Growth of dairy heifers on alternative forages and the effects of heifer live weight on reproductive parameters at first breeding.

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ABSTRACT

Abstract

Dairy heifers in industry at present are frequently falling short of the recommended liveweight targets. Rearing of dairy heifers is expensive and involves a two-year non-productive period after which, if she becomes pregnant, income can be received from milk production. Milk yield in first and second lactation is affected by a heifer's live weight prior to calving and therefore meeting liveweight targets is critical for subsequent milk production. Those heifers that fail to become pregnant are of considerably lower value than those that become pregnant. To maximise the chance for heifers to become pregnant, heifers need to have completed a number of oestrus cycles prior to the planned start of mating. Mating of heifers during the third oestrus cycle compared with the first oestrus cycle after reaching puberty, provides an increased probability of the heifer becoming pregnant.

This thesis contains two experiments. The aim of the first experiment was to measure the effects on average daily gain, wither height, girth and crown-to-rump length, of feeding 6-month-old dairy heifers on alternative feeds, over the summer period when pasture quality and availability is limiting. Sixty 6-month-old Friesian-Jersey crossbred heifers were assigned to 1 of 3 treatments (pasture (P), conserved forages (C) or Lucerne (L), with all treatments receiving supplementary meal). Heifers were weighed at 0, 3 and 6 weeks of treatment period, and wither height, girth and crown-to-rump length were measured at the start and end of the experiment. L heifers had a greater ($P<0.05$) average daily gain (1.22 ± 0.03 kg/day) than P heifers (0.57 ± 0.03 kg/day), and C heifers were intermediate (0.78 ± 0.03 kg/day).

The aim of the second experiment was to determine the effect that live weight, percentage of individual liveweight target achieved and achieving individual liveweight target at 6, 9, 12 and 15 months of age had on 5 reproductive parameters: reaching puberty by 12 & 15 months of age; becoming pregnant during a 7 week mating period; becoming pregnant in the first 3 weeks of mating; and becoming pregnant in the first 6 weeks of mating. Heifer live weights were recorded approximately every month. Scanning of the heifers' ovaries at 12 and 15 months of age was completed to determine whether each heifer had reached puberty by the respective age. Natural mating was completed over a seven-week period, and age of the fetus was estimated at pregnancy scanning was to determine in which cycle the heifer became pregnant. There was no

effect on the pregnancy parameters measured as a result of live weight, reaching live weight target and the percentage of liveweight target achieved. Heifers that were heavier at 6, 9 and 12 months of age had an increased likelihood of reaching puberty by 12 months of age. Increased average daily gain was achieved from heifers grazing Lucerne, with supplementary meal also fed, although these increased average daily gains had limited benefit on reproductive performance of the heifers at first breeding.

ACKNOWLEDGEMENTS

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Acid Detergent Fibre content …………………………………………………… ADF%

Ash content …………………………………………………………….. Ash%

Average Daily Gain ………………………………………………….. ADG

Body Condition Score ………………………………………………… BSC

Breeding Values …………………………………………………….. BV

Conserved Forages ………………………………………………….. C

Corpus Luteum ……………………………………………………… CL

Crude Protein ……………………………………………………… CP

Day …………………………………………………………………. D

Dry Matter ………………………………………………………... DM

Dry Matter Intake ………………………………………………... DMI

Faecal Egg Count ………………………………………………... FEC

In Vivo Dry Matter Digestibility ……………………………………….. *In vivo* DMD%

In Vivo Digestibility of Organic Matter in Dry Matter ……………….. *In vivo* DOMD%

In Vivo Organic Matter Digestibility …………………………………… *In vivo* OMD%

Kilogram …………………………………………………………… kg

Lucerne …………………………………………………………… L

Metabolisable Energy …………………………………………….. ME

Nitrogen …………………………………………………………... N

Neutral Detergent Fibre content ………………………………………… NDF%

Pasture ……………………………………………………………… P

Planned Start of Calving ………………………………………………… PSC

CHAPTER ONE

REVIEW OF LITERATURE

1.0 Introduction

Dairy heifer replacements are not currently achieving the recommended liveweight targets during the rearing period. During the heifer rearing period there are many milestones that heifers must achieve, these are: to achieve puberty at approximately 12 months of age, become pregnant at approximately 13-15 months of age, and enter the milking herd at approximately 22-24 months of age with the ability to produce sufficient levels of milk. Sufficient levels of milk can be described as an amount of milk production that allows the income received from the milk to pay off the money invested in the heifer during the heifer rearing period within the first lactation. There are many different challenges that heifers face to achieve all of these milestones, and the live weight in relation to the liveweight targets of the heifer indicate how well she is going during the rearing period.

Currently, within the New Zealand dairy industry, heifers are failing to achieve the recommended liveweight targets with 73% of heifers at 22 months of age being more than 5% below liveweight target (McNaughton & Lopdell, 2012). Potential milk production is lost as a result of heifers not achieving liveweight targets, especially the liveweight target at 22 months of age.

1.1 Requirements of heifers

There are two key requirements of heifers at the completion of the rearing period. These two requirements are pregnancy and milk production. Heifers become pregnant at 13-15 months of age, which is during the rearing stage, with a successful gestation lasting approximately 9 months and once completed initiates lactation. Milk production starts once the heifers have calved and is repeated every year throughout her life.

1.1.1 Pregnancy

The reproductive performance of cows in the New Zealand dairy industry has declined over the last 30 years (Harris et al., 2006). Heifer rearing has been identified as one of the eight components for achieving good reproductive performance (Burke et al., 2007). Successful heifer rearing concludes with the heifer calving and entering the milking herd at approximately 22-24 months of age, and heifers need to become pregnant at 13-15 months of age for this to happen.

Pregnancy is important because it is necessary for the heifer to calve and lactate. Typically, heifers in the New Zealand dairy industry calve at 22-24 months of age which equates to the heifers becoming pregnant at 13-15 months of age. For this to occur, heifers have to have reached puberty prior to the start of mating at approximately 12 months of age. Puberty is defined as the stage when mature gamete production occurs and reproductive activity starts (Foster, 1999). The age at which puberty is achieved, is negatively correlated with the plane of nutrition and live weight of the animal (Short & Bellows, 1971; Yelich et al., 1996; Macdonald et al., 2005; Sejrsen et al., 2013). Puberty is not just the maturing of gametes but also the physical development of the reproductive tract to a point necessary for pregnancy (McNaughton, 2003). It is suggested that heifers reach puberty at approximately 45-50% of their expected mature live weight (Garcia-Muniz, 1998; McNaughton, 2003). For heifers that are achieving liveweight targets, 50% of mature liveweight should be achieved at 12 months-of-age (Troccon, 1993) and therefore heifers should reach puberty by 12 months-of age.

If heifers are achieving liveweight targets and as a result reaching puberty at approximately 12 months-of-age, they have an increased submission rate and conception rate when mated at 14-15 months of age (MacMillan, 1994). There are differences seen between breeds of cattle as to when they reach puberty (Eckles, 1915; Hickson et al., 2008). Hickson et al. (2008) reported in beef heifers, dairy-beef

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crossbred heifers and dairy heifers, a range of ages at which the heifers reached puberty and live weights at which puberty was reached. Straight bred Jersey heifers reached puberty the earliest at 294 days of age with a live weight of 189 kg (Hickson et al., 2008). Straight-bred Friesian heifers reached puberty at 364 days of age at a live weight of 265 kg and the straight bred Angus heifers reached puberty at the latest age, 395 days of age and at the heaviest live weight 297 kg (Hickson et al., 2008).

There are a number of additional factors that may contribute as to when puberty in heifers occurs. Live weight and nutrition are known to influence the when puberty is reached (Foster, 1999; Hafez & Hafez, 2000) and as stated earlier, heifers have been observed to reach puberty at 45-50% of expected mature live weight (Garcia-Muniz, 1998; McNaughton, 2003). When growth rates, or average daily gains (ADG), are manipulated resulting in changes in a heifer's live weight, the age at which a heifer reaches puberty changes but generally not the live weight (Barash et al., 1994; Lammers et al., 1999), although Bergfeld (1994) reported that heifers fed a high-energy diet reached puberty younger and heavier than those fed a low-energy diet. Similarly, inadequate nutrition delays puberty by delaying reaching the necessary live weights (Barash et al., 1994; Short & Bellows, 1971; Yelich et al., 1996; Macdonald et al., 2005; Sejrsen et al., 2013).

Live weight is associated with puberty (Garcia-Muniz, 1998; McNaughton, 2003), and when heifers reach puberty in respect to mating has shown some effects on conception rates in heifers (Byerley et al., 1987; Staigmiller et al., 1993). Byerley et al. (1987) and Staigmiller et al. (1993) both observed that beef heifers that were bred during the third oestrus cycle after puberty had greater pregnancy rates compared to heifers that were bred during the first oestrus cycle after puberty. Staigmiller et al. (1993) observed a pregnancy rate of 13% in those heifers that were bred during first oestrus after puberty compared to a pregnancy rate of 53% in those heifers bred during the third oestrus cycle after puberty. There are some suggested targets for measuring how good heifer reproductive performance is. The aim is to get 75% and 92% of their heifers calved by the end of the third and sixth week of calving, respectively, if the intended planned start of calving for the heifers was the same date as the cows (Burke et al., 2007).

Live weight of the heifer has been observed to influence the reproductive performance of heifers. A lower percentage of liveweight target at 15 to 17 months of age has been

observed to be associated with a reduced reproductive performance in heifers (McNaughton & Lopdell, 2013). McNaughton & Lopdell (2013) reported that heifers in New Zealand that failed to calve at 22-24 months of age (based on no recorded calving date) had achieved a significantly lower percentage of liveweight target at 15 to 17 months of age. The heifers that failed to record a calving date achieved 84.2% of the recommended liveweight target compared to the 86.5% of liveweight target for the heifers which did have a recorded calving date (McNaughton & Lopdell, 2013). In addition, McNaughton & Lopdell (2013) also observed that of the heifers which had calved once 17% failed to record a second calving. The heifers that had only one recorded calving only achieved 83.4% of the liveweight target at 15 months of age compared to 87.1% for the heifers that recorded a second calving date (McNaughton & Lopdell, 2013).

1.1.2 Milk production

Before lactation is initiated at first calving, the development of the mammary gland starts from conception and continues until the end of the heifer's lifespan. The development of the mammary gland, or mammogenesis, can be split into five distinct periods. These periods are: conception to birth; birth to pregnancy; pregnancy; lactation; and the dry period (Holmes et al., 2007; Sejrsen et al., 2013). The two main periods that are associated with heifer rearing are the birth to pregnancy period and the pregnancy period. The prepubertal period is associated with early mammary development (Daniels et al., 2009) and falls within the birth to pregnancy period. The post-pubertal period falls within the last few months of the birth to pregnancy period and the whole of the pregnancy period during the heifer's first pregnancy.

When a calf is born it possesses four small glands with each containing a teat, a teat and gland cistern and a system of collecting ducts (Holmes et al., 2007). After birth the mammary gland grows at a rate proportional to the growth of the heifer (Holmes et al., 2007). During this stage it is the non-epithelial tissue that grows (Sejrsen, 1994). The growth rate then increases at approximately two to three months-of-age, well in advance of when the heifer reaches puberty (Sejrsen, 1994; Holmes et al., 2007; Sejrsen et al., 2013). This sudden increase in the growth of the mammary gland is called positive allometric growth, with the allometric coefficient having a value of between three to four (Sinha & Tucker, 1969; Holmes et al., 2007). During this stage of increased mammary gland growth, it is the rapid growth of the fat pad and of the ducts that branch

into the fat pad that account for the increased growth of the mammary gland (Sejrsen, 1994, Sejrsen et al., 2013). It is thought that this positive allometric growth phase is closely linked to the gradual maturation of the ovaries (Sejrsen, 1994).

After the positive allometric growth of the mammary gland the growth rate of the mammary gland reduces back to a growth rate that is proportional to the growth of the heifer (Sejrsen, 1994, Holmes et al., 2007). The point at which the growth of the mammary gland reduces is not known with some stating that it occurs once puberty has been reached or shortly thereafter (Sinha & Tucker, 1969; Pritchard et al., 1972; Sejrsen et al., 1982) and others stating that it occurs once several oestrus cycles have been completed (Holmes et al., 2007).

