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**Investigating methods to improve the reproductive performance of
hoggets**

A thesis presented in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

In

Animal Science

at Massey University, Palmerston North, New Zealand

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2011

Abstract

Mulvaney FJ. Investigating methods to improve the reproductive performance of hoggets.

PhD thesis, Massey University, Palmerston North, New Zealand, 248pp. 2011.

The first two chapters identified that in comparison to mature multiparous ewes, fewer hoggets are bred, a greater proportion return to oestrus, have a lower proportion that ovulate and of those that do ovulate, the ovulation rate is lower, and there is a greater reproductive loss in early to mid pregnancy, fewer and lighter singleton counterparts lambs at birth, poorer mothering ability and lighter and fewer lambs at weaning.

As a result of these findings, nutritional management experiments were designed to investigate the effects of nutrition on the reproductive performance of hoggets. The results indicate that offering *ad-libitum* levels of herbage prior to ram introduction can increase the proportion of hoggets bred which leads to a better pregnancy rate. However, *ad-libitum* levels herbage immediately after the completion of the breeding period could be associated with hoggets that were bred returning to oestrus. The efficiency of lamb production was reduced when the hoggets were offered *ad-libitum* levels of herbage during pregnancy. However, when twin-bearing hoggets were offered *ad-libitum* levels of nutrition from mid- to late-pregnancy the efficiency of lamb production was similar between nutritional levels. The twin-bearing hoggets may have both been offered a level of nutrition that did not lead to a sufficient nutritional intake restriction in the medium group to allow for hogget live weight differences to occur. Hoggets that were offered *ad-libitum* levels of nutrition during pregnancy were heavier than the hoggets offered medium levels of nutrition. Weaning single

lambs born to hoggets at 10 weeks of age whilst weaning twin lambs at 9 weeks of age did not have an impact on hogget or lamb live weight compared to weaning at 13 or 14 weeks of age.

This thesis has identified reproductive differences between hoggets and mature multiparous ewes and the impact of nutritional management on hogget reproductive performance and the effect of weaning age on lamb and hogget live weight. Implementing the results from the nutritional experiments into farm practice could improve hogget reproductive performance and help alleviate the issue of the negative impact of hogget breeding on subsequent breeding live weight, while also offering options to the farmer when planning the management of weaning lambs born to hoggets.

Acknowledgements

Thank you to my team of supervisors Professor Steve Morris, Associate Professor Paul Kenyon, Professor Dave West and Associate Professor Patrick Morel for the expert comments and suggestions helped me develop my thesis into what it is now, quick return of work and, the helpful critique of the thesis. Also, thank you for the 'open door' policy that you all have had throughout the PhD.

I have had the experience of being involved in the sheep post-graduate group. They have all helped out in my field work and a special mention of the 'lambing team' of 2007 is required. Completing all the behaviour recording during the lambing period was a huge job and I thank you all for the help. Dean Burnham, Kim Fraser, Geoff Purchas and AJ Wall, thank you for being the group of knowledgeable and practical group of technicians during my study. Thank you to the farm staff at the Keeble farm at Massey University and especially to Graeme Poole for the help and fun during the field work in 2009. Also, thank you to Carolina and Kirsty for the help provided during the transrectal ultrasound observation period. The help in answering questions about the administrative side of the study provided by Wendy Graham and Debbie Hill also needs to be acknowledged.

A would like to also acknowledge the 'eccentric' discussions with Rebecca Hickson over the past few years. I'm not sure if much value came out of them but definitely a laugh and on the odd occasion they were scarily intelligent and worth while. I would also like to thank her for the help she has provided me over the past decade I have known her!!! To my Massey

mothers, Barbara and Anne, thank you for having something to say that took my mind of things and having the ability laugh.

To Peter, Anna and Toni Scott, thank you for providing me with some farming 'reality' and a couple of weeks of physical work during a period when I really needed it. I really appreciated the opportunity.

To Mum and Dad, I could not have completed this thesis without your patience and encouragement. You installed a belief in me that I could do it. To Dad, thank you for allowing me to be 'at your hip' and 'second in charge' when I was young and answering my questions. This inspired my interest in agriculture. The questions will keep coming, although I hope that one day, you won't be able to answer them as easily which will mean I have developed further than we could have expected. To Hamish and Anna, thank you for your patience with me over the past few years, it wasn't easy but you have stuck with me and I appreciate that. Thank you to Nana who always had a bed and a good feed when I came down for the meetings during the last year of this PhD.

Finally, I would like to thank the C. Alma Baker Trust, Massey University and Beef and Lamb New Zealand for the funding provided. Without their assistance, this thesis would not have been possible. The experiments in reported on in this thesis were conducted with the approval of the Massey University Animal Ethics Committee.

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Chapter 1: Introduction

The lambing percentage (lambs weaned/hogget joined) of hoggets (7-9 months old) in New Zealand pastoral conditions is currently significantly lower than that of mature ewes (60 vs. 127%) (Kenyon *et al.* 2004b; Anon 2010). Lambs weaned from hoggets represented only 4% of the total lamb crop in 2010; up from 3.3% in 2009 (Anon 2010). Table 1.1 clearly outlines the pattern of the percentage of hoggets joined with the ram in New Zealand.

Table 1.1. The number (millions, at 30th June) and the percentage of hoggets joined with the ram (Anon 2010).

	1987	1996	2009	2010
Hoggets joined with the ram	1.6	0.9	1.8	2.1
Total hoggets carried through winter	11.9	8.9	6.5	10.1
Percentage joined	14	11	28	21

Although it does appear from Table 1.1 that there has been a substantial increase in the percentage of hoggets joined with the ram during the past three decades, there is still room for improvement. Farmers balance the potential advantages and disadvantages to determine whether to breed hoggets or not. The improvement in hogget lambing percentage requires an increase in the proportion of hoggets joined with the ram and an increase in the breeding performance of the hoggets. The stated advantages of hogget breeding include; improved fertility throughout the ewe breeding component of the farm (Gavigan & Rattray 2002), greater utilisation of spring herbage (Gavigan & Rattray 2002) more lambs and increased

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income (Tyrrell 1976; Hight 1982; Gavigan & Rattray 2002), increased efficiency (Tyrrell 1976; McCall & Hight 1981), improved lifetime performance (Dyrmundsson 1973; McCall & Hight 1981; Gavigan & Rattray 2002) and higher genetic gain (Baker *et al.* 1978; Hight 1982).

The potential disadvantages from hogget breeding that have been identified include; poor hogget fertility (Kenyon *et al.* 2004b) potentially reducing two-year-old breeding performance (Keane 1974; Gavigan & Rattray 2002), extra herbage requirements during the winter (Hight 1982; Gavigan & Rattray 2002), higher mortality of hogget and their lambs (Gavigan & Rattray 2002), reduced wool production (Tyrrell 1976; McMillan & McDonald 1983; Gavigan & Rattray 2002), extended lambing period (Hight 1982; Gavigan & Rattray 2002), higher animal health costs (Gavigan & Rattray 2002), additional ram requirements (Gavigan & Rattray 2002), increased farm labour (Gavigan & Rattray 2002) and potential for smaller, less marketable lambs born to hoggets (Hight 1982; Gavigan & Rattray 2002). Also, the proportion of hoggets bred is very low (Allison *et al.* 1975) and the lambing percentage is poor (Kenyon *et al.* 2004b) which varies from year to year (Gavigan & Rattray 2002). Of these stated disadvantages, reduced two-year old breeding performance (primarily due to reduced live weight) is the major factor limiting New Zealand farmers' uptake of hogget breeding (Kenyon *et al.* 2004b). Therefore, identifying management factors that can optimise two-tooth (18 months of age) breeding live weight could lead to a greater number of farmers joining their hoggets with the ram.

Chapter 1: Introduction

Gavigan & Rattray (2002) speculated that from 1000 hoggets bred, a pregnancy rate of 70% and a lamb survival of 70% would lead to 490 lambs weaned. It was then postulated that the lambs would be sold when 20 kg live weight and this would add \$22,050 to the farm revenue. Therefore, there would be substantial economic benefits from getting more farmers to join their hoggets with the ram and increasing the lambing percentage of the hoggets. Thus, this thesis presents experiments that firstly identify differences in the reproductive performance between hoggets and mature ewes (Chapters 3 and 4). Following these chapters, experiments were conducted to investigate methods to improve the reproductive performance of hoggets and the performance of their lambs (Chapters 5, 6, 7 and 8). Experiments investigated the impact of commencing differing nutritional levels prior to the breeding period, during the breeding period and throughout gestation on pregnancy (Chapter 5) and weaning (Chapter 7) outcomes.

These experiments were carried out at Massey University's Keeble farm (5 km southeast of Palmerston North, latitude 41° 24' south, longitude 175° 36' east; chapters 3, 4, 5, 6, 7, 8, 9 and 10) and Tuapaka farm (15 km east of Palmerston North; 41° 24' south, longitude 175° 36' east; chapter 3).

Chapter 2: Literature review: The onset of puberty, comparing the reproductive performance of primiparous (hogget and two-year-olds) and mature multiparous ewes, effects of nutrition during pregnancy and the impact of early weaning of lambs on lamb and dam live weight and lamb carcass traits



Hoggets in the yards at Limestone Downs - a selection of these were used in chapter 8 and 10

Onset of puberty

Puberty has been defined as the process whereby the young becomes capable of spontaneous ovulation followed by fertile breeding (Ryan & Foster 1980). The endocrine control of puberty involves a complex set of interactions within the hypothalamic-pituitary-ovarian (HPO) axis (Ronayne *et al.* 1991). The HPO axis is extremely sensitive to the inhibition of the release of gonadotrophin by oestradiol prior to the onset of puberty (Ronayne *et al.* 1991). This results in low luteinising hormone (LH) and follicle stimulating hormone (FSH) secretion (Foster *et al.* 1975, 1985) and this insufficient LH and FSH hormone concentration leads to restricted follicle growth (Foster *et al.* 1985). The transition from non-pubertal to pubertal involves a reduction in the sensitivity of the negative feedback mechanism of oestradiol. This ultimately leads to an increase in the frequency of LH, culminating in a sufficient LH peak (Foster 1984) and a pre-ovulatory LH surge (Keisler *et al.* 1985) resulting in ovulation (Berardinelli *et al.* 1980).

The pre-ovulatory surge of LH has been stimulated as early as 3 weeks of age following oestrogen (Foster & Karsch 1975), GnRH (Land 1978) or LH (Foster *et al.* 1984) treatments. This suggests that the pituitary and ovary points on the HPO axis are developed sufficiently to initiate puberty. However, the hypothalamus requires additional cues to initiate puberty. Metabolic cues lead to changes in the LH pulse frequency indicate an adequate physiological and metabolic size to display puberty are then transferred to the GnRH pulse generator that initiates puberty (Foster *et al.* 1985). Melatonin concentrations are implicated and are indicative of a shorter day length and can stimulate a reduction in the sensitivity to the

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negative feedback actions of oestradiol (Foster *et al.* 1985). The transition from the non-pubertal state to the pubertal state requires an interaction between age, body weight and hours of day light (Foster & Ryan 1985). Therefore, a simplistic manipulation of either the day length or the nutritional status could turn the switch on for the transition from non-pubertal to pubertal. van der Linden *et al.* (2007) reported that the mean age of hoggets at puberty did not differ but their live weight varied by 2kg. This may suggest that these hoggets had reached a live weight threshold for that breed required for the attainment of puberty. Bizelis *et al.* (1990) found hoggets which were offered *ad-libitum* levels of nutrition from 3 months of age until their first breeding season grew faster and attained a sufficient live weight at the start of the breeding season and reached puberty earlier in the breeding season compared to hoggets fed a restricted diet. This suggests that if the hogget has reached a sufficient live weight when the day length is the optimum for breeding to occur, puberty will be activated earlier in the breeding season. Hoggets that had not reached the live weight threshold were still sensitive to the day length changes and could not react to the stimulatory changes in day length due to being lighter.

Nutrition and the onset of puberty

Increasing nutrition post-weaning increased the proportion of hoggets reaching puberty (Moore & Smeaton 1980; McCann *et al.* 1989; Bizelis *et al.* 1990; Boulanouar *et al.* 1995), increased the proportion displaying oestrus (Burfening & Berardinelli 1986) and increased fertility (Gaskins *et al.* 2005).

Chapter 2: Literature review

A comparison of the reproduction of hoggets and mature ewes

Proportion bred

There is a dearth of information that enables a clear comparison between the proportion of mature ewes and hoggets bred (i.e. as identified with a rump harness crayon mark from the ram). However, Hare & Bryant (1985) reported 74% of hoggets were bred over 51 days and the proportion increased from the first monitored oestrus to the second and third oestrus and 81% of hoggets were bred following hormonal treatment (O'Doherty & Crosby 1990). In addition, van der Linden *et al.* (2007) reported 90 to 98% of hoggets displayed oestrus during Autumn (March to June) and Kenyon *et al.* (2007) reported the proportion of hoggets bred over 34 days ranged from 83 to 89% in New Zealand pastoral conditions.

Ovulation rate

Quirke & Hanrahan (1977), Quirke *et al.* (1981) and Beck *et al.* (1994, 1996) reported that ovulation rate was lower in hoggets compared to multiparous ewes (by 0.18 to 1.56, Table 2.1) while Davies & Beck (1993) found that ovulation rate did not differ between hoggets and multiparous mature ewes.

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Table 2.1. Studies that involve a direct comparison between reproduction parameters of primiparous and mature multiparous ewes (age and/or parity indicated in table for each experiment). Within columns, data with different superscripts differ significantly ($P < 0.05$).

Experiment	Ovulation rate	First trimester pregnancy loss (%)	Pregnancy rate (%)	Lamb birth weight (kg)	Lamb Survival (%)	Lamb growth (g/day)/ weaning weight (kg)	Comment
Donald <i>et al.</i> (1968)			77 vs. 95 vs. 96				Hoggets, 2 and 3 year olds
Forrest & Bichard (1974)	1.15 ^a vs. 1.55 ^b vs. 1.75 ^c		56 ^a vs. 93 ^b vs. 95 ^b				For hoggets, 2 or 2+ yr old ewes
Quirke & Hanrahan (1977)	1.51 ^a vs. 3.07 ^b	66 ^b vs. 27 ^a					Based on ewes that ovulated. Reduced to 1.25 and 2.75 when all ewes included. 1 year old and multiparous ewes 3-5 year old
Wohlt <i>et al.</i> (1981)				3.5 vs. 3.1 vs. 4.0			1.5-2-year old (1 st parity) vs. 2-4 4-8 yr old dams
Alexander <i>et al.</i> (1993)					44 ^b vs. 19 ^a vs. 29 ^a		Involved 2 and 5 yr old primiparous ewes and 5 year old multiparous ewes

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Study	Ovulation rate	First trimester pregnancy loss ¹ (%)	Pregnancy rate (%)	Lamb birth weight (kg)	Lamb Survival (%)	Lamb growth (g/day)/ weaning weight (kg)	Comment
Davies & Beck (1993)	1.1 vs. 1.5						Hogget vs. mature multiparous ewes
Beck <i>et al.</i> (1996)	1.07 ^a vs. 1.25 ^b						Hogget vs. mature multiparous ewes 2-5 years old
Morris <i>et al.</i> (2000)					91 ^a vs. 93 ^b vs. 94 ^b vs. 93 ^b 78 ^a vs. 81 ^b vs. 81 ^b vs. 77 ^a		2 (1 st parity), 3, 4 and 5+ year old dams. Perinatal survival then survival to weaning
Dwyer <i>et al.</i> (2005)				3.95 vs. 4.45 vs. 4.52			1 vs. 2 vs. 3 parities. 18 months old when lambred at 1 st parity
Gbangboche <i>et al.</i> (2006)				1.9 vs. 1.9		35 ^a vs. 58 ^b g/day	20 month old (1 st parity) vs. mature multiparous ewes
Annett & Carson (2006)			67 ^a vs. 85 ^b	4.73 ^a vs. 5.29 ^b	63 ^a vs. 79 ^b	217 ^a vs. 251 ^b 28.6 ^a vs. 31.8 ^b	18 month old (1 st parity) and mature multiparous ewes
Gootwine & Rozov (2006)				3.74, 4.2-4.3 3.9-4.1			2 yr vs. 3-8 yrs vs. 9-10 yrs old
Gardner <i>et al.</i> (2007)				Largest birth weight increase of .35 kg from 1 st to			Only provided changes in birth weight but was significant from 1 st to 2 nd parity. 1 yr for 1 st parity

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Khan *et al.*
(2007)

50^a vs. 75^b

2nd parity

Hoggets vs. mature multiparous
ewes (no indication of age)

^aEquivalent to the stage in pregnancy loss_{P7-P68} in chapters 3 and 8

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The mechanism behind the lower ovulation rate in hoggets is largely unknown. However, Davies & Beck (1993) reported that the lower episodic LH peaks observed in hoggets was associated with a lower ovulation rate. In addition, Quirke & Hanrahan (1977) found the proportion of hoggets that ovulated at the beginning of the breeding season was smaller than the proportion of mature multiparous ewes, and that the incidence of oestrus without ovulation is high in hoggets (Edey *et al.* 1977). There is also variation between and within breeds and between seasons (Hafez 1952). These factors may help explain the reduced ovulation rate in hoggets compared to multiparous mature ewes. In addition, Christenson (1993) reported that the ovulation rate increases as the number of oestrus occurrences increase after puberty. Therefore, increasing the number of oestrus occurrences prior to joining hoggets with the ram may increase their ovulation rate when they are joined. The lack of sufficient hogget oestrus occurrences prior to ram joining may contribute to the reduced ovulation rate compared to mature multiparous ewes.

Early pregnancy loss

Embryonic loss is higher in hoggets compared to mature multiparous ewes (Al Wahab & Bryant 1978; Edey *et al.* 1978; Hamra & Bryant 1979; Quirke 1981; Hare & Bryant 1985; McMillan & McDonald 1983; Beck *et al.* 1994, 1996; Michels *et al.* 1998) (Table 2.1). In addition, Quirke & Hanrahan (1977) reported hoggets have high cleavage rates (80%) but very low implantation rates (<40%). This indicates that the embryo begins to develop but is not developed enough to permit implantation. Further investigations have identified the majority of embryonic loss in hoggets occurs between Days 3 and 26 of pregnancy (Al

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Wahab & Bryant 1978; Quirke 1979; Quirke & Hanrahan 1983; McMillan & McDonald 1985; Beck *et al.* 1996).

Quirke & Hanrahan (1977) suggested that it is possible the ova produced by hoggets do not have the same potential for development as those from older ewes or the conditions in the reproductive tract of the hoggets are less favourable for embryo survival. In support of this, O'Brien *et al.* (1996, 1997) and Ptak *et al.* (2003) reported early stage embryos from pre- or peri-pubertal ewes had poor developmental competence. However, very early stage embryos derived from hoggets that reach the blastocyst stage are just as likely to develop until term compared to those derived from mature multiparous ewes (O'Brien *et al.* 1996; Kochhar *et al.* 2002) indicating that it is critical that the embryo reaches the 8-16 cell blastocyst stage during the first week of gestation.

Transferring one (Quirke 1979) or two (Quirke & Hanrahan 1983) 8-16 cell embryos from mature multiparous ewes to either hoggets or mature multiparous ewes resulted in no difference in the pregnancy rate. Transferring 8-16 cell embryos derived from hoggets and mature multiparous ewes to hoggets resulted in greater survival of the embryos derived from adults compared to hoggets (McMillan & McDonald 1985). This indicates that it is the quality of the embryo that determines the survivability of the embryo and not the uterine environment which may explain why embryonic loss is higher in hoggets (Michels *et al.* 1998).

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Morton *et al.* (2005) and Leoni *et al.* (2006) found blastocysts from hoggets took longer to form compared to blastocysts from mature ewes, consequently the embryo was less likely to survive. This may also explain why embryonic loss is higher in hoggets. The delay in the formation of a blastocyst could be due to poorer ability of the developing embryo to metabolise glutamine (O'Brien *et al.* 1996), poorer rates of incorporating amino acids (Kochhar *et al.* 2002) and reduced ability to complete zygotic genomic activation (a critical stage in embryonic development) (Ptak *et al.* 2003). During the early stages of pregnancy, progesterone is released by the corpora lutea (Wilmot *et al.* 1985). An elevated concentration of progesterone is believed to be responsible for rapid blastocyst growth resulting in more interferon-tau secretion and consequently, improved embryo survival (Khan *et al.* 2007). Progesterone concentration is lower in hoggets compared to mature multiparous ewes (Davies & Beck 1993) which may explain why embryo survival in hoggets is lower compared to mature ewes. However, the associated increase in progesterone concentration that has occurred using hormonal treatments (Nephew *et al.* 1994; Beck *et al.* 1996; Khan *et al.* 2007, 2009) has not improved embryo development in hoggets compared to no progesterone treatment (Khan *et al.* 2007), which contradicts the findings of Davis & Beck (1993).

Pregnancy rate

Annett & Carson (2006) and Khan *et al.* (2007) reported pregnancy rate was lower in hoggets compared to mature multiparous ewes (Table 2.1). In addition, Forrest & Bichard

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(1974) reported the proportion of hoggets pregnant was 56% and this increased to above 90% for ewes at least 2 years old. A similar pattern was observed by Donald *et al.* (1968).

Late pregnancy loss

There is a paucity of data that directly examines whether pregnancy loss after pregnancy diagnosis differs between mature multiparous and primiparous ewes. However, Atta & El Khidir (2005) reported the incidence of pregnancy loss was greater (13-17%) in hoggets compared to two-year-old ewes (0-5%) but these authors did not provide a stage in pregnancy when the pregnancy loss occurred. Ptak *et al.* (1999) reported 92 % of the fetuses present on Day 80 of pregnancy in multiparous mature ewes were represented by a lamb at term, while only 29% (2/7) of the fetuses present in the hogget were represented by a lamb at term.

Litter Size at Birth

Annett & Carson (2006) reported that litter size at birth is greater in mature multiparous ewes (2.28 lambs/ewe that lambed and 1.91 lambs/ewe bred) compared to hoggets (1.38 lambs/hogget that lambed and 0.94 lambs/hogget bred) while Koycegiz *et al.* (2009) found litter size increased from the first and second parity to the third and fourth. In addition, Morel *et al.* (2010) reported that litter size did not differ between ewe parity when the first parity was as a hogget or a two-year old.

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Lamb Survival

There is a lack of data that allows for the direct comparison of lamb survival between hoggets and multiparous mature ewes. Therefore, this section compares the survival of lambs born to two-year-old primiparous and mature multiparous ewes. The only data that allowed a direct comparison (Annett & Carson 2006, Table 2.2) reported that litter size was different at birth but not at weaning between hoggets and mature multiparous ewes; thus, indicating a difference in lamb survival. The same pattern was identified by Koycegiz *et al.* (2009) who reported litter size was lower at birth in first and second parity ewes compared to third and fourth parity ewes, however, the litter size at weaning did not differ which indicates there was an affect on lamb survival until weaning. Ekiz *et al.* (2007) reported lamb survival did not differ between parities up to the fourth parity but there was no indication of ewe age at the first parity (Table 2.1). However, Morris *et al.* (2000) found the perinatal survival of lambs born to two-year-old primiparous dams was lower than multiparous three- and four-year-old dams but similar to five-year-old multiparous ewes: but survival until weaning was lowest in lambs born to two- and five-year-old ewes and highest in lambs born to three- and four-year-old ewes. Interestingly, Alexander *et al.* (1993) reported lamb survival until 4 days of age was lower in five-year-old primiparous ewes compared to five-year-old multiparous mature ewes, but was not different from two-year-old primiparous ewes. However, they did not report whether there was a difference between five-year-old multiparous ewes and two-year-old primiparous ewes.

Table 2.2. Litter size at birth and weaning for hoggets and mature multiparous ewes used to calculate lamb survival (adapted from Annett & Carson 2006).

	Hoggets	Mature multiparous ewes
Litter size at birth	1.38	2.28
Litter size at birth	0.91	1.79
Lamb survival (%)	66	79

The survival of lambs born to hoggets (Schreurs *et al.* 2010) and twin (Morel *et al.* 2009) and triplet (Morel *et al.* 2008) lambs born to mature multiparous ewes is associated in a ‘bell-shaped-curve’ manner with lamb birth weight. This would suggest that the relationship would be the same for both age groups, with a lower point of the ‘bell’ for the birth weight of lambs born. If so, this may indicate that the survivability of the lambs of equivalent weight born to both age groups could well be the same.

Lamb birth weight

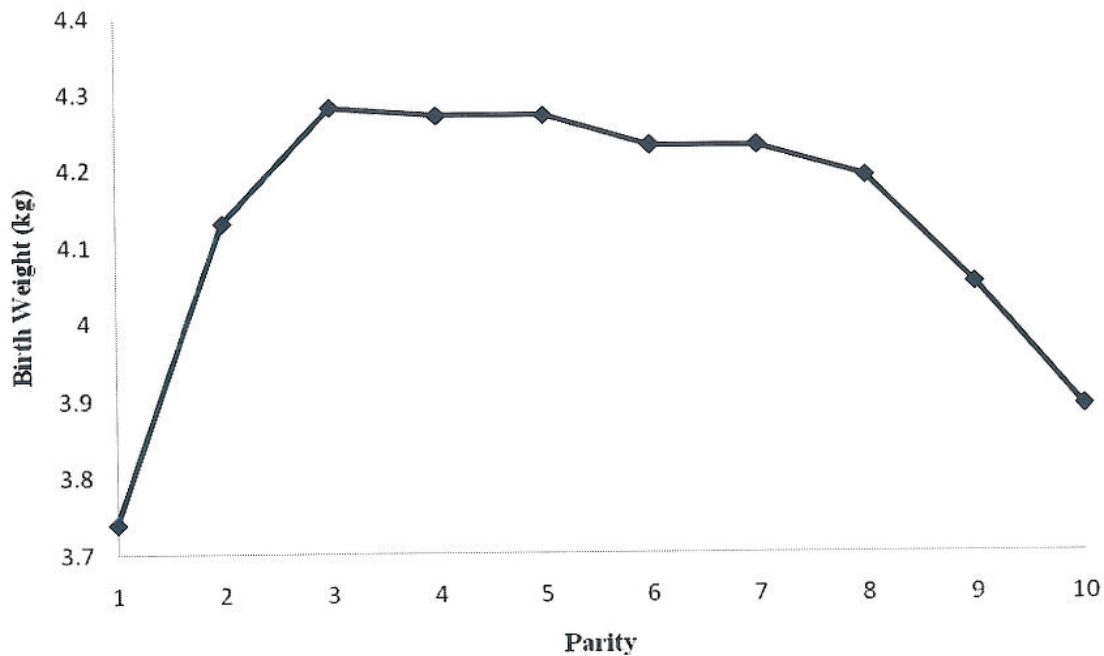
Lambs born to hoggets (Annett & Carson 2006; Gootwine *et al.* 2007) and two-year-old ewes (Dwyer & Lawrence 2000; Dwyer *et al.* 2005; Gootwine & Rozov 2006; Gardner *et al.* 2007) are lighter at birth compared to singleton lambs born to multiparous mature ewes (Table 2.1). In addition, Gootwine & Rozov (2006) reported that the relationship between lamb birth weight and maternal age was “bell-shaped” (Figure 2.1).

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Notter *et al.* (2005) found lamb birth weight of lambs born to hogget represented only 76% of the birth weight of lambs born to mature multiparous ewes. Gootwine *et al.* (2007) reported the birth weight of lambs born to hoggets was lighter than lambs born to 20 month old ewes and the birth weight increased at monthly intervals. However, from 21 months of age onwards the birth weight remained constant. They suggested that the birth weight of lambs born hoggets was restricted by the competition for nutrients between the developing conceptus and the still-growing hogget. In support of this, Annett & Carson (2006) reported that birth weight represented 11% of hogget and 9% of mature multiparous ewe live weight at the start of the breeding period. Therefore, the birth weight of lambs born to hoggets may just be restricted by maternal body weight at the start of the breeding period.

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Figure 2.1. The relationship between ewe parity and lamb birth weight. (Adapted from Gootwine & Rosov 2006).



The first pregnancy has been suggested to leave a ‘physiological imprint’ on the uterus (Gardner *et al.* 2006). This priming of the uterus can enhance vascularisation (Khong *et al.* 2003) or provide greater blood volume during the second pregnancy (Campbell & MacGillivray 1984) which will facilitate improved conceptus growth (Gardner *et al.* 2006). In addition, Dwyer *et al.* (2005) reported the placenta was smaller and less efficient in two-year-old primiparous ewes. Therefore, the lighter lambs born to young primiparous ewes could be due a reduced vascularisation, a lower volume of blood and a smaller less efficient placenta and, once the ewe has successfully completed a pregnancy, the ‘physiological imprint’ provided leads to improved lamb birth weight.

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Lamb growth

Annett & Carson (2006) reported lambs born, at the same time and managed in one group during lactation; to mature multiparous ewes grew faster than lambs born hoggets from birth until 15 weeks of age (Table 2.1). In addition, Notter *et al.* (2005) reported lamb live weight at 60 days represented 83% of the maximum lamb weaning weight born to hoggets and this increased to 95 and 99% of the maximum for lambs born to two- and three-year-old ewes, respectively.

Greenwood *et al.* (1998) reported that heavier birth weight was associated with an elevated lamb growth rate. Annett & Carson (2006) found lambs born to mature multiparous ewes were heavier at birth than lambs born to hoggets. This may partly explain why lambs born to mature ewes are heavier at weaning. Primiparous two-year-old dams have been reported to produce less milk (Peeters *et al.* 1992; El-Saied *et al.* 1999) with a lower fat, protein and lactose content (Peeters *et al.* 1992); which indicates poorer quality (Sevi *et al.* 2000) compared to multiparous mature ewes. Thus hoggets produce less milk which is of poorer quality compared to mature multiparous ewes. This may further explain why lambs born to hoggets grow slower and are lighter at weaning compared to lambs born to mature multiparous ewes.

Maternal and lamb behaviour

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There is no present data that provides a comparison between hogget and mature multiparous ewe behaviour and the behaviour of their lamb around the time of lambing. The only comparison available is between two-year-old primiparous and mature multiparous dams. Two-year-old primiparous dams are less likely to display physical contact (Otal *et al.* 2009) and groom and/or lick their lamb(s) (Owens *et al.* 1985; O'Connor *et al.* 1992; Ekiz *et al.* 2007) leading to a reduced acceptance of their lambs (Dwyer & Lawrence 2000; Otal *et al.* 2009) compared to mature multiparous ewes. In addition, in comparison to mature multiparous ewes, the two-year-old primiparous dams when the lambs are attempting to suckle are more likely to back away from and circle her lamb (O'Connor *et al.* 1992; Dwyer & Lawrence 2000) and step over her lamb (O'Connor *et al.* 1992). The two-year-old primiparous dam is also more likely to display a greater fear reaction to humans (Dwyer *et al.* 1998) and reduced responsiveness to her lamb (Dwyer & Lawrence 2000) compared to mature multiparous ewes. Moreover, whilst Ekiz *et al.* (2007) reported maternal behaviour score did not differ between ewe parity, they also reported that the two-year-old primiparous dams were less likely to groom their lambs compared to mature multiparous ewes. The aforementioned studies indicate that the maternal behaviour of two-year-old primiparous ewes is poorer than mature multiparous ewes. In addition, Keller *et al.* (2003) found the ability of first parity dams to select their own lamb at suckling was reduced compared to second parity and multiparous mature ewes.

The release of noradrenalin and acetylcholine during parturition stimulates the olfactory bulb (Kendrick *et al.* 1991; Lévy *et al.* 1993) and ultimately led to recognition of the smell of amniotic fluid (Lévy *et al.* 1983; Lévy & Poindron 1987; Otal *et al.* 2009) and/or the

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newborns' coat (Lévy & Poindron 1984). These events lead to the development of appropriate maternal behaviour. The under-developed maternal behaviour of the two-year-old primiparous dam may be due to any events that disrupt this sequence of events. The primary stimulation that leads to the release of noradrenalin and acetylcholine is the physical event of giving birth ("vaginocervical stimulation"). However, it would be expected that the stimulation would lead to similar concentrations of noradrenalin and acetylcholine if only it was the stimulation of giving birth was required. This does not appear to be the case as Lévy *et al.* (1983) found noradrenalin and acetylcholine concentrations were lower after parturition in two-year-old primiparous ewes compared to mature multiparous ewes. It may be that the prolonged parturition reported in two-year-old primiparous ewes (Alexander *et al.* 1993) may disrupt the sequence of events in some way that does not allow appropriate maternal behaviour to develop.

Summary

This section has summarised studies which have involved a comparison between two-year-old primiparous and mature multiparous ewes. It is apparent that there are relatively few studies which have followed both hoggets and mature multiparous ewes which had been bred and subsequently followed in pregnancy and lactation. Overall, compared to mature multiparous ewes, two-year-old primiparous ewes:

- Are less likely to be bred by the ram.
- Have a lower ovulation rate.

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- Have greater first trimester pregnancy loss.
- Have lower pregnancy rate.
- Give birth to lighter lambs.
- Give birth to lambs that are less likely to survive.

The effect of nutrition during pregnancy on hogget reproductive outcome

The following section predominantly comprises of two groups of studies conducted in the United Kingdom (U.K.) and New Zealand. The U.K. studies utilised a sheep model to investigate the mechanisms behind increased human pre-term deliveries, shorter gestation length, lower infant birth weight and lower infant survival of babies born to adolescent girls compared to multiparous woman (Eisner *et al.* 1979; Alexander *et al.* 1987; Brown *et al.* 1991; Adelson *et al.* 1992; Cooper *et al.* 1995; Olausson *et al.* 1999). The U.K. sheep nutrition studies led to poorer conception rates, greater incidence of spontaneous pregnancy loss, reduced fetal and birth weight, reduced lamb survival, reduced colostrum yield and lamb growth rate. The U.K. studies primarily consisted of young (148 - 224 days old), heavy (44.4 - 47.4 kg) ewes which had conceived via embryo transfer. They were offered a complete concentrate diet that consisted of 30 % milled hay, 50 % barley, 10 % molasses, 9 % fishmeal, 0.3 % salt, 0.5 % dicalcium phosphate and 0.2 % of a vitamin mineral supplement and was approximately 86 % dry matter. The diet contained 10.2 MJ ME/kg DM and 13.7 % crude protein. The U.K. studies utilised three nutritional treatments, restricted (maintenance), normal maternal growth (medium) and rapid maternal growth (*ad-libitum*) and investigated the effects on the reproductive outcomes of hoggets. The maintenance treatment hoggets were fed to maintain body condition for the duration of the experimental period. The medium treatment hoggets were fed to achieve 50-75 g/day during the first 100 days of pregnancy. From Day 100 until term, the nutrient intake was adjusted to maintain condition score of 2 and to meet the requirements for the developing conceptus. The *ad-libitum* treatment hoggets were fed *ad-libitum* levels of the complete diet from Day 1 of pregnancy until term, to ensure maximum liveweight change.

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In 2004, an extensive survey (Kenyon *et al.* 2004a) identified that the main reason behind farmers joining with the ram less than 50 % of the eligible hoggets in New Zealand was the lighter live weight at the time of two-year-old breeding. A series of New Zealand studies attempted to duplicate the U.K. results to examine the effect of nutrition during pregnancy of hoggets under outdoor pastoral conditions. The New Zealand studies comprised of older (210 – 270 days old), lighter (35 – 38 kg) hoggets which were bred under natural breeding conditions. The hoggets were allocated to either a maintenance, medium or *ad-libitum* levels of a predominantly perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) herbage mixed sward. The aim of the maintenance level of herbage was to maintain the pre- and post-grazing herbage mass between 1000 and 800 kg DM/ha to ensure no maternal liveweight change occurred and the liveweight change was only due to conceptus growth. The hoggets allocated to the medium treatment group were managed to achieve a total liveweight change of 100 g/day. This was achieved by maintaining pre- and post-grazing herbage mass not higher than 1400 and 1000 kg DM/ha. *Ad-libitum* treatment hoggets were offered *ad-libitum* (>1400 kg DM/ha) levels of herbage with the aim of achieving a total liveweight change > 200 g/day for the duration of the experimental period.

The main results for the U.K. and N.Z. studies are outlined in Table 2.3.

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Table 2.3. Summary of the experiments comparing the reproductive performance of hoggets fed varying levels of nutrition studies conducted in the U.K. and New Zealand. Within columns and within experiments and within superscripts differ significantly ($P < 0.05$).

