Chapter One

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1.1 : Literature Review

1.1.1 : Taxonomy of Fallow Deer

Deer make up the family Cervidae of the order Artiodactyla and sub-order Ruminantia. According to Whitehead (1972), the Cervidae family consists of seventeen genera, forty species, and over 190 different sub-species. More recently, it has been said that some uncertainty still exists about the exact taxonomic classification of some of the deer species (Geist 1999), but for fallow deer, the taxonomy shown below is generally accepted. Deer are usually characterised by branching antlers which regenerate annually. Unlike the hollow and permanent horns of many other ruminants, the antlers of deer are solid and bony, and with the exception of the caribou (Rangifer tarandus) and in rare cases, roe deer (Capreolus capreolus), are possessed only by the males of each species (Chapman & Chapman 1975).

European fallow deer, the species primarily used in this study, are taxonomically classified as follows:

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<tr>
<th>Phylum</th>
<th>Chordata</th>
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<tr>
<td>Class</td>
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<tr>
<td>Order</td>
<td>Artiodactyla</td>
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<td>Sub Order</td>
<td>Ruminantia</td>
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<td>Family</td>
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<td>Species</td>
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There are two sub-species of fallow deer - the typical, or European fallow, *Dama dama dama*, and *Dama dama mesopotamica*, generally known as the Persian or Mesopotamian fallow deer, who have an extremely limited distribution in Southern Iran. On the verge of extinction in its natural habitat, Mesopotamian fallow deer, through their ability to be hybridised with European fallow deer, have become very valuable in farm production situations (Mulley 1989, Hogg et al 1993, Mulley et al 1993).
1996), improving the longevity of the species as a consequence. European fallow deer have an extensive natural home range in Europe and countries bordering the Mediterranean, and have been well conserved in estates and private landholdings in many other parts of Europe (Whitehead 1972), as is illustrated in Figure 1. A program of reintroduction of Mesopotamian fallow deer is currently being undertaken, with up to 60 breeding females known to be surviving outside captivity (Saltz et al 1998).

![Map of Europe showing distribution of Dama dama and Dama dama mesopotamica](image)

**Figure 1**: Distribution of fallow deer (*Dama dama dama* and *Dama dama mesopotamica*) in Europe. (Whitehead 1972)

### 1.1.2: Origins and Domestication

Deer are said to have appeared early in the Oligocene epoch in Asia approximately 38 million years ago, with the first remains of fallow deer dating back to the second interglacial period 250,000 years ago (Chapman 1993). However, the intensive husbandry of fallow deer in farmed environments is relatively new to agriculture. Although the historical evolution of their nomenclature suggests early
breeding and utilisation by man from 9000 BC (Reinken 1997), with many of the deer on farms today less than twenty generations from their wild progenitors. As such, deer exhibit comparatively nervous behaviour, with their ancestry having marked effects on their patterns of feed intake, growth and reproduction in managed pastoral environments. Within a short time, deer have been domesticated, but have undergone little genetic selection for improved domesticity. As such, farmed deer are essentially wild animals habituated to the farm environment. This is in stark contrast to domesticated ungulates such as cattle, sheep and goats, which have undergone extensive physiological, morphological and behavioural changes as a result of thousands of years of selection for domesticity (Asher et al 1996).

Throughout the 1980's, a large percentage of the fallow deer on deer farms in Australia were either captured from the wild or were directly derived from wild stock. With adult does attaining prices of $1200 per head in the early 1980's (Mulley 1989), their value was primarily seen as possession of the species, as opposed to productivity as a farm animal. Many herds were comprised of mixed age animals, and despite the large degree of genetic heterogeneity that existed in these herds (Asher et al 1996), productivity in regard to reproductive performance was not prioritised, let alone measured.

However, with fallow deer formally gazetted as domestic ruminants in Australia and New Zealand in 1978, and stock valued accordingly, productivity of this species has assumed much greater importance and prompted comparisons with traditionally farmed, now "competitive" ruminant livestock such as sheep and cattle. In contrast, the average value of fallow does in 1999 ranged between $40 and $50/hd, dependent on carcass weight (RIRDC 1999), emphasising the importance of the reproductive performance of these animals if a deer farming enterprise is to be financially viable. It has been widely accepted that nutrition has been associated with many of the productive indices in farmed deer, although as outlined by Kilgour (1988), behavioural stress due to animal management practices and the farming environment may also account for the relatively poor level of reproductive success achieved for fallow deer compared with other farmed ruminants. While there is documented evidence of free-ranging fallow deer in Australia having equivalent
growth, reproductive and fawn rearing success compared with their farmed counterparts (Mulley 1989), there is also anecdotal evidence to suggest that wild fallow deer are often in better body condition despite the absence of animal husbandry and pasture management (Small 1999, personal communication).

Whilst fallow deer are highly fertile in the wild (Chapman & Chapman 1975) and on farms (Mulley 1989), many authors have cited problems with foetal resorption (Chapman & Chapman 1975, Asher 1992), higher levels of fawn mortality (English & Mulley 1992), low weaning rates (Mulley 1989, Asher 1992), and slow growth to slaughter/joining weights (Mulley 1989, Asher 1992) than other domesticated species. While the reasons for high pre-weaning and perinatal loss on most farms is rarely diagnosed, it is generally thought to be attributable to lack of specific knowledge of nutritional requirements and resultant management of breeding stock.

While it is generally assumed that further domestication through selection for temperament and various production traits such as growth characteristics and carcass quality will occur in the future, it is also prudent for farmers to maximise production from both the animals and infrastructure currently possessed. With the behavioural plasticity of fallow deer to farming environments well noted (Kilgour 1988), managing existent wild behaviours within ‘acceptable levels’ (Asher et al 1996) through modifications of the farm environment to be more conducive to natural behaviour patterns, should be practiced by farmers.

Considerations such as the provision of visual barriers between mating paddocks, room for doe isolation during parturition and provision of fawning shelters (Kilgour 1988) are ways of addressing some of the behavioural traits of fallow deer without losing productivity. Fisher & Bryant (1993) note that deer are amongst the first species to be domesticated where there was a good knowledge of their natural behaviour in the wild, and this knowledge should be used to assist adaptation of deer to the farm environment.
1.1.3: Characteristics and Physiology of Fallow Deer

Fallow deer exhibit features typical of most temperate deer species. Male fallow, known as bucks, have a photoperiodically regulated annual antler cycle, with casting occurring in September in the Southern Hemisphere (Mulley 1989). Characterised by palmate antlers (Plate 1) which lack a bez tine, fallow are one of only two species of deer displaying palmation of antlers, the other being moose (Alces alces). Juvenile males (spikers) grow a single spike from each pedicle for their first antler cycle, after which antlers may vary in size to a length of 70 cm (Whitehead 1972). Bucks are reported to reach an adult weight of between 80 and 100 kg (Chapman & Chapman 1975, Bentley 1978, Asher 1986), but larger specimens up to 115 kg are now common among farmed deer (Mulley 2000, pers. comm.). Female fallow deer, known as does (Plate 2), generally attain an adult weight between 38 and 54 kg (Mulley 1989), although larger specimens are again common amongst farmed deer (Mulley 2000 pers. comm.).

Fawns, born in summer, typically range between 3.5 and 5.0 kg at birth (Asher et al. 1981, Mulley et al. 1990). Fawns, classed as ‘hiders’ (Chapman & Chapman 1975) remove themselves from the rest of the herd for several days after birth (Plate 3). Suckling activity, primarily instigated by the doe, can occur up to ten times per day in this time (Kilgour 1988), and can continue for up to eight months although generally on farms, ends with weaning of fawns at approximately 100 days (Asher 1993). Fallow deer vary greatly in colour, and may range from totally black to white, although they are typically known in their menil colouration, consisting of ginger with white spots. Fallow deer moult at the end of summer and again at the end of winter.

The woodland fringe of their native environment provides shelter as well as food, and acute senses of smell and hearing are used to avoid predation. Fallow deer are gregarious by nature, and have well defined home ranges. Vocalisations are predominant around the rut and during fawning.

Introduction
Plate 1: Entire fallow buck in hard antler.

Plate 2: Fallow doe and fawn (menil colouration).

Plate 3: Day old fallow fawn.
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During the rut, bucks emit a groan as they search for does in heat and as a challenge to rival males. Does vocalise to their fawns with a harsh bleat, which is answered with a squeal. Fallow deer also mew submissively to dominant animals, and bark an alarm call (Kilgour 1988). Body posture is also used to communicate danger, such as tail raising, exposing the white hair on the rump and underside of the tail (Alvarez et al 1976).

1.1.4: Digestive Physiology

The suborder Ruminantia comprising 176 species, have proved to be quite successful herbivores, and are found in a range of climatic zones from tropical rain forests, temperate woodlands, arctic tundra and deserts (Kay et al 1980). As a consequence of competition in their wild environments, different species have developed dietary niches and complementary feeding habits. This selection pressure, together with climatic and seasonal variations, has led to a plethora of adaptations of physiology, digestive anatomy, and behaviour, making each species uniquely adapted to their environment.

Deer, falling within this suborder, have also adapted to a wide range of environments and climatic regions, with their behaviour, reproductive cycles, feeding characteristics and digestive physiology suited accordingly. Some of these adaptations are advantageous in their domestication/farming, such as their ability to tolerate large seasonal variations in forage species and quality, and natural genetic heterogeneity (Fisher & Bryant 1993), whilst others, including their innate flightiness, may be possible hindrances. Fallow deer in particular, although more suited to temperate regions, are noted for their adaptation to a diverse range of environmental and pastoral conditions.

Temperate species of deer evolved on the forest-pasture fringe, and are well adapted to mixed browsing and grazing. Hoffman (1973) showed that animals of the sub-order Ruminantia may be divided into three categories based on their digestive physiology. Domestic sheep (Ovis ovis sp.) and cattle (Bos taurus and Bos indicus) fall within the 'Bulk Grazer' category, based on their ability to consume large quantities of highly fibrous plant material. Bulk Grazers are generally herd animals,
and may migrate seasonally in pursuit of feed. “Concentrate Selectors” are the second category, and include such species as moose (*Alces alces*) and muntjac (*Muntiacus spp.*), whose diet consists largely of browse. These animals are largely sedentary, foraging over wide areas to satisfy their discerning feeding preferences and digestive requirements.

Temperate species such as red and fallow deer are morphologically classed as “Intermediate Feeders”, with dietary intake varying between pasture and browse seasonally. Animals belonging to this group are generally gregarious and opportunistic in their feeding habits. Data on rumen content analysis from fallow deer (Jackson 1977) indicated that browse accounted for more than half of their annual diet, even accounting for a large proportion of daily feed intake in the English Spring, when pasture was abundant. These data, and other studies on fallow deer (Thirgood 1995, Flesch 1996), roe deer (Jackson 1980, Hosey 1981), black-tailed deer (Radwan & Crouch 1974) and white-tailed deer (Warren et al 1982, Weckerley et al 1987), indicate a large behavioural aspect to dietary preference.

Despite the classified distinction between these three groups of ruminants, rumen physiology may change seasonally and or with feed availability. Hoffman (1973) reported morphological changes in omasal laminae between impala (*Aepyceros melampus*) with different feed quality. Ruminal papillation in roe deer (*Capreolus capreolus*) has also been reported to vary with seasonal changes in forage diversity (Kay et al 1980). It has been demonstrated that dietary changes in domestic ruminants results in alterations in ruminal volatile fatty acids and micro-organism concentrations (Chaplin 1977), which has direct implications on the capacity and mucosal structure of the rumeno-reticulum (Kay et al 1980, Engelhardt et al 1985).

However, few controlled feeding experiments have been undertaken on wild ruminants, and it remains uncertain how far the quantity and nature of feed consumed determines the structure of the stomach, and of more importance to animal production, how far the genetic determinants of stomach structure and adaptability determine feeding habits (Kay et al 1980). Comparisons of digestion between red deer and sheep (Fennessy et al 1980, Domingue et al 1991) showed that red deer have
similar, if not superior fibre digestion efficiency than sheep, in addition to an increased ability to digest soluble carbohydrates and protein.

Similarly, (Ramanzin et al 1997) aligned the digestive efficiency of fallow deer more closely to grazers when compared with sheep, although as with red deer, they showed marked seasonality in voluntary feed intake. While there are no data comparing production outcomes of deer fed an ‘intermediate’ diet and deer fed exclusively pasture as on farms, much of the literature highlights the success of deer in their adaptation to the enforced pasture based farm environment.

1.1.5: Growth and Development

The temperate origin of fallow deer is linked to highly seasonal patterns of voluntary feed intake (VFI) and growth, which has a large bearing on management of these animals in farming situations. The seasonal patterns are not governed by availability and quality of pasture, but are a response to changing daylength, mediated by the hormone melatonin, which is secreted by the pineal gland (Barry et al 1989). Similar seasonal patterns of growth and VFI have also been shown in red deer (Pollock 1975, Kay 1979, Suttie et al 1983), white-tailed deer (Verme 1965), mule deer (Wood et al 1962, Bandy et al 1970) and moose (Renecker & Hudson 1985). Characteristically, the shorter the length of daylight (autumn / winter), the lower the feed intake and vice versa.

Seasonal variations in VFI and growth also differ with sex, and the age of the animal (Mulley et al 2000). The most rapid period of post natal growth in fallow deer is from birth to weaning, which generally lasts up to 100 days on commercial farms (Asher 1993, Flesch et al 1998). Sexual dimorphism between birthweights of doe fawns and buck fawns continues through suckling, with bucks having a higher growth rate than does. Asher (1993) reported growth rates for buck and doe fawns of between 160-189g/hd/day and 142-160g/hd/day respectively, which is similar to growth rates of fallow deer fawns under Australian conditions (Mulley 1989, Lenz et al 1993).
Liveweight gains subsequent to weaning are lower, with animals on average growing at half the rate of that during suckling, somewhere in the region of 70-80 grams per head per day (Mulley 1989, Asher 1993, Flesch et al 1999). Weaning disrupts growth patterns as fawns adapt to life without their mothers, and often new surroundings. As outlined by Mulley et al (1994), post-rut weaning, although allowing the fawns to suckle for longer, has no productive advantages in terms of fawn growth, although Pollard et al (2000) reported that red hinds conceived later as a result of post-rut weaning. This practice also provides the slight chance of precocious doe fawns attaining puberty at 8 months of age and conceiving, leading to dystocia problems in the next breeding season. Many farmers castrate male fawns at this time which also has a negative effect on growth of weaners, though has benefits in the following years through negating the annual liveweight cycles of the rut. Castration of fallow deer (Mulley 1993) also altered carcass characteristics and meat yields, and extended the killing season.

The decrease in growth rates over winter is thought to be determined by both feed quality and VFI, when fawns are between 6-8 months of age. Similarly, the degree to which liveweight will surge over spring and summer is commensurate with pasture availability and quality (Mulley et al 1996), although photoperiod changes trigger increased grazing behaviour and VFI.

While there has long been a correlation between fertility and liveweight (Asher 1986), photoperiod still has strong associations with attainment of puberty (Adam 1994). With fallow deer, critical weights are thought to be between 28 and 30 kg for both does and bucks (Asher 1986) and puberty is usually attained by the second autumn of life. Puberty in does is regarded as the age at first oestrus, with the threshold weight representing approximately 70% of their mature pre-rut liveweight (Asher 1993). At this stage, bucks may at best maintain their autumn liveweights through winter to the following spring, and consequently, many farmers take this opportunity to sell for slaughter bucks not required for breeding. Adequate nutrition for does during lactation and for growth of fawns once weaned are critical if production objectives for animals to reach slaughter weight, and for females to reach
threshold weights for joining (Flesch et al 1998, Mulley et al 2000) are to be achieved.

After puberty, bucks begin to display annual liveweight cycles, with some animals shedding 25% of their pre-rut liveweight (Mulley 1989). While does also exhibit annual cycles of liveweight, they are less pronounced than bucks, with the increase in pre-fawning liveweight largely reflected in the weight of the unborn fawn and other products of conception (Asher 1993).

1.1.6 : Reproductive Cycles of Fallow Deer

The temperate origins of certain deer and resultant photoperiod cycles have a major influence on their production potential for farming (Suttie & Simpson 1985). Seasonal breeding in such northern temperate species as fallow, red deer and elk, benefits the species within its natural range, but creates a misalignment in the southern hemisphere between the high nutritional demands of lactation in summer and the earlier peak of pasture production in spring (Asher et al 1996). This misalignment of nutritive demand to available feed supply has the potential to compromise fawn growth rates and depress dam liveweights and resultant condition for joining. While there have been various attempts to advance the onset of oestrus through hybridisation (Asher et al 1988a) and melatonin implants (Asher et al 1988b, 1990, 1993), feed budgeting to overcome the serendipity in Australian patterns of pasture growth remains the only practicable means in matching feed supply to demand.

Fallow does that become receptive to sexual advances from the buck are described as being in heat, or oestrus. In the southern hemisphere does show first signs of oestrus in mid April to early May, and if not mated, will continue to cycle every 21-25 days into winter (Asher 1988). However, short ovulation cycles may also occur several weeks prior to the first fertile oestrous cycle in fallow does. Referred to as ‘silent ovulations’, these short oestrous cycles do not result in pregnancy, but are thought to be responsible for the high degree of natural synchrony within any one herd (Asher et al 1986). The hormonal events leading to oestrus are closely related to ovulation. The peak LH surge and rupture of the mature ovarian
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Follicle usually occurs within 24 hours of one another (Asher 1993). Oestrus, or standing heat may last from as little as 15 minutes to 24 hours, depending on copulation (Asher 1993). The length of the first oestrous cycle in fallow deer is $21 \pm 0.64$ days (Asher 1985, Mulley 1989) with most does being joined on their first ovulation, although up to six oestrous cycles have been recorded with fallow does in one season (Asher 1993). This high conception rate in the first cycle, in conjunction with the high level of natural synchrony seen in many herds generally leads to a very condensed fawning period in mid December, with average gestation lengths of $234\pm2$ days (Asher & Morrow 1993).

Fawns born in January or later generally represent those does joined on their second or third oestrus cycles. Some does may conceive on fourth or even fifth cycles if sire bucks remain with the does. Fawns resulting from late conceptions have lower survival rates than fawns born from first cycling does, and also pose management problems, particularly when moving does and fawns to fresh pasture, and when weaning (Mulley 1989). For this reason, many farmers remove sire bucks from breeding herds in early winter, to avoid late pregnancies and to condense the fawning season to allow maximum utilisation and management of pasture quality during the fawning period.
1.2 : Deer Farming in Australia

1.2.1 : Introduction of Fallow Deer to Australia

There are no deer species native to Australia. However, approximately 20 species of deer were released by various Acclimatisation Societies and wealthy landholders in the early to mid 1800’s. There are now stable populations of six species of deer in the wild in Australia, comprised of red deer (*Cervus elaphus*, spp. elaphus, scoticus, hippelaphus), fallow deer (*Dama dama dama*), rusa deer (*Cervus timorensis*), sambar deer (*Cervus unicolor*), axis or chital deer (*Axis axis*), and hog deer (*Axis porcinus*) (Whitehead, 1972, Chapman and Chapman, 1975).

Fallow deer first landed in Australia in 1836, with the introduction of six does and six bucks in Tasmania (Bentley 1978). These deer were bred in captivity, and liberated once numbers reached approximately 100 (Roberts 1993). These animals formed the base of today’s wild Tasmanian fallow deer herds, now estimated at between 15 and 20 thousand (Hall 2000 pers. comm.). This herd provided a base from which animals were drawn from and subsequently introduced into other states, and by the 1850’s, several small herds gained establishment in Victoria (Bentley 1978).

New South Wales became home to several herds of fallow deer following their introduction in 1862, although the most notable release occurred on a southern highlands property named “Currandooly” in 1875, with the release of two breeding pairs (Mulley 1989). This herd grew to be one of the largest herds of fallow deer on mainland Australia and later became an important source of animals in the pioneering stage of the Australian deer industry in the early 1980’s. Fallow deer were also released in other areas of NSW, such as the Royal National Park south of Sydney in 1885, and in the New England region in 1934 (Bentley 1978), the latter still harbouring several thousand animals due to the favourable combination of farmland and mountainous timbered country and their preservation as a hunting resource.

There were numerous other releases of fallow deer in other states as well. Queensland received several breeding pairs of Tasmanian origin in 1865, with
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releases at Toowoomba, Stanthorpe and the Darling Downs, with animals still existing in these areas. South Australia and Western Australia were also recipients of fallow deer in the 1890’s. The South Australian herds rapidly spread and are still numerous today, while the releases in Western Australia existed in meagre numbers until the mid 1930’s where habitat loss, hunting pressure and poor fertility were attributed to their disappearance (Roberts 1993). Figure 2 illustrates the locations of some of the larger feral populations of red, fallow rusa and chital deer in Australia.

![Map of Australia showing the distributions of different deer species.]