Growth rates of the heifers and the subsequent growth of the mammary gland during the prepubertal period have been associated with potential reductions in milk production (Sejrsen, 1978; Harrison et al., 1983; Johnsson, 1988; Troccon & Petit, 1989; Waldo et al., 1989; Foldager & Sejrsen, 1991; Sejrsen, 1994). It is thought that the plane of nutrition that the heifer receives around the time of puberty, the positive allometric growth period, can affect the lifetime milk production of the heifer (Sejrsen, 1994; Holmes et al., 2007).

1.1.3 Longevity of heifers

Once healthy, well-grown heifers with good fertility have entered the milking herd, these heifers should then be able to fulfil their genetic potential by leading a long and productive life (Brickell & Wathes, 2011). There are a number of factors that determine the longevity of a cow and culling varies from farm to farm as it is influenced by management style (Hare et al., 2006). There are two types of culling, involuntary and voluntary. Involuntary culling is culling of cows due to health or disease-related issues or unsatisfactory reproductive performance, whereas voluntary culling is culling of cows that are still healthy but have low milk production (Rogers et al., 1988). Some of the more common health or disease issues that are observed in cows resulting in them being culled are mastitis, udder health issues, and lameness (Rogers et al., 1988; Holmes et al., 2007). Reducing the amount of involuntary culling has been associated with increases in farm profitability (Rogers et al., 1988). Currently within the New Zealand dairy industry 87.6% of 2-3 year old cows are surviving to the next lactation (DairyNZ, 2014b).

1.2 Growth rates of heifers

There are two distinct periods during the heifer rearing period, with the first being the prepubertal period and the second being the postpubertal period. Different growth rates are required during each of these periods based on recommended liveweight targets (Troccon, 1993). The prepubertal period can be defined as the period from weaning until the heifer reaches puberty, which usually occurs around 12 months of age. The postpubertal period can be defined as the period from puberty until the heifer returns to the milking herd prior to calving at approximately 22-24 months of age. There have been a range of effects observed as a result of different growth rates achieved in these periods and the live weights as a result of different growth rates on milk production in heifers. The length of time that these effects are observed for ranges from only during the first lactation and up to the third lactation (Little & Kay, 1979; Macdonald et al., 2005). The growth rates that heifers achieve during these two periods determines what live weights the heifers will be throughout the rearing period.

1.2.1 Prepubertal growth rates and the effects of prepubertal growth rates on production

The growth rate of heifers during the prepubertal period is less than that required during the postpubertal period. For example, a heifer that has an expected mature live weight of 500kg is expected to be 20% of this or 100 kg at 3 months of age (Troccon, 1993). The liveweight target at 12 months of age is 50% or 250 kg (Troccon, 1993), which equates to a growth rate of approximately 0.55 kg/day. For the postpubertal period the liveweight target is 86% or 430 kg at 21 months of age (Troccon, 1993), which equates to a growth rate from 12 months to 21 months of 0.66 kg/day. Macdonald et al. (2005) reported, in a New Zealand-based study, an ADG in the range of 0.37 to 0.77 kg/day for Holstein Friesian heifers and 0.30 to 0.61 kg/day for Jersey heifers, across a number of different feed allowance treatments. McNaughton & Lopdell (2012) reported that in the New Zealand dairy industry, heifers are achieving ADG in the range of 0.32 to 0.59 kg/day during the prepubertal period.

During the prepubertal period, excessive growth rates have been associated with reduced mammary parenchymal development (Capuco et al., 1995; Meyer et al., 2004) although there are inconsistences in the literature, with Van Amburgh et al. (1998) and Radcliff et al. (2000) observing a negative/positive effect of increased pre-pubertal growth rates on milk production and a number of studies not observing any effect

(Troccon, 1993; Gaynor et al., 1995; Pirlo et al., 1997; Van Amburgh et al., 1998; Abeni et al., 2000; Carson et al., 2000). Average daily gains that are >0.70 kg/day during the prepubertal period are considered as high (Daniels et al., 2009). Van Amburgh et al. (1998) and Radcliff et al. (2000) have all reported that there are some negative effects on milk production seen from high growth rates in heifers during the prepubertal period (Table 1.1).

In contrast, Van Amburgh et al. (1998) reported that there was no effect on milk production of prepubertal growth rates after live weight differences that occurred after puberty had been corrected for. Similarly, Pirlo et al. (1997) reported no difference in milk production for heifers that achieved growth rates of 0.6 or 0.8 kg/day during the prepubertal period, and Carson et al. (2000) reported no difference in milk production from heifers that achieved growth rates of 0.70 or 1.05 kg/day during the prepubertal period on milk production. Macdonald et al. (2005) reported that heifers that were placed in various nutritional treatments which resulted in different growth rates during the prepubertal period, which later resulted in difference live weight at calving, did not have any difference in milk production or milk composition. Although, when milk production was corrected for live weight at calving, increases in feeding allowance during the prepubertal period resulted in reduced milk production, but the reason behind this observation was not discussed by Macdonald et al. (2005), but could be because growth rates and live weight are confounded.

Table 1.1. Differences observed in milk production between heifers that had a greater growth rate during the prepubertal period compared to those that had a lessor growth rate during the prepubertal period.

Reference	Breed	Growth rate	Milk period	Milk Production Difference	Pvalue
Van Amburgh et al. (1998)	Holstein	1.0 kg/day (vs 0.6 kg/day)	1st lactation	-486 kg (-4.9 %)	P<0.05
	Holstein	1.0 kg/day (vs 0.6 kg/day)	1st lactation (4% Fat corrected)	-450 kg (-5.0 %)	P<0.05
Radcliff et al. (2000)	Holstein	1.1 kg/day (vs 0.8 kg/day)	1st lactation (270 days)	-945 kg (-12.0 %)	

It has been suggested that rather than the growth rates the heifers achieved during the prepubertal period affecting milk production, that it is the time that the heifer has to reach puberty that affects future milk production (Capuco et al., 1995; Abeni et al., 2000; Meyer et al., 2004). Meyer et al. (2004) observed no effect of growth rates during the prepubertal period on daily parenchymal development rather that the prepubertal period was shorter for those heifers that had a higher growth rate. As a result of having a shorter prepubertal period the total amount of parenchymal development during the first allometric period was less (Meyer et al., 2004). Capuco et al. (1995) found a similar reduction in total parenchymal development during the first allometric phase but did not measure any milk production in the heifers once they started lactating.

Macdonald et al. (2005) highlighted that the inconsistencies that have been observed in regards to the effect of prepubertal growth rates on milk production may be as a result of a number of factors. The first factor is that under grazing conditions the cow's genetic potential to produce is rarely exploited and therefore any retarded growth in the mammary gland may not result in reduced milk production (Macdonald et al., 2005). A number of other factors have also been described: these are the confounding effects of postpubertal management (Van Amburgh et al., 1998), age at first calving (Abeni et al., 2000), the type of feed used to achieve the higher growth rates (Silva et al., 2002) and a

combination of all of these factors as well as the duration of the studies not being sufficient to observed the complete effects of prepubertal growth rates on milk production (Macdonald et al., 2005).

1.2.3 Postpubertal growth rates and the effects of postpubertal growth rates on production

The growth rates that heifers are required to achieve during the postpubertal period are greater than those that are required during the prepubertal period, as previously described. Greater live weight at calving resulted in an increase in milk production in a number of studies (Cowen et al., 1974; Kerr et al., 1985; Crosse & Gleeson, 1988; Freeman, 1995; van der Waaij et al., 1997; Macdonald et al., 2005), whereas other studies have not reported any effect (Thomas & Mickan, 1987; Stewart & Taylor, 1990; Troccon, 1993; Carson et al., 2000). There have been differences observed in milk production as a result of increased postpubertal growth rates with these differences observed over a number of lactations (Macdonald et al., 2005). There has been a range of growth rates observed in heifers during the postpubertal period, with Macdonald et al. (2005) reporting growth rates of 0.49 to 0.69 kg/day in Holstein Friesian heifers and 0.43 to 0.58 kg/day in Jersey heifers. In the Jersey heifers, the increased growth rate (0.58 kg/day) resulted in a reduction of 299 kg of milk in the heifers first lactation (Macdonald et al., 2005).

McNaughton & Lopdell (2012) reported that in the New Zealand dairy industry heifers were achieving growth rates in the range of 0.60 to 0.65 kg/day, which is below the average growth rate required by heifers during the postpubertal period to ensure that they reach recommended liveweight targets. A one percentage increase in liveweight target achieved between 18 and 21 months of age resulted in an additional 23.2 L of milk in a heifers first lactation (McNaughton & Lopdell, 2013).

The observations of increased milk production as a result of increased heifer size or live weight at calving are inconsistent. van der Waaij et al. (1997) reported that for every 1 kg heavier a heifer was at 15 months of age an increase of 6.7 L of milk and 0.43 kg of milksolids was observed in the first lactation for heifers in New Zealand. Dobos et al. (2001) reported a similar effect, for every 1 kg heavier a heifer was at calving resulted in an increase in milk production of 5.35 L and 0.42 kg milksolids. From these experiments (van der Waaij et al., 1997; Dobos et al., 2001) for every 1% increase in

live weight at calving resulted in an increase of 26.8-30.0 L of milk in the first lactation (McNaughton & Lopdell, 2013).This was similar to what McNaughton & Lopdell (2012) observed, which was that for every 1% increase in liveweight target attained between 18-21 months of age resulted in an additional 23.2 L of milk production in a heifer's first lactation for heifers in the New Zealand dairy industry. Macdonald et al. (2005), found no effect of live weight at calving, as a result of prepubertal growth rates, on milk production but that live weight at calving, as a result of postpubertal growth rates did have an effect milk production. Freeman (1993) found that each extra kilogram at first calving resulted in 20.8 L per lactation of extra milk was produced over the first 3 lactations and Cowan et al. (1974) observed a very similar effect, with 23.0 L extra milk for every 1 kg extra at calving per lactation.

Thomas & Mickan (1987) reported that increased live weight at calving had an effect on milk production of Friesian heifers, with an increase in milkfat production of 0.25 kg/day during the first lactation per kg of live weight at calving. No such relationship was found in Jersey heifers (Thomas & Mickan, 1987). Stewart & Taylor (1990) observed heifers of a 'big' (416 kg at calving) or 'small' (381 kg at calving) size to have milk production in the first 20 weeks of lactation of 1882 L and 1721 L, respectively, which was not significantly different.

The inconsistencies around the effect that live weight at calving has on milk production may be due to the fact that it is not simply a heifer's live weight at calving that affects milk production but rather the way in which the live weight has been achieved (Macdonald et al., 2005). This theory is supported by Crichton et al. (1960) who observed that an elevated feeding allowance during the prepubertal period followed by a lower feeding allowance while heifers were pregnant resulted in reduced milk production in first lactation. This theory is leading towards the potential effects of prepubertal growth rates and a reduced amount of parenchymal development or the importance of feeding and development in pregnancy.

Increased live weight at calving is also presumed to increase the dry matter intake (DMI) required by the heifer once the heifer has calved due to the increased maintenance requirements. Macdonald et al. (2005) stated that this effect is still uncertain and is difficult to obtain accurate measurements in pasture based dairy system were cows cannot always achieve the DMI unlike that which has been reported in cows

that are in stall feeding systems which can achieve maximum DMI (Kolver & Muller, 1998). Similarly, those heifers that are required to still grow during lactation would be required to have a greater DMI if they are to grow and meet production targets simultaneously. The inconsistency that surrounds the literature of greater prepubertal growth rates reducing milk production may be clarified (Macdonald et al., 2005) if prepubertal growth rates, live weight at calving, dry matter intake once calved and subsequent milk production were also measured, as they have not been measured in studies which observed the effect of prepubertal growth rates on future milk production (Kolver et al., 2002; Thorne et al., 2003).

1.2.5 Compensatory growth

Heifers that do not achieve liveweight targets at 22-24 months of age, would need to continue to grow once they have calved and entered the milking herd. The amount of feed that a cow can consume is limited by the pasture quality and animal's physical ability to consume feed (Waghorn et al., 2007b). The amount of feed offered may also limit the amount of feed consumed. The amount of feed that can be consumed is limited to a set amount and the energy gained from this feed is proportioned towards certain aspects (i.e. maintenance & production) within the heifer. Therefore if a heifer is required to continuing to grow whilst lactating, firstly the amount of feed that she could consume would be less as her physical abilities will limit the amount that she consume compared to that of a well grown heifer that does not require to continue to grow during lactation (Waghorn et al., 2007b), and secondly less energy can be proportioned towards milk production.