Study	Age (d)	Weight (kg)	Treatment group	Liveweight change (g/day)	Conception rate (%)	Pregnancy loss (%)	Gestation Length	Birth or foetal weight (kg)	Colostrum yield (g)	Lamb Survival (%)	Lamb weight (kg)/growth (g/day)
U.K. studies											
Wallace <i>et al.</i> (1996, 1997a)	148	44.4	Medium	75 ^a	85 ^b	8 ^a	143.1 ^b	4.34 ^b (0.65, d95)	247 ^b	91 ^b	
			<i>Ad-libitum</i>	234 ^b	57 ^a	33 ^b	140.2 ^a	2.74 ^a (0.82, d95)	35 ^a	38 ^a	
Wallace <i>et al.</i> (1997b)	224	47.4	Medium	84 ^a	59 ^a		145.4 ^a	4.82 ^b	547 ^b		
			<i>Ad-libitum</i>	294 ^b	90 ^b		142.7 ^b	3.49 ^a	206 ^a		
Palmer <i>et al.</i> (1998)	200	43.7	Medium	84 ^a				1.57 (d104)			
			Medium / <i>Ad-libitum</i>	294 ^b	78			1.37 (d104)			
Wallace <i>et al.</i> (1999), Thomas <i>et al.</i> (2001) ¹	190	43.7	Medium / <i>Ad-libitum</i>	64 ^a				4.94 ^b			
			Medium / <i>Ad-libitum</i>	258 ^c				3.11 ^a			
			<i>Ad-libitum</i> / <i>Ad-libitum</i>	338 ^d	79			3.03 ^a			
			<i>Ad-libitum</i> / Medium	150 ^b				4.45 ^b			

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Study	Age (d)	Breeding weight (kg)	Treatment group	Liveweight change _{P1-P140} (g/day)	Conception rate (%)	Second and third trimester pregnancy loss (%)	Gestation length	Birth or foetal weight (kg)	Colostrum yield (g)	Lamb Survival (%)	Lamb weight (kg)/growth (g/day)
Wallace <i>et al.</i> (2000)	210	43.6	Medium <i>Ad-libitum</i>	90 ^a 301 ^b				4.19 ^b (d128) 2.65 ^a			
Wallace <i>et al.</i> (2002a)	210	45.6	Medium	52 ^a				4.19 (d130)			
Wallace <i>et al.</i> (2002b)	210	45	<i>Ad-libitum</i> Medium <i>Ad-libitum</i>	282 ^b 52 ^a 275 ^b				2.65 ^a 4.6 ^b (d134) 3.3 ^a	155 ^a		304 ^a
Da Silva <i>et al.</i> (2002)	210	46	Medium	68 ^a				4.3 ^b (d131)			
Wallace <i>et al.</i> (2003) ²	210	46	<i>Ad-libitum</i> Medium	308 ^b 66 ^a			148 ^b 144 ^a	2.96 ^a 5.16 ^b			
Da Silva <i>et al.</i> (2003)	210	43.5	<i>Ad-libitum</i> <i>Ad-libitum</i> + P4 Medium	299 ^b 289 ^b 57 ^a				2.89 ^a 4.15 ^b 1.42 (d103)			
Wallace <i>et al.</i> (2004) ³	210	46	Medium + GH <i>Ad-libitum</i> <i>Ad-libitum</i> + GH	255 ^b 81 ^a 78 ^a 270 ^b 313 ^b				1.38 0.40 (d81) 0.42 0.42 0.44			

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Study	Age (d)	Weight (kg)	Treatment group	Liveweight change (g/day)	Conception rate (%)	Pregnancy loss (%)	Gestation length	Birth or foetal weight (kg)	Colostrum yield (g)	Lamb Survival (%)	Lamb weight (kg)/growth (g/day)
Wallace <i>et al.</i> (2006) ⁴	255	43.1	Medium	143 ^a				4.7 ^c			
			<i>Ad-libitum</i>	303 ^b				3.03 ^a			
			<i>Ad-libitum</i> +GHearly	299 ^b				2.96 ^a			
			<i>Ad-libitum</i> +GHlate	280 ^b				3.84 ^b			
Wallace <i>et al.</i> (2007)	255	45	Medium	32 ^a				4.37 ^b			
			<i>Ad-libitum</i>	187 ^b				2.97 ^a			
New Zealand studies											
Morris <i>et al.</i> (2005)	240	35.9	Maintenance	80 ^a			147.9	3.91		72	22.1 ^a (100 days old)
			Medium	145 ^b			147.9	3.78		71	23.7 ^b
Mulvaney <i>et al.</i> (2008)	240	36.1	<i>Ad-libitum</i>	210 ^c			146.1	3.94		76	23.9 ^b
			Maintenance	70 ^a	28 ^b			3.50 ^a		36 ^a	18.1 ^a (87 days old)
Kenyon <i>et al.</i> (2008b) ⁵	210	36.1	Medium	117 ^b	66 ^b	3 ^a		4.00 ^b		53 ^a	20.6 ^b
			<i>Ad-libitum</i>	225 ^c	46 ^a	32 ^b	145.8 ^a	4.00 ^b		85 ^b	21.8 ^b
			Medium	134 ^a	51	8		4.02		76	15.9 ^a (68 days old)
	210	39	Medium/ <i>Ad-libitum</i>	201 ^b	51	5	144.6 ^b	3.74		70	17.1 ^{ab}
	210	39	<i>Ad-libitum</i>	237 ^c	48	7	144.8 ^b	4.21		67	17.7 ^b

¹ Study involved a nutritional switch at Day 50 of pregnancy and the liveweight change is presented until Day 104 as no data was provided until term and the pregnancy rate was only provided for *ad-libitum* and medium groups, ² Study involved progesterone (P4) supplementation to *ad-libitum* group from Day 5 until Day 55, ³ Study involved

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growth hormone (GH) supplementation from Days 35 to 80 of pregnancy,⁴ Study involved growth hormone (GH) supplementation between Day 35 and Day 65 (early) and Day 95 and Day 125 (late),⁵ Study involved a nutritional switch on day 36 of pregnancy that involved half of the medium group being re-allocated to the high level of nutrition.

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Conception rate

The affect of nutrition on the conception rate in the New Zealand and the U.K. studies has varied between years but, on average, nutrition did not affect conception rate (proportion pregnant at pregnancy diagnosis) (Table 2.3). Mulvaney *et al.* (2008) reported conception rate was decreased as a result of *ad-libitum* level of herbage from 5 days after the commencement of the breeding period compared to medium and low levels of herbage. In contrast, under similar pastoral New Zealand conditions, Morris *et al.* (2005) and Kenyon *et al.* (2008) reported that nutrition had no affect on the conception rate of hoggets. The study of Kenyon *et al.* (2008) reported that a greater number of hoggets returned to oestrus activity (identified by vasectomised rams) in the high treatment hogget group compared to medium and medium/high, but that did not lead to a difference in the conception rates between nutritional treatment groups. Infectious abortions were later identified as a potential interfering factor in the study of Mulvaney *et al.* (2008) and may have affected conception rate in high treatment hoggets. In addition, the study of Morris *et al.* (2005) commenced their nutritional treatment 13 days after the mid-point of the breeding period and the embryo has already began to develop at this stage of gestation (Symonds 2007). Therefore, restricting the potential affect variable nutritional levels may have on conception rate. However, the study of Kenyon *et al.* (2008) commenced their nutritional regimens on Day 5 of pregnancy. Therefore, the lack of an effect on conception rate can not be explained by the timing of the nutritional regimens.

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The U.K. study of Wallace *et al.* (1996) reported conception rate following embryo transfer was reduced in rapidly growing hoggets when compared to normally growing hoggets. However, in contrast, Wallace *et al.* (1997b) found the conception rate of rapidly growing hoggets was higher than that of normally growing hoggets. In addition, Wallace *et al.* (1999, 2010) reported conception rate did not differ between nutritional treatment groups. In these studies the condition scores and live weights of the young ewes were the same at the start of the study. Wallace *et al.* (2010) investigated the effect of two different condition scores (2.6 vs. 2.1) and reported that conception rate was not affected. However, these two groups also differed in live weight at the start of the study. The liveweight change achieved in the *ad-libitum* treatment group in the N.Z. studies was about 80 g/day lower than that achieved in the equivalent treatment group in the U.K. studies. This may further explain the differences in the conception rate between the two groups of studies. However, Annett & Carson (2006) reported that feeding *ad-libitum* levels to hoggets reduced conception rate than the medium levels of nutrition but were the same as maintenance levels. However, the hoggets that were fed the *ad-libitum* level only gained 90 g/day and was similar to that reported in medium treatment hoggets in the U.K. and the New Zealand studies.

This extensive variability observed indicates that the timing of the nutritional treatment is determining the conception rate and there are other intrinsic mechanisms that influence conception rate.

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Pregnancy loss

The pregnancy loss for both groups of studies was defined as:

$$\frac{((\text{Number of hoggets pregnant} - \text{number of hoggets that did not lamb}) / \text{number of hoggets pregnant}) * 100$$

The U.K. studies of Wallace *et al.* (1996, 1997a, 1997b) have consistently shown the incidence of pregnancy loss was higher in rapidly growing hoggets when compared to normally growing hoggets (Table 2.3). Wallace *et al.* (1996, 1997a) reported the pregnancy loss occurred on an average Day 125 of pregnancy, while Wallace *et al.* (1997b) reported the losses occurred between Days 135 and 142 of pregnancy. In addition, Mulvaney *et al.* (2008) reported *ad-libitum* levels of nutrition during pregnancy increased the incidence of pregnancy loss during the last third of pregnancy. However, the studies of Morris *et al.* (2005) and Kenyon *et al.* (2008) have not replicated the results observed by Mulvaney *et al.* (2008). During the study of Mulvaney *et al.* (2008) there were infectious disease identified on the same Massey University research farm (West *et al.* 2006, Howe *et al.* 2008). Therefore, the results of Mulvaney *et al.* (2008) need to be treated with caution.

A difference between the two groups of studies is the growth restricted foetuses and shorter gestation length resulting from the *ad-libitum* treatment hoggets in the U.K. studies and not in the N.Z. studies. The growth-restricted fetus is predetermined by an inefficient placenta which may play a critical role in maintaining pregnancy during late gestation. By contrast, an

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inadequate placenta in hoggets growing rapidly (i.e. in the U.K. studies) may lead to insufficient maternal nutrient transfer to the fetus to maintain pregnancy to term (Wallace *et al.* 1996). In addition, hogget breed (Suffolk or Dorset Horn X Greyface vs. Romney or Finn/Romney/Texel), the breeding method (embryo transfer vs. natural), type of diet (concentrate based ration vs. pastoral), age and live weight at the start of the experiments may have contributed to the differences observed in the results between the two groups of studies

Lamb birth weight

Lamb birth weight has consistently been shown to be reduced in *ad-libitum* fed hoggets in the U.K. studies (Wallace *et al.* 1996, 1997a, 1997b, 1999, 2000, 2002a, b, 2001, 2002a, b 2003, 2004, 2006, 2007; Da Silva *et al.* 2002, 2003, details in Table 2.3) compared to the medium treatment hoggets. However, lamb birth weights of lambs born to hoggets in the New Zealand studies has not been affected by *ad-libitum* levels of nutrition (Morris *et al.* 2005; Kenyon *et al.* 2008b; Mulvaney *et al.* 2008, for details see Table 2.3). However, Mulvaney *et al.* (2008) reported hoggets maintaining live weight during the first 100 days of pregnancy resulted in reduced lamb birth weight. In addition, severe nutritional restriction (60% of hogget maintenance requirements) during the first 31 days of pregnancy did not affect lamb birth weight compared to maintenance or *ad-libitum* levels of nutrition (Annett & Carson, 2006). While Swanson *et al.* (2008) reported allowing similar maintenance levels of a complete concentrate diet and *ad-libitum* had a detrimental affect on lamb birth compared to maintenance levels of the concentrate diet.

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Wallace *et al.* (1996) suggested that reduced lamb birth weight from *ad-libitum* concentrate feeding was due to reduced number of attachment sites and consequently restricted the surface area at the materno-placental interface. This results in restricted nutrient supply to the fetus. The growth retardation is not observed until the third trimester when the nutrient requirement for conceptus growth is increasing exponentially (Wallace *et al.* 1996, 1997a, 2004; Palmer *et al.* 1998). In addition, a switch from the *ad-libitum* to medium treatment increased lamb birth weight compared to the hoggets that were fed *ad-libitum* for the entire duration of pregnancy (Wallace *et al.* 1999). Supplementation of progesterone to *ad-libitum* fed hoggets from Day 5 to Day 55 of pregnancy increased lamb birth weight to an intermediate level between the two nutritional treatments. Also, supplementing growth hormone to the *ad-libitum* treatment hoggets from Day 80 to Day 125 of pregnancy increased lamb birth weight compared to *ad-libitum* fed hoggets that were either supplemented with growth hormone from Day 35 until Day 65 of pregnancy or no supplementation at all (Wallace *et al.* 2006). However, these lambs remained lighter than the lambs born to medium treatment hoggets (Wallace *et al.* 2006). These studies outline potential methods that can be utilised to alleviate the reduced birth weight of the lamb born to *ad-libitum* fed hoggets in the U.K. studies.

Gestation length

The U.K. studies of Wallace *et al.* (1996, 1997a, 1997b, 2003) and the New Zealand study of Kenyon *et al.* (2008b) reported that the gestation length was increased as a result of hoggets

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being fed medium levels of nutrition compared to *ad-libitum* feeding (Table 2.3). In contrast, the study of Morris *et al.* (2005) reported that nutrition did not affect gestation length.

Birth weight and gestation length are positively correlated (Wallace *et al.* 1996) and the shorter gestation length of the rapidly growing hoggets in the U.K. studies may explain the lighter birth weight of their resulting lambs. However, Mulvaney (2006) suggested that the three day difference in the gestation length between rapidly and normally growing hoggets did not completely explain the difference in lamb birth weight between the two groups and other mechanisms may also be involved in the lamb birth weight difference. In support of this, the difference in gestation length between medium and high treatment hoggets reported by Kenyon *et al.* (2008) was not associated with a difference in lamb birth weight.

Lamb survival

Lamb survival has been reported to be lower in the lighter lambs born to rapidly growing hoggets in the U.K. studies (Wallace *et al.* 1996). The New Zealand study of Mulvaney *et al.* (2008) found lamb survival was lower in lambs born to nutritionally restricted hoggets compared to lambs born to hoggets that were allowed medium and *ad-libitum* levels of herbage. However, Morris *et al.* (2005) and Kenyon *et al.* (2008) reported that nutrition did not affect lamb survival.

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Wallace *et al.* (1996) suggested that restricted nutrient supply to the placenta and restricted placental growth led to lambs suffering from hypoxia and hypoglycaemia which, may in turn, be detrimental to the development of the lambs' organs, hence, affect the survivability of the lamb. However, this issue has not been followed up in subsequent follow on studies, therefore, a clear conclusion can not be made.

The lighter lambs from the studies of Wallace *et al.* (1996) and Mulvaney *et al.* (2008) born to *ad-libitum* and maintenance fed hoggets, respectively, would have had a larger surface area per unit of weight. This could make the lambs more susceptible to hypothermia (McCutcheon *et al.* 1981). The reduction of adipose and glycogen stores in the lambs born to the rapidly growing hoggets in the study of Wallace *et al.* (2000) may have been expected to have a major impact on the viability of these lambs born into adverse environmental conditions. However, the study was conducted indoors and the lambs were not exposed to any climatic effect. In the outdoor study of Mulvaney *et al.* (2008) the lambs were also exposed to adverse environmental conditions and this may have further impacted on the viability of the lamb, however, the adipose and glycogen status of these lambs are unknown.

Lamb birth weight has previously been associated with the survival of singleton lambs born to hoggets (e.g. McMillan & McDonald 1983). However, Schruers *et al.* (2010) has recently reported that the birth weight of singleton lambs born to hoggets is not associated with the survival. This may indicate that the relationship between lamb birth weight and lamb survival is not very strong in hoggets. Other factors such as maternal and lamb behaviour, milk quality

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and colostrum intake could have more of an effect on the survival of singleton lambs born to hoggets.

Colostrum yield

Colostrum yield has consistently been lower in rapidly growing hoggets compared to normally growing hoggets (Wallace *et al.* 1996, 1997b, 2001; Da Silva *et al.* 2001) and this may have been caused by a reduction in the secretion of placental hormones that stimulate mammary gland development (Wallace *et al.* 1996). The U.S.A. study of Swanson *et al.* (2008) found providing a maintenance levels of nutrition to hoggets reduced the weight of the mammary gland compared to restricted (60% of the hogget maintenance requirements) or *ad-libitum* (1.4 times maintenance) levels of nutrition. The maintenance level of nutrition led to an increase in the colostrum yield compared to the restricted or *ad-libitum* levels of nutrition. This may indicate that the suggestion of Wallace *et al.* (1996) that the reduced colostrum yield of the hoggets growing rapidly was due to differences in mammary growth may not completely explain the difference in colostrum yield. However, the level of the nutrition provided by Wallace *et al.* (1996, 1997b, 2001), Da Silva *et al.* (2001) and Swanson *et al.* (2008) differed significantly. The *ad-libitum* level of nutrition in the study of Swanson *et al.* (2008) allowed for similar liveweight change during pregnancy as in the normally growing hoggets. Due to these differences in the nutritional regimens provided it makes it difficult to accurately compare the different results reported in the U.K. studies and the study of Swanson *et al.* (2008).

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Lamb growth and live weight

The growth rate of lambs during the first 12 weeks of life born to rapidly growing hoggets is lower than lambs born to normally growing hoggets; this difference remained up to 25 weeks of age (Da Silva *et al.* 2001). Also, Morris *et al.* (2005) and Mulvaney *et al.* (2008) reported that lambs born to hoggets which had had their nutrition restricted during pregnancy were lighter at 14 and 12 weeks of age, respectively. Likewise, Kenyon *et al.* (2008) reported lambs born to hoggets that were offered medium levels of nutrition during pregnancy were lighter at 11 weeks of age than lambs born to hoggets offered high or *ad-libitum* levels of nutrition during pregnancy.

The lower growth rate of the lambs born to rapidly growing hoggets or the lighter lambs from the restricted level of herbage treatment hoggets could be due to a positive association between birth weight and lamb growth rate (Greenwood *et al.* 1995). Morris *et al.* (2005) and Kenyon *et al.* (2008) found lamb birth weight was not affected by nutrition. However, the live weight of lambs born to hoggets that were offered maintenance (Morris *et al.* 2005) or medium (Kenyon *et al.* 2008) levels of nutrition was lighter than lambs that had dams that were offered *ad-libitum* levels of nutrition during pregnancy. This may suggest that the hoggets that were offered *ad-libitum* levels of nutrition during pregnancy produced more milk than hoggets offered maintenance or medium levels of nutrition during pregnancy. The difference in the live weight of lambs throughout lactation may be due to nutritional affects on milk production. However, no references to the effect of nutrition on milk production in hoggets could be found.

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Summary

This section outlined the effects of offering concentrate or pastoral based diets during pregnancy on reproductive performance. Offering *ad-libitum* concentrate diets consistently increased the incidence of abortion, reduced lamb birth weight, colostrum yield and lamb growth. The pastoral based diets resulted were more variable but they generally showed that there was no effect of different levels of intake on pregnancy rate, incidence of abortion or lamb birth weight. Interestingly, none of the reviewed studies examined the potential interaction between breeding performance and nutrition around the time of breeding.

Impacts of early-weaning

Early-weaning can be defined as the withdrawal of milk supply before weaning would 'normally' occur (Brown 1964). In New Zealand, lambs born to hoggets are usually weaned approximately 14 weeks of age (Kenyon *et al.* 2004a).

The survey of Kenyon *et al.* (2004b) identified that an important reason why farmers in New Zealand were not joining their hoggets with the ram was the reduced breeding performance of two-tooths (approximately 18 months of age) due a lighter live weight the time of breeding. To circumvent this problem, the lambs born to hoggets could be weaned earlier to enable preferential feeding of hoggets between weaning and the next breeding to ensure that two-tooth target live weights are met. However, there is no information that investigates the effect of early weaning and the impacts on the live weight of the hogget and her lamb(s). The following section reviews the information provided on early weaning of lambs born to mature multiparous ewes.

Ewe live weight

Early weaning of lambs born to mature multiparous ewes has led to an increase in ewes live weight (Corbett & Furnival 1976; Smeaton *et al.* 1979) or has had no effect on their live weight (Earl *et al.* 1990) (Table 2.4). Smeaton *et al.* (1983) reported that the greater ewe live weight as a result of early weaning was not reflected in a higher ovulation rate, whilst Fogarty *et al.* (1992) found that weaning the lambs at 6 weeks of age increased the

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proportion of ewes ovulating at the start of the subsequent breeding season than ewes weaned when their lambs were 9 and 12 weeks of age (for data see Table 2.4).

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Table 2.4. The effect of weaning age on mature multiparous ewe and lamb live weight. Within columns, data with different superscripts differ significantly ($P < 0.05$)

Study	Weaning age (weeks)	Lamb live weight (kg)	Ewe live weight (kg)	Comments
Geenty 1979	Study 1			
	4 (Cr)* ¹	30.4 ^a (24 weeks old)		Paper included numerous studies that included creep grazing (Cr) and slaughter data.
	12	31.1 ^{ab}		
12 (Cr)	32.6 ^b			
Study 2				
5		28.3 ^a (24 weeks old)		Lambs allowed to suckle for 8 hrs a day
9		32.9 ^b		
15		32.8 ^b		
Study 3				
4		38.9 ^a (30 weeks old)		
6		42.1		

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Study	Weaning age (weeks)	Lamb live weight (kg)	Ewe live weight (kg)	Comment
Furnival & Corbett (1976)	6	Lamb growth check after weaning up to 12 weeks of age		
	Unweaned at 12 weeks	Constant growth up 12 weeks of age		
Corbett & Furnival (1976)	18	48.1		
	6			Ewe live weight change increased after weaning
	12			Ewe live weight change increased after weaning
Rattray <i>et al</i> (1976)	Study 1			
	4	28.2 (18 weeks old)		
	6	29.8		
	8	30.8		
	Study 2			
	3.5	17.3 (12 weeks old)		
	12	23.4		

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Study	Weaning age (weeks)	Lamb live weight (kg)	Ewe live weight (kg)	Comment
Smeaton <i>et al.</i> (1979)	8	23.5 ^{ab} (14 weeks of age)	+2.5 kg (14 weeks post-lambing)	Only presented differences in the ewe live weight and only data on early vs. late). Also had nutritional levels (4.7 kg DM/ewe vs. 2 kg DM/ewe) during the weaning period
	14 (4.7 allowance)	23.8 ^a	-2.5 kg	
	14 (2 allowance)	22.9 ^b	-2.5 kg	
Earl <i>et al.</i> (1990)	Unweaned		0 kg difference when lambs are 18 weeks of age	
	8		0	
	9		0	
Fogarty <i>et al.</i> (1992)	6	20.7 ^a (12 weeks), 27.1 ^x (20 weeks)		
	9	23.1 ^b , 29.3 ^y		
	12	25.6 ^c , 31.1 ^z		
deNicolò <i>et al.</i> (2006)	10	24.2 ^a (17 weeks old)	51.9	
	13	25.9 ^b	53.9	

*Cr indicates that lambs were weaned using creep grazing

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Lamb live weight and survival

Weaning lambs born to mature multiparous ewes at 3 to 5 weeks of age has led to reduced lamb survival one week after weaning compared to lambs weaned at 12 weeks of age (Ratray *et al.* 1979), whilst weaning prior to 8 weeks of age has either reduced lamb live weight up to 18 weeks of age (Furnival & Corbett 1976; Ratray *et al.* 1979; Geenty 1979; Smeaton *et al.* 1979; Geenty & Sykes 1981; Earl *et al.* 1990) or had no effect on lamb live weight when weaned at 8 weeks of age (Furnival & Corbett 1976; Ratray *et al.* 1979; Smeaton *et al.* 1979; Earl *et al.* 1990) (for data see Table 2.4). In contrast, Jagusch *et al.* (1970) reported lambs born to mature ewes could be weaned at 3 to 5 weeks with no detrimental affect on lamb live weight compared to lambs that remained suckling until 11 weeks of age.

The rumen in the lamb develops to adult proportions between 3 to 8 weeks of age. The rate of development is determined by the amount of solid feed ingested (Wardrop & Coombe 1961). Lambs start to ingest herbage by 3 weeks of age (Joyce & Ratray 1970). Geenty & Sykes (1981) found that lambs which were weaned at 4 weeks ingested more herbage at 6, 9 and 12 weeks of age compared to lambs weaned at 12 weeks of age. However, there was a marked reduction in energy intake of lambs weaned at 4 weeks of age, although, the reticulo-rumen of the early weaned lambs would have been substantially more developed than in the later weaned lambs (Ratray *et al.* 1976). In addition, Fogarty *et al.* (1992) suggested that the younger the lamb at weaning, the greater requirement for milk as the energy source. Consequently, the lambs weaned at a very young age need to substitute herbage from reduced

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milk intake and cannot obtain the sufficient energy intake to maintain growth. It has also been reported that the size of the rumen will limit intake (Conrad 1966). This indicates that the cause of growth restriction of early weaned lambs could be due to reduced energy intake, and/or a reduced ability to digest the substantially greater volume of herbage ingested by the early weaned lambs versus greater volumes of milk in the lambs that had their weaning delayed. In addition, at low herbage availability, weaning as early as 8 weeks of age will not reduce lamb growth rate. However, when herbage availability is moderately restricted, delaying weaning improves lamb growth (Fogarty *et al.* 1992).

Carcass traits

Dressing out percentage was either reduced (Geenty 1979; Rattray *et al.* 1976) or not affected by early weaning (Earl *et al.* 1990; Fogarty *et al.* 1992). Geenty (1979) reported that early weaning reduced the total carcass fat primarily due to reduced kidney fat. In contrast, Gibb *et al.* (1981) reported fat depots were not affected solely by weaning age and was primarily due to the differences in lamb live weight associated with early weaning. In addition, Fennessy *et al.* (1972) reported that very early weaning (3.5 weeks old) resulted in fat mobilisation of body fat in response to a low energy intake (Geenty & Sykes 1981) while Rattray & Jagusch (1977) found early weaned lambs were in a negative energy balance and mobilising fat which may explain why the early weaned lamb carcass had reduced fat levels.

Summary

Chapter 2: Literature review

This section has shown that early weaning of lambs can increase mature multiparous ewe live weight, whilst the live weight of the lamb could be decreased as a result of early weaning. It is apparent that there is a lack of data examining this aspect of breeding hoggets.

Overall summary of literature

This review has shown that there is a lack of literature that:

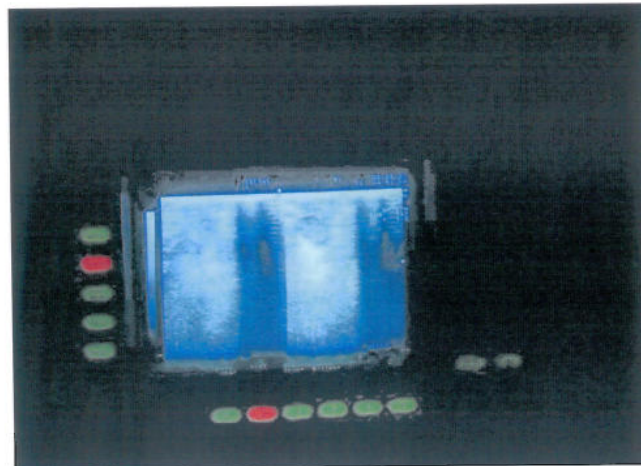
- Compares the reproductive performance and pregnancy loss of hoggets and mature multiparous ewes when they are bred at the same time.
- Investigates the effects of different nutritional levels around the time of breeding and there is inconsistencies in the results studies that investigated the effects of different levels of nutrition during pregnancy.
- Investigates the effect of early weaning of lambs born to hoggets on hogget and lamb live weight.

This thesis will compare the effects of breeding hoggets and mature multiparous ewes in the same flock under New Zealand pastoral conditions on reproductive performance and pregnancy loss. It will also investigate the effects of different levels of pastoral nutrition around the time of breeding on the reproductive performance of hoggets and the effect of early weaning of lambs born to hoggets on hogget and lamb live weight.

Chapter 3: A comparison between the reproductive performance of hoggets and mature multiparous ewes



The setup for the transrectal ultrasound scanning in Experiment 3.2



The computer screen from which the ovarian data were collected

This chapter is to be submitted to: Animal Production Science.

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

Introduction

Under New Zealand pastoral conditions, the docking percentage (number of lambs present at the time tail removal/number of lambs born *100/1) of hoggets is 60% (Kenyon *et al.* 2004b) whilst the lambing percentage of mature multiparous ewes is 127 % (Anon 2010). Currently in New Zealand, hoggets are joined with the ram approximately a month later than mature multiparous ewes and are bred separately. Therefore, directly comparing the reproductive outcomes of the hoggets and mature multiparous ewes is difficult. Comparing the reproductive performance of hoggets and mature multiparous ewes when they have been bred simultaneously may identify key reproductive differences between the types of ewes. This knowledge may help to develop better management practices to maximise the reproductive performance of hoggets.

Previous studies that included hoggets and mature multiparous ewes that were bred separately, have shown that the ovulation rate is higher (Dyrmundsson 1973; Quirke & Hanrahan 1977; Beck *et al.* 1996; Khan *et al.* 2007) and embryonic loss is lower (Edey *et al.* 1978; Hamra & Bryant 1979; Quirke 1979; McMillan & McDonald 1985; Beck *et al.* 1994, 1996) in mature multiparous ewes compared to hoggets. Furthermore, it has been reported that in mid- to late-pregnancy, pregnancy loss is greater in hoggets compared to mature multiparous ewes (Ptak *et al.* 1999; Atta & Khidir 2005). This results in a higher rate of pregnancy failure in hoggets (Bichard *et al.* 1974; Forrest & Bichard 1974).

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

Therefore, the objective of the current experiments was to compare the proportion bred, ovulation rate, proportion that returned to oestrus, early pregnancy loss, pregnancy rate, pregnancy rank and late pregnancy loss between hoggets and mature multiparous ewes that have been bred at the same time of the year under New Zealand pastoral conditions. This knowledge could then be used to identify where further research is required to increase hogget reproductive performance.

Materials and methods

This chapter reports on two experiments that were conducted between May and October in 2007 (Experiment 3.1) and April and July in 2008 (Experiment 3.2).

Experiment 3.1

Experimental design and animals

Two hundred and ninety six Romney hoggets (40.0 ± 0.47 kg with a body condition score of 2.60 ± 0.03) and three-hundred-and-seven Romney mature multiparous ewes (3-5 years of age) (62.2 ± 0.46 kg with a body condition score of 2.71 ± 0.03) were utilised. Both groups were managed as one group and a CIDR (type G, Livestock Improvement Corporation, Hamilton, New Zealand) was inserted on 1st May twelve days prior to ram introduction (P-12). CIDRs were removed on P1. Fifty crayon harnessed Romney rams were introduced on 13th May (ram to ewe ratio 1:12) for a 5-day breeding period (P1-P5). Crayon rump marks were recorded daily. To ensure ease of management during the laparoscopy examination period (see later section for

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

details), the rams were removed at the end of P7 and re-introduced on the morning of P9 and were re-joined for a further 17 days (P9-P26). Rump crayon marks for this period were recorded on P26. Hoggets and mature multiparous ewes that were not identified as having crayon rump marks between P1 and P26 were removed from the remainder of the experiment.

Animal measurements

Hoggets and mature multiparous ewes were weighed, within 1 hour off pasture, on P1, P24, P52, P81, P102 and P143.

The condition score of the hoggets and mature multiparous ewes was determined on a 5 point scale (Jefferies 1961, 1=emaciated and 5=over-fat) at P1 and P143.

Determination of ovulation rate

On P8, laparoscopic examination of both ovaries was undertaken in all ewes. The ewes were restrained in a cradle for the duration of the examination period. Prior to examination, ewes were sedated with acetyl promazine (10 mg: Acezine 10 %, Ethical Agents Ltd., Auckland New Zealand); and lignocaine hydrochloride (20 mg/ ml, Nopaine: Phoenix Pharmaceutical Distributors Ltd., Auckland, New Zealand) was used at the site of entry of the laparoscope. The number of corpora lutea identified was used to determine the ovulation rate (number of corpora lutea/ewe that ovulated).

Pregnancy diagnosis and pregnancy loss

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

Ultrasonic examinations were conducted on all ewes utilising a real-time, B-mode scanner (Aloka SSD 5000 Echo Camera, Monitor Corp. Ltd, BC, Canada) using a 7.5 MHz transducer via abdominal on P69 to allow for the determination of pregnancy rank (0, 1 or 2 fetuses). On P110 and P143 the ewes were re-scanned and the subsequent pregnancy status (pregnant vs. not pregnant) was determined to allow for calculating pregnancy loss. Pregnancy loss between P69 and P110 was assumed to have occurred if the ewe was identified pregnant at P69 and not pregnant at P110, while pregnancy loss was assumed to occur between P110 and P143 if the ewe was identified as pregnant at P110 and not pregnant at P143.

Experiment 3.2

Experimental design and animals

Ninety-one Composite ($\frac{1}{2}$ Romney, $\frac{1}{4}$ Texel and $\frac{1}{4}$ Finn) hoggets and ninety-one mature Composite ewes (3-5 years of age) had a CIDR (type G, Livestock Improvement Corporation, Hamilton, New Zealand) inserted on 6th May for 12 days (P-12). Twelve days later (P1), CIDRs were removed and on 18th May, sixteen crayon harnessed, Dorset Down rams (8 months of age, ram to ewe ratio 1:12) were introduced to each sub-group (16 in total). Crayon rump marks were recorded daily for 5 days (P1-P5). At the conclusion of this breeding period, the two ewe groups were merged and six, crayon harnessed, vasectomised rams were introduced for a further 17 day period. Crayon rump marks were recorded on P12 and P21 to determine the ewes that returned to oestrus.

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

Animal Measurements

Ewes were weighed, within 1 hour off pasture, on P-32, P1, P6 and P69 and the body condition score recorded on P1 (Jefferies 1961).

Blood samples

To determine if puberty had been attained, a 10 ml blood sample, was taken by jugular venepuncture (SST gel and heparin clot activation, Becton Dickinson Vacutainer Systems, USA) from all hoggets on P-32, P-29, P-26, P-24, P-22, P-19 and P-15 before the progesterone CIDR was inserted. Puberty was defined as peripheral progesterone concentration >1 ng/ml for 2 or more consecutive samplings (Boulanouar *et al.* 1995).

To determine the progesterone clearance rate following CIDR removal, 10 hoggets and 10 mature multiparous ewes had 10 ml blood samples taken by jugular venepuncture (SST gel and heparin clot activation, Becton Dickinson Vacutainer Systems, USA) every 3 hrs for the 24 hrs immediately after CIDR removal (P1).

Samples were immediately placed on ice and then centrifuged at 905g for 15 minutes. The plasma was then frozen (-20°C) until analysis for progesterone concentration. Serum progesterone concentrations were analysed using radioimmunoassay (RIA kit, MP Biomedicals, USA). Using 10 μL aliquots, the intra- and inter-assay coefficients of variation were 9.7 and 10.4%, respectively and the assay sensitivity was 0.5 ng/ml.

Ultrasound examinations

Chapter 3: Hoggets and mature multiparous ewes: breeding performance

Ultrasonic examinations were conducted on all ewes utilising a real-time, B-mode scanner (Aloka SSD 5000 Echo Camera, Monitor Corp. Ltd, BC, Canada) using a 7.5 MHz transducer for transrectal examination on P9.

The diameter and number of follicles and corpora lutea were recorded (Vinoles *et al.* 2004). The number of corpora lutea identified was used to determine the ovulation rate (number of corpora lutea/ewe that ovulated). Follicles within the ovaries appear as black spherical structures whilst corpora lutea appear as distinct, homogenous structures (Vinoles *et al.* 2004).

Pregnancy diagnosis

All hoggets and mature multiparous ewes that displayed crayon marks had their pregnancy status (0, 1, 2 or fetuses) determined via trans-abdominal Real-Time Ultrasound Scanner using a 3.5hz probe, on P69 to allow for the determination of pregnancy rank.

Data analysis

Experiment 3.1

The fixed effects of the proportion of hoggets and mature multiparous ewes identified as having been bred during each stage (during the first 5 days only (P1-P5), the second 17 days only (P9-P26), during both periods (P1-P5 and P9-P26) or not bred at all), pregnancy rate (percentage of ewes joined with the ram scanned pregnant at P69), reproductive loss_{P7-P69} ((number of corpora lutea identified at P7- fetuses identified

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at P69/number of corpora lutea identified at P7)*100), percentage of the ewes that ovulated (at least one corpora lutea present at P7/number of ewes that were joined with the ram)*100) and pregnancy loss (percentage of ewes not pregnant at P110 or P143 but were pregnant at P69) were analysed using the generalised linear model for categorical data (GENMOD procedure, SAS 2005). Mature multiparous ewe and hogget condition score, ovulation rate (number of corpora lutea at P7/ewe that ovulated) and pregnancy rank (foetuses identified at P69/ewe that ovulated) were analysed using the generalised linear model for categorical data (GENMOD procedure, SAS 2005).

The mean ovulation rate, pregnancy rank and reproductive loss_{P7-P69} were analysed when each parameter was calculated based on all ewes joined with the rams.

Mean hogget and mature multiparous ewe live weight were all analysed using Generalised Linear Model (SAS 2005). In the models for liveweight, fixed effects of ewe group (hoggets vs. mature multiparous ewes) and pregnancy rank and their interaction were tested. Non-significant ($P>0.05$) interactions were removed from the model and re-run.

Experiment 3.2

The presence of follicles was analysed using the generalised linear model for categorical data (GENMOD procedure, SAS 2005). In both models, fixed effect of ewe group was tested.

