The third and most prolonged period of feeding occurred around midnight ($P<0.01$) and lasted for 2.3 (SEM±0.52) hours. Figures 27 and 28 are examples of common diurnal feeding profiles of penned does in this study, showing the relationship of daylight to dawn and dusk feeding events.

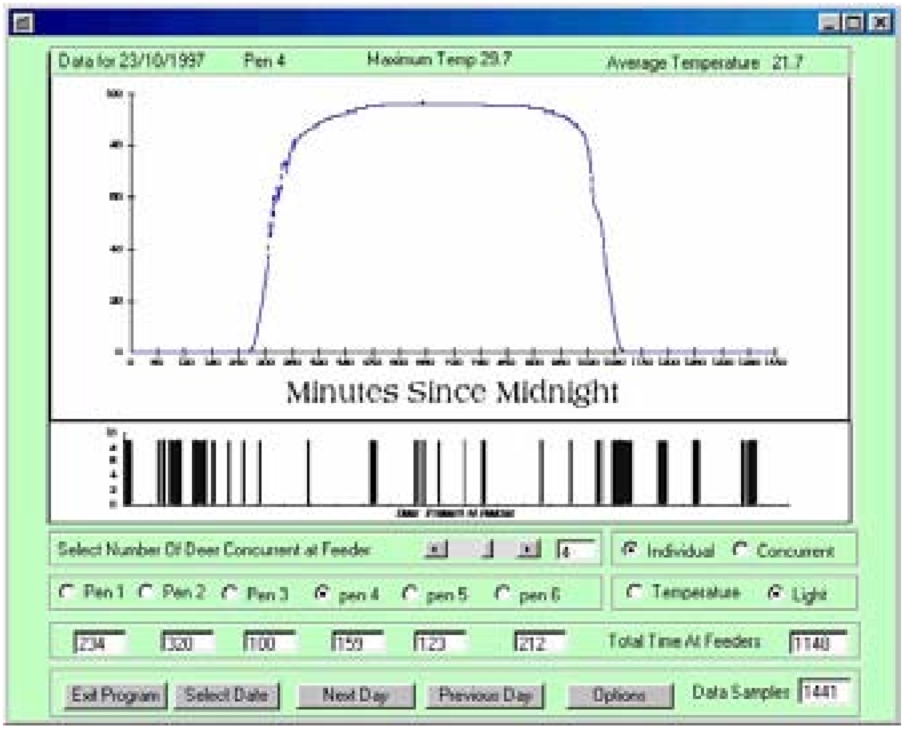

Figure 27 : Diurnal pattern of feeding activity of a pregnant doe during T3, displaying regular feeding intervals

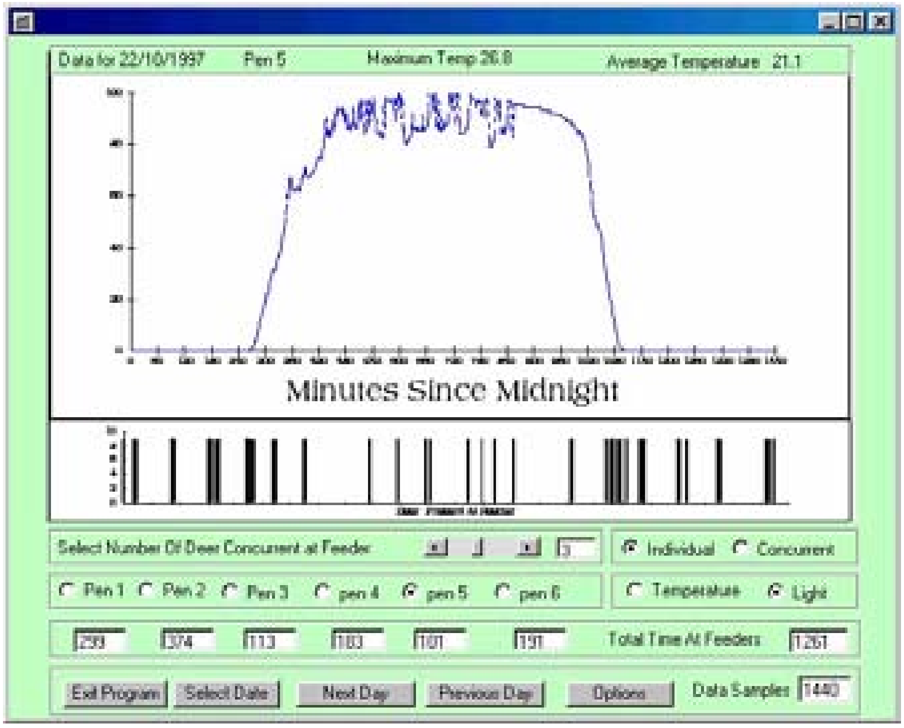

Figure 28 : Diurnal pattern of feeding activity of a pregnant doe during T3, displaying inconsistent feed visits

Several does also displayed significant periods of feed during the middle of the day, although this period was not significant across all replicates in this study. Intermittent bouts of feeding were often observed during the night, although there were no significant patterns to these feeding events. Figure 27 illustrates a typical pattern of diurnal feeding activity of does who conformed to a predominantly crepuscular pattern of feeding behaviour, with another major feeding event occurring around midnight, while Figure 28 illustrates the diurnal patterns of feeding activity of a doe who had short regular visits to the feed troughs at other times of day and night.

Anecdotal information from feed intake and animal handling procedures suggested that the animals displaying intermittent short bouts of feed intake were generally flightier and harder to handle during weekly weighing than does who conformed to regular patterns of feed intake. One of the H does who failed to fawn from undiagnosed reasons also displayed inconsistent feeding patterns, adding strength to the observation that the temperament of individually housed does was reflected to a certain extent by patterns of feeding behaviour.

However, the high levels of sensitivity of movement detectors located above each feed trough may have inadvertently recorded feed visits without the presence of a deer at the feeder. Rats, mice and birds were observed on videotape from several of the monitored pens, with feed data on several occasions logging these periods as feeding events. Given this, data for patterns of feeding were analysed on movement at feeding troughs for a set threshold of 4 out of 6 pens over one hour averages in an attempt to discount false readings of feeding events from vermin or from deer just walking to the door of the pen to look outside. At the conclusion of the trial once deer were removed from the pens, the feed troughs were re-filled and data logging kept in place to determine the level of false readings from vermin. As shown in Figure 29, the majority of false readings were derived from the presence of birds during daylight hours, and occasionally rats during darkness. Both animals were observed via video to consume feed in the absence of deer, although it is unsure whether relative levels of error associated with vermin increased or decreased with the presence of deer in the pens.

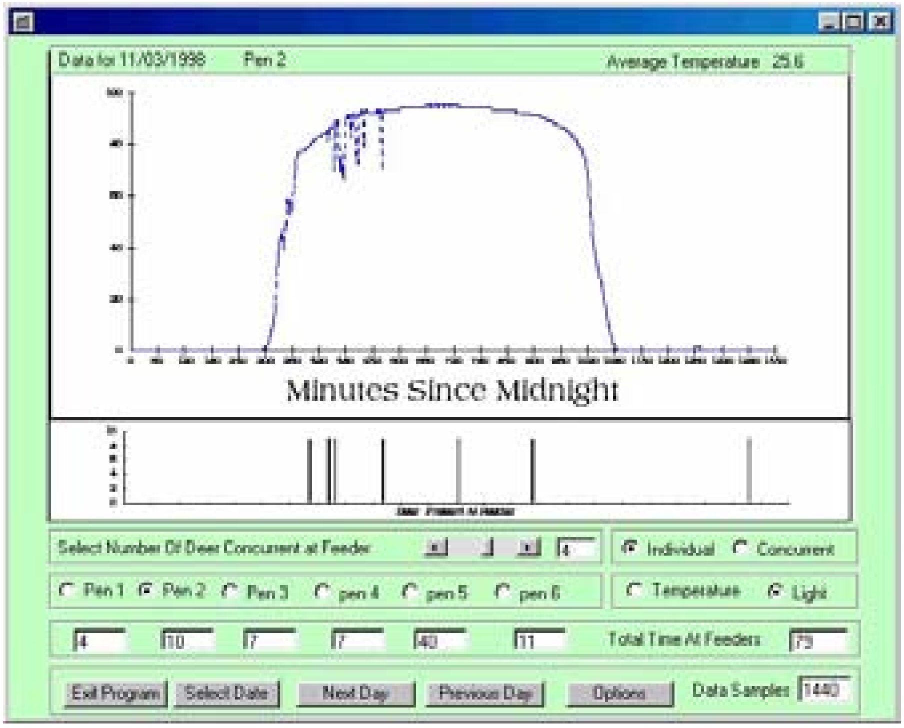

Figure 29 : Graph of movement in a pen after deer removal, indicating the presence of birds and rodents at the feed trough

As Figures 27 and 28 indicate, there were differences in feeding patterns between does of varying temperaments during T3, although there were no significant differences in total ME intake between these animals over 3 consecutively analysed days (P=0.489). Temperature had a significant effect on feed intake. It was shown that temperatures above 35°C during a recognised period of feeding activity (sunrise and sunset) negatively affected feeding behaviour (P=0.002). Reduced feeding time during periods of high temperature also suppressed average feed intake over a 24-hour period (P=0.020). Conversely, average ambient temperatures over a 24-hour period below 20 °C during recognised periods of feeding increased the average length of time by each doe spent at the feed trough (P=0.033). Does also spent on average greater time feeding at other times of the day when temperatures were below 15 °C. Temperatures in between these maximum and minimum thresholds had no significant effect on time spent at the feed through, or on feed intake.

The increase in MEI over the first 6 weeks of lactation (P=0.000) was reflected by the increased number of visits to the feed troughs (Figure 42), with individual visits being significantly higher (P<0.001). As with feeding behaviour during T3, patterns of feeding activity between does of varying temperament did not change during lactation, with flighty does still not conforming to even and lengthy bouts of feeding activity. The increase in feeding activity during lactation was positively correlated with MEI, although there were statistical differences between timing or duration of feeding events between the high and low energy rations (P=0.506). The observations on relationships between VFI, compensatory feed intake and stress activities were not reflected by the number of visits to feed troughs, with number or periodicity of pen visits by individual does not significantly affected (P=0.587) the following day after stress events such as weighing or pen cleaning.

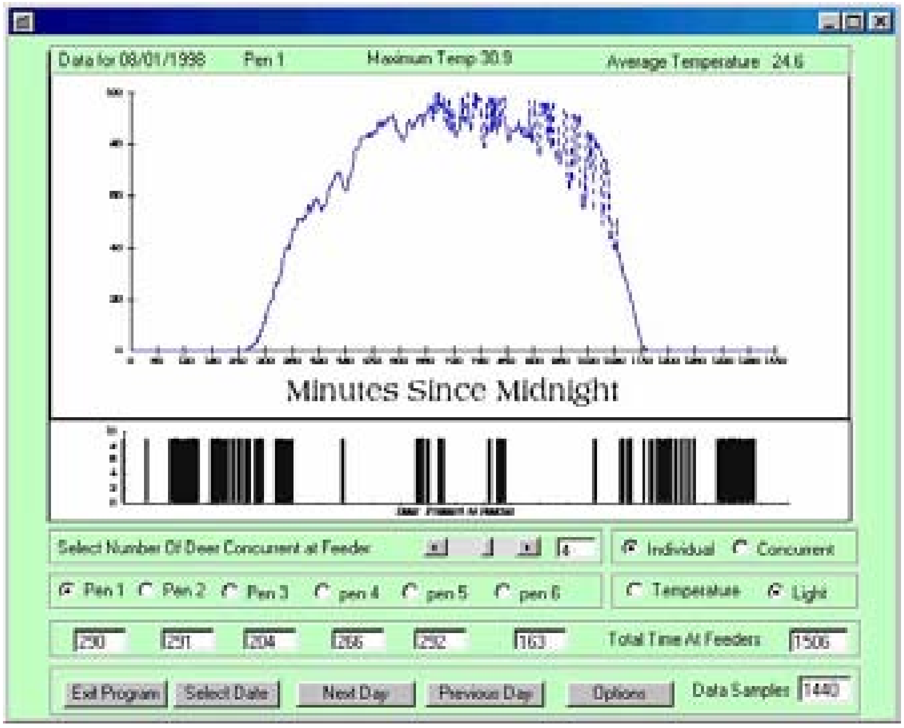

Figure 30: Diurnal pattern of feeding activity of a doe during early lactation, displaying regular feed visits

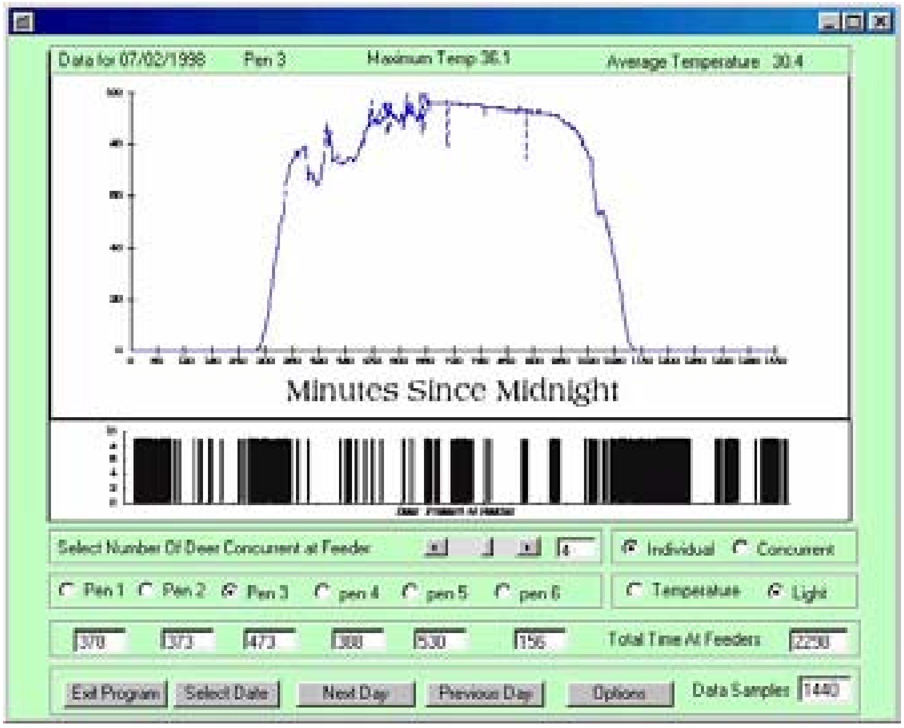

Figure 31 : Diurnal pattern of feeding activity during mid lactation, indicating the large number of pen visits due to both the doe and fawn consuming concentrate feed

Fawns were also thought to make considerable contributions to the overall number of visits, especially throughout weeks 6-12 of lactation. As illustrated in Figure 31, the number of visits to the feed troughs increases significantly during mid lactation when fawns began eating concentrate feed. Video surveillance from several of the pens suggested that even when suckling, fawns follow similar patterns of diurnal feeding behaviour to their mothers. Data on diurnal feeding patterns from individually housed weaned fawns (see next section) also suggested that patterns of feed intake post-weaning follow that of adult does.

Pasture-Fed Fallow Does

Patterns of feeding activity of pasture-fed does were very similar to individually housed concentrate-fed does. One of the main differences between feeding activities between the concentrate and pasture-fed does were the interactions by pasture-fed animals in a group situation. Feeding activity of penned does appeared to be triggered by either daylight or hunger, with no visual stimuli between does to signal the beginning or completion of a feeding session. Contrastingly, pasture-fed does in this study appeared to be greatly influenced by other deer in the mob, with individual does appearing to instigate feeding periods, direction of grazing, resting and resultant rumination. Such allelomimetic behaviour by fallow deer has been documented elsewhere (Chapman & Chapman 1975, Kilgour 1988) and is common with gregarious herd animals. Despite the available pasture area for does to forage, the animals predominantly grazed as a mob, with individual does rarely leaving the group formation.

Whilst the does appeared to be acclimatised to the research environment at UWS-Hawkesbury, disturbances were frequently seen during the course of the observations. The majority of disturbances that caused disruptions in grazing activity were mainly visual distractions, with the deer being almost totally desensitised to frequent aircraft and traffic noise. While on certain occasions, vehicles that stopped next to the deer fence, or close proximity of horse riders temporarily interrupted grazing activity, there were few occasions where an alarm bark by one or more does would precipitate into movement away from the disturbance. During evening observation sessions, the does appeared to be even less affected by people near the boundary fence and disturbances were almost zero. However, when alarmed, the does quite often would not resume normal patterns of grazing for between 5 and 10 minutes.

Feeding behaviour varied between the three daily observations periods, and between the T3 and mid-lactation observations. Figures 32 to 34 represent grazing trends of does during T3 during the morning, at midday and evening respectively.

T3 Morning Observations (5-8:30 am)

Morning feeding observations commenced at 5:00am during T3. The weather, sometimes made individual does difficult to distinguish due to both distance from the observation deck and low light conditions. Consequently, does were viewed before daybreak on a number of occasions, and found to be grazing well before sunrise before average numbers of does participating in grazing behaviour dropped (Figure 32), with the majority of animals resting and ruminating by 2-2.5 hours after sunrise. During the first major period of grazing activity between 5:00am and 6:30am, indicated that 82% of animals were actively involved in grazing behaviour, with 49% of animals grazing for the total observation period.

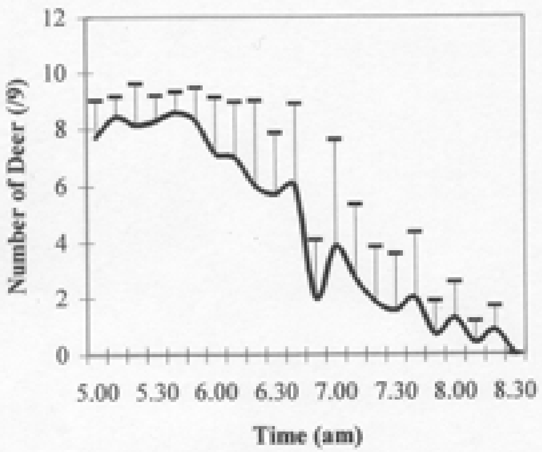

Figure 32 : Mean number of does observed grazing (±SEM) over the first 3 hours after sunrise during T3

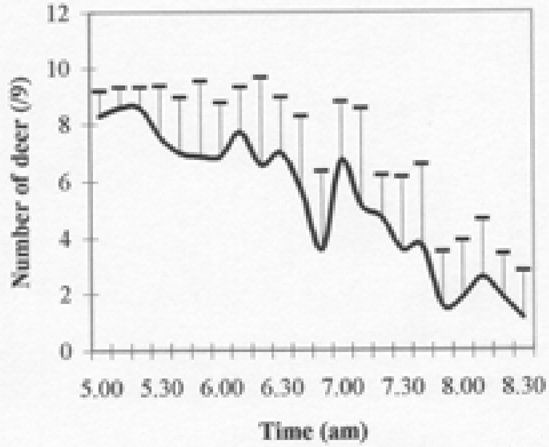

Figure 35 : Mean number of does grazing (±SEM) over the 3 hours after sunrise during mid lactation

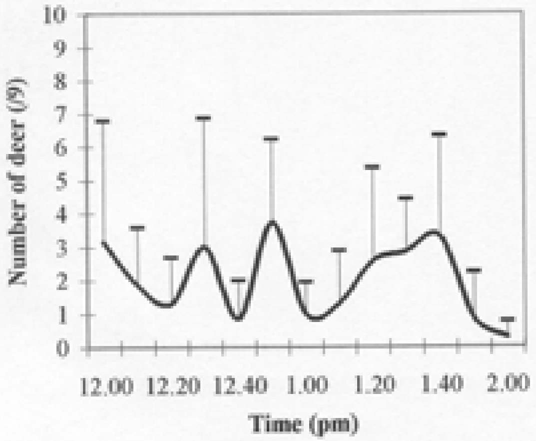

Figure 33 : Mean number of does observed grazing (±SEM) between 12 midday and 2pm during T3

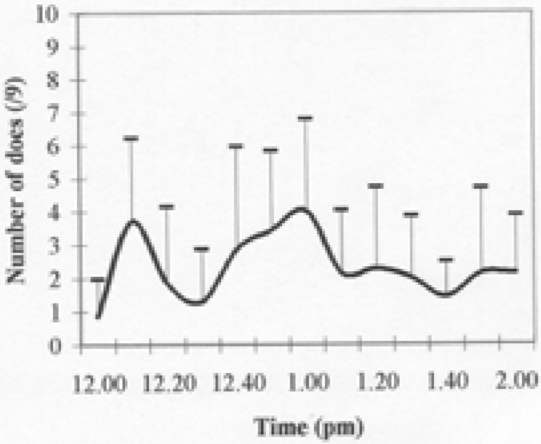

Figure 36 : Mean number of does observed grazing (±SEM) between 12 and 2 pm during mid lactation

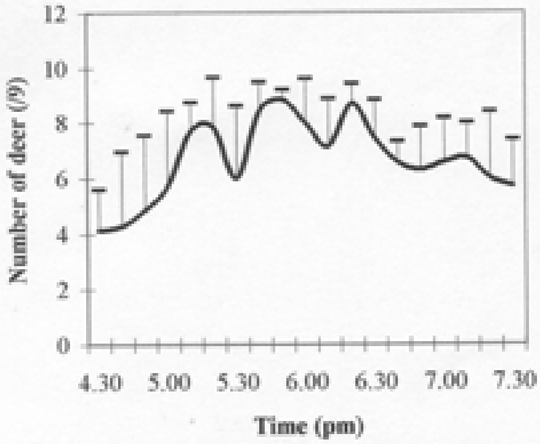

Figure 34 : Mean number of does observed grazing (±SEM) over the last 3 hours before sunset during T3

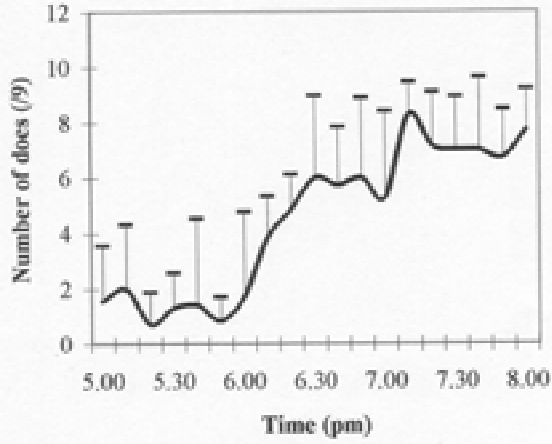

Figure 37 : Mean number of does observed grazing (±SEM) over 3 hours before sunset during mid lactation

T3 Midday Observations (12-2pm)

Unlike the morning observations on grazing behaviour, there was no clear trend on feeding activity during this time period. Although does were observed to graze for a total of 22% of this time period, there were no individual sustained grazing periods (Figure 33), with the majority of deer ruminating. Whilst there appeared to be no hierarchical effects on grazing during the morning observations, the dominant does attempted to maintain their positions under the limited shade provided by several trees in these paddocks. As a result, most grazing activity occurred after individual does had been displaced from their resting areas by more dominant animals. As shown in Figure 33 the SEM during this observation period was quite high, with no clear trends of grazing patterns or duration. Although not evident in Figure 33, there was light to moderate rain and lower temperatures on two of the observation days, which was associated with sustained periods of grazing around midday.

T3 Evening Observations (5-8pm)

As with the grazing activity around midday, there appeared to be no significant trends in feeding behaviour during the afternoon periods, with individual doe behaviour very inconsistent during these evening observations (Figure 34). Whilst there was a sustained period of grazing activity throughout the observation periods (74% of does feeding), feeding behaviour appeared to be very social, and unlike during the 5:00 to 6:40 am grazing period where the majority of animals would put their heads down and graze whilst standing or at a slow walking pace, does were 'searching' for newer or fresher feed, and would often walk and graze without stopping.

Mid-Lactation Morning Observations (6:00 - 8:30am)

Patterns of morning grazing during mid lactation were similar to mornings during T3. From sunrise to approximately 6:30am, the majority of does grazed continually, although bouts of suckling activity disrupted the individual grazing patterns of deer sporadically. Although not recorded, fawns appeared to follow similar patterns of grazing to the does. Unlike morning feeding behaviour during T3, there was a gentler decline in grazing activity from approximately 2 hours after sunrise to the end of the observation period at 8:30am (Figure 35).

However, as the SEM indicates, while the period of grazing was prolonged, the number of does grazing at any given point in time was unpredictable. It is not possible to say whether the increased energy demand during lactation increased average grazing time, or whether disruptions to feed intake caused by suckling and other fawn related disturbances lengthened the amount of time actively spent grazing by individual does. However, does grazed for 59% of the time during the observation period, and given the average number of animals grazing at sunrise, it would be assumed that the morning feeding session started well before dawn. Does in pens often commenced feeding before dawn, and overall the patterns of feeding activity for concentrate-fed and pasture-fed deer were very similar, so this would appear to be a reasonable assumption.

Mid-Lactation Midday Observations (12-2pm)

As with midday observations on grazing behaviour during T3, there were no set patterns of feeding activity during mid lactation (Figure 36) although does engaged in feeding behaviour 25% of the time during the 2 hour period. Temperature also affected both the number of does grazing and duration of feeding periods, with heat being a limiting factor to grazing activity on two of the observation days. The reverse of this trend was seen on an overcast day, where a larger proportion of does were observed grazing during this session.

Mid-Lactation Evening Observations (4:30-7:30pm)

As with patterns of feeding activity around midday, afternoon and evening feeding activity appeared to be affected by temperature. There were no significant trends in feeding patterns until after 1 hour of observations, where grazing activity increased significantly (Figure 37). Social interactions between does and fawns were a feature of the afternoon and early evening observations. Does fed for 74% of the time from 6:30 - 8:00pm, with feeding continuing on after observations ceased.

Discussion

Patterns of feed intake by individually housed pregnant does in this study reflected characteristic seasonal patterns of VFI, with visits to the feed troughs increasing from Winter through Spring and increasing dramatically in Summer with the increased ME demand of lactation. The feeding patterns of one doe who failed to fawn through either being mis-diagnosed pregnant or through foetal loss, showed significant increases in feeding activity from October through to Mid December, when hours of daylight peaked at 14.2 hours/day. While patterns of VFI from studies on housed red deer stags have suggested strong photoperiod effects of feed intake in relation to daylength (Sibbald 1994). However, the association between daylength and feed intake could not be measured with individually penned fallow deer in the current study, as volumes of feed consumed at each feeding event could not be measured.

If it is assumed that the prolonged presence of a doe at a feeding trough indicates feed intake, it could be said that daylight regulates the two largest feeding events measured with fallow does. Thus, the gregarious nature and herding structures of feeding activity seen with free-ranging fallow deer described by other authors (Chapman & Chapman 1975, Thirgood 1995) appear to be triggered by photoperiod, and followed individually without obvious visual cues from other deer. While individually penned does may not have been able to clearly see does in neighbouring pens, it is likely that they may have been able to hear other does eating from the feeders which may have played some role in the synchrony seen in major feeding events with these deer.

Observations of pasture-fed does suggest that morning feeding activity starts before daylight and steadily declines 1.5-2 hours after sunrise, while afternoon feeding activity commences approximately 1.5-2 hours before dusk and intensifies at sunset. Individually housed does also displayed a similar periodicity of feed intake, although there were much stronger feeding periods around midday and midnight. As observations of feeding activity with pasture-fed does were not able to be undertaken during the hours of darkness, the extent to which grazing takes place before sunrise, after sunset and, as with penned does, at midnight, is not known.

While observations on both individually penned and pasture-fed deer revealed similar diurnal patterns of feeding behaviour between the two groups, individual patterns of feeding activity were also shown to be widely varied within each group. Individual variations in diurnal patterns of feeding with individually housed animals were shown to be affected by temperature and stage of gestation, and although there were no statistical difference in patterns of feed intake after stress events such as weighing or pen cleaning, even though VFI was shown to be lower on days following such procedures. While the observations on pasture-fed deer did not generate sufficient data for statistical analysis of diurnal patterns of feeding activity, the data does indicate strong trends towards crepuscular patterns of feeding, as has been observed with this species by other authors (Thirgood 1995, Mattiello *et al* 1997), with little average deviation in feeding periodicity seen between pen-fed and pasture-fed animals.

Other studies on grazing behaviour of deer have found feeding activity higher in the evening than morning (Sibbald 1994, Mattiello *et al* 1997), although pregnancy status, temperature and feed quality have also been demonstrated to have an affect on both duration and periodicity of feeding events. In this study, it was difficult to compare patterns of feeding behaviour with pasture-fed does throughout pregnancy with grazing patterns during lactation, primarily because of the much lower pasture quality during mid-lactation and confounding effects of high Summer temperatures.

As graphs of feeding intensity for pasture-fed does during pregnancy (Figures 32-34) and mid-lactation (Figures 35-37) illustrate, there were no distinct differences in grazing patterns between late pregnancy and mid-lactation, despite the increase in daily ME intake requirements by lactating does, and lower pasture ME values which should consequently lengthen grazing time, as observed by Clutton-Brock *et al* (1982a) with lactating red deer hinds. Although the duration in grazing events for lactating hinds during that study were not commensurate with large increases in ME requirements compared with non-pregnant hinds, pregnant hinds still grazed for longer than dry hinds. Comparatively, for the period of time for which pasture-fed does were observed during lactation, average periods of grazing activity did not reflect the increased ME intake as expected. It is assumed however, that pre-dawn feeding activity, continuation of the afternoon feeding period into darkness, or the midnight period of feeding activity, as seen with individually penned does would compensate for the apparently moderate level of feeding activity seen during the study period.

As noted by Mattiello *et al* (1997), fallow deer have been observed to modify their grazing behaviours in response to temperature, herd structure and supplementary pen-fed and pasture-fed does were of little consequence to animal performance over the period of this study. The data also raise the possibility that more effective production systems for deer can be developed if feeding behaviour is accounted for, particularly in intensive feeding systems.

4. Energy Intake and Growth Rates of Fallow Deer Fawns Between 12 and 20 Weeks of Age.

4.1 Literature Review : Feed Requirements and Growth Rates of Fallow deer Fawns

It is well known that the serendipity of pasture growth and availability in Australian farming situations is misaligned with the well-defined seasonal energy requirements of deer. Fawns are often weaned at a time of rapidly decreasing pasture quality, or are weaned naturally after by their mothers in early winter when liveweight gain is of paramount importance in achieving target liveweights. Although weaner deer will undergo a period of compensatory spring growth (Milne *et al* 1987, Mulley 1989, Asher 1993), growth rates from weaning to spring are still vitally important if slaughter and breeding target weights are to be achieved.

While weaning post-rut (>25 weeks of age) has less of an effect on fawn growth rates (Mulley *et al* 1994), the majority of Australian deer farmers wean fawns pre-rut (approximately 12 weeks of age) as normal management practice, although the daily energy requirement of fallow deer from 12 weeks of age is currently unknown. Although daily growth rates and energy intake of adult fallow deer to slaughter weight are now known (Mulley *et al* 2000), there has been no precise information gathered on daily metabolisable energy intake of fallow deer weaners. Current estimates for weaner energy requirements at pasture are based on interpolations from red deer stags housed indoors over winter in New Zealand (Fennessy *et al* 1981), and as with such interpolations made for pregnant fallow does, may not be an accurate indication of the energy intake requirements of fallow weaners under Australian grazing conditions.

Existing Estimates of Fawn Energy Requirements

As has been well documented, patterns of growth from weaning to puberty have wide ranging effects on animal development, influencing subsequent breeding performance for does, carcass characteristics, and time taken to attain slaughter weight for entire and castrated animals. Patterns of liveweight gain for fallow does and bucks between birth and 12 months of age and beyond have been described (Asher 1984, Mulley 1989), with the first 12 months being the most rapid period of post-natal liveweight gain seen in deer.

Current estimates of male weaner requirements (Asher 1993 interpolated from Fennessy *et al* 1981) on a seasonal basis are 11.0, 11.8, 14.2 and 13 MJME/hd/day for autumn, winter, spring and summer respectively, or between 1.0 and 1.3 kg DM per day of high quality feed. A proportionately lower level is prescribed for weaner does, being 9.7, 10.4, 11.3 and 11.3 MJME/hd/day over the corresponding seasons.

Growth From Weaning to Puberty

Growth of juvenile fallow deer from weaning to puberty is vital to the overall productivity of a deer farming enterprise. Annual trends of liveweight change in fallow bucks is well known (Asher 1984, Mulley 1989), with growth and resultant feed conversion ratios dropping dramatically from 14 months of age at the onset of the first rut, highlighting the importance of post-weaning growth to slaughter weight (Mulley *et al* 2000). Similarly, and of greater long-term importance, breeding females have a long productive life, and the impact of patterns of liveweight gain from weaning to puberty on subsequent reproductive performance is paramount to farm productivity.