**Figure 2 :** Locations of significant feral populations of fallow, red, rusa and chital deer in Australia.

*Introduction*
1.2.2: Industry Development

The Australian deer farming industry began in the 1970's, following closely behind the establishment of intensive deer farming systems in New Zealand (Falepau 1999). Similarly, the initial supply of animals for the Australian deer industry came from the live capture of fallow deer from feral herds in NSW (Mulley 1989) with over three thousand animals removed from one herd alone (Small 1999). Large numbers of red deer were also captured in Queensland in the Brisbane Valley, along with rusa deer in the Royal National Park south of Sydney. Although limited numbers of chital deer, rusa deer and sambar deer were captured for farming purposes, red and fallow deer dominated the industry, with fallow deer accounting for at least 70% of animals on farms in the 1980's (Mulley 1989) due to their more ready availability from wild herds. In 1985, relaxed import protocols allowed large numbers of red deer and wapiti (Cervus elaphus canadensis) to be imported from New Zealand, with up to 900 animals imported annually between 1985 and 1991 (RIRDC 1999). These importations improved the genetic potential of Australia's red deer population for both venison and velvet antler production.

Average prices for breeding females during this period were extremely high. This reflected the demand for animals that, at that stage, were somewhat of a novelty in Australian agriculture, and indicated the high expectations many people had on both the production potential of deer as a domesticated species and the industry itself. Fallow deer does and red deer hinds attained prices in excess of $1200 and $3000/hd respectively (Mulley 1989, Falepau 1999), and became an attractive alternative livestock enterprise producing high returns off small areas of land, quickly paying off investment on infrastructure (Falepau 1999).

With the large financial returns on investment achieved by some of the early pioneers from the buying and selling of breeding stock, interest in deer farming spread to people not traditionally associated with farming or agriculture. Numerous investment schemes emerged to attract the capital required to hold the large numbers of red deer being imported from New Zealand (Falepau 1999). The genetic structure of farmed deer in Australia has also changed considerably over the last ten years, with importation of various bloodlines of fallow deer from England and Hungary,
primarily for venison production, although velvet antler harvests have also markedly improved. Importation of both semen and live animals of Mesopotamian origins also occurred in the early 1990's, with Mesopotamian hybrids now commonplace on many fallow deer farms. With the gradual increase of numbers through both importation of live animals, and natural increase through breeding, Australia began to initiate markets for venison, velvet and by-products. In the 1990's the Australian industry began a period of consolidation as it grappled with the reality of international competition.

1.2.3: Current Situation

Evolving from the Deer Farmer Federation of Australia (DFFA), the Deer Industry Association of Australia (DIAA) coordinates research and development projects and is instrumental in facilitating the development of the Australian deer industry. The current objective of the DIAA, as outlined by RIRDC (1999), is to significantly increase both the number of deer farmers and consequently, number of deer on farms in Australia to increase venison exports. Recent census data suggests that there may be between 220,000 and 250,000 deer on farms (Sinclair 1997, RIRDC 1999). Fallow deer comprise approximately 49% of this total, while red and red deer hybrids account for 39%. The remainder of the population is made up of elk, chital and rusa deer, accounting for approximately 3%, 2.5% and 6.5% respectively.

Breeding females over two years of age account for approximately 60% of the population of farmed deer in Australia (RIRDC 1999), and precise information concerning nutrition during pregnancy and lactation has the capacity to significantly improve productivity in the Australian deer industry.
1.3 Project Objectives

1.3.1 Background to the Project

There is currently no information available on the nutritional requirements of pregnant and lactating fallow deer that has been derived by thorough experimental appraisal. Current estimates (Milligan 1984, Asher 1993) have been 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 does penned in 2 groups of 5 (Mulley 1989). In line with DIAA objectives, the deer industry must expand to achieve greater viability, and supply of animals for slaughter, with recent industry estimates (RIRDC 1999) predicting deer numbers in Australia to increase to 320 000 by 2008. Furthermore, it is imperative that carcasses 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 because of the low level of research funding available through industry levies, and the costly nature of such long term research.

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 reproductive wastage in breeding stock. Only recently has data become available for VFI 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. 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 this is the period of most rapid growth in the life of any animal.

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 in late pregnancy has not been
investigated to any extent. Production of an easy to follow guide to feed management for fallow deer farmers, one of the objectives of the current study, will lead to greater efficiency of resource utilisation, and should result in better nutrition for farmed 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.

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 (RIRDC 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 (RIRDC 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 the outcomes of the present research are applicable to most of the approximately 1200 deer farmers in Australia (RIRDC 1999).

However, 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.

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 a user friendly industry manual 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:
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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 vegetables 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.

1.3.2: Industry Recommendations / Feedback

This may be accomplished through the distribution of the manual to all deer farmers registered with the Australian deer Farmers Association. There are approximately 225 000 deer on Australian deer farms producing 1000 tonnes of venison per annum, 85% of which is sold for export (Falepau 1999). Comparatively, in New Zealand in 1998, in excess of 400 000 deer were slaughtered (RIRDC 1999), providing some indication of Australia’s position on the international market.

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. There is little information available to deer farmers on the nutritional requirements of farmed deer, and no information at all on the requirements of pregnant and lactating
fallow deer. The availability of accurate data on the annual feed demands of breeding stock, in conjunction with a standardised means of identifying and communicating the condition of live animals and carcasses, will assist farmers with their feed budgeting and strategic feeding programs, which will enhance the quality and quantity of deer available for slaughter on Australian deer farms in the future. The current study will address both of these areas.
Chapter Two

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2.1 : Research Environment and Practices

2.1.1 : University of Western Sydney - Hawkesbury Deer Research Facilities

The University of Western Sydney Deer Research and Teaching Unit consists of approximately 25 acres divided by a road (Piggery Lane) running north to south. The Western Side of Piggery Lane consists of 4 large paddocks, (as illustrated in Figure 3) recently annexed from the UWS-H Dairy farm in 1997. These paddocks have no recent history of cropping or pasture improvement, and were used primarily for non-experimental animals and for fawning, due to the number of well established trees in these paddocks. Irrigation was also not possible for these areas, with stocking rates being heavily affected by the incidence of rainfall over the Summer months.

The western side of the unit is also bounded by various buildings of other faculties within UWS-H, and thus were largely unsuitable for the majority of experimental activities. Kikuyu was the dominant pasture species on this side of the unit, with couch grass, white clover and perennial ryegrass also persisting in some areas. Woody weeds were also consumed in limited quantities by the deer, including Stinging Nettles and Black Thistle. These were controlled by applications of Banvel M (Sandoz Australia Pty Ltd) although Castor Oil plants, often growing to over 1.5m high, were left in 10m round clumps to allow red deer calves to hide.

The eastern side of the road was of greater importance to experimental work. It consists of six ¼ ha paddocks and six other paddocks of varying sizes, and is bounded by farmland. Paddocks 1-6 were oversown with perennial ryegrass and oats in early April on a two-year rotation (Plate 4) and were able to be irrigated with treated effluent water from the Richmond sewage works. Each ¼ ha paddock joins to a common laneway to facilitate the movement of stock to the handling shed or abattoir. The majority of the experimental work was undertaken in the ¼ ha paddocks, allowing ease of monitoring sward height, pasture intake and behavioural patterns. However, due to a lack of shade and adequate shelter, some of the fawning was carried out in paddocks with more shelter and shade.
When this was not feasible, wooden fawn shelters constructed from industrial pallets were placed in the paddocks, and were well used. All paddocks on the eastern side of Piggery Lane contained predominantly Kikuyu, whilst some of the less used paddocks contained couch. No dams were present on the UWS - H deer unit. All paddocks contained self-filling (float valve type) semi-circular plastic or concrete water troughs serviced by town water.

The climatic characteristics of the Hawkesbury region, and resultant pasture growth patterns were sometimes unpredictable. Supplementary feeding of stock was occasionally used during periods of pasture shortfall, the extent of which depended on the number of stock on the UWS - H deer unit. Winter feed-gap was overcome to a certain extent by the ryegrass and oats, although due to irrigation limitations, cropping was limited. Unless specified, no deer participating in nutrition trials were supplemented, although superfluous stock were provided with a combination of barley and prime lucerne hay. No other species of livestock were given access to the UWS - H deer unit and for the majority of the time, only two people were involved in the day to day management of the unit, including moving stock from paddock to paddock, supplementary feeding and animal handling.

The pens used for the individually housed animals involved in nutrition trials were converted from piggery farrowing pens, originally constructed in the 1940's. They exist in two parallel banks of six pens attached to the handling shed via separate wire laneways, with no animal having to travel more than 30 metres to the handling shed. The pens were approximately 2.25 m tall, and 3 m x 4 m in area. Concrete dividing walls extended 1 m off the ground, on top of which were attached 3x1 inch dressed pine slats, which extended to the roof. Each pen had a gate of steel construction, covered with 1-inch square steel mesh at the bottom, and marine grade plywood from half way up, allowing each animal to see out of the pens (Plate 5).

Hinged steel feed troughs were attached to each gate, which allowed feed to be dispensed and removed without entering the pens. Troughs were installed approximately 30 cm from the pen floor, which allowed fawns access to concentrate
Plate 4: Ryegrass/oats pasture in experimental paddock.

Plate 5: Bank of six individual deer pens and laneway.

Plate 6: Interior of pen, illustrating natural light, sawdust bedding, water trough and mesh-covered window (closed).
feed and minimised the chance of contamination from the bedding material. Air flow in and around the pens was assisted by the 1 cm gaps between the pine slats, the mesh in the gates and a 50 x 150 cm mesh covered window at the back of each pen, which also allowed natural light to enter (Plate 6). Light also entered the pens via a clear Laserlite® panel in the roof of each pen, which substituted a sheet of corrugated iron. In summer, sprinklers were placed on the roof of both banks of pens, which was seen to lower the pen temperature by as much as 2 °C.

The concrete floor of each pen was covered with approximately 15 cm of coarse pine sawdust, changed regularly throughout each of the trials. Ad libitum fresh cool drinking water was also supplied to each pen via a self-filling trough, located on the wall in the back corner of each pen. Water troughs were also located at a height that enabled both does and fawns to drink with ease.

2.1.2: Temperature and Rainfall

Temperature and rainfall were monitored daily over the duration of the study via an automated system at the UWS - Hawkesbury Weather Station located approximately 800 metres from the deer unit. Data of relevance to the study includes daily maximum temperatures and rainfall. The figures for 1997 inclusive to December 1999 are shown in Figures 4-9. They provide a useful insight into the trial conditions and have associations with pasture growth curves, deer growth and feed intake. An irrigation system was installed in 1998, allowing the six trial paddocks to be watered, giving the deer unit a greater deal of autonomy in its pasture production.

In 1998-99, temperature sensors, infrared movement detectors and light sensors were installed in the individual feeding pens, as outlined in Chapters 3 and 4. Data presented in these chapters associated with diurnal feeding behaviour has been taken individually from each feeding pen, and is thus independent from the UWS - H weather station data.
Figure 4: 1997 Daily maximum temperatures

Figure 5: 1998 daily maximum temperatures

Figure 6: 1999 daily maximum temperatures
Figure 7: Daily rainfall for UWS - Hawkesbury, 1997

Figure 8: Daily rainfall for UWS - Hawkesbury, 1998

Figure 9: Daily rainfall for UWS - Hawkesbury, 1999
2.1.3: Description of Breeding and Fawning Seasons

As outlined in detail in Chapters 3 and 6, all fallow does participating in nutrition experiments, (ie, animals housed individually in pens and those fed on pasture) received a single intra-vaginal progesterone releasing device (EAZI-BREED CIDR-G®, InterAg Pty Ltd, Hamilton, NZ) containing 0.3g of progesterone for oestrus synchronisation. The implants remained in the animals for 14 days, and does came on heat between 12 and 24 hours after CIDR removal. Synchronisation of oestrus commenced in mid April of each year with insertion of CIDR devices, with the animals joined in late April after CIDR removal. A ratio of 1 buck per 10 does was usually employed for mating synchronised does. Initial ultrasound scanning for pregnancy revealed that conception rates with these buck : doe ratios were high (>90%) although on one occasion, the conception rate fell to <70% when 3 year old bucks serving for the first time were used with these numbers of synchronised animals.

In each of the 1997, 1998 and 1999 breeding seasons, the breeding groups were combined into a single group after mating and a mature buck was left with the synchronised animals for 25 days in order to join does who were missed on the first oestrus cycle. Using this procedure, only eight animals failed to conceive following two oestrus cycles with a buck out of approximately 150 animals joined over three consecutive breeding seasons. Deer were scanned for pregnancy trans-rectally on day 35 post CIDR removal. Does not diagnosed pregnant (NDP) on this day were not included in individual pen trials, but remained with pasture fed deer (control group) throughout the trial for which to compare with the penned animals. With minor variations according to pen allocation and trial starting dates, does were then re-scanned 50 days post CIDR removal, both to differentiate pregnancy in does joined on the second cycle, and to monitor foetal and placentomic development.

Fawning times for the synchronised does who conceived on their first oestrus cycle in each breeding season ranged from 15th of December to the 25th of December, while second cycle conceptions extended as far as January 10th, although these were uncommon. These fawning dates fell within the range of birth dates observed from non-synchronised does not participating in nutrition trials. As reported by Mulley
(1989) the breeding season in NSW for fallow deer begins in Early April, and extends into mid to late May.

2.1.4: Fallow Deer Handling Facilities

Deer were mustered on foot via a 12 foot wide laneway and through a large sliding wooden door into the handling shed consisting of 4 main rooms of diminishing size, a race with rope operated guillotine-type dividers and a drop-floor handling crush. The custom built crush was of steel construction with a sliding door at the rear and hinged door at the front end of the crush allowing access to either end of the restrained animal (Plate 7). An adjustable back press was included to restrict the movement of animals whilst involved in operational / surgical procedures, and to minimise the chances of injury to the animal handler (Plate 8). The crush was seated on two 250kg load bars, attached to Ruddweigh scales (Ruddweigh Pty Ltd, Guyra, NSW Australia) and digital readout. Deer were weighed to the nearest 0.5 kg.

The handling shed had thick concrete exterior walls and a concrete floor, covered with 10-15 cm of coarse hardwood sawdust. The dividing walls and doors were all of wooden construction with steel frames, and were 2.25 m high. Four fluorescent lights were hung from the high ceilings in the shed, one over the crush area, and the other over the second pen from the door. Varying amounts of natural light also entered the shed via two large skylights located over the start of the race and over the entry pen (Plate 9).

Observations on deer social, feeding and breeding behaviour were performed from an elevated platform constructed between two silos at the rear of the handling shed. Elevated approximately four metres above ground level, the enclosed platform provided an unobstructed view of the experimental paddocks from which deer could be identified and monitored.
Plate 7: Custom made drop-floor crush with digital scales.

Plate 8: Deer restrained in crush (black hood over head).

Plate 9: Elevated view of fallow deer handling shed.
2.1.5 : UWS Abattoir Facilities

The UWS-H abattoir was located adjacent to the UWS-H deer farm with access to the lairage yards from the Eastern side of Piggery Lane. This ease of access to the abattoir minimised stress to animals, as no transport was required. The abattoir consists of two dark rooms, leading to a drop-floor crush where deer were restrained for slaughter. Stunning and exanguination were performed as described by Falepau (1999). Skinning and evisceration were performed with carcasses hanging from a meat rail. The coolroom was large enough to hang at least 30 carcasses.

2.1.6 : Pasture Management and Soil Profiles

Pasture samples were routinely collected from the UWS - H deer unit over the duration of the research. Paddock size allowed grazing to be strictly monitored, with pasture sward height being the main determinant of grazing rotations. During experiments concerning nutritional intake of pregnant and lactating does, paddocks containing animals used for comparison with individually penned animals were sampled (from July to March), while at other times, composite samples from a number of paddocks were analysed. Figure 10 illustrates metabolisable energy (ME) values of pastures over the years 1997, 1998 and 1999, while Figure 11 illustrates estimates of seasonal pasture production (kg DM / Ha) of Kikuyu, ryegrass and oats in the Richmond area. Increases in ME during winter reflect oats / ryegrass growth over the dormant period of Kikuyu. ME was calculated from DMD, as outlined by Oddy (1978). Pasture energy values for 1997 are lower than latter years, prior to installation of an irrigation system.

Nitram (Incitec Fertilizers Ltd, Australia) was applied to ryegrass and Kikuyu pastures following the first grazing, (May and November respectively) at the rate of 60 kg per Ha. Recent independent soil tests indicate a very fertile soil providing more than adequate amounts of soil nutrients for growth of the various pasture species. Samples were taken to a depth of 10 cm in two transects across all paddocks, and the composite soil analysed.
Figure 10: Metabolisable energy values of pastures grazed by pregnant and lactating does at UWS - Hawkesbury over the years 1997-1999.

Figure 11: Estimates of seasonal pasture production (kg DM/Ha/day) of kikuyu, ryegrass and oats in the Richmond area.
2.1.7: Livestock and Management

All stock involved in research trials at the UWS - H deer unit were derived from one commercial deer property in Central NSW. All stock were ear-tagged prior to purchase. European (*Dama dama*) does were differentiated from hybrid ¼ Mesopotamian does (75% *Dama dama* and 25% *dama mesopotamica*) via metal tags in each animal's right ear. On arrival at UWS - H, numbered plastic collars (Cross Range Collars - Te Pari Products Limited, Palmerston North, New Zealand) were attached to each animal as both a secondary means of identification, and for long range identification of animals during behavioural observations.

Both the pasture fed and individually penned animals were weighed on a weekly basis up until three weeks prior to the calculated fawning date, based on a gestation length of 234 days (Asher & Morrow 1993). This was especially necessary for the penned animals, where the process of moving them from their respective pens down laneways and into the handling shed posed a possible threat to the foetus from both collisions with gates, walls and corners in the handling shed, and particularly the process of restraining in the crush. For each experiment, weekly weighings were performed at set times, which not only habituated the animals to the process, but was also a means of attempting to standardise animal liveweight in relation to gut fill at each weekly interval.

The time of weighing was also regulated so as to minimize interference of the normal feeding patterns of the deer. Observations of feeding patterns of deer grazing at pasture and infrared monitoring of does in individual pens revealed a major feeding event from sunrise to mid-morning (8-10), followed by a period of rest and rumination until the next major feeding period around midday. Subsequently, deer were weighed during this mid-morning period, which in the Summer months, was also cooler and less stressful. Similarly, individually penned animals were also routinely fed at regular intervals to minimize stress and interference of natural feeding behaviour. Unlike pasture fed deer whose evening feeding patterns start in late afternoon, the penned animals would rarely begin feeding in full light, normally nearing the feeding trough in semi-darkness.
Daily monitoring of breeding does was carried out between late November and early January in the 1997/98 and 1998/99 fawning seasons. Newborn fawns in pens and paddocks were weighed and eartagged between 12 and 36 hours after birth (Plate 10). Newborn fawns still wet were not handled, and fawns unable to be caught were assumed to be greater than 36 hours old. Does in pens were moved into the handling shed during weighing and tagging to prevent injury to the fawn. Weighing was accomplished by catching the fawn and placing it in a hessian bag suspended from a set of 15 kg Salter Scales (Salter Scales Pty Ltd, Marrackville, NSW). Fawns were weighed to the nearest 100 g. Fawns were eartagged (left ear for does, right ear for bucks) with numbered medium sized Allflex eartags (Allflex Australia Pty Ltd, Victoria). Eartags were colour coded for each season. Following the tagging procedure, fawns were placed back in their resting place (Plate 11). Sex, colouration, and location within the paddock were also noted. Dead fawns were photographed and removed for post-mortem examination.

2.1.8: Commercial Property Description

Comparative data on doe nutrition throughout pregnancy and lactation in relation to fawn birthweights and growth rates to weaning was gathered on a commercial deer property located at Bathurst (33° 25’ S, 149° 34’ E) in Central NSW, approximately 200 km West of Sydney. Elevated approximately 800m above sea level, this property has greater temperature extremes than the UWS - H deer unit, with occasional snow in winter and summer maximum temperatures frequently reaching 40°C. With an average annual rainfall of 18 inches, supplementary feeding is sometimes necessary in both summer and winter, with over 200 Ha of lucerne grown annually for hay. Stocking rates on this property were extremely high over the period of this study. A large number of stock that had attained slaughter weight were not killed due to poor market prices, and were still on the farm consuming valuable pasture (Mons 2000, pers. comm.).

This privately owned property contained a herd of approximately 3560 fallow deer, 2012 of which were breeding does, and 156 of which were sire bucks. European does, including Hungarian bloodlines, along with \( \frac{1}{4} \) and \( \frac{1}{2} \) Mesopotamian does were
grazed on 1400 acres of improved pasture, including phalaris, paspalum, fescue and ryegrass (Plate 12). Terrain was flat to undulating, with some native forested areas. The property was divided into 15 paddocks of uneven size, and contained several large dams for stock, although water was pumped to troughs in several paddocks.