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The size (measured using a ruler on the screen of the ultrasound) of the follicle and corpora lutea were analysed using the Generalised Linear Model procedure (SAS 2005). In both models, fixed effect of ewe age was tested.

Results

Experiment 3.1

Live weight and condition score

Mature multiparous ewes were heavier ($P < 0.05$) than hoggets on P1 (61.7 ± 1.4 vs. 39.7 ± 1.2 kg), P50 (65.2 ± 0.9 vs. 44.4 ± 1.0 kg), P99 (73.3 ± 1.0 vs. 51.5 ± 1.1 kg) and P143 (78.2 ± 1.6 vs. 56.3 ± 1.7 kg).

Breeding performance

A greater ($P < 0.05$) proportion of mature multiparous ewes were bred during the first 5 days (P1-P5) than hoggets, while more ($P < 0.05$) hoggets were bred between P9 and P26 than mature multiparous ewes (Table 3.1). Fewer ($P < 0.05$) mature multiparous ewes than hoggets were not bred by the end of the breeding period. There was no difference ($P > 0.05$) in the percentage of mature multiparous ewes and hoggets bred during both breeding periods.

Reproductive performance based on all ewes joined with the ram

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Of all the ewes that were joined with the ram, the ovulation rate (1.70 ± 0.04 vs. 0.90 ± 0.04) and pregnancy rank (1.42 ± 0.05 vs. 0.61 ± 0.05) was higher ($P < 0.05$) in mature multiparous ewes when compared to hoggets, respectively. Reproductive loss_{P7-P69} was lower ($P < 0.05$) in mature multiparous ewes (-1.62 ± 0.21 logit value, back-transformed percentage (16%)) compared to hoggets (-0.78 ± 0.23 , (31%)). The pregnancy rate was higher ($P < 0.05$) in mature multiparous ewes (-1.70 ± 0.16 , (98%)) compared to hoggets (0.12 ± 0.16 , (47%)).

Reproductive performance of only those ewes which ovulated

A greater ($P < 0.05$) percentage of mature multiparous ewes (-0.08 ± 0.12 (99%)) ovulated compared to hoggets (-0.47 ± 0.13 (68%)). The ovulation rate and the pregnancy rank was higher ($P < 0.05$) in mature multiparous ewes compared to hoggets (Table 3.2). The apparent reproductive loss_{P7-P69} was lower ($P < 0.05$) in mature multiparous ewes compared to hoggets.

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Table 3.1. Experiment 3.1, the mean (\pm s.e.) proportion of hoggets and mature multiparous ewes bred between P1 and P5 (First 5 days only), between P9 and P26 (Second 17 days only), in both periods (P1-P5 and P9-P26, Both periods) or not mated. Data is presented as logit-transformations \pm s.e. (back transformed percentages). Within columns, means with different superscripts differ significantly ($P < 0.05$).

	First 5 days only	Second 17 days only	Both periods	Not mated at all	
	n				
Hogget	296	-0.40 \pm 0.11 ^{a,1} (60 ²)	2.80 \pm 0.25 ^b (6)	1.77 \pm 0.17 (14)	1.39 \pm 0.02 ^b (20)
Mature multiparous ewe	307	-1.57 \pm 0.15 ^b (83)	5.72 \pm 1.00 ^a (0)	1.66 \pm 0.16 (17)	4.62 \pm 0.58 ^a (0)

¹Logit-transformed

²Back-transformed (%)

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Table 3.2. Experiment 3.1, the mean (\pm s.e.), pregnancy rank and reproductive loss_{P7-P69} (logit-transformations \pm s.e. (back transformed percentages)) of hoggets and mature multiparous ewes that ovulated. Data for ovulation rate, pregnancy rank and reproductive loss_{P7-P69} is based on only those ewes from each age group that ovulated. Within columns, means with different superscripts differ significantly ($P < 0.05$).

	n	Ovulation rate	Pregnancy rank	Reproductive loss _{P7-P69}
Hogget	201	1.14 \pm 0.04 ^a	0.67 \pm 0.05 ^a	-0.16 \pm 0.13 ^{b,1} (41 ²)
Mature multiparous ewe	305	1.82 \pm 0.03 ^b	1.59 \pm 0.04 ^b	-0.83 \pm 0.21 ^a (13)

¹Logit-transformed

²Back-transformed (%)

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Pregnancy loss

Pregnancy loss between P69 and P110 and between P110 and P143 did not differ ($P>0.05$) between groups (data not shown). The overall pregnancy loss from P69 to P143 was 2% and 5% for the hoggets and mature ewes, respectively, however this was not significant ($P>0.05$).

Experiment 3.2

Live weight and condition score

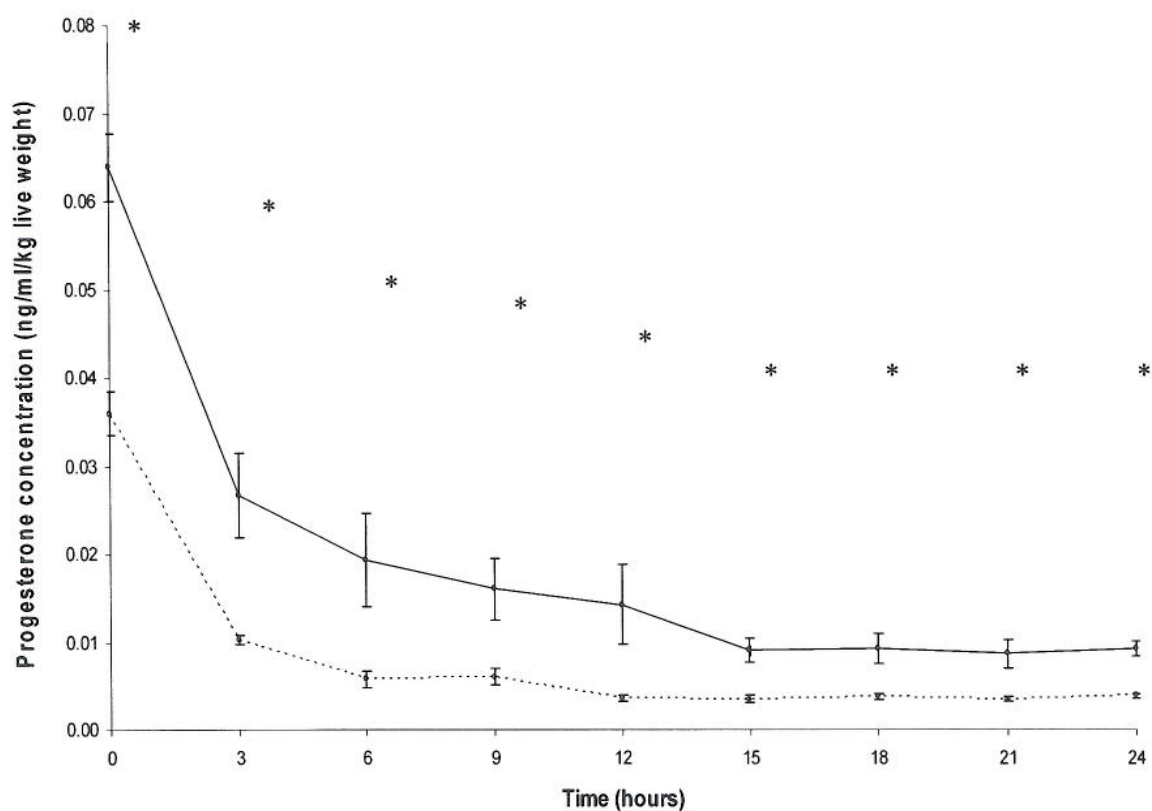
Mature multiparous ewes were heavier ($P<0.05$) than hoggets on P-32 (60.9 ± 0.3 vs. 37.2 ± 0.7 kg), P1 (58.0 ± 0.3 vs. 35.4 ± 0.7 kg) and P69 (63.6 ± 0.8 vs. 36.8 ± 0.8 kg). The condition score of mature multiparous ewes (2.24 ± 0.05) was higher than hoggets (1.99 ± 0.05) at P1.

Peripheral progesterone concentration 24 hrs post CIDR removal

Absolute peripheral progesterone concentration did not differ ($P>0.05$) between groups for the 24 hr period after CIDR removal (data not shown). When progesterone concentration is presented as a proportion of live weight at the time of CIDR removal, progesterone concentrations in hoggets remained higher ($P<0.05$) than in mature multiparous ewes at each time point during the 24 hr period after CIDR removal (Figure 3.1).

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Figure 3.1. The progesterone concentration (ng/ml) as a proportion of ewe group live weight at the time of CIDR removal (mean \pm s.e.) of hoggets and mature multiparous ewes during the 24 hour period immediately after CIDR removal in experiment 2. (—●— = hoggets, - - - o - - - = mature multiparous ewes, * indicates significant ($P < 0.05$)).



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Breeding performance

No hoggets reached puberty, as detected by peripheral progesterone concentration, prior to progesterone treatment (P-12). More ($P<0.05$) mature multiparous ewes were bred during the 5-day breeding period than hoggets (Table 3.3). A greater ($P<0.05$) proportion of hoggets returned to oestrus as identified by crayon rump mark between P6 and P26 compared to mature multiparous ewes.

Reproductive performance based on all ewes joined with the ram

Based on all ewes joined with the ram, the ovulation rate (1.84 ± 0.15 vs. 0.40 ± 0.16), pregnancy rank (1.38 ± 0.16 vs. 0.09 ± 0.14) and the pregnancy rate (1.12 ± 0.13 , 7% vs. -0.79 ± 0.13 , 86%) was higher ($P<0.05$) in mature multiparous ewes compared to hoggets. Apparent reproductive loss_{P6-P69} was lower ($P<0.05$) in mature multiparous ewes compared to hoggets (0.50 ± 0.13 , 24% vs. -0.50 ± 0.14 , 78%).

Reproductive performance based on ewes that ovulated

A greater ($P<0.05$) percentage of mature multiparous ewes (1.50 ± 0.12 , 97) ovulated compared to hoggets (-0.43 ± 0.14 , 27). When analysed based only on those which ovulated as detected by ultrasound, the ovulation rate and the pregnancy rank were higher ($P<0.05$) while the reproductive loss_{P7-P69} was lower ($P<0.05$) in mature multiparous ewes compared to hoggets (Table 3.4).

At ultrasound examination on P7, fewer ($P<0.05$) mature multiparous ewes had follicles present and a greater proportion ($P<0.05$) had corpora lutea present compared

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to hoggets (Table 3.5). Follicles and the corpora lutea were larger ($P < 0.05$) in mature multiparous ewes ($P < 0.05$) than in hoggets.

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Table 3.3. Experiment 3.2, the proportion of hoggets and mature multiparous ewes (mean \pm standard error, s.e.) bred between P1 and P5 (Bred P1-P5), returning to oestrus between P6 and P26 (Total return). Data are presented as logit-transformations \pm s.e. (back transformed percentages). Within columns, means with different superscripts differ significantly ($P < 0.05$).

	Bred P1-P5		Total return _{P6-P26}	
	n		n	
Hogget	91	0.37 \pm 0.12 ^{a,1} (30 ²)	27	0.23 \pm 0.11 ^{b,1} (36 ²)
Mature multiparous ewe	91	1.47 \pm 0.07 ^b (97)	88	0.69 \pm 0.08 ^a (18)

¹Logit-transformed

²Back-transformed (%)

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Table 3.4. Experiment 3.2, hogget and mature multiparous ewe (\pm s.e.) percentage that ovulated (logit-transformations \pm s.e. (back transformed percentages)) ovulation rate, pregnancy rank, reproductive loss_{P7-P69} (logit-transformations \pm s.e. (back transformed percentages)). Data for ovulation rate, pregnancy rank and reproductive loss _{P7-P69} is based on only those ewes from each age group that ovulated. Within columns, means with different superscripts differ significantly (P<0.05).

	n	Ovulation rate	Pregnancy rank	Reproductive loss _{P7-P69}
Hogget	25	1.44 \pm 0.16 ^a	0.32 \pm 0.13 ^a	-0.50 \pm 0.14 ^{b,1} (78 ²)
Mature multiparous ewe	88	1.84 \pm 0.15 ^b	1.42 \pm 0.16 ^b	0.50 \pm 0.13 ^a (23)

¹Logit-transformed

²Back-transformed (%)

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Table 3.5. Experiment 3.2, the presence of follicles and corpora lutea (CL) and the mean (\pm s.e.) diameter of follicles (mm) and the mean (\pm s.e.) cross sectional area of CL (mm^2) in hoggets and mature multiparous ewes. The presence of follicles and corpora lutea is presented as logit-transformations \pm s.e. (back transformed percentages). Within columns, means with different superscripts differ significantly ($P < 0.05$).

	Presence of		Diameter of follicles		Area of CL	
	Follicles	CL	n^1	n^2	n^1	n^2
Hoggets	91	0.35 \pm 0.08 ^{b,3} (31 ⁴)	24	3.46 \pm 0.19 ^a	34	70.45 \pm 5.54 ^a
Mature multiparous ewes	91	1.06 \pm 0.12 ^a (8)	8	5.57 \pm 0.41 ^b	167	93.73 \pm 2.38 ^b

¹Number of follicles

²Number of CLs

³Logit-transformed

⁴Back-transformed (%)

Discussion

These two experiments were designed to investigate the difference in reproductive performance between mature multiparous ewes and hoggets after synchronisation of oestrus with progesterone. Progesterone synchronisation was utilised to enable the intensive measurements to be undertaken, although it is acknowledged that this probably induced puberty in some of the hoggets, since progesterone treatment would have increased the progesterone concentration which mimics the increase in the progesterone concentration prior to puberty (Ryan *et al.* 1991). Both of the experiments were conducted during the middle of the breeding season of the mature multiparous ewes. Therefore, it was assumed that all mature multiparous ewes would be displaying spontaneous oestrous cycles. The insertion of progesterone containing CIDRs led to oestrus synchrony in mature multiparous ewes and would have probably disturbed the normal oestrous cycle in some of the ewes. However, without this synchrony it would not have been possible to examine the two age groups under the same experimental conditions.

Fewer hoggets were bred in both experiments. This could be due to hoggets not having reached puberty or displaying less intense oestrus or having irregular length oestrous cycles (Hare & Bryant 1985). In Experiment 3.2, no hoggets had reached puberty prior to progesterone synchronisation, but 30% of the hoggets were bred following progesterone treatment, which has been previously reported by Burfening & Berardinelli (1986). This indicates that progesterone treatment can stimulate puberty in a proportion of hoggets but not all. The hoggets that were involved in this experiment were within the live weight range where they would have been expected

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to have displayed oestrus activity. The progesterone treatment occurred in May (Autumn). In New Zealand, most hoggets are bred in May. Further studies could consider a comparison in mid- to late-May when more hoggets would have naturally reached puberty. A possible explanation for the smaller proportion of hoggets bred post progesterone synchronisation could be due a slower progesterone clearance rate as indicated in Experiment 3.2. This may have restricted the rapid increase in oestrogen (Moore *et al.* 1969) that is required to stimulate a sufficient LH peak for ovulation.

Experiment 3.2 identified a greater proportion of hoggets returning to oestrus between P6 and P26. Previous studies have not investigated this and it is a section of potential reproductive loss that requires further investigation. It has been reported that the majority of early embryonic loss occurs by Day 26 of pregnancy (Al Wahab & Bryant 1978; Beck & Davies 1994; Beck *et al.* 1996). Following embryonic loss, the hogget has variable inter-oestrus intervals and some hoggets do not return to oestrus at all after embryo loss (Beck *et al.* 1996). Annet & Carson reported that fewer hoggets conceived compared to mature multiparous ewes which may also explain why more hoggets returned to oestrus activity.

The ovulation rate was lower in hoggets in both experiments and reflects the results of previous experiments (Dyrmundsson 1973; Quirke & Hanrahan 1977; Beck *et al.* 1996; Khan *et al.* 2007). The ovulation rate sets the potential number of lambs that can be weaned. Therefore, further studies are required to investigate methods to increase the proportion of hoggets that ovulate within the breeding period. Secondly,

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means to increase the ovulation rate may be worth considering although multiples may not be ideal in hoggets.

Reproductive loss in early pregnancy was greater in hoggets than mature multiparous ewes in both experiments. Possible explanations for the greater reproductive loss in the hoggets include poor oocyte developmental competency (Wright *et al.* 1976; McMillan & McDonald 1985; O'Brien *et al.* 1996, 1997; Morton *et al.* 2005), a delay in the formation of blastocysts (Ptak *et al.* 1999; Morton *et al.* 2005) and insufficient luteal function to facilitate prolific blastocyst growth (Khan *et al.* 2007). In experiment two, the corpora lutea in hoggets were smaller than those in the mature multiparous ewe and may not have released sufficient progesterone to facilitate blastocyst growth, leading to embryo mortality.

Conclusion

These experiments have identified a number of reproductive traits that were poorer in hoggets. These include a lower proportion of hoggets bred, a lower ovulation rate, a greater proportion of bred hoggets returning to oestrus, fewer hoggets ovulating and a greater reproductive loss in early- to mid-pregnancy, all culminating in a reduced reproductive performance of hoggets in both experiments.

Implications

Further experiments are now required to investigate methods to evaluate methods to increase the proportion of hoggets that were bred and reducing early reproductive loss

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to allow for improved reproduction in hoggets. These experiments may benefit from utilising non-synchronised ewes as there is potential for synchronisation to affect the results obtained.

Chapter 4: A comparison of the lambing behaviour of hoggets and mature multiparous ewes and the fitness of their lambs for survival



A hogget and her lamb with another curious pregnant hogget ‘interfering’

This chapter is to be submitted to: Animal Production Science.

Chapter 4: Hoggets and mature multiparous ewes: Maternal and lamb behaviour

Introduction

Comparing hoggets and mature multiparous ewes and their lambs' performance in the immediate post-partum period and during lactation could provide information for the development of improved farm management systems for managing the hoggets during this period. Maternal and lamb behaviour, lamb survival and lamb weaning weight have not been compared between the offspring of hoggets and mature multiparous ewes.

There is a paucity of data that offers a comparison between hoggets and mature multiparous ewes of the survival and birth weight of their lambs. The exception is the study of Annett & Carson (2009) who reported that lambs born to hoggets were lighter at birth compared to those born to mature multiparous ewes. The studies of Alexander *et al.* (1993) and Ekiz *et al.* (2007) of housed sheep in Australia and Europe, respectively, reported that lamb survival of lambs born to two-year-old primiparous and mature multiparous ewes did not differ. However, under New Zealand pastoral conditions, the survival of lambs born to primiparous two-year-old ewes has been reported to be lower compared to mature multiparous ewes (Morris *et al.* 2000). Lamb birth weight is known to be strongly related with the survival of lambs born to mature multiparous ewes (Everett-Hincks & Dodds 2008; Morel *et al.* 2009). Lambs born to primiparous two-year-old ewes are lighter than lambs born to mature multiparous ewes (Dwyer & Lawrence 2000; Dwyer *et al.* 2005; Notter *et al.* 2005; Gardner *et al.* 2007) possibly due to smaller and less efficient placentas (Dwyer *et al.* 2005). Lambs born to two-year-old primiparous ewes are also lighter during lactation and at weaning (Notter *et al.* 2005; Gbangboche *et al.* 2006). Primiparous

Chapter 4: Hoggets and mature multiparous ewes: Maternal and lamb behaviour

two-year-old dams produce less milk (Peeters *et al.* 1992; El-Saied *et al.* 1999) and it is of poorer quality (Sevi *et al.* 2000) with reduced fat, protein, lactose (Peeters *et al.* 1992), and IgG (Annett & Carson 2006) content compared to mature multiparous ewes.

There is also a lack of data that allows comparison of the behaviour of the lamb and its dam between hoggets and mature multiparous ewes. However, it is known that primiparous two-year-old dams are more likely to delay physical contact (Otal *et al.* 2009) and grooming of their offspring (Owens *et al.* 1985; O'Connor *et al.* 1992; Ekiz *et al.* 2007) than mature multiparous ewes. They are also more likely to move away from their lamb (O'Connor *et al.* 1992; Dwyer & Lawrence 2000), step over (O'Connor *et al.* 1992) and circle their lamb when it attempts to suck (O'Connor *et al.* 1992; Dwyer & Lawrence 2000) compared to multiparous mature dams. They also display an increased fear response to the presence of humans, have slower dam-lamb bond formation (Dwyer *et al.* 1998) and show increased rates of rejection of their lamb (Dwyer & Lawrence 2000; Otal *et al.* 2009). In addition, lambs born to two-year-old primiparous dams display a higher frequency of suckling during the first three days (Dwyer *et al.* 2003) compared to mature multiparous ewes. Overall, as a result of these negative behavioural characteristics, two-year-old primiparous dams are less likely to bond with their young lambs (O'Connor *et al.* 1992; Dwyer *et al.* 1998, 2003; Dwyer & Lawrence 2000; Otal *et al.* 2009). There have been no published studies that compare the behaviour of primiparous ewe lamb and mature multiparous ewe around the time of lambing and the interaction of the dam with their offspring.

Chapter 4: Hoggets and mature multiparous ewes: Maternal and lamb behaviour

It is hypothesised that hoggets are likely to be poorer mothers compared to mature multiparous ewes and their lambs would be lighter at birth and weaning, have reduced colostrum intake, be less likely to survive compared to lambs born to mature multiparous ewes. To test this hypothesis, mature multiparous ewes and hoggets and their offspring were compared from birth to weaning.

Materials and Methods

Experimental design and animals

Two hundred and ninety six Romney hoggets and 307 Romney mature multiparous ewes (3-5 years of age) had progesterone CIDRs inserted (type G, Livestock Improvement Corporation, Hamilton, New Zealand). After 12 days, CIDRs were removed (P1) and 50 eight month old, crayon harnessed, Romney rams were introduced for 26 days (P1-P26). For further detail of the breeding system see Chapter 3.

Only one hundred and two single-bearing hoggets, 122 single- and 114 twin bearing mature multiparous ewes that had conceived during P1-P6 or P9-P26 period were used in the present study. The mature multiparous ewes and hoggets were managed as one group under commercial conditions from P1 until P143 when the pregnant ewes were set stocked.

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All pregnant ewes were set stocked in six paddocks on P143 at 15 ewes/ ha with a minimum herbage mass of 1200 kg DM/ha. Each paddock contained both mature multiparous ewes and hoggets. To aid in management during the lambing period, ewes that were identified as having conceived during the period P1-P6 or P9-P26 were managed in separate groups under the same pastoral conditions until 38 days after the start of the lambing period (L38) when both groups were re-joined.

Ewe live weight and condition score

Unfasted ewe live weight was recorded on P1, P50, P99, P143, L38, L59 and L75. The condition score of the ewes was recorded on P1, P143 and L75 (scale 0 to 5, 1=emaciated and 5=grossly fat, Jefferies 1961).

Lamb measurements

New born lambs were tagged within 12-18 hrs of birth, identified to their dam and their date of birth recorded, litter size and sex determined and live weight recorded. Additionally, crown rump length (CRL), thoracic girth (circumference of the chest immediately posterior to the forelimb), forelimb length (FL, distance from the shoulder joint to the tip of hoof on the left leg) and hind limb length (HL, distance from the hip joint to the tip of hoof on the left leg) were measured. Lambs were re-weighed, unfasted, on L38, L59 and L75.

Dam and lamb behaviour at tagging

Dam maternal behaviour was observed during the tagging process (within 12-18 hrs of birth) and scaled (range of one to five), using the maternal behaviour score (MBS,

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O'Connor *et al.* 1985). A score of one indicated that the dam left the tagging site by more than five metres and did not return while her lambs were handled and a score of five indicated that the dam stayed within five metres of the tagging site.

Immediately post-tagging, dam and lamb behaviour and vocalisation was recorded over a further five minute period. During this period, the time for the lamb to stand on all four feet, time for the lamb(s) and its dam to make contact, time for the lamb to bleat and number of bleats emitted by the lamb(s), time for the lamb to suck (lamb(s) holding the teat in its mouth and appeared to be suckling and remained in this position for at least five seconds (Dwyer *et al.* 2005)), time to follow dam at least five metres away from the tagging site (for twin litters, both lambs were required to follow) and the number of low (emitted with mouth closed (Dwyer *et al.* 1998)) and high pitch (emitted with mouth open (Dwyer *et al.* 1998)) bleats emitted by the dam were recorded. In the case of twin lambs born to mature multiparous ewes, recording any behaviour trait for both the dam and the lamb(s) was only conducted if complete litters were present at tagging.

Lamb plasma collection and analysis

Twenty-four to thirty-six hrs after birth, two five ml blood samples were collected from 40 single-lambs born to hoggets, 40 single- and 40 twin-lambs born to mature multiparous ewes (n=120 in total) by jugular venepuncture into a lithium heparin and a sodium fluoride-potassium oxalate vacutainers (Becton Dickinson Vacutainer Systems, USA). Blood samples were immediately placed on ice and centrifuged at approximately 905g for 15 minutes. The plasma was then frozen at -20°C until

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analysis for glucose and gamma-glutamyl transferase (GGT) concentration. Glucose was analysed using a hexokinase assay and GGT was analysed using a radioimmunoassay diagnostic kit (Roche Diagnostics Ltd, Switzerland). The inter- and intra-assay covariation was 4 and 6% for glucose and 6.2 and 7.3% for GGT, respectively.

Data analysis

Dam and lamb live weight, lamb dimensions, GGT and glucose concentrations, dam and lamb behaviour and vocalisation parameters were analysed using the generalised linear model procedure for continuous data (GLM, SAS 2005). In the models for the above parameters, single-rearing and twin-rearing mature multiparous ewes and single-rearing hoggets were compared. In the model for lamb live weight at L1, L38, 59 and L75 and lamb dimensions at L1, sex of lamb was used as a fixed effect and date of birth was included as a covariate. The lamb dimensions were also analysed with birth weight included in the model as a covariate. In the model for lamb live weight at L38, 59 and L75 four groups were compared (single lambs born to hoggets and mature multiparous ewes, twin lambs born to mature multiparous ewes raised as twin or a single).

Lamb survival to L75 (lambs present at L75/lambs born) were analysed using the generalised linear model procedure for binomial categorical data (GENMOD, SAS 2005). This model included the fixed effect of dam group.

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Maternal behaviour score was analysed using the generalised linear model procedure for categorical data (GENMOD, SAS 2005). The presence or absence dams that emitted a high or low pitch bleat was analysed using the generalised linear model procedure for categorical data (GENMOD SAS 2005) and the model included the fixed effect of dam group. Of the dams that emitted low or high pitch bleats, the low and high pitch bleats were expressed as a percentage of total dam bleats (i.e. for the low pitch bleats, $(\text{low pitch bleats}/(\text{low}+\text{high pitch bleats}))\times 100$) and was analysed using the generalised linear model for continuous data (GLM, SAS 2005) and the fixed effects of dam group were included.

The percentage of lambs that emitted at least one bleat, stood, suckled, made contact and if the lamb followed the dam if the dam left the tagging area was analysed using the generalised linear model procedure for categorical data (GENMOD, SAS 2005). For those lambs that displayed that behaviour, lamb time to bleat and the number of bleats emitted, lamb time to stand, time to make contact, time to stand and time to follow. These parameters were analysed using the Generalised Linear Model procedure (SAS 2005) and the fixed effect of dam group was included in the model.

Results

Ewe live weight and body condition score

Live weight of single- and twin-bearing mature multiparous ewe did not differ ($P>0.05$) at P1 and P50 but both dam groups were heavier ($P<0.05$) than single-bearing hoggets (Table 4.1). At P79, P99 and P145, twin-bearing mature multiparous

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ewes were heavier ($P < 0.05$) than single-bearing mature multiparous ewes, which were in turn heavier ($P < 0.05$) than single-bearing hoggets. On L38, L59 and L75, mature multiparous ewes rearing a single lamb or twin lambs and mature multiparous ewes rearing a single lamb that was born as a twin were heavier ($P < 0.05$) than hoggets rearing single lambs. On L38, L59 and L75, the live weight of hoggets rearing a singleton was heavier ($P < 0.05$) than mature multiparous ewes rearing twin lambs but both dam groups did not differ ($P > 0.05$) from the live weight of mature multiparous ewes that were born as a twin but reared a single lamb.

On P1, the condition score of twin-bearing mature multiparous ewes (2.75 ± 0.04) was greater ($P < 0.05$) than single-bearing hoggets at (2.61 ± 0.03) but did not differ from single-bearing mature multiparous ewes (2.69 ± 0.05). On P145, the condition score of single-bearing mature multiparous ewes (3.05 ± 0.05) were greater ($P < 0.05$) than the condition score of twin-bearing mature multiparous ewes (2.80 ± 0.05). The condition score of single-bearing hoggets (2.23 ± 0.04) was lower ($P < 0.05$) than the condition score of twin-bearing mature multiparous ewes on P145. By L75 single-bearing mature multiparous ewes (2.48 ± 0.06) and mature multiparous ewes that gave birth to twin but only reared a single (2.47 ± 0.12) did not differ ($P > 0.05$) in condition score. Both of these dam groups had greater ($P < 0.05$) condition scores than hoggets rearing a single lamb (2.10 ± 0.04) or mature multiparous ewes rearing twins (2.14 ± 0.04). The latter two groups did not differ ($P > 0.05$).

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Table 4.1. The effect of dam group (single-bearing hoggets vs. single-bearing mature multiparous ewes vs. twin-bearing mature multiparous ewes vs. twin-bearing mature multiparous ewes that reared a single) on dam live weight (\pm s.e., kg) during pregnancy and in lactation. Within rows, means with different superscripts differ significantly ($P < 0.05$).

	Single-bearing hoggets		Single-bearing mature multiparous ewes		Twin-bearing mature multiparous ewes		Twin-bearing mature multiparous ewes that reared a singleton	
	n		n		n		n	
P1	102	40.2 \pm 0.6 ^a	106	61.5 \pm 0.7 ^b	240	62.6 \pm 0.7 ^b	25	69.0 \pm 1.8 ^{bc}
P50	102	40.2 \pm 0.5 ^a	106	61.6 \pm 0.7 ^b	240	63.2 \pm 0.6 ^b	25	64.1 \pm 1.9 ^{bc}
P79	102	44.4 \pm 0.6 ^a	106	67.8 \pm 0.7 ^b	240	70.0 \pm 0.6 ^c	25	64.2 \pm 1.6 ^{bc}
P99	102	46.4 \pm 0.5 ^a	97	69.0 \pm 0.7 ^b	227	72.0 \pm 0.6 ^c		
P145	102	54.9 \pm 0.5 ^a	96	77.1 \pm 0.8 ^b	226	81.2 \pm 0.7 ^c		
L38	81	50.9 \pm 0.6 ^a	90	70.4 \pm 0.9 ^c	201	67.2 \pm 0.8 ^b	25	69.0 \pm 1.8 ^{bc}
L59	81	48.6 \pm 0.8 ^a	90	65.8 \pm 0.9 ^c	192	62.3 \pm 0.8 ^b	25	64.1 \pm 1.9 ^{bc}
L75	81	48.5 \pm 0.7 ^a	89	66.0 \pm 0.9 ^c	192	62.7 \pm 0.8 ^b	25	64.2 \pm 1.6 ^{bc}

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Lamb live weight and dimensions

Single lambs born to mature multiparous ewes were heavier ($P < 0.05$) at birth than single lambs born to hoggets or twin lambs born to mature multiparous ewes (Table 4.2). On L38 and L75, single lambs born to mature multiparous ewes were heavier ($P < 0.05$) than single lambs born to hoggets or twin lambs born to mature multiparous ewes and reared as twins, but did not differ ($P > 0.05$) from twin lambs born to mature multiparous ewes reared as singles (Table 4.2). The live weight of single lambs born to hoggets did not differ ($P > 0.05$) from the live weight of twin lambs born to mature multiparous ewes and reared as twins on L38, L59 and L75.

Crown rump length did not differ ($P > 0.05$) between lambs born to hoggets or mature multiparous ewes (Table 4.3). Thoracic girth circumference and foreleg length was greater ($P < 0.05$) in single lambs born to mature multiparous ewes than twin lambs born to mature multiparous ewes which in turn was greater ($P < 0.05$) than single lambs born to hoggets. The rear leg length of single lambs born to mature multiparous ewes was longer ($P < 0.05$) than either single lambs born to hoggets or twin lambs born to mature multiparous ewes. The latter two groups did not differ ($P > 0.05$). The crown rump length and rear leg length did not differ ($P > 0.05$) between groups when lamb dimensions were analysed with birth weight as a covariate. The thoracic girth of single and twin lambs born to mature multiparous ewes did not differ ($P > 0.05$). The thoracic girth of single lambs born to hoggets was smaller ($P < 0.05$) than single lambs born to mature multiparous ewes. The foreleg length of single and twin lambs born to mature multiparous ewes did not differ ($P > 0.05$) but single lambs born to hoggets had

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a shorter ($P < 0.05$) foreleg length when compared to lambs born to mature multiparous ewes.

Lamb survival

Lamb survival did not differ ($P > 0.05$) between single (logit value 2.05 ± 0.21 , back-transformed percentage (89%)) and twin lambs (2.22 ± 0.39 , (89%)) born to mature multiparous ewes or single lambs (1.35 ± 0.24 , (79%)) born to hoggets.

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Table 4.2. The effect of dam group (hoggets rearing a single lamb (hogget-single) vs. mature multiparous ewes rearing a single lamb (mature multiparous ewe-single) vs. mature multiparous ewes rearing a single lamb but born as a twin (mature multiparous ewe- 2-1) vs. mature multiparous ewes rearing twin born lambs (mature multiparous ewe-2-2)) on lamb live weight (\pm s.e., kg) at L1, L38, L59 and L75. Within columns, means with different superscripts differ significantly ($P < 0.05$).

	L1		L38		L59		L75	
	n		n		n		n	
Hogget-single	101	4.04 \pm 0.14 ^a	80	11.22 \pm 0.29 ^a	15.23 \pm 0.47 ^a	16.77 \pm 0.56 ^a		
Mature multiparous ewes-single	122	5.33 \pm 0.14 ^b	109	14.10 \pm 0.31 ^b	19.50 \pm 0.50 ^b	21.60 \pm 0.57 ^b		
Mature multiparous ewe-2-1			25	12.99 \pm 0.58 ^b	18.08 \pm 0.89 ^b	20.83 \pm 1.01 ^b		
Mature multiparous ewe-2-2	226	4.41 \pm .13 ^a	178	11.38 \pm 0.26 ^a	15.00 \pm 0.44 ^a	17.28 \pm 0.52 ^a		

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Table 4.3. The effect of dam group (hogget-single bearing vs. mature multiparous ewe-single vs. bearing mature multiparous ewe-twin) on mean (\pm s.e.) lamb birth weight (Birth weight, kg), crown rump length (CRL, cm), thoracic girth (Girth, cm), rear leg length (RL, cm) and fore leg length (FL, cm). Within columns, means with different superscripts differ significantly ($P < 0.05$).

	n	CRL	Girth	RL	FL
Hogget-single	102	50.51 \pm 3.56	38.33 \pm 0.54 ^a	37.18 \pm 2.83 ^a	36.89 \pm 0.54 ^a
Mature multiparous ewe-single	122	55.19 \pm 3.39	42.05 \pm 0.53 ^c	42.76 \pm 2.70 ^b	39.86 \pm 0.52 ^c
Mature multiparous ewe-twin	228	54.40 \pm 3.27	39.69 \pm 0.50 ^b	38.15 \pm 2.60 ^a	38.14 \pm 0.50 ^b

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Maternal behaviour

The maternal behaviour score was lower ($P < 0.05$) for hoggets who gave birth to singles (2.32 ± 0.15) than for mature multiparous ewes who gave birth to either single (3.34 ± 0.14) or twin lambs (3.46 ± 0.11). The later groups did not differ ($P > 0.05$).

The percentage of ewes that moved more than five metres from the tagging site, did not differ ($P > 0.05$) between ewe groups (0.27 ± 0.28 , (57%), 0.50 ± 0.62 , (62%), 0.76 ± 0.20 , (68%)) for hoggets that gave birth to a single lamb and mature multiparous ewes that gave birth to single or twin lambs, respectively).

Ewe vocalisation

A greater ($P < 0.05$) percentage of hoggets that gave birth to a single lamb emitted high pitch bleats than did mature multiparous ewes that gave birth to twin lambs. The percentage of mature multiparous ewes that gave birth to single lambs emitting high pitch bleats did not differ ($P < 0.05$) from that of the mature multiparous ewes that gave birth to twins (Table 4.4). The percentage of ewes that emitted low pitch bleats did not differ ($P > 0.05$) between ewe groups.

Of the dams that bleated, mature multiparous ewes that gave birth to twin lambs emitted more ($P < 0.05$) low pitch bleats compared to either hoggets or mature multiparous ewes that gave birth to a single lamb (Table 4.4) with neither of the latter dam groups differing ($P > 0.05$) from each other. Of the dams that bleated, mature multiparous ewes that gave birth to twin lambs emitted more ($P < 0.05$) high pitch bleats compared to hoggets that gave birth to a single lamb, but did not differ

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($P < 0.05$) from mature multiparous ewes that gave birth to twins (Table 4.4). In addition, mature multiparous ewes that gave birth to single and twin lambs did not differ ($P > 0.05$) from each other.