1.2.6 Longevity in relation to live weight & liveweight targets

Heavier heifers or heifers that achieve a greater percentage of liveweight target are more likely to be pregnant and/or have higher milk production which results in a lessor likelihood of these heifers to be culled. Bryant & McRobbie (1991) found that heifers that weighed 385 kg versus those that weighed 315 kg at 18 months of age had a 15% greater chance of reaching a fourth lactation.

1.3 Liveweight targets

Liveweight targets were first suggested to the New Zealand dairy industry as a way to assist in the successful rearing of heifers by McMeekan (1954). Increased profit could be received immediately from providing pasture to milking cows rather than to heifers (Bryant et al., 1991) so a greater number of New Zealand dairy farmers started grazing-off their heifers (Penno et al., 1997). With the increase in grazing-off of heifers, it was determined that dairy farmers required information on the potential benefits on milk production, reproduction and longevity as a result of better feeding heifers during the rearing period (Penno et al., 1997). It was thought that by knowing the potential benefits of heifers achieving liveweight targets that farmers would be motivated to ensure that heifers reached liveweight targets.

The current New Zealand dairy industry liveweight targets for heifers are based on research completed by Troccon (1993) in Italy, which have further been supported by Penno et al. (1997) who completed a New Zealand based study. Troccon (1993) suggested that heifers should reach 30%, 60% and 90% of the expected mature live weight at 6, 15 and 22 months-of-age, respectively. Penno et al. (1997) found that these estimations of the liveweight targets were appropriate for heifers in the New Zealand dairy heifers. Linear interpolation between the liveweight targets that Troccon (1993) recommended provides further liveweight targets of 20%, 40%, 50%, 73% and 86% of the expected mature live weight at 3, 9, 12, 18 and 21 months-of-age, respectively (DairyNZ, 2014). The liveweight target at 22 months of age for heifers is the live weight that the heifers are expected to be 2 months prior to planned start of calving (PSC) before the foetus grows significantly (Burke et al., 2007).

Troccon (1993) reported that heifers became pregnant when they weighed 60% of their mature adult weight. Penno et al. (1997) justified this liveweight target, as the 60% of mature live weight at 15 months of age corresponding to the average live weight which minimised the incidence of non-cycling heifers. Troccon (1993) observed that primiparous Holstein heifers reached 90% of their adult weight before first calving. The recommended liveweight target of 90% of mature live weight target was close to the live weight of heifers that achieved the highest milk production level (Penno et al., 1997).

1.3.2 Expected mature liveweight targets

Currently within the New Zealand dairy industry there are two recommended methods for determining the expected mature live weight of heifers from which liveweight targets can be calculated from (Burke et al., 2007). The first option is based on the average mature live weight of a cow within the milking herd (Burke et al., 2007). The live weight should be that of 6 to 8 year old cows as this is when mature live weight is reached (Burke et al., 2007). For spring calving cows, they should be weighed during December to January or in April to May, when the cows should be at a body condition score (BCS) of approximately 4.0 to 5.0 and pregnancy would not have much influence on live weight (Burke et al., 2007).

The second option is using the liveweight breeding value of a heifer or a line of heifers (Burke et al., 2007). The liveweight breeding value is used in the following equation to calculate the heifers genetic potential for mature live weight:

$$Expected\ mature\ live\ weight = 503kg\ +\ live\ weight\ breeding\ value\ (Burke\ et\ al., 2007)$$

It is recommended that this option is not used on an individual heifer basis but rather as a method to establish an average mature live weight breeding value and subsequent expected mature live weight for a mob of heifers (DairyNZ, 2014). The reason behind this recommendation is that there is low accuracy on individual breeding values based on parental records due to the effects of Mendelian sampling and random environmental effects but the accuracy of a group average breeding value is greater and therefore the recommended option. In addition to breeding value for mature live weight there is also a production value for mature live weight which is potentially higher due to the effects of heterosis (McNaughton & Lopdell, 2012). The effect of heterosis on the mature live weight of Holstein Friesian x Jersey first-cross animals has been estimated at 7.7kg or 1.7% of live weight (Lopez-Villalobos et al., 2000) and it will be less for back-crosses or second and subsequent crosses. This is a relatively small increase and thus breeding values are likely to be an adequate indicator of mature live weight.

1.4 Current situation of heifers in industry

Currently within the New Zealand dairy industry, the majority of heifers fail to meet liveweight targets (McNaughton & Lopdell, 2012). At 3 months-of-age, heifers were on average 2% below liveweight target which suggests that the calf rearing practices in the New Zealand dairy industry are adequate (McNaughton & Lopdell, 2012). By 22 months-of-age heifers were on average 11% below liveweight target (McNaughton & Lopdell, 2012). This is the result of ADG from 3 to 12 and 15 to 22 months of age not being adequate. Of many periods observed, only once was the ADG achieved by the heifers meeting the required ADG (McNaughton & Lopdell, 2012). The ADG achieved during this period did not compensate for the shortfalls that occurred throughout the rest of the rearing period (McNaughton & Lopdell, 2012).

Management, which was measured through the variable 'herd', has been identified as having the most influence on whether or not heifers achieved liveweight targets irrespective of breed and region (McNaughton & Lopdell, 2013). Jersey heifers had a greater probability of reaching liveweight targets followed by Crossbred heifers and then Friesian heifers (McNaughton & Lopdell, 2013). This indicates that the current heifer rearing practices in New Zealand are adequate for Jersey heifers more so than Friesian heifers. McNaughton & Lopdell (2013) stated that one possible reason as to why this is the case is because with a mob that has heifers of different breeds the amount of feed offered is not sufficient for Friesian heifers to achieve the required ADG and as a result they do not meet liveweight targets. Friesian heifers have a greater expected mature live weight which therefore equates to these heifers requiring higher ADG.

1.5 Growth of heifers on pasture in New Zealand

Currently within the New Zealand dairy industry a large proportion of heifers are reared off farm on a run-off block or with a grazier (McNaughton & Lopdell, 2013). Heifers are reared off farm from either weaning or 9-10 months of age until approximately 2 months prior to calving (Holmes et al., 2007). On these run-off blocks or grazier's farms the majority of the feed provided to the heifers is in the form of pasture (i.e. perennial ryegrass (*Lolium perenne*) & white clover (*Trifolium repens*) swards) because these are the cheapest form of feed (Holmes et al., 2007). Some alternative forages or

supplements may be used during periods throughout the year. The period from 3 to 12 months of age has been observed to be when ADG achieved by heifers in New Zealand dairy industry are not adequate to meet recommended liveweight targets (McNaughton & Lopdell, 2012). The 6-9 months-of-age period, for spring born heifers, aligns with summer during which pasture quality declines with increased dry matter content of pastures (Litherland et al., 2002).

1.6 Alternative methods for increasing live weight gains/ADG

There are a number of alternative feed sources to pasture that have the potential to produce sufficient growth rates in dairy heifers. There are two different types of alternative feed sources; these are supplements and alternative forages that can be grazed by the heifers.

1.6.1 Supplementary meal and conserved forages

Supplementary meal has been shown to increase ADG of various livestock classes but comes at an increased cost compared to that of grazed forages. Berry (2013) reported that the use of meal (12.5 MJ ME/kg DM & 18% crude protein) in 6-month-old Friesian bull calves that were grazing old pasture achieved an ADG of 1.08 kg/day. A farmer-based study in New Zealand, reported growth rates in dairy bull calves during their first summer/autumn (i.e. as 6 month old) 0.93 kg/day when provided 0.8 kg meal/day (the meal was a blend of Palm Kernel Extract and kibbled maize; Beef & Lamb, 2015). In the same study, dairy bull calves that were fed the same meal at a rate of 1.6 kg/day only achieved a ADG of 0.84 kg/day (Beef & Lamb, 2015), purportedly because the calves became reliant on the meal and reduced the amount of time grazing.

1.6.2 Alternative forages

The use of alternative forages in sheep and some cattle studies has shown that increased ADG can be achieved by livestock grazing alternative forages. Lucerne (*Medicago sativa*), mixed herb swards (plantain (*Lantago lanceolata*), chicory (*Cichorium intybus*), white clover and red clover (*Trifolium pratense*)) and brassica crops have all shown potential to increase either lamb ADG or cattle ADG (Hare et al., 1987; Fraser et al., 1988; Clark et al., 1990; Robertson et al., 1995; Burke et al., 2002; Muir, 2009; Golding et al., 2011; Parish et al., 2012). Hare et al. (1987) and Fraser et al. (1988) observed weaned Friesian bulls, that were 7 to 10 months of age, achieved an ADG of 0.90

kg/day when grazing pure chicory swards, in New Zealand. Clark et al. (1990) completed a similar study, where 4-month-old bull calves grazing pure chicory swards achieved an ADG of 0.57 kg/day on a low allowance and 0.62 kg/day on a high allowance. Clark et al. (1990) observed no difference between the ADG of the calves grazing the pure chicory sward versus those grazing the pasture sward. Parish et al. (2012) observed approximately 12 month old steers grazing a pure chicory sward achieve an ADG of 1.07 – 1.22 kg/day. Muir (2009) observed dairy bull calves that were 12 weeks old grazing a brassica crop achieved an ADG of 1.09 kg/day, but there was no comparison to pasture under the same conditions. Berry (2013) observed 6-month-old Friesian bull calves achieved an ADG of 1.21 kg/day on a mixed herb sward (plantain, chicory, red and white clover) with an ADG of 1.06 kg/day achieved by similar bull calves grazing a first-year pasture sward.

Increased ADG are achieved because of the greater feeding value of alternative forages in comparison to pasture swards of predominantly perennial ryegrass and white clover. The metabolisable energy content (ME) of chicory is 11.4–13.1 MJ ME/kg DM (Waugh et al., 1998; de Ruiter et al., 2007), the ME of plantain is 9.4–12.1 MJ ME/kg DM (Fulkerson et al., 2008) and the ME of Lucerne is 9.3–13.2 MJ ME/kg DM (Fulkerson et al., 2007). In comparison the ME of pasture is usually 8.9–12.0 MJ ME/kg DM (Waghorn et al., 2007).

The crude protein content (CP) of chicory is 16.0–17.6 % CP/kg DM (de Ruiter et al., 2007), the CP of plantain is 15.5–15.7 % CP (Kemp et al., 2014) and Lucerne has a CP of 12.9–36.8 % CP/kg DM (Woodman et al., 1933). In comparison perennial ryegrass usually has a CP of 6–15 % CP/kg DM (Waghorn et al., 2007). Chicory and plantain are also known to contain a secondary compound called condensed tannins (Barry, 1998). Condensed tannins act in protecting proteins from readily fermenting in the rumen of ruminant animals (Min et al., 2003). There is a large loss of nitrogen (N) from within the rumen as proteins are digested resulting in the formation of ammonia with an overall result of inefficiency in the use of N (Min et al., 2003). Condensed tannins increase the efficiency in which N is used by making the proteins rumen-protected proteins which allows for these proteins to be more efficiently absorbed further along the gastrointestinal tract than in the rumen (Min et al., 2003). Alternative forages have the potential to increase heifer ADG due to their increased feeding values in comparison to pasture. Increased ADG of heifers during the late summer/early autumn period by

grazing of alternative forages would allow for heifers to have a greater likelihood of achieving recommended liveweight targets.

1.7 Summary and objectives

Heifers are required to become pregnant at 13-15 months of age with the result being that they calve and enter the milking herd at 22-24 months of age. Achieving liveweight targets will assist with this and contribute to increased longevity and milk production. Currently, in the New Zealand dairy industry, heifers are failing to achieve recommended liveweight targets and are losing potential milk production. Heifers are failing to meet that required ADG during the late summer/early autumn period and alternative forages have the potential to increase the ADG that heifers can achieve during this period.

The objectives of this experiment are:

- To observe the effect of grazing 6-month-old dairy heifers on alternative forages on the average daily gain, wither height, girth and crown-to-rump length.
- To determine the effect that live weight and percentage of liveweight targets achieved at 6, 9, 12 and 15 months of age has on puberty and pregnancy status of heifers.

CHAPTER TWO

The effect of feeding alternative forages on the growth rates, wither height, girth and crown to rump length of 6-month-old dairy heifers.

2.1 Introduction

Dairy heifers in industry at present are frequently falling short of recommended liveweight targets (McNaughton & Lopdell, 2012). Milk yield in first and second lactation is affected by a heifer's live weight prior to calving (MacDonald et al., 2005; Carson et al., 2002; Dobos et al., 2001; Van der Waaij et al., 1997) so meeting liveweight targets is critical for subsequent production. McNaughton & Lopdell (2013) identified "herd" (a variable incorporating management factors) as the variable with the greatest effect on the percentage of heifers achieving liveweight targets. Heifers are frequently failing to meet target ADG during the age periods of 3-6 and 6-9 months despite generally meeting 3-month liveweight targets (McNaughton & Lopdell, 2012).