Bucks, primarily ½ and 7/8 Mesopotamian, were put out with the does in early April with a buck to doe ratio of 3 : 100, and removed from the does in mid June. This condensed the fawning season and assisted with weaning, which occurred pre-rut on this property. Sound management and good stockmanship resulted in weaning rates greater than 90% in all mobs of deer on this property. Male fawns were routinely castrated in May each year, and reached slaughter weight before 14 months of age.
Plates 10 & 11: The author with a newborn fallow fawn on the Case Study Farm, before and after weighing and eartagging.

Plate 12: A mob of 9 month old fallow deer castrated grazing improved pasture on the Case Study Farm.
2.2 : Feed Analysis and Procedures

2.2.1 : Pasture Sampling and Preparation

Pasture samples were collected when deer were transferred into a new paddock, and fortnightly throughout each experiment. A 0.25 m² quadrat was broadcast to randomly select several areas of pasture for analysis in each paddock. Pasture within this area was removed with electric shears to a height of 10 cm above ground level. With the pasture management strategies employed, sward height generally exceeded 20 cm, and rarely dropped to below 10 cm, thus it is assumed that the pasture matter removed for analysis constituted the range of material the deer would naturally consume when grazed in those paddocks over a certain period of time. This procedure was performed in triplicate at each sampling event, creating a composite pasture sample for analysis.

Samples of each of the manufactured feeds were acquired at the commencement of each experiment or when a new batch of each feed was made. Approximately 500 g samples were randomly removed from silos/bags. All feed samples were placed in labeled paper bags and dried to a constant weight at 65°C. Samples were ground through a 1 mm screen and stored in plastic vials for analysis.

2.2.2 : Dry Matter and Ash

The dry matter of a feed was determined from the loss of weight that resulted from a known weight of a sample to a constant weight through drying at 105°C. The ash fraction of the forage was determined by ignition of a known weight of feed at 600°C until all carbon was removed in the form of CO₂. The ash residue was taken to represent the inorganic components of the feed. Major inorganic elements would include Ca, Mg, P, Na and K, while trace elements include Fe, Mn, Se and Zn. Ash fractions of feed samples were determined by ramped heat combustion in a muffle furnace (Carbolite Company, Sheffield, England).
2.2.3: Acid Detergent Fibre Determination

Acid detergent fibre (ADF) was determined via the method of Van Soest (1963). Samples were analysed in duplicate, and the mean of the two used. Acid-detergent solution was prepared by volumetrically adding 20 g of cetyltrimethylammonium bromide (CTAB) (technical grade) to 1L of 0.5M 98% AR H2SO4 (A2005). Approximately 1 gram of each feed sample was weighed on a Sartorius analytical balance (Sartorius Analytic, A 200s, Germany) directly into tared berzelius beakers and refluxed with 100 ml ADF solution and 2ml Decalin: (decahydronaphthalene - reagent grade) for 60 minutes (Gerhardt Scientific, Bonn Germany). The solution was allowed to cool, before being filtered through individually weighed and numbered sintered glass crucibles (coarse, porosity #1). Particulate matter was rinsed with 150 ml hot boiled distilled water (>80°C) and decolourised with 5ml acetone before being dried at 105°C for 8 hours. Crucibles were desiccated and weighed, before being ashed in a muffle furnace (Carbolite Company, Sheffield, England) at 600°C for 4 hours. Acid detergent fibre was calculated as the loss of weight on ashing as a proportion of the sample dry matter (determined simultaneously).

2.2.4: Neutral Detergent Fibre Determination

Neutral detergent fibre (NDF) was determined via the method of Goering & Van Soest (1967). Samples were analysed in duplicate, and the mean of the two used. NDF solution was prepared by volumetrically adding 150 g sodium laurel sulphate (Technical), 93.05 g disodium hydrogen EDTA, 22.8 g disodium hydrogen phosphate, 34.05 g sodium borate decahydrate and 50 ml 2-ethoxyethanol (ethylene glycol) to 5.0L cooled boiled distilled water and adjusted to pH 7.0.

Approximately 1 gram of each feed sample was weighed into beakers and refluxed with 100 ml NDF solution and 2 ml Decalin (decahydronaphthalene - reagent grade), 0.5 g anhydrous sodium sulfite and 6 glass anti-bumping beads (to facilitate even boiling) for 60 minutes (Gerhardt Scientific, Bonn Germany). The solution was allowed to cool, before being filtered through individually weighed and numbered
sintered glass crucibles (coarse, porosity #1). Particulate matter was rinsed with 150 ml hot boiled distilled water (>80°C) and decolourised with 5ml acetone before being dried at 105°C for 8 hours. Crucibles were desiccated and weighed, before being ashed in a muffle furnace (Carbolite Company, Sheffield, England) at 600°C for 4 hours. NDF was calculated as the loss of weight on ashing as a proportion of the sample dry matter (determined simultaneously).

2.2.5 : Nitrogen and Crude Protein

Nitrogen (N) was determined by the Kjeldahl method (Anon. 1987), a wet oxidisation technique, by which nitrogen in protein in the feedstuff is converted to ammonium (NH₄⁺) by digestion with 18M sulfuric acid (H₂SO₄) in the presence of a catalyst (3.5 mg selenium (Se) and 3.5 gm potassium sulfate (KSO₄). Approximately 0.5 g of the ground feedstuff was digested with 10 ml of H₂SO₄ for 40 minutes at 400-410°C (Tecator Digestion system 1015 digester). Residue was allowed to cool before distillation (Tecator Kjeltec 1026 distillation unit) using a 10M alkali complexed with 50 ml boric acid indicator solution. The liberated ammonia (NH₃) was then titrated against 0.1M hydrochloric acid (HCl) to reach a neutral grey endpoint. Millilitres of titrant used was substituted into the following equation : N% = 0.014 x 0.1 x (ml titrant) / DM sample wt x 100. Since most proteins contain 16% N, CP is derived by the following equation : CP% = (N% x 6.25)

2.2.6 : Digestibility and Energy Equations

Nitrogen and ADF figures for each feedstuff analysed are required for in-vivo dry matter digestibility (DMD) and metabolisable energy (ME) to be calculated. ME is calculated from DMD following substitution in the following regression equation developed by Oddy et al (1983) from data derived from cattle and sheep digestion :

\[ DMD\% = [83.58 - (0.824 \times ADF\%) + (2.626x N\%)] \]

As described by Low et al (1983), ME is then derived from DMD% : ME = 0.15 x DMD%, with ME calculated as MJ/kg on a dry matter basis. As no equivalent model exists for deer, the existing ruminant equation was utilised. Discrepancies between theoretical DMD and in-vitro DMD possibly reflect the variation in digestive morphology between deer and cattle and sheep, through which the equation was derived.
2.2.7: In-vitro Dry Matter Digestibility

In-vitro dry matter digestibility (IVDMD) was undertaken as a secondary means of establishing the ME values of feeds trialed. Two stage in-vitro digestion was undertaken as described by Tilley & Terry (1963) and Clarke et al (1982) simulating both ruminal and abomasal digestion, enabling results to be compared with in-vivo DMD data.

Rumen fluid was obtained from freshly slaughtered animals by filtering digesta through several layers of muslin into a thermos flask and food grade CO₂ bubbled through the fluid. Feed substrate to be tested was matched to the diet of the animal slaughtered. Fluid samples from several animals of each diet were taken and composite samples made. Rumen fluid was maintained at 37°C in a water bath before digestion. 0.5g feed samples were measured in quadruplicate into 16 x 100ml centrifuge tubes. McDougalls artificial saliva was prepared by volumetrically adding 0.1 g calcium chloride, 0.16 g magnesium chloride, 0.94 g sodium chloride, 1.14g potassium chloride, 18.6 g di-sodium hydrogen phosphate and 19.6 g sodium hydrogen carbonate to 2.0 L of distilled water. 10 mls of rumen fluid was added to each labelled tube, along with 40 mls McDougalls artificial saliva. CO₂ was bubbled through the fluid mixture in each tube, before sealing with vented rubber stoppers and incubated at 37°C for 48 hours with constant agitation.

Stage 2 of digestion commenced with addition of 1 ml mercuric chloride and 2ml sodium carbonate, ending microbial activity. Tubes were centrifuged at 2000 rpm for 15 minutes. Acid pepsin solution was prepared using porcine stomach mucosa (1 : 10 000, Sigma Chemical Company, St. Louis, USA). 25 mls were added to tubes and incubated for 48 hours. Particulate matter remaining was filtered through sintered glass crucibles and dried at 105°C for 8 hours, weighed, and ashed at 550 °C for four hours. IVDMD was calculated as the difference between the mean residue minus mean inoculum residue (less ash weight) as a percentage of the original substrate sample.
Chapter 2

2.3 : Measurements and Analysis of Biological Samples

2.3.1 : 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°C. Care was taken to remove any splinters of bone from the resultant marrow sample. As illustrated in Plate 13, the solid consistency of the majority of the marrow samples facilitated removal from the bone.

Due to the high levels of fat in femur, samples of marrow were hydrolysed with 4M HCL to liberate protein-bound fat before being subjected to continuous ether extraction. Marrow samples were brought to room temperature and macerated. Homogenous samples of approximately 2 grams were boiled with 65 ml distilled water and 35 ml 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. 190 ml of petroleum spirit (Type II 40-60 °C AR) 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%.

2.3.2 : Kidney Fat Index (KFI)

Following the method described by Riney (1955), kidneys were excised from carcases 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 (Torbit 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. Plates 14 & 15 illustrate the extent of fat trimming before decapsulation. 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.

2.3.3 : 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° 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 along the sternum parallel to the longitudinal axis of the carcass. Plates 16 to 19 illustrate the incisions made to take these measurements.
2.3.4: Conceptus Measurements

Following evisceration, the pregnant uteri were sealed in labelled plastic bags and refrigerated for 24 hours. Total conceptus mass (TCM) was weighed on a digital scale to the nearest gram, and included the unbroken uterus severed at the cervix. Uteri were then carefully punctured and fluids allowed to drain. Placentomes were excised from the epithelium with a pair of scissors and weighed on a digital scale to the nearest 0.5 gram. The amniotic sac was then carefully punctured with a scalpel, and fluid allowed to drain.

Umbilical cords were severed at the amnio-somatic junction and foetuses weighed to the nearest 0.5 gram. Foetuses were also sexed and crown-rump length (CRL) measured with a plastic ruler. Plates 20 & 21 illustrate size relationships between the foetus and placentomes at the end of the first trimester of gestation.
Plate 13: Cracked femur from an adult fallow buck.

Plate 14: Kidneys removed from a BCS 3 fallow castrate.

Plate 15: Kidneys shown in Plate 14 following trimming and decapsulation as described by Riney (1955).
Plate 16: Incision made for measurement of fat over the rump

Plate 17: Incision made for measurement of fat over the loin

Plate 18: Incision made for measurement of fat over the brisket

Plate 19: Incision made for measurement of fat over the foreleg
Plate 20: Fallow foetus and uterus (drained) at the end of T3.

Plate 21: The same foetus as shown in Plate 20 (excised) showing the relationship in size between foetus and placentomes.
2.4: Blood Sampling and Analysis

2.4.1: Blood Sampling Techniques

Blood samples were collected from deer via jugular venepuncture whilst restrained in a drop-floor crush and blindfolded. Samples were taken using 18G, 1 inch needles (Becton Dickinson Vacutainer systems Pty Ltd, England) and lithium heparinised vacutainers (Bacto Lab Supplies, Sydney Australia) and centrifuged for 15 minutes at 3500 rpm to separate plasma. Plasma was transferred into labeled vials and stored at -20°C. Blood was also collected from some animals during exsanguination at slaughter, in which case blood was caught in a beaker and transferred to a vacutainer for further processing.

2.4.2: Cortisol Method Using DPC Iodinated Tracer

Samples were analysed in duplicate using a second antibody assay. The antiserum was raised in a New Zealand white rabbit against 4-pregnen-11B, 17, 21-triol-3, 20-dione 3-CMO:BSA. Cross reactivities were, 11-deoxycortisol 8.0%, cortisone 40.5%, 6B hydroxycortisone 2.6%, corticosterone 5.2%, 21-deoxycortisol 2.2% and progesterone <0.1%. The iodinated tracer was supplied by Diagnostic Products Corporation (Los Angeles, CA, USA). Standards were made in charcoal stripped deer (cervine) plasma.

Duplicate 5-1 samples or standards were incubated overnight with 100-1 buffer, 200-1 tracer and 100-1 antiserum used at an initial tube dilution of 1:5000. The tubes were incubated for 24 hours at 4°C. On day two, 100-1 of pre-precipitated sheep anti-rabbit second antibody was added and the tubes were incubated for 2 hours at 4°C. Before centrifuging at 1800g for 35 minutes, 1 ml of buffer containing 8% W/V polyethylene glycol 6000 was added. Dilutions of a high cortisol plasma in charcoal stripped plasma were parallel to the standard curve.
2.4.3 : Betahydroxybutyrate

Samples of plasma were analysed for betahydroxybutyrate (β-OHB) in an atomic absorption spectrometer at wavelengths of 405-340 nm with a detection limit of 0.07 mmol/l and an upper linearity limit of 8.00 mmol/l. Two reagents were prepared, the first containing Tris, EDTA and oxalic acid in water. The second reagent was prepared using NAD⁺, reagent 1 and 3-β-HDH. The increase in absorbance at 340 nm due to formation of NADH is a-proportional to β-OHB concentration. To suppress interference from LDH, oxalate (a competitive inhibitor of LDH) was added.

2.4.4 : Free Fatty Acids

Samples were analysed for free fatty acids in duplicate using a Wako NEFA C kit (Wako Pure Chemical Industries, Ltd, Osaka, Japan). Non-esterified fatty acids (NEFA) in serum when treated with acyl-CoA synthetase (ACS) in the presence of ATP magnesium cations and CoA, form the thiol esters of CoA known as acyl-CoA as well as the by products AMP and pyrophosphate.

The acyl-CoA is oxidised by added acyl-CoA oxidase to produce hydrogen peroxide which in the presence of added peroxidase allows the oxidative condensation of 3-methyl-N-ethyl-N(b-hydroxyethyl) aniline with 4-aminoantipyrine to form a purple coloured adduct with an absorption maximum at 550nm. Ascorbic acid causes significant interference, therefore ascorbate oxidase is added to the reaction mixture at the outset to completely remove all the ascorbic acid from the sample. Oleic acid is used as the standard.

2.4.5 : Plasma Ketones

Nitroprusside reagent was prepared using sodium nitroprusside, ammonium sulphate and sodium carbonate which was dried in a vacuum oven at 60°C. Nitroprusside reagent was placed in wells on a ceramic spotting plate. Serum was transferred by pipette onto the reagent. Purple colouration indicated a positive result for elevation of ketone bodies (acetone, acetoacetate and 3-HBA) in the blood.
2.5 Ultrasonography

Rectal ultrasonography was performed on does as a means of confirming pregnancy and in measuring placental and foetal development. Ultrasonography was performed with does blindfolded and restrained in a drop floor crush. Two ultrasound units were involved in these procedures. For diagnosing pregnancy only, a Microimager 2000 ultrasound unit (sector) and a 5 MHz transrectal probe was used (Ausonics Australia Pty Ltd), which was sufficient for viewing uterine fluid, placental and foetal mass.

For the experiments discussed in Chapter 6 concerning the growth of the foetus and placentomes, deer were scanned with a Honda HS-1201 linear scanner with 5 MHz probe (Honda Electronics Co. Ltd, Toyohashi Aichi, Japan). This unit provided superior picture clarity and enabled accurate measurements to be taken.

2.6: Statistical Analysis

Growth rate comparisons and physiological data collected in condition scoring experiments were analysed using the student’s t-test (Balaam 1972) and ANOVA. Results of foetal and placental development across varying planes of maternal nutrition and certain data across condition score indices were subject to repeated measures analyses of variance using the GLM procedure of SPSS (1999). Ryan’s Q-test was used to compare means where treatment differences were significant. Analyses of variance (ANOVA) was used for correlating periodicity and frequency of diurnal feeding patterns of individually housed does with stage of pregnancy and lactation. ANOVA was also used in determining differences between ME intake between ration type for concentrate-fed does.

Differences in daily energy intake for Experiments I & II between penned animals of both genotypes and pasture-fed animals of both genotypes were estimated using a residual maximum likelihood (REML) as implemented in Genstat 5 version 4.1 (1993).
Chapter Three

Metabolisable Energy Intake of Fallow Does of Two Genotypes throughout Pregnancy and Lactation

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3.1 : Literature Review : Nutritional Requirements of Fallow Does

3.1.1 : Available Knowledge on Maternal Nutrition

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 & Flesch (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 et 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 present study.

While there have been various 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 red deer data from the south island of New Zealand may not be representative of the temperature ranges experienced by the majority of fallow deer farms in Australia, promulgating domestic appraisal of doe energy requirements. 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
Chapter 3

It's 5 year strategic plan, RIRDC 1996, RIRDC 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 (RIRDC 1999) are generally thought to be nutritionally related. 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, Mulley 1989, English & Mulley 1992), with this trend also well demonstrated with other species such as red deer (Blaxter & Hamilton 1980), elk (Thorne et al 1976) and sheep (Gunn & Robinson 1963, Alexander 1964, Houston & Maddox 1974). Subsequent growth rates of surviving low birthweight neonates have also been demonstrated to be significantly slower with fallow deer (Mulley 1989, Pelabon 1997), red deer (Blaxter & Hamilton 1980) and sheep (Mellor & Murray 1982). The effect of body condition at calving and subsequent feeding levels has also been demonstrated to influence the interval to first post-partum oestrus in dairy cows (Robinson 1996). The onset of puberty may also be affected in offspring on a poor plane of nutrition during and after weaning, with males and females attaining puberty at older ages and lighter body-weights (Robinson 1996). Undernutrition from birth, weaning and beyond in seasonal breeders like deer, goats and sheep, may also delay puberty for a whole year (Asher 1986, Adam 1994).

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, and an increase of basic knowledge of seasonal nutritional requirements of breeding stock will assist fallow deer farmers to meet this objective. Fallow deer are ruminants, and principles of feeding through pregnancy and lactation are likely to be similar to other species of domestic ruminants. There have been numerous publications outlining the nutritional requirements of other domestic ruminant species (Anon 1975, Anon 1976, Anon 1978, Hutchings 1997, Robinson et al 1999), some of which have provided useful comparisons for deer farmers to
estimate feed requirements and carrying capacity of land for fallow deer (DSE’s : dry sheep equivalents).

Interpolations of fallow deer energy intake (Milligan 1984) from Fennessy et al 1981) suggest a figure of 0.85 MJME/kg^{0.75}/day for maintenance, thus a 45kg fallow doe would consume 15 MJME/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 55 kg 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 & Flesch 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.
3.1.2: 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 (Barry et al. 2000).

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. One publication made available to deer farmers (Mackay 1990) stated that deer are more efficient converters of pasture to meat than other livestock species, and suggested DSE’s of 1.0-1.5 for fallow deer. There is no evidence in the literature to support this suggestion, and considering the varying conditions under which sheep and cattle are farmed in Australia, calling fallow deer “efficient converters” and putting them on a nutritional par with sheep was perhaps more useful as a marketing strategy than to improve nutrition per se for this species, let alone maternal nutrition and subsequent effects on production. Comparisons with other domestic livestock species, especially sheep, may also be misleading in terms of the need to supplement nutrition according to different seasonal demands, with some farmers seeing supplementary feeding as synonymous with drought feeding.

Statements of this kind can easily be seen to have been misleading to deer farmers, particularly during the early stages of development in the Australian deer industry when investors rather than farmers were purchasing stock (Falepau 1999). Another problem that has been identified through discussions with many Australian deer farmers is a lack of understanding of basic terminology (Flesch, unpublished). 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 2\textsuperscript{nd} or even 3\textsuperscript{rd} 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 the majority of deer farmers develop their own systems of both pasture and animal assessment in identifying nutritional adequacy (past performance, weaning rates, inter-farm comparisons etc), statistics for both deer production and development of the Australian deer industry in terms of the farmed deer population suggest that current methods employed by Australian deer farmers as a whole are proving inadequate. 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, although notwithstanding, is clear that feeds and feeding in general are not conducive to the high levels of productivity required for continued investment and industry expansion.

3.1.3: Discussion

Despite the obvious need for dissemination of fallow deer feed requirements to Australian deer farmers, there is already a vast amount of information available, that either is not understood, unknown or under-utilised. While the lag in technology and information transfer with the deer industry has been lamented by other authors (Drew 1997, Falepau 1999) there are methods by which dissemination of information to farmers may be accelerated, such as field days held on deer farms, dissemination of information to existing extension and livestock officers within the Department of Agriculture or respective state organisations, and the proposed “Guide to Feeding” manual as discussed in Chapter 1.