When the number of low pitch bleats were expressed as a percentage of the total bleats (i.e. low + high pitch bleats), mature multiparous ewes that gave birth to twin lambs (67.0 ± 3.1) had a greater ($P < 0.05$) percentage of low bleats compared to hoggets that gave birth to a single lamb (54.6 ± 4.6). The percentage of low pitch bleats of the total bleats did not differ ($P > 0.05$) between hoggets that gave birth to a single lamb or mature multiparous ewes that gave birth to a single lamb (57.40 ± 4.3). In addition, mature multiparous ewes that gave birth to single and twin lambs did not differ ($P > 0.05$) from each other.

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Table 4.4: The effect of dam group (hoggets-single vs. mature multiparous ewe-single vs. mature multiparous ewe-twin) on the proportion (logit value \pm s.e. (back transformed percentage) of dams that emitted low pitch bleats (Low), the proportion of dams that emitted high pitch bleats (High) and the mean (\pm s.e.) number of low pitch bleats (Low pitch) and high pitch bleats (High pitch) emitted by the dam within the five minute period immediately post-tagging. Means within columns with different superscripts differ significantly ($P < 0.05$).

	Percentage of dams emitting			Number of bleats ³			
	Low		High	Low pitch		High pitch	
	n			n	n	n	
Hogget-single	53	1.19 \pm 0.27 ¹ (94 ²)	1.19 \pm 0.24 ^b (94)	50	12.00 \pm 2.45 ^a	50	11.02 \pm 1.13 ^b
Mature multiparous ewe-single	61	0.79 \pm 0.24 (86)	0.60 \pm 0.32 ^{ab} (80)	53	11.06 \pm 2.38 ^a	49	9.02 \pm 1.12 ^{ab}
Mature multiparous ewe-twin	58	0.95 \pm 0.26 (90)	0.39 \pm 0.32 ^a (71)	52	18.44 \pm 1.70 ^b	41	6.78 \pm 0.85 ^a

¹Logit-transformed, ²Back-transformed (%), ³Calculated only from dams that emitted that type of bleat

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Lamb vocalisation

The percentage of lambs that emitted bleats and the time for the lamb to emit at least one bleat did not differ ($P>0.05$) between the three ewe groups (Table 4.5).

The number of bleats emitted by the lamb did not differ ($P>0.05$) between single and twin lambs born to mature multiparous ewes; but these two groups differed ($P<0.05$) such that single lambs born to hoggets emitted more bleats ($P<0.05$) than twin lambs born to mature multiparous ewes. The number of lamb bleats of single lambs born to hoggets did not differ ($P>0.05$) from single lambs born to mature multiparous ewes.

Lamb behaviour

There was no difference ($P>0.05$) in the percentage of lambs that made contact with their dam, stood, or followed their dam and moved more than five metres from the tagging between the three dam groups (Table 4.6). A higher ($P<0.05$) percentage single lambs born to hoggets suckled during the five minute observation period compared to mature multiparous ewes with a single lamb, but did not ($P>0.05$) differ from mature multiparous ewes with twin lambs. The percentage of single or twin lambs born to mature multiparous ewes that suckled did not differ ($P>0.05$) from each other.

The time for the lamb to bleat, follow, stand and suckle did not differ ($P>0.05$) between the three dam groups for lambs which displayed that trait (Table 4.7). Single lambs born to hoggets took longer ($P<0.05$) to make contact with their dam compared to twin lambs born to mature multiparous ewes, but did not differ ($P>0.05$) from

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single lambs born to mature multiparous ewes. The time for the lamb to make contact with their dam did not differ ($P>0.05$) between single and twin lambs born to mature multiparous ewes.

Lamb metabolite and GGT concentrations

There was no difference ($P>0.05$) between the groups in glucose concentration (5.96 ± 0.26 , 6.10 ± 0.26 and 5.83 ± 0.25 mmol/L for single lambs born to hoggets or mature multiparous ewes and twin lambs born to mature multiparous ewes, respectively) or GGT concentration (1048 ± 147.1 , 1238 ± 144.7 and 1217 ± 140.3 U/L for single lambs born to either hoggets and mature multiparous ewes and twin lambs born to mature multiparous ewes, respectively) of the lambs at 24 to 36 hrs post-birth.

Table 4.5. The effect of dam group (hogget-single vs. mature multiparous ewe-single vs. mature multiparous ewe-twin) on the percentage (logit value \pm s.e. (back transformed percentage) of lambs that emitted at least one bleat (Bleated) and the mean (\pm s.e) time for the lamb to bleat (LTTB, seconds) and number of bleats (NOB) within the five minute period immediately post-tagging. Within columns with different superscripts, differ significantly ($P < 0.05$).

	Percentage that bleated		
	Bleated	LTTB ³	NOB ³
	n	n	n
Hogget-single	1.38 \pm 0.18 ¹ (96 ²)	15.9 \pm 4.9	22.8 \pm 3.1 ^b
Mature multiparous ewe-single	1.28 \pm 0.23 (95)	20.0 \pm 4.7	15.9 \pm 3.0 ^{ab}
Mature multiparous ewe-twin	1.51 \pm 0.15 (97)	12.2 \pm 3.3	13.0 \pm 2.1 ^a

¹Logit-transformed, ²Back-transformed (%), ³Calculated only from dams that emitted at least one bleat

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Table 4.6: The effect of dam group (hogget-single vs. mature multiparous ewe-single vs. mature multiparous ewe-twin) on the percentage (logit value \pm s.e. (back transformed percentage) of lambs that stood on all four feet (Stood), that made contact (Contact), that suckled (Suckled) and followed their dam if she moved greater than 5 metres (Lamb followed) within the five minute period immediately post-tagging. Within columns with different superscripts, differ significantly ($P < 0.05$).

	Percentage of lambs that displayed that behaviour			
	Stood	Contact	Suckled	Lamb followed
N				
Hogget-single	53 1.38 \pm 0.28 ¹ (96 ²)	0.79 \pm 0.27 (86)	-0.12 \pm 0.28 ^b (43)	0.09 \pm 0.28 (55)
Mature multiparous ewe-single	61 1.28 \pm 0.30 (95)	0.91 \pm 0.29 (89)	-0.48 \pm 0.30 ^a (25)	0.31 \pm 0.28 (67)
Mature multiparous ewe-twin	116 1.51 \pm 0.18 (96)	0.91 \pm 0.20 (89)	-0.41 \pm 0.21 ^{ab} (28)	0.05 \pm 0.19 (53)

¹Logit-transformed, ²Back-transformed (%)

Table 4.7. The effect of dam group (hogget-single vs. mature multiparous ewe-single vs. mature multiparous ewe-twin) on the mean (\pm s.e.) time for lambs to stand (LTTS, seconds), lamb to make contact with dam (TTC, seconds), lamb to suckle (TTS, seconds) and to follow the dam if she left the tagging site (TTF, seconds) within the five minute period immediately post-tagging. Within columns with different superscripts, differ significantly ($P < 0.05$).

	LTTS ¹		TTC ¹		TTS ¹		TTF ¹	
	N	n	n	n	n	n	n	n
Hogget-single	51	36.8 \pm 7.5	44	42.9 \pm 6.4 ^b	22	95.4 \pm 12.3	29	116.8 \pm 12.7
Mature multiparous ewe-single	56	32.9 \pm 7.3	54	32.3 \pm 5.9 ^{ab}	14	102.5 \pm 16.4	41	111.5 \pm 10.7
Mature multiparous ewe-twin	106	35.6 \pm 5.1	102	20.8 \pm 4.3 ^a	32	121.2 \pm 11.1	60	110.9 \pm 8.8

¹Calculated only from dams that emitted at least one bleat

Discussion

The objective of this chapter was to compare the behaviour of the hoggets and mature multiparous ewes and their lamb(s) soon after birth, dam and lamb live weight and lamb survival to L75. To allow for a valid comparison the two age types of ewes were bred together in the same groups and exposed to the same rams and then managed during pregnancy and lactation as one groups.

The lighter single lambs born to hoggets compared to single lambs born to mature multiparous ewes could be due to a less efficient placenta (Dwyer *et al.* 2005) or an absence of a 'physiological imprint' (Gardner *et al.* 2007) and supports similar findings in yearling primiparous ewes (Annett & Carson 2006) and two-year-old primiparous ewes (Dwyer & Lawrence, 2000; Dwyer *et al.* 2005; Gardner *et al.* 2007). It has been suggested that the first pregnancy primes the uterus for subsequent pregnancies (Gardner *et al.* 2006). In the present study, the live weight of single lambs born to hoggets represented 11 % of the dam live weight at the start of the breeding period compared to 9% in mature multiparous ewes that gave birth to a single lamb. This suggests that maternal live weight at the start of the breeding period may limit lamb birth weight. In support of this, Schruers *et al.* (2010) found lamb live weight was positively correlated with live weight at the start of the breeding period (i.e. early May). In addition, providing *ad-libitum* levels of herbage during pregnancy has not had any affect on the birth weight of single lambs born to hoggets that were the same live weight at the start of the experiment (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008; Chapter 5 in this thesis)

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The live weight of single lambs born to hoggets remained lighter throughout lactation than that of single lambs born to mature multiparous ewes. The results of Annett & Carson (2006) and Gbangboche *et al.* (2006) support this finding. The lighter lambs born to the hoggets will be of less economic value (Gavigan & Rattray 2002). However, the options for the farmer include delaying the sale of the lambs until a later date or sell on the store market (Gavigan & Rattray 2002).

The maternal behaviour score was lower in hoggets, indicating poorer mothering ability than mature multiparous ewes with single or twin lambs. Interestingly, Vierin *et al.* (2002) reported that the fear response of two-year-old primiparous dams to humans was higher than the multiparous mature dams, which may indicate that the human interaction during the lambing process may have caused a bias in determining the MBS. Other authors investigating maternal behaviour of two-year-old primiparous ewes have found a delay in physical contact (Poindron & Le Neindre 1980; Otal *et al.* 2009), a depressed attraction to amniotic fluid on the lamb (Levy *et al.* 1983; Levy & Poindron 1987; Otal *et al.* 2009), poorer recognition of lamb odours (Dwyer & Lawrence 2000) and less accurate in selecting their lamb 4 to 6 hrs post-partum than multiparous dams (Kendrick *et al.* 1991). These combined studies indicate a substantial impairment of MBS in hoggets compared to mature multiparous ewe dams.

Dam low-pitched bleats have been strongly associated with the development of the ewe-lamb bond (Nowak 1996). Low-pitched bleats have been linked to ‘care-giver’

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bleats, while high-pitched bleats are considered 'protest' or distress bleats (Dwyer *et al.* 1998). In the present study, hoggets emitted a greater number of high-pitched bleats, but the number of low-pitched bleats did not differ between dam groups. It would have been expected that the mature multiparous ewe dam would have emitted more low-pitch bleats in parallel with their better MBS. The greater number of high-pitch bleats may over-ride the effect in determining the MBS and may indicate that the hoggets are more disturbed by the lambs being handled during the tagging process and that that disturbance continues until the conclusion of the observation period. It could also be indicative of inexperience in dam-lamb bonding displayed by the hogget.

In the current study, single lambs born to hoggets emitted more bleats and took longer to make contact with their mother than the mature multiparous ewes with a single lamb, further suggesting the immaturity of maternal behaviour development (Dwyer *et al.* 2003). Weary & Fraser (1995) suggested that vocal behaviour is an expression of need. The greater number of bleats emitted by single lambs born to hoggets may indicate they require more attention from their dam at this early age. This factor, along with a greater percentage of single lambs born to hoggets observed to be suckling during the 5 minute observation period in the present study may add to the suggestion by Dwyer *et al.* (2003) that the increased requirement for suckling was due to reduced milk ingestion per suckling bout which may partially explain the lighter weaning weight of the single lamb born to hoggets.

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The poorer maternal behaviour of the hogget with a single lamb, coupled with the lighter lamb birth weight would have been expected to significantly reduce lamb survival compared to the survival of single or twin lambs born to mature multiparous ewes. However, this was not observed in the present study, which supports the findings of Ekiz *et al.* (2006) and Alexander *et al.* (1993). Interestingly, Morris *et al.* (2000) reported that survival of lambs born to two-year-old primiparous dams was lower compared to lambs born to three- and four-year-old mature multiparous (91.0 vs. 93.1 vs. 93.9%, dams but was similar to lambs born to five-year-old dams (91.0 vs. 92.8%). However, the study of Morris *et al.* (2000) utilised a substantially larger data set than the present study, and the lack of a difference in the lamb survival between all dam groups in the present study may be insufficient to detect small differences on lamb survival. Further, colostrum intake, as assessed by GGT and glucose concentration, was the same in all dam groups in the present experiment and birth weight was within the optimal range (Everett-Hincks & Dodds 2008; Morel *et al.* 2009; Schruers *et al.* 2010) and this may also help explain the lack of a difference in lamb survival.

Conclusion

This study clearly shows that hoggets with singleton lambs have poorer mothering ability compared to mature multiparous ewes with single or twin born lambs. The behaviour of lambs born to hoggets indicates an insufficient ewe-lamb bond compared to the mature ewe and their lamb(s) which may be detrimental to lamb performance. Despite these differences, lamb survival did not differ between groups. Single lambs born to hoggets were lighter throughout lactation than single lambs born to mature

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multiparous ewes but the live weight did not differ from twin lambs born to mature multiparous ewe dams at L75.

Implications

The lighter lambs from the hoggets would reduce the economic value of the lamb. Improving maternal behaviour, dam-lamb bonding and gaining knowledge of the milking ability of hoggets in relation to mature multiparous ewes could provide farmers with management systems to increase total weight of lamb weaned per ewe. In addition, the differences in the live weight between single and twin lambs born to mature multiparous ewes may also be observed in their hogget counterparts and may warrant investigation.

Chapter 5: Effect of nutrition pre-breeding and during pregnancy on breeding performance of hoggets



A selection of hoggets involved in Experiment 5.1 in this chapter

Publication arising from this chapter: Mulvaney FJ, Morris ST, Kenyon PR, Morel PCH, West DM (2010) Effect of nutrition pre-breeding and during pregnancy on breeding performance of ewe lambs. *Animal Production Science* **50**, 953-960.

Chapter 5: Effects of nutrition pre-breeding and during the breeding and pregnancy period on reproductive performance

Introduction

Chapter 3 identified that fewer hoggets were bred and conceived and Chapter 4 showed that fewer hoggets lambed compared to mature multiparous ewes. Chapter 5 investigates the effect of nutrition prior to and during the breeding period and during pregnancy on reproductive performance, Chapter 6 investigates the relationship between average live weight and different nutritional treatments on reproductive performance and Chapter 7 investigates the effect of nutrition prior to and during the breeding period and during pregnancy on late pregnancy loss, lamb and hogget live weight and lamb survival. It is hypothesised that hoggets which are heavier at the time breeding and are offered higher levels of nutrition will have superior reproductive performance than lighter hoggets and hoggets fed lower levels of nutrition.

Under New Zealand pastoral systems, hogget reproductive performance is varied and often disappointing with lambing percentages ranging from below 5% to 120% (Kenyon *et al.* 2004b). In 2010, only 21% of total hoggets were joined with the ram with an average lambing percent of 40% compared to 125% in mature multiparous ewes (Anon 2010). These results suggest there is potential to increase hogget reproductive performance. A major reason offered by farmers for not joining hoggets with rams is their poor lambing percentage (Kenyon *et al.* 2004b).

Live weight of the hogget at the time of breeding is positively associated with the proportion displaying oestrus (Allison *et al.* 1975; Kilgour 1977), while Moore & Smeaton (1980) reported increasing live weight gain from 4 to 11 months of age increased the proportion of hoggets displaying oestrus.

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Increasing the herbage allowance to mature multiparous ewes for 1 to 6 weeks (Ratray *et al.* 1978; Ratray *et al.* 1980; Smeaton *et al.* 1982; Smith *et al.* 1983) or supplementing with lupin 4 or 6 days prior to breeding has increased reproductive rate of unsynchronised (Fletcher 1981; Stewart & Oldham 1986; Kenney & Roberts 1987) and synchronised (Nottle *et al.* 1997) mature Merino ewes. In hoggets, increasing the level of nutrition prior to breeding has either increased the proportion reaching puberty (Boulanouar *et al.* 1995) and displaying oestrus (Kassem *et al.* 1989), therefore, it is possible that increasing the level of nutrition to hoggets prior to breeding could increase the proportion bred.

These combined results potentially indicate that increasing the live weight of hoggets and/or increased levels of nutrition could be a means of increasing the proportion of hoggets displaying oestrus and improving their subsequent breeding performance. New Zealand pastoral grazing studies have either reported a reduction (Mulvaney *et al.* 2008) or no effect (Morris *et al.* 2005; Kenyon *et al.* 2008) in the proportion pregnant as a result of providing *ad-libitum* herbage during the breeding period and throughout pregnancy compared to medium levels of pasture. In addition, extreme liveweight gains as a result of utilising a complete concentrate diet has led to either decreased (Wallace *et al.* 1996), increased (Wallace *et al.* 1997b) or unaffected (Wallace *et al.* 1999) conception rates. The U.K. concentrate diet (Wallace *et al.* 1996; 1997b; 1999) and the New Zealand pastoral studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008) commenced their nutritional regimens after embryo transfer and natural breeding, respectively.

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The objective of the studies in this chapter were to investigate the effect of differing nutritional levels prior to breeding and during pregnancy on the proportion of hoggets bred, pregnancy rate, the number of fetuses identified at pregnancy diagnosis and pregnancy loss.

Materials and Methods

This chapter reports on two experiments that were conducted between May and July in 2006 (Experiment 5.1) and May and August in 2008 (Experiment 5.2).

Experiment 5.1

Experimental design and animals

Seventeen days (P-17) prior to ram introduction, 330 Romney hoggets were exposed to 8 harnessed vasectomised rams (ram to ewe ratio 1:40) to assist the transition to puberty. On P-4, hoggets were randomly allocated to 1 of 2 nutritional treatments ('medium' or '*ad-libitum*', n = 165). The aim of the 'medium' nutritional treatment was to achieve a total liveweight gain of 100 g/day through offering pre- and post-grazing herbage masses of 1400 and 1000 kg DM/ha, respectively, from P-4 to P64. The '*ad-libitum*' fed hoggets were offered *ad-libitum* herbage with the aim of them achieving a total liveweight gain of 200 g/day with pre- and post grazing herbage masses of 1800 and 1200 kg DM/ha, respectively, between P-4 and P64. The hoggets rotationally grazed a total area of 16 ha of mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) sward. The size of the grazing area and grazing interval for each nutritional treatment was determined by the previous live weight (see live weight measurements below), with herbage availability adjusted to ensure that liveweight targets were met. Herbage mass was monitored via a rising

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plate meter (Ashgrove Pastoral Products, Palmerston North) to determine the length of the interval spent on each grazing area. No herbage samples were collected from Experiment 5.1.

Animal measurements

Live weight

Hoggets were weighed un-fasted (within 1 hour off pasture) on P-17, P7, P15, P22, P29, P36, P50 and P64.

Reproduction

On P1, 4 Cheviot crayon harnessed mature rams (ram to hogget ratio of approximately 1:40) were introduced to the 'medium' and '*ad-libitum*' treatment groups (8 rams in total) for a 34-day breeding period (P1-P34). Crayon rump marks were recorded on P6, P17 and P34 and used as an indicator of breeding activity. Crayon colour was changed on all rams on P6 and P17. On P34 rams were removed. Hoggets were identified as being bred (crayon-marked by rams) during the first 6-day period only (P1-P6), bred in the first 17-day period only (P1-P17), bred in the second 17-day period only (P18-P34), bred in both 17-day periods (P1-P17 and P18-P34, returning to service) or not bred at all. All hoggets not bred during the entire 34-day breeding period were removed from the experiment, but this was recorded.

From P34 to P63, 4 vasectomised rams were introduced to each nutritional treatment to identify hoggets returning to service. Crayon harness marks were recorded on P50 and P63. Those hoggets identified as returning to service on either P50 or P63 were removed for the

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remainder of the experiment. Hoggets were identified as returning to service between P34 and P50 (P34-P50), between P50 and P63 (P50-P63) and between P34 and P63 (P34-P63).

Ultrasonic examinations were conducted on all ewes utilising a real-time, B-mode scanner via the abdomen (Aloka SSD 5000 Echo Camera, Monitor Corp. Ltd, BC, Canada) using a 7.5 MHz transducer and identified as bearing 0, 1 or 2 fetuses on P64.

Experiment 5.2

Experimental design and animals

Nutritional management pre-breeding and to the end of breeding

Three hundred and eighty two Romney hoggets were used in the experiment and were randomly allocated to 1 of 4 nutritional treatments. Ninety-six hoggets were allocated to a ‘maintenance’ nutritional treatment group, 96 were allocated to a ‘medium’ group, 97 to a ‘medium/*ad-libitum*’ group and 93 hoggets were allocated to the ‘*ad-libitum*’ treatment. The aim of the ‘maintenance’ treatment was to achieve no liveweight change from P-17 to P5 (pre- and post-grazing herbage masses of 1000 and 800 kg DM/ha, respectively), the target of the ‘medium’ treatment as to achieve 100 g/day gain from P-17 to P5 (pre- and post-grazing herbage masses of 1400 and 1000 kg DM/ha, respectively). For the ‘medium/*ad-libitum*’ treatment, the objective was to achieve 100 g/day from P-17 to P-4, thereafter, they were offered *ad-libitum* levels of herbage (pre- and post-grazing herbage masses of 1800 and 1200 kg DM/ha, respectively) from P-4 to P5. The ‘*ad-libitum*’ treatment was offered *ad-libitum* herbage (pre- and post-grazing herbage masses of 1800 and 1200 kg DM/ha, respectively) from P-17 to P5. The ‘medium’ and ‘medium/*ad-libitum*’ treatments were

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managed as one group from P-17 to P-4 while the ‘medium/*ad-libitum*’ and ‘*ad-libitum*’ treatments were managed as one group from P-5 to P5.

The hoggets rotationally grazed a total area of 16 ha of mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) sward. The size of the grazing area and grazing interval for each nutritional treatment group was managed in a similar manner as Experiment 5.1.

Oestrus was synchronised in all hoggets using intravaginal implants inserted on P-12 (CIDR, Pharmacia & Upjohn, New Zealand). Twelve days later, CIDRs were removed and 32 Dorset Down crayon harnessed ram lambs (8 months of age, ram to hogget ratio 1:12) were evenly allocated to the 4 groups (8 per group). Crayon rump marks were recorded daily for 5 days (P1 to P5) as an indicator of breeding activity. Following the 5-day breeding period, 3 crayon harnessed vasectomised rams were introduced into each group until P53. Crayon harness colour was changed on the vasectomised rams on P22 and P39. Crayon marks were recorded on P22, P39 and P53. Teasers were removed from the groups on P53.

Nutritional management from the end of breeding

On P5, ewes in each pre-breeding nutritional treatment groups were re-randomly allocated to either a ‘medium’ or ‘*ad-libitum*’ nutritional treatment and remained in their post-breeding nutritional treatments till P124. This resulted in 8 nutritional treatments (‘maintenance-medium’, ‘maintenance-*ad-libitum*’, ‘medium-medium’, ‘medium-*ad-libitum*’, ‘medium/*ad-libitum*-medium’, ‘medium/*ad-libitum*-*ad-libitum*’, ‘*ad-libitum*-medium’ and ‘*ad-libitum*-*ad-libitum*’).

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Animal measurements

Live weight

Hoggets were weighed un-fasted (within 1 hour off pasture) on P-17, P-6, P0, P6, P21, P40, P52, P87, P122. On P-15, the 'maintenance' treatment and on P-4, the 'medium/*ad-libitum*' treatments were re-weighed to monitor gut fill changes following a change in nutrition.

Breeding performance

Hoggets were identified as having been bred during the first 5-day breeding category (P1-P5). Hoggets that were marked by the vasectomised rams in the subsequent 17-day breeding category (P6-22) or marked by the vasectomised rams in the subsequent 30-day breeding category (P23-P53) were identified as returning to service.

Pregnancy diagnosis

Pregnancy diagnosis via a real time ultra sound scanner on P54 was carried out on all hoggets that did not return to service and were identified as bearing 0, 1 or 2 fetuses. All hoggets that were on P54 were again pregnancy diagnosed on P89 and P124. Non-pregnant hoggets were recorded and removed from the remainder of the experiment on each of these days.

Determining pregnancy loss

Pregnancy loss was assumed to occur if the hogget was identified as being pregnant on P54 but later diagnosed as not pregnant on either P89 or P124.

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Herbage analysis

Pre- and post- grazing herbage pluck samples were taken on P-17, P-6 and P5 from the 'maintenance', 'medium' and *ad-libitum* grazed areas and dried in a convection oven overnight at 105°C. Crude protein content of the herbage was determined by the total combustion method (LECO model, AOAC 968.06). Metabolisable energy was calculated using the formula: $0.163 \times \text{digestible organic matter digestibility (DOMD)}$ (Roughan and Holland (1977)). Neutral detergent fibre (NDF) and acid detergent fibre was determined using a Tecator Fibretec System (Robertson and van Soest 1981).

Data analysis

Experiment 5.1

Hogget live weight was analysed using the generalised linear model procedure for continuous data (GLM, SAS 2005). In the models for hogget live weight, fixed effects of pregnancy rank (bearing 0, 1 or 2 fetuses) and nutritional treatment and their interactions were tested for each parameter. Non-significant ($P > 0.05$) interactions were removed and the model re-run.

The proportions of ewes within each breeding category, mean pregnancy rate were analysed using the procedure generalised linear model for binomial categorical data with more than 2 groups (CATMOD, SAS 2005). The mean number of fetuses identified at pregnancy diagnosis was analysed using the procedure generalised linear model for binomial categorical data with more than 2 groups (CATMOD, SAS 2005).

Experiment 5.2

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Hogget live weight, breeding pattern (bred during the first 5 days and returning to cycling behaviour between P6 and P22 and P23 and P53), pregnancy rate, pregnancy rank at pregnancy diagnosis were analysed as in Experiment 5.1.

Pregnancy loss was analysed using the procedure generalised linear model for binomial categorical data with more than 2 groups (CATMOD, SAS 2005).

Results

Experiment 5.1

One hundred and sixty five hoggets were in each treatment group at the start of the experiment. Of these, 134 and 155 hoggets were bred in the 'medium' and '*ad-libitum*' treatments, respectively. Thirty-one and 10 hoggets, respectively, were not bred and were removed from the experiment. Thirty one and 25, respectively, returned to service (between P6 and P53) leaving 104 and 130 in the 'medium' and '*ad-libitum*' treatments, respectively, that were presented for pregnancy diagnosis at P64.

Live weight

On P-4, hogget liveweight did not differ ($P>0.05$) between treatment. On P7, '*ad-libitum*' treatment hogget were heavier ($P<0.05$) than 'medium' treatment hoggets and this difference was maintained throughout the experiment (Figure 5.1).

Breeding performance

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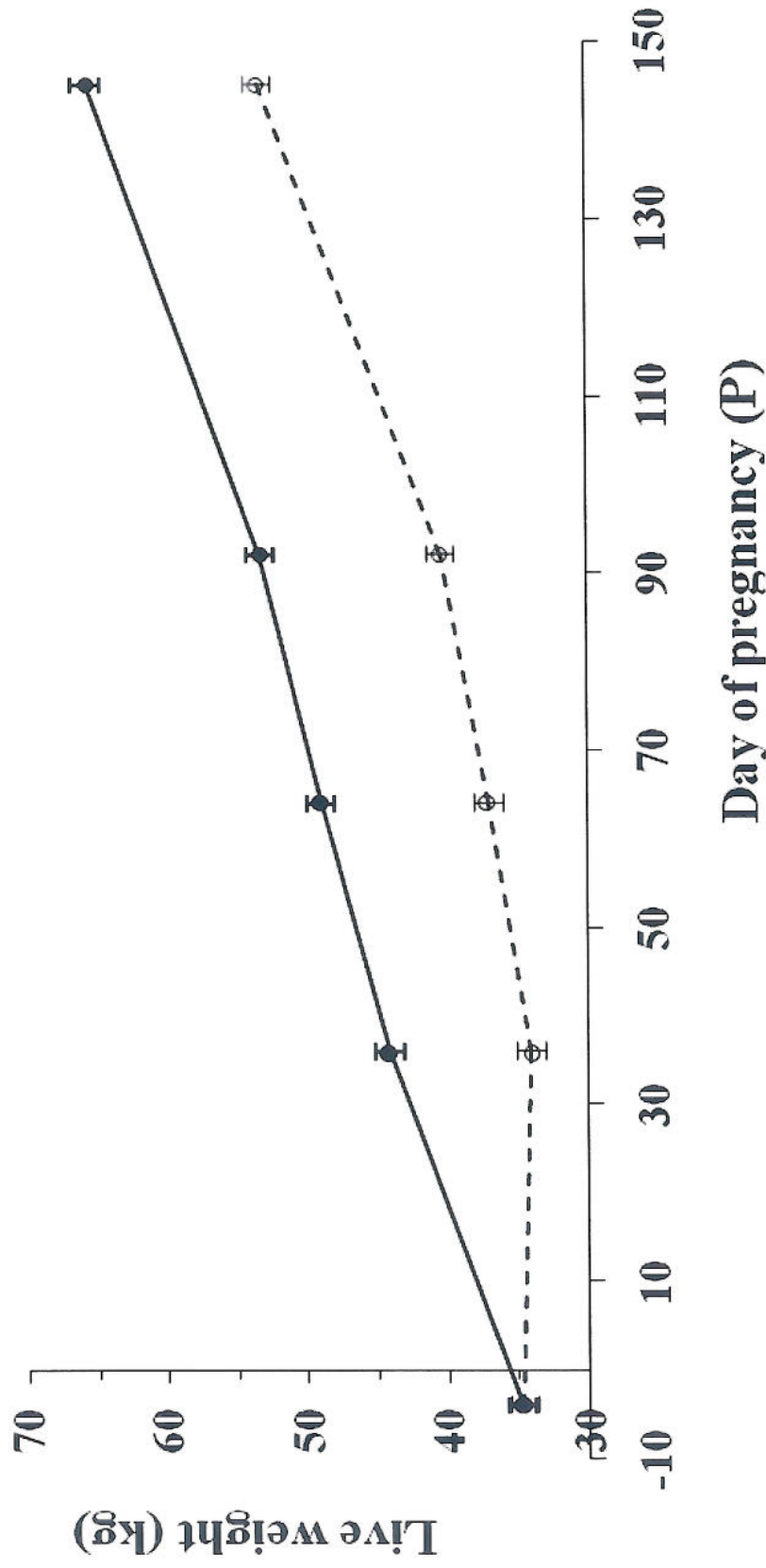
Nutrition had no effect ($P>0.05$) on the proportion of hoggets bred during the first six days (logit value -0.83 ± 0.17 , back transformed percentage (30%) vs. -0.66 ± 0.16 , (34%) for 'medium' and '*ad-libitum*' groups, respectively). More hoggets ($P<0.05$) were bred during the first 17-day period from the '*ad-libitum*' than the 'medium' treatments (Table 5.1). There was no effect ($P>0.05$) of nutritional treatment on the proportion of hoggets bred during the second 17-day period or during both 17-day periods. A greater proportion ($P<0.05$) of 'medium' hoggets were not bred compared to the '*ad-libitum*' treatment.

Hoggets bred returning to oestrus

More ($P<0.05$) of the 'medium' (-1.38 ± 0.32 , (20%)) treatment returned to oestrus during the P34-P50 period than the '*ad-libitum*' (-2.03 ± 0.23 , (12%)) treatment. However, nutritional treatment had no effect ($P>0.05$) on the proportion of hoggets that returned to oestrus during the P50 to P63 period (-3.55 ± 0.59 , (3%) and -2.92 ± 0.39 , (5%) for 'medium' and '*ad-libitum*' treatments, respectively).

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Figure 5.1. The effect of hogget nutrition ('medium' and 'ad-libitum') commencing 4 days prior to the start of the breeding period until day 64 of pregnancy (mean \pm s.e.). (--- = 'medium' and —●— = 'ad-libitum').



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Table 5.1. The effect of nutritional treatment ('medium' and *ad-libitum*') from 4 days prior to the start of the breeding period to day 64 of pregnancy on the mean (\pm s.e.) proportion (logit-transformation) of hoggets with crayon marks by rams recorded during the first 17-day period only (first 17-day period only, P1-P17), crayon marks by rams recorded in the second 17-day period only (second 17-day period only, P18-P34), crayon marks by rams recorded during both 17-day periods (both 17-day periods, P1-P17 and P18-P34) or no crayon mark recorded at all during the 34 day period (not bred).

Within columns, means with different superscripts differ significantly ($P < 0.05$).

	n			
	First 17-day period only	Second 17-day period only	Both 17-day periods	Not bred
'medium'	165	165	165	165
	0.01 \pm 0.16 ^{1,a} (50%) ²	-1.50 \pm 0.20 (18%)	-1.93 \pm 0.23 (13%)	-1.46 \pm 0.20 ^b (19%)
' <i>ad-libitum</i> '	165	165	165	165
	0.51 \pm 0.16 ^b (62%)	-1.46 \pm 0.20 (19%)	-1.93 \pm 0.23 (13%)	-2.74 \pm 0.33 ^a (6%)

¹Logit-transformed

²Back-transformed (%)

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Pregnancy data

Of the hoggets present at pregnancy diagnosis (n=104 for 'medium' and 130 for the 'ad-libitum' groups), pregnancy rate was not affected ($P>0.05$) by nutritional treatment (Table 5.2). However, the 'ad-libitum' treatment had a greater ($P<0.05$) proportion of hoggets identified as twin-bearing compared to the 'medium' treatment.

When the data were analysed using all the hoggets present at the start of the experiment, a greater ($P<0.05$) proportion of the 'medium' treatment were diagnosed not pregnant on P64 (-0.08 ± 0.16 , (48%)) compared to the 'ad-libitum' (-0.58 ± 0.16 , (37%)) treatment. In addition, the proportion of single-bearing hoggets was not ($P>0.05$) affected by nutritional treatment (0.01 ± 0.16 , (50%) vs. 0.32 ± 0.16 , (42%) for the 'medium' and the 'ad-libitum' treatment, respectively). However, more 'ad-libitum' (-1.28 ± 0.19 , (22%)) treatment hoggets were identified twin-bearing compared to the 'medium' (-3.98 ± 0.58 , (2%)) treatment. This resulted in a greater ($P<0.05$) number of fetuses identified per hogget presented for breeding in the 'ad-libitum' (0.86 ± 0.05) treatment compared to the 'medium' (0.57 ± 0.05) treatment.

Experiment 5.2

Of the original number of the hoggets joined with the ram, 58, 77, 86 and 76 hoggets were bred. Sixteen, 27, 32 and 24 returned to service, leaving 42, 50, 54 and 52 hoggets presented for pregnancy diagnosis on P54. Thirty-nine, 46, 50 and 49 hoggets were diagnosed pregnant on P54 for the 'maintenance', 'medium', 'medium/ad-libitum', 'ad-libitum' treatments, respectively.

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Table 5.2. The effect of nutritional treatment ('medium' and 'ad-libitum') from 4 days prior to the start of the breeding period to day 64 of pregnancy on the mean (\pm s.e.) proportion (logit-transformed) of hoggets present at pregnancy diagnosis that did not return to service that were diagnosed as not pregnant, single or twin bearing at day 64 of pregnancy. Within columns, means with different superscripts differ significantly ($P < 0.05$).

	n	Not Pregnant at Scanning		Twins
		Single	Twins	
'medium'	104	-1.58 \pm 0.26 ¹ (18%) ²	-0.12 \pm 0.18 (80%) ^b	-3.94 \pm 0.71 (2%) ^a
'ad-libitum'	130	-1.39 \pm 0.22 (20%)	-1.33 \pm 0.24 (53%) ^a	-0.92 \pm 0.19 (28%) ^b

¹Logit-transformed

²Back-transformed (%)

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Herbage quality

The metabolisable energy (ME) in the herbage during the pre-breeding period was 10.3 (range of 9.7 to 11.2), 11.2 (11 to 11.4) and 11.2 (10.7 to 11.4) megajoules ME for the 'maintenance', 'medium' and '*ad-libitum*' treatment paddocks, respectively. The crude protein percentage of the herbage was 27.3 (range of 25 to 29.1), 30.2 (26.6 to 34.4) and 25.9 (24.3 to 27.5) % for the 'maintenance', 'medium' and '*ad-libitum*' treatment paddocks, respectively. The NDF percentage of the herbage was 40.4 (range of 38.3 to 42.2), 33.4 (32.7 to 36.7) and 36.3 (34.8 to 37.6) % for the 'maintenance', 'medium' and '*ad-libitum*' treatment paddocks, respectively and the ADF percentage of the herbage was 19.7 (range of 17.5 to 22), 16.8 (15.2 to 18.3) and 16.9 (15 to 18.8) % for the 'maintenance', 'medium' and '*ad-libitum*' treatment paddocks, respectively.