While the mechanism for faster growth in male fawns is not well understood, male-biased post-natal 'maternal investment' has been suggested to be responsible for sexually di-morphic growth variances (Birgersson & Ekvall 1997), although Gauthier and Barrette (1984) reported no inter-sex differences in total suckling time with fallow deer fawns between birth and 80 days of age. Other authors have suggested that differences in growth rates between male and female juvenile deer are largely physiological. Male deer appear to be able to assimilate nutrients more efficiently (Verme 1989) and allocate nutrients differently. It has also been shown that male juvenile red deer deposit less fat than females (Clutton-Brock *et al* 1982), with energy intakes hypothesised to be concentrated on structural development.

Irrespective of the means by which these variations occur, male fawns have a higher average rate of growth than females. Data on average growth rates of fallow fawns from birth to weaning in New Zealand (Asher 1993) reflect this, with male fawns growing at the rate of between 160 and 190 g/day and female fawns between 142 and 160g/day. Similarly, data produced in Australia from E and H fawns indicated similar trends, with males growing significantly faster than females (Lenz *et al* 1993). These growth variances between fawn sexes usually result in male fawns being approximately 10%, -12% heavier than female fawns when weaned at 12-14 weeks of age. Post-weaning growth rates are significantly lower in response to the photoperiod induced winter reduction in VFI, being approximately 80g/day (Asher 1993).

There have been very few studies on the nutritional intake of weaner deer. Kelly & Culleton (1994) found that fallow weaners fed a high energy ration (12.6 MJME/kg DM) grew significantly faster than those maintained on a low energy ration (9.9 MJME/kg DM), although variance in liveweight gain did not affect the date of onset of puberty, or conception rates with the does. This does however, show that an elevated plane of nutrition during the pre-pubertal growth phase is advantageous to attaining liveweight targets, one of the major challenges facing the Australian deer industry at present in producing even lines of animals for slaughter.

This section describes an experiment to measure the metabolisable energy intake of weaner age fallow deer, an opportunity arising upon the conclusion of Experiment II, 1999 (see Section 2) . Fawns were an average of 12 weeks of age (± 3 days) when the does were liberated onto pasture, effectively weaning them from their fawns and initiating the feeding trial. With the aid of infra-red illumination and video cameras installed in the pens fawns were observed to both consume the concentrate feed at 6 weeks of age, and drink water from the trough at 4 weeks of age. Thus no adjustments to troughs were necessary to wean the fawns.

4.2 Methods

There were 29 fawns used in this experiment, 20 of which were fawns from Experiment II does. Nine fawns of the same age were obtained from a commercial deer farm at Werombi, South West of Sydney. There were three treatment groups in this experiment :

Group 1 : Individually Penned Weaned Fawns

Fawns that were born in individual pens (n=10) continued on a high energy concentrate diet containing 14 MJ ME/ kg DM and 14% CP, fed ad libitum. Feed offered and residue were measured to calculate energy intake on a daily basis for these animals. Daily energy intake of these fawns was calculated over an 8 week period, (from 12 to 20 weeks of age) after which the trial was terminated and individual pens were used for another experiment.

Group 2 : Pasture-Fed Weaned Fawns

Pasture-fed fawns (n=9) were weaned from their mothers at 12 weeks of age (± 3 days) and grazed in quarter hectare paddocks containing mixes of either oats / ryegrass or kikuyu. The diet of these animals was predominantly kikuyu until mid- May when the oats and ryegrass grew to a level suitable for grazing. The diet and liveweight gain of group 2 animals was monitored for a period of 13 weeks until fawns were 25 weeks of age.

Group 3 : Pasture-Fed Unweaned Fawns

Unweaned fawns, also from Experiment II does (n=10) were grazed in quarter hectare paddocks of similar pasture composition to Group 2 animals, although they remained with their mothers for the duration of the experiment. As with Group 2 fawns, liveweight gain and available pasture was monitored until these animals were 25 weeks of age.

As with previous trials with pregnant and lactating does, paddock rotations were based on a minimum sward height of 10 cm. Pasture samples were taken down to 10cm above ground level, thus the main section of pasture grazed by fallow deer was analysed.

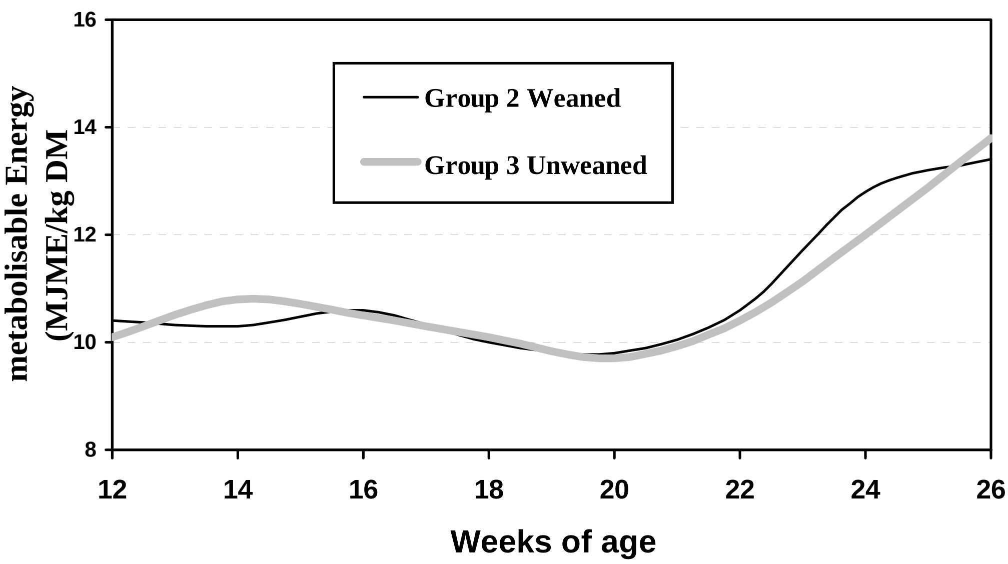

Figure 38: ME values of pasture grazed by Group 2 and Group 3 fawns from 12 to 26 weeks of age

ME values for pasture ranged between 9.7 and 13.8 MJME/kg DM over the duration of the study, as indicated in Figure 39. In weeks 7 and 8 of the trial fawns from Groups 2 and 3 began grazing young ryegrass and oats, hence the rapid increase in pasture ME over this period. Fawns in all three groups were weighed weekly to calculate growth rates.

Pasture samples were collected fortnightly from paddocks containing Group 2 and Group 3 animals. Although paddock rotation occurred more frequently with Group 3 animals, pasture was still sampled on a fortnightly basis.

4.3 Results of Fawn Feed Intake Study

The mean weights of doe and buck fallow fawns at the beginning and end of the 10-week trial, and their rate of growth in grams per head per day are shown in Table 7 Buck fawns grew significantly faster than doe fawns (P<0.05), although the total number of buck fawns was low due to a skew in the sex ratio of deer available for the study. Data from several fawns were also omitted from analysis due to an outbreak of parasitism in the pasture-fed deer. At this point, fawns in all treatment groups (and does in Group 3 were treated with a commercial drench (Cydectin ™).

Table 7 : Growth rates and average bodyweights of male and female fawns across all feeding treatments at 12 and 25 weeks of age.

Treatment Group	Sex of Fawn	Fawns per Group (n)	Weight at 12 weeks of age ± SEM (kg)	Weight at 25 weeks of age ± SEM (kg)	Growth Rate 12-25 weeks ± SEM (g/day)
1	Does	6	20.4 (±0.8)	25.2 (±0.9)	77 (±3.0) *
Weaned	Bucks	3	23.2 (±1.5)	27.5 (±1.7)	89 (±5.1) *
Conc. Fed	Total	9	21.3 (±1.4)	25.9 (±1.4)	82 (±7.2) *
2	Does	6	18.3 (±1.5)	25.3 (±1.5)	77 (±4.5)
Weaned	Bucks	2	21.5 (±0.8)	28.0 (±1.2)	73 (±2.8)
Past. Fed	Total	8	19.1 (±1.6)	25.9 (±1.6)	76 (±4.1)
3	Does	5	20.8 (±1.1)	27.3 (±1.2)	72 (±4.0)
Unweaned	Bucks	4	22.6 (±1.3)	30.3 (±1.2)	85 (±2.3)
	Total	9	21.6 (±1.3)	28.6 (±1.4)	78 (±3.7)
All Groups	Does	17	19.8 (±1.4)	25.8 (±1.3)	75 (±3.8) a
	Bucks	9	22.6 (±1.3)	28.8 (±1.5)	84 (±4.1) b
	Total	26	20.8 (±1.5)	26.9 (±1.6)	79 (±4.0)

a, b Denotes significantly different growth rates between male and female fawns (p<0.05)
* Growth rates calculated over an 8-week period between 12 and 20 weeks of age.

Table 7 shows that there were no significant differences in growth rates between the two weaning strategies, indicating that farmers could choose the method best suited to their management program and available pasture. The growth rates of both males and females were higher than those reported by Kelly & Culleton (1994) and Mulley *et al* (1994) for fallow deer of the same age fed on high energy pasture and concentrate feed. Average growth rates were also similar to post-weaning growth rates of fallow fawns in New Zealand (Asher 1995).

As is common with weaning of domestic ruminants, fawns in the pasture-feeding treatment group experienced a period of negative growth over the initial stages of the experiment (between 5 and 7% of bodyweight). While the individually penned concentrate-fed fawns did not lose weight with the stress of weaning and isolation, there was a period of zero gain. However, when these animals were liberated onto pasture at 20 weeks of age, there was a moderate degree of liveweight loss for a period of three weeks, presumably due to a change of diet and environment, before liveweight gain took place at the previous rate. Similarly, the fawns in the unweaned treatment (Group 3) also experienced negative growth when weaned at the completion of the study. These patterns of liveweight change are illustrated for each treatment and sex in Figures 39 to 42.

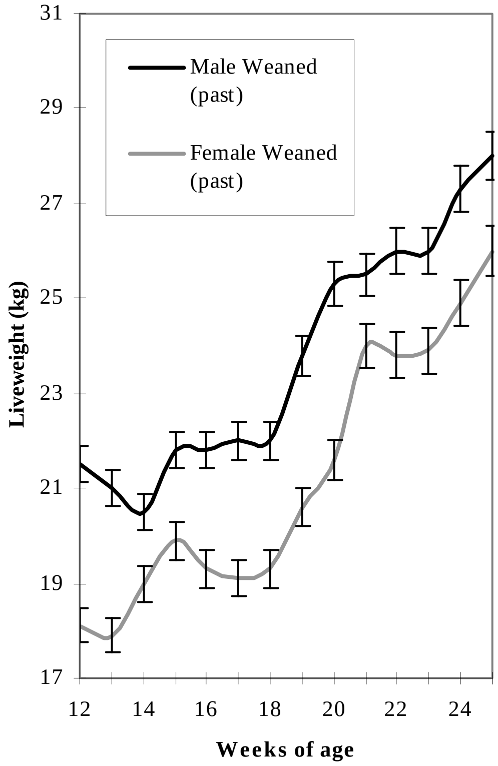

Figure 39 : Mean LWG of male and female fawns weaned onto pasture

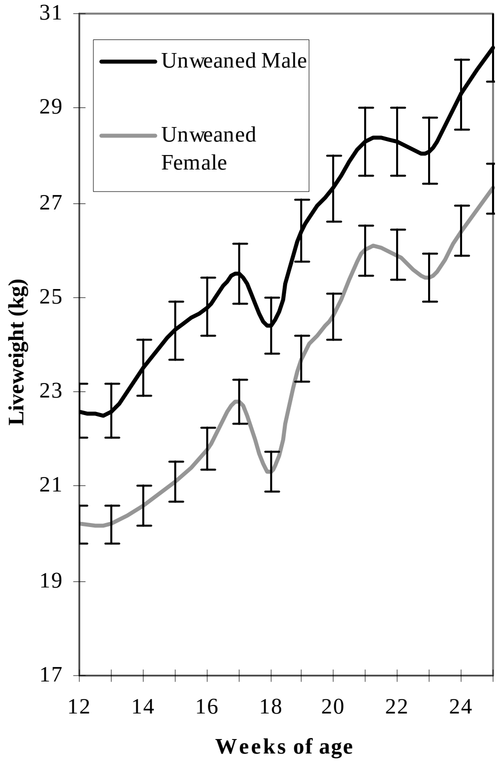

Figure 40 : Mean LWG of unweaned male and female fawns

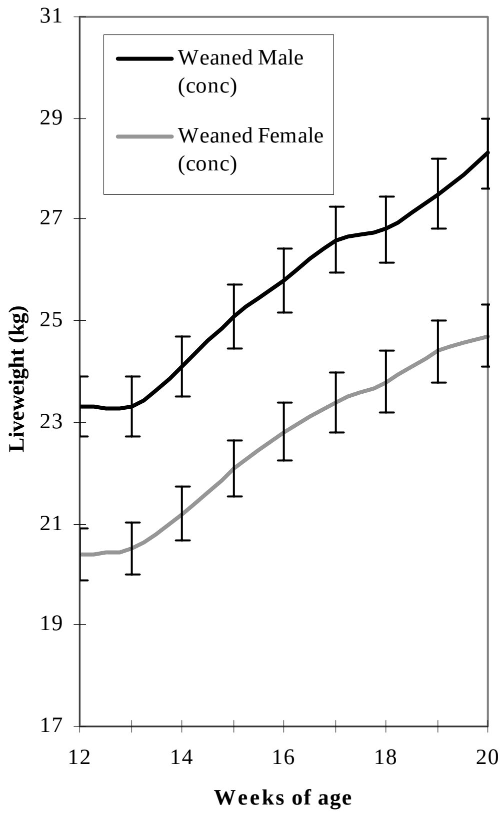

Fig. 41 : Mean LWG of male and female fawns weaned onto concentrate

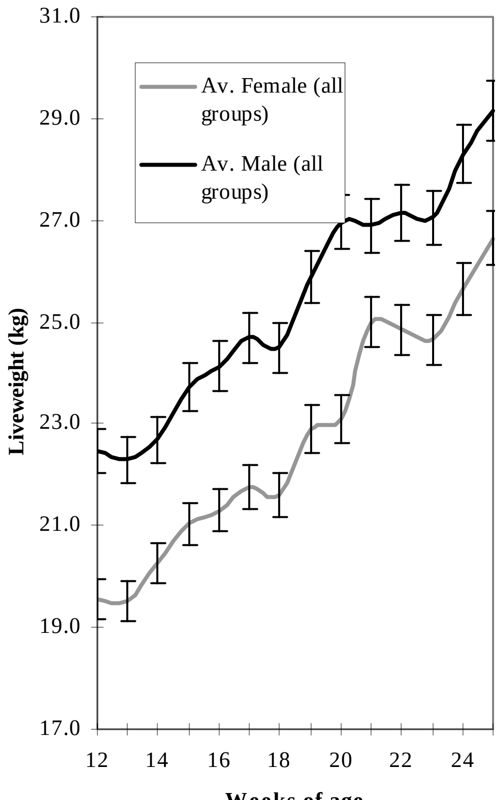

Fig. 42 : Mean LWG of male and female fawns from all treatment groups

Although no data were gathered on doe liveweight and condition score from Group 3 fawns, it was noted that the condition of these does was somewhat lower (estimated between 0.5 - 1 condition score lower) than does who had been weaned from their fawns, even though does forming part of Group 3 had access to the same, and towards the latter stages of the trial, superior quality feed. As documented by Mulley *et al* (1994) there are trade-offs between doe condition and fawn growth rates to consider when employing a weaning strategy.

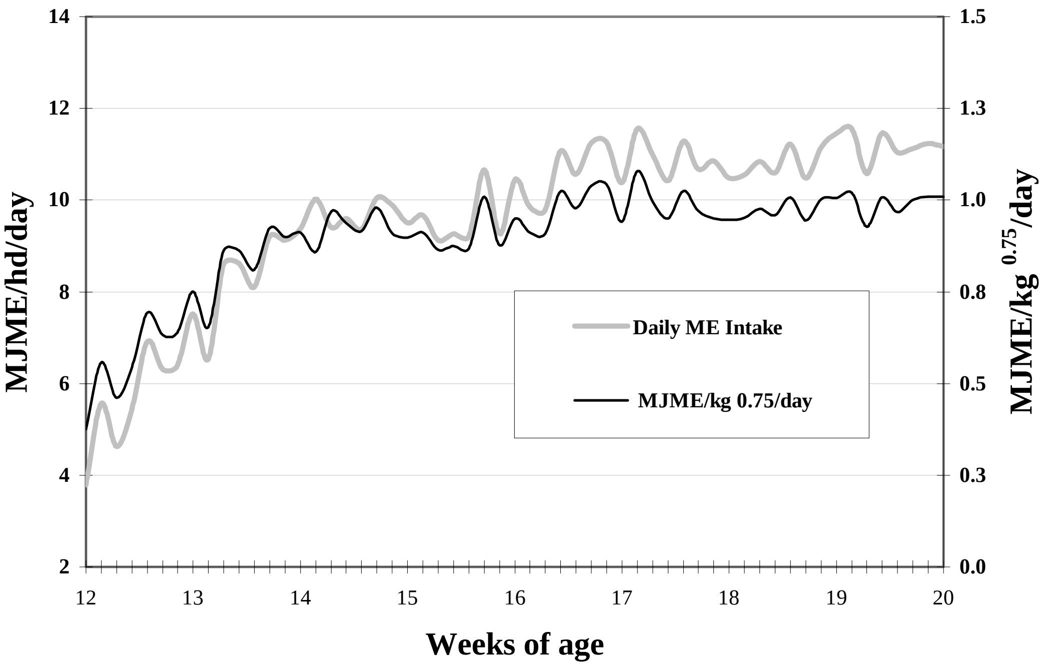

Figure 43 : Average daily ME intake and ($W^{0.75}$) of individually penned concentrate-fed fawns from 12 to 20 weeks of age

There were no significant differences in growth rates between female deer in any of the treatment groups. This indicates that farmers may employ different weaning strategies without jeopardising future farm productivity. As previously discussed, growth from weaning to puberty and oestrus is of particular importance in relation to conception rates, fawn viability, and attainment of adult doe liveweight. There was a significant and expected difference in growth rates between male and female fawns in all feeding treatments ($P<0.05$), as has been observed by other authors.

The stress of weaning had an effect on VFI with Group 1 fawns, as illustrated in Figure 43. Feed intake gradually rose from below 4 MJME/day to a stable pattern of energy intake between 10 and 11 MJME/day over the first three weeks post weaning. This equated to an approximate metabolic bodyweight energy intake of 0.95 MJME/kg$^{0.75}$ /day.

This level of ME intake was sustained throughout the remainder of the eight week trial period, peaking at 11.6 MJME/day on several occasions. As with other experiments with individually penned animals, stress incidents negatively affected VFI, although such oscillations had no significant effect on gross ME intake over the trial period, as illustrated in Figure 43.

4.4 Discussion and Implications

Data for ME intake from this trial were very similar to interpolated figures for seasonal ME intake for male and female fallow fawns in New Zealand (Asher 1995). These data for average daily ME intake and $W^{0.75}$ with concentrate-fed weaners will assist farmers to feed budget for periods of feed shortage. With the average growth rates of concentrate-fed weaners equivalent to their pasture-fed counterparts, farmers may also consider supplementation or even feed-lot production for animals of this age, especially considering the waning energy values of pasture during autumn and the onset of winter.

The quality of feed in terms of digestibility and ME consumed by weaner fawns appears to be of vital importance for growth, especially considering the large intake per $W^{0.75}$. Concentrate-fed fawns in this study offered a ration containing 14MJME/kg DM consumed up to 850g/hd/day to fulfil their daily energy requirements of approximately 11.5MJME. While this appears to be a low figure compared to the DM intake for does, this equates to 3.4% of bodyweight given a 25kg animal. Thus, it is possible that on less palatable and digestible feeds, 'gut fill' may prohibit fawns from ingesting sufficient feedstuff to extract the required ME and CP for optimal growth.

For example, autumn pasture values, particularly Kikuyu or supplements such as average quality hay as provided by many farmers after weaning, may contain approximately 8.0MJME/kg DM. Fawns would have to consume in excess of 1.4kg DM/day (nearly 6% of bodyweight) of these feeds to ingest 11.5MJME/day as seen with the concentrate-fed fawns. With the high mean rumen retention times of these low-quality feeds, it is likely that gut fill would preclude fawns from ingesting optimal ME, and thus optimum growth rates would not be realised. This is also evident from the results of Vigh-Larsen (1993), Kelly & Culleton (1994) and Fischer *et al* (2000) who showed that fawns on high-energy rations grew significantly faster than those fed low energy rations.

Furthermore, fawns displaying low daily growth rates through inadequate nutrition after weaning were also shown to have low rates of LWG during spring (Fischer *et al* 2000), which is a period of rapid growth of fallow deer of that age (Asher 1986, Mulley 1989). This reinforces the necessity to double feed availability of does at parturition and continue at that level of feeding at weaning (ie, weaners are fed to the level of non-pregnant does) if weaners are to attain slaughter weight by 14 months of age (Mulley *et al* 2000)

Energy intake data from concentrate-fed weaners from 16 weeks of age in this study was shown to be equivalent, if not marginally higher than that of adult fallow does (Mulley *et al* 1999). Data presented in section 2 for pregnant does also demonstrated the T2 ME intake average of 10.3MJME/day to be slightly lower than the 11.5 MJME/day intake for weaner fallow fawns. Considering the continual decline in pasture quality at this time of year, supplementation may be necessary to fulfil the energy requirements of weaner fallow. Studies with red deer in New Zealand have suggested that concentrate-feeding strategies should be implemented with weaned stock to ensure target liveweights are met and also suggests that a high level of CP (approximately 16%) is advantageous if rapid LWG is to be achieved.

Personal communication with many deer farmers and anecdotal information on stock management and pasture allocation, has indicated that the majority of farmers are unaware of the energy requirements of their weaner fawns, most of whom assume the pasture requirements of weaners to be less, (some farmers believe even half) than that of adult does. Some farmers even give does access to better feed than weaners, in an attempt to increase the condition score of the does before joining. While this practice may be a worthy trade-off in certain circumstances between future reproductive success and weaner growth rates, neglecting the nutritional requirements of weaned stock may incur higher costs to the farmer in the long run (in terms of efficiency of pasture utilisation and financial return) than reduced or late conceptions due to lower than optimal condition score of breeding stock. Irrespective, in venison production systems, reproductive success of does and optimal growth rates of slaughter stock are of equal importance, and inadequate nutrition should not be a limiting factor to the genetic potential of each.

There are several major misconceptions by farmers regarding VFI, energy requirements of different classes of stock, and growth characteristics which need to be addressed if farmers are to improve productivity and the Australian deer industry is to expand. The controlled feed intake experiments with fallow deer in this study showed that intake requirements of breeding does double at parturition, (ie, energy requirements of does in lactation are double to that of the first trimester of pregnancy or for non-pregnant does) and that the feed intake requirements do not change at weaning, with both the fawns and non-pregnant does consuming well in excess of 10.0 MJME/day each. These data have serious implications for management of both breeding stock and pasture maintenance, and should also allow farmers to more accurately plan feeding management of stock grown out for slaughter or breeder replacement.

The previous estimate of 1.6 DSE for breeding age fallow does appears to have been underestimated by 20%, and should be increased to 2.0 due to these outcomes. The current allowance of 0.8 DSE for weaner stock should also be increased to 1.1 DSE. However, given the seasonality of both feed intake requirements and VFI of fallow deer, it is unlikely that DSE's are of any great value in assessing either feed demand or nutritional sufficiency, especially considering the vast mismatch between pasture supply and demand under Australian conditions with fallow deer. It is clear that deer farmers must understand the requirements of the animals they farm, and adjust their management practices accordingly.

While this was only a pilot study, it has revealed some very important aspects of deer nutrition, and should be the precursor to more extensive research on energy requirements from weaning through to joining or slaughter weight. More importantly, such data should be utilised in the exploration of possible pasture and stock management practices to ensure that the genetic potential for growth is not limited by inadequate nutrition under Australian pasture conditions. Further work must also include explanation of other forage species that can assist farmers to better exploit the growth potential of deer in their first year.

5. Studies on the nutritional requirements of adult red deer hinds during late pregnancy

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Preamble

The work presented in this section was conducted at AgResearch Invermay in New Zealand. The data were analysed and presented as part of the annual conference of the Deer Branch of the New Zealand Veterinary Association held in conjunction with the 25th Anniversary of the New Zealand Deer Farmers Association at Queenstown in 2000. The paper is reproduced here with permission of the authors and Agresearch.

5.1 Introduction

The reproductive efficiency of adult red deer hinds under NZ pastoral conditions is far from optimum. Despite 25 years of intensive management regimens, approximately 15 percent of hinds each year still fail to produce or raise calves. Numerous studies to date indicate that the main cause of reproductive wastage is calf mortality (Asher & Adam 1985; Moore *et al* 1985; Wilson & Audigé 1998; Walker *et al* 1999; Beatson *et al* 1999).

In particular, perinatal calf losses due to starvation (i.e. mismothering), dystocia (difficult birth process) and stillbirth (non-viability syndrome) together account for >50% of all calf deaths. Rather than focus just on the proximate causes of such loss, we wondered if there may be predisposing factors related to management of hinds during pregnancy; in particular, nutrition during the last third of pregnancy.

There are considerable differences of opinion among deer farmers on the appropriate nutritional management of hinds during the last trimester of pregnancy, ranging from *ad libitum* feeding to highly restricted feeding leading up to calving. Such approaches reflect differing perceptions of the nutritional needs of the hind/foetus for maximum calf survival, with emphasis on reducing incidences of dystocia while ensuring optimum birth weights.

In the present study, the relationship between daily feed intake during the third trimester and conceptus development/dam fatness was examined. In doing so, we tested the following two hypotheses:

(1) Under-nutrition retards foetal growth and reduces hind energy reserves, leading to reduced birth weights, retarded mammary development and slower calf growth rates.

(2) Over-nutrition leads to excessive foetal development and hind fat accretion that inhibits normal parturition processes, resulting in increased incidences of calf mortality.

5.2 Methods

A total of 36 mature (>5 years old) hinds were used across two consecutive years (1998 and 1999). They were selected from larger groups of hinds that were treated with intravaginal CIDR devices and run with pure red deer stags, within the breeding season, to synchronise conceptions within respective years. Rectal ultrasonography was performed 45 days from CIDR device removal to assess the presence of an appropriately sized foetus. Pregnant hinds selected for the trial were assumed to have conceived 48 h after CIDR device removal. The conception dates were 16 April for 1998 (year 1) and 28 March for 1999 (year 2).

Hinds were maintained at pasture until Day 130 of pregnancy. During the last three weeks at pasture they were offered increasing amounts of concentrate supplementation to facilitate acceptance of feed and ruminal adaptation to diet change. On Day 130 the hinds were placed in individual pens on total concentrate ration, which was provided ad libitum for the first 3 weeks of confinement. Thereafter, until turnout on pasture 70 days later (Day 220), each hind received daily an allocated amount of a grain-based pelletised ration ("Invermay Formula", Harraway and Sons Ltd, Dunedin, NZ) containing 11 MJME/kg DM and 16% crude protein. In addition to pellets, 5% by weight of daily offer was chaffed lucerne hay to maintain an adequate intake of rumen roughage.

Each hind was allocated to one of 3 feeding levels (n=6 hinds per level per year). The "High" group remained on *ad libitum* offer throughout the trial. In year one, the "Medium" group were offered a daily ration estimated to be ~30% less than the *ad libitum* intake of the "High" group averaged over the previous week. Similarly, the "Low" group received ~50% of the daily feed intake of the "High" group. In effect, the "Medium" and "Low" groups received a stepwise increase in offer during the study to maintain approximate relativity with the "High" group (Figure 44). In year two, feeding levels of the "Medium" and "Low" groups were matched exactly with those of the previous year based on gestational age (i.e. given a 3-week disparity in conception dates between years).

At weekly intervals from one week before indoor penning until 12 weeks after calving at pasture, the hinds were yarded to record liveweight, body condition score (BCS) and lactation score (LS). BCS was based on a standardised 5-point ranking, whereby very low scores represent emaciation and very high scores represent obesity. For ethical reasons, contingencies were established to "rescue" hinds attaining a BCS of ≤1.5 by re-introducing an *ad libitum* offer (necessary on one occasion in year one). LS was based on a 5-point ranking of palpable mammary development (Asher *et al* 1994), representing the range from no palpable tissue (0) to full mammary and teat extension (5). Both BCS and LS were assessed by the same observer throughout the course of the study.

Once returned to pasture on Day 220 of gestation, the hinds were monitored closely at least twice daily until calving was complete. Calves were tagged within 12h of birth and data recorded included birth date, birth weight, sex and dam. Calves remained with their dams for 12 weeks, during which time they were weighed weekly. Contingencies for assessment of calf mortalities were established but were not needed as all calves survived.

In year one, body composition was measured in the live hinds using x-ray computed tomography (CT scan) on two occasions; once at the start of feed regimens (Day 150 of pregnancy) and again 60 days later. Hinds were scanned using a Seimens Somatom ARC CT scanner following procedures described by Jopson *et al* (1997). Hinds were anaesthetised (0.02 ml kg^{-1} liveweight i.v. Fentazin; Parnell Laboratories, Auckland) and physically restrained on a purpose-built bed. Cross-sectional images were recorded at 70 mm intervals along the body. Additional CT images were recorded through the uterus (35 mm intervals). CT images were analysed using a semi-automated procedure, with images transferred to a PC and rescaled to a 256 grey scale to maximise the contrast between lean and fat tissue. Images were manually "dissected" into carcass, non-carcass (viscera), uterus and foetal components, and then the program "AutoCAT" (Jopson *et al* 1995) automatically segmented the various components into lean, fat and bone. Tissue areas for each depot were numerically integrated to estimate tissue volume, which was then corrected in density between depots to estimate tissue weight.

Data were analysed by ANOVA, fitting treatment, year and their interaction. This included data measured over time, for which selected intervals were defined in two ways for calculating summary statistics, such as growth rates or differences. Firstly, during pregnancy data were synchronized between years relative to date of conception, and secondly, from a month before parturition data were synchronized between hinds relative to date of parturition.

5.3 Results

The data from 4 hinds in year one were completely removed from the final analysis due to various ineligibility factors; including a death from MCF, a late-term abortion (probably due to anaesthetics delivered for CT scanning), hind rescue (low BCS) and one case of misdiagnosed conception date (detected at the first CT scan). The overall analysis involved the complete data set for 32 hinds and their calves (all surviving to 12 weeks of age).

The weekly means of daily dry matter (DM) intake for the three treatment groups in both years are presented in Figure 44. Hinds on *ad libitum* offer exhibited a progressive increase in daily DM intake from about 1.6 - 1.8 kg around Day 150 to 2.6 - 2.8 kg around Day 220. However, a change in feed batch around Day 195 in year two was associated with a transient depression in DM intake over a period of ~1 week. There was no variance in mean daily intake of the "Medium" and "Low" group as no daily feed residues remained (they licked their troughs clean!).

Mean hind liveweights (Figure 45) increased during late pregnancy in all treatment groups. Hinds in the "High" group attained higher mean liveweights immediately pre-calving ($P<0.05$), although this was more obvious in year one than year two. Post-calving mean liveweights were not significantly different between treatments ($P>0.05$). Mean BCS (Figure 46) showed marked differentiation towards the end of pregnancy, especially in year one ($P<0.05$). This persisted throughout the lactation period in year one but not in year two. Interestingly, mean BCS for the three treatment groups generally declined in parallel over lactation in year one, but merged and increased over lactation in year two, reflecting a large difference between years in climatic/pasture conditions over summer/autumn.

Mean lactation scores (Figure 47) likewise differentiated between treatment groups towards the onset of calving ($P<0.05$). Again, this was more obvious in year one, with the "Low" group having a significantly lower mean score three weeks before actual calving date (i.e. 1.5 vs 2.6 for "Low" vs "High"). However, there were no detectable differences between treatment groups post-calving (>0.05).

CT scan measurements of year one hinds 10 weeks after the start of indoor feeding regimens indicate a significant effect of treatment on hind fatness ($P<0.01$) and total lean tissue ($P<0.05$) but not bone or gut components ($P>0.1$).