The “Deer Master” scheme carried out by the New Zealand Deer Farmers Association (NZDFA) has been effective in comparing production parameters between deer farms (Campbell 1998) and has assisted farmers in diagnosing possible problems with their management and thus improving animal performance and financial returns. The “bench marking” process also facilitates additional farmer interaction, competitiveness, and is another means by which farmers can compare productivity and management processes. Although the geographic distribution of deer farms in Australia relative to the total number of farms (estimated at 1500 Australia-wide - RIRDC 1999) may be seen as a hindrance to such a bench marking scheme, the increasing number of deer farms and proposed goal of increasing the total population of farmed deer may induce a more pro-active approach from the DIAA in assisting it’s members to increase overall production and productivity.

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, Fennessey & 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 Experiment 1 (described later in this chapter), 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 (see chapter 5). 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.

In conjunction with such methods of estimating nutritional adequacy, the management program of a deer farming enterprise can be adjusted to assist with meeting feed demands. 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.

Providing inadequate nutrition to farmed deer is not an option, and it is imperative that this shortfall be addressed if Australia is to maintain it’s share of the world venison market. 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.
3.2 : Metabolisable Energy Intake of Pregnant and Lactating Fallow Deer Does of Two Genotypes

3.2.1 : Introduction

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.

3.2.2 : Materials and Methods

In April 1997, eighteen 3 year old European (E) fallow deer does with an average liveweight of 40 kg, and eighteen 3 year old hybrid (H) fallow deer does (3/4 European and 1/4 Mesopotamian fallow deer) with an average liveweight of 42.5 kg were obtained from a commercial deer farm at Bathurst. On the 14\textsuperscript{th} of April, each doe received a single intra-vaginal progesterone-releasing device (CIDR-\textsuperscript{G®}) containing 0.3g of progesterone for oestrus synchronisation. Fourteen days after insertion on the 28\textsuperscript{th} 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 \textit{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.
Chapter 3

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/kgDM 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 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/kgDM 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 in 2.2.6. In-vitro dry matter digestibility was also calculated as a secondary measure of digestibility of both concentrate feeds, as described in 2.2.7. 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 (Table 1). 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.

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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 in section 3.5). 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 in, 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 as described in Chapter 2.

**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.

**3.2.3 : 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 11.2 MJME 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 12), the previously determined ME averages of 14 and 10.3 MJ ME/kg DM for each ration were used in calculations of MEI over pregnancy to assist with both repeatability and inter-species comparisons.

![Figure 12: In-vivo and in-vitro DMD and ME comparisons for M and M+ rations](image)

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 13 presents pasture values from April 1997 when does conceive, through until March 1998 when fawns were weaned at approximately 12 weeks of age. The blue bars represent kikuyu, which is clearly of lower energy value and less palatable than the ryegrass / oats pasture, seen in red. The yellow 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.
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/kgDM for kikuyu and 12.7 MJME/kgDM for oats / ryegrass pastures.

3.2.3.1 Liveweight Changes

Weight increases and growth rates by trimester are shown in Table 2. 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 (T1), and regained between 21 and 29 g/hd/day over T2. Growth rates for T3 were calculated for a period of 56 days, as does were not weighed for the three weeks prior to the calculated fawning date. 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.
Table 2: 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.

<table>
<thead>
<tr>
<th>Trimester</th>
<th>Concentrate-Fed</th>
<th>Pasture-Fed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>E</td>
</tr>
<tr>
<td>Trimester 1</td>
<td>-2.0kg -26g/day</td>
<td>-3.3kg -43g/day</td>
</tr>
<tr>
<td>Trimester 2</td>
<td>1.8kg 23g/day</td>
<td>2.2kg 29g/day</td>
</tr>
<tr>
<td>Trimester 3</td>
<td>6.4kg 83g/day</td>
<td>6.9kg 90g/day</td>
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</table>

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 2, 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 14-17, all of which illustrate the rapid growth rates of both pasture and concentrate-fed does of both genotypes in T3.
Fig. 14: LWC of concentrate-fed H does 1997-98.

Fig. 15: LWC of concentrate-fed E does 1997-98.

Fig 16: LWC of pasture-fed H does 1997-98.

Fig. 17: LWC of pasture-fed E does 1997-98.

Energy Intake Requirements
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).

3.2.3.2 : Metabolisable Energy Intake

Figure 18 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 to 1800g/day 2 weeks into lactation. Feed offerings were usually increased in 100 gram increments with zero residue, although over this period, increases in VFI were rapid enough to increase feed offered to 200 grams/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. 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.

![Graph of ME intake of concentrate-fed E and H does throughout pregnancy and lactation; 1997-98.](image)

**Figure 18**: ME intake of concentrate-fed E and H does throughout pregnancy and lactation; 1997-98.

### 3.2.3.3: Metabolic Bodyweight Energy Intake

Energy intake for E does ranged from 0.47 to 0.69 MJME/kg$^{0.75}$ and 0.55 to 0.71 MJME/kg$^{0.75}$ for H does between weeks 14 and 31 of pregnancy. H does had a higher metabolic bodyweight energy intake over T2 (Figure 19), with intake levels between the two genotypes levelling throughout the remainder of pregnancy.

### 3.2.3.4: 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.

![Graph showing energy intake over weeks of pregnancy]

**Figure 19: Metabolic bodyweight energy intake of E and H does from weeks 12 to 31 of pregnancy; 1997-98**

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.

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 20). 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 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 4.9 (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 22 and 23 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 20: Mean LWC ($\pm$SEM) of fawns from concentrate-fed E does

Figure 21: Mean LWC ($\pm$SEM) of fawns from concentrate-fed H does

Figure 22: Fawn birthweight as a percentage of pasture-fed doe liveweight at conception, T2 and parturition

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

* Analysis by genotype of fawns from pasture-fed does was not possible, so an E and H average birthweight of 5.2kg was used in calculations of fawn : doe relationships.
3.2.3: 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 et al 1993, Hanlon et al 1994) and some other domesticated species, eg, goats (Carbonaro et al 1982) sheep (Parrott et al 1987) and pigs (Hansen et al 1982, Gonyou et al 1992).

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). Initial behavioural responses to isolation were similar to those reported for other domestic ruminants. Cockram et al (1994) reported disturbances in feeding patterns and excessive vocalisations with sheep, as did Price & Thos (1980) with goats kept in isolation. While initial levels of energy intake were low (0.2 - 0.3 MJME/kg\(^{0.75}\)), feed intake rose to maintenance levels for other ruminants of similar size (eg, sheep), around 0.45 MJME/kg\(^{0.75}\) 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).
Chapter 3

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.

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 18) 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 (1982a), 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 1978). 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 favourably 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 $W^{0.75}$ 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$^{0.75}$ 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 (Mulley 1989, Asher & Adam 1985), 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. Similarly, liveweight and plasma glucose of sheep has been reported to remain stable between days 30 and 80 of pregnancy (Ehrhardt & Bell 1995, Clarke et al 1998), the period of most rapid placental growth in sheep (Symonds & Clarke 1996).

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 18, 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 the T3 and lactation.
3.3: Metabolisable Energy Intake of Pregnant and Lactating Fallow Does of Two Genotypes

3.3.1: Introduction

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.

3.3.2: Materials and 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.
Chapter 3

Pen Feeding

Twelve does, 6 of each genotype, were housed individually in pens 12 m². 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/kgDM 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/kgDM 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.

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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 (as discussed in section 3.5). 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.
3.3.3: 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 24 presents pasture values from April 1997 when does conceived, through until March 1998 when fawns were weaned at approximately 12 weeks of age. The blue bars represent kikuyu, which is clearly of lower energy value and less palatable than the ryegrass / oats pasture, seen in red.

![Figure 24: Metabolisable energy values of pasture grazed by pregnant European and Hybrid does, 1998-99.](image)

The yellow 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/kgDM for kikuyu to 12.9 MJME/kgDM for oats / ryegrass pastures. While energy values are comparable to the 1997-98 breeding season, there were some minor variations in pasture growth.

3.3.3.1 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 4. 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. 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 4: Average liveweight change (kg) and average daily weight gain (g/hd/day) of concentrate and pasture-fed E and H does over each trimester of pregnancy, 1998-99.

<table>
<thead>
<tr>
<th></th>
<th>Concentrate-Fed</th>
<th>Pasture-Fed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H</td>
<td>E</td>
</tr>
<tr>
<td>Trimester 1</td>
<td>1.0kg 13g/day</td>
<td>0.9kg 12g/day</td>
</tr>
<tr>
<td>Trimester 2</td>
<td>3.7kg 48g/day</td>
<td>3.7kg 48g/day</td>
</tr>
<tr>
<td>Trimester 3</td>
<td>4.9kg 88g/day</td>
<td>5.5kg 98g/day</td>
</tr>
</tbody>
</table>
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 22 & 23 and 33 & 34 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 26-29 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 4, 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 25-28, 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.
Fig. 25: Liveweight change (±SEM) of concentrate-fed European does from week 10 to 31 of gestation

Fig. 26: Liveweight gain (±SEM) of concentrate-fed Hybrid does from week 10 to 31 of gestation

Fig. 27: Liveweight change (±SEM) of pasture-fed European does from week 10 to 31 of gestation

Fig. 28: Liveweight change (±SEM) of pasture-fed Hybrid does from week 10 to 31 of gestation
3.3.3.2: Metabolisable Energy Intake

Figure 29 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 25 MJME/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.

3.3.3.3: 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 30, (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 30: Metabolic bodyweight energy intake (MJME/kg^{0.75}/day) for H and E does from weeks 12 to 31 of pregnancy; 1998-99.

3.3.3.4: Fawn Birthweight

As described in Chapter 2, 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 31. 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 32). 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 December (10 days), although the majority of fawns were born in mid December. Two does not diagnosed pregnant (NDP) at day 50 via ultrasonography formed part of the pasture fed group, and from the spread of fawning dates, it was assumed that both of these does 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 31 and 32 illustrate, there were no significant differences in fawn weights between genotypes or feeding treatments. Figures 33 and 34 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.
Figure 31: Mean LWC (±SEM) of fawns from concentrate-fed E does, 1998-99.

Figure 32: Mean LWC (±SEM) of fawns from concentrate-fed H does, 1998-99.

* Fig. 33: Fawn birthweight as a percentage of pasture-fed doe liveweight at conception, T2 and parturition, 1998-99.

* Fig. 34: Fawn birthweight as a percentage of concentrate-fed doe liveweight at conception, T2 and parturition, 1998-99.

* Analysis by genotype of fawns from pasture-fed does was not possible, so an E and H average birthweight of 4.9 kg was used in calculations of doe : fawn relationships.
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 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.
3.3.4: 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 (RIRDC 1999) it is still difficult to explain how up to 15% of does 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 1982b and Albon et al 1986), fallow deer (Chapman & Chapman 1975) and white-tailed deer (Langenau & Lerg 1976) and many 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}), 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, 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 (1982a), lactating red deer hinds will graze for up to 2 hours longer per day than dry hinds, with similar observations on grazing behaviour made on lactating ewes (Arnold & Dudzinski 1967), indicating greater energy requirements over the period of lactation. 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, although the nervous disposition of some of the H animals should be considered when planning such prolonged and intensive experimentation.

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 Ofstedal (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 not significant (P>0.05), as seen in average fawn birthweights across both feeding treatments.
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The overall LWC and patterns of growth from conception to parturition differed from those of animals in the 1997-98 breeding season. As discussed in 3.3.3.1, a lower condition score and overall liveweight at joining is thought to be responsible for the different patterns of liveweight gain over early pregnancy and lactation. Comparisons of results with Experiment I 1997-98 breeding season data are discussed in section 3.4.
3.4: 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 (GENSTAT 5, 1993) 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 35 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 36 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 2 and 4. Using average birthweight, these growth relationships are particularly apparent, as illustrated in Figures 22 and 23 for 1997-98 and 33 and 34 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.
Figure 35: ME intake of concentrate-fed E and H does throughout pregnancy and lactation over 2 consecutive breeding seasons

Figure 36: Average ME intake of fallow does over two consecutive breeding seasons
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 5 and 6 summarise T2 and T3 data respectively over the two breeding seasons. Using a figure of 10.5 MJME/kg DM as an average figure (Table 5), 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).

Table 5: Average and total MEI, DMI, LWC and FCE of fallow deer of 2 genotypes over the second trimester of pregnancy.

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

Table 6: Average and total MEI, DMI, LWC and FCE of fallow deer of 2 genotypes over the third trimester of pregnancy.

<table>
<thead>
<tr>
<th>Year Geno.</th>
<th>Av. T3 ME (MJ)</th>
<th>Total MEI (MJ)</th>
<th>LWC (kg)</th>
<th>FCE (MJ/kg)</th>
<th>DMI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-98 E</td>
<td>13.2</td>
<td>1019</td>
<td>6.4</td>
<td>159</td>
<td>97</td>
</tr>
<tr>
<td>1997-98 H</td>
<td>12.2</td>
<td>940</td>
<td>6.9</td>
<td>136</td>
<td>90</td>
</tr>
<tr>
<td>1998-99 E</td>
<td>13.1</td>
<td>1102</td>
<td>4.9</td>
<td>225</td>
<td>105</td>
</tr>
<tr>
<td>1998-99 H</td>
<td>13.4</td>
<td>1117</td>
<td>5.5</td>
<td>203</td>
<td>106</td>
</tr>
<tr>
<td>Mean</td>
<td>13.0</td>
<td>1045</td>
<td>5.9</td>
<td>181</td>
<td>99</td>
</tr>
</tbody>
</table>
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 7). 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 8. This table clearly shows how feed demand in terms of DMI has doubled since T2.

Table 7: Average and total MEI and DMI of fallow deer of 2 genotypes over the first 6 weeks of lactation.

<table>
<thead>
<tr>
<th>Year and Genotype</th>
<th>Av. L6 ME (MJ)</th>
<th>Total L6 MEI (MJ)</th>
<th>DMI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-98 E</td>
<td>19.4</td>
<td>817</td>
<td>78</td>
</tr>
<tr>
<td>1997-98 H</td>
<td>19.4</td>
<td>822</td>
<td>78</td>
</tr>
<tr>
<td>1998-99 E</td>
<td>18.4</td>
<td>775</td>
<td>74</td>
</tr>
<tr>
<td>1998-99 H</td>
<td>19.5</td>
<td>818</td>
<td>78</td>
</tr>
<tr>
<td>Mean</td>
<td>19.2</td>
<td>808</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 8: Average and total MEI and DMI of fallow deer of 2 genotypes over the first 12 weeks of lactation.

<table>
<thead>
<tr>
<th>Year / Geno.</th>
<th>Av. L12 ME (MJ)</th>
<th>Total L12 MEI (MJ)</th>
<th>DMI (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997-98 E</td>
<td>20.7</td>
<td>1741</td>
<td>166</td>
</tr>
<tr>
<td>1997-98 H</td>
<td>19.6</td>
<td>1778</td>
<td>169</td>
</tr>
<tr>
<td>1998-99 E</td>
<td>20.5</td>
<td>1736</td>
<td>165</td>
</tr>
<tr>
<td>1998-99 H</td>
<td>20.8</td>
<td>1756</td>
<td>167</td>
</tr>
<tr>
<td>Mean</td>
<td>20.4</td>
<td>1753</td>
<td>167</td>
</tr>
</tbody>
</table>

Tables of trimester and lactation data provide a total energy intake of 3597 MJME over the 238-day period of data collection. Combining the two years of data has allowed the following means to be developed (Figure 37).
Figure 37: Metabolisable energy intake of fallow does over the second and third trimesters of pregnancy and first 12 weeks of lactation
3.5: Diurnal Feeding Behaviour of Pregnant Fallow Does.

3.5.1: Literature Review: Feeding Behaviour

Whilst the seasonal nutritional requirements of most species of intensively farmed deer have been well studied, there has been little quantitative data produced on the diurnal patterns of feed intake and changes thereof, during different periods of the production cycle. While the seasonal patterns in VFI of farmed red stags and fallow bucks 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), the diurnal patterns of feeding activity of farmed deer, particularly breeding stock, have not been as extensively studied.

Whilst the aforementioned studies were mainly concerned with the effects of photoperiod and VFI, the influence of photoperiod has also been reported to have effects on the feed intake cycle, and could be considered to operate at two levels, through its effect on the pattern of melatonin secretion providing a seasonal cue for increased or decreased levels of feed intake and through the direct stimulus of daylight to feeding behaviour (Sibbald 1994). Thus, while it 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 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 also 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 these 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) sheep (Dulphy et al 1980) and cattle (Cowan 1975).
Chapter 3

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 (1982a) 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 spend 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.

3.5.2: Relevance of Feeding Knowledge to Industry

Knowledge of diurnal patterns of feeding behaviour may be of importance in several productive 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. As discussed earlier in this Chapter, the concept of strategic feeding as prescribed by Sutcliffe et al (1996) may also 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.

3.5.3: Materials and Methods

The investigations into feeding behaviour of fallow deer consisted of 2 main components, being the monitoring of individually housed concentrate-fed pregnant does, and 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 in this Chapter. 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 RISC microprocessor (P1C16C84, MICROCHIP Industries, USA) coupled to an eight channel 12 bit analogue to digital converter (MAXIM 186, Maxim Integrated Products, Sunnyvale, California). This configuration provided 8 analogue input channels for temperature and ambient light measurement and utilised unused digital I/O 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. A temperature sensor (Analogue Devices, AD 590) 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) (Phillips ORP 12) 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 (Micron pulse count P.I.R,
Melcrom Products, England) 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, 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 (blue line) 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 selected 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, 1997 (T3) and from the 9th to 14th of February 1998 (during mid-lactation). Does were fitted with numbered collars for identification after previous attempts at long-distance individual animal identification from eartag numbers and coloured spray paint proved unsuccessful. 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 with the aid of binoculars (Pentax 20 X 50 PCF III, Asahi Optical, Japan), with ear-tag numbers and colours also used as secondary means of identification. The pastures grazed by these animals were described earlier in this Chapter.

Observations by other authors (Chapman & Chapman 1975, Reinken 1997) 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 before 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 and reacting to disturbances.
3.5.4 : 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.

3.5.4.1 : 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. As discussed earlier in this Chapter, temperature was also thought to be a limiting factor to feed intake in the pen situation, 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 38 and 39 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 38: Diurnal pattern of feeding activity of a pregnant doe during T3, displaying regular feeding intervals.

Figure 39: 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 38 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 39 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 credence 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 40, 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 40: Graph of movement in a pen after deer removal, indicating the presence of birds and rodents at the feed trough

As Figures 38 and 39 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 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 (Figure 41), 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 41: Diurnal pattern of feeding activity of a doe during early lactation, displaying regular feed visits](image)

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 42, 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 Chapter 4) also suggested that patterns of feed intake post-weaning follow that of adult does.

Figure 42: 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

3.5.4.2: 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 alleomimetic 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 43 to 45 represent grazing trends of does during T3 in the morning, at midday and evening respectively.

**T3 Morning Observations (5-8:30 am)**

Morning feeding observations commenced at 5:00am during T3, which depending on 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 43), 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, 82% of animals were actively involved in grazing behaviour, with 49% of animals grazing for the total observation period.
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 44), with the majority of deer ruminating. Whilst there appeared to be no hierarchical effects on grazing during the morning observations, the dominant does (possibly the larger H animals) 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 44, the standard error during this observation period was quite high, with no clear trends of grazing patterns or duration. Although not evident in Figure 44, there was light to moderate rain and lower temperatures on two of the observation days, and sustained periods of grazing around midday were observed on these days.

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 45). 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 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 46).
However, as the standard error 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 an average of 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 47) 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 48). 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.
Figure 43: Mean number of does observed grazing (±SEM) over the first 3 hours after sunrise during T3

Figure 44: Mean number of does observed grazing (±SEM) between 12 midday and 2pm during T3

Figure 45: Mean number of does observed grazing (±SEM) over the last 3 hours before sunset during T3

Figure 46: Mean number of does grazing (±SEM) over the 3 hours after sunrise during mid lactation

Figure 47: Mean number of does observed grazing (±SEM) between 12 and 2pm during mid lactation

Figure 48: Mean number of does observed grazing (±SEM) over 3 hours before sunset during mid lactation
3.5.5: 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, although there were no statistical differences in patterns of feed intake after stress events such as weighing or pen cleaning, despite lower levels of VFI 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 animals housed in pens or at pasture.

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 43-45) and mid-lactation (Figures 46-48) 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.