Live weight

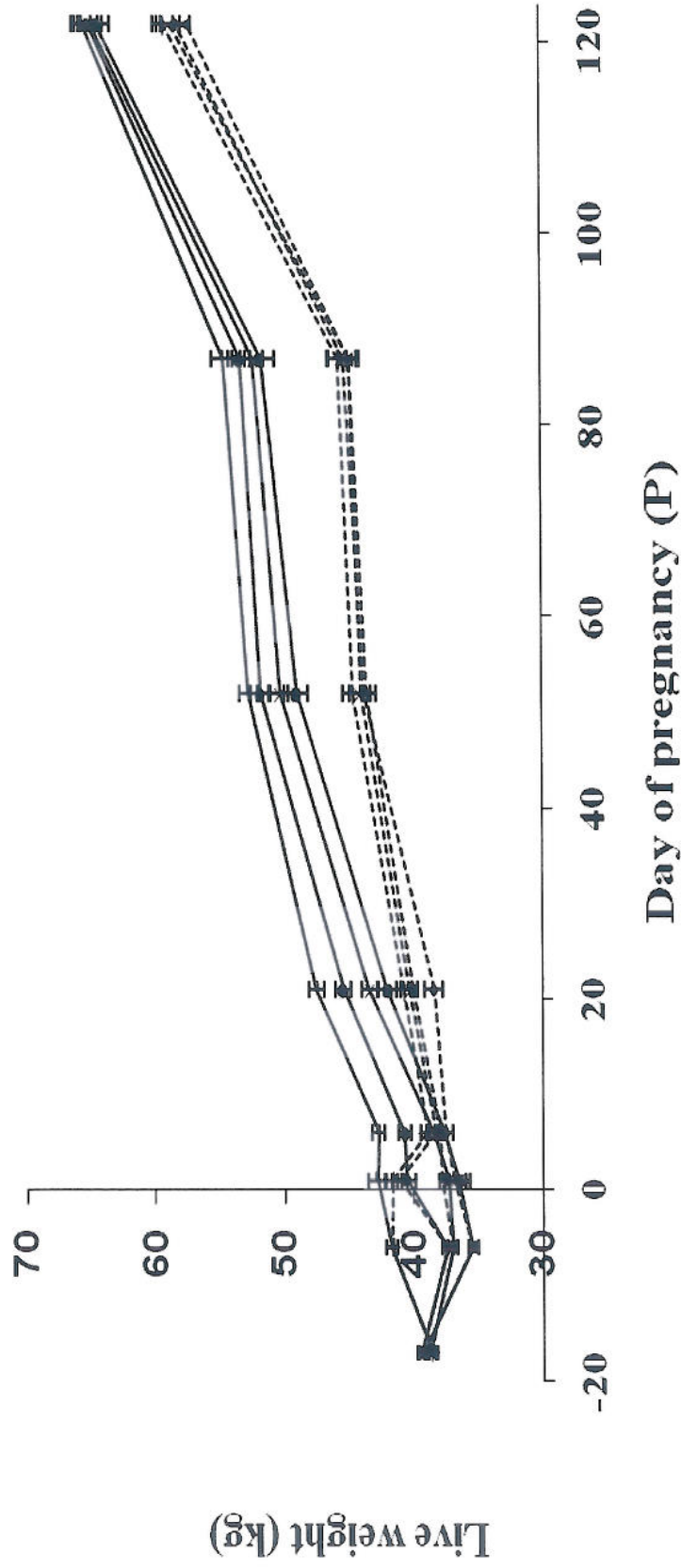
At P-17, hogget live weight (38.9 ± 0.4 kg) did not differ ($P > 0.05$) between pre-breeding nutritional treatment groups (Figure 5.2). At P-6, the 'maintenance' (35.4 ± 0.4 kg) treatment was lighter ($P < 0.05$) than the '*ad-libitum*' (41.7 ± 0.4 kg) treatment group while, the 'medium' (37.0 ± 0.4 kg) and the 'medium/*ad-libitum*' (37.4 ± 0.4 kg) treatment groups did not differ ($P > 0.05$) from the 'maintenance' and '*ad-libitum*' treatment groups. At P6, the 'maintenance' (37.6 ± 0.6 kg) treatment were lighter ($P < 0.05$) than the '*ad-libitum*' (42.7 ± 0.6 kg) and 'medium/*ad-libitum*' (40.8 ± 0.6 kg) treatment groups but did not differ ($P > 0.05$) from the 'medium' (38.3 ± 0.6 kg) treatment group.

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Following breeding, pre-breeding nutritional differences ($P < 0.05$) remained until P20. From P40 to P122, hoggets in the '*ad-libitum*' post-breeding nutritional treatment (P6-P122) were heavier ($P < 0.05$) than the 'medium' treatment by 6.6 to 7 kg.

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Figure 5.2. The effect of nutritional treatment pre-breeding (maintenance, medium, medium/*ad-libitum* and *ad-libitum*) and post-breeding (medium and *ad-libitum*) on liveweight of hoggets. (pre-breeding, ♦ Maintenance, × Medium, ● Medium/*ad-libitum* and ◻ *ad-libitum* and post-breeding, - - - medium, — *ad-libitum*).



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Breeding performance

A smaller proportion ($P < 0.05$) of the 'maintenance' treatment were bred over the 5-day breeding period than in the 'medium', 'medium/*ad-libitum*' and '*ad-libitum*' treatment groups (Table 5.3).

Hoggets bred that returned to oestrus

The proportion of hoggets returning to oestrus, as identified by vasectomised rams, from P6 to P22 was less ($P < 0.05$) in the 'maintenance' pre-breeding treatment group than the '*ad-libitum*' pre-breeding treatment, but did not differ ($P > 0.05$) from the 'medium' or the 'medium/*ad-libitum*' treatments (Table 5.3). Pre-breeding nutrition did not ($P > 0.05$) affect the proportion of the hoggets returning to oestrus between P23 until P53 or the proportion of hoggets joined that were pregnant.

Post-breeding 'medium' levels of nutrition increased ($P < 0.05$) the proportion of hoggets returning to oestrus between P6 to P22, while more ($P < 0.05$) of the '*ad-libitum*' treatment returned to oestrus activity between P23 and P53. However, post-breeding nutrition did not ($P > 0.05$) affect the overall proportion of hoggets returning to oestrus between P6 and P53 (-1.07 ± 0.19 , 31 % vs. -0.84 ± 0.18 , 26 % for 'medium' and '*ad-libitum*' treatment groups, respectively).

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Table 5.3. Effect of pre-breeding nutritional treatment ('maintenance', 'medium', 'medium/*ad-libitum*' and '*ad-libitum*') on mean proportion bred in the five day breeding period (bred first 5 days), proportion of hoggets identified as displaying oestrus from P6 to P22 (Returns6-22) and displaying oestrus between P23 and P53 (Returns23-53). Data are presented as logit-transformed means \pm s.e. (back-transformed percentages.) Within columns, means with different superscripts are significantly different ($P < 0.05$).

		Bred first 5 days	Returns6-22	Returns23-53
	n			
'maintenance'	96	-0.31 \pm 0.211 ^{1, a} (58 ²)	-1.95 \pm 0.40 ^a (13)	-2.12 \pm 0.43 (11)
'medium'	96	-1.41 \pm 0.26 ^b (80)	-1.19 \pm 0.27 ^{ab} (23)	-2.02 \pm 0.36 (12)
'medium/ <i>ad-libitum</i> '	97	-2.06 \pm 0.32 ^b (89)	-1.18 \pm 0.26 ^{ab} (23)	-2.36 \pm 0.39 (9)
' <i>ad-libitum</i> '	93	-1.50 \pm 0.27 ^b (82)	-0.85 \pm 0.25 ^b (30)	-2.67 \pm 0.46 (6)

¹Logit-transformed

²Back-transformed (%)

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Pregnancy data

More ($P < 0.05$) fetuses were identified in the ‘*ad-libitum*’ (0.84 ± 0.04) pre-breeding treatment than the ‘medium’ (0.69 ± 0.06) pre-breeding group per hogget present at P55, while the ‘maintenance’ (0.73 ± 0.05) and the ‘medium/*ad-libitum*’ (0.76 ± 0.03) pre-breeding treatments did not differ ($P > 0.05$).

When only the data from hoggets present on P55 was included in the model, pre-breeding nutritional treatment had no effect ($P > 0.05$) on the proportion of hoggets not pregnant or twin-bearing at P55 (Table 5.4). However, a greater ($P < 0.05$) proportion of the ‘maintenance’ pre-breeding treatment were single-bearing hoggets than the ‘medium/*ad-libitum*’ and the ‘*ad-libitum*’ pre-breeding treatments. The proportion of single-bearing hoggets in the ‘medium’ treatment did not differ ($P > 0.05$) from any of the other treatments. The number of fetuses was greater ($P < 0.05$) in the ‘*ad-libitum*’ pre-breeding group than the other treatment groups, but the number of fetuses in the ‘maintenance’, ‘medium’ and ‘medium/*ad-libitum*’ pre-breeding treatments did not differ ($P > 0.05$).

Post-breeding nutrition had no effect ($P > 0.05$) on the proportion of hoggets that were non-pregnant, single-, or twin-bearing; or on the number of fetuses on P55.

When the pregnancy data was analysed including all the hoggets at the start of the experiment, there was no ($P > 0.05$) effect of pre-breeding (-0.16 ± 0.20 (46 %), -0.41 ± 0.21 (40 %), -0.16 ± 0.20 (46 %) and -0.04 ± 0.20 (49 %) for the ‘maintenance’, ‘medium’,

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'medium/*ad-libitum*' and '*ad-libitum*' treatments) or post-breeding nutrition (-0.49 ± 0.17 (62 %) vs. -0.42 ± 0.17 (60 %) for the 'medium' and '*ad-libitum*' treatments, respectively) had no ($P>0.05$) on the proportion of hoggets pregnant.

The number of fetuses present on P55 per hogget joined was greater ($P<0.05$) in the '*ad-libitum*' (0.69 ± 0.06) and the 'medium/*ad-libitum*' (0.59 ± 0.06) pre-breeding treatments than the 'maintenance' (0.41 ± 0.06) treatment. However, the number of fetuses at P55 in the 'medium' (0.54 ± 0.06) treatment did not differ ($P>0.05$) from the 'maintenance', 'medium/*ad-libitum*' or '*ad-libitum*' pre-breeding treatments.

Pregnancy loss

There was no effect ($P>0.05$) of pre- (0, 2, 2 and 2% for 'maintenance', 'medium', 'medium/*ad-libitum*' and '*ad-libitum*' treatments, respectively) and post-breeding (2 and 1% for 'medium' and '*ad-libitum*' treatments, respectively) nutrition ($P>0.05$) on pregnancy loss from P55 to P124.

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Table 5.4. The effect of nutritional treatment pre-breeding ('maintenance', 'medium', 'medium/ad-libitum' and 'ad-libitum') and post-breeding ('medium' or 'ad-libitum') on the proportion of non-pregnant, single- and twin-bearing hoggets and the number of fetuses per hogget (fetuses/hogget scanned) that did not return to oestrus following the 5-day breeding period. Data are presented as logit-transformed means \pm S.E. (back-transformed percentages.) Within columns, means with different superscripts are significantly different ($P < 0.05$).

	n ¹	Fetuses/hogget scanned		
		Non-pregnant	Single	Twin
Pre-breeding				
'maintenance'	42	-2.56 \pm 0.60 ² (7 ³)	2.56 \pm 0.60 ^b (93)	0*
'medium'	50	-2.20 \pm 0.47 (9)	1.27 \pm 0.34 ^{ab} (79)	-2.00.44 (12)
'medium/ad-libitum'	54	-2.53 \pm 0.52 (7)	1.36 \pm 0.34 ^a (80)	-1.90 \pm 0.41 (13)
'ad-libitum'	52	-2.79 \pm 0.59 (6)	0.47 \pm 0.29 ^a (67)	-1.00 \pm 0.31 (27)
Post Breeding				
'medium'	101	-2.43 \pm 0.37 (8)	1.37 \pm 0.25 (80)	-1.98 \pm 0.31 (12)
'ad-libitum'	98	-2.54 \pm 0.39 (7)	1.21 \pm 0.24 (78)	-1.69 \pm 0.28 (16)

* No hoggets were diagnosed as twin bearing in this treatment group

¹Total number of hoggets identified with a crayon mark between P1 and P5 but did not return to oestrus between P6 and P53.

²Logit-transformed

³Back-transformed (%)

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Discussion

The objective of the present studies was to investigate the effect of nutrition from immediately prior to the commencement of the breeding period through to mid pregnancy on the reproductive performance of hoggets. The overall liveweight changes of the 'medium' and 'ad-libitum' pre- and post-breeding nutritional treatments were within the range of liveweight change reported by Morris *et al.* (2005), Kenyon *et al.* (2008) and Mulvaney *et al.* (2008). However, the 'medium' treatment hoggets in Experiment 5.1 maintained live weight until approximately P36 and then increased until P145 and this section could be categorised as a maintenance level of nutrition during this period. In experiment 5.2, there was an apparent reduction in live weight in the 'maintenance' treatment group immediately after the commencement of the Experiment 5.2. It is believed that this was a result of a change in gut fill, as the average live weight of this group reduced by approximately 3 kg two days after the commencement of the experiment. The liveweight change achieved in the 'maintenance' pre-breeding group was similar to the reported by Mulvaney *et al.* (2008).

Increasing the level of nutrition prior to the time of breeding increased the proportion of hoggets bred, which is similar to previous reports (Bizelis *et al.* 1990; Boulanouar *et al.* 1995). However, the experiments of Bizelis *et al.* (1990) and Boulanouar *et al.* (1995) utilised lower levels of nutrition and the nutritional regimens were imposed for longer periods. These studies, along with the present experiments, are confounded by the difficulty of separating the effects of elevated levels of nutrition (dynamic or short term effect) and greater live weight (static or long term influence) on the breeding performance. The mean hogget live weight at the commencement of Experiment 5.1 was 4 kg heavier than in Experiment 5.2 and the liveweight change of the 'medium' group was similar to the liveweight change in the

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'maintenance' pre-breeding group in Experiment 5.2. In both experiments, the proportion of hoggets bred was lower in these two groups compared to the other groups and may indicate that the *ad-libitum* levels of nutrition may lead to an increase in the proportion of hoggets bred. In addition, McMillan & Moore (1983), although breed dependent, suggested hoggets must be heavier than 33 kg to be reproductively active. The hoggets in both experiments were, on average, heavier than this threshold and the greater proportion of hoggets bred in the '*ad-libitum*' group may be due to increased short term nutrition around the time of breeding. A proportion of the lighter hoggets in the '*ad-libitum*' group may have reached puberty during the pre-breeding period, therefore, increasing the potential number of females being bred. However, the attainment of puberty was not determined or recorded in either of the experiments.

In both experiments, a proportion of ewes returned to oestrus indicating embryonic or pregnancy loss possibly due to fertilisation failure or incomplete implantation. However, the effect of nutrition and the period from the completion of the breeding period to pregnancy diagnosis varied. In Experiment 5.2, *ad-libitum* pre-breeding levels of nutrition for either 4 or 17 days did not affect the rate of return to oestrus between the completion of the breeding period and pregnancy diagnosis, but resulted in a greater proportion of hoggets bred compared to maintenance levels of nutrition. However, Experiments 5.1 and 5.2, Kenyon *et al.* (2008) and Mulvaney *et al.* (2008) reported that *ad-libitum* levels of nutrition post-breeding increased the proportion returning to oestrus up to the time of pregnancy diagnosis. In addition, Parr *et al.* (1982) showed offering two times the maintenance level of nutrition after artificial insemination increased embryonic mortality due an inverse relationship between progesterone metabolism and nutrition. Therefore, to minimise potential pregnancy

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failure, New Zealand farmers should aim to provide *ad-libitum* levels of herbage pre-breeding and possibly reducing the level of herbage post-breeding to maximise the reproductive performance in hoggets.

The pregnancy rate of the hoggets present at the start of the breeding period was increased by *ad-libitum* pre-breeding levels of nutrition in Experiment 5.1, but nutrition did not affect pregnancy rate in Experiment 5.2. A greater proportion of hoggets were bred in the *ad-libitum* group in Experiment 5.2, however, a greater proportion of the bred hoggets returned to oestrus, further outlining the potential benefit of reducing nutrition after breeding as the medium level did not differ from the maintenance or the *ad-libitum* groups. In addition, both experiments found the proportion of hoggets bred that were diagnosed as pregnant was not affected by post-breeding nutrition, which is supported by previous New Zealand pastoral experiments (Morris *et al.* 2005; Kenyon *et al.* 2008). In contrast, one New Zealand pastoral experiment (Mulvaney *et al.* 2008) reported that increased levels of nutrition commencing immediately prior to the breeding period reduced the pregnancy rate. However, an infectious disease was identified as a possible interfering factor in the experiment of Mulvaney *et al.* (2008) (West *et al.* 2006; Howe *et al.* 2008).

Increasing the liveweight gain from 17 days or 4 days prior to the start of the breeding period in Experiments 5.1 and 5.2, respectively, increased the number of fetuses per hogget at pregnancy diagnosis. However, there was no effect of increasing pre-breeding nutrition on P5 following medium levels of nutrition on the number of fetuses diagnosed for each hogget present at pregnancy diagnosis. Supplementing the diet of mature ewes with lupin (Fletcher *et al.* 1981; Gheradi & Lindsay 1982; Stewart & Oldham 1986; Kenney & Roberts 1987; Nottle

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et al. 1997) or pasture (Rattray *et al.* 1978; Smeaton *et al.* 1982; Smith *et al.* 1983) prior to breeding has been shown to increase fecundity. This may explain the results observed in Experiment 5.1. In addition, Robinson *et al.* (2006) found elevated levels of nutrition prior to the start of breeding increased oocyte quality. Therefore, the oocytes from the *ad-libitum* nutrition levels from both experiments, irrespective of the length of *ad-libitum* levels of nutrition, may have been better quality and resulted in a greater number of embryos being formed. However, this does not explain why there was not an increase in the number of fetuses as a result of the 4 days of *ad-libitum* levels of herbage in Experiment 5.2. Under New Zealand pastoral conditions the 4 day period may not be long enough and that the 17 day period is results in an increase in the reproductive rate. This could also be due to using progesterone synchronisation devices that may disturb oestrus, or possibly the shorter breeding period (5 vs. 34 days), and heavier hoggets (38.9 vs. 34.7 kg) at the start of Experiment 5.2. These factors require further investigation.

Conclusion

In both experiments increased nutrition provided at the *ad-libitum* level before and after mating increased the number of fetuses per pregnancy but did not alter the number of hoggets that were pregnant at mid gestation. Furthermore, Experiment 5.2 identified that *ad-libitum* feeding of hoggets during the latter period did not influence either pregnancy rate or fetuses per pregnancy.

Implications

This study indicates to the New Zealand pastoral industry that reproductive benefits from a high level feeding immediately prior to breeding and during breeding and pregnancy of

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hoggets. A strategy of feeding at a medium level of herbage post breeding to meet the demands of hoggets for growth only is recommended.



MASSEY UNIVERSITY
GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Fraser Mulvaney

Name/Title of Principal Supervisor: Professor Steve Morris

Name of Published Paper: Effect of nutrition pre-breeding and during pregnancy on performance of ewe lambs. *Animal Production Science* 50, 953-960.

In which Chapter is the Published Work: 5

What percentage of the Published Work was contributed by the candidate: 76

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Chapter 6: Effect of live weight at the start of the breeding period and liveweight gain during the breeding period and pregnancy on reproductive performance of hoggets and the live weight of their lambs



Pasture conditions for an *ad-libitum* fed hogget and her lamb

Publication arising from this chapter: Mulvaney FJ, Morris ST, Kenyon PR, Morel PCH, West DM (2010) Effect of live weight at the start of the breeding period and liveweight gain during the breeding period and pregnancy on the reproductive performance of hoggets and the live weight of their lambs. *New Zealand Journal of Agricultural Research* **53**, 355-364

Chapter 6: Effect of live weight at breeding and nutrition during pregnancy on reproductive performance

Introduction

Under New Zealand's pastoral systems, reproductive performance of hoggets can be varied and disappointing (Kenyon *et al.* 2004a). In 2010, only 21% of total hoggets were joined with the ram with an average lambing percent of 40%, compared to 125% in mature multiparous ewes (Anon 2010). These results indicate that there is scope to lift the lambing percentage of hoggets considerably. Increased live weight at the time of breeding is positively associated with the proportion of two-tooths and mature multiparous ewes displaying oestrus (Coop 1962; Adalsteinsson 1979; Knight 1980) and increases lambing percentage (Kenyon *et al.* 2004b). In hoggets, it has similarly been reported that increasing live weight at the time of breeding increases the proportion of hoggets cycling (Meyer & French 1979; Craig 1982), displaying oestrus (Allison *et al.* 1975; Moore *et al.* 1978; Moore & Smeaton 1980), conceiving (Kenyon *et al.* 2005, 2006) and hogget lambing percentage (Kenyon *et al.* 2004b).

Hoggets that have reared a lamb tend to be lighter at the time of breeding as a two-tooth than hoggets not bred (Baker *et al.* 1981; McMillan & McDonald 1983; Kenyon *et al.* 2008a), which can reduce two-tooth reproductive performance (Johnston *et al.* 1982; Kenyon *et al.* 2008a). Relatively high levels of nutrition during pregnancy and in lactation of hoggets are a potential means of achieving adequate two-tooth breeding live weight.

Under housed conditions in the United Kingdom, utilising complete concentrate diets, Wallace *et al.* (1996, 1997a, 1997b) and Wallace (2000) have consistently demonstrated that young (5-7 months of age) and well grown (43.7-47.4 kg) hoggets fed to achieve a high liveweight gain (234 to 301 g/day) during pregnancy displayed increased pregnancy loss and

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reduced lamb birth weight and survival rates. Under New Zealand's pastoral conditions, pregnancy loss associated with relatively high liveweight gains (210-230 g/day) in pregnancy have only been reported once (Mulvaney *et al.* 2008) with a number of abortions (35 %) occurring from Day 50 to Day 130. However there was no effect on lamb birth weight or survival. In contrast, further studies (Morris *et al.* 2005; Kenyon *et al.* 2008b) of *ad-libitum* pasture fed hoggets achieving liveweight gains of 210-230 g/day has failed to repeat either the United Kingdom reports of a detrimental effect of high levels of feeding during pregnancy in hoggets or that of Mulvaney *et al.* (2008). It is possible that the abortions reported in the experiment of Mulvaney *et al.* (2008) were associated with *Neospora caninum* infection (West *et al.* 2006; Howe *et al.* 2008), although this is unknown. A clear difference between the United Kingdom housed studies and the New Zealand pastoral studies is in hogget live weight at the start of breeding 44-47 (United Kingdom studies) vs. 36-38 kg (New Zealand studies), respectively (Wallace *et al.* 1996, 1997a, 1997b; Wallace 2000; Morris *et al.* 2005; Kenyon *et al.* 2008b; Mulvaney *et al.* 2008).

The aim of the experiment reported in this chapter was to investigate the effect of live weight at the time of breeding and liveweight gain during pregnancy on the reproductive performance of hoggets, their subsequent live weight at weaning and the live weight and survival to weaning of their progeny.

Materials and methods

Experimental design and animals

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The experiment was a 2 x 2 factorial experiment, incorporating two liveweight groups (light, 36.2 ± 0.3 kg, 'L', n=101, range of 33.0-39.0 kg; and heavy, 42.6 ± 0.3 kg, 'H', n=102, range of 40.0-48.5 kg) and two nutritional treatments during pregnancy ('medium', n= 105 vs. *ad-libitum* levels of nutrition, '*ad-libitum*', n= 98) commencing at ram joining (P1) until P139. The aim of the 'medium' treatment was to achieve a liveweight gain of 100 g/day from P1 to P139. This was to be achieved by maintaining herbage pre- and post-grazing mass between 1000 and 1400 kg DM/ ha, respectively. The '*ad-libitum*' treatment was offered *ad-libitum* levels of pasture (pre-grazing mass >1800 and a post-grazing mass of 1200 kg DM/ha). The hoggets grazed a total area of 16 ha of mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) swards. The size of the grazing area and the grazing interval for both nutritional treatments were determined by the previous weeks' liveweight gain, with the grazing interval adjusted to ensure live weight targets were met. Herbage mass was monitored via a rising plate meter (Ashgrove Pastoral Products, Palmerston North, New Zealand) to allocate the interval spent on each grazing area.

Two hundred and three Romney ewe hoggets were used in the experiment. All hoggets had progesterone releasing intravaginal inserts (CIDRs, Pharmacia & Upjohn; New Zealand) placed for 12 days. At CIDR removal (P1), L and H live weight groups were randomly allocated to either 'medium' or '*ad-libitum*' treatments resulting in 4 groups within the experiment ('L-medium', 'L-*ad-libitum*', 'H-medium' and 'H-*ad-libitum*'). During the experimental period, 'L-medium' and 'H-medium' were managed as one group and 'L-*ad-libitum*' and 'H-*ad-libitum*' as another.

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On P1, 10 Cheviot, crayon-harnessed, mature rams (ram to hogget ratio of 1:10) were introduced into each group (n=20 in total) for a 5-day breeding period. Crayon marks on the rumps of hoggets were used as an indication of breeding activity and were recorded daily from P1 to P5. Following the 5-day breeding period, the harness crayon colour was changed on the rams, and the rams were re-introduced for a further 17-day breeding period. New hogget crayon rump marks were recorded at the conclusion of this period. Hoggets displaying no rump marks were removed from the remainder of the experiment. At the end of the 22-day breeding period, two harnessed vasectomised rams (n=4 in total) were introduced to each group for 34 days (P23-P57). Hoggets returning to service between P23 and P57 remained in the experiment until pregnancy diagnosis. At P140, both liveweight gain treatments were combined for lambing and lactation at a stocking rate of 7 hoggets/ ha. Herbage mass during lactation did not fall below 1800 kg DM/ha.

Animal measurements

Hoggets were weighed un-fasted (within 1 hour off pasture) at 7 to 10 day intervals throughout pregnancy (P1, P7, P13, P20, P26, P34, P41, P48, P55, P62, P74, P88, P102, P117, P139), 35 days after the first lamb was born (L35), L57 and L71 (weaning).

Based on hogget crayon rump marks, the hogget breeding pattern was defined as being bred during the first 5-day period only (P1-P5, synchronised period), bred from P6 to P22 only (P6-P22, post-synchronised period only), bred in both periods (P1-P5 and P6-P22, return to service) or being identified with no crayon rump mark during the 22-day breeding period (not bred at all). Hoggets returning to service after ram removal were recorded on P40 and P57 according to vasectomised rams' crayon rump marks. All hoggets that showed evidence of

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being bred during the 22-day breeding period (P1-P22) had their pregnancy status and number of fetuses (0, 1 or 2) determined via ultrasonic examinations were conducted on all ewes utilising a real-time, B-mode scanner (Aloka SSD 5000 Echo Camera, Monitor Corp. Ltd, BC, Canada) using a 7.5 MHz probe P89 and P118. Pregnancy loss was assumed to occur if the hogget was identified as pregnant at P63 but later diagnosed as not pregnant at either P89 or P118. All non-pregnant hoggets at each pregnancy diagnosis were removed from the remainder of the experiment.

Lamb measurements

Lambs were tagged, identified to their dam, date of birth recorded, litter size and sex determined, and live weight recorded within 12 hrs of birth (L0). In addition, crown rump length (CRL), thoracic girth, fore limb length (FL, distance from the shoulder to the tip of the hoof) and rear limb length (RL, distance from the hip to the tip of the hoof) were measured. Lambs were re-weighed, un-fasted, on L35 and L57 and at L71 (weaning).

Data analysis

Hogget live weight and lamb live weight at birth, L35, L57 and weaning and dimensions were analysed using the fixed effects of hogget live weight group and nutritional treatment and their interaction and the sex of the lamb in the model for lamb live weight using the generalised linear model procedure for continuous data (GLM, SAS 2005). Non-significant ($P>0.05$) interactions were removed and the sum of squares added to the error terms and the model was re-run. The date of birth was used as a covariate for lamb live weights.

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Hogget breeding pattern, percentage of hoggets pregnant per hogget joined at P63, pregnancy loss from P63 to P89 and P89 to P118, number of hoggets lambing per hogget joined and lamb survival from birth to weaning were analysed using the generalised linear model procedure for binomial categorical data (GENMOD, SAS 2005). Fixed effects of hogget live weight group and nutritional treatment were run for each parameter. Non-significant ($P>0.05$) interactions were removed and the model re-run. Foetuses per hogget joined, lambs born and weaned per hogget joined were analysed using generalised linear model procedure for categorical data (GENMOD, SAS 2005). The fixed effects of hogget live weight group and nutritional treatment were applied to each parameter. Non-significant interactions ($P>0.05$) were removed and treatment effects re-analysed.

Results

Hogget live weight during pregnancy

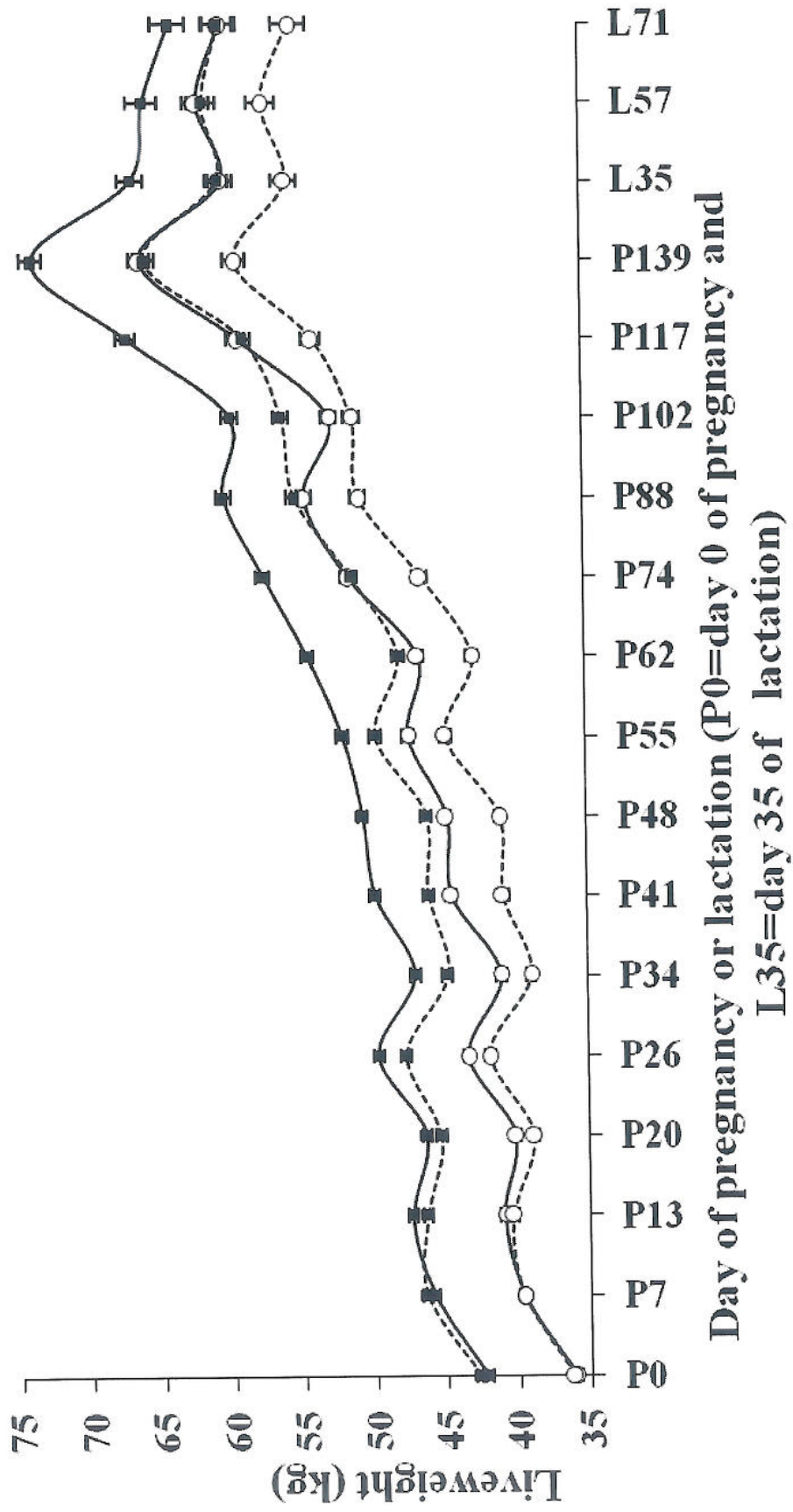
An interaction ($P<0.05$) between live weight group and nutritional treatment was observed where hoggets in the 'H-*ad-libitum*' treatment were heavier ($P<0.05$) than those in the 'L-medium', 'L-*ad-libitum*' and 'H-medium' treatments from P13 to P148 (Figure 6.1). Hoggets in the 'H-medium' treatment were heavier ($P<0.05$) than those in the 'L-*ad-libitum*' and 'L-medium' treatments from P13 to P74. At P74, P88, P117, P139, the hogget in the 'L-*ad-libitum*' and 'H-medium' treatments were heavier ($P<0.05$) than those in the 'L-medium' treatment. There was no difference ($P>0.05$) between hoggets in the 'L-*ad-libitum*' and 'H-medium' treatments from P74 to P139. Liveweight change from P1 to P139 was 216, 151, 194 and 158 g/ day for the 'H-*ad-libitum*', 'H-medium', 'L-*ad-libitum*' and 'L-medium' treatments, respectively.

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Hogget live weight during lactation

From L35 to weaning, the 'H-*ad-libitum*' treatment was heavier ($P < 0.05$) than the 'L-*ad-libitum*', 'L-medium' and 'H-medium' treatments, while the 'L-*ad-libitum*' and 'H-medium' treatments were heavier ($P < 0.05$) than the 'L-medium' treatment from L35 to weaning (Figure 6.1). There was no difference ($P > 0.05$) between the 'L-*ad-libitum*' and 'H-medium' treatments from L35 to weaning.

Figure 6.1. The effect of hogget live weight group ('L' or 'H') and nutritional treatment ('medium' or 'ad-libitum') on hogget live weight during pregnancy (day 1 of pregnancy = P1) and lactation (day 35 of lactation = L35) (mean \pm s.e.). ('L' = \square , 'H' = \blacksquare , 'medium' = --- and 'ad-libitum' = ---).



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Hogget breeding performance

Nutritional treatment had no effect ($P>0.05$) on the proportion of hoggets bred in the synchronised period only (P1-P5), those that return to service (bred in both periods, P1-P5 and P6-P22) or those not bred at all (Table 6.1). However, more ($P<0.05$) of the 'L' group were bred when compared to the 'H' group in the post-synchronised period only (P6-P22).

Hogget nutritional treatment had no effect ($P>0.05$) on the proportion of hoggets bred during the synchronised period only (P1-P5). A greater proportion ($P<0.05$) of the 'medium' treatment were bred during the post-synchronised period only (P6-P22) and not bred at all when compared to the '*ad-libitum*' treatment. More ($P<0.05$) of the '*ad-libitum*' treatment returned to service compared to the 'medium' treatment.

Pregnancy rate, fetuses per hogget joined, number of hoggets lambing and lambs weaned per hogget joined were not affected ($P>0.05$) by live weight group or liveweight gain treatment (Table 6.2). The percentage of hoggets bred that returned to service between P23 and P63 was not affected ($P>0.05$) by live weight group (17 vs. 25 % for the 'L' and 'H' groups, respectively) or nutritional treatment (21 vs. 21 % for 'medium' and '*ad-libitum*' treatments, respectively). Pregnancy loss between P64 and P118 was not affected ($P>0.05$) by live weight group (18 vs. 10 % of those pregnant at P64 that lost pregnancy, for the 'L' and 'H', respectively) or nutritional treatment (13 vs. 13 % of those pregnant at P64 that lost pregnancy, for 'medium' vs. '*ad-libitum*', groups respectively).

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Table 6.1. The effect of hogget live weight group ('L' or 'H') and hogget nutritional treatment ('medium' or 'ad-libitum') during pregnancy on proportion of hoggets bred (% of hoggets joined) in the first 5-day synchronised breeding period only (P1-P5, "synchronised period"), only bred during the 17 day period post synchronised period (P6-P22, "post-synchronised period"), bred in both the synchronised breeding and the 17 day period post synchronised period (P1-P5 and P6-P22, "return to service") and "not bred at all". Values are logit-transformed (means \pm s.e) and numbers in the parentheses are back-transformed percentages. Within columns and treatment, means with letters in common or no superscript do not differ significantly ($P>0.05$).

	n	Synchronised period		Post-synchronised period	Return to service	Not bred at all
		period	period	period		
Live weight group						
'L'	101	0.86 \pm 0.22 ¹ (71) ²	-3.49 \pm 0.59 ^b (3)	-1.83 \pm 0.29 (14)	-2.07 \pm 0.30 (12)	
'H'	102	0.96 \pm 0.22 (72)	-29.37 \pm 0.59 ^a (0)	-1.34 \pm 0.25 (21)	-2.59 \pm 0.39 (7)	
Nutrition						
'medium'	105	1.06 \pm 0.22 (74)	-3.53 \pm 0.59 ^b (3)	-2.37 \pm 0.35 ^a (9)	-1.79 \pm 0.28 ^b (14)	
'ad-libitum'	98	0.77 \pm 0.22 (69)	-29.37 \pm 0.59 ^a (0)	-1.02 \pm 0.23 ^b (27)	-3.16 \pm 0.51 ^a (4)	

¹Logit-transformed, ²Back-transformed (%)

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Table 6.2. The effect of hogget live weight group ('L' or 'H') and hogget nutrition ('medium' or 'ad-libitum') during pregnancy on proportion of hoggets pregnant per hogget joined (Percentage hoggets pregnant), hoggets lambing per hogget joined (Percentage hoggets lambing), number of foetuses identified per hogget joined (Foetuses), number of lambs born per hogget joined (Lambs born), and lambs weaned per hogget joined (Lambs weaned). Values for percentage of hoggets pregnant, percentage of hoggets lambing are logit-transformed (mean \pm s.e.) and numbers in the parentheses are back-transformed percentages. Within columns and treatment, means with letters in common or no superscript do not differ significantly ($P>0.05$).