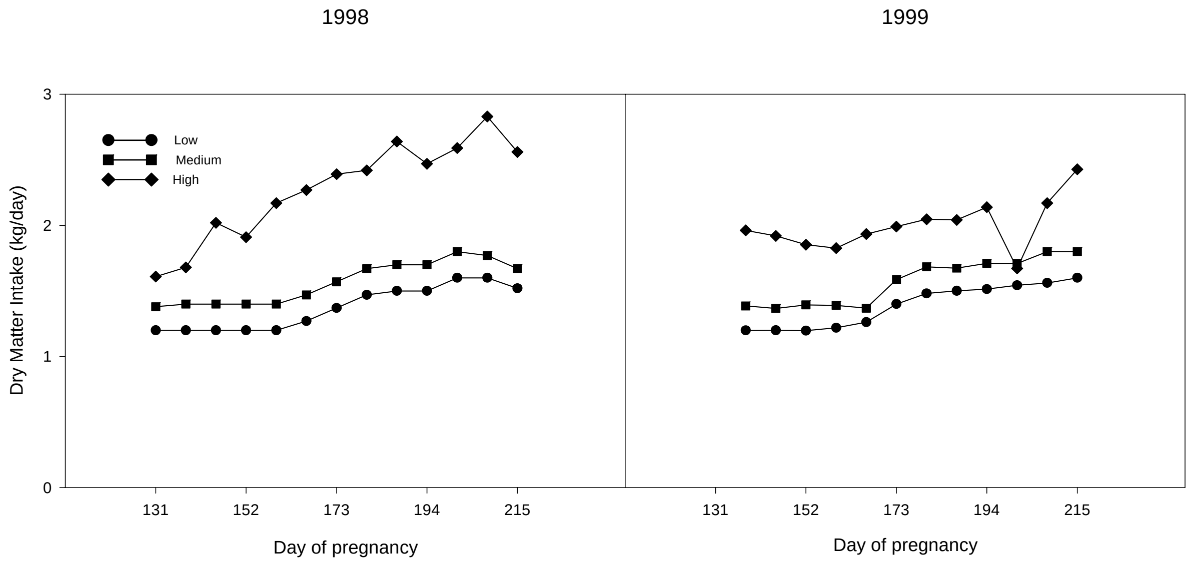


Figure 44: Profiles of weekly means of daily dry matter (DM) intake of High, Medium and Low hinds in year one (1998) and year two (1999). (Profiles represent the indoor confinement period only.)

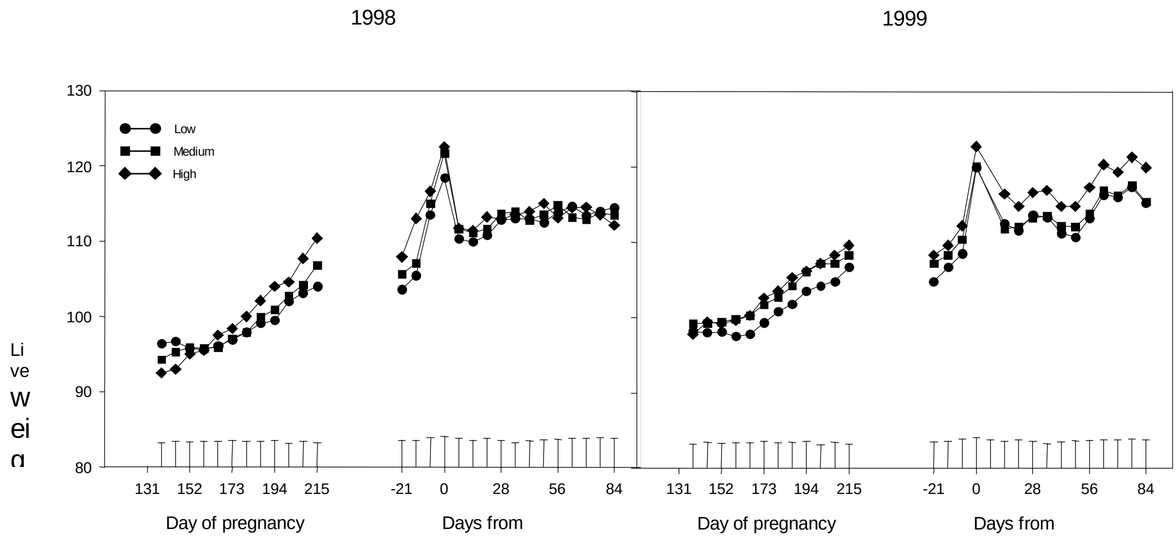


Figure 45: Profiles of weekly means (and SED) of hind liveweight normalised around (1) Day of pregnancy and (2) Days from calving, for High, Medium and Low hinds in year one (1998) and year two (1999).

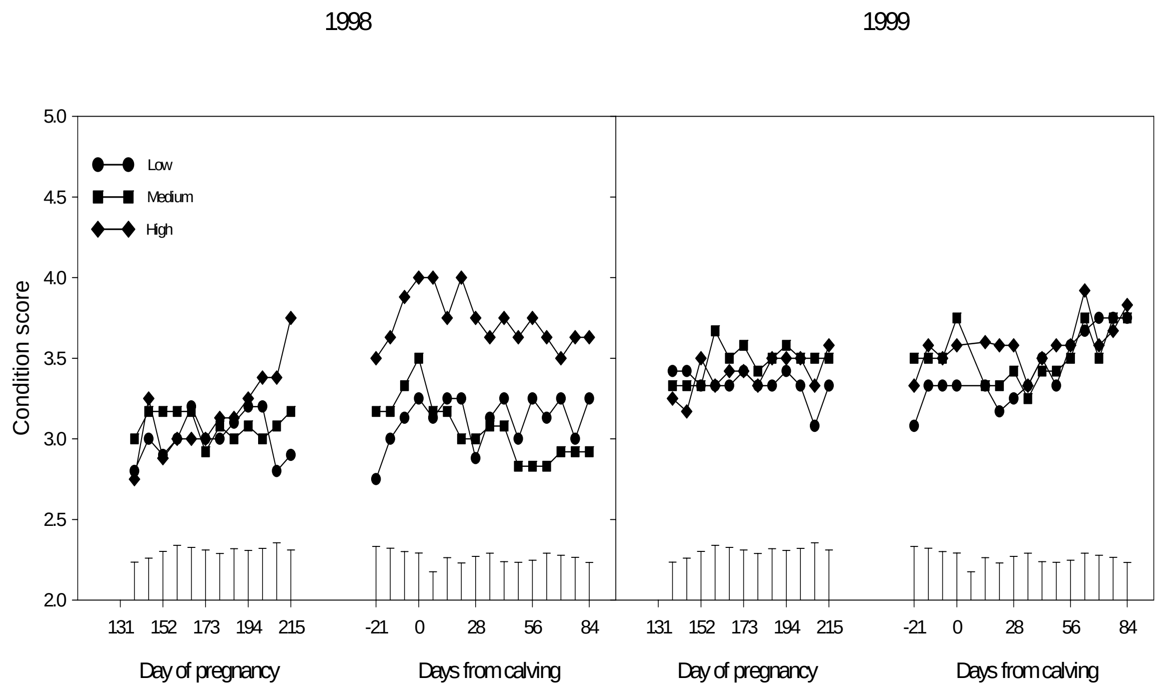


Figure 46: Profiles of weekly means (and SED) of hind BCS of High, Medium and Low hinds in year one (1998) and year two (1999).

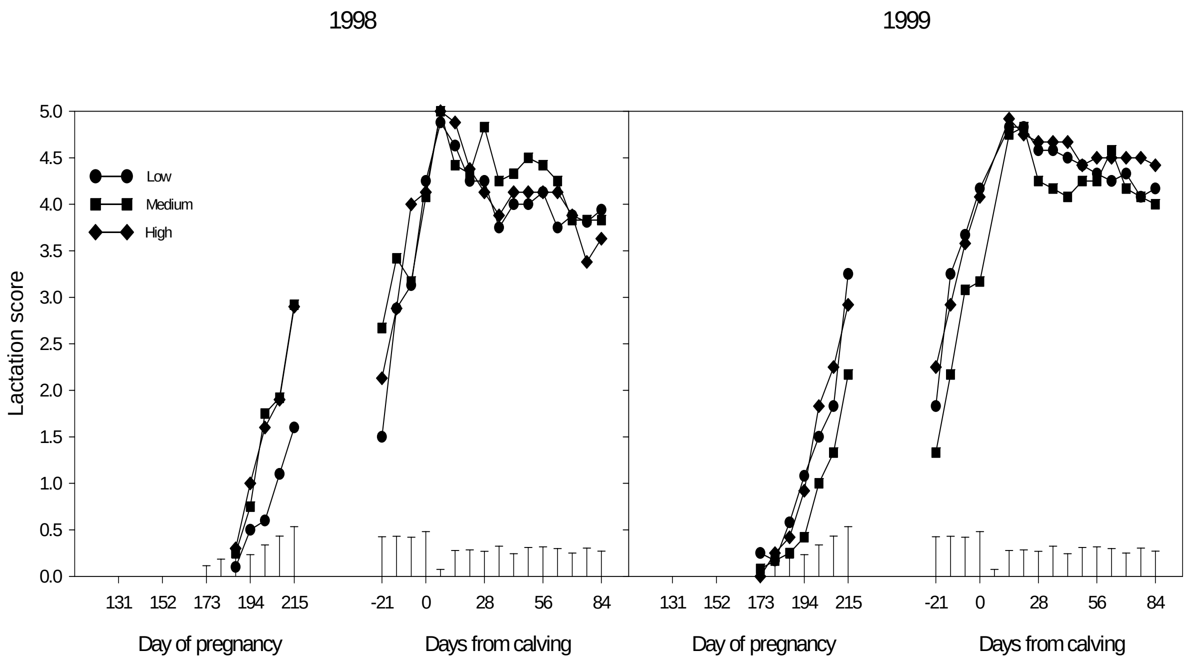


Figure 47: Profiles of weekly means (and SED) of hind lactation scores of High, Medium and Low hinds in year one (1998) and year two (1999).

Table 9: **Adjusted means of CT scan measurements (kg) for hinds in year one (1998) 60 days after the start of composition of feed regimens (adjusted by covariance for initial scan data).**

	Low	Medium	High	SED	Significance
Total body fat	3.89	3.79	8.30	1.10	**
Total body lean	43.84	45.23	46.54	1.00	*
Total bone	7.50	7.64	7.07	0.32	ns
NFVC*	10.60	11.64	10.83	0.51	ns

* Non-fat visceral components (gut)

All calves born in the study survived to weaning at 12 weeks of age. No calving difficulties were experienced. CT scan results of the conceptus (i.e. uterus + fluids + foetus) in year one showed a significant effect of treatment on foetal growth, with adjusted mean weights of the total conceptus and of the foetus exhibiting a linear trend across treatments (Table 10).

However, despite the difference in foetal growth in year 1, calf birth weights in both year one (Table 10) and year two (not shown) were not significantly different between treatments (P>.01).

Table 10: **Adjusted means of pregnancy/foetus weights in year one (1998) at about Day 210 of pregnancy (adjusted by covariance for initial scan data and foetal sex) and sex-adjusted mean birth weights.**

	Low	Medium	High	SED	Significance
Conceptus weight	13.49	14.14	14.55	1.2	*
Foetus weight	6.78	7.05	7.70	0.73	*
Birth weight	9.2	9.5	8.4	0.70	ns

Although all hinds within year groups conceived at the same time, calving dates in both years showed considerable variance, reflecting considerable variation in gestation length (Table 11). There was a significant effect of treatment on gestation length in both years, with the "High" group exhibiting significantly shorter gestations than the "Low" Group.

Table 11: **Mean gestation lengths (days) in year one (1998) and year two (1999) (adjusted for calf sex).**

	Low	Medium	High	SED	Spread
Year one (1998)	239.3	234.7	231.1	2.10	28 days
Year two (1999)	236.1	237.0	233.8	2.10	11 days

While the means differed by 8 days in year one and 3.5 days in year two, the actual spread of calving dates was 28 and 11 days, respectively. The difference between years was not significant (P>0.1).

Due to the spread in calving dates experienced in both years, calf liveweights on given dates varied greatly. However, adjustment to a common age (e.g. 12 weeks) removed the differences between treatments within each year (Table 12). However, there was a highly significant year effect on calf liveweight and growth rate (P<0.05), with calves in year 2 being considerably heavier at 12 weeks than in year one.

Table 12: Mean calf liveweights at 12 weeks of age in year one (1998) and year two (1999) (adjusted for calf sex).

	Low	Medium	High	SED**
Year one (1998)	37.0	39.1	36.9	2.54
Year two (1999)	48.0	46.0	44.1	2.54

** Significant year effect

5.4 Discussion

This study examined the effect of level of nutrition during a specific phase of pregnancy on foetal/calf development. The third trimester of pregnancy in red deer (i.e. Days 150 - 230 of gestation) represents a crucial phase in conceptus development, whereby >70% of conceptus mass accumulation occurs. One could argue, therefore, it is the period when foetal growth is most likely to induce a significant metabolic drain on the hind or, conversely, when inclement extrinsic factors (e.g. nutritional stress) may perturb foetal development.

Under NZ pastoral farming practices, late pregnancy in red deer hinds coincides with the spring pasture flush in many regions, a period normally associated with an abundance of high quality feed. This is perhaps at variance with the northern boreal environments in which this species has evolved a summer calving pattern. Thus we observe a potential mal-adaptation to the NZ environment, whereby the potential for inappropriate nutrition of the pregnant hind exists. For a number of years, some NZ deer farmers have often argued that "over-feeding" of red deer hinds in late pregnancy leads to excessive hind fatness and/or over-development of the foetus that ultimately leads to high incidences of dystocia. To combat this perceived situation, highly restricted hind feeding practices have been commonly employed during spring/early summer in some regions of the country. Other farmers have argued that luxury nutrition to hinds during late pregnancy is beneficial to calving success by optimising birth weights (i.e. avoiding non-viability syndromes resulting from low birth weights) and promoting an optimum lactation response after parturition.

Thus, we observe a dichotomy in opinion and practice, the consequences of which still remain unresolved.

If there is one over-riding theme emerging from the present study, it is this ... *pregnancy in red deer is very robust. There are strong intrinsic mechanisms to compensate for environmental extremes.* The case in point is that while the imposition of extremes in nutrition to hinds clearly impacted on foetal/conceptus development, birth weight (and survival) of calves was ultimately unaffected. However, gestation length varied enormously, with hinds on the low plane of nutrition exhibiting significantly longer pregnancies than those or the high plane of nutrition. Therefore, it appears that the ability to adjust gestation length is a mechanism for compensating for differing growth trajectories of the foetus and thus, maintain calf viability through control of birth weights.

Such putative compensatory mechanisms have not been demonstrated for sheep and cattle (if anything, some studies suggest that nutritionally deprived ewes may actually have shortened pregnancies; presumably to the detriment of lamb survival) (Wallace *et al.*, 1999, Robinson *et al.*, 1999). However, there are indications from the literature that some wild ungulate species (including some cervids) exhibit variable gestation lengths to compensate for seasonal vagaries in food supply during pregnancy (Racey, 1981).

The implications of such variability in gestation length on deer farming practice in NZ need to be considered further. The variability observed within a single group of hinds in the present study represents a range of nutritional conditions imposed within that group. In reality, hinds within a single group are unlikely to face such variation in extremes and, therefore, unlikely to exhibit such variation in gestation length. Nevertheless, some farmers may be compromising calving date within the herd by applying extreme nutritional management practices across the entire herd. Given that the current “push” within the industry is for early calving (i.e. October/November vs November/December) to better align pasture with lactational needs, the imposition of severe nutritional regimens during late pregnancy may negate earlier management aimed at establishing the earliest possible conception dates. Clearly, this is a new area of consideration when planning optimum calving seasons within a district.

Conversely, we cannot ignore the possible negative consequences of luxury nutrition to pregnant hinds. While all hinds in the present study calved with relative ease, and no incidences of dystocia were encountered (despite some animals having BCS of 4.5 - 5.0 around calving time), these hinds represent a highly select group of high performing animals that may not be representative of the wider population. The instigation of luxury feeding practices to further advance calving dates may well comprise the calving ability of many hinds.

In reality, most farmers do, and will, opt for a balance between these extremes. For example, rather than set strict intake levels for hinds in late pregnancy, a more appropriate approach may be to budget feed according to changing BCS or liveweight profiles of hinds.

The present study has also highlighted, in a less direct way, the importance of level of nutrition during lactation on hind BCS and calf growth. By chance alone, the study was conducted over two contrasting summers, one dry (1998) and one wet (1999). This contrast was reflected in the quality of feed the farm staff were able to supply to the lactating hinds. In year one, poorer nutritional conditions over lactation resulted in lower calf growth rates and a progressive loss of hind BCS. It could be further argued that the earlier differences in BCS induced by the artificial nutritional regimen in late pregnancy persisted through lactation, although this was not reflected in lactation score and calf growth. In year two, not only were calf growth rates considerably improved over year one, the hinds were also able to improve in BCS and the relatively between the poor treatment groups all but disappeared. These considerations suggest that good nutritional conditions over summer may, to certain extent, compensate for a “bad” start to calving brought about by sub-optimal nutrition during pregnancy. However, summer conditions are highly unpredictable and certainly cannot be factored into management during the pregnancy period.

While the present study investigated the interaction of nutrition and pregnancy in adult red deer hinds, a note of caution should be sounded when attempting to extrapolate the results to other groups of deer. For example, first calving hinds (rising two-year-olds) are still exhibiting a degree of somatic growth superimposed on foetal growth requirements. The relationship between nutrition and pregnancy may differ considerably in these animals. Also, hinds carrying Wapiti hybrid foetuses may respond differently to nutrition. These are both areas of ongoing research.

6. Development of Body Condition Score Parameters for Farmed Fallow Deer

6.1 Literature Review : Methods and Uses of Body Condition Scores

Methods of Estimating Body Condition

Body condition scores (BCS) are a subjective concept intended to summarise the level of fat cover of an animal in relation to its size (Evans 1978), with the degree of fat deposition throughout the body traditionally used as a general indication of body condition in both farmed and wild animals. This concept is based on the assumption that a particular fat depot is proportional to body-fat reserves in a predictive way (Finger *et al* 1981). Body condition reflects the response of an animal to nutritional, behavioural and climatic changes, and in the case of wild ruminants, is fundamental in establishing relationships between animal populations and their habitats (Torbit *et al* 1988).

In farmed animals, estimation of BCS is necessary to relate the performance of the animal to seasonal, nutritional and reproductive variants. Relationships between body condition and reproductive performance with populations of free-ranging red deer have been well documented (Mitchell & Lincoln 1973, Albon *et al* 1986), while condition indices for breeding red hinds have been described by Audige *et al* (1998). In that study, it was pointed out that body condition may be a more important determinant of reproductive success than the liveweight of the dam. Along with reproductive performance, condition score is also an important indicator of carcass characteristics and meat yield, and has been extensively reviewed with beef cattle (Charles 1974, Gresham *et al* 1986, Bullock *et al* 1991, Perry & Fox 1996) and sheep (Hopkins *et al* 1995, Purchas & Wilkin 1997, Nsoso *et al* 2000) although there has been little work directly relating body condition to carcass characteristics with farmed species of deer. Although vague descriptions of body condition exist among venison processors, there have been no industry-recognised descriptors for farmers and processors to follow in the Australian deer industry.

There have been numerous studies with free-ranging ungulates relating body fat indicators to animal condition, population density and environment. While body condition of live deer in wild populations has been assessed visually (Riney 1955, Watson 1971), only large variations in body condition can be determined at distances. Seasonal variations in coat thickness and hair length, combined with flight distances, make visual assessment difficult. Hence, body condition of wild deer has usually been assessed post mortem by development of kidney fat and other indices, which have been transferred to domestic species. Riney (1955) adopted this technique in estimating body condition for red deer, as did Finger *et al* (1981) for white-tailed deer. Nichols & Penton (1972), Kie *et al* (1983) and Brown *et al* (1995) also reported associations between body fat indices and liveweight condition in white-tailed deer, as did Depperschmidt *et al* (1987) for pronghorn and Torbit *et al* (1988) for mule deer, Gerhart *et al* 1996, ChanMcleod *et al* (1999) and Dauphine (1971) for free-ranging caribou. Greer (1968) also reported relationships between body fat and condition in elk.

There have also been numerous studies on assessment of body condition and development of condition score indices in the majority of farmed ruminant species. Various assessments of condition score and carcass fat have been made with sheep Russel *et al* 1969, Butterfield *et al* 1983, Hopkins *et al* 1995), beef cattle (Johnson *et al* 1973, Gresham *et al* 1986, Nicholson & Sayers 1987, Bullock *et al* 1981, Perry & Fox 1996), dairy cows (Gregory et al 1998, Edmonson e*t al* 1989), goats (May *et al* 1995) and red deer (Kay *et al* 1981, Audige *et al* 1998, Hansen 2000). Non-ruminant species are also well represented, with live condition and carcass studies performed on various breeds of poultry (Gregory & Robbins 1998), pigs (Elsley *et al* 1964) and horses (Henneke 1985).

Condition indices have been frequently calculated for three areas of accumulated fat reserves in mammals : KFI - kidney fat index (Riney 1955), BMF -bone marrow fat (Verme & Holland 1973) and subcutaneous fat on various sites (Harris 1945, Riney 1955), with visual objective validations of these indices made with the aid of live animal palpation. The KFI has been accepted as the most satisfactory means of rating body condition post mortem (Finger *et al* 1981), and has subsequently been used to describe body condition of hares (Flux 1967), white-tailed deer (Ransom 1965, Finger *et al* 1981, Johns *et al* 1984), pronghorn (Bear 1971), chamois (Perezbarberia *et al* 1998), mule deer (Anderson *et al* 1972, Torbit *et al* 1988), caribou (Dauphine 1975) and red deer (Riney 1955, Suttie 1983).

While the KFI provides a useful indicator of body condition in animals in the upper levels of fatness, bone marrow fat is most reliable for deer in poorer condition Riney 1955, Ransom 1965), and is usually used in conjunction with the KFI or some other indicator of body condition. Although usually obtained from the femur, mandibular marrow and tibia marrow have been other sites of collection in attempts to estimate condition from BMF levels (Watkins *et al* 1991). BMF has been used as an indicator of body condition in red deer (Suttie 1983), white-tailed deer (Harris 1945, Ransom 1965), mule deer (Harris 1945), caribou (Neiland 1970), pronghorn (Bear 1971), muskoxen (Adamczewski *et al* 1995) eland, impala and cape buffalo (Brooks *et al* 1977).

As described by Neiland (1970), bone marrow is comprised of fat, water and non-fat residue, with the water and fat being inversely proportional. The four main methods of estimating BMF are visual estimation, compression, oven drying and ether extraction, with the first two methods primarily used as field techniques, providing coarse estimations of around 10% intervals of BMF content. While comparative studies of these methods have been undertaken with several ungulate species, ether extraction was found to be the most accurate method in determining fat concentrations in bone marrow (Verme & Holland 1973, Hunt 1979), although results from the oven drying method were shown to be within 5% of ether extraction results - accurate enough in predicting overall body condition.

Hammond (1932) hypothesised that fat depots in farm animals are deposited in a pre-determined sequence throughout growth and in response to varying planes of nutrition, starting with the bone marrow, then the kidneys, heart and viscera, and finally, subcutaneously. This theory was later adopted by Harris (1945) and Riney (1955), adding that fat is thought to be mobilised in the reverse order to which it is laid down. A later study with fallow deer bucks over the rut (Jopson *et al* 1997), a period of well documented weight loss and decline in body condition, added credence to this belief, with subcutaneous fat mobilised before visceral and other fat depots. With a post-mortem assessment of body condition being a 'snapshot' of an individual animal's recent nutritional history, the concept of reverse mobilisation has assisted researchers in understanding how the animal arrived at its current morphological state: ie, if body condition indices indicate a particular animal is in the upper ranges of 'good condition', comparison of various fat depots may indicate whether the animal is either gaining condition, or mobilising fat from a previously higher level of body fatness. However, as noted by Ransom (1965) and Suttie (1983), emaciated animals with BMF < 80% have been noted to also have comparatively low levels of kidney fat (<40%). As pointed out by Suttie (1983), this decreases the predictability of KFI as an indication of body condition in levels <40%, as bone marrow fat mobilised in parallel with kidney fat, not after it, as suggested by Harris (1945) and Riney (1965). Simultaneous mobilisation of fat depots, particularly in times of extreme feed shortage was also noted by Kistner *et al* (1980) and Depperschmidt *et al* (1987) who advocated the use of two or more indicators in estimating body condition.

Another reason for combining one or more indicators in estimating body condition is the varying relationship between kidney weight to total body mass. Several authors have questioned the underlying assumption that kidney weight is proportional to bodyweight, thus providing a benchmark from which deposition or mobilisation of fat can be measured. Torbit *et al* (1988) detected moderate seasonal variations in kidney weights with mule deer, as did Dauphine (1975) and Gerhart *et al* (1996) with caribou, Batcheler and Clarke (1970) with red deer and Van Vuren and Coblentz (1985) with wild sheep. With the kidneys said to regulate protein catabolism in malnourished deer (Torbit *et al* 1985), KFI may not always be an accurate indicator of body condition, especially with animals experiencing, or recovering from periods of malnutrition.

While relationships between chest girth and animal height have been used in various studies on seasonal fluctuations in animal condition (Riney 1955, Weckerley *et al*, 1987, Houghton *et al* 1990), these measures have been met with limited success in terms of estimating BCS, and were of greater use in estimating liveweight (Smart *et al* 1973) and have been moderately used with wild cervidae. The degree of animal manipulation in obtaining such measurements also reduces their application in farming situations when high numbers of animals are to be condition scored live.

Smart *et al* (1973) also described variations in animal assessment due to inconsistencies in animal alignment when using weight tapes. Weight, height and chest girth relationships have been found to be less effective in predicting BCS amongst animals of dissimilar nutritional histories or of varying age than by palpation or other methods of estimating condition (Klosterman *et al* 1968, Nelson *et al* 1985), although when combined with animal liveweight, may be strongly correlated to body condition (Houghton *et al* 1989). Consequently, weight : height ratios and chest girth relationships are not considered to be practical methods of estimated BCS in many situations, although they may provide interesting comparisons with other means of animal assessment.

Certain blood metabolites may also be accurate in predicting animal body condition and nutritional adequacy at various stages of growth, and have been used successfully with a range of domestic species. However, they do not offer the deer industry any practical benefits at this time, and will not be discussed further in this report.

Estimation of subcutaneous fat by palpation is the most common and accurate method of estimating BCS ante mortem, also overcoming the limitations of visual assessment encountered through seasonal variations in animal coat thickness. Particularly with farmed ruminants, body condition of breeding stock provides useful insights into management practices and nutritional adequacy, necessitating the use of simple but precise observations of an animal’s body condition to be made ante mortem. Although fatty depots are only palpable in animals in good condition, prominence of the spine, pelvic girdle, sternum and ribs are also used as indicators of fat or its absence. Body shape and musculature also form part of the visual cues in assigning a BCS.

Various combinations of these indicators have been widely used in development of BCS systems for many farmed animals as previously discussed. These systems have been demonstrated to have a high level of repeatability (Audige *et al* 1998), with methods easily transferred to other assessors. Such methods have also shown to be easily and quickly performed with minimal animal handling and in low light situations. Ultrasound measurements have also been used in attempts to predict BCS and muscle : fat ratios in animals for slaughter, particularly in cattle (Jansen *et al* 1985, Faulkner *et al* 1990, Bullock *et al* 1991) and sheep (Gilmour *et al* 1994, Stanford *et al* 1995). However, as for biochemical assays, ultrasound technology is unlikely to be used on routine evaluation of BCS in deer, when more practical estimations such as palpation and visual appraisal are available.

Relevance of a Grading System to Industry

In terms of animal production, being able to estimate the body condition of an animal is vitally important for both breeding and slaughter stock. Body condition has been studied in relation to health and reproductive performance in cattle (Gearhart *et al* 1990, Markusfeld *et al* 1997), sheep (Cumming *et al* 1975, Thomas 1990), moose (Testa & Adams 1998) and red deer (Hansen 2000, Audige *et al* 1998). The latter study revealed some important relationships between condition score and reproductive performance, of which some important parallels lie between maternal nutrition and reproductive wastage. Of particular relevance to fallow deer farmers in Australia, and in line with nutritional requirements discussed in Section 2 of this report, it was demonstrated that deer gaining body condition during pregnancy were less likely to lose their progeny up to weaning, and conversely, hinds losing body condition during the last trimester of pregnancy were more likely to have lighter calves at weaning. A strong correlation between high BCS and low conception rates was also shown, although there has been no documented evidence of reproductive wastage occurring due to overfat breeding stock with fallow deer in Australia. Similarly, hinds with a high BCS in the third trimester of pregnancy were more prone to dystocia. As previously discussed, inadequate maternal nutrition and resultant under-condition has been the crux of poor reproductive performance in the Australian deer industry.

Given this strong relationship between body condition score and reproductive success, fallow deer farmers may also use animal condition as a measure of nutritional adequacy at various stages of production. As documented by Audige *et al* (1998), a simple and reproducible system for live animal assessment allows farmers to set seasonal threshold limits for body condition of breeding stock, providing farmers with daily visible cues of animal performance, especially during critical periods of the reproductive cycle such as conception, T3 and lactation.

At present, fallow deer farmers and processors alike have no standardised means of identifying, or communicating the live condition of an animal, and thus find it difficult to estimate the potential meat yield and consequent value of any particular animal. This has been the cause of a continuing rift between the processing and farming sectors, with farmers often unsure of the value of their slaughter stock. A recent pricing schedule published by a prominent venison processing plant in Sydney graded deer from 1 (emaciated) to 5 (fat), paying a premium for grade 4, or 'prime' animals, and stating that grade 1 and 2 animals had "no value at abattoir". However, no animal or carcass descriptions were supplied with the schedule, leaving farmers wondering what a 'prime' animal looks like.

While meat yield and fat content of various age and sex types of fallow deer have been documented (Mulley 1989, Hogg *et al* 1993), there is not always a correlation between liveweight and meat yield among animals of varying body condition. This is particularly apparent when comparing entire and castrate carcasses or when hybrid animals are slaughtered. The GR site (measurement of tissue cover over the 12th rib) has been extensively used as an indicator of carcass fatness with sheep (Hopkins *et al* 1995, Kirton *et_al* 1995), cattle (Ferrell & Jenkins 1984, Faulkner *et al* 1990, Gregory *et al* 1998) and goats (May *et al* 1995), although there has been no documented correlation between this measurement and carcass fat with farmed deer.

Although this study did not investigate total meat yield and fat content of animals in each condition score, it is widely accepted that emaciated animals have a lower meat yield than animals in good condition. Similarly, overfat animals, although providing a greater meat yield than poor animals, are a cost to the processor through excess fat that is removed during processing, and may not necessarily have a higher meat yield than a similar sized animal of a 'medium' condition score. Consequently, farmers are paid a premium by processors for animals deemed to be in 'prime condition', are docked for 'overfat' animals, and in many cases, are not paid at all for animals in 'poor' condition. A condition scoring system for fallow deer will allow farmers to firstly, produce a line of animals that processors are willing to pay for, and secondly, provide farmers with a greater awareness of the condition of their slaughter stock in conjunction with growth rates, targeted slaughter age and subsequent nutritional requirements.

Although this study has not delved into the finer details of meat yield, total body fat and intramuscular fat levels of animals across all condition scores, it has provided the first step of developing a repeatable system through which both farmers and processors are able to firstly, effectively communicate the condition of live fallow deer, and secondly, make accurate predictions on the carcass characteristics of graded animals. This regulation of animal condition also conforms with the need for uniformity of slaughter stock and Quality Assurance if the Australian deer industry is to expand. This section describes live animal and carcass characteristics of farmed fallow deer of varying levels of body condition.

6.2 Methods used in this study

Over 350 deer were assigned a BCS based on live animal appearance and palpation. The majority of animals scored formed part of nutrition trials described elsewhere in this report, and were scored weekly over the duration of the respective experiments. Other animals were purchased from a previously described commercial deer property in Bathurst, expressly for the purpose of live animal and carcass assessment. The majority of animals scored were does and castrates including ¼ Mesopotamian hybrids. Out of the deer assigned live body condition scores, 235 were slaughtered at the UWS-H experimental abattoir as described by Mulley & Falepau (1999), and carcass fat measurements used in developing a range of fat depth thresholds at various sites for each condition score. All animals slaughtered were >14 months of age.

To assign a BCS, deer were palpated whilst restrained in a drop-floor crush and in groups of 3-6 in small pens. The spinal and rump regions of each deer were palpated as described by Audige *et al* (1998). Variations in subcutaneous fat depth were easily detectable in these areas, although changes in body shape and musculature were used as major determinants of condition in addition to prominence of the spine and wings of the pelvis. To a lesser extent, brisket fat and the perineum also served as a guide of BCS, which were particularly prominent with animals in upper BC scores. A body condition score chart has been developed based on the system described by Russel *et al* (1969) for sheep and Audige *et al* (1998) for red deer. Scores range from 1 (emaciated) to 5 (overfat), with half unit increments. Condition score charts for fallow and red deer are seen in Appendices 1, 2 and 3.