However, 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 feeding, displaying yet another facet of behavioural plasticity to production situations. Given this, it is conceivable that the minor differences in feeding behaviour between does in pens or at pasture were of little consequence to animal performance over the period of this study.
3.6 : Case Study : Commercial Farm Comparisons

3.6.1 : Introduction

In conjunction with the controlled feed intake studies carries out at the UWS - H deer unit, several measures of reproductive performance were recorded on a commercial deer farm in western NSW over two consecutive breeding seasons. This study aimed to compare the reproductive performance of does in Experiments I and II with animals in a commercial farming situation. A description of the commercial property and management procedures was given in section 2.1.8. Initial aims were to compare maternal nutrition with average fawn birthweights and growth rates to weaning, although certain management practices made estimations of nutritional intake difficult.

3.6.2 : Materials and Methods

Two mobs of deer were studied in parallel over the 1997-98 breeding season: one containing 680 E does (≥4 years of age) and the other 660 H does (1/4 Mesopotamian, also ≥4 years of age). Normal management practices were employed over the period of the study, and were not altered due to the observations on reproductive performance. Pasture samples were randomly collected on a monthly basis over the duration of pregnancy and lactation from paddocks grazed. Paddock rotation times varied, and with different paddock sizes, it became impossible to estimate pasture availability over the course of the observations. ME contents of pasture collected were determined as described in section 2.2.6.

The diet of pregnant does was also supplemented over winter with lucerne hay and barley, making estimations of ME intake difficult. As described in section 3.1.2, supplementary feeding was performed according to the ‘appearance’ of the deer, and not specifically to condition score or any ME requirement relating to the age, weight or stage of pregnancy of the does.

Fifteen male and 15 female fawns from each genotype were weighed and ear tagged at birth, and re-weighed at weaning, at approximately 12 weeks of age. This allowed comparisons with birth weights and growth to weaning of fawns born to
does in controlled feeding experiments at UWS - Hawkesbury, in an attempt to compare nutritional adequacy of pregnant stock on a commercial deer farm with experimental does under a controlled feeding situation.

3.6.3 : Nutritional Availability

As stated above, estimations of nutritional intake for deer on the commercial property were extremely difficult to make, and with the mixed pasture species, mixed vegetation and varying paddock size, were not attempted. However, as is illustrated in Figure 49, the available pasture had moderate ME levels, comparable with pasture quality seen at UWS-H.

![Figure 49: Monthly ME values of mixed pasture grazed by pregnant and lactating E and H does on case study farm](image)

While at times pasture ME was of similar levels to pasture grazed by experimental does at UWS - H, there appeared to be no seasonal trends in pasture quality, with ME values ranging from 7 to 11.1 MJME/kg DM. On several occasions, available pasture matter was of very low quality (7 MJME, equating to approximately 55% DMD), with almost 100% of the nutritional intake of the does supplied through whole barley and lucerne hay. Furthermore, pasture quantity was also limited, and consequently, ME figures seen in Figure 49 do not reflect the availability of nutritious feed to pregnant does in the current study. While the circumstances that led to the stocking rates on the property reflected a depression in venison prices and were unusual for the property, management practices on this property reflected the
perceived nutritional requirements of breeding stock during times of feed shortage. As discussed previously, experienced deer farmers often successfully manage their stock autonomously of prescribed ME requirements and condition score parameters.

3.6.4: Research / Commercial Comparisons

Relationships between fawn birthweight and growth to weaning were made between UWS-H and case study animals for the 1997-98 breeding season. Although ME intake could not be accurately estimated, fawn birthweight, approximate growth rates to weaning and average weaning weight weights for both fawn genotypes from the case study farm were measured and compared with average fawn performance from both individually housed and pasture-fed E and H does. The results showed that growth rates of fawns were not dissimilar between the research and commercial farms, despite the variances in stocking rates and resultant feeding strategies.

Average Fawn Birthweight

Unlike fawns from individually housed does who were weighed between 12 and 24 hours after birth, fawns weighed in paddocks at both UWS and case study farms were assumed to be under 48 hours old, although some of the weights indicate certain animals may have been in excess of 3 days old. In particular, 3 animals from the case study farm weighed between 6.6 and 6.9kg, although they could still be captured easily by hand. Consequently, liveweights from these three animals were omitted from data analysis. At least 18 of the fawns weighed on the case study farm were known to be within 12 hours old, as they were found with their mothers, still wet and unable to stand after birth. These animals were left undisturbed and weighed later that afternoon or the following morning.

Average fawn liveweights are presented in Table 9. Whilst male fawns on the case study farm were significantly heavier at birth than their female counterparts, there were no significant differences in birthweights between the two genotypes. Conversely, there was no significant sexual dimorphism with E or H fawns from pasture-fed UWS-H fawns. Sexual dimorphism in fawn birthweights is usually seen when maternal nutrition is optimal, (Mulley 1989, Asher 2000 pers.com.), and male fawns will generally be slightly heavier at birth than females. In this study, while there were several males with much higher birthweights than the remainder of the
fawns, there were also some lower weights, which affected the average birthweight for the pasture fed group; an occurrence thought to be attributed to the extremely wide range of pre-rut liveweights seen with both E and H does (see section 3.2).

Table 9: Mean birthweight (± SEM) of male and female fawns of 2 genotypes from UWS - Hawkesbury and case study farms during the 1997-98 breeding season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Male European Fawns</th>
<th>Female Euro. Fawns</th>
<th>Male Hybrid Fawns</th>
<th>Female Hybrid Fawns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathurst</td>
<td>5.3kg (±0.4)</td>
<td>4.9kg (±0.3)</td>
<td>5.3kg (±0.4)</td>
<td>4.9kg (±0.3)</td>
</tr>
<tr>
<td>UWS – H</td>
<td>5.1kg (±0.4)</td>
<td>4.9kg (±0.4)</td>
<td>5.2kg (±0.5)</td>
<td>5.0kg (±0.2)</td>
</tr>
</tbody>
</table>

Since fawns could not be matched with their mothers with the pasture-fed does during the 1997-98 breeding season, averages for fawn weight between genotypes was unattainable. However, as discussed earlier in this Chapter, average birthweight for males and females irrespective of genotype did not differ from fawns born in pens, and as shown above, were comparable to fawn birthweights from the case study farm.

Average Weaning Weights

Deer were weighed at approximately 12 weeks of age at both UWS- H and the case study farm at Bathurst. While fawns from individually housed does were weighed at exactly 12 weeks of age, fawns from pasture-fed does and case study does may be within ±5 days from 12 weeks of age due to the spread of fawning dates. As shown in Table 10, there was no significant difference between E and H fawn birthweights on the case study farm, and as expected, males grew at a faster rate than females.

Table 10: Mean weaning weights (± SEM) of male and female weaners of 2 genotypes from UWS - Hawkesbury and case study farms during the 1997-98 breeding season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Male European Weaners</th>
<th>Female Euro. Weaners</th>
<th>Male Hybrid Weaners</th>
<th>Female Hybrid Weaners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathurst</td>
<td>24.6kg (±1.2)</td>
<td>22.5kg (±2.2)</td>
<td>23.2kg (±2.1)</td>
<td>21.3kg (±1.2)</td>
</tr>
<tr>
<td>UWS – H</td>
<td>23.0kg (±1.6)</td>
<td>20.8kg (±1.4)</td>
<td>23.5kg (±0.6)</td>
<td>21.2kg (±0.8)</td>
</tr>
</tbody>
</table>
Chapter 3

On the case study farm, both male and female E fawns had higher average weaning weights than their H counterparts, which was an unexpected and inexplicable result. Other studies have found H animals to have a markedly faster rate of growth over E fawns to both weaning and slaughter weights (Hogg et al. 1993, Mulley et al. 1996, Mulley et al. 2000), and although there was similar access to pasture and supplements for lactating does and weaners on the case study farm, relative growth rates of E and H fawns did not conform to expectations in this study. Conversely, 12 week weights from UWS-Hawkesbury fawns conformed to expected patterns of growth, with H fawns growing faster than E fawns, and males growing faster than females, as shown in Table 11.

Table 11: Mean daily rates of liveweight gain of male and female fawns of 2 genotypes between birth and 12 weeks of age from UWS - Hawkesbury and case study farms from the 1997-98 breeding season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Male European Weaners</th>
<th>Female Euro. Weaners</th>
<th>Male Hybrid Weaners</th>
<th>Female Hybrid Weaners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathurst</td>
<td>229g/hd/day</td>
<td>210g/hd/day</td>
<td>213g/hd/day</td>
<td>195g/hd/day</td>
</tr>
<tr>
<td>UWS-H</td>
<td>213g/hd/day</td>
<td>189g/hd/day</td>
<td>218g/hd/day</td>
<td>193g/hd/day</td>
</tr>
</tbody>
</table>

3.6.5 : Discussion

Although the performance of the two breeding herds were difficult to compare with animals trialed in this study, there were similarities in weaning weights and herd weaning percentages despite the differences in genotypes between the two treatment groups. Whilst other studies have shown H animals to have considerably higher growth rates than E fawns (Asher 1993), resulting in a faster attainment of slaughter weight for male weaners and puberty/joining weight for female weaners, growth to weaning of the H animals was comparable with the E fawns on the case study farm. While nutrition may have played a role in this occurrence, there is insufficient evidence to directly relate growth rates from birth to weaning with inadequate feed during lactation.

Ultimately, comparisons between UWS-H and the case study farm provided contrasts in management procedures, and although reproductive performance between
the two herds could not be compared, fawn birthweights were reflective of nutritional adequacy throughout gestation. However, this observation also reiterates the importance of utilising secondary means of estimating nutritional adequacy such as condition scoring. Lower than expected growth rates of H fawns to weaning on the Case Study farm may have been detected via lower doe condition score during lactation, and the necessary adjustments made to available feed sources.
Chapter Four

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

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

As discussed in Chapter 3, the serendipity of pasture growth and availability in Australian farming situations is misaligned with the well-defined seasonal energy requirements of deer. Even more than lactating does, fawns are weaned in late autumn/early winter when pasture quality is usually declining rapidly. However, this is also a time when liveweight gain is of paramount importance in achieving target liveweights. Although weaner deer will undergo a period of compensatory spring growth (Asher 1993, Milne et al 1987, Mulley 1989), 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 1994a), the majority of Australian deer farmers wean fawns pre-rut (approximately 12 weeks of age) as normal management practice, although the daily energy requirements of fallow deer from 12 weeks of age is currently unknown. Although there has been considerable research on growth rates and energy intake of adult fallow deer to slaughter weight (Mulley et al 2000), there has been no precise information gathered on daily metabolisable energy intake of fallow deer weaners. Current figures 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.

4.1.1 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 well 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 (or between 0.9 and 1.1 kg of dry matter per day) over the corresponding seasons.

4.1.2 Growth From Weaning to Puberty

As outlined by Mulley (1989), growth of juvenile fallow deer from weaning to puberty is vital to the overall productivity of a deer farming enterprise. Annual trends of liveweight 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. In fallow deer, adult males are 40% heavier than adult females (Chapman & Chapman, 1975) and may range to 100% heavier (Mulley 2000). Male reproductive success has been shown to increase with increasing body size (Clutton-Brock et al 1988) and this may potentially explain the selection for faster growth rates of male fallow deer fawns.

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 1994, 1997), although Gauthier & Barrette (1984) reported no inter-sex differences in total suckling time with fallow and white-tailed 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 1982a), 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%, or 2kg 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 & Cullerton (1994) found that fallow weaners fed a high energy ration (12.6 MJME/kgDM) grew significantly faster than those maintained on a low energy ration (9.9 MJME/kgDM), 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.
4.2 : Experiment III : Individually Housed Fawns

4.2.1 : Introduction

This section describes an experiment to measure the metabolisable energy intake of weaner age fallow deer. 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 offered to the doe (at 6 weeks of age, as seen in Plate 22), and drink water from the trough (at 4 weeks of age); therefore no adjustments to the heights of the troughs were necessary to wean the fawns.

4.2.2 : Materials and 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 MJME/kgDM 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 involving pregnant does, as described in Chapter 6.

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 (Plate 23). 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 (Plate 24). 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 50: ME values of pasture grazed by Group 2 and Group 3 fawns from 12 to 26 weeks of age](image)

ME values for pasture ranged between 9.7 and 13.8 MJME/kgDM over the duration of the study, as indicated in Figure 50. Weeks 7 and 8 of the trial saw the introduction of fawns from Groups 2 and 3 to 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.
Plate 22: Still from video image of a penned fawn (with doe) consuming concentrate feed at 6 weeks of age.

Plate 23: Weaned fawns on emergent ryegrass pasture.

Plate 24: Unweaned fawns on ryegrass pasture.
4.2.3 : Results of Fawn Feed Intake Study

The mean weights of doe and buck fawn fawns at the beginning and end of the trial, and their rate of growth in grams per head per day are shown in Table 12. 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 (Cydecitin™).

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

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

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 12 indicates 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 1992), with fawns in the current study appearing to have grown at an acceptable rate.

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 51 to 54.

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.

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.
Chapter 4

Figure 52: Mean LWC of male and female fawns weaned onto pasture

Figure 53: Mean LWC of unweaned male and female fawns

Figure 54: Mean LWC of male and female fawns weaned onto concentrate

Figure 55: Mean LWC of male and female fawns from all treatment groups

Fawn Energy Intake and Growth Rates
Chapter 4

The stress of weaning had an effect on VFI with Group 1 fawns, as illustrated in Figure 56. 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.

![Graph showing average daily ME intake and (W^0.75) of individually-penned concentrate-fed fawns from 12 to 20 weeks of age.](image)

**Figure 55**: Average daily ME intake and (W^0.75) of individually-penned concentrate-fed fawns from 12 to 20 weeks of age

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 55.
4.3: 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 1992), although there were insufficient animals in this trial to statistically validate any differences between male and female ME intake. These data for average ME intake and $W^{0.75}$ with concentrate-fed weaners will assist farmers to feed budget for periods of feed shortage now that daily feed requirements have been determined. 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/kgDM. 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 2000). Data presented in Chapter three 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 required by 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 (Suttie et al 1996), also suggesting 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 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) 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.

As discussed in Chapter 3, 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 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. This has serious implications for management of both breeding stock and pastures, and should 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 at least 1.0 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.
Chapter Five

Bodyweight and Condition Parameters for Farmed Fallow Deer

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5.1: Literature Review: Methods and Uses of Body Condition Scores

5.1.1: Methods of Estimating Body Condition

Body condition scores (BCS) are a qualitative 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, Mitchell et al. 1976, 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 (Peart 1970, 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. 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, Chan-McLeod et al (1999) and Dauphine (1975) for free-ranging caribou. Greer (1968) has also reported relationships between body fat and condition in elk.


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 tahr, hares (Flux 1971), elk, white-tailed deer (Ransom 1965, Finger et al 1981, Johns et al 1984), pronghorn (Bear 1971), chamois

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), elk (Greer 1968), 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), 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 fitness. 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 & Coblenz (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, Millsapgh & Brundige 1996) 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, Nelsen et al 1985), although when combined with animal liveweight, may be strongly correlated to body condition (Houghton et al 1990). 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 sheep (Russel et al 1967, Bassett 1974, Annison et al 1984) and cattle (Bowden 1973, Coggins & Field 1978). Biochemical parameters are only reliable once benchmarks have been established for the species, and intra-species comparisons may not be indicative of energy levels (Bowden 1971). While glucose is a well recognised indicator of energy status, blood concentrations are easily elevated by factors associated with animal yarding and handling, blood sampling and recent feed intake (Coggins & Field 1978).

The extent to which an animal is catabolizing body fat may be measured by the concentration of free fatty acids (FFA) in plasma (Annison 1960). FFA levels in sheep fed below VFI have been shown to fluctuate markedly over a 24 hour period as a consequence of feeding (Russel et al 1967), with values ranging from 100-200μ-equivalent/l. after feeding when the ewe is laying down surplus nutrients as fat, to 500-600μ-equivalent/l in the latter parts of the 24 hour period when the ewe is mobilising
fat. FFA concentrations are most useful as an index of under-nutrition over a range of 500-1200 μ-equivalent/l, although FFA concentrations can rise as high as 2500 μ-equivalent/l in cases of prolonged under-nutrition (Annison 1960).

FFA are oxidised in the liver to produce ketone bodies (acetoacetic acid and β-hydroxybutyrate (β-OHB). Although acetoacetate only occurs in under-nourished animals and is consequently a more sensitive indicator of changes in energy status, it is less chemically stable than β-OHB (Russel 1978), limiting its application in estimating nutritional sufficiency and subsequent fat mobilisation. Ketone bodies are normally further catabolized to carbon dioxide and water, but accumulate in the blood in conditions of hypoglycaemia or reduced glucose utilization (Russel et al 1967). In adequately nourished animals, the concentration of ketone bodies are extremely low, and thus β-OHB is a less sensitive indicator of fat mobilisation in mildly under-nourished animals, and is more useful in cases of moderate to extreme under-nutrition where FFA concentrations are approaching a maximum (Russel et al 1967).

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, particularly of slaughter age in cattle (Jansen et al 1985, Faulkner et al 1990, Bullock et al 1991), sheep (Gilmour et al 1994, Stanford et al 1995) and also free ranging moose (Stephenson et al 1998). Emphasis is normally placed on eye-muscle area and associated fatty tissue, and may result in an accurate estimation of carcass fat and meat yield (Domecq et al 1995).

5.1.2: 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), caribou, 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 Chapter 3, 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 fallow deer 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.
5.2 : Development of a Condition Scoring System for Farmed Fallow Deer

5.2.1 : Introduction

From a review of the literature, it appears that neither visual nor palpation assessment of body condition has been undertaken with farmed or free-ranging fallow deer. This section outlines descriptions of live animal and carcass characteristics of farmed fallow deer of varying levels of body condition.

5.2.2 : Materials and Methods

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 thesis, 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 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.
5.2.3 : Description of Live Animal Grades

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:

5.2.3.1 : Grade 1 : Very Poor Condition (Emaciated)

Animals in this category 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 atrophy. 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 25 and 26 illustrate the degree of emaciation seen with animals in BCS 1.

5.2.3.2 : 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 27 and 28 illustrate animals in this BCS.
Plate 25: BCS 1 posterior view.
Plate 26: BCS 1 lateral view.

Plate 27: BCS 2 posterior view
Plate 28: BCS 2 lateral view
5.2.3.3: 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 29 and 30 illustrate animals in this BCS.

5.2.3.4: 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 31 and 32 illustrate animals in this BCS.

5.2.3.5: 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 33 and 34 illustrate animals in this BCS.
Plate 29: BCS 3 posterior view.

Plate 30: BCS 3 lateral view.

Plate 31: BCS 4 posterior view.

Plate 32: BCS 4 lateral view.
Plate 33: BCS 5 posterior view.  Plate 34: BCS 5 lateral view.
5.2.4: 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. 1990), 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 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 in Chapter 3, 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 Chapter 6, 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. As discussed in section 5.2.5, 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 (see 5.2.5).

Whilst deer farmers generally aim to minimise the yarding of stock, those times when deer must be brought into the yards should be maximised and a large 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 advisable to avoid diagnosing inadequate nutrition in hindsight. Studies with sheep have also 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 & Kilkenney 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).
5.2.5 : Description of Carcasses by BCS

Following slaughter, carcass characteristics of animals in each grade were compared and fat depth measured, as described in section 2.3.3. Carcass fat and musculature of deer in each BCS was assessed as follows:

5.2.5.1 : Grade 1 : Very Poor Condition (Emaciated)

A dorsal view of a grade 1 carcass (Plate 35) 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 36 & 37). Severe atrophy 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 38), also showing an absence of fat over the loin. This view also illustrates the degree of muscle atrophy of the loin.

5.2.5.2 : Grade 2 : Poor Condition (Lean)

The dorsal photograph of the BCS 2 carcass (Plate 39) 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 41) 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 42), with the atrophication seen in BCS 1 animals not evident. Brisket fat is also seen in BCS 2 animals (Plate 40), Similar to BCS 1 carcasses, there is a distinct v-shape between the hocks and the tail.
Plate 35: Dorsal View BCS 1 fallow carcass.

Plate 36: Caudal View BCS1 fallow carcass.

Plate 37: Lateral View BCS 1 fallow carcass.

Plate 38: Cross sectional view (severed at the 4th vertebra) of a BCS 1 fallow deer carcass.
Plate 39: Dorsal view
BCS 2 fallow carcass.

Plate 40: Caudal view
BCS 2 fallow carcass.

Plate 41: Lateral view of
BCS 2 fallow carcass.

Plate 42: Cross-sectional view (severed at the 4th lumbar vertebra) of a BCS 2 fallow deer carcass.
5.2.5.3: 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 43 & 44), 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 45 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 45 illustrates the extent of fat on the brisket, with coverage extending from the thorax to the end of the sternum. Plate 44 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 46) 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.

5.2.5.4: Grade 4: Good Condition

The dorsal view of a BCS 4 carcass illustrates fat coverage of the entire length of the carcass (Plate 47). 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 49). Fat coverage over the saddle is thicker than BCS 3 carcasses, as revealed in the cross sectional view (Plate 50), 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 of brisket fat extends from the thorax to the sternum (Plate 48), with fat also running under the carcass and up the inside of the hind legs.
Plate 43: Dorsal view BCS 3 fallow carcass.
Plate 44: Caudal view BCS 3 fallow carcass.
Plate 45: Lateral view of BCS 3 fallow carcass.