Live weight group	n	Percentage of		Foetuses	Lambs born	Lambs weaned
		hoggets pregnant	Percentage of hoggets lambing			
L	101	0.60 \pm 0.21 ¹ (65 ²)	0.14 \pm 0.20 (53)	0.70 \pm 0.06	0.58 \pm 0.05	0.54 \pm 0.05
H	102	0.92 \pm 0.23 (72)	0.63 \pm 0.21 (65)	0.85 \pm 0.06	0.68 \pm 0.05	0.61 \pm 0.05
Nutrition						
'medium'	105	0.71 \pm 0.22 (67)	0.33 \pm 0.20 (58)	0.77 \pm 0.06	0.63 \pm 0.06	0.57 \pm 0.05
'ad-libitum'	98	0.80 \pm 0.22 (69)	0.41 \pm 0.21 (60)	0.77 \pm 0.06	0.63 \pm 0.06	0.58 \pm 0.05

¹Logit-transformed, ²Back-transformed (%)

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Lamb dimensions, live weight and survival

Live weight group and nutritional treatment had no effect ($P>0.05$) on lamb live weight at L0, L35 or L57 (Table 6.3). Crown rump length, girth, foreleg and rear leg length did not differ ($P>0.05$) between live weight group and nutritional treatment at L0 (data not shown). At L71, lambs born to 'L' treatment hoggets were lighter ($P<0.05$) than lambs born to 'H' treatment hoggets. Lamb survival was not influenced ($P>0.05$) by hogget live weight group or nutritional treatment during pregnancy.

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Table 6.3. The effect of hogget live weight group ('L' or 'H') and hogget nutritional treatment ('medium' or 'ad-libitum') during pregnancy on the live weight at birth (L0), and at L35, L57 and L71 (mean \pm s.e.) and the proportion of lambs surviving until L71. Values for lamb survival are logit-transformed (mean \pm s.e.) and numbers in the parentheses are back-transformed percentages. Means within columns with letters in common or no superscript do not differ significantly ($P>0.05$).

Live weight group	Liveweight				n	Lamb Survival
	L0	L35	L57	L71		
'L'	59 4.46 \pm 0.20	50 12.85 \pm 0.60	17.40 \pm 0.76	20.11 \pm 0.67 ^a	50	1.78 \pm 0.36 ¹ (86 ²)
'H'	70 4.66 \pm 0.19	61 13.43 \pm 0.62	18.59 \pm 0.78	21.69 \pm 0.90 ^b	61	1.95 \pm 0.36 (88)
Nutrition						
'medium'	67 4.58 \pm 0.19	59 13.22 \pm 0.57	17.55 \pm 0.82	20.29 \pm 0.94	59	2.02 \pm 0.38 (88)
'ad-libitum'	62 4.58 \pm 0.19	52 13.05 \pm 0.62	18.43 \pm 0.73	21.51 \pm 0.84	52	1.70 \pm 0.34 (85)

¹Logit-transformed, ²Back-transformed (%)

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Discussion

This experiment investigated the effect of hogget live weight group and nutritional treatment during the breeding period and pregnancy on breeding performance and live weight of hoggets and the live weight and survival of their progeny. The nutritional treatments resulted in differences in liveweight gains of approximately 50 g/day between treatments, irrespective of liveweight group. However, while total liveweight gains of the ‘*ad-libitum*’ treatment were similar to that of Morris *et al.* (2005) (210 g/day), Kenyon *et al.* (2008b) (225 g/day) and Mulvaney *et al.* (2008) (210 g/day), they were lower than those achieved by Wallace *et al.* (1996, 1997a, 1997b) (234 to 294 g/day) using a concentrate ration. It is possible that 200 g/day is near the maximum that pregnant hoggets can achieve under the pastoral conditions of New Zealand during the late autumn and winter period.

Hogget live weight

Increasing the live weight at the start of the breeding period has been shown to increase the breeding activity (Moore *et al.* 1978; Meyer & French 1979; Craig 1982; McMillan & Moore 1983), therefore, potentially increasing the number of hoggets conceiving (Kenyon *et al.* 2005, 2006). However, in the current experiment an average difference in hogget live weight at the time of breeding of 6 kg did not affect the proportion of hoggets bred. McMillan & Moore (1983) reported a breeding live weight of 33 kg was required for at least 90 % to be reproductively active and Kenyon *et al.* (2004b) suggested hoggets should be at least 36 kg to ensure production is not limited. In the current experiment, the minimum individual live weight was 33 kg and this may explain why there was no live weight group effect on the proportion of the total hoggets bred.

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In the current experiment the live weight at the start of breeding did not affect pregnancy loss from P63 to P118 and the 'H' group were 42 kg which was similar to the live weight at embryo transfer reported in the studies of Wallace *et al.* (1996, 1997b). This might indicate that the pregnancy losses in the studies of Wallace *et al.* (1996, 1997b) was not due to live weight at the beginning of the experiment.

In mature multiparous ewes, the live weight of the ewe at the time of breeding is positively associated with the lamb birth weight of singles (Russel *et al.* 1981) and twins (Kenyon *et al.* 2004c). In contrast, in the current experiment, hogget live weight at the time of breeding of the 'H' did not affect lamb birth weight. Kenyon *et al.* (2006) reported lamb birth weight of single lambs to increase by only 5 grams per kilogram increase in hogget breeding live weight. The numbers used in the current experiment may not have allowed such a small difference to be detected (i.e. 30 grams). In the current experiment, lambs born to the 'H' group were 284 grams heavier at weaning for each kilogram increase in hogget live weight at the time of breeding compared to the lambs born to the 'L' group which was higher than the 146 g/day reported by Kenyon *et al.* (2006). This increased lamb live weight could be due to superior milk production for a longer period of time and improved milk composition although this is unknown and may require further investigation.

The 'H' group were, on average, 6 kg heavier at the start of the experiment and maintained this advantage throughout the experiment. It is unknown if this difference would have remained to two-tooth breeding and potentially affect two-tooth breeding performance. If it did, there is potential to improve ovulation rate by 4-5 % (Smeaton *et al.* 1979) for each kilogram increase in live weight at the start of the breeding period, and 2 % (Morley *et al.*

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1978) and 2.5-3 % (Cumming 1977) for each kilogram increase in mature multiparous ewe live weight at the time of breeding. No previous reports, to the Authors knowledge, have investigated the carry over effect of heavier hoggets that reared a lamb on subsequent live weight and ovulation rate at two-tooth breeding. Further studies are required to determine the impacts of these potential carry over affects.

Nutrition during pregnancy

In the current experiment fewer 'ad-libitum' treatment hoggets were not bred, which indicates that *ad-libitum* levels of nutrition around breeding is beneficial to hogget breeding activity. Increasing the level of nutrition offered to hoggets has previously been shown to increase the proportion displaying oestrus (Moore & Smeaton 1980), which is indicative of increased breeding activity.

However, the higher return to service rates in the 'ad-libitum' treatment hoggets resulted in a similar percentage of hoggets pregnant compared to the 'medium' treatment. This is not the only New Zealand pastoral experiment to report this finding (Kenyon *et al.* 2008b). The hoggets in the current experiment and Kenyon *et al.* (2008b) were progesterone synchronised and the results observed may not be directly applicable non-synchronised natural breeding circumstances. Increasing the level of nutrition offered to mature ewes immediately post breeding has previously led to a reduction in embryonic survival and was associated with low peripheral progesterone concentrations (Parr *et al.* 1987; McEvoy *et al.* 1995). However, the only experiment conducted under New Zealand pastoral conditions investigating progesterone concentration and nutritional treatments during early hogget pregnancy (Mulvaney 2006) reported similar progesterone concentrations between nutritional treatments

Chapter 6: Effect of live weight at breeding and nutrition during pregnancy on reproductive performance

although greater return rates in the higher nutritional regimen were observed also. Absolute progesterone concentration may not be the only possibility for reduced embryo survival. The balance between progesterone and growth hormone may also be a factor due to an increase in growth hormone associated with increased nutrition (McFadden *et al.* 1990) and progesterone concentration decreases under conditions of increased nutrition (Parr *et al.* 1987; McEvoy *et al.* 1995). Increasing concentrations of growth hormone (McFadden *et al.* 1990) and progesterone (Parr *et al.* 1987; McEvoy *et al.* 1995) are related to increased embryo survival.

The current experiment showed pregnancy rate was not affected by liveweight gain during pregnancy, which supports the findings of two previous New Zealand studies (Morris *et al.* 2005 and Kenyon *et al.* 2008b). This suggests that increased hogget liveweight gain under New Zealand pastoral grazing conditions does not negatively affect pregnancy rates as shown by Wallace *et al.* (1996) under indoor concentrate diet systems. Increased liveweight gain has consistently been shown to increase abortions in the studies of Wallace *et al.* (1996, 1997b), however only one New Zealand experiment (Mulvaney *et al.* 2008) has reported that greater liveweight gains resulted in increased abortions. The current experiment supports two other New Zealand studies (Morris *et al.* 2005 and Kenyon *et al.* (2008b) which were undertaken on the same Massey University farm. Overall the combined results indicate that increased liveweight gain during pregnancy under New Zealand pastoral grazing conditions does not affect the incidence of pregnancy loss.

The studies of Wallace *et al.* (1996, 1997a,1997b) have shown a reduction in lamb birth weight as a result of elevated liveweight gain; however, New Zealand experiments, including the current experiment, have consistently shown increased liveweight does not affect lamb

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birth weight. Potential explanations for this could be the different diet types and the resulting differences in metabolic end products and differences in liveweight gains. Altered nutrient partitioning, as result of changes in maternal hormones caused by nutrition, in favour of maternal liveweight gain could have limited the nutrient supply for conceptus growth and placental development as a result of the very high liveweight gains (296 vs. 210-230 g/day) during pregnancy in the U.K. studies (Wallace 2000). In addition, concentrate diets have been found to produce a greater proportion of propionate (a gluconeogenesis precursor) than a pastoral diet (Burke *et al.* 2007). This may have affected nutrient supply to the conceptus and affected the placental growth and development differently under pastoral grazing systems. However, this has not been investigated.

Previous New Zealand experiments (Morris *et al.* 2005, Kenyon *et al.* 2008b Mulvaney *et al.* 2008) and the current experiment have consistently shown that increased liveweight gain during pregnancy did not have a negative affect on post-natal lamb survival. In contrast, Wallace *et al.* (1996) reported high levels of nutrition reduced lamb survival. This could be due to similar lamb birth weights between nutritional treatments in the New Zealand studies. In comparison, the lamb birth weight difference was 1.6 kg (34%) in the experiment of Wallace *et al.* (1996). The ‘*ad-libitum*’ treatment hoggets were 6 kg heavier than the ‘medium’ treatment hoggets at the conclusion of the current experiment. There is potential for this difference to have a positive effect on two-tooth breeding performance, although this was not measured.

Conclusion

Chapter 6: Effect of live weight at breeding and nutrition during pregnancy on reproductive performance

Heavier hoggets at the time of breeding had no effect on the breeding performance, pregnancy loss or lamb survival, however, these hoggets remained heavier and produced heavier lambs at weaning. Increasing the nutrition during pregnancy decreased the proportion not bred during the 22-day period, but did not affect the percentage of hoggets pregnant, pregnancy loss, lamb survival or lamb weaning weight, however, the weaning weight of these hogget dams was heavier.

Implications

These results suggest farmers should aim for hoggets which are at least 42 kg at the time of breeding to maximise their weight and that of their offspring at weaning and should target liveweight gains of 200 g/day to maximise the live weight of the hogget at weaning. In contrast, within the scope of the live weight groups and nutritional regimens used in the current experiment, the data indicate that it is difficult to manipulate ewe hogget reproductive performance.



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STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Fraser Mulvaney

Name/Title of Principal Supervisor: Professor Steve Morris

Name of Published Paper: Effect of live weight at the start of the breeding period and liveweight gain during the breeding period and pregnancy on the reproductive performance of hoggets and live weight of their lambs. *New Zealand Journal of Agricultural Research* 53, 355-364.

In which Chapter is the Published Work: 6

What percentage of the Published Work was contributed by the candidate: 76

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Chapter 7: Effect of nutrition around the time of breeding and during pregnancy on hogget liveweight change, pregnancy loss and live weight and survival of their offspring



Pasture conditions for a 'medium' fed hoggets and their lambs

This chapter was presented at the 2010 New Zealand Society of Animal Production conference. (Mulvaney FJ, Morris ST, Kenyon PR, West DM, Morel PCH (2010) Effect of nutrition around the time of breeding and during pregnancy on hogget liveweight change, pregnancy loss and live weight and survival of their offspring *Proceedings of the New Zealand Society of Animal Production* 70, 91-95).

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Introduction

Under current New Zealand pastoral conditions, only 21 % of the hoggets wintered are put with the ram achieving a lambing percentage of less than 60 % (Anon, 2010). In comparison, mature multiparous ewe lambing percentage averages 125 % (Anon, 2010). This identifies the potential to lift the lambing percentage of hoggets considerably. A major reason for the low proportion of hoggets joined is a perceived negative effect on subsequent live weight as two year olds (Kenyon *et al.* 2008) and, hence, their future reproductive performance (Kenyon *et al.* 2004a).

Under housed conditions in the United Kingdom, utilising concentrate diets, Wallace *et al.* (1996, 1997a, 1997b) have consistently shown that young (5-7 months of age) and well grown (43.7-47.4 kg) hoggets at the time of breeding fed to achieve high liveweight gains (234 to 301 g/day) during pregnancy have increased pregnancy loss, and reduced lamb birth weight and survival rates. One New Zealand study under pastoral grazing condition reported pregnancy loss as a result of a relatively high liveweight change (210-230 g/day) during pregnancy with 35 % of the pregnant *ad-libitum* fed hoggets losing a pregnancy (Mulvaney *et al.* 2008). However, there was no effect on lamb birth or lamb survival. In contrast, the studies Morris *et al.* (2005) and Kenyon *et al.* (2008), in which hoggets achieved growth rates of 210-230 g/day did not report an effect on pregnancy loss. It is probable that the pregnancy losses reported in the study of Mulvaney *et al.* (2008) were associated with *Neospora caninum* infection (West *et al.*, 2006; Howe *et al.*, 2008). Therefore, it is worthwhile to re-investigate the effects of *ad-libitum* levels of nutrition on pregnancy loss under pastoral conditions. Further, to the Author's knowledge, there are no data on the

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effects of different nutritional regimens starting prior to ram introduction on hogget reproductive performance. The studies of Kenyon *et al.* (2008) and Mulvaney *et al.* (2008) began after a 5-day synchronised breeding period, while Morris *et al.* (2005) began after 21 days of breeding.

The aim of this experiment was to investigate the effects of differing nutritional levels, starting four days prior to ram introduction on hogget pregnancy loss and live weight and the live weight and survival of their offspring to weaning.

Materials and Methods

Experimental design and animals

Three hundred and thirty Romney hoggets (34.7 ± 0.3 kg) were offered one of two nutritional treatments (medium ('medium') vs. *ad-libitum* ('*ad-libitum*')) from 4 days prior to ram introduction (pregnancy day-4, P-4) to P145. The aim of the 'medium' (n=165) treatment group was to achieve a total liveweight gain of 100 g/day from P-4 to P145. The aim of the 'medium' nutritional treatment was to achieve a total liveweight gain of 100 g/day and through offering pre- and post-grazing herbage masses of 1400 and 1000 kg DM/ha, respectively, from P-4 to P145. The '*ad-libitum*' fed hoggets were offered an *ad-libitum* level of herbage with the aim of achieving a total liveweight gain of 200 g/day with pre- and post grazing herbage masses of 1800 and 1200 kg DM/ha, respectively, between P-4 and P145. The hoggets grazed a total area of 19 ha of mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The size of the grazing area and the grazing interval for both

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nutritional treatments were based on the recorded liveweight change and herbage availability was adjusted to ensure live weight targets were met.

All hoggets were bred over a 34 day period (P1-P34) with a crayon-harnessed mature Romney rams at ram to hogget ratio of 1:30. Hoggets that did not have a crayon rump mark at P34 were removed from the remainder of the study. To determine pregnancy status (0, 1 or 2 fetuses), ultrasonic examinations were conducted on all ewes utilising a real-time, B-mode scanner via the abdomen (Aloka SSD 5000 Echo Camera, Monitor Corp. Ltd, BC, Canada) using a 7.5 MHz transducer on P64. Eighty-three 'medium' and 105 '*ad-libitum*' hoggets were diagnosed pregnant at P64 to the 34-day breeding period and only the data from these animals are presented here. The breeding and pregnancy data are presented in Chapter 5. The 'medium' treatment group consisted of 81 (98% of the hoggets pregnant within the 'medium' treatment group) single- and 2 twin- (2%) bearing hoggets, while the '*ad-libitum*' contained 69 single- (66%) and 36 twin- (34%) bearing hoggets. Pregnancy diagnosis, via abdominal real-time ultrasound was carried out P109 and P145 to determine if any hogget had lost her pregnancy. Hoggets diagnosed as not pregnant at either P64, P109 or P145 were removed from the remainder of the study but, due to the inability to detect the number of fetuses at this late stage of pregnancy, the number of fetuses was not recorded.

At P145, hoggets that conceived during the first 17 days of the breeding period (1st cycle) were combined from each nutritional treatment and were offered *ad-libitum* levels of pasture at 7 hoggets per ha from P145 to 55 days after the first lamb was born (L55, L=day of lactation). Hoggets that conceived during the second 17 days of

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the breeding period (as identified at pregnancy diagnosis using fetal age prediction, 2nd cycle) remained on their respective nutritional treatments until their average P145 and then managed as described for the 1st cycle hoggets until L55.

Animal measurements

Hoggets were weighed un-fasted (within 1 hour off pasture) on P-4, P7, P15, P22, P29, P36, P50, P64, P80, P92, P126, P145, L41 and L55.

Determining pregnancy loss

Pregnancy loss was assumed to occur if a hogget was identified as pregnant via a real-time ultrasound scanner on P64 but later diagnosed as not pregnant on either P109 or P145.

Lamb measurements

Newborn lambs were tagged, identified to their dam and their date of birth recorded, their sex determined and recorded for litter size and live weight within 12 h of birth (L0). In addition, crown rump length (CRL), thoracic girth circumference (GRT), rear limb length (RL, distance from the hip to the tip of the hoof) and fore limb length (FL, distance from the shoulder to the tip of the hoof) were measured. All lambs were re-weighed unfasted at L41 and L55.

Data analysis

Hogget live weight and lamb live weight and dimensions were analysed using the Generalised Linear Model process (SAS 2005). In the models for hogget live weight,

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fixed effects of litter size and nutritional treatment and their interaction were tested for each parameter. Non-significant ($P > 0.05$) interactions were removed and the model re-run. Note in the models for hogget live weight the numbers changed at each time point when non-pregnant animals were removed. In the models for lamb live weight and lamb dimensions, fixed effects of nutritional treatment and litter size were fitted and non-significant ($P > 0.05$) interactions were removed and the model re-run. Date of birth, birth weight and sex of lamb was used in the model as a covariate for live weight at L0, L41 and L55 and lamb dimensions.

Pregnancy rate on P64 (number of hoggets diagnosed pregnant at P64/ number of hoggets at the start of the breeding period), pregnancy loss between P64 and P109 ((hoggets pregnant at P64 - hoggets pregnant at P109)/hoggets pregnant at P64) and P109 and P145 ((hoggets pregnant at P109 - hoggets pregnant at P145)/hoggets pregnant at P109) and lamb survival to L55 ((lambs born - lambs alive at L55)/lambs born) were analysed using the generalised linear procedure for binomial data (GENMOD, SAS 2005). Fixed effects of nutritional treatment were fitted into the model.

The lambing percentage (lambs present at L55/hoggets joined with the ram) was analysed using the generalised linear procedure for binomial data (GENMOD, SAS 2005). Fixed effects of nutritional treatment were fitted into the model.

Modelling of live weight data

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Ewe Conceptus free live weight was assumed to be the predicted conceptus weight minus the average hogget live weight at P145 for the 'medium' and '*ad-libitum*' treatment groups. The conceptus mass was defined as the weight of the foetus(es), membranes and fluids. The conceptus mass was estimated using the equation from Nicol & Brookes (2007). The '*ad-libitum*' treatment group contained a larger proportion of twin-bearing hoggets, therefore, to calculate the estimated conceptus mass for the treatment a single-bearing hogget was given a weighting factor of 0.7 while a twin-bearing hogget was allocated a weighting factor of 0.3. The conceptus free liveweight change was assumed to be hogget live weight at the start of the study (34.7 kg) minus the conceptus free hogget live weight at P145. The pasture dry matter intake was calculated in two sections. The first section involved estimating the megajoules metabolisable energy (MJ ME) that would be required to achieve the conceptus free live weight gain for each treatment group. The live weight gain was divided into 5 kg sub categories (i.e. 35-39, 40-44 and 45-49 kg) to align with the equations provided in Rattray (1986) to determine the nutrient requirement for liveweight gain. The MJ ME requirement was calculated using the mean liveweight gain during the pregnancy period for each treatment group at each live weight category. The second section involved the summation of each sub-category provided an estimation of the MJ ME intake to achieve the respective liveweight change in each treatment group. It was assumed that each kilogram dry matter of herbage contained 11 MJ ME (Gavigan & Rattray 2002).

The efficiency of the system was then calculated as kilograms of dry matter intake from P-4 to P145/ kg lamb live weight at L55.

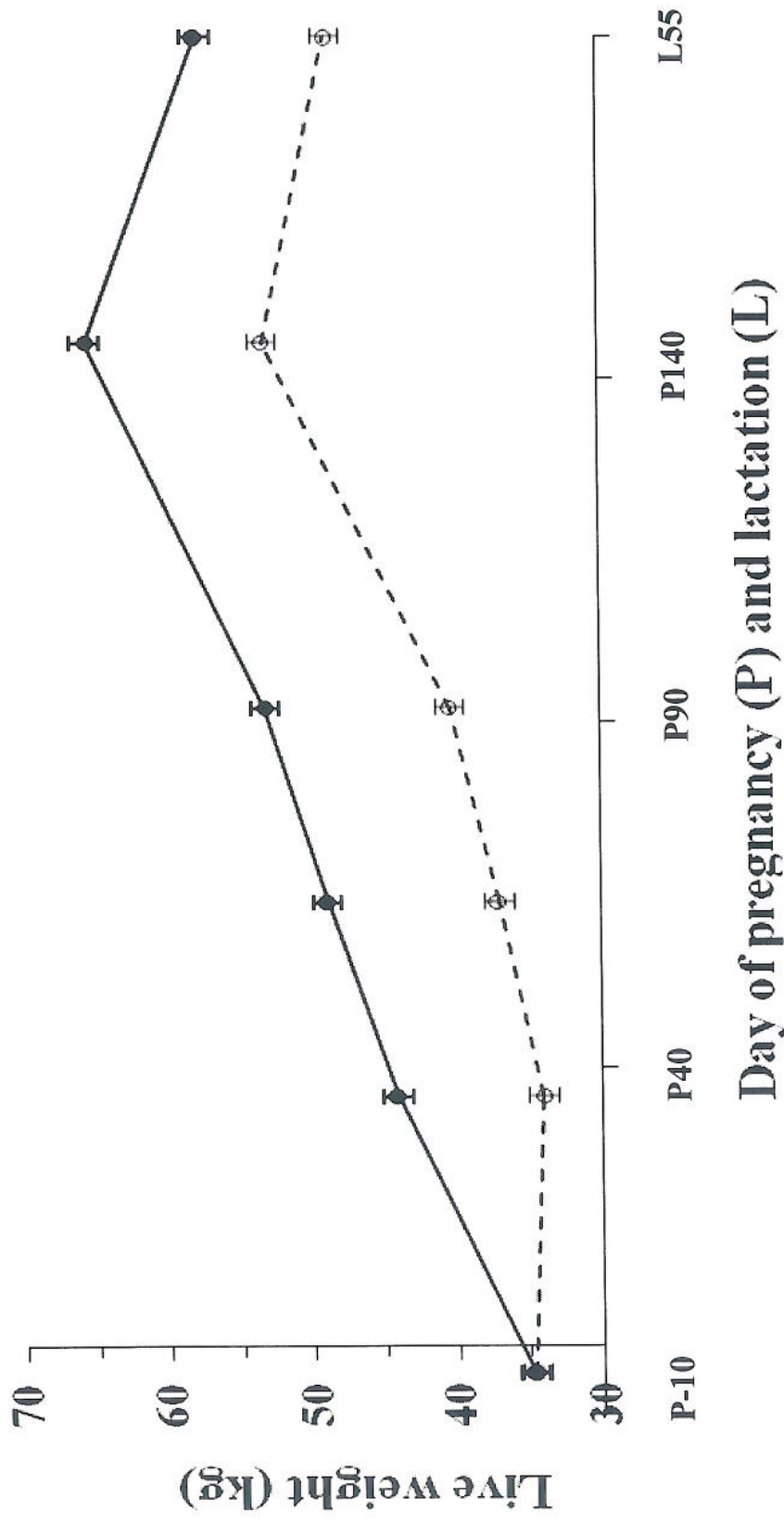
Results

Hogget live weight

At P-4, live weight did not differ ($P>0.05$) between nutritional treatments. However, by P7 and until L55, '*ad-libitum*' treatment hoggets were heavier ($P<0.05$) than their 'medium' counterparts (Figure 7.1). The liveweight change was lower than the target until P36 for the 'medium' treatment hoggets. At P145, the 'medium' and '*ad-libitum*' treatments were 53.4 ± 0.5 and 65.6 ± 0.5 kg, respectively, with average daily liveweight gains of 125 ± 9 and 206 ± 11 g/day (including conceptus), respectively ($P<0.05$). At L55, the live weight of the hoggets in the 'medium' and '*ad-libitum*' treatment groups were 48.9 ± 0.7 and 57.9 ± 0.7 kg, respectively ($P<0.05$).

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Figure 7.1. The effect of hogget nutrition (---○--- = 'medium' and -●- = 'ad-lib') beginning 4 days prior to breeding until P145 on live weight (mean \pm s.e.).



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Pregnancy rate and pregnancy loss

Pregnancy rate at P64 was higher ($P < 0.05$) in the '*ad-libitum*' (105 hoggets pregnant out of 165 hoggets joined, logit value 0.53 ± 0.16 , back transformed percentage (63%)) than the 'medium' (83 hoggets pregnant out of 165 hoggets joined, 0.01 ± 0.16 , (50%)) treatments.

Nutrition of the hogget dam had no impact ($P > 0.05$) on pregnancy loss from P64 to P109 (7 vs. 11 % for 'medium' and '*ad-libitum*' treatments, respectively) or from P109 to P145 (6 vs. 9 % for 'medium' and '*ad-libitum*' treatments, respectively) or from P64 to P145 (14 vs. 19 % for 'medium' and '*ad-libitum*' treatments, respectively).

Lamb live weight, dimensions and survival and lambing percentage

Lamb live weight at L0, L41 and L55 was not affected ($P > 0.05$) by dam nutrition (Table 7.1). Single born lambs were heavier ($P < 0.05$) at L0, L41 and L55 than their twin born counterparts.

Nutrition of the dam during pregnancy had no affect ($P > 0.05$) on lamb CRL, GRT and FL. However, lambs born in the '*ad-libitum*' treatment had longer ($P < 0.05$) RL than lambs born in the 'medium' treatment (Table 7.2). Single born lambs had larger ($P < 0.05$) CRL, GRT and longer ($P < 0.05$) FL and RL compared to twin born counterparts.

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Lamb survival was not affected ($P>0.05$) by nutritional treatment (84 vs. 77 %, for 'medium' and '*ad-libitum*', respectively) or lamb litter size (82 vs. 76 % for single- and twin-born lambs, respectively).

The lambing percentage was higher ($P<0.05$) in the '*ad-libitum*' (62 %) compared to the 'medium' (41%) treatment hoggets.

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Table 7.1. The effect of hogget nutrition ('medium' and '*ad-libitum*') beginning 4 days prior to breeding until P145 on the mean (\pm s.e.) lamb live weight (kg) at L0, L41 and L55. Within columns, means with different superscripts differ significantly ($P < 0.05$).

	L0		L41		L55	
	n		n		n	
Nutrition						
'medium'	82	4.09 \pm 0.08	69	12.84 \pm 0.29	68	13.50 \pm 0.52
' <i>ad-libitum</i> '	139	3.97 \pm 0.12	107	12.09 \pm 0.44	103	14.63 \pm 0.36
Litter Size						
Single	147	4.57 \pm 0.08 ^b	122	14.29 \pm 0.28 ^b	117	15.81 \pm 0.33 ^b
Twin	74	3.49 \pm 0.10 ^a	54	10.64 \pm 0.46 ^a	54	12.32 \pm 0.56 ^a

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Table 7.2. The effect of hogget nutrition ('medium' and '*ad-libitum*') beginning 4 days prior to breeding until P145 on the mean (\pm s.e.) lamb crown rump length (CRL, cm), girth (GRT, cm), fore leg length (FL, cm) and rear leg length (RL, cm). Within columns, means with different superscripts differ significantly ($P < 0.05$).

		CRL	GRT	FL	RL
	n				
Nutrition					
'medium'	82	50.88 \pm 0.61	37.08 \pm 0.49	29.49 \pm 0.37	33.47 \pm 0.39 ^x
' <i>ad-libitum</i> '	139	51.38 \pm 0.41	37.57 \pm 0.33	29.66 \pm 0.25	34.55 \pm 0.26 ^y
Birth rank					
Single	147	53.14 \pm 0.39 ^b	39.10 \pm 0.32 ^b	30.49 \pm 0.24 ^b	35.22 \pm 0.25 ^b
Twin	74	49.13 \pm 0.64 ^a	35.54 \pm 0.52 ^a	28.18 \pm 0.39 ^a	32.79 \pm 0.41 ^a

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Modelling of the live weight results

The estimated conceptus mass was 7.9 (weight of the fetus, membranes and fluids) vs. 8.5 kg (conceptus mass for twins was estimated to be 10.3 kg) and the conceptus free live weight of the hoggets were 45.3 vs. 57.1 kg, for the 'medium' and '*ad-libitum*' treatments, respectively. Conceptus free live weight change was 11.1 vs. 22.4 kg for the 'medium' and '*ad-libitum*' treatments, respectively. The pregnant 'medium' and '*ad-libitum*' treatments required 1210 vs. 2442 MJ ME or 110 vs. 222 kg DM to achieve their respective conceptus free liveweight changes from P-4 to P145. Therefore, the 'medium' treatments consumed 8.14 kg DM/kg of lamb live weight on L55 and the '*ad-libitum*' treatments consumed 15.17 kg DM/kg of lamb live weight on L55.

Discussion

The present study utilised hoggets diagnosed pregnant at P64 to investigate the effect of two differing nutritional regimens beginning 4 days prior to breeding on pregnancy loss and live weight of the dam and her offspring to L55. Hogget liveweight change from P-4 until P145 of the '*ad-libitum*' treatment was similar to previous studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008) on the same farm during a similar period of the year. The liveweight change of the 'medium' treatment group from P-4 until P36 was lower than the target while the liveweight change of both treatment groups during the last third of pregnancy were similar.

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Extreme liveweight gain under indoor U.K. conditions has invariably shown an increase in nutrition associated pregnancy loss (Wallace *et al.* 1996; 1997a; 1997b). Only one New Zealand study (Mulvaney *et al.* 2008) has replicated these results. Other New Zealand pastoral grazing studies (Morris *et al.* 2005; Kenyon *et al.* 2008) undertaken during the same time period on the same farm reported no effect on pregnancy loss. Infectious disease has been identified as a cause of loss of pregnancy in hoggets (West *et al.* 2006; Howe *et al.* 2008) and the results of Mulvaney *et al.* (2008) should be interpreted with caution.

The U.K. studies have consistently shown elevated liveweight gain during the pregnancy period has reduced mean lamb birth weight. However, the New Zealand studies have not led to a reduction in mean birth weight. It has been suggested that this difference may be due to different utilisation and partitioning affecting conceptus growth and development in a different manner in the New Zealand studies (Mulvaney *et al.* 2008). Also, the hoggets were younger and heavier in the UK studies (Wallace *et al.* 1996, 1997a, b), which also utilised embryo transfer techniques rather than natural mating.

In the present experiment, lamb survival was similar between nutritional treatments and similar to the previous New Zealand studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008) and was almost certainly due to similar lamb birth weights between the nutritional regimens.

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

The conceptus free live weight at P145 of the '*ad-libitum*' treatment was substantially higher than that of the 'medium' treatment hoggets and was close to the target two year old breeding live weight of 60 kg (Rattray and Gavigan 2002). If the 9 kg difference in live weight were to be maintained until breeding as a two year old, an enhanced ewe reproductive performance will be observed (Keane 1974; Baker *et al.* 1981; McMillan & McDonald 1983). Also, for the 'medium' treatment hoggets to achieve the target live weight suggested by Rattray & Gavigan (2002) they would require a more intensive management system over the challenging summer period. However, this apparent benefit needs to be balanced against the reduced efficiency (kg DM required/ kg lamb live weight at L55) of the '*ad-libitum*' treatment. This indicates that total hogget liveweight gain during pregnancy in the '*ad-libitum*' treatment, costs more herbage during a hogget's first winter without any increase in the performance of their offspring to L55 compared to a system in which the total hogget gain is 125 g/day.

Conclusion

Allowing hoggets *ad-libitum* levels of pasture beginning 4 days prior to breeding did not affect pregnancy loss, lamb survival or subsequent lamb live weight, although the '*ad-lib*' ewes themselves were heavier at L55. When the results were modelled, the 'medium' treatment group consumed less herbage during the pregnancy period to produce similar lamb live weight at L55. The hogget in the '*ad-libitum*' treatment were 9 kg heavier at L55 and this could have positive effects on their performance as a two year old if this difference is maintained. Alternatively they will need to consume less herbage over the summer period to achieve breeding live weight targets.

Chapter 7: Hogget liveweight change, pregnancy loss, lamb birth weight and survival

Summary

Chapters 5, 6 and 7 have identified that, under New Zealand pastoral conditions, commencing *ad-libitum* levels of nutritional prior to ram introduction and maintaining the same level throughout pregnancy until parturition can increase the reproductive performance of hoggets. Furthermore, once the hoggets have been diagnosed pregnant there is no impact of nutrition on pregnancy loss until parturition. In addition, hoggets offered *ad-libitum* levels of nutrition were at least 7 kg heavier than hoggets offered medium levels of nutrition. Chapter 6 identified that in terms of the herbage consumed to produce 1 kg of lamb at weaning, offering *ad-libitum* levels of nutrition during the pregnancy period was inefficient. However, the additional feed costs required to achieve a target live weight for two-tooth mating could possibly offset the poorer efficiency observed in the *ad-libitum* treatment to weaning. However, this is unknown and following hoggets that had been offered medium or *ad-libitum* during pregnancy through to pregnancy diagnosis as a two-tooth could identify any carry-over effects of the nutritional level during the preceding pregnancy. The effect of different levels nutrition offered to twin-bearing hoggets could have an effect on reproductive performance and this is investigated in chapter 8.



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**STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS**

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Fraser Mulvaney

Name/Title of Principal Supervisor: Professor Steve Morris

Name of Published Paper: Effect of nutrition around the time of breeding and during pregnancy on hogget liveweight change, pregnancy loss and live weight and survival of their offspring. Proceedings of the New Zealand Society of New Zealand Animal Production 70, 91-95.

In which Chapter is the Published Work: 7

What percentage of the Published Work was contributed by the candidate: 76

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Date

Chapter 8: Effect of nutrition from mid pregnancy to parturition on the live weight of twin bearing hoggets and the live weight and survival of their offspring



Hoggets and lambs during lambing at Keeble farm, Massey University

This chapter is to be submitted to: New Zealand Journal of Agricultural Research.