The 6-9 months-of-age period, for spring born heifers, aligns with summer during which pasture quality declines with increased dry matter content of pastures (Litherland et al., 2002). Decreased quality requires greater intakes to achieve the ADG necessary to reach liveweight targets. Intakes are limited by the rumen capacity of the heifer (Waghorn, 2002). The alternative to increasing intakes is to provide herbage of a higher quality that provides the opportunity for heifers to achieve the required ADG.

Alternative feeds that have the potential to increase ADG of dairy heifers during the 3-6 and 6-9 month periods should be explored. Lambs grazing plantain, chicory, white and red clover swards (mixed herb swards) and pure lucerne swards showed increased liveweight gains compared with pasture by 131% and 65% respectively (Golding et al., 2011, Burke et al., 2002; Robertson et al., 1995). These results indicate that mixed herb swards and lucerne could have the potential to increase ADG of dairy heifers. Examples of alternative feeds that have shown similar or increased ADG compared to pasture are pasture silage and brassicas (Muir, 2009). Dairy bull calves fed pasture silage did not achieve ADG greater than 0.65 kg/day and dairy heifers grazed on a brassica crop achieved ADG of 1.09 kg/day, though there was no comparison with pasture under same conditions (Muir, 2009).

The aim of this experiment was to measure the effects on ADG, wither height, girth and crown to rump length, of feeding 6-month-old dairy heifers on alternative feeds, over the summer period when pasture quality and availability is limiting.

2.2 Materials and methods

This experiment was conducted with approval from the Massey University Animal Ethics Committee. This experiment was completed at Massey University Riverside Farm, near Masterton, latitude 40.50° S and longitude 175.37° E. The experiment was conducted for 6 weeks beginning 5th February 2013 (D_0) during severe drought conditions (Porteous & Mullan, 2013). An acclimatisation period ran from D_{-14} to D_{-1}.

2.2.1 Animals

Sixty Friesian-Jersey crossbred heifers (born spring 2012) balanced for live weight and birth date were assigned to one of three treatments. The initial live weight for all heifers on D_{-14} was 137.3 kg (range: 121 kg to 165 kg). The liveweight target for D_{-14} was 143.0 kg and 20% of heifers were at or above this liveweight target on D_{-14}.

2.2.2 Treatments

Heifers were assigned to one of three treatments.

Pasture (P) treatment: P heifers grazed pasture during the period D_{-14} to D_{41}. Meal was fed at a rate of 1.0 kg heifer/day during the period D_{-14} to D_{20}, increasing to 1.5 kg meal/heifer/day during D_{20} to D_{41}.

Lucerne (L) (*Medicago sativa)* treatment: L heifers were acclimatised to grazing lucerne using an on-off grazing system during the period D_{-14} to D_0. L heifers spent 3-4 hours (h)/day grazing lucerne from D_{-14} to D_{-12}, 6-8 h/day grazing from D_{-11} to D_{-8} and 10-12 h/day from D_{-8} to D_{-5}. Time off the lucerne was spent on pasture. From D_{-5} to D_{41} L heifers spent 24 h/day grazing lucerne. Meal was fed at a rate of 1.0 kg heifer/day during period D_{-14} to D_{41}.

Conserved forages (C) treatment: due to weather conditions this treatment used a range of feedstuffs including a mixed-herb crop (plantain (*Plantago lanceolata*), chicory (*Cichorium intybus*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense*)), pit pasture silage and pasture baleage. C heifers grazed the mixed-herb crop during the period D_{-14} to D_{11}, at which time the mixed-herb crop succumbed to the drought conditions and was no longer suitable to be grazed. On D_{11} C heifers were removed from herb crop and placed in a heavily grazed paddock with minimal pasture available and fed 3.0 kg DM pasture baleage/heifer/day. On D_{21} the 3.0 kg DM pasture

baleage/heifer/day was changed to 3.0 kg DM pit pasture silage/heifer/day. Meal was fed at a rate of 1.0 kg/heifer/day from D_{-14} to D_{14} and at a rate of 1.5 kg heifer/day from D_{14} to D_{41}.

Meal provided to all treatments consisted of 60% palm kernel expeller (PKE), 20% maize grain and 20% barley grain, with a CP content of 15.5%, a ME of 10.9 MJ ME/kg DM and a dry matter (DM) content of 93%.

2.2.3 Management

The sixty heifers were drafted from a larger mob on the 11/01/2013. One heifer was replaced with a similar heifer after a visual inspection identified that it had an umbilical hernia. The heifers were transported from Massey University Keebles Farm to Massey University Riverside Farm on the 14/01/13.

The ADG required to reach the 9 months of age liveweight target (40% mature live weight; Troccon, 1993) was used to determine DMI. For these heifers, the liveweight target at 9 months of age was estimated to be 201.2 kg, and the expected mature live weight was 503 kg. The ADG required for the heifers to reach liveweight targets at 9 months of age from D_0 were 719, 876 and 869 g/heifer/day for P, C and L heifers, respectively. The DMI calculator was sourced from CSIRO's GRAZPLAN^{TM} (CSIRO, 2012) and was based on ME of each treatment diet. All treatments were grazed on weekly breaks, determined using herbage available (kg DM/ha/day) and expected herbage growth rates.

Heifers in the C and L treatment groups were dosed with a bloat preventative (Bloatenz Plus®, Ecolab, Hamilton, New Zealand, active ingredient alcohol ethoxylate/ propoxylate), via an in-trough dispenser (3 ml/heifer/day). Bloat preventative was not given to C heifers once removed from mixed-herb crop. All heifers were drenched with a triple combination oral drench based on each individual heifer's liveweight on D_{-25}, D_0, D_{20} and D_{41} to remove any potential gastrointestinal nematode infection that may affect the growth of the heifers (Alliance® triple combination drench, Coopers®, Upper Hutt, New Zealand, active ingredient 2 g/L abamectin, 80 g/L levamisole hydrochloride and 45.3 g/L oxfendazole, with 25mg of cobalt and 5 mg of selenium per 5ml dose) at a dose rate of 1 ml/10 kg live weight + 0.5 ml.

2.2.4 Animal measurements

Individual live weights were measured on D_{-14}, D_0, D_{20} and D_{41}. Wither height, crown-to-rump length and girth were recorded on D_{-25} and D_{41}. Wither height was measured using an adjustable height measuring stick. Crown-to-rump length was measured from the nuchal crest along the spine to the tail until in line with the caudal border of the ischiatic tuberosity, using a tape measure. Girth was measured behind the 13th rib, using a tape measure. All measurements were taken while heifers were individually in a weigh crate standing still.

Faecal samples for Faecal Egg Counts (FEC) were collected from ten randomly selected heifers from within the sixty heifers used in the experiment on D_{-25} to measure the initial amount of gastrointestinal nematode infection. On D_{-14} faecal samples were collected from 10 randomly selected heifers to measure the effectiveness of the drench used on D_{-25}. Faecal samples were collected on D_0, D_{21} and D_{41} from all 60 heifers in the experiment. Ten samples randomly selected from within each treatment were analysed to measure the FEC of each sample. For any treatment group that had a FEC result greater than 0, the remaining 10 faecal samples were analysed.

Faecal samples were processed using a modified version of the McMaster egg counting technique which consisted of a sub-sample of 2g of faeces mixed with 28ml of saturated NaCl with the resulting slurry sieved through a coarse sieve (Stafford et al., 1994). Eggs were counted in two 0.15 ml aliquots of filtrate using a McMaster counting slide (Paracount-EPG, Olympic Equine Products, Issaquah, USA) with the result that each egg counted on the slide representing 50 eggs/g (Stafford et al., 1994).

2.2.5 Pasture measurements

Herbage mass (kg DM/ha) was measured weekly using quadrat cuts (Frame, 1993). For all treatments, four quadrats (0.1 m^2) were cut at ground level from each break, pre and post-grazing. All herbage samples were washed then dried in a draught force oven for a minimum un-interrupted period of 24 hrs at 70°C (Staff, 1961). Mean weights of the 4 dried quadrat cuts from each break were used to determine the pasture mass.

Herbage growth rate for the 3 treatments was measured using herbage growth cages and a quadrat, 0.1 m^2. Herbage growth cages were placed in paddocks used for each treatment with initial herbage material cut to a height of 5 cm for all 3 treatments on D_0 (Kemp et al., 2014). Accumulated herbage material under herbage growth cages was cut

from using a quadrat, 0.1 m^2, when sufficient herbage material was present. As drought conditions were experienced herbage growth rates were minimal, therefore herbage underneath herbage growth cages was cut at irregular time intervals. Herbage material was cut using an electric hand piece. Herbage material collected from underneath herbage growth cages was then washed and dried as per the method for herbage mass described previously.

Weekly hand-grab samples were taken from the pre-grazing breaks for the herbage samples and from supplement fed to the heifers for quality analysis. All samples were analysed using an *in vitro* digestibility assay analysis (Roughan & Holland, 1977) to measure: *in vivo* dry matter digestibility content (*in* vivo DMD%), *in vivo* digestibility of organic matter in dry matter content (*in vivo* DOMD%), *in vivo* organic matter digestibility (*in vivo* OMD%) and ash content (Ash%). Samples were analysed by wet chemistry to measure crude protein content (CP%) (AOAC, 1969). Samples were analysed for neutral detergent fibre content (NDF%) and acid detergent fibre content (ADF%) (Van Soest et al., 1991).

Botanical composition for the 3 treatments was completed on D_0 with herbage material collected from all paddocks used. The herbage material was collected from across the whole paddock with a minimum of 10 cuts taken per bag with one bag collected from each paddock (Grant, 1993). Herbage material was cut at ground level using an electric hand piece. Herbage material from each bag was thoroughly mixed prior to two sub-samples being removed for botanical composition sorting. The size of the sub-samples was 50 g for the P and L treatments and 100 g for the C treatment. A larger sub-sample sized for the C treatment was due to the high proportion of reproductive stems present.

The P treatment sub-samples were sorted into the following categories: vegetative rye grass (*Lolium perenne*), white clover, other vegetative grass, dead matter and weeds. The C treatment sub-samples were sorted into the following categories: chicory stem, chicory leaf, plantain stem, plantain leaf, white clover, red clover, grasses, other and dead matter. The L treatment sub-samples were sorted into the following categories: lucerne, white clover, other and dead matter. Once sorted, sub-samples were dried as per the same method used to dry herbage mass described earlier. Once dried the sorted sub-samples were weighed.

2.2.6 Data handling

The diet quality results for each treatment (Table 2.7) are accumulative proportions of the wet chemistry and *in vitro* digestibility analysis results based on predicted dry matter intakes of both meal and forage. Metabolisable energy content (MJ ME/kg DM) of diets was calculated using the equation:

$$ME = 0.16 \times DOMD \text{ (Geenty et al., 1987)}$$

Liveweight targets were calculated using linear interpolation between industry targets for 6 and 9 months of age. A heifer was considered to be on target if her live weight was equal to or greater than the liveweight target. Change in wither height, change in crown-to-rump length and change in girth were all calculated by subtracting the initial measurement on D_{-25} from final measurement recorded on D_{41} with the resulting figure then divided by the number of days between D_{-25} and D_{41} (67). When age was considered in any calculation a fixed birth date of the 8th of August 2012 was used, which was the mean birth date of all heifers in this experiment.

The botanical composition percentages were calculated by weighing all components from each sub-sample. All components were added together to get total dry matter weight of sub-sample with each components weight then divided by total sub-sample weight to calculate each components proportion of the sub-sample.

2.3.7 Statistical analysis.

Statistical analyses were conducted using SAS (Version 9.3, SAS Institute Inc, Carey, North Carolina, USA, 2013). Average daily gain, wither height, crown-to-rump length and girth and change in these size parameters were all analysed using linear models. The fixed effect of treatment was included for all linear analyses. Age was considered as a covariate but was not significant for all linear model analysis.

Live weight was analysed using a mixed model allowing for repeated measures. The fixed effect of days and treatment, and the random effect of heifer were included for mixed model analysis. For mixed model analysis, age was included as a covariate. The variables DMD%, DOMD%, OMD%, CP%, ME, Ash%, NDF% and ADF% were all analysed using linear models with the fixed effects of treatment and day included in each analysis. Pre-grazing herbage mass and post-grazing herbage mass were analysed

using linear models with the fixed effects of treatment and day included in each analysis. Faecal egg counts are presented as raw means.