6.3 Results – Live Animal Descriptors

Deer were assigned a condition score based on live animal appearance and palpation as described by Audige *et al* (1998). Body condition score of deer was determined as follows :

Grade 1 : Very Poor Condition (Emaciated)

Animals in this category may be very old or are emaciated through malnutrition, old age and or parasitism, disease or injury. Grade 1 animals would be considered to be near death in many cases, with severe muscle atrophication. The wings of the pelvis are extremely prominent, with no palpable fat over the rump, which may be described as concave, with little muscle coverage. The spine is also highly palpable, giving the body an angular appearance. In many cases, ribs may also be palpable or even visible through the skin. Musculature in the hindquarters is also highly visible. Plates 1 and 2 illustrate the degree of emaciation seen with animals in BCS 1.

Grade 2 : Poor Condition (Lean)

Deer in this category are also particularly thin, but are more commonly seen on farms than deer in BCS 1. Some bucks during and after the rut may deteriorate in body condition to BCS 2, especially if they were in poor condition over summer or feed is short during autumn and into winter. Similarly, lactating does may be seen in this BCS in times of feed shortage. As with BCS 1, the wings of the pelvis are prominent and easily palpable. Rump areas are flat, with slight tissue coverage. Sacral spinous processes are easily palpable, with the saddle having a slightly angular appearance. Plates 3 and 4 illustrate animals in this BCS.

Grade 3 : Moderate Condition

Moderate condition could be described as not undernourished, as described in BCS 1 and 2, but not displaying prominent deposits of fat in certain areas of the body. As recommended by Audige *et al* (1998), BCS 3 should be a minimum score for breeding stock. The wings of the pelvis are not as prominent as BCS 1 and 2, but are still palpable with slight finger pressure. The spine is also palpable, but is slightly enveloped in tissue. The body has a more rounded appearance, and greater tissue is palpable on either side of the spine than lower BCS animals. The rump area is still flat, although a greater mass of muscle tissue is felt with firm pressure. Plates 5 and 6 illustrate animals in this BCS.

Grade 4 : Good Condition

Deer in BCS 4 are considered to be in good condition. Wings of the pelvis are rounded, and can be palpated under a thin layer of fat. The spine is also enveloped with fat, and may only be felt with firm finger pressure. The body now has a rounded appearance over the saddle, with no clear delineation between the torso and pelvic area of the animal. The rump areas also have considerable fat coverage, and are slightly convex. Brisket fat is now visible and easily palpated. Plates 7 and 8 illustrate animals in this BCS.

Grade 5 : Very Good Condition (Fat)

BCS 5 describes deer in very good condition. The metabolic debt of pregnancy and lactation usually prevents does from attaining this degree of condition, although bucks with abundant feed may attain BCS 5 over summer. Castrates, if not slaughtered by their second summer may also reach this level of fatness. The wings of the pelvis are concealed in fat and cannot be palpated. Spinal processes are also enveloped in a layer of fat and not felt at palpation, giving the animal a very rounded appearance. The rump is extremely well covered and convex. Brisket fat is highly visible and easily palpated from the thorax to the distal end of the sternum. Plates 9 and 10 illustrate animals in this BCS.

Plate 1 : BCS 1
Rear view

Plate 2 : BCS 1
Side view

Plate 3 : BCS 2
Rear view

Plate 4 : BCS 2
Side view

Plate 5 : BCS 3
Rear view

Plate 6 : BCS 3
Side view

Plate 7 : BCS 4
Rear view

Plate 8 : BCS 4
Side view

Plate 5 : BCS 5
Rear view

Plate 5 : BCS 5
Side view

Footnote:
During this study a collaborative effort between the authors and Dr Chris Tuckwell produced a body condition scoring chart for fallow deer (Appendix 1). This was released for use by Australian deer farmers, along with a condition scoring chart for red deer (Appendix 2), in 2000.

6.4 Discussion

Body condition scores for production animals are useful in evaluating the adequacy of previous feed supply, determining future feed requirements and assessing the health status of individual animals, irrespective of age, sex or reproductive status. It has also been demonstrated with other species such as red deer (Audige *et al* 1998), free-ranging Alaskan moose (Testa & Adams 1998, Keech *et al* 2000) and free-ranging barren-ground caribou (Chan-McLeod *et al* 1999) that BCS is a more important determinant of animal condition than liveweight and thus a more dependable determinant of future reproductive capability.

However, despite the inherent values of BCS systems, one of the main criticisms of subjective condition scoring systems has been that individual assessors or groups of assessors may not be accurate in estimating BCS over time, and thus variations in BCS for individual animals over time may be associated with errors in assessment technique, and not changes in animal BCS (Evans 1978, Domecq *et al* 1995). While validation of BCS over time with quantitative measurements of subcutaneous fat is not always possible on a commercial deer farm (especially over a wide range of scores), other studies have found BCS to be highly correlated with subcutaneous fat depots with sheep (Russel *et al* 1969, Stanford *et al* 1995, Hopkins *et al* 1995a) and cattle (Faulkner *et al* 1989, Houghton *et al* 1989), and it is thus up to the individual farmer or assessor to become familiar with subcutaneous fat levels associated with relevant condition scores.

Audige *et al* (1998) described how deer farmers can employ a BCS system as part of their stock management plan, and proposed a minimum year round BCS of 3 for breeding stock. As discussed previously, energy requirements of fallow does double during lactation, and it is during this period that BCS may be used as a determinant of nutritional sufficiency. If does can be maintained at BCS

3 through to weaning, there is evidence to suggest does will have a better chance of earlier conception (Audige *et al* 1998). Additionally, doe BCS throughout lactation is positively correlated with fawn growth rates, thus elevating the herd average BCS will optimise growth of fawns to slaughter or joining weights. Studies with dairy cattle (Gregory *et al* 1998) have shown that cows with high BCS lose up to 50% of their body fat reserves during the first half of lactation, with subcutaneous fat accounting for 25% of this mobilisation (see section 5.3). Given this, BCS will reflect fat mobilisation subcutaneously, but not the total amount of fat that has been mobilised. As such, minor changes (0.5 BCS) in animal condition below a certain level, particularly during lactation, may have significant effects on total body fat levels and thus the ability of the animal to cope with the metabolic impost of lactation.

The process of estimating BCS of deer is a relatively simple process, which may easily be incorporated in the management program of a commercial deer enterprise. Once familiar with the palpation sites and scoring system, an animal may be quickly allocated a BCS with a minimum of distress. Whilst it is advisable to condition score fallow deer whilst restrained in a drop-floor crush (especially when becoming familiar with palpation sites and the scoring processes), it is possible to palpate animals in a pen or yard. Careful observations can also lead to accurate and consistent condition scoring of the live animal without using palpation as an adjunct, and this may be more useful with nervous or flighty animals. However, seasonal changes in pellage need to be considered when palpation is not used. Furthermore, it may not always be necessary to allocate a BCS to each individual deer in a herd, and the BCS of several animals may provide the farmer with a good indication of the level of condition of the remainder of the herd.

This may also be of assistance to farmers when setting maximum or minimum BCS averages during various seasons or stages of production, with experienced assessors able to provide an accurate estimation of BCS without palpation, such as during supplementary feeding, pasture rotation or just being in close proximity to deer in a paddock, which can be of assistance when monitoring BCS levels within a herd of animals. For example, if a farmer aimed to maintain a herd of fallow does at a minimum of BCS 2.5 during lactation, being able to recognise the characteristics of a 2.5 doe would be of main importance in estimating BCS of the herd, and the accuracy of BCS estimations above a certain score would be of little importance. In this case, recognising the physical descriptors of BCS 2 would be of most importance, with accuracy of grade estimations of grade >2.5 insignificant. However, when slaughter stock are assessed, the visual descriptors of BCS 3.5 and upward would indeed be of significance, and would require a new set of visual and tactile descriptors in setting herd benchmarks.

In one of the experiments described in Section 7, twenty-four pregnant fallow does were condition scored on a weekly basis over early gestation. It was found that a nutritional treatment caused a reduction in BCS over a 12-week period, with visual appearance of does between treatments becoming easily discernible. However, there were variations within treatment groups of up to 1.0 BCS, which highlighted the fact that a threshold number of animals must be scored if nutritional adequacy of a particular herd is to be determined by randomly selecting animals and assigning a BCS to each. Evaluations of BCS on other herds of fallow bucks, does and castrates also revealed wide variations in BCS despite similar nutritional management and animal age.

The ability of farmers to estimate the condition of a herd once a BCS "benchmark" has been set may also be a necessary skill to develop, especially when it is not practical to yard animals for palpation in a crush. As stated by Audige *et al* (1998), visual estimation of BCS is not likely to detect minor changes in body condition, although with assessment calibrated to rate animals at or above a certain BCS, minor changes in average BCS of the herd will not be critical.

While visual estimation of BCS has its advantages in certain production situations, visual assessment also has limitations and should not totally replace palpation of animals in situations where palpation is possible. As noted with other species, seasonal variations in coat length and thickness may make visual assessment of body condition difficult, especially when animals in a herd are at various stages of moulting. Animals in good condition may also have a thicker coat than those in poorer condition, hence the proclivity for scorers to over-estimate at the extremes of animal condition. In this study many of the animals assigned a live BCS were slaughtered, with carcass assessment sometimes revealing minor changes in fat depots which were undetected during live animal assessment. In deer with thick winter coats, although condition score may have been slightly overestimated visually, carcass evaluation revealed that the BCS's assigned after palpation were generally accurate, with no deer assigned a BCS more than 0.5 score outside the carcass definition score.

Whilst deer farmers generally aim to minimise the yarding of stock, those times when deer must be brought into the yards are ideal opportunities to BCS a proportion of the herd palpated and assigned a BCS. Although yarding deer during critical periods of animal condition in relation to feed availability, such as supplementary feeding in winter, do not always coincide with standard management practice, the BCS of does should be critically evaluated at weaning (pre rut), which allows farmers a period of approximately 8 weeks for remedial feeding (if necessary) to bring doe BCS up to the chosen level in time for conception. While weaning provides such an opportunity to estimate BCS via palpation, intermittent monitoring of does throughout lactation would also be useful, if possible, to avoid diagnosing inadequate nutrition in hindsight. Studies with sheep have shown that ewes with low BCS 6-8 weeks prior to mating had a lower probability of successfully rearing lambs to weaning age than ewes with higher BCS, even when placed on an increasing plane of nutrition to parturition (Pollott & Kilkenny 1976). With the current study, it was found that regular scoring also allowed minor changes to be more easily detected with individual animals, who, in a production situation, may be used as indicators of the general condition of the herd. Similarly, farmers should use BCS as a selection criterion in conjunction with liveweight, when selecting animals for slaughter. Until now there have been discrepancies between venison processors and deer farmers concerning the characteristics of 'prime', lean', and 'overfat' carcasses. Venison processors will pay a premium for what they consider to be a well muscled carcass requiring minimum fat trimming, within a given weight range. The BCS descriptors developed for fallow deer in this study will allow farmers, processors and marketers to use a common language industry-wide, and will allow selection of animals for slaughter based on estimated carcass characteristics from live animal assessment.

While visual assessment is the process that the majority of farmers employ to assess animal well being at various stages of production, consciously or not, using BCS is another method of determining nutritional adequacy, and should be of assistance in maximising reproductive performance, and estimating carcass characteristics of slaughter stock. In conjunction with differences in meat yield from animals of different condition scores, meat quality may also be affected by BCS, and may well justify the premiums currently being paid for 'prime' carcases, as is currently being investigated at UWS – Hawkesbury. Preliminary data on entire and castrated fallow bucks suggests that levels of intramuscular fat varies between BCS 2, 3 and 4 (Hutchison 2001 – unpublished data), and may have subsequent effects on meat taste, tenderness and meat shelf life. Such associations between live animal condition, carcass characteristics and meat quality may in future be linked with QA and would assist in promoting Australian venison to both domestic and overseas markets, as recently articulated by Mulley & Hutchison (2001).

6.5 Results – Carcass Descriptors

Following slaughter, carcass characteristics of animals in each grade were compared and fat depth measured. Carcass fat and musculature of deer in each BCS was assessed as follows :

Grade 1 : Very Poor Condition (Emaciated)

A dorsal view of a grade 1 carcass (Plate 11) shows an absence of subcutaneous fat over the rump and loin. Caudal and lateral views also show an absence of fat over the hind legs, forequarters and brisket of the carcass (Plates 12 & 13). Severe atrophication is evident over the rump, saddle and hind legs, with the wings of the pelvis very prominent. The spine is also raised from the loin, and is prominent from the pelvis to the end of the neck. The dorsal view of the carcass reveals the distinct v-shape between the hocks and the tail, indicating very poor musculature and a lack of fat around the base of the tail. The angular appearance of the animal noted during live palpation is evident from cross-sectional view (Plate 14), also showing an absence of fat over the loin. This view also illustrates the degree of muscle atrophication of the loin.

Grade 2 : Poor Condition (Lean)

The dorsal photograph of the BCS 2 carcass (Plate 15) shows small levels of subcutaneous fat on the rump of the animal, with no fat visible over the saddle. As noted during ante-mortem palpation, the wings of the pelvis are prominent, although the degree of protrusion seen in BCS 1 carcasses is not seen. Similarly, the spine is also prominent. A lateral view of the carcass (Plate 17) shows small fat depots over the hind legs, extending down from the base of the tail and in suture lines between muscle groups. A cross-sectional view through the saddle reveals the full musculature of the loin (Plate 18), with the atrophication seen in BCS 1 animals not evident. Brisket fat is also seen in BCS 2 animals (Plate 16), Similar to BCS 1 carcasses, there is a distinct v-shape between the hocks and the tail.

Plate 11 : BCS 1
Dorsal view

Plate 12 : BCS 1
Caudal view

Plate 13 : BCS 1
Lateral view

Plate 14 : BCS 1 Cross sectional view

Plate 15 : BCS 2

Dorsal view

Plate 16 : BCS 2

Caudal view

Plate 17 : BCS 2

Lateral view

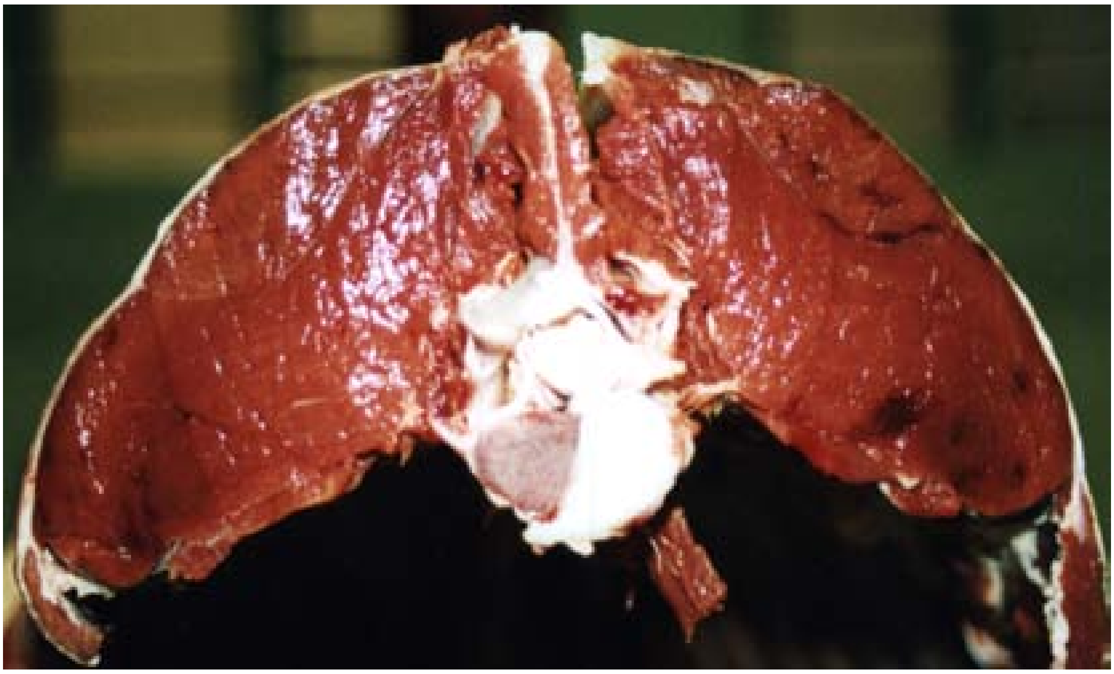


Plate 18 : BCS 2 Cross-sectional view

Grade 3 : Moderate Condition

Dorsal and lateral photographs of a BCS 3 carcass reveal moderate fat depots over the rump, loin and hind legs (Plates 19 & 21), with fat extending anteriorly over the rump and loin towards the shoulders of the animal. As noted during ante-mortem palpation, the rump of the carcass is rounded, and the wings of the pelvis are not easily felt, and not as prominent as BSC 2. Plate 21 also shows the appearance of subcutaneous fat on the forequarter. As with BCS 2 carcasses, muscle groups of the hind legs are still visible, but fat depots encompass suture lines, and the delineation between muscle groups is less clear. Plate 20 illustrates the extent of fat on the brisket, with coverage extending from the thorax to the end of the sternum. Plate 45 also illustrates subcutaneous fatty depots inside the hind legs, making the delineation between muscle groups difficult. A cross sectional view of the carcass reveals a thin layer of fat over the saddle (Plate 22) and a well muscled loin. The shape of this section of the carcass is rounded, as opposed to the angular cross-sections seen with BSC 1 & 2 carcasses.

Grade 4 : Good Condition

The dorsal view of a BCS 4 carcass illustrates fat coverage of the entire length of the carcass (Plate 23). The shape of the rump and hindquarters noted during ante-mortem palpation are reflected by the degree of fat coverage and musculature, with the hindquarters having a distinctly rounded appearance. The dorsal profile of the carcass shows a less angular v-shape between the tail and hocks than with lower BCS grades, primarily due to rump fat. Suture lines between muscle groups on the hindquarters are no longer visible, with only small sections of muscle seen through fat deposits (Plate 25). Fat coverage over the saddle is thicker than BCS 3 carcasses, as revealed in the cross sectional view (Plate 26), with the entire saddle area encompassed by a thick layer of fat. As noted during ante-mortem assessment, the saddle of BCS 3 & 4 animals is rounded, unlike the angular appearance of lower grade animals. A wide depot ob brisket fat extends from the thorax to the sternum (Plate 24), with fat also running under the carcass and up the inside of the hind legs.

Grade 5 : Very Good Condition (Fat)

The dorsal view of a BCS 5 carcass illustrates fat coverage of the entire length of the carcass (Plate 27). A layer of fat extends up to the neck of the carcass and down to the elbow on the forequarter. The subcutaneous fat palpable ante-mortem on the rump of the animal is raised and granular, similar to BCS 5 in red deer. As with BCS 4, suture lines between muscle groups on the hindquarters are no longer visible, with only small sections of muscle seen through fat deposits (Plate 29). Fat coverage over the saddle is thicker than BCS 4 carcasses, as revealed in the cross sectional view (Plate 30), with the entire saddle area encompassed by a thick layer of fat. A wide depot of brisket fat extends from the thorax to the sternum (Plate 28) having a similar lumpy consistency to fat on the rump of the carcass. A layer of fatty tissue also continues under the carcass and up the inside of the hind legs.

Plate 19 : BCS 3

Dorsal view

Plate 20 : BCS 3

Caudal view

Plate 21 : BCS 3

Lateral view

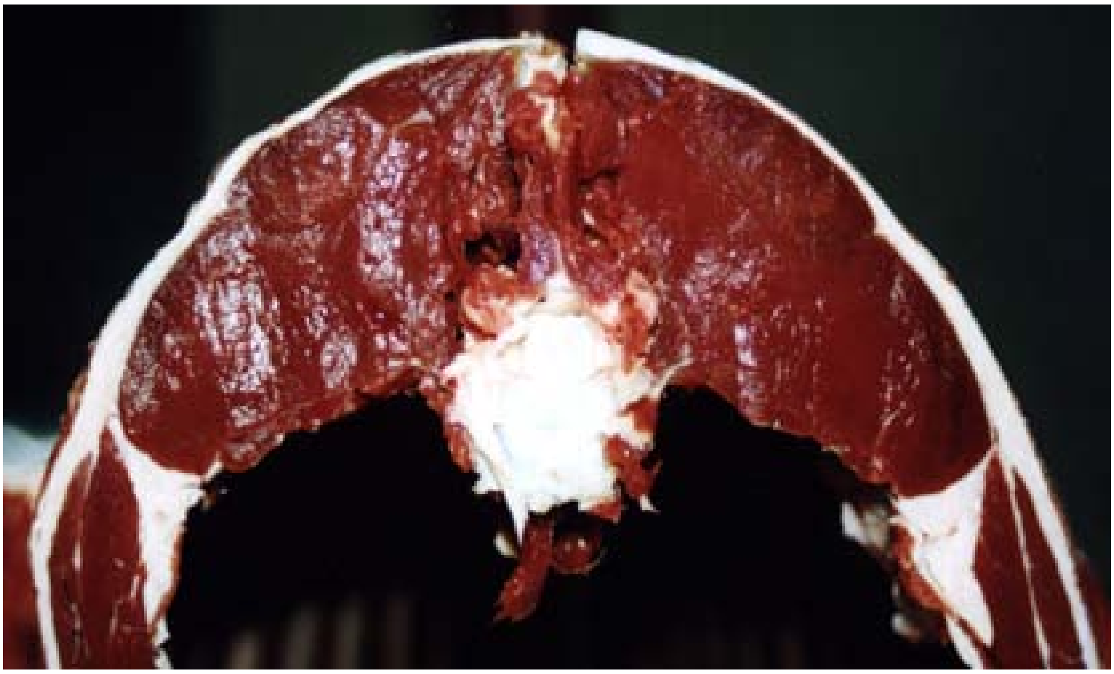


Plate 22 : BCS 3 cross-sectional view

Plate 23 : BCS 4
Dorsal view

Plate 24 : BCS 4
Caudal view

Plate 25 : BCS 4
Lateral view

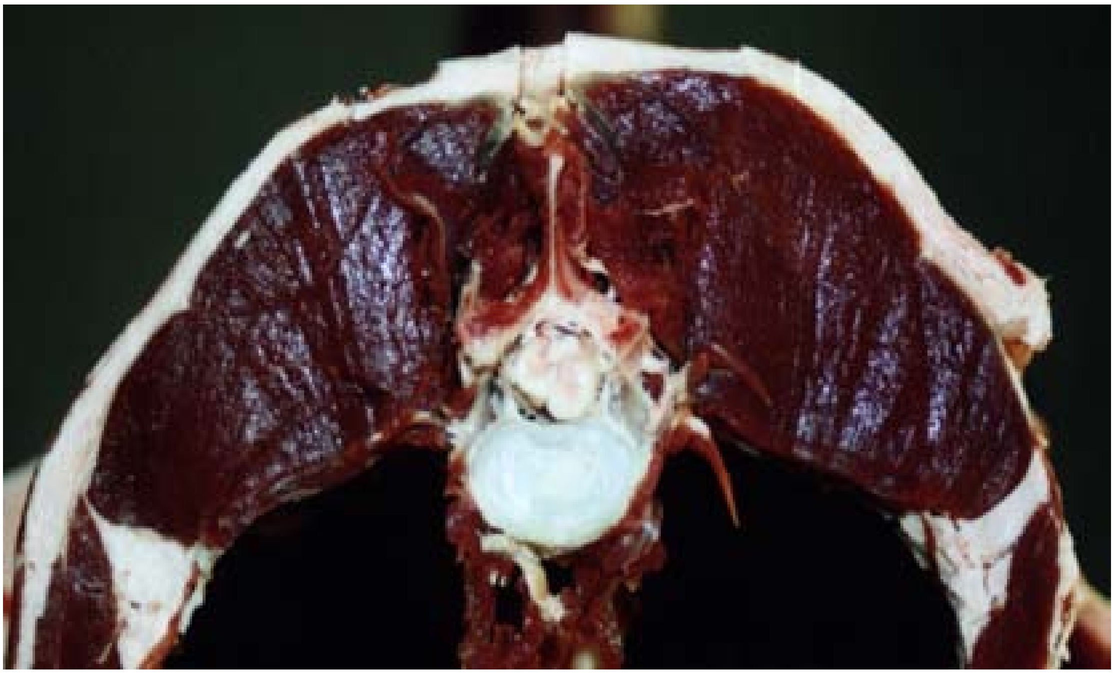


Plate 26 : BCS 4 Cross-sectional view

Plate 27 : BCS 5
Dorsal view

Plate 28 : BCS 5
Caudal view

Plate 29 : BCS 5
Lateral view

Plate 30 : BCS 5 Cross section of loin

6.6 Discussion and Application

Comparing carcass characteristics of animals over BCS grades has illustrated both the degree of muscular atrophication (or inadequate muscular development) seen in deer of lower condition grades and the level of over-fatness and subsequent fat wastage following boning seen in BCS 4 and 5 animals. Table 13 provides a summary of mean fat depths at various sites measured over the period of this study. As indicated, the number of deer at extreme BCS's were not well represented, with the majority of animals measured falling into BCS 2-4, as would be expected to be seen on the majority of deer farms in Australia.

Table 13 : **Mean fat depths (±SEM) at the rump, loin, brisket and foreleg categorising BCS 1 through BCS 5 in adult fallow doe carcasses and yearling (<17 month old) buck and castrate carcasses.**

Location of Descriptor	Grade 1 (n=5)	Grade 2 (n=48)	Grade 3 (n=56)	Grade 4 (n=10)	Grade 5 (n=5)
Rump	0.2 mm (±0.4)	2.3 mm (±0.9)	4.4 mm (±1.6)	7.2 mm (±1.3)	10.0 mm (±1.1)
Loin	0.2 mm (±0.4)	1.9 mm (±0.8)	2.9 mm (±0.7)	4.6 mm (±0.7)	7.0 mm (±0.6)
Brisket	0.6 mm (±0.5)	2.3 mm (±1.0)	4.2 mm (±1.1)	5.5 mm (±0.9)	12.4 mm (±1.9)
Foreleg	0 mm (±0.0)	0.6mm (±0.5)	1.1 mm (±0.7)	2.2 mm (±0.6)	3.0 mm (±0.6)

There were significant differences in fat depth levels between all BCS's at the rump, loin and brisket (P<0.001). The correlation between BCS and depth of fat over the forequarter was not significant across all BCS grades (P=0.515). Fat depth at the rump, loin and brisket were all found to be correlated with BCS (P<0.001) although depth of fat over the rump is a more accurate indicator of BCS. There was a linear relationship (r^2 = 0.759, df = 86, P<0.001) between BCS and depth of fat over the rump. This relationship is described by the equation $y = 0.312x + 1.488$, where y = BCS and x = depth of rump fat. As seen in the BCS transition through Plates 10 to 30, the hindquarters of the animal is the first location for subcutaneous fat to deposit, with fat over the rump being thickest on this area of the carcass.

Whilst each grade has been described, variations in animals and assessors may have an effect on the estimation of the condition of any particular animal. Adult does and yearling bucks and castrates formed the majority of the data set in the current study, with HSCW averaging 24.7kg (SEM±2.8) for does, 25.5kg (SEM±4.2) for castrates and 28.8kg (SEM±5.1) for bucks. Measurements of fat depth at the sites specified in Table 13 from older animals (>2 years old) may not accurately indicate BCS, with an experiment in December 1998 providing an example of this. It was found that in rising 2-year-old fallow deer castrates (n=5) with an average HSCW of 34.7kg (SEM±2.5), fat depth was disproportionate to musculature and animal frame size, and thus the fat depth guidelines shown in the above table would suggest these animals were BCS 5. However, live animal palpation indicated that these deer were BCS 3.5 to 4, and although not performed, the ratio of meat yield : fat wastage may have validated this.

Similarly, deer with a large proportion of Mesopotamian genetics (>5/8 Mesopotamian) may not have fat depots which correlate with the above ranges of fat deposition for each BCS. Technologies used with other species in the meat industry (particularly sheep and cattle) such as electronic GR probes for classifying carcasses (Hopkins *et al* 1995) may well be transferred to deer carcasses with a consequent improvement in grading consistency. Tissue measurements at the GR site may also improve consistency of measurement and thus BCS allocation, as some fat depots, particularly the brisket, tend to lose fat during the skinning process. Measuring tissue depth at the GR site may also be easier than determining fat depth at the loin, rump or brisket as undertaken in this study minimising operator error and discrepancies between carcasses of varying proportions. However, BCS estimations from GR measurements can also be inconsistent due to operator error (Hopkins *et al* 1995).

There were discrepancies in distribution of subcutaneous fat in some deer, particularly does, which was very noticeable with pregnant animals, with fat deposition not appearing to follow a consistent pattern. Bucks also showed seasonal variations in fat deposition within grades, especially when slaughtered in Autumn pre-rut. Therefore, any subjective system of assessing a continuously changing variable within discrete classifications is unlikely to be perfectly repeatable, as carcass results indicate. Although classification of deer to within 0.5 BCS is a simple procedure for deer of slaughter age and for adult does, further research into carcass composition and meat yield across BCS needs to be undertaken. However, the method described in this study will assist farmers and processors in assessing animal condition until these studies are completed.

7. Relationship Between Body Condition Score and Other Quantitative Methods of Estimating Body Condition

7.1 Introduction

While parameters of physical condition of live deer and carcasses have been well defined, other indices of body condition have been used before palpation and visual assessment. A series of physiological measurements have been taken on deer in each of the five condition score grades described in sections 6.2 and 6.3 to see if such indices validate live BCS grades. In many of the measurements and analyses, there were insufficient data from animals of BCS 1 and 5, with the majority of data recorded on animals in BCS 2-4. There have been no previous studies of the correlation between live animal condition score with other quantitative measurement of fat depots in fallow deer. Such as bone marrow fat (BMF) and kidney fat index (KFI), and other morphological measurements. Such relationships may be useful in further studies of the carcass composition of this species to meet commercial QA specifications or for management of wild populations.

7.2 Methods

Deer were assigned a BCS based on live animal assessment as described earlier in this Section before ante mortem or post mortem measurements were recorded.

Measurements taken from deer slaughtered at the UWS-H experimental abattoir between 1997-1999 have been used in developing the following indices. All indices contain animals from each sex type of entire bucks, castrated bucks and does. Calculations of physiological indices such as height / weight ratios were analysed separately across sex groups due to possible differences in morphology. Pregnant does were not used in these experiments due to possible errors associated with conceptus weight.

Extraction and Analysis of Bone Marrow Fat (BMF)

There are several documented methods of determining BMF. Marrow from the central portion of the femur is the standard site for analysis, although mandible marrow has also been shown to demonstrate changes in body condition (Watkins *et al* 1991). Cheatum (1949) described a visual assessment method based on marrow texture and colour, and Greer (1968) described a ‘compression’ method for estimating BMF. However, as outlined by Ransom (1965) and Neiland (1970), the percentage of fat in relation to the dry weight of the bone marrow is a more accurate indicator of BMF, and was the method chosen for use in this study, as described in AOAC (1980).

Either femur (from left or right legs) was removed from carcasses in the boning room. Femurs were cracked open with a ball pane hammer against a firm surface and the bone marrow removed, placed in labelled plastic sample vials and frozen at -20^{o}C. Care was taken to remove any splinters of bone from the resultant marrow sample. The solid consistency of the majority of the marrow samples facilitated removal from the bone for analysis.

Due to the high levels of fat in femur, samples of marrow were hydrolysed with 4M HCL to liberate protein-bound fat before subjected to continuous ether extraction. Marrow samplws were bought to room temperature and macerated. Homogenous samples of approximately 2.0000 grams were boiled with 65ml distilled water and 35ml of 36% 10M HCL (AR, s.g.1.18) for 15 minutes. Sample solution was then quantitatively filtered through 5B filter paper (Whatman Ltd) with boiled distilled water until all acid is removed from sample solution, as indicated by pH indicator strip. Samples were then transferred to soxhlet extraction thimbles (28 x 100 mm, Whatman Ltd) and dried at 100°C for 24 hours. 190ml of petroleum spirit was added to each pre-dried and weighed soxhlet boiling flask, and allowed to extract for at least 6 hours. Extraction was performed in a Buchi 810 soxhlet fat extractor.

Following complete extraction, soxhlet flasks were dried to a constant weight at 100°C, before desiccation and weighing. BMF percentages were calculated from the change in sample weight following extraction. All samples were analysed in duplicate. Precision percentages were within ± 0.5%.

Measurement of Kidney Fat Intake (KFI)

Following the method described by Riney (1955), kidneys were excised from carcasses with a pair of forceps after evisceration. Following removal of adrenal glands, cuts were made with scissors held against each kidney and parallel to its longitudinal axis, removing fat not directly associated with the kidney. Some studies have reported KFI measurements taken on one kidney and its fat (Watkins *et al* 1991). Although discrepancies in kidney weight between sex, age and size of left and right kidneys in some mammals (Torbil *et al* 1988, Dauphine 1975) illustrate the need for decapsulation and weighing both kidneys and their fat.