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Introduction

Studies involving commercial flocks in New Zealand reported that the proportion of hoggets joined with the ram identified as twin-bearing ranged from 16 to 32% (Kenyon *et al.* 2005, 2006a, b; Morris *et al.* 2005). The increased energy requirement to maintain twin fetuses to term and raise twin lambs to weaning, above the energy requirement for the increasing maternal size of the hogget, requires investigation. Kenyon *et al.* (2008) reported a major reason that New Zealand farmers were not consistently joining hoggets with the ram was a perceived negative impact of hogget breeding on the subsequent two year old breeding live weight. Therefore, management practices for twin-bearing hoggets during pregnancy and lactation requires investigation to ensure that target two year old breeding live weight is achieved.

Twin lambs born to mature multiparous ewes that were offered *ad-libitum* herbage from mid-pregnancy until parturition were heavier at birth (Morris & Kenyon 2004; Corner *et al.* 2008), whilst the weaning weight of these lambs was the same (Morris & Kenyon 2004; Everett-Hincks *et al.* (2005)) or heavier (Corner *et al.* 2008) compared to twin lambs born to mature multiparous ewe dams offered a restricted level of herbage from mid-pregnancy until parturition. In addition, the live weight of the mature multiparous ewes that were offered *ad-libitum* did not differ from that of a restricted level of herbage from mid-pregnancy until parturition (Morris & Kenyon 2004; Corner *et al.* 2008).

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New Zealand pastoral studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008; Chapters 6 and 7) have shown that offering *ad-libitum* compared to medium levels of herbage during pregnancy did not affect the birth weight of single lambs born to hoggets. However, the effect of offering differing herbage levels to twin-bearing hoggets from pregnancy diagnosis until parturition on the lamb birth weight and lamb survival is unknown.

The objective of the present study was to investigate the effect of nutrition of twin-bearing hoggets from Day 85 of pregnancy until parturition on live weight, peripheral metabolite concentrations of hoggets and lambs and the survival and live weights of the lambs until Day 29 of lactation.

Material and Methods

Experimental design and animals

A commercial flock of 1786 Composite ($\frac{1}{2}$ Romney, $\frac{1}{4}$ Texel, $\frac{1}{4}$ Finnish Landrace) hoggets were bred over a 34 day breeding period. At the time of pregnancy diagnosis, via abdominal ultrasound, 450 hoggets were identified as twin-bearing. From these, 180 hoggets were selected to ensure they were greater than 40 kg but not heavier than 50 kg and were used in the study. The average live weight at pregnancy diagnosis was 45.9 ± 0.23 kg.

One-hundred-and-two days after ram introduction (average day 85 of pregnancy, range 68-102), hoggets were randomly allocated to one of two treatments ('medium'

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or ‘*ad-libitum*’) until parturition. The aim of the ‘medium’ (n=88) treatment was to offer pre- and post-grazing herbage masses of 1400 and 900 kg DM/ha, while the ‘*ad-libitum*’ (n=92) treatment were offered a minimum herbage mass of 1800 kg DM/ha. The hoggets rotationally grazed a total area of 20 ha of mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The size of the grazing area and grazing interval for both treatments was determined based on herbage mass. All hoggets were removed from the rotational grazing system on Day 52 of the study (P137) in preparation for lambing and remained in the same paddock at 8 hoggets per ha. The herbage mass during the lambing were period 1120 ± 90 kg DM/ha and 1670 ± 70 kg DM/ha for ‘medium’ and ‘*ad-libitum*’ treatment, respectively. Approximately 24 hrs after lambing (L1), all hoggets and their lamb(s) were removed from their respective nutritional treatments and were offered a mean herbage mass of 1780 ± 65 kg DM/ha from L1 until L29 and were managed as one group.

Hogget measurements

Hoggets were weighed unfasted (within 1 hr off pasture) on P85, P99, P113, P127, P141, 24 hrs after parturition (L1), 8 days from the mid point of lambing (L8, range from 5 to 11 days from lambing), L15, L22 and L29. All pregnant hoggets were weighed at least 7 days prior to parturition to enable calculation of conceptus weight.

Plasma collection and analysis

On P137, a 5 ml blood sample was collected from 40 hoggets and on L1, a further sample was collected from 20 hoggets and their twin lambs from each treatment (n=120 hoggets and 80 lambs in total). On L1, a sample was only collected if both

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lambs were present. All blood samples were collected via jugular venepuncture into Lithium Heparin vacutainers (Becton Dickinson Vacutainer Systems, USA). Immediately after the blood samples were taken, they were placed on ice before centrifuging at 905g for 15 minutes. The plasma was then frozen at -20°C until analysis. Plasma from hoggets was analysed for glucose and β -hydroxybutyrate (β OHB) concentration, and the lambs' plasma was analysed for glucose and gamma-glutamyl transferase (GGT) concentration. β OHB was analysed using enzymatic assays (Osaka, Japan and Illinois, USA), glucose using a hexokinase assay and plasma GGT using the Szasz method (Roche diagnostics Limited, Mannheim, Germany). The inter- and intra-assay covariation was 4 and 6% for glucose and 6.2 and 7.3% for GGT, respectively

Lamb measurements

Lambs were tagged, identified to their dam and their date of birth, sex and live weight recorded within 12 hrs of birth (L0). In addition, crown rump length (CRL), thoracic girth circumference (Girth), rear leg length (RL, distance from the hip to the tip of the hoof) and foreleg length (FL, distance from the shoulder to the tip of the hoof) were measured. All lambs were re-weighed, unfasted, at L8, L15, L22 and L29.

Herbage samples

Herbage pluck samples (Wallis de Vries 1995) were collected when the hoggets were moved into a new treatment paddock on P85, P99, P113 and P145. Another sample was collected on L15. The samples from each treatment group were then pooled (5 samples in total) for analysis of crude protein and metabolisable energy (MJ ME/kg

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DM). The samples were dried in a convection oven for 12 hours at 105°C. The crude protein and energy content was determined via near-infrared-spectrometry (Bruker MPA NIR spectrophotometer, Ettlingen, Germany). The resulted NIR spectra were analyzed using Optic user software (OPUS) version 5.0.

Data analysis

Hogget and lamb live weight, the difference in individual birth weights within the litter, total birth weight (the sum of the individual birth weight within a litter), estimated conceptus weight (weight within 7 days of parturition – weight 24 hrs post-lambing) and plasma from the hoggets and the lambs were analysed using the generalised linear model procedure for continuous data (GLM, SAS 2005). In the models for hogget live weight, lamb live weight, the difference in individual birth weight within the litter, total birth weight, and estimated conceptus mass. Fixed effects of nutritional treatment and the sex of the lamb were included in the model for each parameter. Date of birth was included as a covariate. In the model for hogget plasma, the fixed effect of treatment was included in the model. In the model for lamb plasma, the fixed effect of treatment and the sex of the lamb were tested. In the model for hogget live weight during lactation, fixed effects of rearing rank and treatment during pregnancy and their interactions were tested. Date of birth was included as a covariate. Non-significant ($P > 0.05$) interactions were removed and the model re-run. The proportion of lambs that survived until L29 was analysed using the GENMOD procedure (SAS 2005). The fixed effect of treatment was included in each model.

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Modelling of live weight data

Conceptus-free live weight for each treatment was defined as the estimated conceptus weight minus the last live weight prior to parturition for each hogget (within 7 days of parturition). The estimated conceptus weight was defined as the last live weight prior to parturition minus the hogget weight 24 hrs after lambing. The conceptus free liveweight change was assumed to be the last hogget live weight prior to parturition minus the live weight at the start of the study (45.9 ± 0.23 kg).

The herbage dry mater intake was calculated in two sections. The first section involved estimating the required metabolisable energy (MJ ME) that would be required to achieve the conceptus-free liveweight change. The average live weight of the hoggets in each treatment was divided into 5 kg sub-categories (45-49, 50-55, 55-59kg) to align with the equations provided in Rattray (1986) to determine the nutrient requirement for liveweight gain.. The MJ ME required was calculated based on the liveweight change during each sub-category. The second section then provided a total MJ ME required to achieve the total conceptus free liveweight change during the entire period. The total MJ ME was then converted into kg DM required to achieve the liveweight gain during the 60 day period for each treatment. The energy content of the herbage was assumed to be 12 MJ ME.

The efficiency of the system was defined as kilograms of lamb at L29 per kilogram dry matter ingested during the treatment period. The total lamb live weight at L29 was estimated using a weighting factor of 1.55 and 1.6 for the 'medium' and '*ad-libitum*'

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treatments, respectively. This represented the average number of lambs present at L29 per hogget.

Results

Herbage mass and quality

The mean 'medium' treatment pre- and post-grazing herbage mass was 1350 ± 120 and 950 ± 80 kg DM/ha, respectively, and the pre-grazing mass for the '*ad-libitum*' treatment was 1860 ± 150 kg DM/ha throughout pregnancy.

The pooled crude protein content of the herbage offered was 33.4, 25.7, 20.1, 21.8 and 24.5% and the pooled energy content was 12.0, 12.2, 12.1, 12.5 and 12.0 MJ ME/kg DM on P85, P99, P113 P145 and L15 for both treatments.

Hogget live weight during pregnancy and lactation

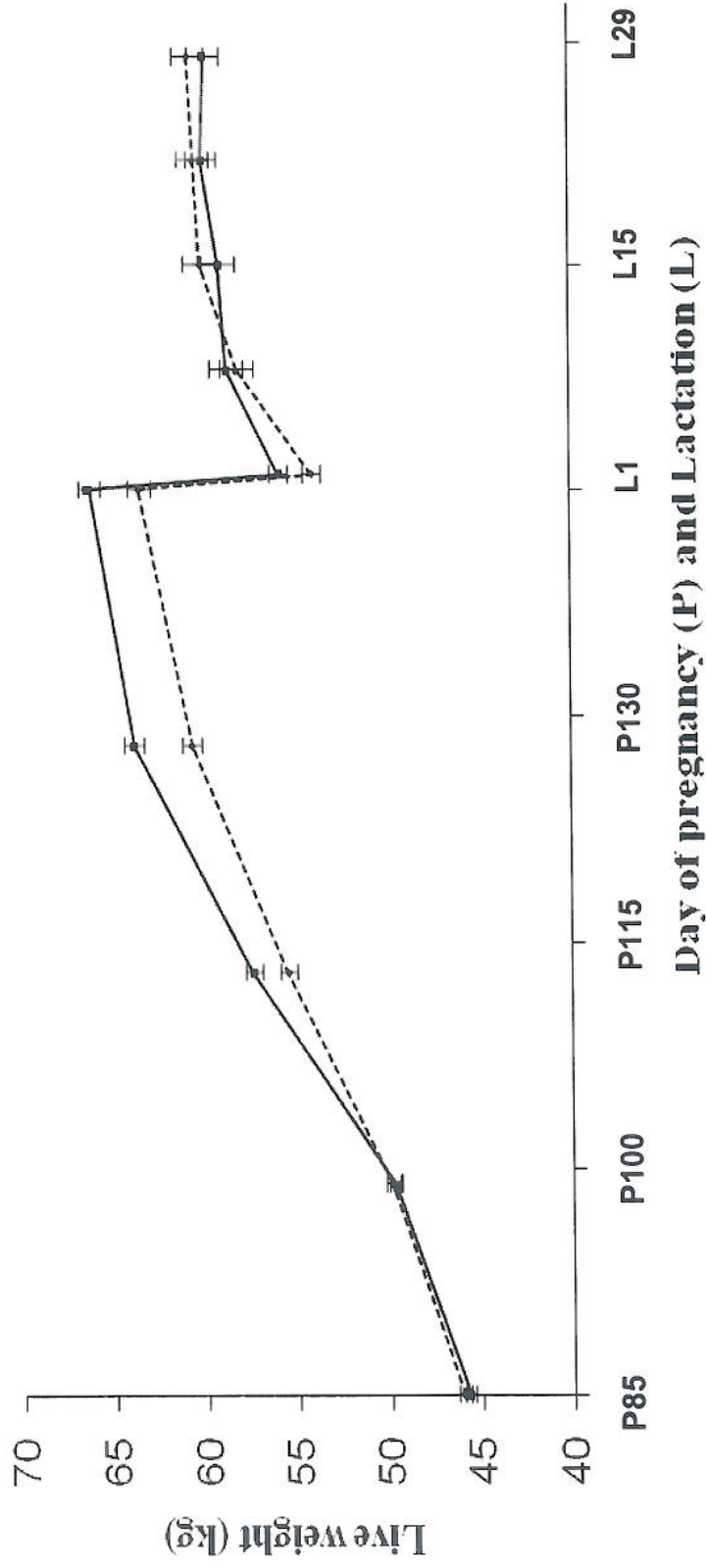
Hogget live weight was not affected ($P > 0.05$) by treatment on P85 or P99. However, on P115, P130 and P145, '*ad-libitum*' treatment hoggets were heavier ($P < 0.05$) than the 'medium' treatment by 2 to 3 kg (Figure 8.1). The liveweight change of the '*ad-libitum*' (343 ± 15 g/day) treatment was lower ($P < 0.05$) than the 'medium' treatment (293 ± 12 g/day). Hogget live weight was greater ($P < 0.05$) in the '*ad-libitum*' compared to the 'medium' treatment hoggets on L1, but on L8, L15, L22 and L29 hogget live weight did not differ ($P > 0.05$) between treatments.

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The estimated conceptus mass was not affected ($P>0.05$) by nutrition ($9.49 \pm 0.49\text{kg}$ vs. $10.35 \pm 0.49\text{kg}$ for 'medium' and '*ad-libitum*' treatments, respectively).

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Figure 8.1. The effect of nutrition ('medium' (- - -) vs. 'ad-libitum' (—)) from day 85 of pregnancy until parturition on hogget live weight from day 85 of pregnancy (P85) until average lamb age of 29 days (L29) (mean \pm s.e.).



L1= All hoggets were weighed the day after parturition

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Glucose and β OHB concentrations of hoggets

Glucose concentration on P145 and L1 did not ($P>0.05$) differ between nutritional treatments (Table 8.1). β OHB concentration did not differ ($P>0.05$) between treatments on P145. However, β OHB concentration on L1 was higher ($P<0.05$) in the 'medium' treatment hoggets compared to '*ad-libitum*' treatment hoggets.

Lamb live weight, dimensions and survival

Lambs born to the '*ad-libitum*' treatment hoggets were heavier ($P<0.05$) at birth than lambs born to 'medium' treatment hoggets (Table 8.2). Lamb live weight at L8, L15, L22 and L29 did not differ ($P>0.05$) between treatment. The mean birth weight difference within a litter did not ($P>0.05$) differ between treatment (0.60 ± 0.1 vs. 0.58 ± 0.1 kg for the 'medium' and the '*ad-libitum*' treatment groups, respectively).

Crown rump length and rear leg length were longer ($P<0.05$) in lambs born to the '*ad-libitum*' treatment hoggets compared to lambs born to the 'medium' treatment hoggets. Thoracic girth and foreleg length did not differ ($P>0.05$) between nutritional treatments (Table 8.3).

Lamb survival was not affected ($P>0.05$) by treatment (logit value, -0.12 ± 0.18 , back transformed percentage (80%) vs. -0.18 ± 0.21 , (78%) for 'medium' and '*ad-libitum*' treatment respectively).

Lamb glucose and GGT concentration

On L1, treatment had no effect ($P>0.05$) on lamb glucose or GGT concentrations (Table 8.3).

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Table 8.1. The effect of nutrition ('medium' vs. 'ad-libitum') from day 85 of pregnancy until parturition on the mean (\pm s.e.) glucose (Glucose, mmol/L) and β -hydroxybutyrate (β OHB, mmol/L) concentrations of hoggets on Day 145 of pregnancy (P145) and 24 hours after birth (L1). Within columns, means with different superscripts differ significantly ($P < 0.05$).

			Glucose	β OHB
		n		
P145				
	Medium	40	3.31 \pm 0.09	0.47 \pm 0.03
	<i>Ad-libitum</i>	40	3.49 \pm 0.08	0.47 \pm 0.03
L1				
	Medium	20	4.10 \pm 0.21	0.69 \pm 0.05 ^b
	<i>Ad-libitum</i>	20	4.60 \pm 0.20	0.48 \pm 0.48 ^a

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Table 8.2. The effect of hogget nutrition ('medium' vs. 'ad-libitum') from day 85 of pregnancy until parturition on the mean live weight (\pm s.e., kg) of twin lambs at birth (L1), 7 days old (L8), L15, L22 and L29. Data within columns with different superscripts differ significantly ($P < 0.05$).

	L1		L8		L15		L22		L29	
	n		n		n		n		n	
Medium	158	3.73 \pm 0.08 ^a	126	5.61 \pm 0.13	7.41 \pm 0.17	9.72 \pm 0.21	11.18 \pm 0.25			
<i>Ad-libitum</i>	168	4.04 \pm 0.08 ^b	132	5.86 \pm 0.13	7.60 \pm 0.18	10.07 \pm 0.22	11.31 \pm 0.26			

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Table 8.3. The effect of treatment ('medium' vs. 'ad-libitum') from day 85 of pregnancy until parturition on the mean (\pm s.e.) crown rump length (CRL, cm), thoracic girth (Girth, cm), foreleg length (FL, cm) and rear leg length (RL, cm), glucose concentration (mmol/L) and GGT concentration (U/l). Within columns, means with different superscripts differ significantly ($P < 0.05$).

	CRL	Girth	FL	RL	Glucose	GGT
	n					
Medium	158	47.87 \pm 0.30 ^a	36.77 \pm 0.26	34.98 \pm 0.21	35.05 \pm 0.19 ^a	40
<i>Ad-libitum</i>	168	48.75 \pm 0.26 ^b	37.22 \pm 0.27	35.34 \pm 0.19	35.59 \pm 0.19 ^b	40
					6.48 \pm 0.26	2163 \pm 236
					6.53 \pm 0.27	1752 \pm 245

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Modelling of live weight

The mean conceptus mass was 9.5 and 10.4 kg for the 'medium' and '*ad-libitum*' treatments, respectively. The conceptus free live weight at P145 was 54.1 and 55.9 kg for the 'medium' and '*ad-libitum*' treatments, respectively. Conceptus free live weight change was 8.2 and 10.0 kg from P85 until P145 for the 'medium' and '*ad-libitum*' treatments, respectively. The hoggets carrying lambs until term required 1183 and 1444 MJ ME from P85 until P145 in the 'medium' and '*ad-libitum*' treatments, respectively, to achieve their respective liveweight change. This equated to 99 and 120 kg DM for the 'medium' and '*ad-libitum*' treatments, respectively. Therefore, the 'medium' and the '*ad-libitum*' treatment hoggets produced 0.18 and 0.15 kg of lamb at L29 per kg DM ingested from P85 until P145, respectively.

Discussion

The objective of the present study was to investigate the effect of nutrition commencing approximately Day 85 of pregnancy until parturition on twin-bearing hogget live weight and metabolic indices, lamb live weight, indices of colostrum intake and survival until 29 days of age.

The pre- and post-grazing masses of the medium and *ad-libitum* treatments were met. However, the actual live weight change achieved by both the medium and the *ad-libitum* treatments were much higher than that previously reported under similar grazing conditions (Morris *et al.* 2005, Kenyon *et al.* 2008, Mulvaney *et al.* 2008) to achieve approximately 130 and 215 g/day for the medium and *ad-libitum* treatments, respectively. The similarity in liveweight gain only resulted in a 3 kg increased live

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weight of the *ad-libitum* treatment at P145 which was eliminated after parturition. Rattray *et al.* (1982) has shown that the liveweight gain plateaus when the post-grazing mass is greater than 1000 kg DM/ha with similar pre-grazing masses. Therefore, the pre- and post-grazing conditions of 1400 and 1000 kg DM/ha for the medium treatment did not appear to limit intake and the additional herbage allowance offered to the *ad-libitum* treatment did not allow additional maternal live weight. Further experiments investigating a greater range of nutritional treatment levels warrants further investigation.

In twin-bearing mature multiparous ewes, increasing the level of nutrition from mid-pregnancy also increased lamb birth weight under New Zealand pastoral conditions (Morris & Kenyon 2004; Corner *et al.* 2008), supporting the results obtained in the present study from hoggets. Conversely, pastoral studies involving single-bearing hoggets (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008) and mature multiparous ewes (Kenyon *et al.* 2009) reported that nutrition did not affect lamb birth weight. This indicates that the birth weight of single- and twin-bearing mature multiparous ewes and hoggets is affected by pastoral nutrition in the same manner for each age group.

Lamb survival was not affected by maternal nutrition in the present study. Previous pastoral studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008 and Chapters 6 & 7) have shown the survival of single born lambs was not affected by levels of nutrition above maintenance. Morel *et al.* (2009) reported lower survival rates in the lighter lamb within a twin litter and that large variation in birth weight was

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associated with lower survival. The variance in lamb birth weight within litters in the present study did not differ between nutritional groups. The birth weight of the lambs from both treatments was within the optimal range (3.3-4.1kg) for survival proposed by McMillan & McDonald (1983). The glucose and GGT concentration (indices of colostrum intake) did not differ between treatments. Therefore, these data would suggest that there would not be a difference between nutritional treatments on lamb survival. In addition, the numbers in the present experiment may not have allowed for a significance to be identified.

Lamb liveweight gain until 29 days of age was not affected by their dams nutrition. Previous hogget pastoral studies (Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008 and Chapters 6 & 7) have also shown that under similar herbage levels the live weight of the lamb was not affected by herbage intake. Also, similar pasture studies (Morris & Kenyon 2004; Corner *et al.* 2008) involving twin lambs born to mature multiparous ewes reported that similar nutritional levels did not affect the weaning live weight of the lambs. This suggests that nutrition during pregnancy does not affect lamb live weight of twin lambs born to hoggets during lactation.

Hogget live weight did not differ between treatments at L29. However, Morris *et al.* (2005), Kenyon *et al.* (2008) and Mulvaney *et al.* (2008) and Chapters 6 & 7 have consistently shown that single-bearing hoggets offered *ad-libitum* levels of nutrition were heavier than those offered a medium level. The results of the current experiment indicate that the herbage allowance offered to the medium treatment is not limiting intake. Rattray *et al.* (1982) found post-grazing masses of greater than 1000 kg DM/ha

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in late pregnancy does not increase the liveweight gain. Therefore, it would be expected that the post-grazing mass of 1000 kg DM/ha in the medium treatment was not limiting liveweight gain.

The conceptus free live weight gained during the experimental period did not differ between the treatments and each kilogram of dry matter ingested between P85 and P145 was represented by 180 and 150 grams of lamb live weight at L29 for the medium and *ad-libitum* treatments, respectively. Chapter 7 showed that the *ad-libitum* treatment consumed two times the herbage content to produce one kilogram of lamb live weight compared to the medium treatment. Chapter 7 primarily involved single-bearing hoggets, and the *ad-libitum* hoggets were heavier at the conclusion of the study and would not need to consume as much herbage during the difficult summer/autumn period. The current experiment indicates that offering greater than 1400 kg DM/ha from Day 85 of pregnancy until parturition does not lead to an increase in hogget lamb live weight at L29.

Conclusion

Increasing the level of nutrition offered to twin-bearing hoggets from Day 85 of pregnancy until parturition increased lamb birth weight but did not lead to an increase in lamb live weight during lactation, lamb survival or hogget live weight at L29. The twin-bearing *ad-libitum* treatment hoggets had similar lamb production efficiency compared to the medium treatment hoggets.

Implications

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This suggests that farmers should allow a pasture mass between 1000 and 1400 kg DM/ha to optimise lamb production of twin-bearing hoggets.

Chapter 9: The effect of early weaning on the hogget and its lambs liveweight change



Hoggets and lambs prior to weaning grazing pastures at Keeble farm

This chapter was presented at the New Zealand Society of Animal Production conference in 2009. (Mulvaney FJ, Morris ST, Kenyon PR, West DM, Morel PCH (2009) The effect of early weaning on the hogget and its lambs liveweight change *Proceedings of the Animal Society of Animal Production* **69**, 68-70).

Introduction

Kenyon *et al.* (2004b) revealed via an extensive survey, that a major reason New Zealand farmers have for not breeding hoggets is its perceived detrimental effects on two-tooth breeding weight, resulting in reduced two-tooth reproductive performance. Kenyon *et al.* (2008) confirmed this by showing that hoggets that reared a lamb to weaning had reduced two-year-old live weight and condition score at breeding. A potential means of minimising any potential negative effects on the young dam's live weight is early weaning of her offspring. Lambs born to mature multiparous ewes have been weaned at 8 weeks of age with no detrimental effect on lamb growth rate (Rattray *et al.* 1976; Smeaton *et al.* 1979; Earl *et al.* 1990). However, weaning lambs at 3 to 5 weeks of age can reduce lamb survival and liveweight gain when compared to lambs weaned at 12 weeks of age (Rattray *et al.* 1976). Geenty (1979) suggested that weaning at 4 to 6 of weeks of age could remove herbage competition between the hogget dam and its lamb, particularly when herbage availability is limited. Early weaning has led to an increase in ewe liveweight when compared to a later weaning (Corbett & Furnival 1976; Smeaton *et al.* 1979). These data suggest that lambs could be weaned relatively early without any detrimental effect. Chapter 4 identified that hoggets raise lighter lambs to weaning compared to mature multiparous ewes. It is possible that earlier weaning could be utilised to reduce the pressure on the hogget of raising a lamb and both the hogget and the weaned lamb could be preferentially fed aiming to improve the live weight of the lamb when sold and at least maintain hogget live weight. Figures 6.1 and 7.1 show that the live weight of hoggets reduces considerably during the last 3-4 weeks of lactation, so weaning early and removing the stressor of raising a lamb may aid in reducing this substantial reduction in hogget live weight.

Chapter 9: Early weaning of lambs born to hoggets

The objective of the current experiment was to examine the effect of weaning lambs born to hoggets at 10 weeks of age.

Materials and Methods

Experimental design and animals

One-hundred-and-sixty hoggets that had been offered two levels ('medium' and '*ad-libitum*') of nutrition during pregnancy were used in this experiment. The aim of the 'medium' treatment was to achieve a liveweight gain of 100 g/day from P1 to P139. This was to be achieved by maintaining herbage pre- and post-grazing mass between 1000 and 1400 kg DM/ ha, respectively. The '*ad-libitum*' treatment was offered *ad-libitum* levels of pasture (pre-grazing mass >1800 and a post-grazing mass of 1200 kg DM/ha).

Ten weeks after the mid-point of lambing, the hoggets (mean live weight of 47.5 ± 0.13 kg) and their lambs (mean live weight of 19.2 ± 0.46 kg) were allocated to one of two groups, early-weaned or suckling, for the period 10 to 14 weeks after the mid-point of lambing. The mean litter size was 1.30 and 1.33 for the 'early-wean' and 'suckling' treatments, respectively. The treatments were balanced for previous nutritional treatment and sex of the lamb. In one treatment, half of the lambs were weaned at an average of 10 weeks after the mid-point of lambing (age range 8 to 12 weeks of age) ('early-wean') while the other half remained un-weaned ('suckling') for the duration of the experimental period. Hogget live weight, lamb birth date and lamb live weight did not ($P > 0.05$) differ between groups at 10 weeks of age. The treatments were

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replicated in separate paddocks. Within each paddock, there were 'early-wean' hoggets without their lambs, 'early-wean' lambs without their dams and 'suckling' lambs and their dams. Each group were rotated around 8 paddocks.

Pasture measurement

Each treatment group were grazed on an area of 19 hectares of perennial ryegrass (*Lolium perene*) and white clover (*Trifolium repens*). Hoggets and lambs did not graze above 2200 kg DM/ha or below 1200 kg DM/ha throughout as measured by rising plate metre (Ashgrove Pastoral Products, Palmerston North).

Pasture analysis

Plucked herbage samples were taken from each paddock at the start of the experiment when the lambs were an average of 10 weeks of age. The paddocks were again sampled when the lambs were 12 and 14 weeks of age. Individual grass samples were dried in a convection oven at 105°C for 12 hours. Crude protein content of the herbage was determined by total combustion (LECO model, AOAC 968.06). Metabolisable energy was calculated from *in vitro* digestibility (0.16 * digestible organic matter content), neutral detergent fibre and acid detergent fibre content was determined using a Tecator Fibretec System (Robertson & van Soest 1981).

Animal Measurements

Hoggets and lambs were weighed unfasted (within 1 hour off pasture) when lambs were, on average 73, 87 and 101 days old.

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Data Analysis

Hogget and lamb liveweight were analysed using the generalised linear model procedure for continuous data (GLM, SAS 2005). Fixed effects of birth rank, lamb sex and the age at weaning and their interactions were tested for each parameter. Non-significant ($P>0.05$) interactions were removed and the model re-run. Individual lamb age and paddock group were analysed as a covariate.

Results

Treatment group had no effect ($P>0.05$) on lamb live weight gain throughout the experimental period (Table 9.1).

Hogget liveweight change was not affected ($P>0.05$) by treatment group between Weeks 10 and 12 (Table 9.1). 'Early-wean' hogget ewe live weight change was higher ($P<0.05$) from weeks 12 to 14 than 'suckling' hoggets and the 'early-wean' hoggets liveweight change was also higher ($P<0.05$) from weeks 10 to 14 than the 'suckling' hoggets.

Chapter 9: Early weaning of lambs born to hoggets

Table 9.1. Average daily liveweight change (kg/day) of hoggets and their lambs for 4 weeks after the lambs were either weaned at 10 weeks of age ('early-weaned') or remained suckling at until 14 weeks of age ('suckling'). Means within rows with different superscripts differ significantly ($P < 0.05$).

	<i>n</i>	10-12 weeks	12-14 weeks	10-14 weeks
Hoggets				
Early-wean	81	0.38 ± 0.03	-0.26 ± 0.02 ^b	0.06 ± 0.01 ^b
Suckling	79	0.33 ± 0.02	-0.34 ± 0.02 ^a	0.00 ± 0.01 ^a
Lambs				
Early-wean	78	0.18 ± 0.03	-0.05 ± 0.02	0.07 ± 0.01
Suckling	82	0.16 ± 0.02	-0.05 ± 0.02	0.06 ± 0.01

Discussion

Weaning prior to 8 weeks of age has been shown to reduce lamb growth rate (Corbett & Furnival 1976; Furnival & Corbett 1976; Rattray *et al.* 1976; Geenty 1979). In the current experiment early weaning at an average of 10 weeks of age did not affect lamb liveweight change. Early weaning in the current experiment occurred when individual lambs ranged from 7 to 12 weeks of age; therefore rumen development should have been completed (Rattray *et al.* 1976) and would not have restricted lamb growth rate. Two-year-old primiparous ewes have been reported to produce less milk than mature multiparous ewes (Peeters *et al.* 1992; El-Saied *et al.* 1999), therefore it is possible that lambs born to hoggets may suckle for a shorter period and begin to ingest herbage at a younger age, further limiting the impact of early weaning.

Furnival & Corbett (1976) stated that a greater pasture availability led to a reduction in the lamb growth check observed immediately post-weaning and reduced the effect of early weaning on lamb live weight. In the current experiment, herbage mass was managed to ensure it was within the range of 1200 and 2200 kg DM/ha so that the lambs would not experience any restriction in nutrient intake. Nevertheless, it may be worthwhile to repeat the current experiment with higher quality herbage to determine if a similar result would occur.

Early weaning increased hogget live weight gain in the current experiment, which supports the results of Smeaton *et al.* (1979). Early weaning in the current experiment occurred at an average lamb age of 10 weeks, when it would be expected that a large proportion of the hoggets were still lactating. Both weaning age treatment groups lost live weight when the lambs were between 12 and 14 weeks of age. However, pasture

Chapter 9: Early weaning of lambs born to hoggets

quality remained the same throughout the study and the availability remained within the same range (1200 to 2200 kg DM/ha) during the entire 4 week experimental period. The pasture quality (9.4 MJ ME/ kg DM) throughout the experiment is poor and may have affected the treatment groups in a negative manner.

Smeaton *et al.* (1979) stated that early weaned mature multiparous ewes were heavier than later weaned mature multiparous ewes at the subsequent breeding, however this difference did not equate to the expected increase in ovulation rate of 7%. It is unknown whether the small difference (1.6 kg) in live weight would have still been present at the subsequent breeding period and whether it could be large enough to affect two-year-old breeding performance. Fogarty *et al.* (1992) found a longer suckling period increases the period to first oestrus and the lambing interval when mature multiparous ewes were bred to lamb in spring. Future studies should attempt to measure this.

Conclusion

Under the conditions of the current experiment, lambs born to hoggets were weaned at an average age of 10 weeks with no detrimental effect on lamb live weight. Hoggets whose lambs were weaned when they were 10 weeks of age gained more live weight during the following 4 weeks than those hoggets who were allowed to continue to suckle their lambs. This might suggest that early weaning as a potential strategy to increase the two-year-old breeding live weight. It is unknown if the live weight difference for the hoggets and lambs observed in this experiment would have been similar if the hoggets and her lambs had been offered higher quality herbage.

Chapter 9: Early weaning of lambs born to hoggets

Implications

This chapter involved both twin and single reared lambs born to hoggets. The effect of early weaning of twin on the live weight of the twin reared lambs and their hogget dam is unknown. Future studies could investigate the effect of early weaning of twin reared lambs born to hoggets on lamb and hogget live weight.



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**STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS**

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Fraser Mulvaney

Name/Title of Principal Supervisor: Professor Steve Morris

Name of Published Paper: The effect of early weaning on the hogget and its liveweight change. Proceedings of the New Zealand Society of Animal Production 69, 68-70.

In which Chapter is the Published Work: 9

What percentage of the Published Work was contributed by the candidate: 76

Fraser Mulvaney

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Chapter 10: Is there any advantage of early weaning of twin lambs born to hoggets?



Outlook over Limestone Downs at Port Waikato - the source of the hoggets in this chapter

This chapter will be presented at the New Zealand Society of Animal Production conference in 2011

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Introduction

The perceived negative effect of hogget breeding on two-year old performance is a major reason New Zealand farmers have for not breeding hoggets (Kenyon *et al.*, 2004b). In 2010, only 21% of hoggets wintered were joined with the ram (Anon 2010). In support of this, Baker *et al.* (1981), McMillan & McDonald (1983) and Kenyon *et al.* (2008) reported that hoggets that raised a lamb until weaning were lighter at two-tooth (18-20 months of age) breeding and had poorer reproductive performance as a two-tooth than those that were not bred as a hogget.

Hoggets that are twin-bearing tend to be heavier than single-bearing hoggets at the time of breeding (Kenyon *et al.* 2006). However, their live weight at weaning has been reported to be similar to that of single-bearing hoggets (Morris *et al.* 2005) indicating that twin-bearing hoggets lose more live weight during lactation compared to single-bearing hoggets. As observed in mature ewes, twin lambs born to hoggets are lighter at weaning than singleton born lambs (Morris *et al.* 2005). Early weaning of twin lambs born to hoggets is a potential method to minimise the apparent negative affect on the hogget live weight. However, any change in weaning age should have a minimum impact on the live weight of the twin lambs reared by those hoggets.

For mature ewes, early weaning (prior to 8 weeks of age) has had variable effects on lamb growth. Some researchers (Rattray *et al.* 1976; Furnival & Corbett 1976; Geenty 1979; Smeaton *et al.* 1979; Earl *et al.* 1990) have reported reduced lamb growth rate and lamb survival. Conversely, others (Furnival & Corbett 1976; Rattray *et al.* 1976; Smeaton *et al.* 1979; Earl *et al.* 1990) have reported that weaning lambs born to mature ewes at 8 weeks of

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

age did not affect lamb growth rate. Rattray *et al.* (1976) reported that 8 week old lambs that were reared by mature ewes had a sufficiently developed rumen to ferment herbage. This indicates that the growth of lambs weaned older than 8 weeks lamb should not be restricted due to the ability to compensate the milk requirement with herbage.

Chapter 9 showed that later weaning (10 vs. 14 weeks of age) of lambs born to hoggets had no effect on lamb growth rate. In addition, Earl *et al.* (1990) and Caneque *et al.* (2001) reported that weaning lambs born to mature ewes at 7 to 9 weeks of age reduced dressing out percentage up to 18 weeks of age when 24 or 28 kg compared to not weaned.

Early weaning of singleton lambs born to mature ewes has been reported to increase (Corbett & Furnival, 1976 (6 vs. 12 weeks of age); Smeaton *et al.*, 1979 (8 vs. 14 weeks of age)) or have no effect (Earl *et al.*, 1990 (7 vs. 9 weeks of age); de Nicolo *et al.*, 2006 (9 vs. 13 weeks of age)) on ewe live weight compared to later weaned ewes. The only study that has investigated the impact of early weaning of hoggets (Chapter 9 (10 vs. 14 weeks of age) has reported an increase in hogget live weight from weaning earlier. However, that study did not differentiate between single- and twin-reared lambs.

The objective of the present experiment was to examine the effect of weaning at 9, 11 or 13 weeks of age on the live weight of twin-rearing hoggets and their offspring.