2.3 Results

2.3.1 Live weight

Heifers in all treatments had similar initial liveweight (Table 2.1). L heifers grew faster (P<0.05) than C and P heifers so that by D_{41} L heifers were 18.1 kg heavier than C heifers and 20.3 kg heavier than P heifers (Table 2.1).

Table 2.1. Initial live weight and live weight of heifers in Pasture, Conserved Forages and Lucerne treatment groups. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved Forages	Lucerne	Liveweight target
n	20	20	20	
Initial liveweight (kg)				
D_{-14}	137.5 ± 2.4	136.8 ± 2.4	137.5 ± 2.4	143.2
Liveweight (kg)				
D_0	143.8 ± 2.6	137.2 ± 2.6	137.5 ± 2.6	150.9
D_{20}	158.7 ± 2.9	161.2 ± 2.9	160.5 ± 2.9	162.5
D_{41}	167.9 ± 3.3[a]	170.1 ± 3.3[a]	188.6 ± 3.3[b]	174.0

[abc]Values between columns within rows with different superscripts are significantly different (P <0.01).

2.3.2 Average daily gains

The ADG of L heifers for D_{0-41} was greater (P<0.001) than the ADG for P heifers, with C heifers being intermediate (Table 2.2). The ADG of C and L heifers for D_{0-20} was greater (P<0.001) than the ADG of P heifers (Table 2.2). The ADG of L heifers for D_{20-41} was greater (P<0.001) than the ADG of P and C heifers (Table 2.2).

Table 2.2. Average daily gain (ADG) of heifers in Pasture, Conserved Forages and Lucerne treatment groups. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved Forages	Lucerne
n	20	20	20
D_{0-20}	0.71 ± 0.04^a	1.14 ± 0.04^b	1.10 ± 0.04^b
D_{20-41}	0.44 ± 0.05^a	0.42 ± 0.05^a	1.34 ± 0.05^b
D_{0-41}	0.57 ± 0.03^a	0.78 ± 0.03^b	1.22 ± 0.03^c

[abc]Values between columns within rows with different superscripts are significantly different (P <0.01).

2.3.3 Liveweight targets

All treatments had a similar number of heifers at or above liveweight target on D_0 (Table 2.3). L treatment had a greater number of heifers at or above liveweight target by D_{41} than the P or C treatments (Table 2.3).

Table 2.3. Percentage of heifers that reached liveweight target in Pasture, Conserved Forages and Lucerne treatment groups. Liveweight targets were calculated by linear interpolation between industry targets for 6 to 9 months of age and percentage heifers that reached liveweight target on each date.

Measurement	Pasture		Conserved Forages		Lucerne	
n	20		20		20	
D_{-14}	20%	(4/20)	15%	(3/20)	25%	(5/20)
D_0	20%	(4/20)	15%	(3/20)	20%	(4/20)
D_{20}	35%	(7/20)	35%	(6/20)	40%	(8/20)
D_{41}	30%	(6/20)	20%	(4/20)	85%	(17/20)

2.3.4 Girth

L heifers had a greater (P<0.01) increase in girth D_{-25-41} compared to P or C heifers (Table 2.4).

Table 2.4. Girth and change in girth of heifers in Pasture, Conserved Forages and Lucerne treatment groups. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved Forages	Lucerne
n	20	20	20
Girth (cm)			
D_{-25}	145.9 ± 1.3	143.5 ± 1.3	144.6 ± 1.3
Change in girth (cm/day)			
D_{-25-42}	0.22 ± 0.02[a]	0.16 ± 0.02[a]	0.30 ± 0.02[b]

[abc]Values between columns within rows with different superscripts are significantly different (P <0.05).

2.3.5 Height at wither

L heifers had a greater (P<0.01) increase in wither height D_{-25-41}, than the P heifers with C heifers being intermediate (Table 2.5).

Table 2.5. Wither height and change in wither height of heifers in Pasture, Conserved Forages and Lucerne treatment groups. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved Forages	Lucerne
n	20	20	20
Wither height (cm)			
D_{-25}	93.9 ± 0.6	94.6 ± 0.6	94.8 ± 0.6
Change in wither height (cm/day)			
D_{-25-41}	0.11 ± 0.01[a]	0.14 ± 0.01[ab]	0.15 ± 0.01[b]

[abc]Values between columns within rows with different superscripts are significantly different (P <0.05).

2.3.6 Crown-to-rump length

There were no difference in crown-to-rump length and change in crown-to-rump length (Table 2.6).

Table 2.6. Crown-to-rump length and change in crown-to-rump length of heifers in Pasture, Conserved Forages and Lucerne treatment groups. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved forages	Lucerne
Crown-to-Rump length (cm)			
D_{-25}	127.0 ± 1.4	128.4 ± 1.4	128.8 ± 1.4
Change in Crown-to-Rump length (cm/day)			
D_{-25-41}	0.02 ± 0.03	0.02 ± 0.03	0.05 ± 0.03

2.3.7 Quality of herbage

The diet of the L treatment had a greater ($P<0.05$) CP% and ADF% than the diets of P and C treatments (Table 2.7). The diet of the L treatment had a greater ($P<0.05$) ME, NDF%, *in vivo* DOMD% and *in vivo* OMD% content than the diet of P treatment, with the diet of C treatment being intermediate (Table 2.7). The diet of the L and C treatments had a greater ($P<0.05$) *in vivo* DMD% than the diet of the P treatment (Table 2.7).

Table 2.7. Results from wet chemistry and *in vitro* digestibility analysis of hand grab samples for complete diets of Pasture, Conserved Forages and Lucerne treatment groups measuring: Crude Protein % (CP%), Neutral Detergent Fibre % (NDF%), Acid Detergent Fibre % (ADF%), *in vivo* Dry Matter Digestibility (DMD), *in vivo* Digestibility of Organic Matter in Dry Matter (DOMD), i*n vivo* Organic Matter Digestibility (OMD) and Ash %. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved forages	Lucerne
CP%	14.00 ± 1.10^a	17.35 ± 1.10^a	22.93 ± 1.10^b
ME	9.97 ± 0.14^a	10.53 ± 0.14^b	11.08 ± 0.14^c
NDF %	48.96 ± 2.39^c	40.66 ± 2.39^b	31.25 ± 2.39^a
ADF %	26.13 ± 1.11^b	22.88 ± 1.11^b	18.21 ± 1.11^a
In Vivo DMD	66.80 ± 1.01^a	70.26 ± 1.01^b	73.28 ± 1.0^b
In Vivo DOMD	62.28 ± 0.89^a	65.79 ± 0.89^b	69.23 ± 0.89^c
In Vivo OMD	68.51 ± 1.99^a	72.56 ± 1.99^b	76.61 ± 1.99^c
Ash %	6.86 ± 0.61	6.92 ± 0.61	7.98 ± 0.61

[abc]Values between columns within rows with different superscripts are significantly different ($P <0.05$).

The CP% of L treatment was relatively consistent except for D_{20} (Figure 2.1). Whereas the CP% of C treatment was inconsistent from D_0 to D_{13} but was more consistent with a decreasing trend from D_{20} to D_{34} and the CP% of P treatment was consistent with a decreasing trend (Figure 2.1). The NDF% of P treatment had a slight increasing trend, the NDF% of C treatment was initially inconsistent but then was more consistent with an increasing trend and the NDF% of the L treatment was consistent (Figure 2.2). The ADF% of P, C and L treatments were inconsistent throughout the experiment (Figure 2.3). The *in vivo* DMD, *in vivo* DOMD and *in vivo* OMD of P treatment was relatively consistent throughout the experiment with a slight decreasing trend, the C treatment

initially had varying results with a decreasing trend towards the end of the experiment and the L treatment had a decreasing trend (Figure 2.4, 2.5 & 2.6).

The ash% of L treatment had a slight increasing trend, C treatment had varying results and P treatment had a slight decreasing trend throughout the experiment (Figure 2.7). The ME for L treatment had a slight decreasing trend, the C treatment initially had varying results with more consistent results that had a slight decreasing trend and P treatment had a decreasing trend throughout the experiment (Figure 2.8).