Each kidney, with and without attached fat and its capsule of connective tissue (*tunica fibrosa*) was weighed to the nearest 0.5 gram. Kidneys were refrigerated and weighed on a digital scale within 48 hours after evisceration of the carcass. The total difference in weight, which represented the fat and connective tissue from both kidneys, was divided by the combined weight of both kidneys without fat or connective tissue. The quotient multiplied by 100/1 gives the kidney fat index in percent.

Carcass and Fat Depth Measurements

Several measurements were taken from both live animals and carcasses during development of a body condition scoring system for fallow deer. Measurements were made ante and post-mortem, as follows:

Live Animal Measurements

Chest girth and height of deer were measured in conjunction with live animal weight and HSCW and other parameters of body condition. Height of the animals was measured from the plantar surface of the hoof to the highest point of the shoulder. Graduations were scribed inside a drop-floor deer crush and measurements to the nearest centimetre recorded with the deer standing. Chest girth was measured following exsanguination as outlined by Smart *et al* (1973). A cloth tape measure was extended around the chest of the animal at the largest circumference, approximately midway between the diaphragm and scapulae . Chest girth was also measured to the nearest centimetre.

Live deer were also palpated whilst restrained in a drop-floor crush as additional determinants of fat coverage when allocating the animal a condition score. Variations in subcutaneous fat depth were easily detectable along the spine, rump and brisket. Musculature and body shape were also used as determinants of condition, and were used in conjunction with palpation. To a lesser extent, the perineum also served as a guide of fat depth, which was particularly prominent with overfat animals.

Carcass Measurements

Four areas of sub-cutaneous fat depth were measured on carcasses. Fat coverage on the foreleg was measured approximately halfway between the elbow joint and shoulder. An incision was made through the fat to muscle tissue and fat depth was measured with a Hennessy probe to the nearest millimetre. Back fat thickness was also determined with a Hennessy probe, from an incision made perpendicular to the backbone at the last sacral vertebra and measuring fat depth at the thickest point in millimetres.

Depth of rump fat was measured from an incision cut at a 45^{o} angle from the spine, starting from the base of the tail and proceeding anteriorly across the rump, as described by Riney (1955). Brisket fat was measured at the thickest point from an incision made at the 3^{rd} rib parallel to the longitudinal axis of the carcass.

7.3 Results

Bone Marrow Fat (BMF)

Samples of bone marrow fat were analysed from 84 deer from BCS 1-4 (Table 14). There were significant differences in levels of BMF between BCS grades 1 and 2 (P<0.001) and between BCS 2 and 3 (P<0.001). There was no significant difference in BMF% between BCS 3 and 4 (P=0.256). BMF% ranged from 63.3 (BCS 1) to 98.6 (BCS 4), although the majority of deer sampled did not have BMF% below 80. Insufficient sample numbers from BCS 5 deer precluded analysis between animals in BCS 4 and 5.

Table 14 : Mean percentages (±SEM) of bone marrow fat (BMF) for adult fallow deer in BCS grades 1 to 4.

BMF %	# deer	BMF range	BMF average
1	n=3	63.3-65.1	65.5 (±0.2)
2	n=24	73.2-91.3	85.4 (±5.6)
3	n=52	83.6-95.7	91.3 (±2.1)
4	n=6	91.3-98.6	94.5 (±2.6)

Results from BMF assays indicate that fat mobilisation of bone marrow does not occur until deer fall below BCS 3, at which point there is a significant reduction in BMF%. Within each assigned condition score, percentages of bone marrow fat fluctuate, with BMF% overlapping between BCS 2, 3 and 4.

Kidney Fat Index (KFI)

Kidneys were obtained from yearling (12-14 month old) bucks and castrates and from adult does (>3 years old) between September 1997 and September 1999. Values for the KFI ranged from 5.2 to 155.2 (Table 15), although only one BCS 5 animal had KFI calculated in this study and was not included in the analysis. There was a linear relationship (r^2 = 0.847, df = 77, P<0.001) between BCS and KFI. This relationship is described by the equation y = 0.02243x + 1.292, where y = BCS and x = KFI.

Table 15 : Mean KFI (±SEM) and range for adult fallow deer in BCS grades 1 to 4.

BCS	# deer	KFI range	KFI average
1	n=3	5.2-10.4	7.9 (±2.1)
2	n=45	23.9-51.5	33.9 (±8.0)
3	n=52	51.0-97.3	71.2 (±12.6)
4	n=6	96.5-128.2	115.1 (±19.7)
5	n=1	-	155.2

Morphological Measurements

Deer height, chest girth and HSCW were measured and analysed against BCS for bucks, does and castrates. Deer were assigned a BCS via palpation before slaughter. Measurements were recorded as described in 2.3.3.

Hot Standard Carcass Weight (HSCW)

There were significant differences in HSCW between BCS's with does and castrates, although not with bucks, although there were insufficient data on BCS 1 and 5 carcasses for analysis. Tables 16, 17 & 18 show data for bucks, does and castrates respectively**.**

Table 16: Mean (±SEM) and range of HSCW's for 12-15 month old fallow bucks in BCS 2 and 3.

BCS	# deer	HSCW range	HSCW Av.
2	n=34	21.5-39.0 kg	28.6 (±4.9)
3	n=27	23.5-39.0 kg	28.7 (±5.1)

There was no significant difference between BCS 2 and 3 with fallow bucks (P=0.851), with large variances in age and time of slaughter possibly responsible for both differences in live BCS and HSCW.

Table 17 : Mean (±SEM) and range of HSCW's for adult (>3 years old) fallow does in BCS 2, 3 and 4.

BCS	# deer	HSCW range	HSCW Av.
2	n=18	20.0-25.0 kg	22.8 (±1.5)
3	n=26	21.5-27.5 kg	25.1 (±1.7)
4	n=4	29.5-33.5 kg	31.3 (±1.8)

There were significant differences between BCS groups in the relationship between BCS and HSCW with fallow does. Ryan's Q-test showed that BCS 2 does had significantly lower carcass weights than BCS 3 does (P=0.007), and BCS 3 does had lower carcass weights than those of BCS 4 (P=0.002).

Table 18 : Mean (±SEM) and range of HSCW's for 12-15 month old fallow castrates in BCS 2, 3 and 4.

BCS	# deer	HSCW range	HSCW Av.
1	n=3	20.0-21.5 kg	20.5 (±0.9)
2	n=18	21.0-25.0 kg	23.4 (±1.2)
3	n=13	25.0-30.0 kg	26.6 (±1.2)
4	n=5	31.0-37.5 kg	34.7 (±2.5)

BCS 1 castrates had a significantly lower HSCW than BCS 2 deer (P=0.058). BCS 2 were also lighter than BCS 3, (P=0.001) and 3 lighter than BCS 4 (P=0.005). Ryan's Q-test found significant differences in HSCW between BCS 1-4 in fallow castrates.

Chest Girth

Relationships between chest girth (CG) and BCS were analysed with does and bucks separately due to differences in size and liveweight. Adult does (n=84) and yearling bucks (n=51) were measured prior to slaughter as described in Section 7.2. As shown in Tables 19 and 20, there were only slight variations in CG between BCS with both does and bucks.

Table 19 : Mean (±SEM) and range of chest girth (CG) measurements for 12-15 month old fallow bucks in BCS 2, 3 and 4.

BCS	# deer	CG range	CG Av.
2	n=29	70-95 cm	81.1 (±6.3)
3	n=18	70-90 cm	81.6 (±6.1)
4	n=4	85-95 cm	90.0 (±4.1)

Chest girth was not shown to be an accurate predictor of BCS with fallow bucks. There was no significant difference in CG measurements between BCS 2 and 3 (P=0.768). Differences in CG between BCS 2 and 3 does were also insignificant (P=0.347). However, there were significant differences between BCS 2 and 4 (P=0.008). The differences between CG with BCS 3 and 4 bucks, although significant (P=0.032) may be misleading due to the small number of BCS 4 bucks measured.

Table 20 : Mean (±SEM) and range of chest girth measurements for adult (>3 years old) fallow does in BCS 2 and 3.

BCS	# deer	CG range	CG Av.
2	n=33	72-85 cm	78.2 (±3.2)
3	n=51	78-90 cm	82.7 (±3.6)

Height

The height of adult (>3 years old) does (n=52) 12-15 month old bucks (n=25) was not correlated with BCS. However, for adult does, height approached significance between BCS 2 and 3 (P=0.087), and height between BCS 2, 3 and 4 was not significantly different with yearling fallow bucks (P=0.234).

7.4 Discussion

While the majority of alternative methods of assessing animal condition had a degree of correlation with BCS, they were generally not consistent enough to be used as sole indicators of BCS and when factors such as sex, age and genotype are taken into consideration, they are limited in their use at predicting animal condition on the live animal and carcass basis. However, this research has made it apparent that certain morphological measurements (taking into account such variable factors) may be useful techniques for estimating BCS, particularly when combined with one or more condition indices.

β-OHB was found to be a reliable indicator of body condition in adult does, and may be of use to farmers in assessing nutritional adequacy over gestation, particularly in T3 when feed requirements have been shown to increase (see Section 2). While the current study did not study seasonal variations in doe condition to set seasonal BCS thresholds for fallow does, other studies with red deer have suggested annual BCS minimums for breeding hinds (Wilson & Audige 1996, Audige *et al* 1998), which may be validated through circulating β-OHB concentrations. As with some of the other measurements recorded in this study, β-OHB concentrations may not be of direct use in assigning a BCS, but instead provide an indication of condition above or below a threshold level, as advocated by Wilson & Audige (1996).

In the case of yearling red deer hinds, minimum threshold BCS recommendations at weaning, pre-rut and during winter of 3, 2.5-3.5 and 3 respectively, could be adequately assessed by circulating β-OHB concentrations for fallow deer in the current study if these criteria were applied to the species. As shown in section 7.3, there were significant differences in β-OHB concentrations between BCS 2 and BCS 3 animals (P=0.05), which would allow β-OHB concentrations to be used in conjunction with live animal palpation as a secondary means of determining if the herd were above the designated BCS threshold for that part of the reproductive cycle. However, data from the current study found differences in β-OHB concentrations to be insignificant at BCS's above 3, and thus maintaining a herd of does to a maximum BCS threshold of 4 pre-fawning to avoid dystocia (Audige *et al* 1998) could not be determined using this method and live animal palpation would be required. Pre-fawning, and on some occasions pre-joining would be the only times a maximum BCS threshold would be required for breeding stock, with lower than optimal body condition usually responsible for poor reproductive performance in fallow deer. While BCS of 3.5 or more may reduce the chances of conception in red deer (Audige *et al* 1996), the seasonal reduction in liveweight seen in fallow does prior to mating appears to be autonomous of the quantity and quality of feed available (Asher 2000, Muley 2000, pers. comm.) and thus overfatness in fallow does is not recognised as a factor in poor reproductive performance.

Morphological measurements carried out in this study demonstrated that although animal size and liveweight have only a poor correlation with BCS per se, in herds of animals of the same cohort or of the same age, certain morphological measurements such as chest girth may reflect BCS above or below certain scores. Data from these measurements showed chest girth in BCS 4 animals to be significantly larger than BCS 2 and 3, the differences between which were insignificant. Such findings appear to be of little value, and were not correlated with any other condition indices. Although chest girth has been used to predict liveweight in other studies on mammals (Talbot & McCulloch 1965, Weckerly *et al* 1987), it appears to be of little use in predicting BCS with fallow bucks and does. The method would also be quite difficult to obtain from live animals, and if deer were slaughtered, other more reliable methods of determining BCS could be employed.

As with animal height and chest girth, while there were significant differences in HSCW between BCS's with does and castrates, these differences appeared to be a function of age, and not necessarily body condition, especially with castrates. However, the significant difference in HSCW between adult fallow does of BCS 2, 3 and 4 was reflective of nutritionally-induced body condition reductions and liveweight loss, indicating that value per animal, both in terms of carcass weight, and premium paid for 'prime' carcasses is lower for BCS 2 does.

Despite the largely inconsistent results of morphometric measurements, direct measurement of fat depots (BMF and KFI) were found to be useful in estimating BCS above and below certain levels of fatness. KFI was found to have the highest correlation with BCS in this study (r^2 = 0.847, P=0.001). Ransom (1965) reported KFI values as high as 150, with Johns *et al* (1984) reporting a figure of 264 from a white-tailed doe, although as shown in Table 15, the highest KFI value seen in this study was 155.2. Studies with white-tailed deer have found KFI to be highly correlated with total body fat (Finger *et al* 1981), and with the linear relationship seen between KFI and BCS in the current study, it would appear that a similar relationship may exist with fallow deer. Furthermore, this emphasises the use of the KFI as a secondary means of determining animal condition, as advocated by a number of authors cited in this Section. However, as discussed earlier, kidney weights in other ruminants are known to fluctuate seasonally, thus affecting the KFI.

While there have been no studies on seasonal fluctuations of kidney weight with fallow deer, such variations have been documented in white-tailed deer (Johns *et al* 1980), red deer (Batcheler & Clarke 1970), caribou (Dauphine 1975) and sheep (Van Vuren & Coblentz 1984), which according to authors of the first two studies, may substantially alter inter-seasonal comparisons of KFI as an indicator of total body fat. For this reason, several authors found relationships between kidney fat and total body fat with various free-ranging deer species (Torbit *et al* 1988, Watkins *et al* 1991, Chan-McLeod *et al* 1995), thus negating the seasonal variations found in kidney weights. Irrespective of the degree of seasonal fluctuation in kidney weights, KFI by its design is still a function of kidney size (Riney 1955), and not animal liveweight, and data from this study suggests that the magnitude of changes in mean kidney weight within deer populations are unlikely to limit the effectiveness of the KFI as an indicator of body condition above or below a threshold limit.

Despite the known seasonal fluctuations in kidney weight of many species, these are normally associated with seasonal feed availability (Batcheler & Clarke 1970), and given the highly seasonal nature of VFI and bodyweight of fallow deer, it is likely that KFI would still be indicative of total levels of body fat at the point of slaughter. A number of studies on KFI with free ranging deer and ungulates have found relationships between KFI and total body fat, similar to the KFI – BCS relationships seen in the current study. In studies on a free-ranging mule deer population, Andersen *et al* (1972) found the average KFI of adult deer to be under 30, with younger animals having even lower mean KFI's. Accordingly, no juvenile deer, and over 60% of adult deer had no measurable back fat, which, in relation to the fallow deer data generated in the current study, reflects the relationship between BCS 1 and 2 animals and their relative KFI. A similar study with pronghorn antelope revealed that animals with KFI values below 15% had exhausted all other fat depots, and were near death (Depperschmidt *et al* 1987).

As shown in Table 15, mean KFI levels dropped substantially below BCS 3, with BCS 1 animals often having no measurable kidney fat, and thus over a range of BCS, the KFI appeared to be a good indicator of body fat, and unlike BMF, was not constrained by the apparent sequential fat deposition patterns seen with fallow deer in this study and others (Suttie 1983, Chan-McLeod 1995). This pattern of sequential deposition / mobilisation was highly apparent with BMF samples in the current study, with animals below BCS 3 having significantly lower percentages of BMF than BCS 3 and 4 deer. Many authors have been critical as to the value of BMF in estimating body fat due to its non-linear relationship between total body fat, although for the purposes of estimating body condition and setting minimum BCS thresholds for mobs of farmed fallow deer (or wild fallow deer populations) this characteristic may be of use.

Data from this study suggests that animals with a BMF% of below 91.3% (SEM±2.1) fall into the BCS 2 category, with BMF levels above this appearing to have no correlation with BCS. Hence, when requiring an accurate estimation of animal condition above BCS 3, a more sensitive indicator of body fat at the upper range of fatness is required. Relationships between BMF and KFI with other ungulate species have also confirmed this. Suttie (1983) demonstrated with red deer that KFI levels below 50% may not be an accurate indicator of condition due to the parallel mobilisation of BMF, and vice versa, with BMF levels below 80%, although studies with white-tailed deer (Ransom 1965) suggest a KFI of 20 to 30 as a minimum level for predicting animal condition. As such, differences in the sequences or rates of fat mobilisation between species may prohibit comparisons between fallow deer and other deer species and ungulates, and provide further evidence that two or more indices are required to accurately assess animal condition, particularly over the lower ranges of body fatness.

However, parallel patterns of fat mobilisation as shown by KFI and BMF relationships have been observed in Caribou (Chan-McLeod *et al* 1995), pronghorn antelope (Bear 1971, Depperschmidt *et al* 1987) and mule deer (Anderson *et al* 1972), with all of these authors reinforcing the findings of the current study. While either one of these two indices may not be totally reliable in extrapolating total body fat across the entire spectrum of animal condition, this study has provided evidence that both KFI and BMF would be useful in predicting BCS above or below a set BCS threshold, which would be the primary use of such data to the deer industry. With such post-mortem assessments being secondary means of identifying BCS after live animal palpation and subcutaneous fat depth measurements, KFI particularly would provide a quick and simple method of verifying the condition of an individual animal within BCS specifications.

7.5 Conclusions

Body condition scores represent a subjective visual and tactile evaluation of the amount of subcutaneous fat on an animal, and have been developed for the majority of farmed animals. While inadequate detail and the use of esoteric terminology has led to criticism of many BCS systems, the scoring chart for fallow deer (RIRDC 2000) is easily understood, and has been primarily developed for use by fallow deer farmers. This study has demonstrated that a number of methods may be employed to determine the BCS of fallow deer, including live animal and carcass assessment. As discussed earlier in this chapter, it has been established by a number of authors that the ability to assess BCS of both breeding and slaughter stock is of paramount importance to farm productivity, with BCS often being of more importance to production parameters than liveweight. The setting of threshold BCS’s, and more importantly, the ability of farmers to judge body condition is an important part of forward sale contracts (Wilson & Audige 1996).

The maintenance of threshold BCS’s of breeding stock has been demonstrated to have a high association with conception rates, fawning percentages and fawn weaning weights (Wilson & Audige 1996). Similarly with animals of slaughter weight, the ability of the farmer to assess BCS may have an important influence on the timing, age and selection of animals for slaughter, with premiums paid for animals of good condition. Monitoring the BCS of a herd of animals also allows farmers to target live animal condition and adjust access to feed accordingly. While energy intake of fallow does over gestation and lactation for successful reproduction have been derived, these would be well complimented and nutritional adequacy verified by animal BCS.

The majority of fallow deer on Australian deer farms fall into BCS 2, 3 or 4. Very rarely, if ever will breeding does reach grade 5, although breeding bucks should attain BCS 5 over summer in preparation for the rut and subsequent period of weight loss. Similarly, no farmed deer should reach BCS 1. Many of the indices from the current study indicate a significant mobilisation of subcutaneous fat under BCS 3, as verified by live animal palpation and carcass assessment. Below BCS 2, the degree of fat mobilisation leaves an animal that is unfit for both reproduction or slaughter, with body fat reserves at critical levels. The BCS system developed in the present study has documented the differences between these two grades, which should allow farmers to differentiate between animals of these two scores.

Data from this study and others (Chan-McLeod *et al* 1995, Audige *et al* 1998) indicate that below BCS 2, body fat levels are prohibitive to growth and reproductive capabilities. Farmers should aim to maintain stock at BCS 3, allowing stock to absorb possible periods of nutritional shortfall without dangerously mobilising body fat reserves. As previously discussed, flow on effects of increased reproductive performance through setting minimum BCS thresholds extend to faster growth rates of fawns, higher weaning percentages and faster attainment of breeding / slaughter weights. Monitoring the BCS of breeding herds should be a rudimentary part of farm management, which in conjunction with regulation of energy intake requirements, should increase the productivity of many Australian deer farms.

8. Effects of Varying levels of Nutrition on Foetal Development and Doe Condition

8.1 Literature Review : Pregnancy and Nutrition

Metabolisable Energy Requirements for Pregnancy in Ruminants

In a recent review of the ME requirements of sheep, goats, beef and dairy cattle throughout pregnancy, Oftedal (1984) quoted increases from 0.42 to 0.55 MJ ME/kg$^{0.75}$/day at maintenance to 0.58 to 0.71 MJ ME/kg $^{0.75}$/day during late pregnancy. Further rises to between 1.0 and 1.13 MJME/kg$^{0.75}$/day were also quoted for early lactation in non-dairy animals. As illustrated in Chapter 3, pregnant fallow does displayed similar increases in energy consumption on a metabolic bodyweight energy intake basis, perhaps eclipsing the 1.13 MJME/kg$^{0.75}$/day figure in mid lactation due to the lower propensity of fallow deer as a species to carry excess bodyfat as a supply of maternal nutrients.

As has been found with other wild cervids such as elk (Thorne *et al* 1976, Robbins *et al* 1981), chital deer (Mulley *et al* 1994), white-tailed deer (Silver *et al* 1969, Ullrey 1970, Brown *et al* 1995) red deer (Kay 1969, Simpson *et al* 1978, Fennessy 1981, Asher *et al* 2000) and fallow deer (Asher 1984, Mulley 1989, Flesch & Mulley 1998, Mulley *et al* 2000), metabolisable bodyweight energy intake in deer is generally higher than that of domestic livestock species, with ME requirements for pregnancy, where studied in these species, also shown to be comparatively higher than domestic ruminants. Despite this, the energy requirements during pregnancy for a range of ungulates, both domestic and wild, are sufficiently different to make prediction from one to the other unreliable (Loudon 1985), as previously demonstrated with interpolation of red deer MEI in predicting fallow doe requirements through pregnancy (Milligan 1984, Asher 1992).

Robbins (1983) suggested that the requirements for ME to support foetal growth in ungulates peaks at about 40% above the requirement of corresponding non-pregnant animals, irrespective of body size. Data for penned fallow deer over gestation (see Section 2) approached this 40% increase during the last trimester of pregnancy compared with non-pregnant does, bucks and castrates (Mulley *et al* 2000), reinforcing the need for increased feed availability for breeding stock.

In conjunction with maternal energy intake, energy requirements throughout lactation (shown to be almost double maintenance requirements in this study) are also of vital importance to successful reproduction. In long-lived mammals like deer, the price of lactation is frequently measured in terms of its impact on the future fertility of the dam with the metabolic toll of lactation in fallow deer often manifest in “dry years”, where does do not conceive, presumably due to low body fat reserves as a result of inadequate nutrition over the previous breeding season.

Maternal Nutrition and Conceptus Development

Excessively high or low birthweights in sheep, cattle and deer are typically synonymous with an increase in neonatal mortality. Dams carrying large offspring are susceptible to dystocia (Thomas 1990, Hansen 2000), while neonates with low birthweights may suffer from starvation or exposure (Alexander & Peterson 1961, McCutcheon *et al* 1981, Mulley 1989). While there are multiple factors controlling foetal development, maternal nutrition is the major component affecting neonate viability. Though dystocia can be a major cause of postnatal mortality (often including the dam), inadequate nutrition during gestation has wider ranging effects on conceptus development, body condition and future reproductive performance of the dam, and is frequently linked to reproductive failures in domestic livestock farming systems.

Maternal nutrition controls foetal growth directly by providing glucose, amino acids and essential chemical elements for the conceptus. It also controls foetal growth indirectly by modifying the expression of the endocrine mechanisms that influence the uptake and utilisation of nutrients by the conceptus (see review by Robinson *et al* 1999). The expression of these mechanisms is further modified by maternal characteristics, such as body size, body condition score, age and reproductive history of the dam (Robinson *et al* 1994). These features influence the partitioning of nutrients between the uterus and maternal body, affect the growth and function of the placenta and consequently alter the growth response of the foetus to fluctuations in maternal nutrition.

Placental development begins soon after conception, when the chorion fuses to many endometrial caruncles to form individual placentomes, which together constitute the placenta (Hamilton et al 1960). In pregnancies where there is only one foetus, which is usual in fallow deer (Armstrong *et al* 1969), the number of placentomes involved in the placental structure for an individual foetus is greater than would be expected when there are multiple foetuses. In pregnancies where there are multiple foetuses such as sheep, foetal size is limited to some extent (Donald & Russell 1970, Foot *et al* 1984). As documented by Robinson *et al* (1977), the average ratio of individual twin lamb weight to the weight of single lambs being approximately 0.8, reflecting their smaller and shared placental mass and consequent competition for nutrients (McCoard *et al* 1997). However, twinning is rare in fallow deer (Chapman & Chapman 1975) and thus not considered a restriction to foetal development in this species. Total placental mass rather than placentome number is also of greater significance to foetal development (Alexander 1964), and in many species, size at birth is correlated with placental weight (Heasman *et al* 1998).

In sheep, maternal bodyweight and condition score at conception influences the ability of ewes to maintain placental development following nutritional deficiencies during mid gestation (Robinson *et al* 1994, Clarke *et al* 1997). Lower than normal bodyweight and condition score at joining results in lower than average lamb birthweights and reduced survivability (Russel *et al* 1981, Mellor 1983, Clarke *et al* 1997). Furthermore, inadequate maternal nutrition during early pregnancy in sheep can result in a significant decline in maternal bodyweight that may extend into late gestation if undernutrition continues (West 1996, Heasman *et al* 1998), reiterating the importance of setting BCS thresholds in conjunction with, or instead of liveweight thresholds for joining in order to minimise effects of nutritional perturbations during early gestation. As reviewed by Gluckman (1986), foetuses of similar genetic background grow faster in-utero in larger dams. Along with maternal size, parity has also been shown to affect foetal development and birthweight in mammals, particularly pigs (Penny *et al* 1971). It has been shown that lambs from primiparous sheep generally have lower birthweights than those from multiparous ewes (Wallace *et al* 1996, 1997), a phenomenon also seen with fallow deer (Asher & Adam 1985).

Until recently, studies of the impact of nutrition on foetal development tended to concentrate on late pregnancy when the majority of foetal growth takes place (Cooper *et al* 1998). As reviewed by Robinson *et al* (1996) the plane of maternal nutrition and size of the placenta are well recognised as major determinants of foetal growth rate and neonate viability. It has been shown that the survivability of the foetus in lambs is jeopardised more by a small placenta than by maternal underfeeding (Davis *et al* 1981, Clarke *et al* 1997).

Clarke *et al* (1997) also demonstrated that restricted levels of nutrition from days 30 to 90 of gestation resulted in a decrease in placental weight in ewes with low bodyweights at joining, giving birth to smaller lambs, despite *ad libitum* feeding during the remainder of pregnancy.

In practice, the size of the placenta and maternal nutrition act simultaneously and their effects may be confounded, as a high plane of maternal nutrition can partly offset the growth retarding effects of poor placentation. Recent studies on maternal nutrition during mid-gestation with sheep (Krausgrill *et al* 1999) have indicated that while significant reductions in maternal energy consumption (causing ewes to lose between 25 and 30% of their joining weight) during early gestation have moderate effects on placental development resulting in shorter crown-rump lengths and foetal weights during mid gestation, lamb birthweights and survivability were not affected by the early pregnancy feed restriction when ameliorated with *ad libitum* feeding for the remainder of pregnancy. Furthermore, post-natal growth to weaning was also unimpaired, with lambs from ewes on a restricted feed intake attaining weaning weight at the same time as their *ad libitum* fed control counterparts.

Increases in gestation length in sheep have also been reported in response to sustained reductions in maternal energy intake (Davies *et al* 1966, Holst *et al* 1986), with similar observations also made in penned white-tailed deer (Verme 1965) and with red deer hinds on low planes of nutrition during the second and third trimesters of pregnancy (Asher *et al* 2000).

The implications for optimal conceptus development and neonate viability are apparent, particularly in deer, where high levels of perinatal mortality due to poor foetal growth are the causes of significant financial loss (Mulley 1989). While the major cause of poor foetal growth and viability may be directly attributable to poor placental development imposed by dietary restrictions during early gestation, age, parity and body condition of the dam also influence the direction and magnitude of placental responses to maternal nutrition (Robinson *et al* 1999). Each of these have consequences for immediate reproductive success of the dam, as well as neonate survivability, longer-term growth and indeed, future reproductive performance.

8.2 Effects on Conceptus Development throughout Pregnancy from FeedingPregnant Fallow Does a Maintenance Level of Metabolisable Energy.

Introduction

While the energy intake requirements of fallow does has been experimentally derived, there has been little or no data available on the consequences of sub-optimal maternal nutrition on foetal and placental development. Most of the data available on placental and foetal measurements are from other studies with pregnant fallow deer (Weber & Thompson 1994) have concluded that conceptus development over early pregnancy poses little metabolic challenge to the dam, with a recent study on varying levels of maternal energy intake with red deer hinds (Asher *et al* 2000) also demonstrating the ability of the dam to absorb nutritional stress without compromising foetal development.

With the misalignment of fallow doe energy requirements with pasture availability well known, and furthermore, the VFI and consequent ME intake of pregnant fallow does experimentally derived, it was concluded that many pregnant fallow does on commercial deer farms may not receive the level of energy suggested by individual pen feeding trials. Complimenting the ME data which led to this suggestion are the statistics for reproductive performance of fallow deer in Australia, indicating that nutrition, or lack of, may be responsible for the current lower than expected level of fawns weaned per one hundred does mated each year. As lamented by Mulley (1989), perinatal mortality has long been a concern with fallow deer, with low levels of maternal nutrition synonymous with the prevalence of low birthweight dysmature fawns that do not survive beyond their first few days of life.

In conjunction with various farm observations, personal communication with other deer biologists and research scientists, it was concluded that figures for the maintenance level of intake, as derived by Mulley *et al* (2000) may reflect the level of feeding received by breeding stock seen on many Australian deer farms. As discussed in Section 2, daily ME intake for individually housed pregnant E and H does was shown to surpass that of non-pregnant does by the end of T1. As demonstrated by Weber & Thompson (1994), body composition of pregnant does as determined by computer-aided tomography remained the same as non-pregnant does by the end of week 8 of gestation, reflecting the insignificant maternal effects of conceptus development over T1. However, as previously discussed, the nutritional intake and resultant energy reserves of the dam prior to and at conception, affect the ability of the dam to absorb nutritional stresses imposed by, and during gestation. The aim of this study was to determine the effects of restricted maternal nutrition on conceptus development at various stages of gestation, possibly reflecting the degree of maternal energy restrictions unknowingly imposed on fallow does in commercial deer farms in many regions of Australia.

Methods

On the 16th of March 1998, thirty-six multiparous (>4 years) E fallow does and thirty-six multiparous H fallow does were weaned from their fawns and assigned a feeding treatment which lasted until slaughter.

Reduced Intake Treatment

Thirty six does (18 E and 18 H) were assigned to a maintenance level of feeding based on $W^{0.75}$ of non-pregnant fallow deer, derived from Mulley *et al* (2000), at the time, unpublished data (see Figure 61). This group were fed a modified dairy ration (described previously) containing 14MJME/kg DM and 16% CP.

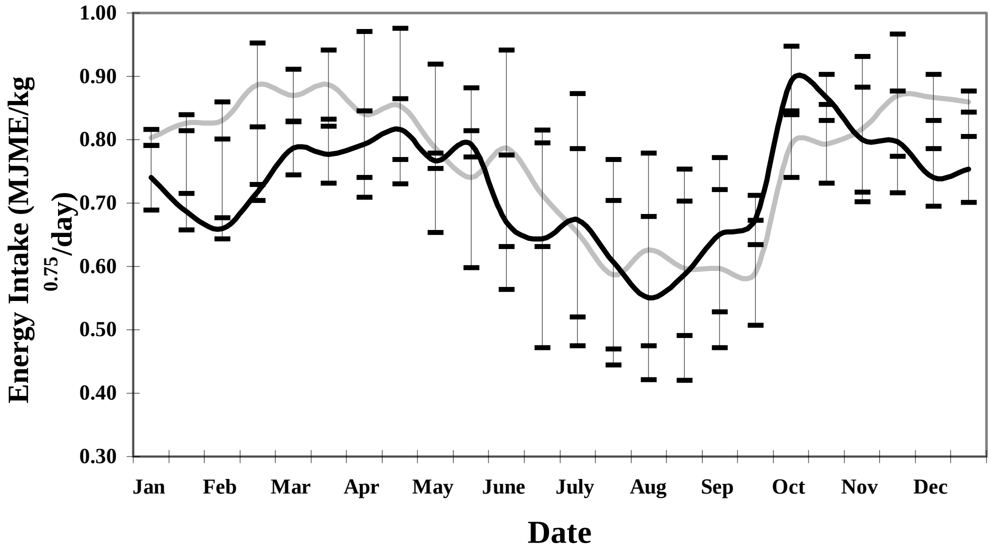


Figure 48 : Fortnightly averages (±SEM) of MJME/kg$^{0.75}$/day for non-pregnant E and H fallow does

Weekly doe liveweights were used to calculate feed offered for each doe. Bi-weekly averages of metabolic bodyweight energy intake from the above figures were pooled between genotype and used to determine ME intake on a weekly basis, contingent on animal liveweight (Table 21) which was measured weekly. The sum total of feed based on treatment liveweight and allocated maintenance level of feeding for that fortnight were pooled and fed via four large plastic feed troughs, approximately 2 metres long each and 30cm wide. These reduced intake (RI) does were located in a bare ¼ Ha paddock, devoid of edible grass.