Materials and methods

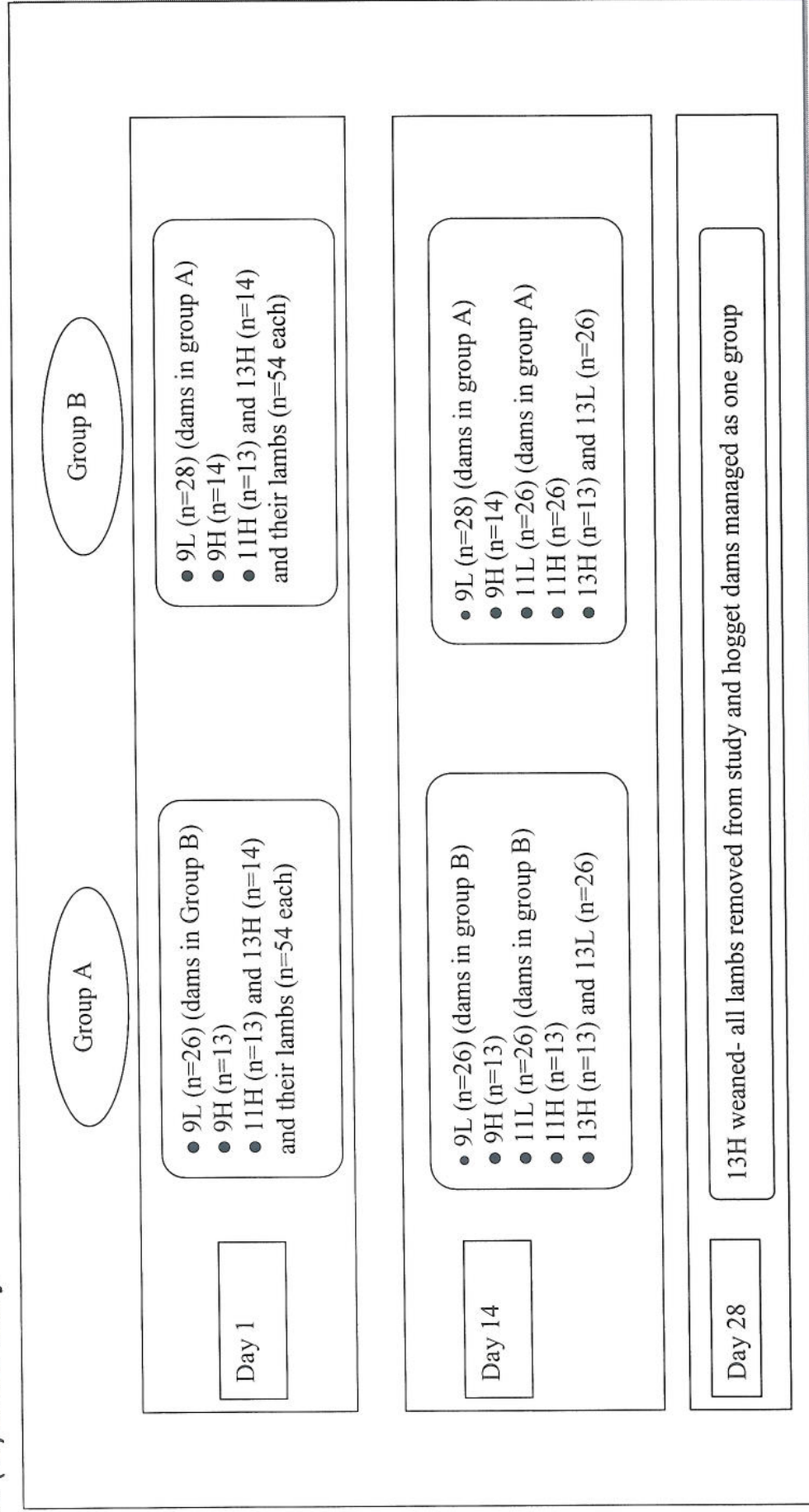
Animals and experimental design

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

At an average lamb age of 9 weeks (63 days, range 56-70 days, D1), seventy-seven Composite hoggets ($\frac{1}{2}$ Romney and $\frac{1}{2}$ Finn) (mean live weight of 57.2 ± 0.6 kg (range 47-71 kg)) and their lambs (mean individual live weight of 21.4 ± 0.3 kg (range 16-29 kg) $n=154$) were allocated to one of three weaning age treatments (9-week vs. 11-week vs. 13-week). The weaning age treatment groups were balanced for hogget and lamb live weight. Hoggets and their lambs were then further divided so that half of the hoggets and their lambs were allocated to either Group 'A' or Group 'B', which were managed in separate paddocks. Group 'A' contained half of the 9-week hoggets (9H) (their lambs remained in group 'B'), half of the 9-week lambs (9L) (their dams remained in group 'B'), half of the 11-week hoggets (11H) and lambs (11L) and half of the 13-week hoggets (13H) and lambs (13L). Group 'B' contained the remaining half of the 9H (their lambs remained in group 'A'), half of the 9L (their dams remained in group 'B') half of the 11H and their 11L and half of the 13H and their 13L. On D14, 11H were weaned, therefore, the 11L in group 'A' were moved to group 'B' and the 11E in group 'B' were moved to group A. On D28, 13H were weaned, therefore, the 13L in group 'A' were moved to group 'B' and the 13E in group 'B' were moved to group 'A'. On D28, all lambs were removed from the study but the hoggets remained in the study until D70. Figure 10.1 outlines the composition of each group for D1, D14 and D28.

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Figure 10.1. Experimental design- group composition of hoggets (H) and lambs (L) for days 1 (9 weeks of age), 14 (11) and 28 (13) of the study.



Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Animal measurements

Hoggets and their lambs were weighed within 1 hour off pasture, on D1, D7, D14, D21 and D28. Hoggets were also weighed on D35, D42 and D70.

Herbage measurement and analysis

The hoggets and lambs were managed on a total area of 11 ha of a mixed sward of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The pre- and post-grazing herbage mass of the 6 paddocks was monitored weekly and determined using a rising plate metre (Ashgrove Pastoral Products, Palmerston North).

Plucked herbage samples were collected on D1 and D35 for each group and one sample collected on D70. The samples were dried in a convection oven for 12 hours at 105°C. The crude protein and energy content was determined via near-infrared-spectrometry (Bruker MPA NIR spectrophotometer, Ettlingen, Germany). The resulted NIR spectra were analyzed using Optic user software (OPUS) version 5.0.

Data analysis

Hogget live weight and lamb live weight were analysed using the repeated measures procedure (SAS, 2005). The fixed effect of weaning age treatment was included in the model for comparing hogget and lamb live weight. The live weight of the hogget on D1 was included in the univariate model for hogget live weight for all days and the individual lamb age were included in the model for lamb live weight as covariates.

Results

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Herbage quality

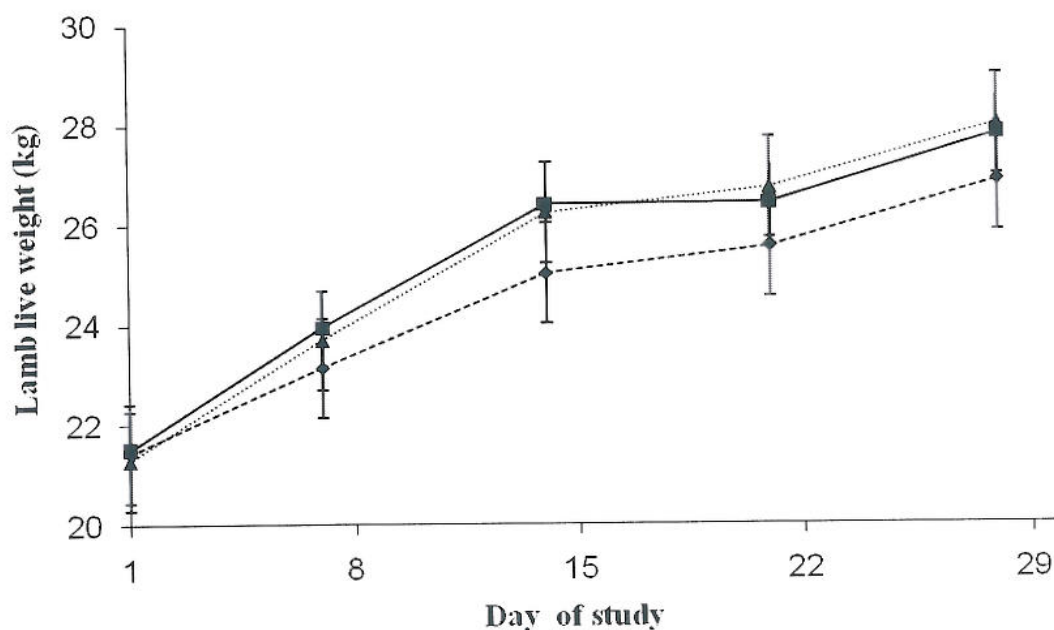
The crude protein content of the herbage offered was 22.7 and 20.9 % on D1 for groups 'A' and 'B', respectively, 23.7 and 25.7 % on D35 and 15.8 % on D70. The metabolisable energy content of the herbage offered was 11.4 and 12 MJ ME/kg DM on D1 for groups 'A' and 'B', respectively, 11.7 and 12.3 MJ ME/ kg DM on D35 for groups 'A' and 'B', respectively and 11.8 MJ ME/ kg DM on D70.

Hogget and lamb live weight

Weaning age treatment had no effect ($P>0.05$) on hogget live weight from D1 to D70 (Figure 10.1) or lamb live weight from D1 to D28 (Figure 10.2).

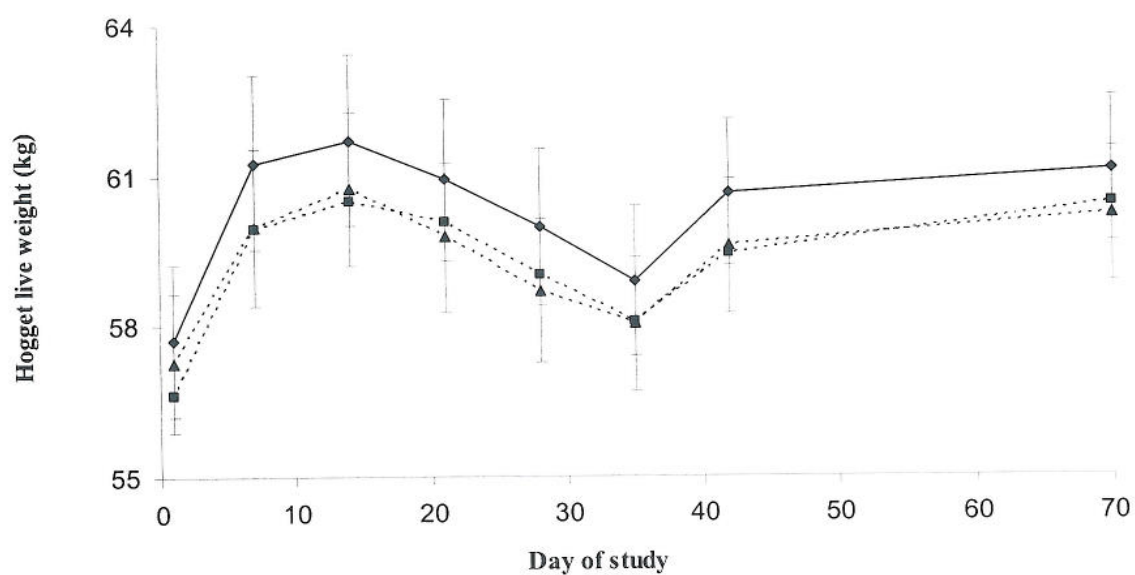
Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Figure 10.1. The effect of weaning age (9-weeks, 11-weeks or 13 weeks) on the mean (\pm s.e.) live weight of twin lambs born to hoggets from day 1 (D1) until day 28 (D28) of the study (···◆··· 9-weeks, ---▲--- 11-weeks and —■— 13-weeks).



Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Figure 10.3. The effect of weaning age (9-weeks, 11-weeks or 13 weeks) on the mean (\pm s.e.) hogget live weight from day 1 (D1) to day 70 (D70) of the study ((\cdots ■ \cdots 9-weeks, $---$ ▲ $---$ 11-weeks and $—$ ◆ $—$ 13-weeks).



Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

Discussion

The objective of the present study was to investigate the effect of weaning lambs at either 9, 11 or 13 weeks of age on the live weight of the hogget dam and their lambs. Previous studies that have involved early weaning of lambs reared by mature ewes (Furnival & Corbett 1976; Rattray *et al.* 1976; Geenty 1979) and hoggets (Chapter 9) have reported no effect of early weaning on lamb live weight which is similar to the results of the current experiment. Weaning 3-5 week old lambs reduced lamb survival (Rattray *et al.* 1976) and growth rate (Rattray *et al.* 1976; Geenty 1979). In addition, Rattray *et al.* (1976) reported that 8 week old lambs reared by mature ewes had a sufficiently developed rumen to ferment herbage. The lambs in the present experiment were at least 8 weeks of when they were weaned. At this age, the rumen should have been capable of fermenting herbage and this may help explain why the age at weaning did not impact on lamb live weight.

Chapter 9 reported that early weaning of lambs improved hogget liveweight gain. Therefore, weaning twin lambs reared by hoggets early would have been expected to relieve the burden of raising twin lambs and possibly enhance their live weight. However, hogget live weight in the present experiment was not affected by the weaning age of the lamb. This suggests that, under favourable pastoral conditions, early weaning is not necessary to improve hogget live weight.

Potential factors affecting the extent of early weaning on hogget and lamb live weight include herbage availability and quality (Furnival & Corbett 1976). In the present experiment, herbage availability remained between 1400 and 1850kg DM/ha and the herbage had a high energy content (11.4-12.3 MJ ME/ kg DM), indicating that the herbage availability and

Chapter 10: Effects of early weaning of twin rearing hoggets on hogget and their lambs live weight

quality was not limiting. Therefore, further studies may consider investigating the potential interaction between herbage availability and quality and weaning age on the live weight of the hogget and its lambs.

Conclusion

These results show that early weaning of twin lambs reared by hoggets did not show any advantage over later weaning. This indicates that early weaning is not a successful technique to increase hogget live weight under favourable pastoral conditions. Further studies should consider investigating the effects of early weaning and different levels of nutrition that represent less favourable pastoral conditions.



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STATEMENT OF CONTRIBUTION
TO DOCTORAL THESIS CONTAINING PUBLICATIONS

(To appear at the end of each thesis chapter/section/appendix submitted as an article/paper or collected as an appendix at the end of the thesis)

We, the candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of Candidate: Fraser Mulvaney

Name/Title of Principal Supervisor: Professor Steve Morris

Name of Published Paper: Is there any advantage of early weaning of twin lambs born to hoggets?. Proceedings of the New Zealand Society of Animal Production 71, 79-82.

In which Chapter is the Published Work: 10

What percentage of the Published Work was contributed by the candidate: 76

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Date

Chapter 11: Concluding Discussion



Hoggets in yards at Limestone Downs during pregnancy diagnosis

Chapter 11: Concluding discussion

The objective of the research detailed in this thesis was to:

1. Compare the overall reproductive performance of hoggets and mature multiparous ewes (Chapters 3 and 4).
2. Investigate methods to improve the reproductive performance of hoggets (Chapters 5, 6, 7 and 8)
3. Determine the effects of lamb weaning age on the live weight of the hogget and her offspring (Chapters 9 and 10).

Comparing the breeding performance of hoggets and mature multiparous ewes (Chapters 3 & 4).

The combined results of the chapters indicate that compared to mature multiparous ewes, fewer hoggets were bred (80 vs. 98%). This suggests many hoggets had not reached puberty when they were between 5 and 7 months of age. Further, it is unknown what proportion of hoggets reached puberty naturally or if progesterone treatment had induced puberty. Additional studies may wish to compare the breeding performance of the two age groups in late May which is the period when the majority of the hoggets should have reached puberty naturally (Ch'ang & Raeside 1957). It is also probable that because they were bred together, the hoggets and mature multiparous ewes interacted differently with the ram and that the mature multiparous ewes spent the most time with the ram which may have resulted in fewer hoggets being bred. Further studies could compare the breeding performance of hoggets and mature multiparous ewes when they are run separately but at the same time of the year. The

Chapter 11: Concluding discussion

fewer hoggets bred compared to mature multiparous ewes represents a large reduction in the reproduction potential of hoggets.

Comparing the reproductive loss of hoggets and mature multiparous ewes

Table 11.1 outlines the reproductive performance and reproductive loss of hoggets and mature multiparous ewes. The data are the combined results of Chapters 3 and 4.

Chapter 11: Concluding discussion

Table 11.1. A comparison of the reproductive loss from ovulation until weaning between mature multiparous ewes and hoggets (based on Chapters 3 & 4)

Reproductive trait	Hoggets	Mature multiparous ewes
Ovulation rate ¹	1.14	1.82
Litter size at P68	0.67	1.59
Early pregnancy loss ²	41%	13%
Pregnancy rate	47%	97%
Late pregnancy loss ³	1%	2-3%
Litter size at lambing ⁴	0.66	1.59
Singleton lamb birth weight	4.2kg	5.3kg
Litter size at weaning ⁵	0.52	1.42
Lamb survival ⁶	79%	89%

¹defined as the number of CL/female that ovulated

²defined as the ovulation rate minus litter size at P68 divided by the ovulation rate*100/1.

³defined as the ewes pregnant at P68 but not at P145*100/1.

⁴number of lambs born per female that ovulated

⁵number of lambs weaned per female that ovulated

⁶defined as the percentage of lambs born that were alive at the time of weaning*100/1.

Table 11.1 indicates that even if the hoggets had reached puberty and ovulated, they released fewer ova than mature multiparous ewes. Increasing the ovulation rate in hoggets would allow hoggets to produce more multiple lambs, but this may not be entirely beneficial as the additional nutrient requirement to raise multiple lambs adds to the pressure on the hogget that

Chapter 11: Concluding discussion

still needs gain live weight. Further studies could focus on increasing the proportion of hoggets that reach puberty and ovulate and not on increasing the ovulation rate per se. Those hoggets that reached puberty and ovulated, on average, released 1.14 ova but only weaned 0.52 lambs per hogget. This represents a loss of 54%. In comparison, mature multiparous ewes released, on average, 1.82 ova and weaned 1.42 lambs per ewe which represents a loss of 23%. These results are supported by numerous authors (Al Wahab & Bryant 1978; Edey *et al.* 1978; Hamra & Bryant 1979; Quirke 1981; Hare & Bryant 1985; McMillan & McDonald 1983; Beck *et al.* 1994, 1996; Michels *et al.* 1998). Both age groups lost the largest number of potential lambs between the time of ovulation and pregnancy diagnosis. Other researchers have identified that the majority of this pregnancy loss occurs during the first month of pregnancy, primarily due to poor developmental competence of hogget ova (O'Brien *et al.* 1996, 1997; Kochhar *et al.* 2002; Ptak *et al.* 2003). Kochhar *et al.* (2002) reported that embryos that reached the 8-16 cell blastocyst stage of development have increased likelihood of the embryo developing into a fetus. Therefore, it appears that early pregnancy, especially the first week, is a critical area in hoggets that required further investigation (this was investigated in Chapters 5 and 6). Once the hoggets were diagnosed pregnant, there was no difference in apparent pregnancy loss from mature multiparous ewes in late pregnancy.

Lamb survival did not differ between dam age group despite poorer maternal behaviour score and lighter singleton lamb birth weight (Table 11.1). However, it is accepted that lamb numbers may not have been sufficient to detect a difference in lamb survival.

Chapter 11: Concluding discussion

Summary of the effects of nutrition pre-breeding, during the breeding season and pregnancy on the reproductive performance of hoggets.

Percentage of hoggets bred

This thesis presents the first data on the effect of different levels of herbage commencing prior to (chapter 5) or at the start of the breeding period (Chapter 6) on the proportion of hoggets bred. Chapter 5 showed that the proportion of hoggets bred could be increased by short term (4 days) *ad-libitum* (target of at least 200 g/day) feeding. These results from this thesis indicate that offering *ad-libitum* levels of herbage immediately prior to or at the time of breeding could have positive effects on the proportion of hoggets bred. Increasing the live weight prior to breeding increases the proportion of hoggets displaying oestrus (Allison *et al.* 1975; Kilgour 1977, Moore *et al.* 1978; Moore & Smeaton 1980) and conceiving (Kenyon *et al.* 2005, 2006a). Therefore, it would be expected that increasing the live weight at the time of joining would increase the proportion of hoggets displaying oestrus and increase the percentage bred. However, in chapter 6 when medium (100-150 grams liveweight change/day) and *ad-libitum* (at least 200 grams liveweight change/day) levels of herbage were offered to light (mean of 36kg) or heavy (mean of 42kg) ewes from the start of the breeding until the end of pregnancy there was no difference in proportion of hoggets bred or pregnant between the live weight groups.

The differences in the mean live weight of the live weight groups did not allow for any differences in the breeding performance to be detected. The progesterone treatment may have

Chapter 11: Concluding discussion

also stimulated the onset of puberty (Ryan *et al.* 1991) in the lighter hoggets. Therefore, the fact that differences in the live weight groups did not result in a difference in breeding performance could be due to a larger proportion of the heavier hoggets already having attained puberty prior to progesterone treatment, whilst the progesterone treatment stimulated puberty in a greater proportion of the lighter hoggets.

Return to oestrus

Returning to oestrus is an early indication of reproductive loss. It can be due to fertilisation failure, poor blastocyst formation or failure to implant. In the present studies it was measured based on rump marks from crayon harnessed vasectomised males after the completion of the breeding period. *Ad-libitum* nutrition after breeding increased the proportion of hoggets that returned to oestrus (Experiment 5.2 in Chapter 5, Chapter 6 and Kenyon *et al.* (2008)). However, in Experiment 5.1 this was not the case which indicates variability in the effect of the level of herbage provided after breeding on the proportion of hoggets that return to oestrus. Further research is required to determine the effect of nutrition after the completion of the breeding period on the proportion of hoggets that return to oestrus. However, until this is determined, farmers should offer a medium (pre- and post-grazing masses of 1400 and 900 kg DM/ha) level of nutrition after the completion of the breeding period to help minimise the proportion of hoggets that return to oestrus activity.

Chapter 11: Concluding discussion

Pregnancy rate

Nutrition commencing 17 days prior to the breeding period, during the breeding period and during the pregnancy period did not affect the pregnancy rate in hoggets under New Zealand pastoral conditions (Chapters 5 and 6, Morris *et al.* (2005) and Kenyon *et al.* (2008)). Further studies are required to determine the effect of herbage levels from weaning until breeding on the pregnancy rate of hoggets. Utilising the results of this thesis and those of Morris *et al.* (2005) and Kenyon *et al.* (2008), to ensure maternal liveweight gain, farmers should offer *ad-libitum* levels of nutrition immediately prior to breeding and during the breeding period to optimise the pregnancy rate. After the breeding period has been completed, to minimise the risk of early pregnancy loss, nutrition should be reduced to a medium level (pre- and post-grazing masses of 1400 and 1000 kg DM/ha, target liveweight change between 100 and 150 g/day) to ensure fewer hoggets return to oestrus and to maximise pregnancy rates. The combined results of this thesis and that of Morris *et al.* (2005) and Kenyon *et al.* (2008) show that the very high liveweight gains that caused pregnancy failure in the U.K. studies (Wallace *et al.* 1996, 1997a, b) are not comparable to New Zealand pastoral conditions.

Late pregnancy loss

It can be concluded from this thesis and from Morris *et al.* (2005) and Kenyon *et al.* (2008) that the range of nutritional levels under New Zealand pastoral conditions does not affect pregnancy loss in late pregnancy, (although, one New Zealand pastoral study (Mulvaney *et al.* 2008) provides variance to this conclusion). However, it was noted that a higher rate of

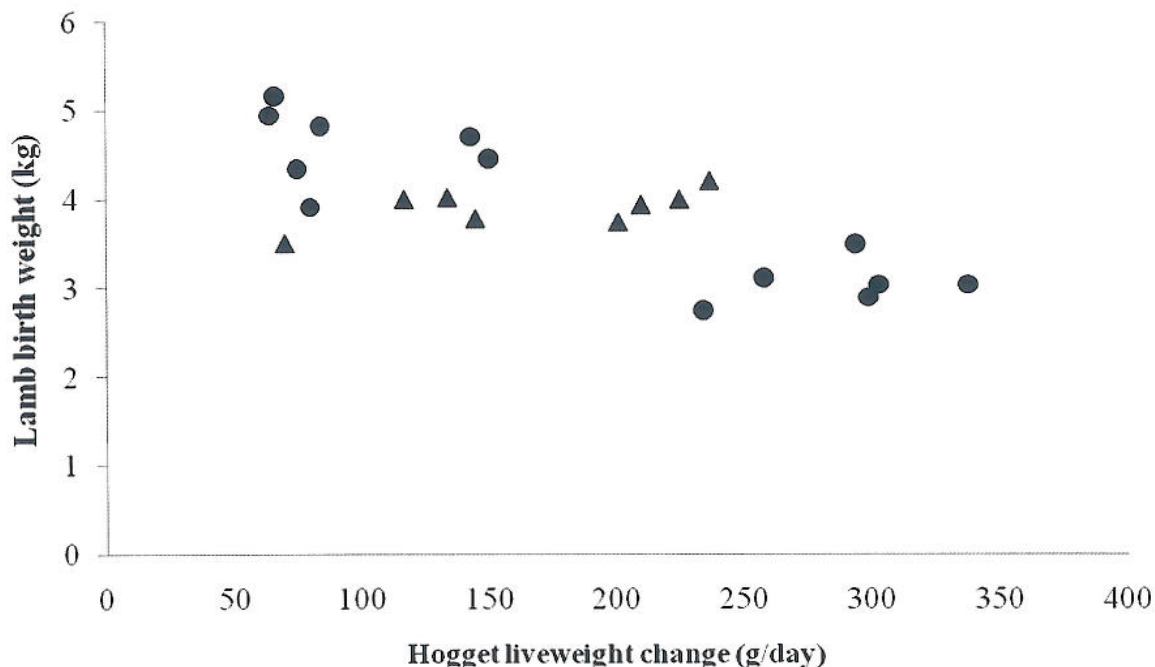
Chapter 11: Concluding discussion

late abortions in this study was not replicated and may have been caused by an infectious disease (*Neospora caninum*) which was observed in that study (West *et al.* 2006; Howe *et al.* 2008). The results of Chapters 5, 6 and 7 and the studies of Morris *et al.* (2005) and Kenyon *et al.* (2008) suggests that the herbage levels could be increased after pregnancy diagnosis to allow for additional liveweight gain in excess of the developing conceptus.

Lamb birth weight and live weight until weaning

The relationship between hogget liveweight change (i.e. nutritional level) during pregnancy and mean singleton lamb birth weight from a number of New Zealand and U.K. studies is outlined in Figure 11.1. This indicates that under New Zealand pastoral conditions there is little scope to alter lamb birth weight by altering the feed available to the hogget. Although the research conducted under U.K. concentrate feeding conditions resulting in very high liveweight gains are associated with a reduction in lamb birth weight. The *ad-libitum* level of herbage offered in the pastoral experiments in this thesis failed to replicate the U.K. findings.

Figure 11.1. The relationship between hogget liveweight gain during pregnancy and lamb birth weight* (\blacktriangle = New Zealand experiments, \bullet = U.K. experiments).



*The data are sourced from those New Zealand and U.K. experiments that solely investigated liveweight change during pregnancy with no nutritional changes or hormonal supplementation. Data is from Wallace *et al.* (1996, 1997a, b 1999, 2000, 2001), Morris *et al.* (2005), Kenyon *et al.* (2008) and Mulvaney *et al.* (2008).

Schruers *et al.* (2010) modelled the effect of hogget liveweight change on lamb live weight. The data included data from Chapters 6 and 7 of this thesis. They reported a small positive relationship between lamb birth weight and hogget live weight during pregnancy, with the greatest increases occurring early in pregnancy (15g/kg increase in hogget live weight). However, for this relationship to result in a significant difference in lamb birth weight between nutritional treatment groups, the hogget liveweight change would need to be extreme. The extreme liveweight change required is not attainable in New Zealand pastoral systems.

Chapter 11: Concluding discussion

Nutritional level during pregnancy did not affect lamb live weight at weaning (Chapter 6, 7 and 8). This suggests that *ad-libitum* levels of nutrition during pregnancy may not be an efficient way to produce lambs. Although it needs to be noted that the hoggets in these chapters were offered *ad-libitum* levels of herbage during the lactation period. If a restricted diet during lactation was fed it could be expected that milk production could be hampered and hence depress lamb growth rate. *Ad-libitum* levels of herbage may allow for a milk production and hence lamb growth rate may not be affected. Schruers *et al.* (2010) reported that the live weight of lambs at weaning was positively associated with liveweight gain during pregnancy. The mean live weight of the lambs were reported in this thesis while the Schruers *et al.* (2010) utilised individual liveweight change and was irrespective of nutritional treatment. However, Schruers *et al.* (2010) does indicate that hogget live weight needs to be increased during pregnancy to maximise lamb weaning weight.

Hogget live weight

Offering single-bearing hoggets *ad-libitum* levels of nutrition during pregnancy has increased hogget live weight at weaning (Chapters 6 and 7; Morris *et al.* 2005; Kenyon *et al.* 2008; Mulvaney *et al.* 2008). The heavier single-bearing hoggets would allow for easier management during the summer and autumn period. These hoggets would not require as much feed to attain an adequate two-tooth breeding live weight. However, when twin-bearing were offered medium or *ad-libitum* levels of herbage from mid-pregnancy until parturition, there was no effect on the live weight at weaning. The medium fed twin-bearing hoggets were probably offered a diet that did not restrict nutrient intake.

Weaning age

Weaning lambs early can provide additional options to farmers when feed is limited or the hoggets are in poorer condition. This would remove the stress of raising a lamb and the nutrients ingested could be utilised for the hoggets own benefit and the lambs could be sold to the store market. Weaning single reared lambs at 10 vs. 14 weeks of age (Chapter 9) resulted in an increased hogget live weight, but weaning twin reared lambs at 9 vs. 11 vs. 13 weeks of age (Chapter 10) did not have an impact on hogget or lamb live weight. This indicates that farmers can successfully wean twin or single lambs at 9 or 10 weeks of age.

Management strategy for hogget breeding to maximise lamb production and hogget live weight from the results of this thesis

The main issue with hogget breeding is ensuring that the hogget is growing during pregnancy whilst not limiting lamb production. The following points provide a guideline:

- ✓ Hoggets should be greater than 40kg at the time of ram introduction.
- ✓ Hoggets should be offered *ad-libitum* levels of herbage prior to ram introduction.
- ✓ Level of nutrition should be reduced to medium levels (pre- and post-grazing masses of 1400 and 900 kg DM/ha) after the completion of the breeding period until pregnancy diagnosis.
- ✓ Level of nutrition should be increased after pregnancy diagnosis and offered *ad-libitum* until parturition and during lactation.

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- ✓ Lambs can be successfully weaned as young as 9 weeks of age if herbage quality or quantity is not limiting.

To successfully implement these strategies would require alterations to the whole farm system, a major change in the feed budgeting and change in how the farmers prioritise their stock classes.

Suggested potential further studies

Increasing the proportion bred

Background-Live weight and puberty

Hoggets must reach puberty prior to breeding and the greater number of oestrous cycles the greater the likelihood of a successful breeding (Hare & Bryant 1985). Currently, in New Zealand, hoggets are bred in May. Therefore, manipulation of the timing of puberty to maximise the number of oestrous cycles prior to breeding would be advantageous. Puberty is attained when the animal has attained 40-60% of its mature live weight (Dyrmundsson 1973). Achieving this target live weight early would mean earlier puberty and more oestrous cycles prior to breeding. The live weight can be achieved from heavier lambs at weaning and high lamb growth rates from 14 weeks of age (weaning) until breeding to attain a live weight of at least 40 kg (Kenyon *et al.* 2004b).

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Experimental design

A production based experiment could be designed to achieve these high growth rates. Such an experiment could utilise a legume based feed (e.g. red or white clover), a herb based feed (e.g. plantain) and a normal mixed sward herbage (perennial ryegrass and white clover). The hoggets could have their live weight monitored and then be exposed to males. Then all hoggets involved would be exposed to crayon harnessed entire rams. The breeding data will be related to live weight and liveweight change data. It will be used to determine if there is any affect of a predominantly herb or legume or a mixed sward from weaning until ram introduction on the breeding and pregnancy performance of the hoggets.

Background- manipulation of day length

Manipulation of day length could potentially alter melatonin concentration and induce puberty (Hansen 1985). Therefore, melatonin levels could be manipulated to artificially induce puberty in the hogget.

Experimental design- manipulation of day length

Melatonin implants could be used prior to breeding and progesterone concentration of the hogget would be used to determine puberty. Hoggets would then be exposed to entire crayon harnessed rams for 2 natural oestrous cycles and the crayon rump marks recorded and the breeding performance of both groups compared.

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Background- short term exposure to progesterone

Progesterone treatment has been reported to stimulate puberty in ewes (Burfening & Berardinelli 1986; Ryan *et al.* 1991) and progesterone treatment could have been involved in stimulating puberty in Chapter 3.

Experimental design- short term exposure to progesterone

An experiment could be designed that involves progesterone enriched devices such as CIDRs which could be inserted into hoggets early in the breeding season for a short period. Progesterone concentration could be used to determine when puberty has been reached. Crayon harnessed teasers would be introduced to each group and then the hoggets would then be joined with entire crayon harnessed rams and the breeding performance recorded. The breeding performance would determine, firstly, if the progesterone treatment induced puberty and, secondly, if it did, was there an effect on the breeding performance of the treated hoggets compared to the untreated hoggets.

Reducing reproductive loss from breeding until pregnancy diagnosis

Manipulating nutritional levels after the breeding period

This thesis has identified that the greatest reproductive loss in hoggets occurs between the time of ovulation and pregnancy diagnosis. The literature suggests that this could be due to poor oocyte quality (O'Brien *et al.* 1996, 1997; Ptak *et al.* 2003). Therefore, improving the

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oocyte quality would be beneficial and strategies that improve the quality of the oocyte would potentially reduce pre-implantation loss. *Ad-libitum* levels of nutrition prior to breeding have led to an increase in oocyte quality of the hogget (Robinson *et al.* 2006). Oocyte quality improves with each successive oestrous cycle the hogget has during the breeding season (Hamra & Bryant 1979). Hence manipulation of the timing of puberty through different nutritional types, melatonin and progesterone treatment may improve the hogget oocyte quality. Therefore, if those studies are successful it may relate to improved oocyte quality and improved pregnancy rates. Chapters 5 and 6 and Kenyon *et al.* (2008) have indicated that possibly *ad-libitum* levels of nutrition after the completion of the breeding period may increase the proportion of hoggets returning to oestrus.

Experimental design- manipulating nutritional levels after the breeding period

A possible production based experiment could allow *ad-libitum* (post-grazing mass of 1400 kg DM/ha) compared to a medium (pre- and post-grazing masses of 1400 and 1000 kg DM/ha, respectively) feeding prior to breeding. After breeding there could be a nutritional switch between medium and *ad-libitum* levels of nutrition until pregnancy diagnosis. At the start of the breeding period the ovulation rate and pregnancy status will need to be determined. From these two parameters the pregnancy loss can be determined.

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Improving blastocyst growth

Supplementation of PMSG could increase pregnancy rate (Crosby & Murray) while hCG 12 days post-breeding has increased blastocyst formation (Khan *et al.* 2009). An experiment could be designed to determine the affect of supplementing PMSG or hCG around the time of breeding and if such a treatment could enhance blastocyst growth and implantation and ultimately reduce reproductive loss.

Experimental design- improving blastocyst growth

Hoggets that had been identified as bred via crayon harness rump marks could be supplemented with hCG during the 12 days post breeding. Hoggets would have their ovaries observed via ultrasound to determine ovarian activity. During this period and up until pregnancy diagnosis anti-luteolytic factors (e.g. interferon tau) and progesterone concentration would be analysed. Interferon tau has been associated with prolific blastocyst growth (Khan *et al.* 2009) while progesterone is critical in embryo implantation (Parr *et al.* 1987). It would be assumed that elevated concentrations of interferon tau and progesterone would be associated with increased blastocyst and implantation. This information would then be correlated to pregnancy diagnosis status and used to determine whether there is any benefit in supplementing PMSG or hCG to hoggets that have ovulated and bred

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Lamb live weight

Background- determining the optimal weaning age and nutritional level

Weaning lambs born to hoggets at 9 weeks of age did not affect lamb live weight compared to lambs weaned at 13 weeks of age. However, the milk production and the shape of the lactation curve of hoggets in New Zealand pastoral conditions are undetermined.

Experimental design

Hoggets that have a live lamb at foot could be milked and the milk production recorded and then the lactation curve could be determined. An optimal weaning age could be determined once this has been determined. An additional experiment could utilise this information to wean the lambs late in lactation or when there is a substantial decline in milk production. The hoggets and lambs could be offered medium or *ad-libitum* levels of nutrition and weighed frequently to determine if there is any interaction between weaning age and nutritional level on hogget and lamb live weight.

Summary

Hogget breeding is currently under utilised by New Zealand farmers with only 30% of hoggets carried through the winter joined with the ram (Anon 2010). There is huge potential to increase the proportion of hoggets bred and, hence, the profitability of New Zealand sheep farming. Provided the farmers utilise the management strategies provided in this thesis,

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farmers can make hogget breeding successful and profitable under New Zealand pasture based farming systems.

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