Figure 2.1. Crude Protein content (CP%) for the whole diets of Pasture (P) (———), Conserved Forages (C) (·······) and Lucerne (L) (▬ ▬ ·) treatments from D_0 to D_{34}.
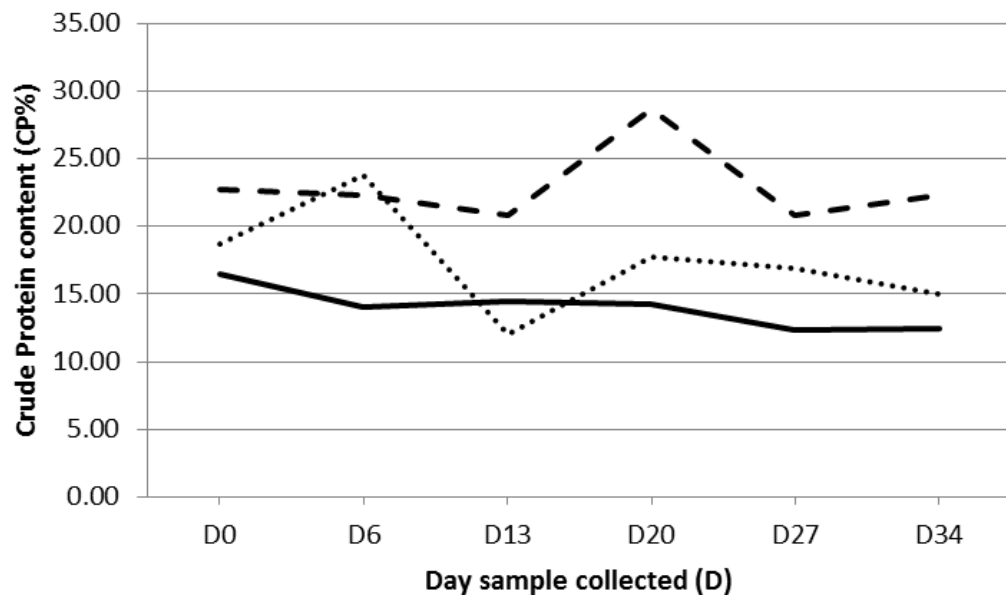
Figure 2.2. Neutral Detergent Fibre content (NDF%) for the whole diets of Pasture (P) (———), Conserved Forages (C) (••••••••) and Lucerne (L) (— — —) treatments from D_0 to D_{34}.
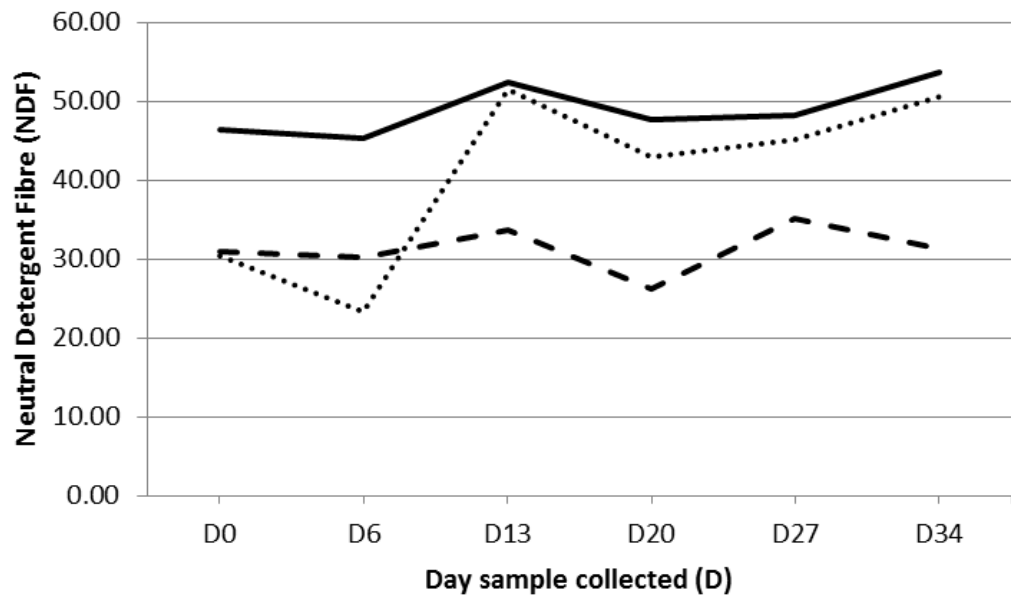
Figure 2.3. Acid Detergent Fibre content (ADF%) for the whole diets of Pasture (P) (———), Conserved Forages (C) (••••••••) and Lucerne (L) (— — —) treatments from D_0 to D_{34}.
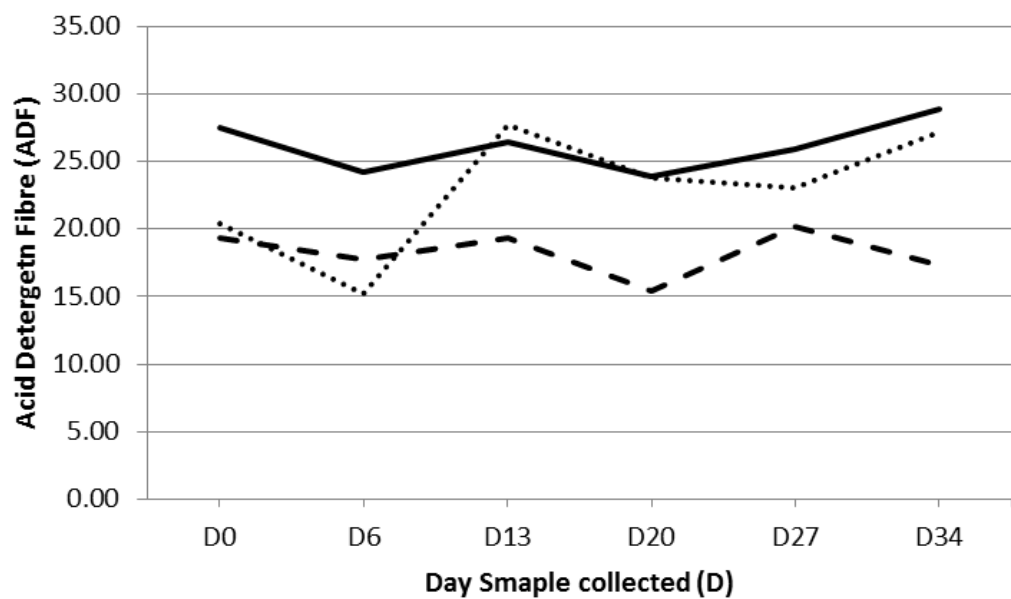
Figure 2.4. *In Vivo* Dry Matter Digestibility (*In Vivo* DMD) for the whole diets of Pasture (P) (————), Conserved Forages (C) (·········) and Lucerne (L) (– – – ·) treatments from D_0 to D_{34}.
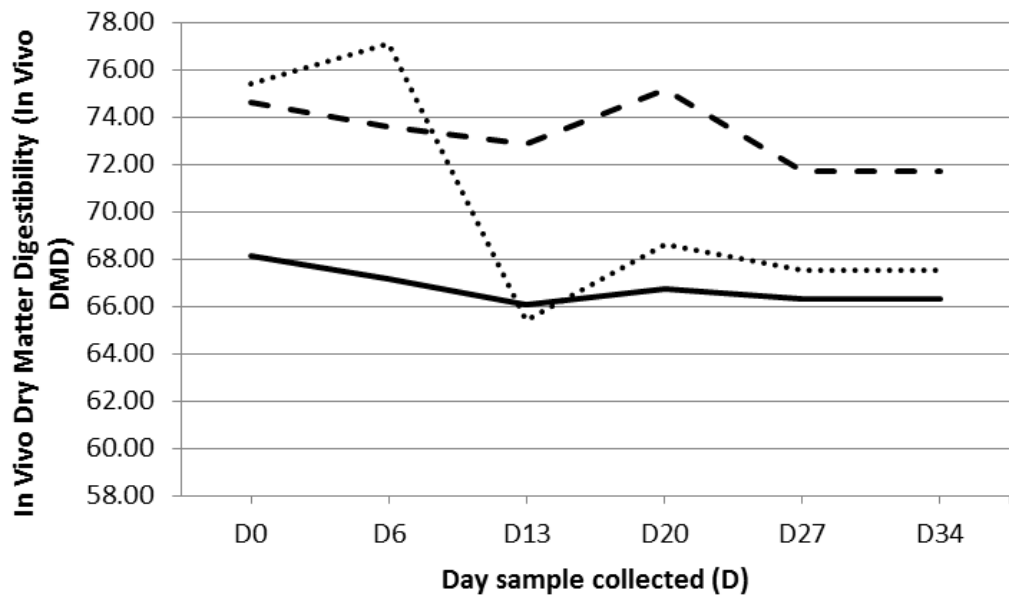
Figure 2.5. *In Vivo* Digestibility of Organic Matter in Dry Matter (*In Vivo* DOMD) for the whole diets of Pasture (P) (————), Conserved Forages (C) (······) and Lucerne (L) (– – –) treatments from D_0 to D_{34}.

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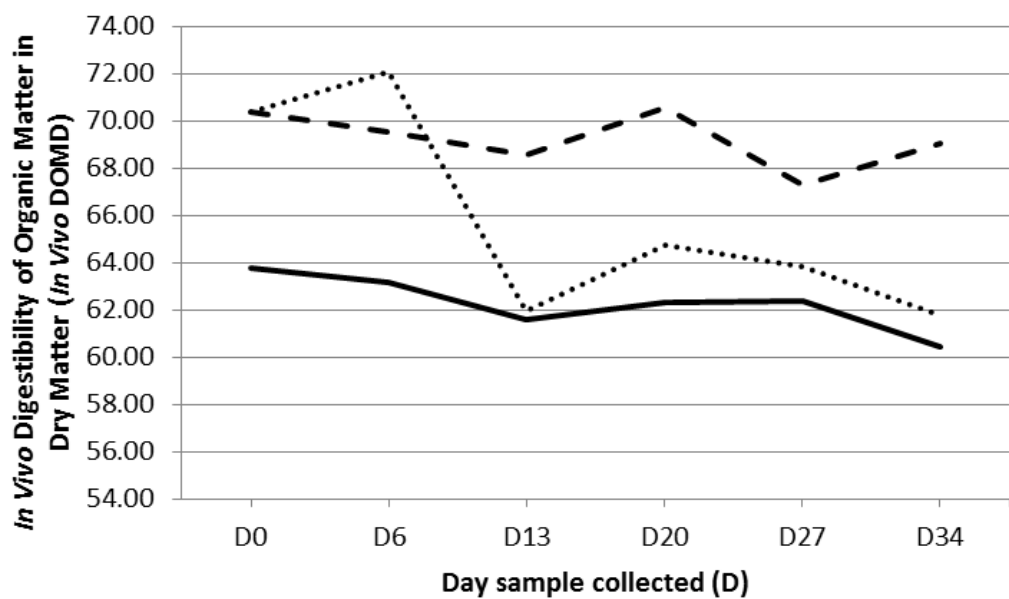
Figure 2.6. *In Vivo* Organic Matter Digestibility (*In Vivo* OMD) for the whole diets of Pasture (P) (——), Conserved Forages (C) (•••••) and Lucerne (L) (– – –) treatments from D_0 to D_{34}.
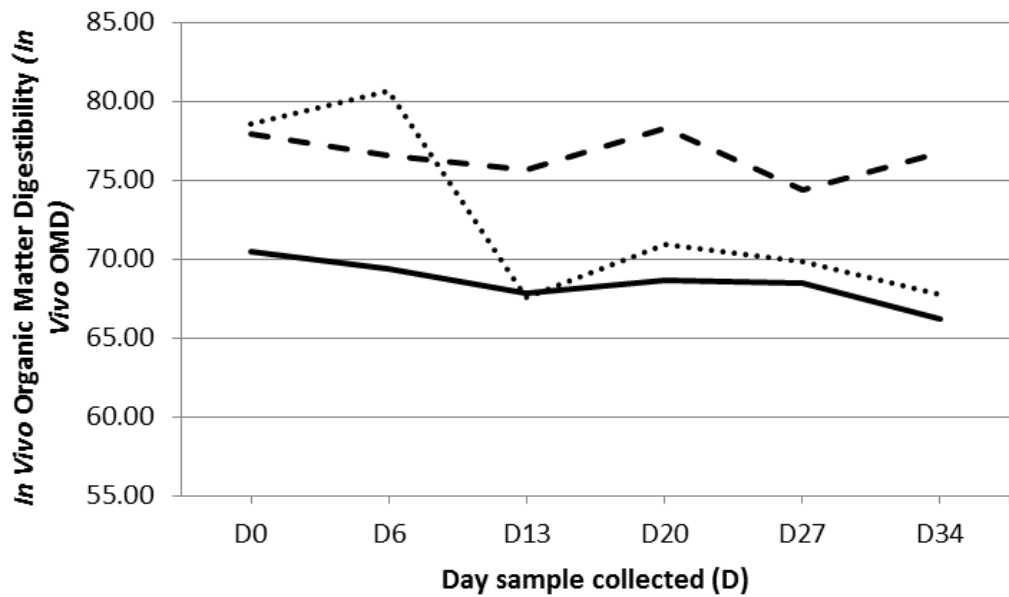
Figure 2.7. Ash Percentage (Ash %) for the whole diets of Pasture (P) (——), Conserved Forages (C) (•••••) and Lucerne (L) (– – –) treatments from D_0 to D_{34}.
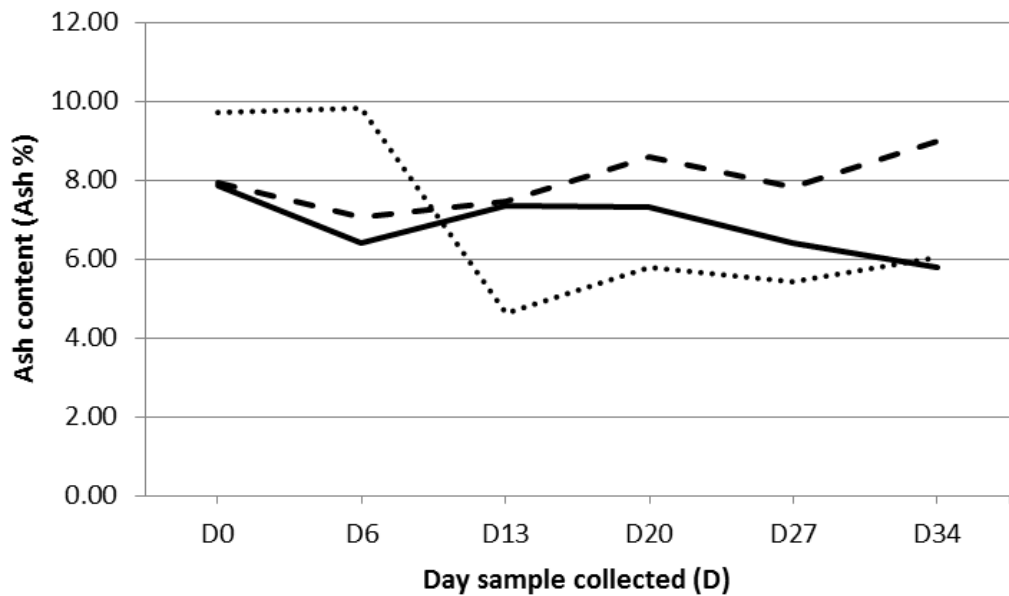
Figure 2.8. Metabolisable Energy Content (ME) for the whole diets of Pasture (P) (——), Conserved Forages (C) (••••••) and Lucerne (L) (— — —) treatments from D_0 to D_{34}.
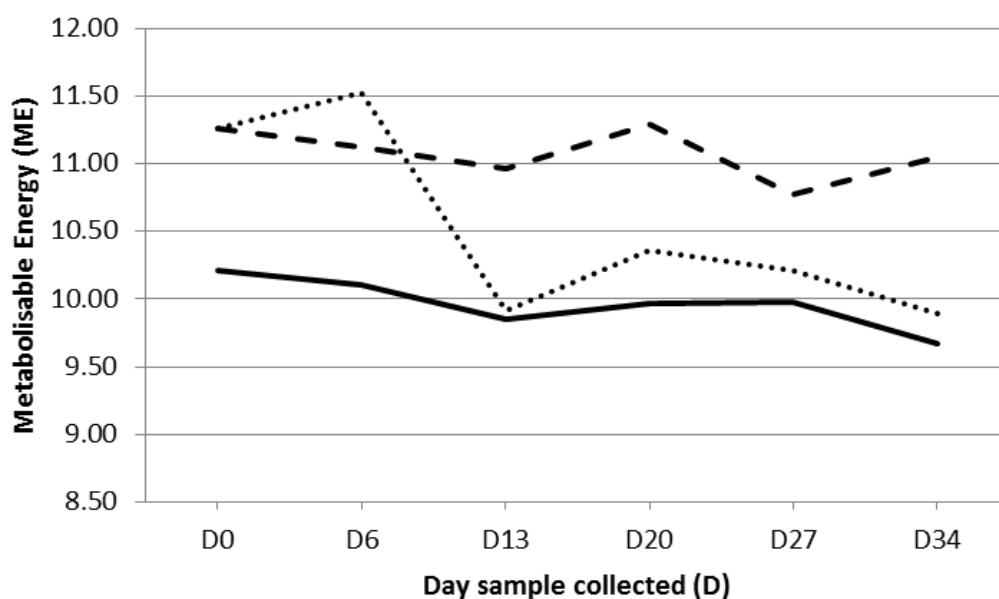
2.3.8 Herbage masses

The pre-grazing herbage masses were similar at the start of the experiment (D_0) (Table 2.8). The pre-grazing herbage mass for L treatment was greater (P <0.05) on D_7 than C treatment with P treatment being intermediate (Table 2.8). The pre-grazing herbage mass for P treatment was greater (P <0.05) on D_{28} than L treatment (Table 2.8).