Table 20 : Bi-weekly averages of metabolic bodyweight energy intake (MJME/kg$^{0.75}$/day) derived from individually housed non-pregnant fallow does (Mulley *et al* 2000).

	Mar	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*
Weeks1-2	0.71	0.78	0.73	0.66	0.59	0.62	0.84	0.81	0.81
Weeks 3-4	0.71	0.77	0.68	0.60	0.59	0.63	0.83	0.83	0.83

Concentrate feed was offered between 2 and 4pm daily and residual feed weighed. RI does had access to *ad libitum* fresh water, and trees also provided shelter from wind and rain. Over the course of the experiment, an area of the paddock holding RI does grew a small amount of pasture, although this was negligible in terms of doe energy intake.

Ad Libitum Feeding

Thirty-six does (18 E and 18 H) were fed *ad libitum* pasture and concentrate over the duration of the study. As with RI does, *ad libitum* (AL) fed does received the modified dairy ration in conjunction with pasture. As described previously, pasture quality varied seasonally, and paddock rotations were based on a 10cm sward height threshold. Concentrate feed was offered daily between 2 and 4pm in large plastic troughs. Residue was removed daily and replaced with fresh feed, with previous residual feed levels used to inform future feed offers. MEI of AL does on a daily basis was not calculated.

Synchronisation of Oestrous and Mating

On the 13th of April 1998, each doe received a single intra-vaginal progesterone-releasing device (CIDR-G®) containing 0.3g of progesterone for oestrus synchronisation. Fourteen days after insertion on the 27th of April, the CIDRs were removed (Day 0). Each genotype group was split into two (18 per group) and randomly assigned a mature fallow buck (≥ 5 years) for natural mating. Throughout the breeding period, the RI group was divided into two groups to avoid fighting between bucks and maximise chances of conception. As such, two bare paddocks were used, and an allowance of 1.5kg of feed per day made for each buck in each RI paddock.

Five days after CIDR removal (Day5), the RI groups were merged, and one buck remained with the group until day 25 to mate with does who may not have conceived on their first oestrous cycle. Ultrasonography was performed on Day 30 post CIDR removal. Does not identified pregnant on this date were re-tested on Day 50 and removed from all data collection if negative. Pregnancy was determined by observing fluid within the uterine horns, the presence of placentomes and or the presence of a foetus as described by Mulley *et al* (1987).

Blood sampling and trans-rectal ultrasonography were performed while the deer were restrained in a drop-floor crush. Blood samples were obtained via jugular venepuncture at the time of CIDR removal (conception) and fortnightly until midway through the second trimester of pregnancy. Blood samples were centrifuged, the plasma harvested, and stored at -20ºC. Blood plasma was analysed for free fatty acids (FFA), betahydroxybutyrate (β-OHB) and plasma ketone (PK) concentrations as indicators of energy status. Body condition score was not used as an indicator of energy status with does in this experiment, as the methods for estimating BCS were still under development. However, carcasses from this study were used in development of BCS methods (as reviewed in Section 6).

Conceptus Measurements

Six does of each genotype from each feeding treatment (24 does) were slaughtered as described by Falepau (1999) at the end of weeks 6 (Day 42), 20 (Day 140) and 31 (Day 217 - approximately 2 weeks from parturition). The entire conceptus mass of each slaughtered doe was weighed. Placentomes were cut from the chorionic membrane, drained, weighed and counted. For each foetus crown-rump length (CRL) was measured and weight and sex of recorded. The sexes of foetuses with CRLs of less than 35mm were unable to be confidently determined.

Results

Results of the reduced feed intake study are presented in terms of conceptus development at three stages of gestation. Liveweight changes of does are also presented in terms of nutritionally related liveweight change.

Liveweight Change over Gestation

Growth rates over T1 and T2 were calculated on eleven week (77 day) averages, although does killed at week 6 were not used in LWC calculations. Growth rates for the remaining does over T3 were calculated for a period of 63 days, as does were slaughtered 2 weeks prior to the calculated fawning date. There was a significant difference in liveweight between E and H does at treatment commencement ($P<0.003$), although there was no significant difference ($P=0.684$) between doe liveweight in RI and AL treatments. As with the experiments described in Section 2, the majority of liveweight gain occurred during T3, more specifically, over the last 6 weeks in which liveweight was measured. Liveweight change (LWC) and growth rates by trimester (g/hd/day) are shown in Table 22.

Table 22 : Mean liveweight change (kg) and mean daily weight gain (g/hd/day) of concentrate and pasture-fed E and H does over each trimester of pregnancy, 1997-98.

	Ad Libitum (AL)				Restricted Intake (RI)			
	E		H		E		H	
Trimester 1	-0.9kg	-12g/day	-0.5kg	-7g/day	-0.2kg	-3g/day	-1.1kg	-14g/day
Trimester 2	4.8kg	62g/day	3.5kg	45g/day	4.4kg	57g/day	4.8kg	62g/day
Trimester 3	6.5kg	103g/day	6.3kg	100g/day	5.5kg	87g/day	6.9kg	110g/day

RI E and H does had mean conception liveweights of 39.5 (SEM±3.1) and 41.6 (SEM±2.8) kg respectively. RI E does lost on average 4.8% of their liveweight by conception after 6 weeks of their feeding treatment, with their H counterparts shedding on average 4.0% liveweight over the same period (Figures 49-52).

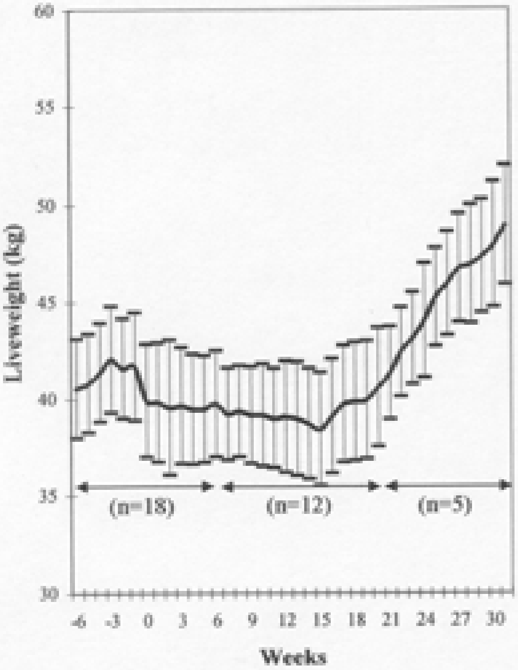


Fig. 49 : Mean LWC (±SEM) of AL E does from 6 weeks pre-conception to 2 weeks before parturition

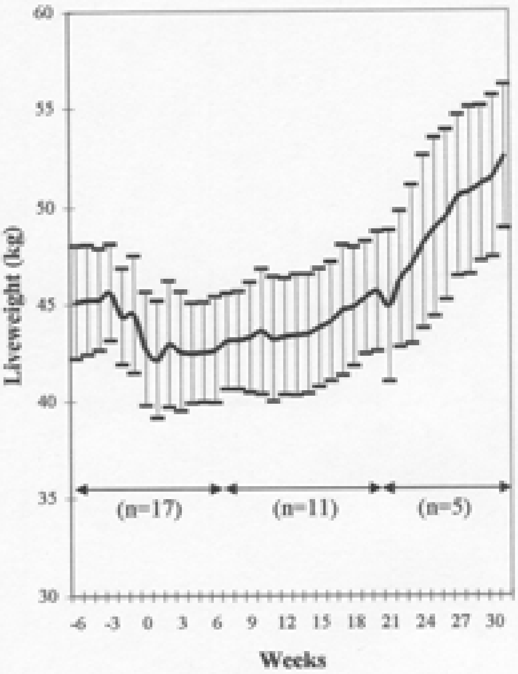


Fig. 50 : Mean LWC (±SEM) of AL H does from 6 weeks pre-conception to 2 weeks before parturition

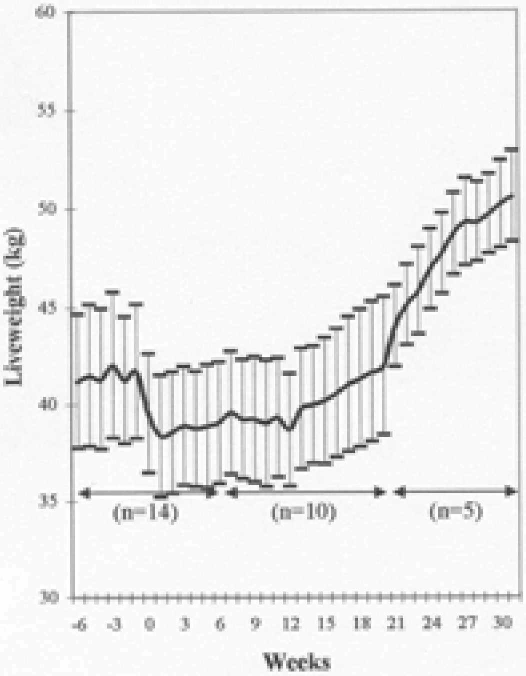


Fig. 51 : Mean LWC (±SEM) of RI E does from 6 weeks pre-conception to 2 weeks before parturition.

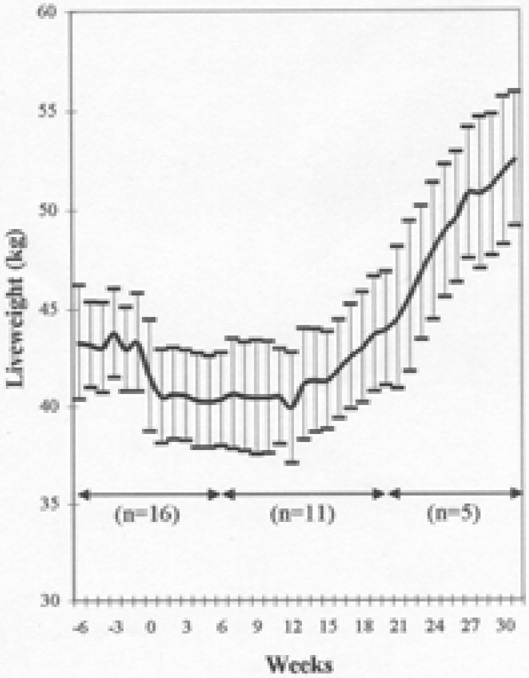


Fig. 52 : Mean LWC (±SEM) of RI H does from 6 weeks pre-conception to 2 weeks before parturition.

There was a very slight weight loss during T1 across both genotypes, with the majority of deer remaining within ±1.0kg of their joining weight over this period. During T3, liveweight gain for both E and H RI does accelerated, gaining 5.5 kg (SEM±0.8) and 6.9kg (SEM±0.6) respectively, corresponding with a significant increase in VFI and the period of greatest foetal growth (Asher *et al* 2000). Overall, RI E and H does had respective liveweight gains of 9.7kg (SEM±1.7) and 10.4kg (SEM±1.4) from conception to 2 weeks from parturition.

AL E and H does had average conception liveweights of 39.9 (SEM±2.9) and 42.7 (SEM±2.9) kg respectively, losing 1.7kg (5.3%) liveweight respectively over the six weeks of *ad libitum* feeding before conception. As with RI does, the AL does also had a period of liveweight recovery over T2 before a rapid period of liveweight gain to the last weighing at week 31. AL E and H does had mean liveweight gains of 11.0kg (SEM±1.5) and 9.6kg (SEM±1.9) respectively from conception to two weeks prior to parturition. There were no significant differences in LWC between genotypes within feeding treatments from conception to 2 weeks prior to parturition (P=0.877). Although the initial liveweight response of the RI does to their feeding treatment was more apparent than AL does, feeding treatments appeared to have no affect on the rate of LWC over T2 and T3 when ME requirements have been shown to increase with pregnant fallow deer (Flesch *et al* 1998).

Energy Intake of RI Does

As shown in Figure 53, energy intake of RI does was calculated on weekly liveweight changes, with ME intake assigned according to the data from non-pregnant fallow does produced by Mulley *et al* (2000) on a metabolic bodyweight basis. During mid-pregnancy, it became apparent that the nutrition regime in place had little or no effect on either LWG or conceptus development between the two treatment groups (see discussion). When compared with data from pregnant does housed in individual pens, the $W^{0.75}$ calculations of energy intake for the RI treatment showed that RI does were in fact not restricted (Figure 62).

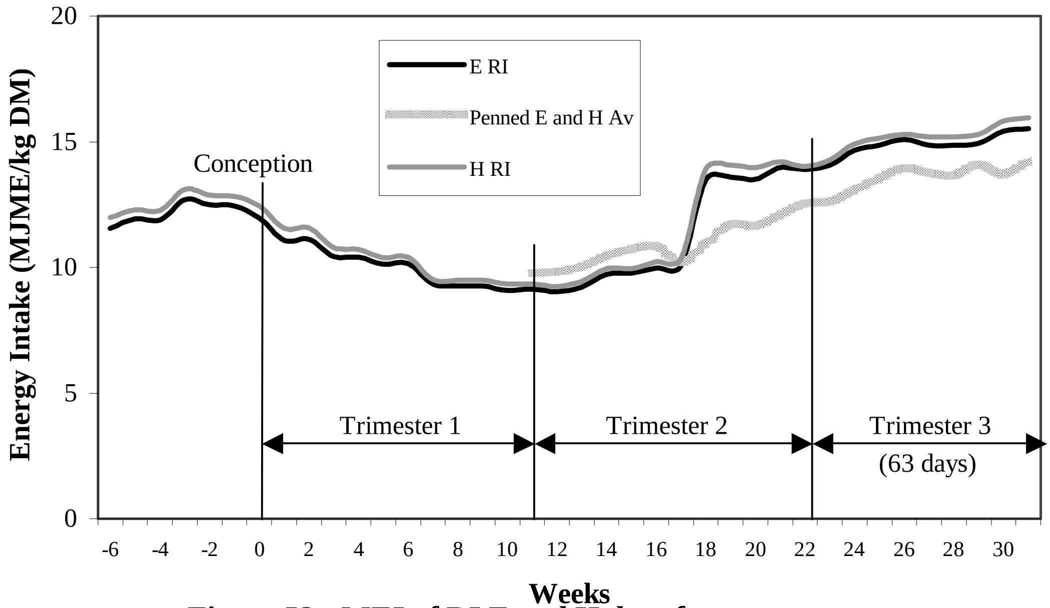


Figure 53 : MEI of RI E and H does from treatment commencement to week 31 of gestation, compared with average MEI of *Ad libitum* penned E and H does through T2 and T3.

During T3, daily residues of the allocated ration were frequent, indicating that RI does were receiving sufficient ME from their calculated feed volumes. As shown in Figure 53, the calculated feed allocation for RI E and H does only fell to below that of individually housed penned E and H does (as described in Section 2) during weeks 11-17 of gestation, with the shortfall approximating 1.0-1.5 MJME/kg DM/hd/day. Average daily MEI of RI E and H does during T3 was closer to 13MJME/kg DM (once average ME of residue feed was averaged), unlike the 15MJME offered, as indicated in Figure 53 as a result of the non-pregnant doe average intake of 0.81 and 0.83 MJME/kg$^{0.75}$/day taken from Mulley et al (2000).

As such, RI does were shown to be only moderately restricted during the first half of T2, and not nutritionally restricted at all during T3. As there have been no experimentally derived ME intake data on pregnant fallow does during early gestation (Experiment I described energy intake from week 11, or T2 onwards), energy status cannot be accurately defined, although from other studies, it appears that early conceptus development does not require MEI levels higher than maintenance over this period. Conceptus development at three points over gestation is described.

Trimester 1 : Conceptus Development

At the end of week 6 of gestation (Day 42) following 12 weeks on their assigned feeding treatments, 6 does of each genotype from each feeding treatment were randomly selected and slaughtered. Data on conceptus development was collected from 20 out of the 24 does slaughtered. Several does slaughtered at Day 42 had conceived on their second oestrous cycle (two AL H and one RI E), and one AL H doe had not conceived at all, leaving a treatment group of three AL H does. No measurements were recorded from does who conceived on their second oestrous cycle (foetuses 21 days old). There were no significant differences between feeding treatments and conception rates ($P<0.05$) with both genotypes. Conceptus development for RI and AL does is shown in Figures 54-57.

Foetuses from E and H RI does had average weights of 4.1g (SEM±0.47) and 4.9g (SEM±0.55) respectively, with their AL E and H counterparts averaging 4.1g (SEM±0.54) and 4.2g (SEM±0.54). There were no significant differences in foetal weight between genotypes ($P=0.133$) or feeding treatments ($P=0.194$). CRL ranged between 33.5 and 45.4mm between feeding treatments and genotypes, although differences were respectively insignificant ($P=0.199$), ($P=0.320$). Foetuses from RI E and H does displayed similar CRL averages of 38.6mm (SEM±2.77) and 37.6mm (SEM±2.53), while foetuses from AL H does had a slightly higher average of 42.0mm (SEM±3.49) when compared with E foetuses 38.0mm (SEM±2.35).

RI does of both genotypes had a significantly higher number of placentomes than AL does ($P=0.008$), although this did not correlate to greater placental mass. RI E and H does had on average 6.2 (SEM±0.75) and 6.0 (SEM±0.63) placentomes respectively, compared with the 5.2 (SEM±1.46) and 3.7 (SEM±0.94) placentomes with AL E and H does. Placentome weights for RI E and H does averaged 2.9g (SEM±0.42) and 3.0g (SEM±0.42), while total placentomic mass from AL E and H does averaged 2.7g (SEM±0.51) and 2.8g (SEM±0.26) respectively.

Trimester 2 : Conceptus Development

At Day 140 of gestation, and after being on their allocated feeding treatments for 26 weeks (182 days), 12 does (6 E and 6 H) from each treatment group were slaughtered. Data on conceptus development was collected from 21 out of the 24 does slaughtered. Two AL E does had not conceived, and the foetus in one RI E doe had died and autolyzed. Although there were moderate variations in foetal and placental sizes between genotypes and treatments (Figures 58-61), it was assumed that all foetuses were the same age and there were no second cycle conceptions.

Foetuses from E and H RI does had average weights of 900.0g (SEM±45.4) and 936.3g (SEM±83.9) respectively, with their AL E and H counterparts averaging 929.7g (SEM±86.5) and 956.4g (SEM±66.8). There were no significant differences in foetal weight between genotypes (P=0.523) or feeding treatments (P=0.420). CRL ranged between 238 and 282 mm between feeding treatments and genotypes, although differences were respectively insignificant (P=0.106), (P=0.320). Foetuses from RI E and H does displayed similar CRL averages of 254.5 (SEM±12.2) and 263.2 mm (SEM±13.9), while foetuses from AL H does had a slightly higher average of 257.0 mm (SEM±17.1) when compared with E foetuses 269.0 mm (SEM±10.4).

Unlike the average number of placentomes seen at Day 42, there was no significant difference in placentome number or total placental mass between treatments or genotypes at Day 140 (P=0.109, P=0.390), although the average number of placentomes had increased across treatments and genotypes. RI E and H does had on average 8.5 (SEM±1.12) and 8.3 (SEM±0.94) placentomes respectively, compared with 9.3 (SEM±0.94) and 8.9 (SEM±0.99) placentomes with AL E and H does. While the average number of placentomes had increased moderately since Day 40, there was a large increase in placental mass across feeding treatments. RI E and H does had average placental weights of 322.3 (SEM±15.1) and 325.8g (SEM±59.5) respectively, while total placental mass from AL E and H does averaged 333.1 (SEM±29.6) and 354.1 g (SEM±51.8) respectively.

Trimester 3 : Conceptus Development

At 31 weeks gestation (Day 217) and after being on their allocated feeding treatments for 37 weeks (259 days), the remaining 12 does from each treatment group were slaughtered. Data on conceptus development was collected from 21 out of the 24 does slaughtered (Figures 62-65). One doe was euthanased due to an injury incurred during weekly weighing, and two does NDP at Day 50 were excluded from the experiment.

Foetuses from E and H RI does had average weights of 4520g (SEM±453) and 4940g (SEM±651) respectively, with their AL E and H counterparts averaging 4267g (SEM±682) and 4475g (SEM±536) respectively. There were no significant differences in foetal weight between genotypes (P=0.136) or feeding treatments (P=0.436). CRL ranged between 390 and 510 mm between feeding treatments and genotypes, although differences were respectively insignificant (P=0.268), (P=0.244). Foetuses from RI E and H does had identical CRL averages of 466mm (E SEM±24.9), (H SEM±40.3), while foetuses from AL H does had a slightly higher average of 450mm (SEM±21.6) when compared with E foetuses 436 mm (SEM±29.7). RI E and H does had on average 10.2 (SEM±0.75) and 8.8 (SEM±0.49) placentomes respectively, compared with the 9.7 (SEM±1.17) and 8.6 (SEM±1.17) placentomes with AL E and H does, with differences between feeding treatments insignificant (P=0.184). RI E and H does had average total placental weights of 622.8 (SEM±114) and 635.6g (SEM±60), while total placental mass from AL E and H does averaged 711.0 (SEM±115) and 813.3 g (SEM±103) respectively. Total conceptus mass was difficult to measure at Day 217 due to the large uterine volume.

The majority of uteri were punctured and lost fluid during removal from each animal or storage before measurement, and thus were not used as indicators of nutritionally related conceptus development.

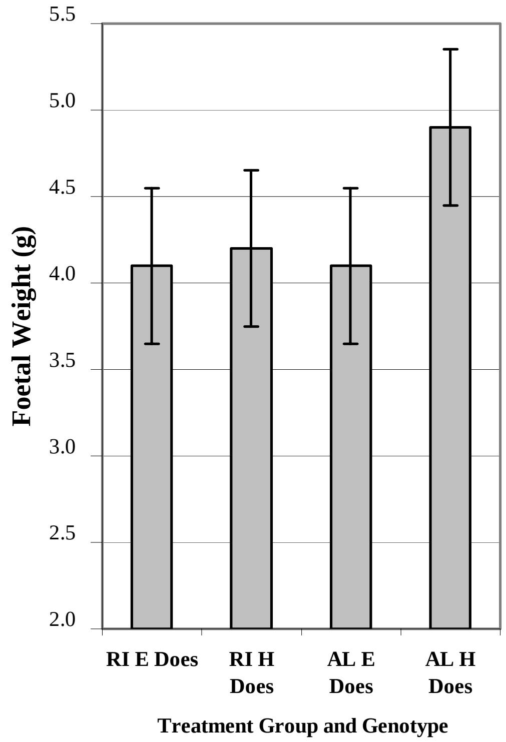


Fig. 54 : Mean foetal weight (±SEM) from RI and AL does of 2 genotypes at 42 days gestation

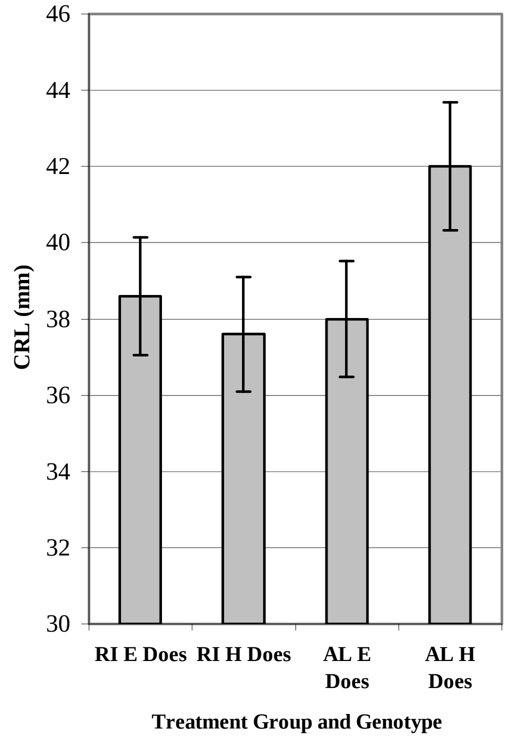


Fig. 55 : Mean CRL (±SEM) of foetuses from RI and AL does of 2 genotypes at 42 days gestation

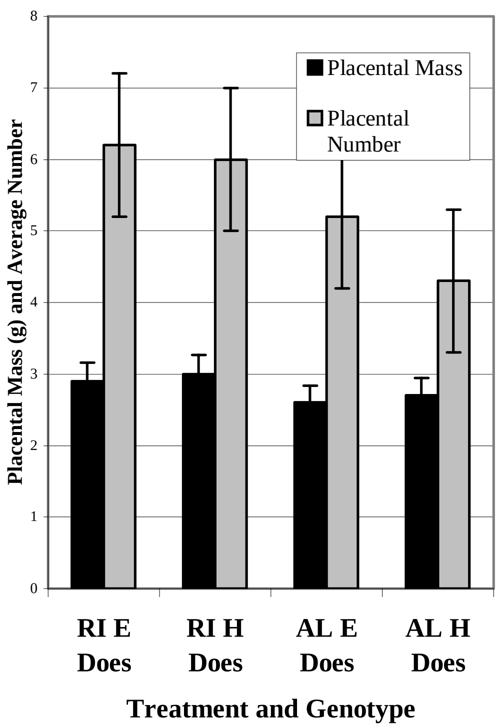


Fig. 56 : Mean placental mass (±SEM) and number from RI and AL E and H does at 42 days gestation

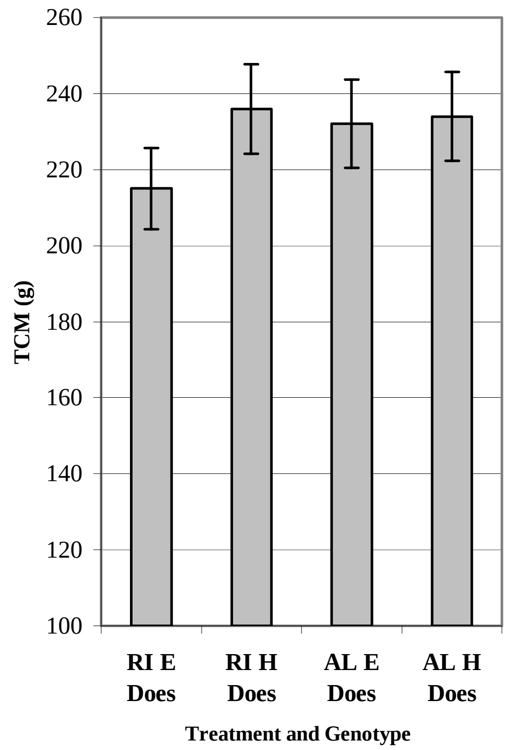


Fig. 57 : Mean total conceptus mass (TCM) (±SEM) of RI and AL does of two genotypes at 42 days gestation

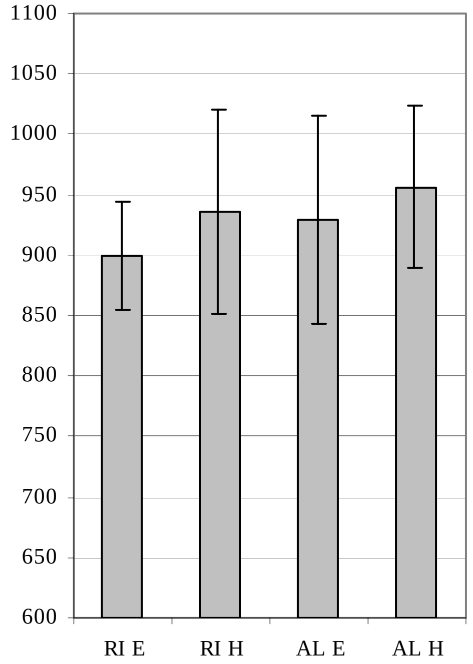


Fig. 58 : Mean foetal weight (±SEM) from RI and AL E and H does of 2 genotypes at 140 days gestation

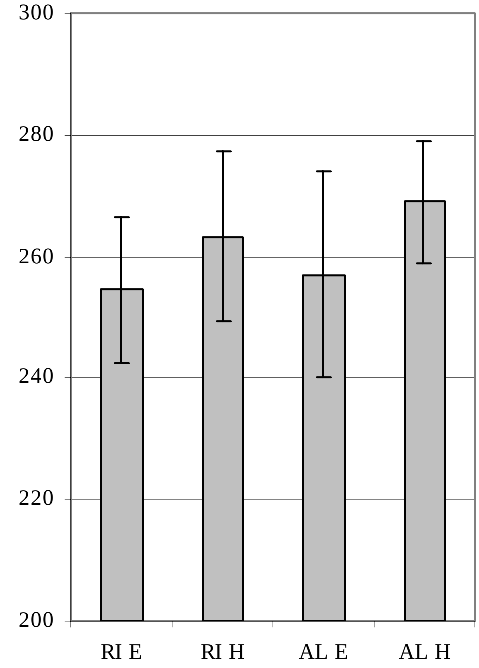


Fig. 59 : Mean CRL (±SEM) of foetuses from RI and AL does of 2 genotypes at 140 days gestation

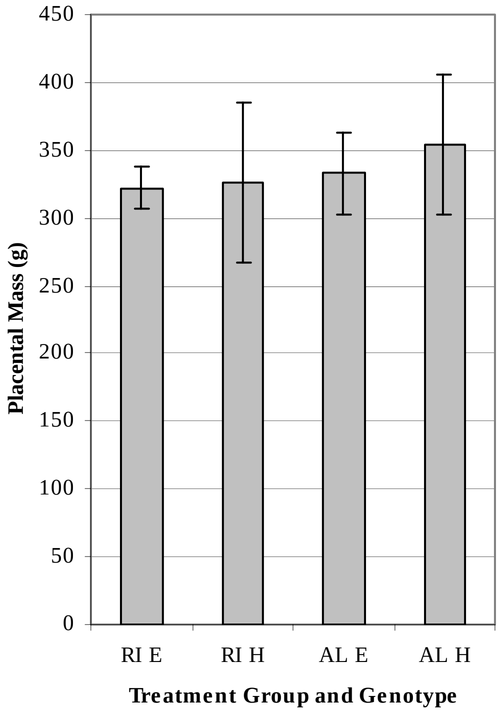


Fig. 60 : Mean placental mass (±SEM) from RI and AL E and H does at 140 days gestation

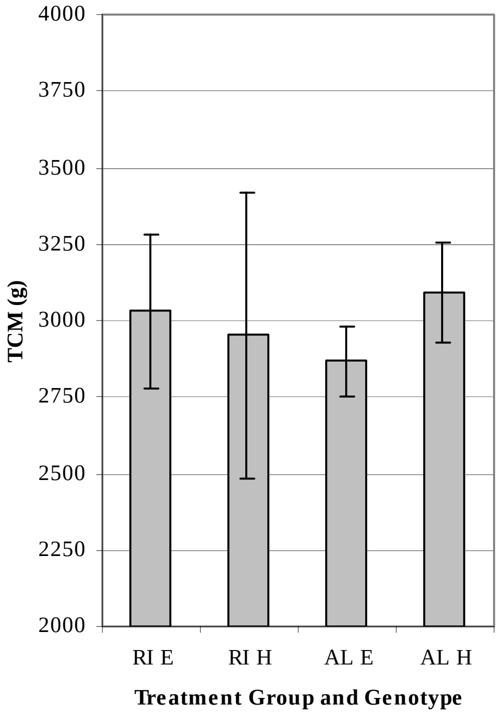


Fig. 61 : Mean TCM (±SEM) of RI and AL does of 2 genotypes at 140 days gestation

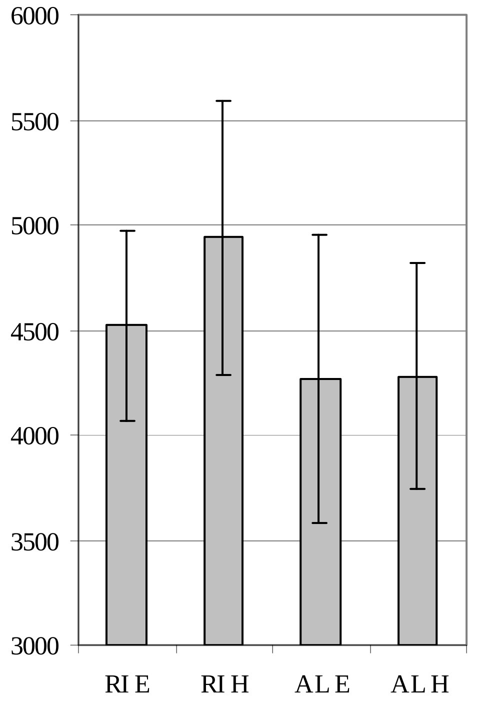


Fig. 62 : Mean foetal weight (±SEM) from RI and AL E and H does at 31 weeks gestation

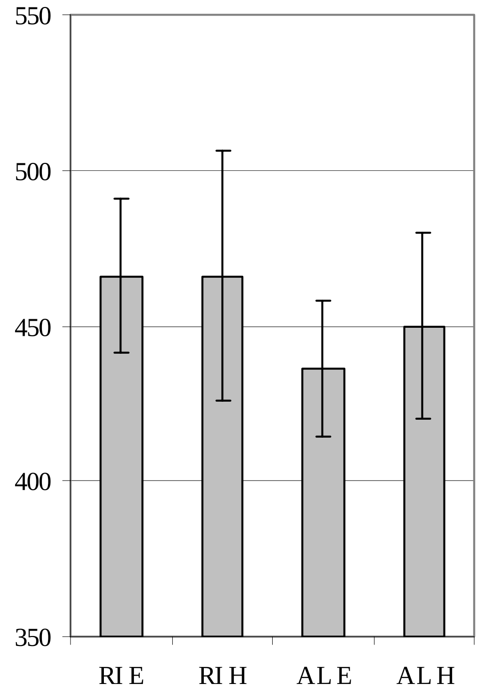


Fig. 63 : Mean CRL (±SEM) of foetuses from RI and AL E and H does at 31 weeks gestation

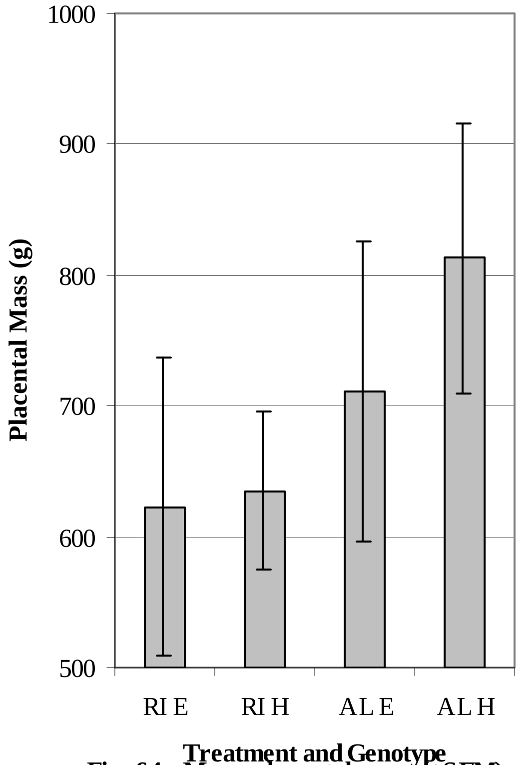


Fig. 64 : Mean placental mass (±SEM) from RI and AL E and H does at 31 weeks gestation

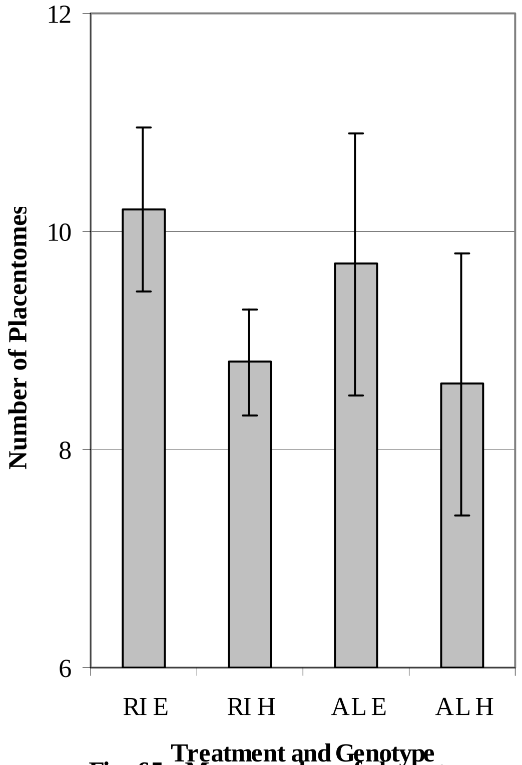


Fig. 65 : Mean number of placentomes (±SEM) in RI and AL E and H does at 31 weeks gestation

Discussion

Results from this study demonstrated that feeding pregnant does the maintenance level of ME for non-pregnant does from 6 weeks prior to conception to 6 weeks post conception (Day 42) had no significant effect on conceptus development or doe liveweight. Although H does were shown to be heavier than E does at treatment allocation, both genotypes lost similar proportions of total liveweight over T1, indicating that seasonal changes in VFI or energy metabolism, common to fallow deer throughout autumn (Asher 1993), were responsible for this loss, rather than the imposed feeding treatments. From week 17 onwards, it was shown that the chosen feed regimen failed to reduce ME intake to below maintenance requirements for the RI treatment group. However, despite the shortcomings in experimental design, this study provided new data on placental and foetal development at known ages of gestation and highlighted the importance BCS may play in the effects of available maternal nutrition on both conceptus growth and metabolic status of the dam.