Plate 46: Cross-sectional view (severed at the 4th lumbar vertebra) of a BCS 3 fallow deer carcass.
Plate 47: Dorsal view of BCS 4 fallow carcass.
Plate 48: Caudal view of BCS 4 fallow carcass.
Plate 49: Lateral view of BCS 4 fallow carcass.

Plate 50: Cross-sectional view (severed at 4th lumbar vertebra) of a BCS 4 fallow deer carcass.
5.2.5.5: 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 51). 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 red deer (see Appendix 2). 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 53). Fat coverage over the saddle is thicker than BCS 4 carcasses, as revealed in the cross sectional view (Plate 54), 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 52) 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 51: Dorsal view BCS 5 fallow carcass.
Plate 52: Caudal view BCS 5 fallow carcass.
Plate 53: Lateral view of BCS 5 fallow carcass.

Plate 54: Cross-sectional view (severed at 4th lumbar vertebra) of a BCS 5 fallow deer carcass.
5.2.6: Discussion and Application

Comparing carcass characteristics of animals over BCS grades has illustrated both the degree of muscular atrophy (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.

<table>
<thead>
<tr>
<th>Location of Descriptor</th>
<th>Grade 1 (n=5)</th>
<th>Grade 2 (n=48)</th>
<th>Grade 3 (n=56)</th>
<th>Grade 4 (n=10)</th>
<th>Grade 5 (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rump</td>
<td>0.2 mm (±0.4)</td>
<td>2.3 mm (±0.9)</td>
<td>4.4 mm (±1.6)</td>
<td>7.2 mm (±1.3)</td>
<td>10.0 mm (±1.1)</td>
</tr>
<tr>
<td>Loin</td>
<td>0.2 mm (±0.4)</td>
<td>1.9 mm (±0.8)</td>
<td>2.9 mm (±0.7)</td>
<td>4.6 mm (±0.7)</td>
<td>7.0 mm (±0.6)</td>
</tr>
<tr>
<td>Brisket</td>
<td>0.6 mm (±0.5)</td>
<td>2.3 mm (±1.0)</td>
<td>4.2 mm (±1.1)</td>
<td>5.5 mm (±0.9)</td>
<td>12.4 mm (±1.9)</td>
</tr>
<tr>
<td>Foreleg</td>
<td>0 mm (±0.0)</td>
<td>0.6mm (±0.5)</td>
<td>1.1 mm (±0.7)</td>
<td>2.2 mm (±0.6)</td>
<td>3.0 mm (±0.6)</td>
</tr>
</tbody>
</table>

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 (r² = 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 35 to 55, 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 that 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. In that experiment 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 simpler than determining fat depth at the loin, rump or brisket as undertaken in this study (see section 2.3.3), minimising operator error and discrepancies between carcasses of varying proportions. However, BCS estimations from GR measurements have also been 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.
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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.
5.3 : Relationship Between Body Condition Score and Other Quantitative Methods of Estimating Body Condition

5.3.1 : 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 5.1 and 5.2 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 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.

5.3.2 : Materials and Methods

Materials and methods for determining BCS through other quantitative methods were described in section 2.3.3 in Chapter 2. Variations in method involving group size and sex are described accordingly. Deer were assigned a BCS based on live animal assessment as described earlier in this Chapter 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.
5.3.3 : Results

5.3.3.1 : 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 (BCS5), 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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>BMF range</th>
<th>BMF mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>n=3</td>
<td>63.3-65.1</td>
<td>65.5 (±0.2)</td>
</tr>
<tr>
<td>2</td>
<td>n=24</td>
<td>73.2-91.3</td>
<td>85.4 (±5.6)</td>
</tr>
<tr>
<td>3</td>
<td>n=52</td>
<td>83.6-95.7</td>
<td>91.3 (±2.1)</td>
</tr>
<tr>
<td>4</td>
<td>n=6</td>
<td>91.3-98.6</td>
<td>94.5 (±2.6)</td>
</tr>
</tbody>
</table>

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.

5.3.3.2 : 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 (r² = 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.

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

5.3.3.3: Betahydroxybutyrate

Blood samples were taken via jugular venepuncture from does of known BCS from September 1997 to September 1999. Does of BCS 2 and 3 formed the majority of the sample population (n=84 and n=67 respectively), with only 3 does sampled attaining BCS 4. β-OHB concentrations ranged from 0.15 to 0.52 across all deer sampled, with BCS 2 and 3 does averaging 0.30 mmol/l (SEM±0.08) and 0.24 mmol/l (SEM±0.05) respectively. While a student’s t-test showed there was no significant difference in β-OHB concentrations between BCS 3 and 4 deer (P=0.645), there were insufficient data for regression analysis. The data show that BCS 2 deer had significantly higher concentrations of circulating β-OHB than BCS 3 animals (P=0.05).

5.3.3.4: 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 and 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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>HSCW range</th>
<th>HSCW Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>n=34</td>
<td>21.5-39.0 kg</td>
<td>28.6 (±4.9)</td>
</tr>
<tr>
<td>3</td>
<td>n=27</td>
<td>23.5-39.0 kg</td>
<td>28.7 (±5.1)</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>HSCW range</th>
<th>HSCW Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>n=18</td>
<td>20.0-25.0 kg</td>
<td>22.8 (±1.5)</td>
</tr>
<tr>
<td>3</td>
<td>n=26</td>
<td>21.5-27.5 kg</td>
<td>25.1 (±1.7)</td>
</tr>
<tr>
<td>4</td>
<td>n=4</td>
<td>29.5-33.5 kg</td>
<td>31.3 (±1.8)</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>HSCW range</th>
<th>HSCW Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>n=3</td>
<td>20.0-21.5 kg</td>
<td>20.5 (±0.9)</td>
</tr>
<tr>
<td>2</td>
<td>n=18</td>
<td>21.0-25.0 kg</td>
<td>23.4 (±1.2)</td>
</tr>
<tr>
<td>3</td>
<td>n=13</td>
<td>25.0-30.0 kg</td>
<td>26.6 (±1.2)</td>
</tr>
<tr>
<td>4</td>
<td>n=5</td>
<td>31.0-37.5 kg</td>
<td>34.7 (±2.5)</td>
</tr>
</tbody>
</table>

BCS 1 castrates had a significantly lower HSCW than BCS 2 deer (P=0.005). 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.
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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 2.3.3. 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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>CG range</th>
<th>CG Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>n=29</td>
<td>70-95 cm</td>
<td>81.1 (±6.3)</td>
</tr>
<tr>
<td>3</td>
<td>n=18</td>
<td>70-90 cm</td>
<td>81.6 (±6.1)</td>
</tr>
<tr>
<td>4</td>
<td>n=4</td>
<td>85-95 cm</td>
<td>90.0 (±4.1)</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>BCS</th>
<th># deer</th>
<th>CG range</th>
<th>CG Av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>n=33</td>
<td>72-85 cm</td>
<td>78.2 (±3.2)</td>
</tr>
<tr>
<td>3</td>
<td>n=51</td>
<td>78-90 cm</td>
<td>82.7 (±3.6)</td>
</tr>
</tbody>
</table>

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).
5.3.4: 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 for 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 Chapter 3). 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 5.3.3.3, 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 fitness. 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 chapter. However, as discussed earlier in this chapter, 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 & Coblemtz 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 used 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 (Deppenschmidt 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
der 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.
5.4: 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 (see Appendix 1) 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 animals with morphological indices equivalent to BCS 2, have body fat levels 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.
Chapter Six

Effects of Varying Levels of Maternal Nutrition on Placental and Foetal Development

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6.1 : Literature Review : Pregnancy and Nutrition

6.1.1 : Energy Requirements for Pregnancy in Ruminants

The ME requirements at various stages of growth and development, and the physiological cost of pregnancy have been studied extensively for farmed ruminant species, and comprehensively reviewed elsewhere (Anon 1975, 1976, 1978, 1981; Robbins 1983, Annison et al 1984, Findlay 1984, Loudon 1985, Gluckman 1986, Hutchings 1997). So too have the nutritional factors effecting conceptus development and neonate viability over various stages of pregnancy and lactation, particularly with other domestic ruminants (see section 6.1.2).

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 MJME/kg$^{0.75}$/day at maintenance to 0.58 to 0.71 MJME/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 1994b), white-tailed deer (Silver et al 1969, Ulrrey 1970, Brown et al 1995) red deer (Kay 1979, Simpson et al 1978, Fennessey et al 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 Chapter 3) 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.

The production of offspring is clearly expensive when the energy costs of reproduction are added to the overall costs of normal maintenance metabolism, and in practice, the effects of sub-optimal maternal nutrition at various stages of gestation are well documented, particularly with farmed deer species. Inadequate feed availability over gestation may have detrimental effects on foetal and placental development (see section 6.1.2), as well as causing decreases in dam BCS. Underfeeding in late pregnancy can also retard udder development delaying lactogenesis and reduce the rate of secretion of colostrum in sheep (Mellor & Murray 1982, Mellor 1985). This has been known to reduce lamb survivability (Mellor 1983) through insufficient quantities of colostrum at parturition (Mellor & Murray 1982) and inhibited development of maternal instincts (Russel 1984). Inadequate maternal nutrition resulting in smaller than average or non-viable fawns has also been observed to effect post-partum maternal behaviour in white-tailed deer (Langenau & Lerg 1976) and roe deer (Liberg et al 1994), resulting in maternal rejection and neonate starvation. This so-called density-dependant mortality is hypothesised to be a mechanism of population control in response to feed shortage (Liberg et al 1994).

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 (Louden & Kay 1984), 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.

6.1.2: 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, Russel et al 1977, McCutcheon et al 1981, Mulley 1989). While there are multiple factors controlling foetal development, maternal nutrition is the major component effecting 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 1995). 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, McMahon et al 1997). 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 (McCord 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 at conception influences the ability of ewes to maintain placental development following nutritional deficiencies during mid gestation (Robinson et al 1995, Clarke et al 1997), and also results in lower than average lamb birthweights and reduced survivability (Russel et al 1977, 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, Wallace et al 1997 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 effect 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), with approximately 70 percent of lamb birthweight gained during the final six weeks of gestation (Russel 1984). This is primarily due to the fact that
during early pregnancy, the foetus has a relatively small nutritional requirement relative to the dam, and it is therefore generally assumed that differential maternal nutrition at this time is unlikely to influence foetal growth (Robinson et al 1999). However, through its impact on placental development, nutrition in early and mid gestation may have profound effects on foetal development, especially considering that with sheep and cattle, placental weight reaches its maximum at approximately 90 and 140 days gestation respectively (Robinson et al 1977, Cooper et al 1998) and may also determine foetal development in later gestation (Alexander 1964, Mellor & Murray 1982).

As reviewed by Robinson et al (1999) 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). With sheep, almost two thirds of the variation in birthweight is attributable to variations in placental weight (Mellor 1983). Experimentally, placental performance and affects on foetal development have been demonstrated via the process of carunclectomy which has been shown to produce low-birthweight lambs with low post-natal survivability (Harding et al 1985), although this procedure does not produce a consistent and predictable level of growth retardation of the foetus (Robinson et al 1979).

Clarke et al (1997) 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. Conversely, ewes with higher liveweights at conception showed no reduction in placental mass despite the same nutritional treatment, suggesting that dam liveweight, and by inference, body condition, may be important in offsetting the effects of differential nutrition during early and through mid-gestation. Paradoxically, in certain circumstances, reductions in maternal feed intake may actually accelerate placental development. Several studies have revealed that mild restrictions in maternal energy intake between days 30 to 90 of gestation enhance placental mass
in mature ewes in good body condition (Wallace et al 1997, 1999), whereas for young ewes in poorer condition, it has the opposite effect (Kelly 1992). As discussed by Robinson et al (1999) increases in placental weight associated with mild feed restrictions may not always result in an increase in its surface area for nutrient exchange. Similarly, the adverse effects of undernutrition on placental mass have been accompanied by foetal cotyledon hypoplasia but an enhanced haemoglobin content, thus the detrimental effects of retarded placental size may be ameliorated by enhanced blood flow (Clarke et al 1998).

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 (Symonds et al 1998). 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. Similarly, Oddy & Holst (1991) and Holst et al (1992) reported no significant differences in lamb birthweights from ewes on restricted energy intake diets during early gestation, suggesting that maternal energy intake during the last week prior to parturition was paramount in increasing lamb birthweight when growth had been restricted during early and mid gestation.

Similar experiments have been undertaken which have revealed compensatory mechanisms following periods of maternal energy restriction. Reduced energy intake during early gestation leading to a loss in maternal bodyweight has seen enhanced or possibly compensatory placental development during later pregnancy (Faichney & White 1987, McCrabb et al 1992, Robinson et al 1995), even though placental size is
considered to have peaked at approximately 90 days gestation (Alexander 1964, Robinson et al 1977). Heasman et al (1998) reported increases in total placenta weight and placentome numbers at term from ewes fed at half maintenance during days 28 to 77 of gestation, accompanied by a lower foetal to placental weight ratio than ewes fed to requirements throughout pregnancy.

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).

While energy restrictions in early gestation have been demonstrated to reduce conceptus development and neonate viability, maternal energy restrictions over late pregnancy also have profound effects on placental size and lamb birthweight. Pregnancy toxaemia, although usually associated with ewes with twins or triplets, can also occur with large single foetuses in cases of severe feed restriction during late gestation (Kronfeld 1972). Recently, West (1996) demonstrated compensatory placental development at term in ketotic twin-bearing ewes induced through moderate nutritional restrictions during late pregnancy. While ketosis resulted in a significant increase in placental mass, gestation length was reduced along with lamb birthweights and survivability, indicating that while mobilisation of maternal body tissue may buffer foetal growth over short periods of feed restriction during mid pregnancy, the high rate of foetal growth over late gestation limits nutrient partitioning.

As lamented by Heasman et al (1998), numerous experiments producing nutritionally mediated alterations in placental and foetal development during early gestation have been confounded by compensatory feed intake and or conceptus development in later pregnancy, with maternal and or foetal mechanisms existing to compensate for reduced nutrient supply, thus masking the direct results of inadequate maternal nutrition during specific periods of gestation. Sharing this view, Robinson et al (1999) pointed out that data produced from numerous experiments on maternal
energy intake and conceptus development over the last 20 years, albeit interesting, have not as yet led to modification of existing sheep feeding strategies, and yet the majority of reproductive wastage is still directly correlated with inadequate maternal nutrition prior to conception and or during gestation.

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.

6.1.3: Determination of Nutritional Sufficiency

Inadequate nutrition can reduce reproductive performance and increase the incidence of metabolic disorders in ruminants. As discussed in Chapter 5, changes in liveweight and BCS are obvious and useful indices of the adequacy of nutrition at various stages of growth, but in many cases the time taken for such changes to become manifest, particularly with animals with very high or low BCS's, is too great to allow remedial feeding. When excessive nutritional insufficiency has been detected by such assessments, unacceptable production penalties may have occurred. When breeding stock are concerned, fawns with low birthweights may be an example of such a penalty (Mulley 1989).

While liveweight can be a useful measure of body condition in the first and second trimesters of pregnancy within deer herds, variations in conception dates, doe age and genetic factors make liveweight an inconsistent gauge of nutritional adequacy over late gestation (Russel 1984, Mulley 1989). Condition scoring on the other hand, overcomes variations in frame size and weight that exist between individuals within a herd (Russel 1984, Audige et al 1998), and as discussed in Chapter 5, it may not be
necessary to assign every deer in the herd a BCS in order to ascertain nutritional sufficiency.

A limitation to the use of traditional measurements of nutritional adequacy, such as liveweight or condition score, is that they provide information in hindsight (Russel 1984). An immediate assessment of the adequacy of animal nutrition is allowed by the measurement of circulating concentrations of blood metabolites such as glucose, free fatty acids, beta-hydroxybutyrate and plasma ketones. Particularly with sheep, these metabolites have been found to be useful as indices of nutritional adequacy (Russel 1978, Coggins & Field 1978, Russel 1984, Annison et al 1984, Foot et al 1984) especially over late pregnancy (Mulley 1989). When levels of the chosen metabolite fall outside the accepted range for individual animals, remedial feeding strategies can be implemented. In practice, nutrition during late pregnancy is a matter of achieving a compromise in which the costs of feeding are balanced against the penalties incurred by excessive reductions in birth weight (Mulley 1989).

Biochemical measurements are only useful when reliable techniques and reference values have been established for each of the chosen metabolites, for the species under scrutiny. Mulley (1989) showed threshold levels of β-OHB in pregnant fallow deer to be considerably lower than that of sheep under nutritional stress. Of the three principal blood parameters shown to be useful indices of energy status, Russel (1978) considered that plasma ketone concentrations were the most useful because they were less affected by extraneous factors associated with handling and blood sampling than were concentrations of both glucose and free fatty acids. Acetoacetate and β-hydroxybutyrate (β-OHB) are the two principle ketone bodies that can be used as indices of energy status in ruminants, with acetoacetate being preferred because it only occurs in the undernourished animal. However, acetoacetate is chemically less stable than β-OHB (Russel 1978) and the careful handling of samples, which is required, may not always be possible under field conditions. In general, measurement of concentrations of β-OHB is a more practicable measurement and has been shown to be a useful index of the extent to which food intake fails to meet requirements in ruminants (Russel 1984, Foot et al 1984).
Chapter 6


6.2.1 : 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. The effects of sub-optimal maternal nutrition on immediate and future reproductive success have been well documented with a number of ruminant species (Robinson et al 1999), although effects of poor maternal nutrition on conceptus development with fallow deer are yet to be investigated. In fact, there is limited experimentally derived data on placental and foetal measurements over the period of gestation with farmed fallow deer, with the majority of measurements obtained from wild shot deer (Harrison & Hyett 1954, Armstrong et al 1969).

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 suggested that the majority of 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. 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.

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 Chapter 3, 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. This study aims 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.

6.2.2 : Materials and 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 (Figure 57). This group were fed a modified dairy ration (described previously) containing 14MJME/kg DM and 16% CP.
Figure 56: Fortnightly averages (±SEM) of MJME/kg$^{0.75}$/day for non-pregnant E and H fallow does

Weekly doe liveweight 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 30 cm wide. These reduced intake (RI) does were located in a bare $\frac{1}{4}$ Ha paddock, devoid of edible grass.

Table 21: 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).

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<tr>
<td>Weeks1-2</td>
<td>0.71</td>
<td>0.78</td>
<td>0.73</td>
<td>0.66</td>
<td>0.59</td>
<td>0.62</td>
<td>0.84</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>Weeks 3-4</td>
<td>0.71</td>
<td>0.77</td>
<td>0.68</td>
<td>0.60</td>
<td>0.59</td>
<td>0.63</td>
<td>0.83</td>
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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 10 cm sward height threshold. Concentrate feed was offered daily between 2 and 4 pm 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 0.3 g 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 1.5 kg of feed per day made for each buck in each RI paddock.

Five days after CIDR removal (Day 5), 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).
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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 -20°C. Blood plasma was analysed for free fatty acids (FFA), beta hydroxybutyrate (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 Chapter 5).

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. Crown-rump length (CRL) measured and weight and sex of each foetus recorded. The sexes of foetuses with CRLs of less than 35 mm were unable to be confidently determined. Plates 55, 56 and 57 illustrate differences in conceptus characteristics at Days 42, 140 and 217 respectively.
Plate 55: Fallow deer foetus and placentomes at the end of T1.

Figure 56: Fallow deer foetus and placentomes at the end of T2.

Plate 57: Fallow fawn 10 days prior to parturition.
6.2.3 : 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.

6.2.3.1 : 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 Chapter 3, 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>
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<tr>
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<th>Ad Libitum (AL)</th>
<th>Restricted Intake (RI)</th>
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<tr>
<td></td>
<td>E</td>
<td>H</td>
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<tr>
<td>Trimester 1</td>
<td>-0.9kg -12g/day</td>
<td>-0.5kg -7g/day</td>
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<tr>
<td></td>
<td>4.8kg 62g/day</td>
<td>3.5kg 45g/day</td>
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<tr>
<td>Trimester 2</td>
<td>6.5kg 103g/day</td>
<td>6.3kg 100g/day</td>
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<td>Trimester 3</td>
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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.

Mean liveweight changes within treatment and genotype groups from feeding treatment commencement to 2 weeks before calculated parturition are illustrated in Figures 57-60. 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.
Fig. 57: Mean LWC (±SEM) of AL E does from 6 weeks pre-conception to 2 weeks before parturition.

Fig. 58: Mean LWC (±SEM) of AL H does from 6 weeks pre-conception to 2 weeks before parturition.