Table 2.8. Pre-grazing herbage masses (kg DM/ha) from the weekly breaks, for the forages within the Pasture, Conserved Forages and Lucerne treatments. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved forages	Lucerne
Pre-grazing herbage mass (kg DM/ha)			
D_0	3788 ± 559	5075 ± 559	3638 ± 559
D_7	4079 ± 559[ab]	3766 ± 559[a]	5595 ± 559[b]
D_{14}	3778 ± 559	NA	3589 ± 559
D_{21}	4594 ± 559	NA	3897 ± 559
D_{28}	5593 ± 559[b]	NA	3634 ± 559[a]
D_{35}	4332 ± 559	NA	3311 ± 559

[ab] Values between columns within rows with different superscripts are significantly different (P <0.05)
NA There were no grazed forages in this treatment at this time.

The post-grazing herbage masses were similar from D_6 to D_{20} (Table 2.9). The post-grazing herbage mass for P treatment were greater ($P < 0.05$) on D_{27}, D_{34} and D_{41} than L treatment (Table 2.9).

Table 2.9. Post-grazing herbage masses (kg DM/ha) from the weekly breaks, for the forages within the Pasture, Conserved Forages and Lucerne treatments. Values are least squares means ± standard error of the mean.

Measurement	Pasture	Conserved forages	Lucerne
Post-grazing herbage mass (kg DM/ha)			
D_6	2920 ± 334	2963 ± 334	2783 ± 334
D_{13}	2920 ± 334	3179 ± 334	3515 ± 334
D_{20}	2842 ± 334	NA	3400 ± 334
D_{27}	3547 ± 334^b	NA	2444 ± 334^a
D_{34}	4058 ± 334^b	NA	1986 ± 334^a
D_{41}	3416 ± 334^b	NA	1906 ± 334^a

[ab] Values between columns within rows with different superscripts are significantly different ($P < 0.05$)
NA There were no grazed forages in this treatment at this time.

2.3.9 Botanical composition

The pasture used in the P treatment had an average of 10.1% as vegetative ryegrass and an average of 83.8% as dead matter (Table 2.10).

Table 2.10. Botanical Composition results on D_0 for pasture used in the Pasture treatment.

Measurement	Sample 1	Sample 2	Average
Vegetative Ryegrass	10.1%	10.2%	10.1%
White Clover	0.4%	0.1%	0.2%
Other grasses	10.5%	0.6%	5.5%
Weeds	0.5%	-	0.2%
Dead Matter	78.6%	89.1%	83.8%

The herb crop used in the C treatment had an average of 47.2% as dead matter, an average of 37.8% as chicory reproductive stems and an average of 7.7% as chicory leaf (Table 2.11). Plantain leaf was present in 2 of 6 sub-samples analysed, resulting in an overall average of 1.4% of the average botanical composition being plantain leaf (Figure 2.11).

Table 2.11. Botanical composition results on D_0 for herb crop (plantain (*Plantago lanceolata*), chicory (*Cichorium intybus*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense*) used in the Conserved Forages treatment.

Measurement	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average
Chicory Stem	21.8%	22.8%	44.2%	29.3%	49.7%	59.2%	37.8%
Chicory Leaf	10.5%	11.4%	1.4%	3.2%	8.0%	11.7%	7.7%
Plantain Stem	6.8%	6.5%	2.8%	1.8%	0.7%	4.3%	3.8%
Plantain Leaf	6.1%	2.5%	-	-	-	-	1.4%
White Clover	3.1%	7.0%	-	-	-	0.7%	1.8%
Other	-	-	-	-	0.8%	0.6%	0.2%
Dead Matter	51.7%	49.8%	51.6%	65.8%	40.8%	23.5%	47.2%

The lucerne used in the L treatment had an average of 48.6% as lucerne and an average of 48.2% as dead matter (Table 2.12). White clover was present in 2 of the 4 sub-samples, with an overall average of 2.5 % of the average botanical composition being white clover (Table 2.12).

Table 2.12. Botanical composition results on D_0 for lucerne (*Medicago sativa)* used in the Lucerne treatment.

Measurement	Sample 1	Sample 2	Sample 3	Sample 4	Average
Lucerne	46.0%	59%	46.1%	43.8%	48.6%
White Clover	-	-	5.5%	4.5%	2.5%
Dead Matter	51.7%	41.3%	48.2%	51.7%	48.2%
Other	2.3%	-	0.1%	-	0.6%

2.3.10 Faecal egg count

Faecal egg counts for P and C treatments were greater ($P < 0.05$) on D_0 than L treatment (Table 2.13). Faecal egg counts for all treatments on D_{21} and D_{41} do not differ (Table 2.13).

Table 2.13. Faecal egg count results from 10 randomly selected heifers from all heifers used in the trial on D_{-25} and D_{-14}, and from the samples collected from Pasture, Conserved Forages and Lucerne treatments on D_0, D_{21} and D_{41}. Values are raw means.

	All Heifers	Pasture	Conserved Forages	Lucerne
Faecal egg count (eggs/g)				
D_{-25}	0.0	-	-	-
D_{-14}	0.0	-	-	-
D_0	-	15.0[1]	20.0[2]	0.0
D_{20}	-	0.0	0.0	0.0
D_{41}	-	0.0	0.0	0.0

[ab] Values between columns within rows with different superscripts are significantly different ($P < 0.05$).
[1] A total of 14/20 heifers sampled had FEC = 0.
[2] A total of 13/20 heifers sampled had FEC = 0.

2.4 Discussion

The aim of this experiment was to measure the effect of feeding 6-month-old dairy heifers on alternative feeds, on ADG and growth parameters (wither height, girth and crown-to-rump length). This experiment demonstrated that a combined diet of lucerne and supplementary meal can be used to accelerate growth of heifers during the dry summer period and that feeding conserved forages (mixed herb crop & pasture baleage/silage) resulted in greater liveweight gain than grazing on poor quality summer pasture. To the authors knowledge the ADG of 6-month-old dairy heifers grazing lucerne has not previously been recorded in New Zealand. The diet quality parameters were generally best for L treatment, worst for P treatment and intermediate for C treatment.

The ADG seen in this experiment for L heifers was 114% greater than the ADG seen in P heifers which is greater than the 65% increase in ADG of lambs grazed on lucerne compared to lambs grazed on pasture (Golding et al., 2011; Burke et al., 2002). The greater ADG for L heifers seen in this experiment compared to that in studies which have grazed lambs on lucerne may be as result of the drought conditions exacerbating the quality differences normally seen between pasture and lucerne. The addition of the meal may have also contributed to the greater ADG seen in L heifers.

The diet of the L heifers had a greater ME, CP% and digestibility compared to both the C and P heifer diets, which would contribute to the increased ADG in the L heifers. The greater digestibility of the L diet would increase the rumen outflow of the L heifers which would lead to an increased intake by the L heifers leading to a greater amount of energy and protein available for growth (Orskov et al., 1988). With the addition of the meal a greater amount of ME is available to capture excess CP on lucerne which is important for growth, particularly muscle deposition (Webster, 1993).

It is evident that the general quality of the forages within each of the diets declined as the experiment progressed, with the drought conditions experienced exacerbating the decline that is normally seen over the summer months. The *In vivo* DMD, *In vivo* DOMD, *In vivo* OMD, ME for all of the diets decreased as the experiment progressed. Increases in the NDF% and ADF% of the diets were also seen as the experiment progressed. This is typical of forages as summer progresses with drought conditions

making these changes even more evident (Sheath & McCall, 1994). Although only done at the start of the experiment the results of the botanical compositions also depict a similar conclusion that the quality of the forage in the treatments was poor, with high dead matter contents and reproductive stems present.

Despite the experiment being run for a short length of time, treatment effects were seen in the change in girth, with L heifers being greater than other treatments, and also the change in height between L and P heifers. Given that the absolute change in these parameters was of 0.02 to 0.30 cm/day, it is likely that heifers would need to be grazed on these diets for a longer period of time to determine if there are greater effects. As mentioned earlier, L heifers may have been able to capture excess CP as a greater amount of energy was available resulting in increased growth. A proportion of this increased growth may be growth in the skeletal size of the heifers, with wither height, a measure of skeletal size, being positively correlated with milk yield in first lactation (Heinrichs & Hargrove, 1987).

The heifers used in this experiment were below target at the start of the experiment (Table 2.1 & 2.3). Though not significant, ADG slowed in both the C and L treatments during the adjustment period as heifers adapted to new diets. Throughout the experiment an average liveweight was used for each treatment group to calculate the required ADG to reach the liveweight targets. Each treatment had a range of live weights, both above and below liveweight target. The results present here show by accepting that an average liveweight of a herd (or in this case each treatment group) has reached the liveweight target there are always going to be some heifers that will fail to meet liveweight targets. Assessing each heifer's liveweight on an individual basis allows for those below liveweight target to be preferentially fed. Dry matter intakes estimated from pre- and post-grazing cuts showed sufficient dry matter offered to meet ADG required for all treatments based on the predicted DMI calculated but heifers did not catch up to liveweight targets. It may be possible that the DMI calculator under-calculated the DMI intakes required for the P and C treatments based on the fact that P and C heifers did not achieve the required ADG needed to reach liveweight targets. The required DMI calculated were greater than the industry recommendations (DairyNZ, 2012). As the heifers were below liveweight targets the calculated ADG would have to be greater than industry recommendations to allow heifers to reach liveweight targets.

The positive faecal egg count on D_0 for P and C treatments is an indication that during the adjustment period some of these heifers had a minor gastrointestinal nematode infection. Gastrointestinal nematode infections are known to reduce growth rates in young grazing livestock (Sykes, 1994; Charlier et al., 2009). During the period of D_0 to D_{41}, which was the experimental period, the 0 faecal egg count results on D_{20} and D_{41} indicate that no gastrointestinal nematode infection was present in these heifers. Therefore as faecal egg counts were negative during the experimental period, lower growth rates of C and P heifers was not due to gastrointestinal nematode infections.

2.5 Conclusion

Lucerne with the addition of supplemental meal was a suitable alternative feed source for dairy heifers enabling heifers to achieve target growth rates. The mix of herbages used in the supplement treatment was also a suitable alternative feed to dry summer pasture but the allowance fed did not enable heifers to grow sufficiently and to achieve liveweight targets. This was also demonstrated in P treatment where the use of meal and poor quality dry summer pasture did not enable liveweight targets to be met.

CHAPTER THREE

The effects of live weight, achieving or not achieving individual liveweight targets, and the percentage of individual liveweight targets achieved from 6 to 15 months of age on reproductive parameters of dairy heifers.

3.1 Introduction

Rearing dairy heifer replacements is expensive and there is a two-year non-productive period after which, if the heifer successfully gets pregnant at 13-15 months of age, income can be received from milk production. For the heifers that fail to get pregnant, the income that is received from the sale of them is minimal compared to that which could be received from milk production had she conceived. An American based study only valued empty heifers at approximately 40% of the value of pregnant heifers (Ettema & Santos, 2004). Therefore it is crucial that heifers become pregnant at 13-15 months of age. For heifers to have the best chance of becoming pregnant at 13-15 months of age within the planned mating period, they need to have completed a number of oestrus cycles prior to the planned start of mating. A heifer has an increased probability of becoming pregnant when mated during the third oestrus cycle compared with being mated during the first oestrus cycle after reaching puberty (Byerly et al., 1987; Staigmiller et al., 1993).