Although the data used to inform the level of daily feed intake for RI does was derived from individually housed non-pregnant does between 9 and 21 months of age (Mulley *et al* 2000), these animals were young and growing, and were shown to have a higher daily MEI than pregnant adult does. As documented in Section 3, individually housed fallow fawns were shown to consume in excess of 11.0 MJME/hd/day between 12 and 20 weeks of age, and it appears that this high level of feed intake continues through to at least the second spring, possibly until a stable adult bodyweight is attained. Higher than expected levels of MEI have also recently been reported with yearling red deer hinds (Asher 2001, unpublished), with the feed requirements of young growing stock often eclipsing requirements of older animals, in this case, pregnant stock during the first trimester of pregnancy

In the current study, although conceptus characteristics of RI does at Day 42 did not reflect any degree of maternal energy deprivation when compared with their AL counterparts, it cannot be said that conceptus development would not have been perturbed had the same level of deprivation continued into mid pregnancy. As seen with fallow deer (Mulley 1989, Flesch *et al* 1998) and red deer (Asher *et al* 2000), while the metabolic toll of pregnancy is great in terms of total feed requirements, energy intake does not significantly increase until mid-gestation when foetal growth accelerates. However, it must also be noted that by the time maternal energy intake increases, placental growth has stopped (Robinson *et al* 1977), thus limiting compensatory foetal development in the event of higher feed availability in later gestation. The nutritional deficit incurred by RI does in the 6 weeks pre and post conception in the current study, albeit mild, was probably manifest in increased levels of doe fat mobilisation and resultant decreases in average BCS, if indeed, the ME shortfall had any effect at all.

Hence, given the mild nature of the nutritional deficit imposed on RI does prior and immediately following conception, it is unlikely that conceptus development would have been in any way compromised by mid-gestation, as was shown by conceptus measurements at Day 42. Furthermore, considering that the feeding regime inadvertently provided an *ad libitum* level of feed availability for RI does from Week 17 onwards, any effects of reduced ME intake, whether maternal or natal, would have been confounded by a higher level of feed availability. Again, conceptus measurements at Days 140 and 217 confirmed that differential nutrition in early gestation either had no affect on conceptus development, or impaired conceptus growth was ameliorated by higher energy intake in late T2 and T3.

If fallow does conform with similar responses seen with sheep after periods of nutritional deficit, such a reduction in energy intake may even result in enhanced placental and foetal growth, with consequent increases in birthweight and survivability. While with sheep, the mechanisms underlying this phenomenon remain unexplained, the strong seasonal patterns of VFI and LWC displayed by fallow deer are perhaps responsible for their relatively low autumn feed requirement, although there are no annual profiles of BCS or relevant blood metabolites to validate this. While this does not suggest that high or *ad libitum* energy intake may limit placental development, fallow deer, by way of photoperiod induced patterns of feed intake, may not require ME intake above the maintenance levels (RI treatment) fed in the current study in order to achieve satisfactory conceptus growth over early gestation.

Although the feeding regime imposed on RI does in this experiment did not affect conceptus development when compared with their AL counterparts, it was demonstrated that moderate reductions in maternal energy intake over early gestation, resulting in similar feed energy intake conditions encountered on many deer farms in Australia, could be accommodated by a mob of adult multiparous does. Furthermore, it was shown that these does, once provided with *ad libitum* feed intake throughout pregnancy (although unintentionally), would have produced viable fawns with a birthweight average above 4.5kg.

8.3 Effects on Conceptus Development of Restricted Maternal Energy Intake Over the First Twelve Weeks of Gestation.

Introduction

In line with the aims of the previous experiment (8.2), it was deemed important to experimentally produce similar situations to which farmed fallow deer does may experience from conception through early pregnancy. As previously reviewed, declining pasture quality, the physiological effects of lactation and doe BCS have a bearing on the degree to which early maternal nutrition may affect reproductive performance in fallow deer. As documented for a range of domestic and free-ranging ruminants (Cumming *et al* 1975, Markusfeld *et al* 1997, Audige *et al* 1988, Keech *et al* 2000), it has been demonstrated that sub-optimal nutrition and low BCS during the pre-mating period may reduce the chances of conception, retard conceptus development and reduce the capacity of the dam to absorb nutritional stress in later pregnancy. Such maternal restraints may have profound effects on lactation, neonate development, survivability and ultimately farm productivity.

The aim of this study was to restrict maternal feed intake over early to mid gestation to test whether sub-optimal maternal nutrition affected doe BCS and conceptus development. This was necessary given that many of the does described in section 8.2 were unintentionally fed to appetite.

Methods

On the 14th of April 1999, twenty-four mature (>5 years) European fallow does with an average BCS of 2.7 (SEM±0.4) received a single intra-vaginal progesterone-releasing device (CIDR-G®) containing 0.3g of progesterone for oestrous synchronization. Fourteen days after insertion (28th of April) the CIDRs were removed (Day 0). The mob of does was randomly divided in two (12 per group) and randomly assigned a mature fallow buck (≥ 5 years) for natural joining. Five days after CIDR removal, the groups were merged and one clean-up buck remained with the does until Day 15, at which time the does were randomly assigned a feeding treatment : *ad libitum* (AL) or reduced energy intake (RI).

Pen Feeding

Twelve of the does were individually housed, as described in Chapter 3. Six of these does were provided *ad libitum* with a pelleted oats / lucerne ration, containing approximately 10.5 MJME/kg DM and 12% CP. The remaining six does also consumed the same ration, although their daily intake was reduced to 70% of the average intake of the six AL does on a metabolic bodyweight energy intake basis. Daily metabolic bodyweight energy intake of penned AL does was totalled and a weekly average calculated. RI does were then fed to 70% of this average for the following week on a $W^{0.75}$ basis, which continued throughout the trial. RI does were fed at the rate of 0.50MJME/kg$^{0.75}$/day for week one of the trial (70% of the maintenance level of feeding during April for non-pregnant fallow does as calculated from data from Mulley *et al* 2000) until $W^{0.75}$ averages from the six AL does could be used to inform individual week 2 rations.

Group Feeding

The remaining 12 does were divided into two groups of six, and group fed via large plastic feed troughs. These does also consumed the same ration, although one group was fed *ad libitum* and had access to kikuyu and ryegrass pastures, the other group fed at 70% of the average intake of the six individually housed RI does on a $W^{0.75}$ basis. ME intake of group-fed AL does was not calculated. The RI does were also located on a bare ¼ Ha paddock, devoid of pasture. As with pen-fed RI does, group-fed RI animals were fed to a 0.50MJME/kg$^{0.75}$/day level for week one. Both group-fed treatment groups had *ad libitum* access to fresh water, and trees for shade and shelter.

Ultrasonography Measurements

Trans-rectal ultrasonography was performed while does were restrained in a drop-floor crush. Ultrasonography for pregnancy testing was performed using a Microimager 2000 ultrasound unit and a 5 MHz transrectal probe (Ausonics Pty Ltd, Sydney Australia) etc). Scanning was performed on Day 25 post CIDR removal, with does NDP on this date scanned weekly and removed from all data collection if not diagnosed pregnant by Day 50. Pregnancy was determined by observing fluid within the uterine horns, the presence of placentomes and or the presence of a foetus, as described by Mulley *et al* (1987). Does were scanned at Days 50, 65 and 80 with a Honda HS-1201 linear scanner with 5 MHz probe (Honda Electronics Co. Ltd, Toyohashi Aichi, Japan), in an attempt to determine if nutritionally mediated variances in foetal development over early gestation could be detected by ultrasonography.

All does were weighed and scored for body condition weekly (as described in Section 7), and slaughtered on Day 87 of gestation. HSCW and BCS of each doe were also determined after slaughter. The BCS derived from the final carcass assessment stood as the final score for feeding treatment analysis. The total conceptus mass of each slaughtered doe was removed and weighed. Conceptus characteristics were measured as described in Section 8.2.

Results

Treatment effects on doe liveweight, BCS and circulating blood metabolites were analysed and interrelationships between these parameters and conceptus development were assessed. Data is presented as does fed *ad libitum* (AL) and does whose feed intake was restricted (RI). These two treatments have also been bisected and discussed in terms of penned *ad libitum* (PAL) and group-fed *ad libitum* (GAL), and penned restricted intake (PRI) and group-fed restricted intake (GRI).

ME Intake Across Feeding Treatments

As seen with Experiments I and II, it took several days before individually penned does resumed consistent patterns of feed intake. Large feed residues were recorded for the first two days of the feeding treatment with PAL and PRI does, with feed intake of PAL does for the remaining 4 days of week one of the feeding treatment used to inform week 2 feed intake for RI does. The 0.50MJME/kg$^{0.75}$/day calculated for week 1 ration allocations to RI does was seen to be an accurate estimation of energy restriction in line with the 70% schedule, with restricted levels of MEI on a W$^{0.75}$ basis remaining between 0.46 and 0.52 MJME/kg$^{0.75}$/day for the remainder of the experiment (Figure 66).

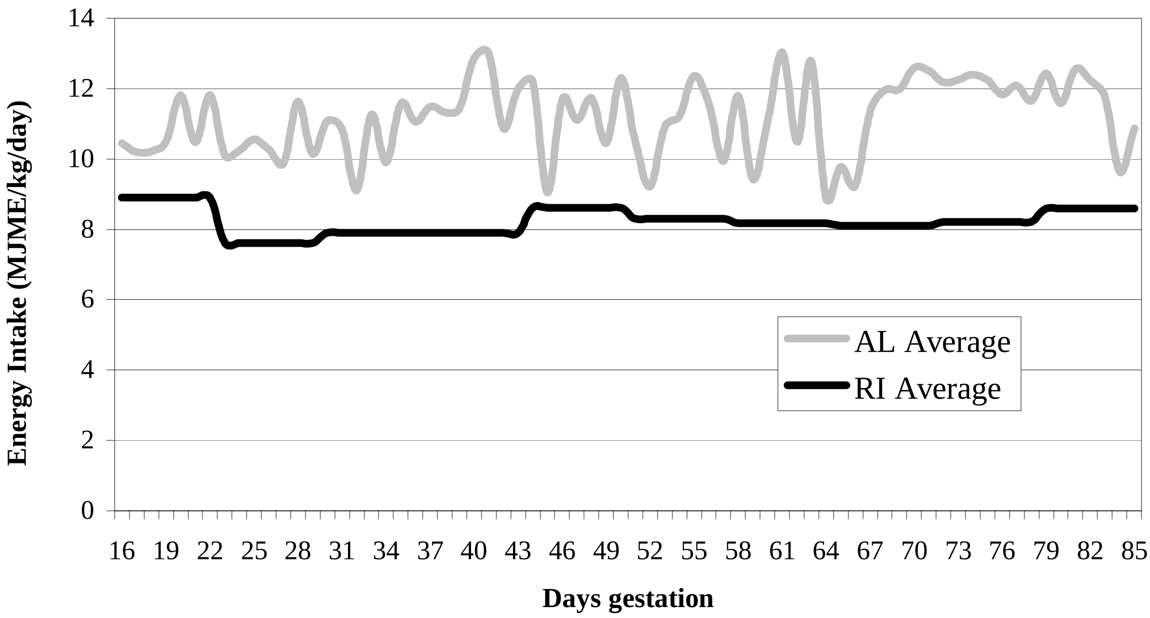


Figure 66 : Average ME intake of individually penned AL and RI does from Day 16 to 87 of gestation

One doe with consistently lower patterns of feed intake was NDP at Day 25 and was excluded from data collection, although feeding records indicate that ME intake was higher than that of RI does. This non-pregnant doe also had a reduction in liveweight and BCS over the treatment period despite *ad libitum* feeding. MEI of PAL does was similar, if not slightly elevated above levels recorded with individually penned pregnant does during the second trimester of pregnancy in Experiments I and II, (Table 23) with does averaging between 10 and 12 MJME/hd/day. Comparatively, RI does had approximate allocations of between 7 and 9 MJME/day, which was below the VFI of non-pregnant fallow does as recorded by Mulley et al (2000).

Table 23 : Weekly means (±SEM) of the daily metabolic bodyweight energy intake (W $^{0.75}$) and daily metabolisable energy intake for PAL, PRI and GRI does between weeks 2 and 12 of gestation.

Days of Gestation	*Week of Treatment*	*W $^{0.75}$ (PAL)*	*W $^{0.75}$ (PRI + GRI)*	*MEI of PAL does (±SEM)*	*MEI of GRI does (±SEM)*	*MEI of PRI does (±SEM)*
15-21	1	0.65	0.50	11.15 (±0.70)	8.63 (±0.75)	8.90 (±0.27)
22-28	2	0.65	0.46	10.41 (±0.53)	7.60 (±0.63)	7.61 (±0.10)
29-35	3	0.69	0.48	10.69 (±0.81)	7.58 (±0.69)	7.90 (±0.17)
36-42	4	0.69	0.48	11.85 (±0.75)	7.51 (±0.66)	7.89 (±0.20)
43-49	5	0.74	0.52	11.22 (±1.07)	8.08 (±0.64)	8.62 (±0.24)
50-56	6	0.71	0.50	10.82 (±0.97)	7.79 (±0.70)	8.29 (±0.22)
57-63	7	0.70	0.49	11.07 (±1.47)	8.40 (±0.75)	8.17 (±0.22)
64-70	8	0.69	0.48	11.34 (±1.23)	7.86 (±0.73)	8.09 (±0.23)
71-77	9	0.70	0.49	12.09 (±0.24)	8.00 (±0.73)	8.22 (±0.18)
78-84	10	0.73	0.51	11.58 (±0.96)	8.37 (±0.74)	8.60 (±0.21)

Comparisons of average total energy consumed over the trial period indicate the degree of feed deprivation of RI treatments. PAL does consumed on average 788 (SEM±66.3) MJ of energy over the 10-week period, while PRI and GRI does averaged 568 (SEM±11.7) and 558 (SEM±55.4) MJ respectively. The PAL intake average is comparable with Experiment I and II levels throughout the second trimester of pregnancy (calculated as 11 weeks), indicating that early gestation is not necessarily a period of low feed requirement.

Liveweight Change

Although does were randomly selected at the time of treatment allocation, the wide range of liveweights seen across the group of deer (39.0 to 50.0 kg) caused a large variation in feed allowances with PRI and GRI treatments, also affecting liveweight SEM between and within treatment groups (Figures 76-81). The presence of two particularly light-for-age does unbalanced the liveweight averages of PAL and GRI treatment groups. While access to feed was not a concern for the light PAL doe, feed access for the 39.0 kg doe in the GRI treatment may not have been optimal with most does in that treatment weighing in excess of 45kg.

As such, total feed volumes and resultant MEI between AL and RI treatments may only be used as a guide when comparing experimental intakes seen in the current study with deer in other locations, given that liveweight was used to inform daily ME allowances. While the average liveweight of AL and RI does at conception was 44.7 (SEM±3.4) and 43.5kg (SEM±3.3) respectively, average liveweight of treatment sub-groups varied. GAL does had an average liveweight of 46.0kg (SEM±1.9kg), while GRI does averaged 43.3kg (SEM±4.5) at conception (Figures 67-70).

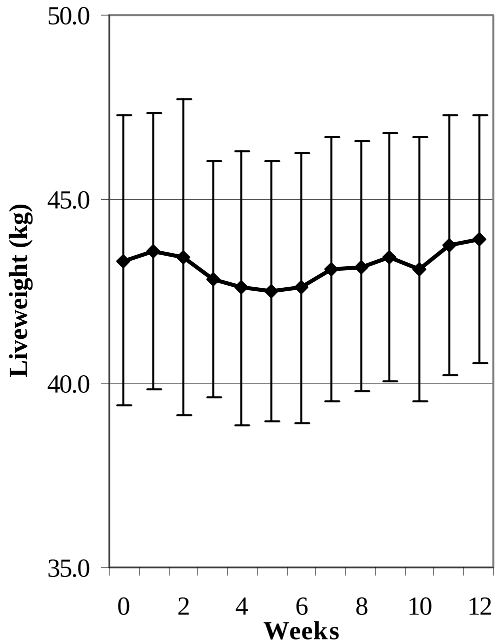


Fig. 67 : Mean weekly LWC (±SEM) of PAL does from conception to week 12 of gestation

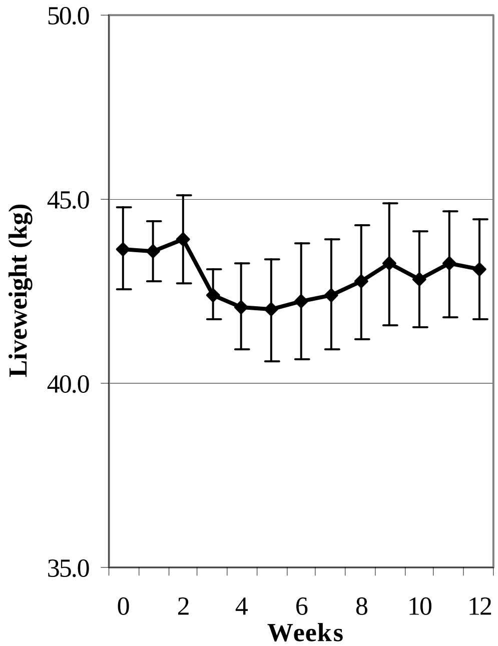


Fig. 68 : Mean weekly LWC (±SEM) of PRI does from conception to week 12 of gestation.

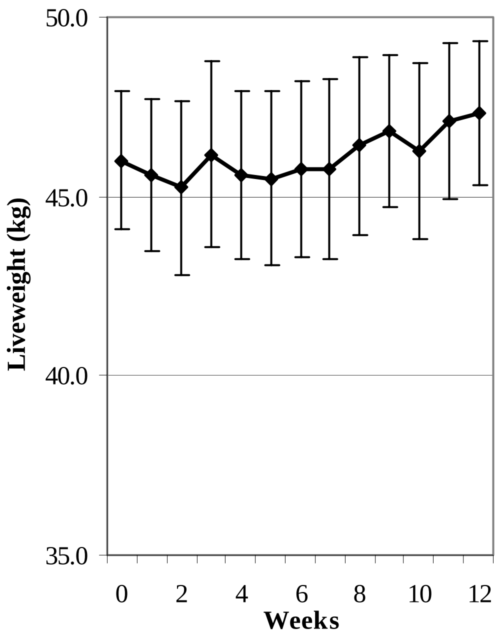


Fig. 69 : Mean weekly LWC (±SEM) of GAL does from conception to week 12 of gestation

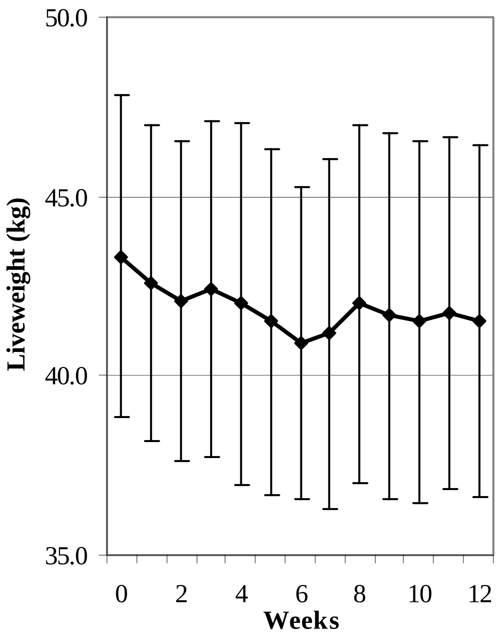


Fig. 70 : Mean weekly LWC (±SEM) of GRI does from conception to week 12 of gestation

Feeding treatments had a significant affect on patterns of LWG. AL treatment groups had a significantly higher liveweight gain than RI treatments by week 12 of gestation (P=0.043), although there was no significant difference between individually fed and group fed does within feeding treatments (P=0.636). Both PAL and GAL treatment groups maintained or increased average liveweight between conception and week 12 of gestation. There were discrepancies in patterns of LWG with PAL does, with two does having reductions of 0.5 and 1.0 kg over the 12 week period, while the remaining four increased their conception liveweight leading to a PAL average liveweight gain of 2.0 kg (SEM±0.6). All six GAL does showed moderate increases in liveweight between conception and week 12 of gestation, averaging 1.3kg (SEM±0.8). Conversely, both PRI and GRI treatment groups showed reductions in average liveweight between conception and week 12 of gestation.

Beta – Hydroxy Butyrate Concentration

Trends in β-OHB indicated a degree of nutritional stress with both RI treatment groups. While there were no significant differences in respect to both energy intake (P=0.738) and group/penned does (P=0.690), there was an upward trend in β-OHB concentrations in both RI and Al treatments by week 12, although both RI treatments showed higher average levels of the metabolite through weeks 4-12 of the experiment. Particularly at week 12, average β-OHB concentrations were high than over the entire treatment period (with the exception of PAL does, whose average β-OHB concentration increased from 27.6 to 33.8 mmol/1 at week 4), although does were not fasted before slaughter.

As with their PAL counterparts, PRI does produced some discrepancies in patterns of liveweight change, with two does maintaining their conception liveweight by week 12 of gestation. The remaining four does lost weight over the period to slaughter, with PRI does losing on average 0.9kg (SEM±0.6). All six GRI does had moderate decreases in liveweight between conception and week 12 of gestation, shedding on average 1.8kg (SEM±0.9).

Body Condition Score and HSCW

Despite the large variations in doe liveweight, BCS averages between treatments were similar at conception, although scores of individual animals ranged from 2.0 to 3.5. Scores at Day 0 for PAL and GAL does averaged 2.6 (SEM±0.3) and 2.7 (SEM±0.4) respectively, while PRI and GRI does averaged 2.7 (SEM±0.2) and 2.7 (SEM±0.5) respectively. While all does were multiparous, 22 out of the 24 does had raised fawns in the previous breeding season. The two does not lactating over the summer of 1998-99 were scored at 3.0 and 3.5 respectively at Day 0 – higher than the total experimental average of 2.7 (SEM±0.4). Trends in BCS were generally concomitant with rates of LWC over the treatment period (Figures 71-76) with PRI and GRI animals showing significant reductions in BCS compared with their AL counterparts over the trial period (P=0.001). There were no significant differences in average BCS with individually fed or group fed does within feeding treatments (P=0.283).

All does in PAL and GAL treatment groups maintained or increased BCS between conception and week 12 of gestation. Out of the 12 animals, eight does had a BCS identical to that assigned at conception, while the remaining four showed an increase of 0.5 BCS. Conversely, both PRI and GRI treatment groups showed trends towards lower BCS's over the experiment, although the GRI treatment was erratic in BCS trends. Only one PRI doe maintained conception BCS, while the remaining five dropped between 0.5 and 1.0 score. Three GRI does maintained their conception BCS (although all 6 were assigned lower scores in the weeks prior to slaughter), while the other 3 had reductions in BCS of 1.0, 1.0 and 0.5, with this discrepancy thought to be related to access to the limited amounts of feed offered and variations in animal size in conjunction with social hierarchy.

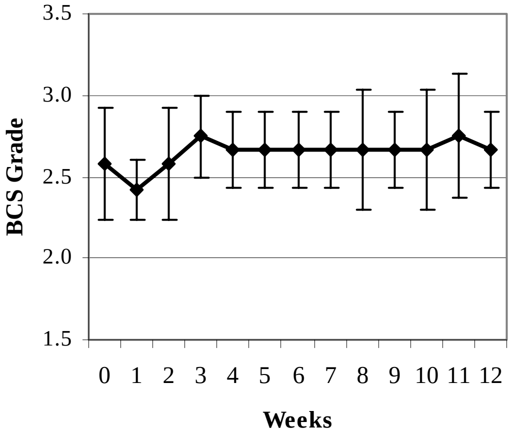


Fig. 71 : Mean weekly BCS (±SEM) of penned AL does from conception to week 12 of gestation

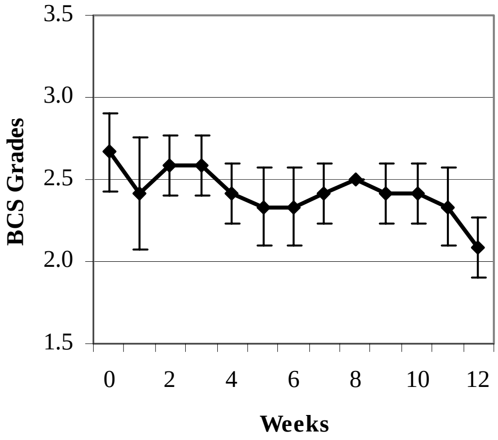


Fig. 72 : Mean weekly BCS (±SEM) of penned RI does from conception to week 12 of gestation

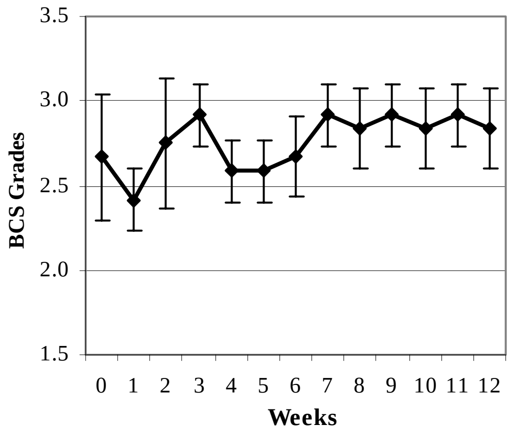


Fig. 73 : Mean weekly BCS (±SEM) of group-fed AL does from conception to week 12 of gestation

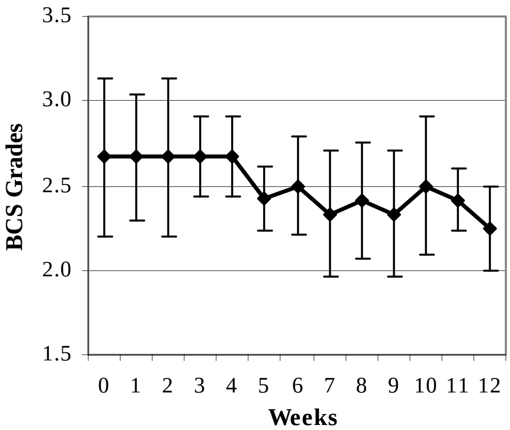


Fig. 74 : Mean weekly BCS (±SEM) for group-fed RI does from conception to week 12 of gestation

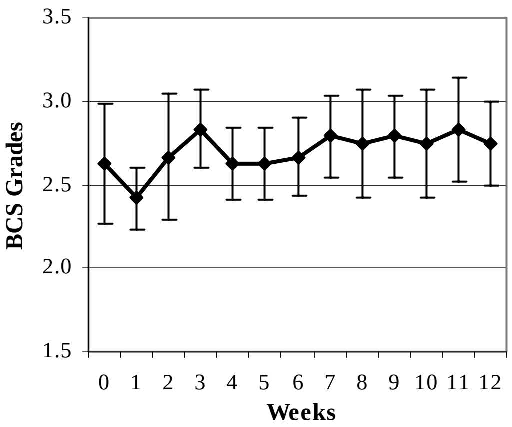


Fig. 75 : Mean weekly BCS (±SEM) for penned and group-fed AL does from conception to week 12 of gestation

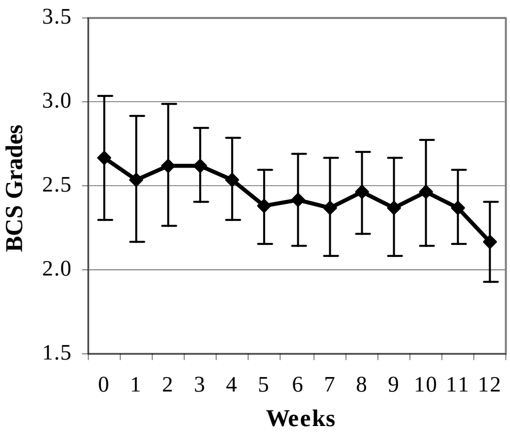


Fig. 76 : Mean weekly BCS (±SEM) of penned and group-fed RI does from conception to week 12 of gestation

Carcase measurements verified that all ante-mortem BCS's allocated prior to slaughter were within fat-depth tolerances (as described in Chapter 5). Hot standard carcass weight (HSCW) of does was also analysed by feeding treatment. AL and RI does had average HSCW's of 26.5kg (SEM±2.4) and 24.2kg (SEM±2.6) respectively, with RI carcasses significantly lighter than their AL counterparts (P=0.039). While the dressing percentage of 57% (SEM±4.7) for non-pregnant fallow does (Mulley *et al* 2000) may not be applicable in the current study due to the additional weight of the conceptus, a 2.4kg average difference in HSCW between treatment groups would probably equate to larger differences in liveweight which did not exist at treatment commencement. Such variation in HSCW would also be reflective of BCS trends seen between feeding treatments.