Fig. 59: Mean LWC (±SEM) of RI E does from 6 weeks pre-conception to 2 weeks before parturition.

Fig. 60: Mean LWC (±SEM) of RI H does from 6 weeks pre-conception to 2 weeks before parturition.
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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 (Figures 57 & 58). 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 effect 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).

6.2.3.2 : Energy Intake of RI Does

As shown in Figure 56, 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 W0.75 calculations of energy intake for the RI treatment showed that RI does were in fact not restricted (Figure 61).
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 61, 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 Chapter 3) 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 13 MJME/kg DM (once average ME of residue feed was averaged), unlike the 15 MJME offered, as indicated in Figure 61 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 levels higher than maintenance over this period. Conceptus development at three points over gestation is described.
6.2.3.3: 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. Foetal and placental development were measured as described in section 2.3.4.

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. There was also no correlation between second oestrous cycle conceptions, feeding treatments or genotypes. Conceptus development for RI and AL does is shown in Figures 62-65.

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). As illustrated in Figure 63, 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 (Figure 64). 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 4.2 (SEM±0.94) placentomes with AL E and H does. Placental weights for RI E and H does
Fig. 62: Mean foetal weight (±SEM) from RI and AL does of 2 genotypes at 42 days gestation

Fig. 63: Mean CRL (±SEM) of foetuses from RI and AL does of 2 genotypes at 42 days gestation

Fig. 64: Mean placentome mass (±SEM) and number from RI and AL E and H does at 42 days gestation

Fig. 65: Mean total conceptus mass (TCM) (±SEM) of RI and AL does of two genotypes at 42 days gestation
averaged 2.9g (SEM±0.42) and 3.0g (SEM±0.42), while total placentome mass from AL E and H does averaged 2.7g (SEM±0.51) and 2.8 g (SEM±0.26) respectively.

6.2.3.4: 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 66-69), 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±45.44) and 936.3g (SEM±83.98) 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). As illustrated in Figure 67, 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 269.0 mm (SEM±17.1) when compared with E foetuses 257.0 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.
Fig. 66: Mean foetal weight (±SEM) from RI and AL E and H does of 2 genotypes at 140 days gestation

Fig. 67: Mean CRL (±SEM) of foetuses from RI and AL does of 2 genotypes at 140 days gestation

Fig. 68: Mean placental mass (±SEM) from RI and AL E and H does at 140 days gestation

Fig. 69: Mean TCM (±SEM) of RI and AL does of 2 genotypes at 140 days gestation
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.

6.2.3.5 : 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 70-73). 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). As illustrated in Figure 71, foetuses from RI E and H does had identical CRL averages, respectively of 466 mm (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.
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**Fig. 70**: Mean foetal weight (±SEM) from RI and AL E and H does at 31 weeks gestation

**Fig. 71**: Mean CRL mm (±SEM) of foetuses from RI and AL E and H does at 31 weeks gestation

**Fig. 72**: Mean placental mass (±SEM) from RI and AL E and H does at 31 weeks gestation

**Fig. 73**: Mean number of placenomes (±SEM) in RI and AL E and H does at 31 weeks gestation

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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.

6.2.3.6: Blood Metabolite Concentrations

Does from all treatments were sampled from conception to midway through T2, at which time the degree of energy deprivation, or lack of, became apparent. There were no significant differences in $\beta$-OHB or FFA concentrations between treatment groups. Ketone bodies were not detected in samples during this study, which may be attributed to a combination of technique insensitivity (see section 2.4.6) and low circulating concentrations of the metabolite, possibly due to insufficient nutritional stress. While there were no significant differences in $\beta$-OHB or FFA concentrations between treatment groups ($P=0.134$ and $P=0.460$ respectively), there were wide variations within and between groups, with concentrations of both metabolites shown to fluctuate markedly over short periods. $\beta$-OHB within AL does ranged from 0.14 to 0.34 mmol/l at conception, with an average of 0.25 (SEM±0.08). Similarly, $\beta$-OHB concentrations for RI does ranged from 0.16 to 0.33 mmol/l at conception with an average of 0.26 (SEM±0.05), with no differences existing between treatments after 6 weeks on their respective feeding treatments. As seen in Figures 74 and 75, $\beta$-OHB concentrations remained stable within both treatment groups, with no major increases seen until week 13, where AL and RI groups returned average concentrations of 0.34 mmol/l (SEM±0.09) and 0.30 mmol/l (SEM±0.05) respectively.

FFA concentrations were also varied both within and between feeding treatments. RI does had higher circulating concentrations of FFA at conception with an average of 935 $\mu$mol/l (SEM±355), although values ranged from 425 to 1605 $\mu$mol/l at that time. Whilst FFA ranges with AL does at conception were also high (265 to 935 $\mu$mol/l), fluctuations over T1 were less acute, as seen in Figures 76 and 77, and although FFA concentrations for RI does were significantly higher than AL does at conception ($P=0.04$) and week 13 ($P=0.02$), differences T1 were not found to be significant.
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**Fig. 74:** Mean weekly BHOB concentrations (±SEM) in AL does from conception to week 17

**Fig. 75:** Mean weekly BHOB concentrations (±SEM) in RI does from conception to week 17

**Fig. 76:** Mean weekly FFA concentrations (±SEM) in AL does from conception to week 13

**Fig. 77:** Mean weekly FFA concentrations (±SEM) in RI does from conception to week 13

**Fig. 78:** Mean weekly cortisol concentrations (±SEM) in AL does from conception to week 13

**Fig. 79:** Mean weekly cortisol concentrations (±SEM) in RI does from conception to week 13
Despite the lack of significance with β-OHB and FFA concentrations between AL and RI treatments, there was a highly significant difference in cortisol concentrations (P=0.00), suggesting that RI does were under a considerable amount of emotional stress compared with their AL counterparts. Average cortisol concentrations for RI does (112 ng/ml ±21) were elevated above that for AL does (93±20 ng/ml) at conception, although average cortisol levels in both treatments dropped over T1 at similar rates (Figures 78 & 79).

6.2.4: 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 Chapter 4, 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.

Conceptus development and maternal feed intake, as reviewed in section 6.1.2, are closely linked, although the interconnectedness of the two may not always be predictable and may be affected by a number of external factors. As demonstrated with sheep (Faichney & White 1987, Wallace et al 1997, Clarke et al 1998), reduced ME intake through early pregnancy is not always synonymous with low neonate viability, and is largely dependant on the degree and length of maternal energy shortfall, the extent of nutritional amelioration, and possibly of most importance, dam BCS at conception. Other studies with pregnant sheep have shown that reduced maternal intake throughout early gestation may affect conceptus development in T2 and T3 if ewes are not fed an increasing plane of nutrition (Clarke et al 1997), although paradoxically, ewes fed sub-optimal levels of feed may even show accelerated conceptus development in later gestation (Wallace et al 1999). The higher average number of placentomes at Day 42 with E and H RI does (P=0.008) may have been an example of such a compensatory mechanism, and although there were no significant differences in placental mass between treatment groups, RI does would theoretically be more capable of transforming increased ME intake in later gestation to foetal development. Given this, it would be difficult to make predictions on the longer term effects on maternal and conceptus development of RI does given the brief and mild nature of energy reduction and with the knowledge that correlations between foetal and placental size may not be linear.

However, 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 effect 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.

Variations in doe BCS, although observed during early stages of the study, could not be measured in relation to feed intake, and would have been of assistance in
firstly, quantifying the visual effects of feed restriction, and secondly in explaining erratic trends in blood metabolites. As visual and palpable descriptors for a BCS system for fallow deer had not been finalised at the time of treatment allocation (or by experiment completion), does were allocated feeding treatments based on genotype and randomised by liveweight, which is autonomous of BCS in many circumstances. As a result, inconsistent reproductive history in conjunction with large variations in liveweight and BCS masked any effect that a reduction in available maternal nutrition may have had on doe metabolic status. As already demonstrated with fallow deer (Weber & Thompson 1998), differential nutrition in early gestation is likely to be absorbed by the dam due to the minimal metabolic impost of the growing conceptus. However, threshold levels of blood metabolites as markers of nutritional stress in other species may not be applicable with fallow deer.

With data on conceptus development at Day 42 shown to be equivocal, treatment effects, if any, would be seen maternally in BCS and or blood metabolites. While β-OHB and FFA did not significantly differ between feeding treatments, trends over T1 did indicate a treatment effect, with AL does showing less volatile patterns of these metabolites than RI does. At conception after 6 weeks on their allocated feeding treatments, RI does had higher circulating concentrations of both FFA and β-OHB, with varying levels of BCS among does possibly increasing the variability to which RI does were able to absorb the nutritional restrictions imposed, thus simultaneously confounding treatment effects and creating large differences within the RI group (Figures 75 & 77). Even so, levels of circulating metabolites were within the lower ranges as seen with other livestock species, and were definitely not indicative of severe nutritional stress. FFA have been documented to range between 600-1500 µmol/l in well nourished dairy cattle (Coggins & Field 1978) and up to 2500 µmol/l in undernourished ewes (Reid & Hinks 1962, Russel et al 1967a), accommodating the range seen with both AL and RI does in the current study, although higher FFA concentrations, as with β-OHB, are generally seen in later gestation where foetal demands may promulgate further maternal fat mobilisation (Annison et al 1984).
\(\beta\)-OHB concentrations in pregnant and lactating ewes have been documented to vary between 0.5 and 1.6 mmol/l depending on the number of foetuses carried (Russell et al 1977, Foot et al 1984), and have been widely used with sheep in determining the extent to which feed availability fails to meet energy requirements. Using the examples of sheep as a guide, neither AL or RI does in the current study could be considered as undernourished, with average \(\beta\)-OHB concentrations for both treatment groups oscillating between 0.23 and 0.34 mmol/l over the trial period. Mulley (1989) reported much higher concentrations of \(\beta\)-OHB in pregnant fallow does in late gestation, although in that study, trends between ad libitum and restricted intake does were also equivocal.

Another possible confounding factor in the current study was the impact of a dominance hierarchy in group-fed does of various frame sizes, and liveweights (associated with both genotype and previous nutritional status) and offering a volume of feed insufficient to satisfy "hunger" for each and every doe. Although feed intake was calculated on a \(W^{0.75}\) basis for every doe in the RI treatment, the feed was pooled as does were group fed. Consequently, individual feed intake could not be controlled, and there was no way of knowing whether the 50kg doe who was allocated 1218g of feed at 0.68 MJ ME/kg\(^{0.75}\) would not consume some of the 1030g of feed allocated for her 40.0kg herd member in addition to her calculated feed allocation. Accordingly, there would have been does (quite possibly the majority of the larger-framed hybrid does) who would have been obtaining ad libitum feed intake requirements at the expense of other, quite probably smaller framed does. Hence, RI does, particularly smaller framed animals, would have endured more day to day stress than their AL counterparts, as indicated by the significant difference in cortisol concentrations over early-mid gestation between AL and RI treatment groups.

Although aggressive and dominance behaviours were not measured throughout the study, there most likely were hierarchical effects, as have been observed with other livestock species such as red deer (Appleby 1980) and pigs (Hansen et al 1982) in herd or group-fed situations. Although observations were not made, it is likely that dominant does displaced lower-ranked does from the feeding trough. Any aggressive
behaviours may have also been exacerbated by only feeding once daily. As discussed in Chapter 3, individually penned and pasture-fed does in Experiment I followed a mainly crepuscular pattern of feeding, but due to the RI ration offered at levels below appetite, the majority of feed intake took place in the evenings, with the feed troughs often emptied before nightfall. In the first 12 weeks of feeding, this interruption of normal feeding patterns appeared to increase aggression between does, and often resulted in larger animals obtaining ad libitum feed intake at the expense of smaller or less dominant does. Reinforcing this notion is data on conceptus development at all stages of gestation, with several RI does at each slaughter date having higher than average large foetuses and large placental masses.

Genetic and sex effects are also implicated in foetal development when optimal feeding occurs. In the current study, foetuses from H does were generally larger than those from E does in both feeding treatments, although this became more apparent on Day 217 (31 weeks gestation). While CRL has been extensively used in foetal aging with several farmed species (Marrable & Ashdown 1967, Mellor & Matheson 1979, Revol & Wilson 1991), large variations in CRL made at Days 42 and 140 between fawn sex and genotype in the current study suggest that CRL be used in conjunction with foetal weight if used as an indicator of comparative development. In fallow deer, buck fawns have higher birth weights than doe fawns in seasons of nutritional sufficiency but birthweights of bucks and does are similar in seasons of relative nutritional stress (Mulley 1989). While fawns were not sexed at Day 42, male foetuses were significantly heavier than female foetuses at Days 140 and 217 of gestation in AL and RI treatments, indicating dietary sufficiency.

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.

6.3.1: Introduction

In line with the aims of the previous experiment, 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.

6.3.2: Materials and 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 0.50 MJME/kg$^{0.75}$ 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 0.50 MJME/kg$^{0.75}$ 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.

**Blood Sampling**

Blood samples were obtained via jugular venepuncture at the time of CIDR removal (Day 0), treatment commencement (Day 17) and fortnightly thereafter until slaughter. Blood plasma samples were analysed for free fatty acid (FFA), plasma ketone (PK) and betahydroxybutyrate (β-OHB) concentrations as indicators of fat catabolism and energy status. Cortisol concentrations were also determined to relate reduced energy intake and or tissue catabolism with stress. Blood samples were centrifuged, the plasma harvested, and stored at -20°C.

All does were weighed and scored for body condition weekly (as described in Chapter 5), 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 Experiment III.
6.3.3 : 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).

6.3.3.1 : 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 0.50 MJME/kg^{0.75} 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 80).

![Figure 80: Average ME intake of individually penned AL and RI does from Day 16 to 87 of gestation](image)

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

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.

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6.3.3.2: 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 effecting liveweight SEM between and within treatment groups (Figures 81-86). 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 (see 6.3.4: Discussion).

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.

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.
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Fig. 81: Mean weekly LWC (±SEM) of PAL does from conception to week 12 of gestation

Fig. 82: Mean weekly LWC (±SEM) of PRI does from conception to week 12 of gestation.

Fig. 83: Mean weekly LWC (±SEM) of GAL does from conception to week 12 of gestation

Fig. 84: Mean weekly LWC (±SEM) of GRI does from conception to week 12 of gestation

Fig. 85: Mean weekly LWC (±SEM) of does in PAL and GAL treatments from conception to week 12 of gestation

Fig. 86: Mean weekly LWC (±SEM) of does in PRI and GRI treatments from conception to week 12 of gestation

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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).

6.3.3.3 : 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 87-92), 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
**Fig. 87**: Mean weekly BCS (±SEM) of penned AL does from conception to week 12 of gestation.

**Fig. 88**: Mean weekly BCS (±SEM) of penned RI does from conception to week 12 of gestation.

**Fig. 89**: Mean weekly BCS (±SEM) of group-fed AL does from conception to week 12 of gestation.

**Fig. 90**: Mean weekly BCS (±SEM) of group-fed RI does from conception to week 12 of gestation.

**Fig. 91**: Mean weekly BCS (±SEM) for penned and group-fed AL does from conception to week 12 of gestation.

**Fig. 92**: Mean weekly BCS (±SEM) of penned and group-fed RI does from conception to week 12 of gestation.
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.

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.

6.3.3.4: Blood Metabolite Concentrations

As in Experiment III, plasma ketones were not detected in samples from either feeding treatment, although 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 (Figures 93-98). Particularly at week 12, average β-OHB concentrations were higher 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/l at week 4), although does were not fasted before slaughter.

Concentrations of cortisol (Figures 99-104) were not reflective of other circulating blood metabolite concentrations, and were within the lower ranges seen in this species under experimental situations (Falepau 1999). There were some peaks in
Fig. 93: Mean weekly BHOB concentrations (±SEM) in PAL does from conception to week 12

Fig. 94: Mean weekly BHOB concentrations (±SEM) in PRI does from conception to week 12

Fig. 95: Mean weekly BHOB concentrations (±SEM) in GAL does from conception to week 12

Fig. 96: Mean weekly BHOB concentrations (±SEM) in GRI does from conception to week 12

Fig. 97: Mean weekly BHOB concentrations (±SEM) in pen and group-fed AL treatments

Fig. 98: Mean weekly BHOB concentrations (±SEM) in pen and group-fed RI treatments
Fig. 99: Mean weekly cortisol concentrations (±SEM) in PAL does from conception to week 12

Fig. 100: Mean weekly cortisol concentrations (±SEM) in GAL does from conception to week 12

Fig. 101: Mean weekly cortisol concentrations (±SEM) in pen and group-fed AL treatments

Fig. 102: Mean weekly cortisol concentrations (±SEM) in PRI does from conception to week 12

Fig. 103: Mean weekly cortisol concentrations (±SEM) in GRI does from conception to week 12

Fig. 104: Mean weekly cortisol concentrations (±SEM) in pen and group-fed RI treatments
cortisol concentrations around weeks 7 to 9 with several of the treatment groups, which may have been attributable to ultrasound scanning undertaken over this period. While differences in cortisol concentrations between feeding treatments were not significant, trends in RI does suggest that the lower level of available nutrition was increasing levels of stress, particularly towards the end of the treatment period.

6.3.3.5: 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). Plates 58 and 59 illustrate images obtainable at these times over gestation.

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

* Measurements from one animal or insufficient data for analysis.
- No measurements recorded for animals in treatment.
Plate 58: Ultrasound image of a fallow deer foetus showing head length measurement at 65 days gestation.

Plate 59: Ultrasound image of fallow deer placentome at 65 days gestation.
Table 25: Foetal and placental measurements made at Day 65 through ultrasonography on AL and RI does.

<table>
<thead>
<tr>
<th>Feeding Treatment</th>
<th>No. of Does scanned</th>
<th>Placentome Width (mm)</th>
<th>Crown Rump Length (mm)</th>
<th>Foetal Chest Depth (mm)</th>
<th>Foetal Head Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAL</td>
<td>n=4</td>
<td>27.3 (±2)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GAL</td>
<td>n=5</td>
<td>29.2 (±1)</td>
<td>116*</td>
<td>-</td>
<td>30.0*</td>
</tr>
<tr>
<td>PRI</td>
<td>n=4</td>
<td>26.5 (±3)</td>
<td>121*</td>
<td>-</td>
<td>27.5 (±5)</td>
</tr>
<tr>
<td>GRI</td>
<td>n=5</td>
<td>29.7 (±3)</td>
<td>-</td>
<td>-</td>
<td>27.1 (±4)</td>
</tr>
</tbody>
</table>

* 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 indicated rapid growth during early gestation.

6.3.3.6: 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 105-110). 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.
Fig. 105: Mean foetal weight (±SEM) from does in all feeding treatments

Fig. 106: Mean placental mass (±SEM) from does in all feeding treatments

Fig. 107: Mean CRL (±SEM) of foetuses from does of all feeding treatments

Fig. 108: Mean size of placentomes (±SEM) in does on all feeding treatments

Fig. 109: Mean total conceptus mass (±SEM) from does in all feeding treatments

Fig. 110: Mean number of placentomes (±SEM) from does in all feeding treatments
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.

6.3.4: 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 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.

Effects of Nutrition on Placentation and Foetal Development
The use of measurements of blood metabolites have been well demonstrated in assessment of nutritional adequacy in sheep (Russel et al 1977, Foot et al 1984), and have been used instead of, or in conjunction with, liveweight or BCS parameters in experimentally maintaining sheep in various states of energy balance (Mellor & Murray 1982, 1985). The ability to be able to experimentally maintain a degree of nutritional deprivation in the present study was to a degree demonstrated with does in RI treatments. With energy intake remaining close to 0.5 MJME/kg$^{0.75}$/day, $\beta$-OHB concentrations remained much more stable than with AL does, where intakes varied greatly depending on appetite and other external factors. In numerous experiments with sheep, it has been clearly demonstrated that under-nutrition, particularly during gestation, increased circulating concentrations of ketone bodies, with the degree of under nourishment normally correlated with ketone body concentrations (Bassett 1974, Coggins & Field 1978, West 1996, Clarke et al 1997). While the trend towards increasing levels of circulating levels of $\beta$-OHB in RI does in the current study was clearly seen from weeks 5 to 9 of gestation, the range of $\beta$-OHB concentrations were still not at the levels associated with nutritional stress seen in other species. Furthermore, trends in $\beta$-OHB were not reflective of the loss of weight and BCS seen in RI does by week 9 of the feeding treatment. Russell (1977) established that a nutritional state characterised by concentrations of $\beta$-OHB of 1.1 mmol/l would constitute an acceptable compromise between uneconomically high-energy output and an excessive reduction in lamb birthweight for Scottish Greyface ewes, with levels less than 0.7 mmol/l indicating adequate nourishment. With average levels of $\beta$-OHB seen in ad libitum fed fallow does in the current study ranging between 0.21 and 0.33 mmol/l over early-mid pregnancy, it appears the threshold level of this metabolite as a marker of nutritional stress is considerably lower in fallow deer than in sheep.