Ultrasonography Measurements

AL and RI does were scanned at various intervals of the study in an attempt to determine if ultrasonography could be used to determine, and or measure the effects of feed deprivation in early gestation. While trans-rectal ultrasonography has been widely used in determining pregnancy with fallow deer (Mulley *et al* 1987) and red deer (Revol & Wilson 1991), with foetal ageing also described by the latter, it was found to be difficult to accurately and consistently measure foetuses in the current study. On many occasions, the orientation of the foetus made longitudinal measurements of the foetus impossible, while at other times, foetuses were obscured by placentomes or by angling away from the probe. However, measurements on foetal and placental dimensions could be made on 18 out of 24 does on Day 50 (Table 24), while only placentome width and foetal head width and length were possible on Day 65 in some animals (Table 25).

Table 24 : Foetal and placental measurements made at Day 50 through ultrasonography on AL and RI does.

Feeding Treatment	*No. of Does Scanned*	*Placentome Width (mm)*	*Crown Rump Length (mm)*	*Foetal Chest Depth (mm)*	*Foetal Head Length (mm)*
PAL	n=4	18 (±1)	32*	-	16*
GAL	n=3	12 (±3)	33 (±2)	12 (±2)	17 (±1)
PRI	n=5	12 (±2)	29*	13*	-
GRI	n=4	15 (±2)	32 (±1)	-	17 (±1)

*** Measurements from one animal or insufficient data for analysis.**
- No measurements recorded for animals in treatment.

Table 25 : Foetal and placental measurements made at Day 65 through ultrasonography on AL and RI does.

Feeding Treatment	*No. of Does Scanned*	*Placentome Width (mm)*	*Crown Rump Length (mm)*	*Foetal Chest Depth (mm)*	*Foetal Head Length (mm)*
PAL	n=4	27.3 (±2)	-	-	-
GAL	n=5	29.2 (±1)	116*	-	30.0*
PRI	n=4	26.5 (±3)	121*	-	27.5 (±5)
GRI	n=5	29.7 (±3)	-	-	27.1 (±4)

*** Measurements from one animal or insufficient data for analysis.**
- No measurements recorded for animals in treatment.

Does being housed in pens were found to be particularly difficult to ultrasound as they all had very full bladders (possibly from lower activity levels), and thus the uterus was displaced. While it was planned to make foetal measurements via ultrasonography before slaughter and then make actual measurements on foetal and placental characteristics, positioning of the uterus and foetal orientation precluded accurate measurements from being recorded on Day 84. While insufficient measurements were recorded at Day 84, foetal and placental measurements made on Days 50 and 65 indicate rapid growth during early gestation.

Foetal and Placental Development

Although bucks were removed from the breeding groups and does allocated a feeding treatment before their second oestrous cycles following CIDR removal, 23 out of 24 does conceived and nourished a foetus until slaughter. The doe who did not conceive (PAL) was excluded from data collection after being correctly diagnosed NDP at Day 25 and on a subsequent scan at Day 32. Foetal weight was condensed within and between treatments, and ranged from 89.9g to 123.8g. There were no significant differences in foetal weight between high and low energy intake treatments (P=0.733) or between group and pen-fed does on the same nutritional intake (P=0.931) (Figures 77-82). Foetuses from PAL and GAL does had average weights of 135.2g (SEM±5.2) and 135.7g (SEM±5.6) respectively, with their PRI and GRI counterparts averaging 135.7g (SEM±3.6) and 134.5g (SEM±3.5) respectively.

CRL ranged between 128 and 145mm between feeding treatments, although differences were insignificant (P=0.701). As with foetal mass, CRL differences between and within feeding treatments were respectively insignificant (P=0.869, P=0.701). Foetuses from PAL and GAL does had CRL averages of 135.2 (SEM±5.2) and 135.7mm (SEM±5.6) respectively, while foetuses from PRI and GRI averaged 135.7mm (SEM±3.6) and 134.5 mm (SEM±3.5) respectively. However, male foetuses were significantly heavier than female foetuses (P=0.00), although differences between AL and RI feeding treatments for male and female foetal weights were not significant (P=0.378, P=0.119 respectively).

As with foetal measurements, there were no statistically significant differences between high and low feeding treatments for either placental mass (P=0.878) or placentome number (P=0.369). PAL and GAL does had average placental masses of 254.4g (SEM±31.9) and 277.5g (SEM±30.8) respectively. Similarly, PRI and GRI does had average placental masses of 262.7g (SEM±19.5) and 274.8g (SEM±22.7) respectively. Unlike in Experiment III, the number of placentomes was uniform across treatment groups, ranging from a minimum of 6 to a maximum of 10. PAL and GAL does averaged 8.8 (SEM±1.5) and 8.7 (SEM±0.9) placentomes respectively, while PRI and GRI does had averages of 8.0 (SEM±1.0) and 8.3 (SEM±1.1) placentomes respectively.

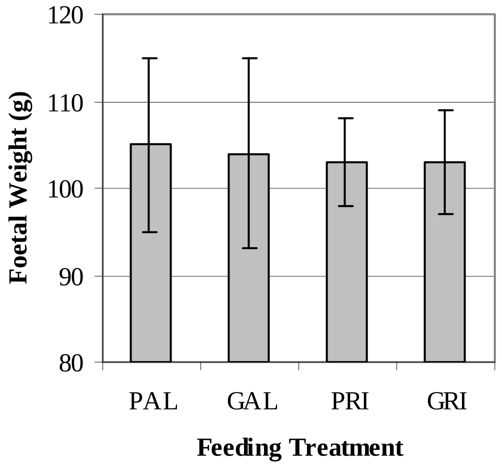


Fig. 77 : Mean foetal weight (±SEM) from does in all feeding treatments

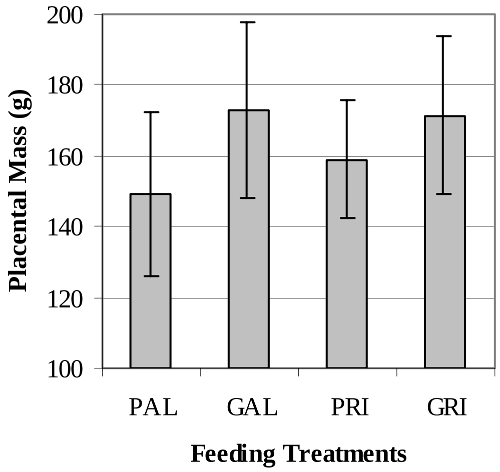


Fig. 78 : Mean placental mass (±SEM) from does in all feeding treatments

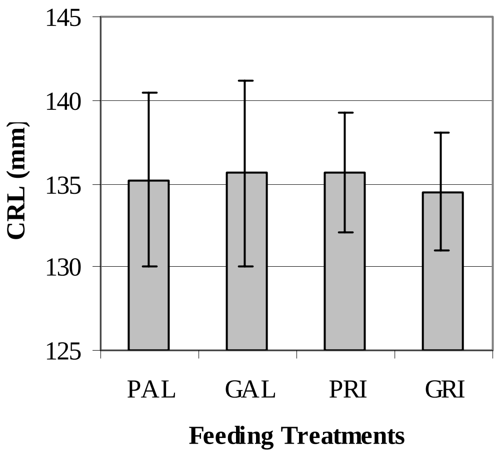


Fig. 79 : Mean CRL (±SEM) of foetuses from does of all feeding treatments

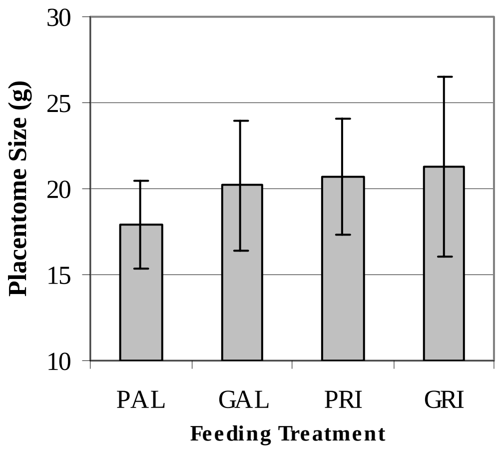


Fig. 80 : Mean size of placentomes (±SEM) in does on all feeding treatments

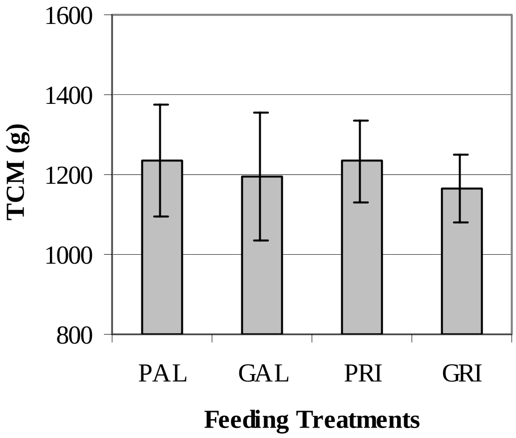


Fig. 81 : Mean total conceptus mass (±SEM) from does in all feeding treatments

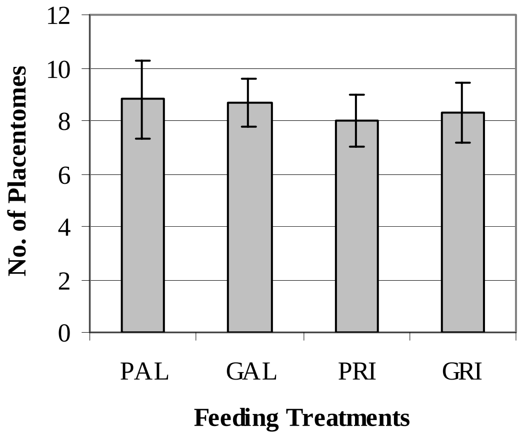


Fig. 82 : Mean number of placentomes (±SEM) from does in all feeding treatments

Discussion

It was demonstrated that a reduced level of maternal energy intake over early gestation had a significant effect on dam BCS and liveweight, although conceptus development at the prescribed level of deprivation remained unimpaired. With the aid of hindsight, this experiment revealed the slight extent to which does in Experiment III were deprived over early gestation, with the current experimental design being much more effective in reducing maternal intake in proportion with *ad libitum* intake of penned does. However, figures recorded for blood metabolite concentrations (data not presented) from this study did not appear to follow trends seen with sheep during periods of nutritional shortfall, especially considering the reductions in average liveweight and BCS seen in the current study.

Mulley (1989) demonstrated that creating nutritionally imposed β-OHB levels of between 0.45 and 0.5 mmol/l through mid pregnancy resulted in lower fawn birthweights than those from does fed *ad libitum* throughout gestation. However, β-OHB levels seen in that experiment, even with does fed *ad libitum*, were significantly higher than concentrations seen in both AL and RI does during the current study. It is unlikely that RI does would have maintained an adequate energy balance at the expense of the conceptus, especially since differences in conceptus development between treatment groups were shown to be equivocal. Hence, it appears that the lower body fat composition of fallow deer in general may account in part for the lower average β-OHB concentrations seen in nutritionally deprived fallow does compared with sheep. On this premise, does of low BCS accompanied with low energy intake may mask the effects of nutritional deficit through low β-OHB concentrations. Given this phenomenon, β-OHB may not be as useful in detecting, or determining the degree of nutritional stress in pregnant fallow does as first thought, although it must be noted that in later gestation, it may be a reasonably sensitive indicator in line with increased maternal / natal energy demand.

It has yet to be demonstrated that under nutrition over early-mid gestation has an affect on conceptus development with lower birthweight as an end result. In replicating feed situations expected to be seen on commercial deer farms, it would be expected that early gestation would be a time of net feed deficit. As reviewed in Section 2, the serendipitous nature of feed supply in Eastern Australia in parallel with gestation, dictates that pasture growth decreases over Summer into Autumn (early pregnancy – T1), increases over Winter (mid-pregnancy – T2) with fodder crops such as oats and ryegrass, and accelerates over Spring (late gestation – T3) with annual species providing abundant feed of medium to high quality.
Consequently, it would appear that obtaining *ad libitum* energy intake over late gestation would be a matter or course, and any perturbations to conceptus development would be attributable to sub-optimal feed availability in early-mid gestation or other external factors to production. Given this, and with the current levels of reproductive performance recorded on deer farms in Australia, it may be that stocking rates and BCS of breeding stock may be more responsible for poor reproductive performance than inadequate nutrition over early gestation, or simply the plasticity of fallow deer to modern production systems may have been overestimated.

While there are various possibilities to the outcome of this experiment had it gone to term, the fact still remains that conceptus development was unimpeded, blood metabolite concentrations were not indicative of nutritional stress, and maternal liveweight change and BCS losses were in no way severe. Studies of a similar nature with sheep support these outcomes, indicating that had RI does in Experiment IV been fed *ad libitum* to term, low fawn birthweight would have been unlikely.

Nutrition during the latter stages of pregnancy is clearly of importance in determining birthweight and, through this, neonatal viability and subsequent growth rates. It may be that despite the high levels of feed availability seen in Spring, if does, for some reason do not consume sufficient quantities of feed, a brief period of mild feed shortage in late gestation may have more of an affect on foetal development (and ultimately birthweight) than more prolonged and severe periods of feed restriction in early pregnancy. Since low birthweight and reduced viability of fallow fawns has been clearly defined as a problem on fallow deer farms, research into nutrition of fallow does in late pregnancy should be undertaken, and would assist in prioritising maternal energy requirements in relation to placental development (early gestation) and foetal development (late gestation).

Despite the possible origins of depressed conceptus growth, low birthweight and reduced neonate viability, there is now sufficient information available to farm managers on energy requirements of pregnant fallow does at all stages of gestation to assist in providing maternal nutritional sufficiency. Feeding levels described in Section 2 and BCS descriptors in Section 7 should be used in conjunction with one another to assist in reducing the current levels of reproductive wastage seen on Australian fallow deer farms at present.

9. Conclusions and Recommendations to Industry

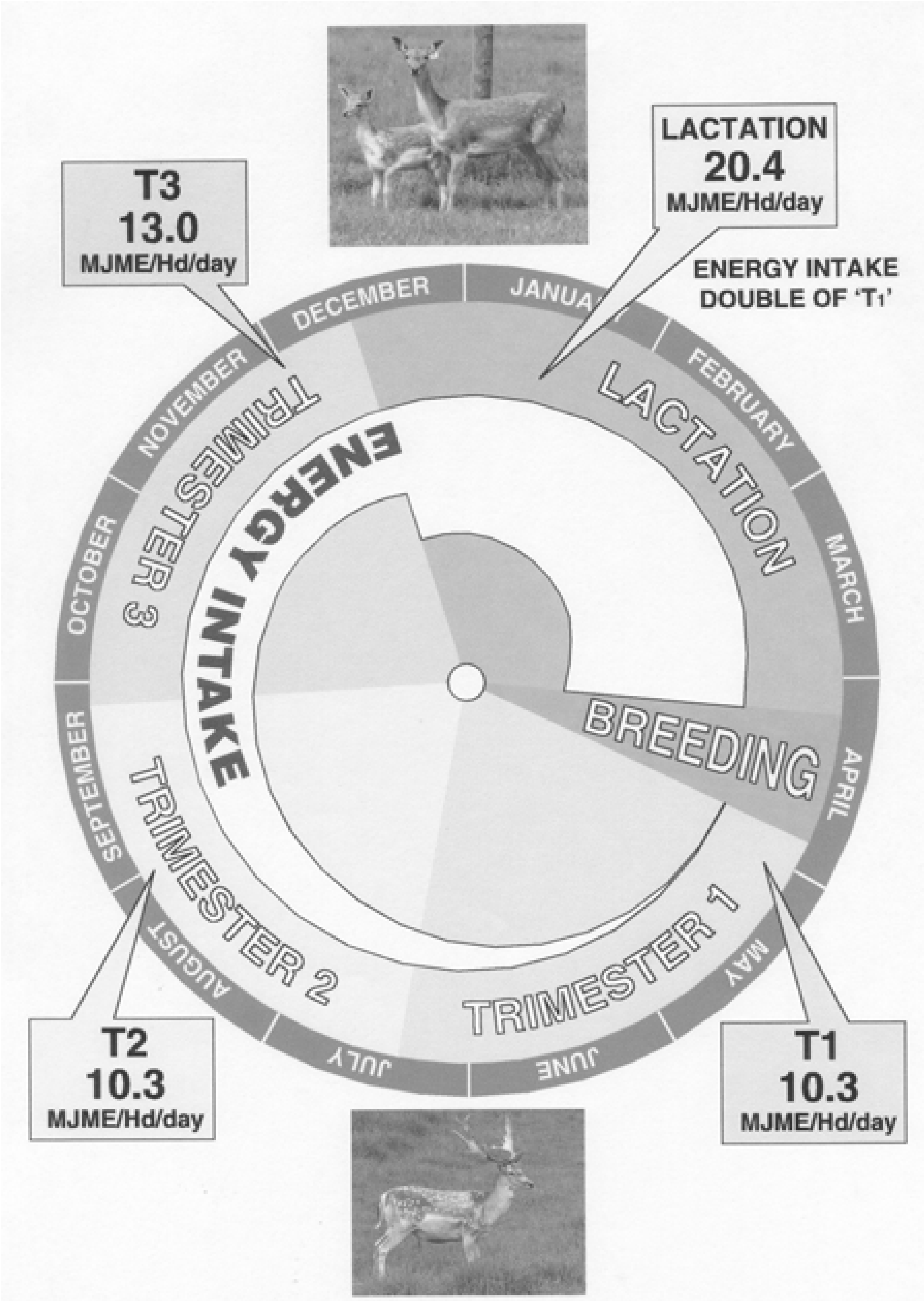
A major outcome of this study was the determination of levels of feeding required to maintain commercial performance of European fallow deer and ¼ bred hybrids. Further expansion of the Australian deer industry will be dependent on the production of uniform carcasses of high quality, promulgating uniform methods of both describing the condition of live animals for sale and grading of carcasses. It is recognized that education of farmers in the management and feeding of high quality feed to deer at critical times during their production cycle (particularly in late pregnancy and lactation) is a vital ingredient in the development of a production system that can consistently produce carcasses of high quality.

Relationships between nutritional requirements and stage of gestation were also clearly shown in the current study, and that adherence to the guidelines provided (Figure 83) should improve the reproductive performance, ethical care and quality assurance of farmed fallow deer in Australia. With the increase in metabolisable energy requirements by does over the third trimester of pregnancy, pasture budgeting in conjunction with adjustment of stocking rates is seen as a necessary requirement in maintaining conceptus development and doe body condition score. However, the marked increase in energy intake following parturition is of most importance to fallow deer farmers, and concepts such as strategic feeding should be implemented to maximize fawn development without compromising doe body condition. The unpredictable nature of pasture supply under Australian farming conditions highlights the importance of maternal nutrition, and makes such feeding knowledge even more valuable to deer farmers in increasing the growth, development and reproductive performance of their stock.

Data in section 2 illustrated the increase in MEI over T3 and lactation compared with that of non-pregnant animals. This data is the first of its kind for fallow deer, and combined with recent data from Mulley *et al* (2000), provides fallow deer farmers with the opportunity to accurately predict annual feed requirements for all stock units and allocate feed accordingly. The increase in daily ME requirements seen following parturition has a significant impact on both the feed availability for lactation in the months leading up to weaning, and on levels of available winter feed. As shown in section 3, this level of joint feed demand by lactating does and their fawns continues at this level, with weaned fawns ≥ 16 weeks of age consuming a similar level of dry matter as adult does.

One of the most important outcomes however, was the clear definition of BCS for fallow deer. A condition scoring system for fallow deer will allow farmers to firstly, produce a line of animals that processors are willing to pay for, and secondly, provide farmers with a greater awareness of the condition of their slaughter stock in conjunction with growth rates, targeted slaughter age and subsequent nutritional requirements. Venison processors will pay a premium for what they consider to be a well muscled carcass requiring minimum fat trimming, within a given weight range. The BCS descriptors developed for fallow deer in this study will allow farmers, processors and marketers to use a common language industry-wide, and will allow selection of animals for slaughter based on estimated carcass characteristics from live animal assessment.

Body condition indices developed for farmed fallow deer have application with both breeding stock and animals for slaughter. While for slaughter age animals, liveweight is usually a good predictor of animal condition, breeding does may have markedly fluctuating seasonal levels of body fat, with age, genotype and reproductive status precluding liveweight as an indicator of body condition. In conjunction with feeding guidelines for all classes of fallow deer, body condition may also be used as an indicator of feed sufficiency (Audige *et al* 1998).


T3
13.0
MJME/Hd/day
LACTATION
20.4
MJME/Hd/day
ENERGY INTAKE
DOUBLE OF 'T1'
DECEMBER
JANUA
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
LACTATION
BREEDING
TRIMESTER 1
TRIMESTER 2
TRIMESTER 3
ENERGY INTAKE
T2
10.3
MJME/Hd/day
T1
10.3
MJME/Hd/day

This additional indicator of nutritional sufficiency will provide farmers with the finesse to produce deer of uniform liveweight to slaughter age, and efficiently manage breeding stock.
It has also been demonstrated with other species such as red deer (Audige *et al* 1998), free-ranging Alaskan moose (Testa & Adams 1998, Keech *et al* 2000) and free-ranging barren-ground caribou (Chan-McLeod *et al* 1995) that BCS is a more important determinant of animal condition than liveweight and thus a more dependable determinant of future reproductive capability. Data from this study and others (Chan-McLeod *et al* 1995, Audige *et al* 1998) indicate that below BCS 2, body fat levels are prohibitive to growth and reproductive capabilities. Farmers should aim to maintain stock at BCS 3, allowing stock to absorb possible periods of nutritional shortfall without dangerously mobilising body fat reserves. Flow on effects of increased reproductive performance through setting minimum BCS thresholds extend to faster growth rates of fawns, higher weaning percentages and faster attainment of breeding / slaughter weights. Monitoring the BCS of breeding herds should be a rudimentary part of farm management, which in conjunction with regulation of energy intake requirements, should increase the productivity of many Australian deer farms.

The lower than expected levels of reproductive performance on Australian deer farms may be attributable to insufficient feed availability throughout trimester 3 of gestation and during lactation, which has potentially far ranging effects on neonate survivability and development, doe metabolic status and future reproductive performance. However, restrictions imposed on feed intake over early to mid gestation with fallow does had no measurable effect on conceptus development, suggesting that does had nourished the foetus at the expense of maternal body tissue, as was reflected in doe liveweight and BCS profiles and circulating β-OHB concentrations. Feed restriction to red deer hinds in trimester 3 produced a similar result. Farmers should note that if does/hinds successfully rear fawns/calves despite nutritional shortfall, their short term reproductive potential may be jeopardised.

This study also demonstrated the crepuscular nature of feeding behaviour of fallow deer, with the majority of feeding activity occurring around dawn and dusk, although intermittent feeding activity was also recorded at midday and midnight, particularly in late gestation and early lactation. It was shown that temperatures above 35^{o}C during a recognised period of feeding activity (sunrise and sunset) reduced the amount of time spent feeding (P=0.002). Reduced feeding time during periods of high temperature also suppressed average feed intake over a 24-hour period (P=0.020). Conversely, average ambient temperatures over a 24-hour period below 20^{o}C during recognised periods of feeding increased the average length of time by each doe spent at the feed trough (P=0.033). Does also spent on average greater time feeding at other times of the day when temperatures were below 15^{o}C. In line with energy intake requirements of fallow deer, such data may be useful for farmers in optimising growth rates of slaughter stock, or in strategic feeding of breeding does. The offer of daily feed supplements during periods of pasture shortfall should also coincide with times of the day when the deer would be naturally feeding.

Maximum profitability and the ability to meet production targets can only be achieved if deer farmers are aware of the seasonal feed requirements of their stock, in combination with hybridisation and other management strategies. The information from this study, the data from red deer reported by Drew (1996) and the work of Mulley *et al* (2000) for fallow deer now makes this possible. Venison from farmed deer is being promoted as a year-round fresh product, and it will be essential for deer farmers to be able to supply deer of repeatable size and quality over most of the year. The finesse of producing livestock to market specifications is a fundamental requirement of meat production systems, and Australian deer farmers now have the opportunity to be market leaders.

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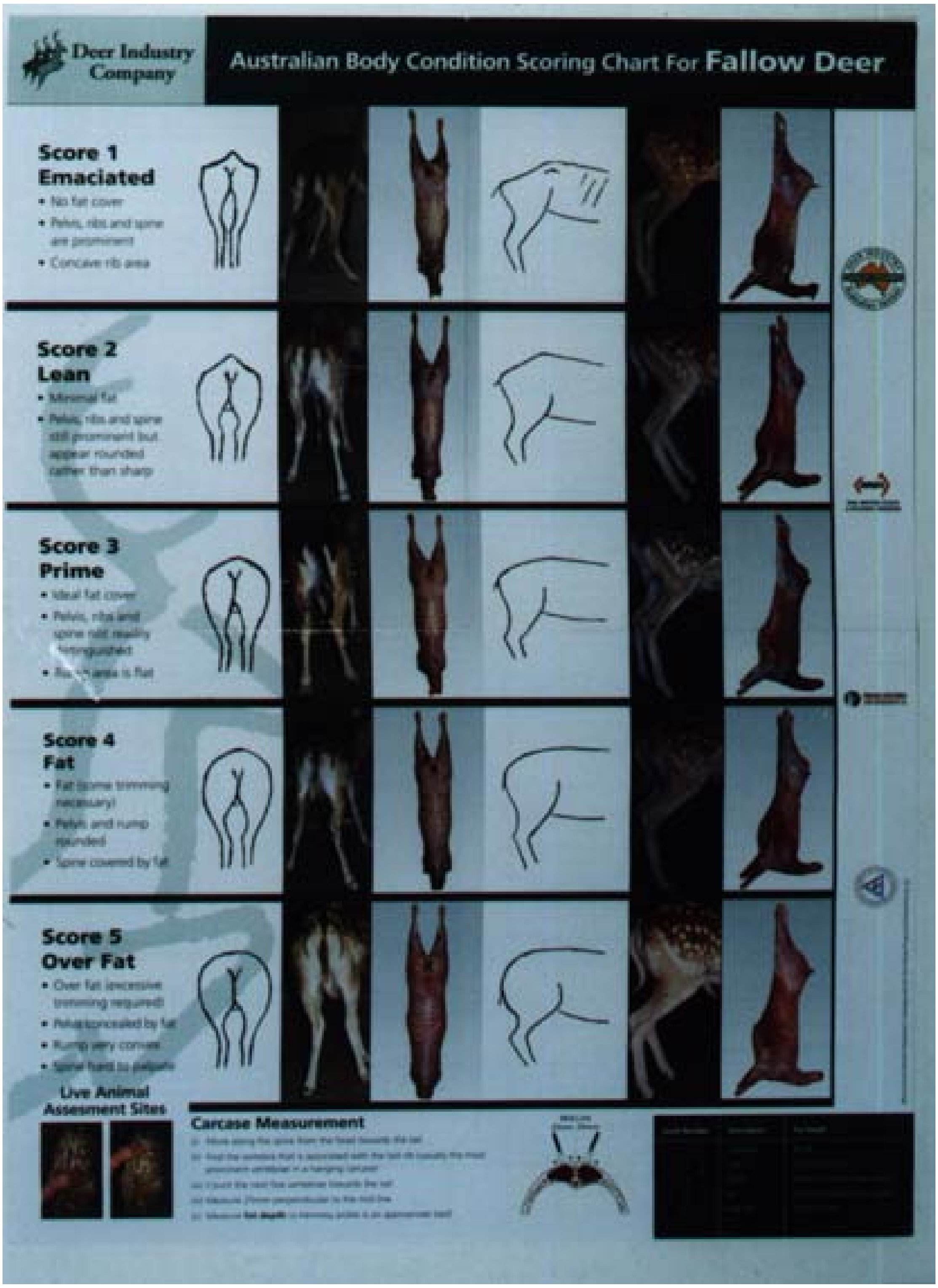
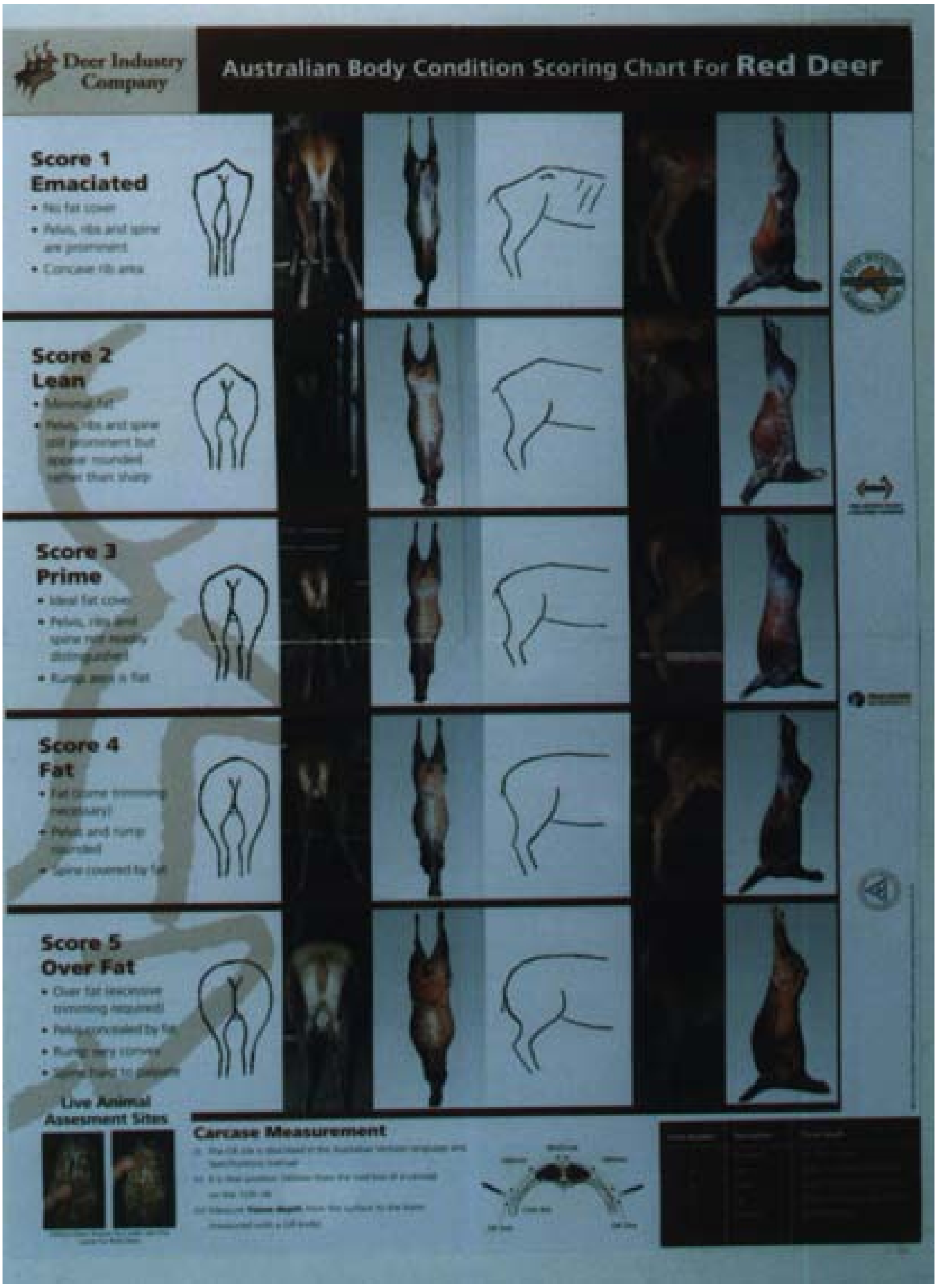
Appendix I


Deer Industry Company
Australian Body Condition Scoring Chart For Fallow Deer
Score 1
Emaciated
Score 2
Lean
Score 3
Prime
Score 4
Fat
Score 5
Over Fat
Live Animal Assesment Sites
Carcase Measurement

Appendix II


Deer Industry Company
Australian Body Condition Scoring Chart For Red Deer
Score 1
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Appendix III