In accord, Mulley (1989) demonstrated that creating nutritionally imposed $\beta$-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, $\beta$-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. Clarke et al (1997) have reported nutritionally-deprived ewes with higher FFA and $\beta$-OHB concentrations at term than ad libitum fed sheep, explaining that a reduced BCS due to prolonged fat mobilisation during mid-gestation may protect against ketosis in late gestation. In addition, Symonds & Lomax (1990) have shown $\beta$-OHB and plasma glucose to be negatively correlated with underfed sheep in late gestation, with variances in circulating metabolite concentrations attributable to nutritionally mediated changes in maternal fat metabolism. Hence, it appears that the lower body fat composition of fallow deer in general may account in part for the lower average $\beta$-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 $\beta$-OHB concentrations. Given this phenomenon, $\beta$-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 more sensitive indicator in line with increased maternal/natal energy demand.

As seen with Experiment III, RI does showed significantly higher cortisol concentrations than AL does, suggesting that the feeding treatment was increasing levels of stress, particularly towards the end of the treatment period. Anecdotal evidence, such as difficulties in yarding and the incidence of jumping in the handling shed suggest that lower levels of available nutrition were affecting the behaviour of does in RI treatments. Although not measured, the incidence of biting and other aggressive behaviours was also apparent with GRI does. As discussed in Experiment III, the occurrence of deer of a wide range of weights being trough-fed a reduced ration, led to rapid development of a hierarchy, which may have affected feed distribution. Even though for the number of deer in the GRI treatment there was much more trough space per animal (approximately 2m per doe) than in the previous experiment, there were still several does who, through size and aggression, may have consumed feed at the expense of other does in the group. Variations in BCS over time were also apparent with GRI animals, with 3 does maintaining their conception BCS
after 12 weeks of reduced energy intake, in line with does in PAL and GAL experiments. It appears that these does achieved this at the expense of the other does in the GRI group.

   However, in line with the hypothesis of this experiment, it has yet to be demonstrated that undernutrition 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 Chapter 3, 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. As lamented by many authors (Lincoln 1985, Mulley 1989, Asher 1993), this abundance of pasture in Spring (late gestation) is misaligned with the greatly increased ME requirements seen during lactation, and has been responsible for numerous studies attempting to advance the onset of oestrous and consequently bring forward fawning to maximise usage of spring feed when energy requirements of the dam are at their highest (Asher 1988, Asher et al 1993).

   Consequently, it would appear that obtaining *ad libitum* energy intake over late gestation would be a matter of 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 permutations 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. Krausgrill et al (1999) showed that ewes deprived for 70 days post conception to lose between 25 and 30% of joining liveweight then fed ad libitum to parturition, showed no significant differences between lamb birthweight from ewes fed ad libitum for the duration of pregnancy. Furthermore, meat from lambs from the ewes deprived through T1 was more tender than from lambs that came from ad libitum-fed ewes during gestation. Given that RI does only lost at maximum 5% of conception liveweight, which as explained, is a common occurrence over autumn autonomous of pregnancy, it would be unlikely that following seasonal patterns of pasture availability through to parturition, conceptus development would be in any way impeded.

However, the discussion so far has assumed ad libitum nutrition over the remainder of gestation, and although patterns of pasture growth would generally accommodate this, other factors such as pasture management and stocking rates may prohibit does from obtaining optimum nutrition over late gestation. Herein lies another possible cause of low birthweight with fallow fawns. Measurements made of foetal growth rates in ewes, given a variety of nutritional treatments over late gestation, indicate a far greater foetal sensitivity to maternal undernutrition than previously suspected (Mellor 1983). 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 effect 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). As reviewed by
Robinson (1996), there has long been uncertainty with animal production as to the importance of maternal nutrition in early or late gestation in relation to placental/foetal interactions and neonate survival.

However, despite the possible origins of depressed conceptus growth, low birthweight and reduced neonate viability, they are avoidable, and the causes appear to lie at the level of farm management. With guidelines for energy requirements of pregnant fallow does at all stages of gestation now established, inadequate maternal nutrition to the point of foetal growth retardation should not occur. Feeding levels described in Chapter 3, in conjunction with BCS descriptors in Chapter 5, should be used in conjunction with one another to reduce the current levels of reproductive wastage seen on Australian fallow deer farms at present.
Chapter Seven

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 ½ bred hybrids. Further expansion of the Australian deer industry will be dependent on the production of uniform carcasses of high quality, necessitating 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 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 (Chapter 3), 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 (Sutte et al 1996) 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 reproductive performance of their stock.
Chapter 7

Data in Chapter 3 also 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 may impact significantly on both the feed availability for lactation in the months leading up to weaning, and on levels of available winter feed (Figure 111). As shown in Chapter 4, this level of joint feed demand by lactating does and their fawns continues at this level, with weaned fawns from 16 weeks of age consuming a similar level of dry matter as non-pregnant or early pregnant (T1 and T2) 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 are more consistent for processing, and secondly, provide farmers with a greater awareness of the condition of their slaughter stock in conjunction with growth rates and targeted slaughter weight. 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 also have application with breeding. While for slaughter age animals, liveweight plus BCS will be combined to predict animal condition, breeding does may have markedly fluctuating seasonal levels of body fat, with age, genotype and reproductive status precluding liveweight as a reliable indicator of body condition. In conjunction with feeding guidelines for all classes of fallow deer, body condition should also be used as an indicator of feed sufficiency as recommended by Audige et al. (1998). 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.

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LACTATION
20.4
MJME/Hd/day

ENERGY INTAKE

T3
13.0
MJME/Hd/day

T2
10.3
MJME/Hd/day

BREEDING

TRIMESTER 1

TRIMESTER 2

TRIMESTER 3

DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER

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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 mobilising body fat reserves to dangerously low levels. Flow on effects of increased reproductive performance through setting minimum BCS thresholds could 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 routine part of farm management, which in conjunction with regulation of energy intake requirements, should increase the productivity, efficiency and profitability of many Australian deer farms.

As alluded to in Chapter 6, the low levels of reproductive performance on Australian fallow 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. Farmers should note that if does successfully rear fawns despite nutritional shortfall, the future reproductive performance of does, and possibly fawns may be jeopardised.

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 consistent body 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 other breeding strategies such as hybridisation. Other controlled feed intake studies that compared ¼ Mesopotamian (H) with European (E) 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 favourably by farmers because of their greater efficiency of feed utilisation and ease of fawning. The data from this study confirms that hybridisation can improve productivity on fallow deer farms.

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 also shown that temperatures above 35°C during a recognised period of feeding activity (sunrise and sunset) limited 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 spent by each doe at the feed trough (P=0.033). Does also spent greater time feeding at other times of the day when temperatures were below 15°C. In line with energy intake requirements of fallow deer, such data may be useful for farmers in optimizing growth rates of slaughter stock, or in strategic feeding of breeding does. The offer of daily feed supplements during periods of pasture shortfall may be more effective if this coincides with the time 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 hybridization and other management strategies. The information from this study and the work of Mulley et al (2000) 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 increase the performance of their stock and to set the benchmark for quality assurance of fallow deer venison on national and international markets.
Appendices

Appendix 1: Australian Body Condition Scoring Chart for Fallow Deer. Prepared by Jason Flesch, Dr Chris Tuckwell and Associate Professor Robert Mulley.

Appendix 2: Australian Body Condition Scoring Chart for Red Deer. Prepared by Dr Andrew Hansen and Bruce Mackay.

Appendix 3: Body Condition Score Chart for Red Deer. Prepared by Dr Laurent Audige, Professor Peter Wilson and Roger Morris. Department of Veterinary Clinical Sciences, Massey University, New Zealand.
Appendix 1

Australian Body Condition Scoring Chart for Fallow Deer

Score 1: Emaciated
- ribs and spine are prominent
- fat (if present) is minimal

Score 2: Lean
- minimal fat
- ribs, spine, and neck are prominent
- fat is thin and sparse

Score 3: Prime
- ideal fat cover
- ribs, spine, and neck are not readily distinguishable
- fat is soft and ample

Score 4: Fat
- fat (some trimming necessary)
- ribs and spine are covered
- fat is soft and ample

Score 5: Over Fat
- excessive fat (trimming required)
- ribs and spine are covered
- fat is soft and ample

Live Animal Assessment Sites:
- neck
- belly

Carcass Measurement:
1. Measure from the spine behind the head through the rump.
2. Record the measurement and subtract the sum from the live animal's weight.
3. Count the ribs in the collapsed state, from the rump.
4. Measure the belly, if applicable.
5. Measure the fat depth.
Appendix 2

[Diagram showing Australian Body Condition Scoring Chart for Red Deer]

**Score 1: Emaciated**
- No fat cover
- Ribs, ribs, and spine prominent
- Lumbar rounded
- Tail thinner than usual

**Score 2: Lean**
- Some fat cover
- Ribs, ribs, and spine prominent but
  lumbar rounded
- Tail thinner than usual

**Score 3: Prime**
- Ideal fat cover
- Ribs, ribs, and spine not prominent
  lumbar rounded
- Rump wider than usual

**Score 4: Fat**
- Rump and spine prominent
  lumbar rounded
- Rump and rump prominent
- Sore covered by fat

**Score 5: Over-Fat**
- Over fat excessive
  trimming required

*Carcass Measurement*
- The spine is located at the Australian Bureau of Agricultural
  and Resource Economics.
- It is the point of reference from which all distances are
  measured from the carcass.
- [Diagram showing measurement points]
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Nutritional Requirements of
Pregnant and Lactating Fallow Deer
(Dama dama).

by

Jason Stefan Flesch

A thesis submitted in fulfillment of the requirements
for the degree of
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University of Western Sydney - Hawkesbury
Faculty of Environmental Management and Agriculture
PLEASE NOTE

The greatest amount of care has been taken while scanning this thesis,

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Apart from the assistance, which is listed in the acknowledgments, this thesis represents the original work of the author. This thesis has not been submitted for any other award, or to any other tertiary institution. The author and University shall not be responsible to any person for the use of suggestions or conclusions contained in this document.

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<td>acid detergent fibre</td>
</tr>
<tr>
<td>AI</td>
<td>artificial insemination</td>
</tr>
<tr>
<td>AL</td>
<td><em>ad libitum</em></td>
</tr>
<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
</tr>
<tr>
<td>BCS</td>
<td>body condition score</td>
</tr>
<tr>
<td>β-OHB</td>
<td>betahydroxybutyrate</td>
</tr>
<tr>
<td>BMF</td>
<td>bone marrow fat</td>
</tr>
<tr>
<td>CIDR</td>
<td>controlled internal drug release</td>
</tr>
<tr>
<td>CG</td>
<td>chest girth</td>
</tr>
<tr>
<td>cm</td>
<td>centimetres</td>
</tr>
<tr>
<td>CP</td>
<td>crude protein</td>
</tr>
<tr>
<td>CRL</td>
<td>crown-rump length</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DIAA</td>
<td>Deer Industry Association of Australia</td>
</tr>
<tr>
<td>DM</td>
<td>dry matter</td>
</tr>
<tr>
<td>d</td>
<td>days</td>
</tr>
<tr>
<td>E</td>
<td>European fallow deer (<em>Dama dama</em>)</td>
</tr>
<tr>
<td>eg</td>
<td>for example</td>
</tr>
<tr>
<td>et al.</td>
<td>et alia</td>
</tr>
<tr>
<td>etc</td>
<td>et cetera</td>
</tr>
<tr>
<td>DMD</td>
<td>dry matter digestibility</td>
</tr>
<tr>
<td>DMI</td>
<td>dry matter intake</td>
</tr>
<tr>
<td>DSE</td>
<td>dry sheep equivalent</td>
</tr>
<tr>
<td>FFA</td>
<td>free fatty acids</td>
</tr>
<tr>
<td>g</td>
<td>gram</td>
</tr>
<tr>
<td>GAL</td>
<td>group-fed <em>ad libitum</em></td>
</tr>
<tr>
<td>GRI</td>
<td>group-fed reduced intake</td>
</tr>
<tr>
<td>H</td>
<td>hybrid fallow deer (¼ Mesopotamian, ¾ European)</td>
</tr>
<tr>
<td>Ha</td>
<td>hectares</td>
</tr>
<tr>
<td>Hd</td>
<td>head</td>
</tr>
<tr>
<td>HSCW</td>
<td>hot standard carcass weight</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>IV</td>
<td>in-vitro</td>
</tr>
<tr>
<td>IVDMD</td>
<td>in-vitro dry matter digestibility</td>
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<tr>
<td>KFI</td>
<td>kidney fat index</td>
</tr>
<tr>
<td>km</td>
<td>kilometres</td>
</tr>
<tr>
<td>LW</td>
<td>liveweight</td>
</tr>
<tr>
<td>LWC</td>
<td>liveweight change</td>
</tr>
<tr>
<td>LWG</td>
<td>liveweight gain</td>
</tr>
<tr>
<td>L6</td>
<td>first 6 weeks of lactation</td>
</tr>
<tr>
<td>L12</td>
<td>first 12 weeks of lactation</td>
</tr>
<tr>
<td>M</td>
<td>molarity</td>
</tr>
<tr>
<td>M+</td>
<td>above maintenance</td>
</tr>
<tr>
<td>M-</td>
<td>sub maintenance</td>
</tr>
<tr>
<td>m</td>
<td>metres</td>
</tr>
<tr>
<td>ME</td>
<td>metabolisable energy</td>
</tr>
<tr>
<td>MEI</td>
<td>metabolisable energy intake</td>
</tr>
<tr>
<td>MJ</td>
<td>megajoules</td>
</tr>
<tr>
<td>mg</td>
<td>milligram</td>
</tr>
<tr>
<td>ml</td>
<td>millilitres</td>
</tr>
<tr>
<td>mm</td>
<td>millimetres</td>
</tr>
<tr>
<td>N</td>
<td>nitrogen</td>
</tr>
<tr>
<td>n</td>
<td>number</td>
</tr>
<tr>
<td>NDF</td>
<td>neutral detergent fibre</td>
</tr>
<tr>
<td>NDP</td>
<td>not diagnosed pregnant</td>
</tr>
<tr>
<td>ng</td>
<td>nanogram</td>
</tr>
<tr>
<td>NS</td>
<td>not significant</td>
</tr>
<tr>
<td>NSW</td>
<td>New South Wales</td>
</tr>
<tr>
<td>OM</td>
<td>organic matter</td>
</tr>
<tr>
<td>P</td>
<td>probability</td>
</tr>
<tr>
<td>PAL</td>
<td>penned <em>ad libitum</em></td>
</tr>
<tr>
<td>PRI</td>
<td>penned reduced intake</td>
</tr>
<tr>
<td>PK</td>
<td>plasma ketones</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>Term</td>
<td>Meaning</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Doe</td>
<td>Adult female fallow deer</td>
</tr>
<tr>
<td>Buck</td>
<td>Adult male fallow deer</td>
</tr>
<tr>
<td>Castrate</td>
<td>Animal with gonads removed, usually male</td>
</tr>
<tr>
<td>Haver</td>
<td>As above</td>
</tr>
<tr>
<td>Fawn</td>
<td>Juvenile fallow deer</td>
</tr>
<tr>
<td>Weaner</td>
<td>Weaned fawn</td>
</tr>
<tr>
<td>Hind</td>
<td>Adult female red deer</td>
</tr>
<tr>
<td>Stag</td>
<td>Adult male red deer</td>
</tr>
<tr>
<td>Calf</td>
<td>Juvenile red deer</td>
</tr>
<tr>
<td>Rut</td>
<td>Deer mating season</td>
</tr>
<tr>
<td>Trimester</td>
<td>One third of gestation</td>
</tr>
<tr>
<td>Lactation</td>
<td>Period of suckling by fawns</td>
</tr>
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**List of Terminology**
# List of Specific Names

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Specific Name</th>
</tr>
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<tbody>
<tr>
<td>Cape Buffalo</td>
<td>Syncerus caffer</td>
</tr>
<tr>
<td>Chamois</td>
<td>Rupicapra pyrenaica parva</td>
</tr>
<tr>
<td>Chital deer</td>
<td>Axis axis</td>
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<tr>
<td>Domestic Sheep</td>
<td>Ovis ovis spp.</td>
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<tr>
<td>Domestic Cattle</td>
<td>Bos taurus / indicus</td>
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<td>Formosa formosa</td>
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<td>Eland</td>
<td>Taurotragus oryx</td>
</tr>
<tr>
<td>Elk / Wapiti</td>
<td>Cervus elaphus canadensis</td>
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<td>Fallow deer</td>
<td>Dama dama</td>
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<td>Feral sheep</td>
<td>Ovis aries</td>
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<tr>
<td>Hog deer</td>
<td>Axis porcinus</td>
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<tr>
<td>Impala</td>
<td>Aepyceros melampus</td>
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<tr>
<td>Mesopotamian fallow deer</td>
<td>Dama dama mesopotamica</td>
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<tr>
<td>Moose</td>
<td>Alces alces</td>
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<tr>
<td>Mule deer</td>
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<tr>
<td>Muntjac</td>
<td>Muntiacus spp.</td>
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<tr>
<td>Pere David’s deer</td>
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<tr>
<td>Pronghorn</td>
<td>Antilocarpa americana</td>
</tr>
<tr>
<td>Red deer</td>
<td>Cervus elaphus</td>
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<td>Reindeer / Caribou</td>
<td>Cervus rangifer</td>
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<td>Roe deer</td>
<td>Capreolus capreolus</td>
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<td>Rusa deer</td>
<td>Cervus timorensis</td>
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<td>Cervus unicolor</td>
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<td>Sika deer</td>
<td>Cervus nippon</td>
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<td>Tahr</td>
<td>Hermitragus jemlaicus</td>
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<td>White-tailed deer</td>
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Publications Arising from this Study


Other Publications by the Author


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I would firstly like to thank Associate Professor Robert Mulley. Rob has fostered my interest of deer and their biology since 1994, and provided an endless supply of patience, encouragement and wisdom over the duration of my PhD candidature. I am also grateful for the friendship and support of his family. Thankyou Dianne, Paul and Adam.

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dissecting carcasses, as well as enduring my moods and frequent absence from family 
activities. I could not have completed this without you. Thank you.
Abstract

This thesis 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 change (LWC) and reproductive performance of pasture-fed fallow does (n=36) were monitored. 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 20.4 MJME/day, which is double the requirement of non-pregnant fallow does reported by Mulley *et al* (2000).

Pregnant European (E) and Hybrid (H) 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. The fawns continued to be fed the same concentrate ration they had been observed to consume with their mothers from 6 weeks of age. Over the next 8 weeks, daily metabolisable energy intake and weekly LWC 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 must be matched by the availability of high quality pasture and/or concentrate feeds for weaners to develop and grow to their genetic potential.

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 for two 7-day periods; once during trimester 3 (1997) and once during mid-lactation in 1998. All individually housed does conformed to 3 main periods of feeding activity over a 24-hour period. The first period started before sunrise and ended 2.5 (SEM±0.45) hours later. The second main period of feeding occurred just prior to sunset and lasted for 1.7 (SEM±0.52) hours. The third major period of feeding occurred around midnight and lasted for 2.3 (SEM±0.52) hours.

Temperature had a significant effect on feed intake. It was shown that temperatures above 35ºC 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 °C during recognised periods of feeding increased the average length of time 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. The increase in MEI over the first 6 weeks of lactation \( (P=0.000) \) was reflected by the significant increase in the number of visits to the feed troughs \( (P<0.001) \). The increase in feeding activity during lactation was positively correlated with MEI, although there were no 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 displayed a similar periodicity of feed intake, although there were much longer feeding periods around midday and midnight.

A 5 point body condition score (BCS) system was developed from live and carcass measurements collected from 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 beta-hydroxybutyrate (\( \beta\)-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 \( (r^2 = 0.847, \text{df} = 77, P<0.001) \) between BCS and KFI.
relationship is described by the equation $y = 0.02243x + 1.292$, where $y = \text{BCS}$ and $x = \text{KFI}$. There were significant differences in 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 for use on the live animal or for the meat processing sectors of the deer industry.

The effects of restricted maternal nutrition on rates of LWC, BCS and conceptus development were evaluated over two consecutive breeding seasons. Does over the first year of the study ($n=12$), 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 $\beta$-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 ($P=0.001$). Although the level of maternal energy restriction had no significant effect on conceptus development in weeks 1-12 weeks of gestation, the reductions in doe liveweight and BCS compared with ad libitum-fed does indicated that the level of maternal restriction been taken to term, fawn viability may have been compromised.

The results from this study make possible the precise strategic feeding of fallow deer breeding stock, which should lead to more consistent reproductive performance and higher quality slaughter animals. Furthermore, use of strategic feeding in conjunction with BCS systems will lead to better resource management and profitability, as farmers consistently produce animals to specification.