In order to have completed a number of oestrus cycles prior to the planned start of mating, a heifer needs to reach puberty by around 12 months of age. It has been observed that heifers achieve puberty at 45-50% of their mature liveweight (Garćia-Muñiz, 1998; McNaughton, 2003). The liveweight target at 12 months of age is 50% of estimated mature liveweight (Troccon, 1993). As well as needing to achieve liveweight target at 12 months of age, it is important that heifers also achieve liveweight targets at 3, 6 and 9 months of age to give best chance of meeting 12 month target and thus becoming pregnant at 13 – 15 months of age.

The aim of this experiment was to determine the effect that live weight, percentage of individual liveweight target achieved and achieving individual liveweight target at 6, 9, 12 and 15 months of age had on 5 reproductive parameters: reaching puberty by 12 & 15 months of age; becoming pregnant during a 7 week mating period; becoming pregnant in the first 3 weeks of mating; and becoming pregnant in the first 6 weeks of mating.

3.2 Materials and methods

This experiment was conducted with approval from the Massey University Animal Ethics Committee. This experiment was completed at Massey University Keebles, Haurongo and Dry Stock Unit farms (latitude 40.23° S and longitude 175.37° E) near Palmerston North, NZ and Massey Riverside farm (40.50° S and longitude 175.37° E) near Masterton, NZ.

3.2.1 Animals

One hundred and sixty three Friesian-Jersey crossbred heifers, born during the spring of 2012 on the Massey University dairy farms, were selected for this experiment. These heifers represented a whole line of replacement heifers for the Massey University No. 1 and No. 4 dairy farms. A sub-group of 60 heifers were included in a previous experiment (Chapter 2). The average birth date for all heifers was 08/08/2012. The PSC for the year that the heifers were born in, was 23/07/2012.

3.2.2 Management

Heifers were reared off-farm by a contract rearer until they reached a live weight of 100 kg. They were then returned to Massey University Keebles farm once at a live weight of 100 kg from the contract rearer where they grazed pasture. On the 11/01/2013, sixty heifers were selected for another experiment (Chapter 2) and transported to Massey University Riverside farm on 14/01/2013, where they were managed as described in Chapter 2. At the conclusion of that experiment (19/03/13) all sixty heifers were placed in a single herd grazing pasture.

The remaining 103 heifers stayed at Massey University Keebles farm where they grazed a Hunter crop (Brassica campestris L. x Brassica napus L.). Once the Hunter crop was finished the heifers were randomly separated into two groups. The first group grazed pasture at Massey University Keebles farm (n = 68) and the second group grazed pasture at Massey University Dry stock unit (n = 35). The heifers at Massey University Riverside farm returned to Massey University Haurongo farm on 27/05/13, and grazed pasture over the winter. All heifers remained on these farms until after natural mating had finished.

Natural mating began on the 10/10/2013 and finished on 27/11/2013 (seven weeks later), with three bulls placed with each herd. The bull to heifer mating ratios were 1:23, 1:21.3 and 1:21.6 for the Massey University Haurongo farm, Keebles farm and Dry Stock Unit farm, respectively.

3.2.3 Animal measurements

Unfasted live weights were measured monthly. The pubertal status of heifers was determined by detecting the presence of a corpus luteum (CL) on either ovary of the heifer via ultrasound scanning on at least one of up to two scans 7 days apart. Ultrasound scanning of the ovaries was completed at 12 months of age (on the 12/08/2013 and 19/08/2013) and just prior to the start of mating when heifers were approaching 15 months of age (on the 26/09/2013 and 03/10/2013). At each of 12 and 15 months, those heifers that did not have a CL present at the first scanning were rescanned at the second scanning. Only those heifers that had been identified as not having reached puberty at 12 months of age were rescanned when the heifers were approaching 15 months of age. Two scanning events were required at each stage because pubertal heifers may have been in the luteal regression stage of the ovulation cycle (when luteolysis may have occurred and therefore a CL may not be present on the ovaries) (Holmes et al., 2007). Such heifers would have a CL present at the second scan thereby allowing these heifers to be identified as pubertal.

Pregnancy scanning was conducted on 12/12/2013 to identify those heifers that had conceived during the first cycle of mating ($43 \leq$ days in calf ≤ 63, on day of pregnancy scanning). Pregnancy scanning was also repeated on the 08/01/2014 to identify those heifers that had conceived during the second cycle ($49 \leq$ days in calf ≤ 69, on day of pregnancy scanning) and the third cycle ($42 <$ days in calf < 49, on day of pregnancy scanning) of mating. Heifers were reported as pregnant if the pregnancy appeared to be a viable pregnancy at the time of the pregnancy scanning.

The scanning of the ovary structures and of pregnancy status was completed by a veterinarian using either a DP6 600 (Mindray Medical International Ltd., Shenzhen, China) or an Easi-scan™ (BCF™ Technology, Auckland, New Zealand) linear array probe (7.5 mHz) scanner.

3.2.4 Data handling

A heifer was considered to have reached puberty at 15 months of age if she had already been confirmed as having reached puberty at 12 months of age or if she had a CL present when scanned on the 26/09/2013 or 03/10/2013.

A heifer was considered to have become pregnant during the first cycle of mating if she was 43-63 days pregnant at scanning on 12/12/2013. A heifer was considered to have become pregnant during the second cycle of mating if she was 49-69 days pregnant at scanning on 08/01/2014. A heifer was considered to have become pregnant during the final week of mating if she was less than 49 days pregnant at scanning on 08/01/2014. A heifer was considered to have become pregnant in the first 6 weeks if she became pregnant in the first or second cycle of mating.

Liveweight targets are based on a percentage of mature live weights. Mature live weights were estimated for individual heifers based on their breeding values (BV) using the equation:

$$Expected\ mature\ live\ weight \\ = 503kg + live\ weight\ breeding\ value\ (Burke\ et\ al., 2007)$$

Liveweight targets for 6, 9, 12 and 15 months of age were calculated using industry recommended targets and individual heifer expected mature liveweight. The industry recommended liveweight targets are 30%, 40%, 50% and 60% of expected mature liveweight at 6, 9, 12 and 15 months of age, respectively (Troccon, 1993). A heifer was considered to have achieved liveweight target at 6, 9, 12 and 15 months of age if her live weight was equal to or greater than her individual liveweight target.

The percentage of liveweight target achieved was calculated using the following equation:

$$Percentage\ of\ liveweight\ target\ achieved \\ = \frac{heifer's\ live\ weight\ (kg)}{heifer's\ liveweight\ target\ (kg)} \times 100$$

Heifer live weights used for the ages of 6, 9, 12 and 15 months were from within 15 days either side of exact date corresponding to each age (McNaughton & Lopdell, 2013) based on a birthdate of 23/07/2012. The PSC in the year that the heifers were born in

was used to determine when the exact 6, 9, 12 and 15 months of age liveweight targets occurred.

3.2.5 Statistical analysis

Regression coefficients, the percentage of heifers that had achieved the reproductive outcome and odds ratios were estimated using a logistic regression model based on a binomial distribution and a logit transformation. The variable of grazing farm was considered but removed because it was not significant.

The analysis of the effect of achieving or not achieving liveweight target at 6, 9, 12 or 15 months of age had on achieving puberty by 15 months of age could not be completed because all heifers that reached liveweight target also reached puberty by 15 months of age. The analysis of the effect of achieving or not achieving liveweight target at 6 months of age had on puberty by 12 months of age could not be completed because all heifers that reached the liveweight target also reached puberty by 12 months of age. The analysis of the effect of reaching or not reaching puberty by 15 months of age on pregnancy and pregnancy in the first 6 weeks of mating could not be completed because all of the heifers that did not reach puberty by 15 months of age were pregnant, and pregnant in the first 6 weeks of mating.

3.3 Results

The majority of heifers had reached puberty by 12 months of age and became pregnant in the first 3 weeks of mating (Table 3.1). Only 5 (3.1%) heifers had not reached puberty by 15 months of age (Table 3.1).

Table 3.1. The number of heifers that did and did not reach puberty by 12 (Pub12) & 15 (Pub15) months of age, become pregnant (Preg), become pregnant in the first 3 weeks of mating (Preg3) and become pregnant in the first 6 weeks of mating (Preg6).

Measurement	Yes	No
Pub12	126 (77.3%)	37 (22.7%)
Pub15	158 (96.9%)	5 (3.1%)
Preg	145 (89.0%)	18 (11.0%)
Preg3	119 (73.0%)	44 (27.0%)
Preg6	141 (86.5%)	22 (13.5%)

Live weights at 6, 9, 12 and 15 months of age (Table 3.3) were all positively correlated (P<0.01) with each other (Table 3.2). The majority of heifers did not reach individual liveweight targets at any stage of the experiment (Table 3.3).

Table 3.2. Correlation coefficients of heifer live weights at 6, 9, 12 and 15 months of age.

Age (months)	9	12	15
6	0.898**	0.803**	0.774**
9	-	0.834**	0.817**
12		-	0.932**

** denotes a P value equal to <0.01

Table 3.3. The mean ($\pm$ standard deviation), minimum and maximum values for live weight of heifers, percentage of individual liveweight target achieved by heifers and the percentage of heifers that had reached their individual liveweight targets at 6, 9, 12 and 15 months of age.

Age (months)	Live weight (kg)	Percentage of individual liveweight target (%)	Percentage reached individual liveweight targets (%)
6			
Mean $\pm$ SD	133.8 $\pm$ 16.2	84.5 $\pm$ 10.2	7.27
Minimum	83.5	51.3	
Maximum	177.5	108.7	
9			
Mean $\pm$ SD	198.5 $\pm$ 22.7	94.0 $\pm$ 10.7	28.48
Minimum	122.0	56.2	
Maximum	251.0	122.2	
12			
Mean $\pm$ SD	239.4 $\pm$ 26.5	90.7 $\pm$ 10.0	17.58
Minimum	169.0	64.2	
Maximum	302.0	115.9	
15			
Mean $\pm$ SD	311.1 $\pm$ 29.6	98.3 $\pm$ 9.2	36.36
Minimum	227.0	70.1	
Maximum	387.0	126.40	

There were no effects of achieving or not achieving individual liveweight targets at 6, 9, 12 and 15 months of age on any of the pregnancy measures (Table 3.4). However, heifers that reached liveweight targets at 9 and 12 months were 95.8% and 96.7% more likely to have reached puberty by 12 months of age, respectively, versus 87.8% and 89.8% for those below liveweight targets (Table 3.4).

Table 3.4. The percentage of heifers that had reached puberty by 12 (Pub12) and 15 (Pub15) months of age, pregnant (Preg), pregnant in the first 3 weeks of mating (Preg3) and pregnant in the first 6 weeks of mating (Preg6) based on achieving or not achieving individual liveweight targets at 6, 9, 12 and 15 months of age. Values are presented as back transformed probabilities ± standard error and odds ratio (95% CI).

Age (months)	Achieved target	n	Pub12	Preg	Preg3	Preg6
6	Yes	12	†	0.920 ± 0.538	0.740 ± 0.346	0.830 ± 0.406
	No	151	†	0.900 ± 0.538	0.750 ± 0.346	0.850 ± 0.406
	Odds	(Y vs N)	†	1.395	1.118	0.763
				(0.169–11.481)	(0.288-4.335)	(0.156–3.740)
9	Yes	47	0.958 ± 0.375^{b}	0.917 ± 0.298	0.729 ± 0.193	0.875 ± 0.257
	No	116	0.879 ± 0.375^{a}	0.899 ± 0.298	0.730 ± 0.193	0.868 ± 0.257
	Odds	(Y vs N)	10.059	1.525	0.994	1.131
			(2.312–43.759)	(0.475–4.894)	(0.456–2.121)	(0.414–3.092)
12	Yes	29	0.967 ± 0.518^{b}	0.933 ± 0.390	0.867 ± 0.285	0.867 ± 0.297
	No	134	0.898 ± 0.518^{a}	0.910 ± 0.390	0.795 ± 0.285	0.866 ± 0.297
	Odds	(Y vs N)	10.763	1.915	2.796	1.017
			(1.414–81.936)	(0.416–8.812)	(0.916–8.534)	(0.318–3.258)
15	Yes	60	NA	0.902 ± 0.264	0.787 ± 0.190	0.869 ± 0.238
	No	103	NA	0.892 ± 0.264	0.744 ± 0.190	0.866 ± 0.238
	Odds	(Y vs N)	NA	1.222	1.612	1.054
				(0.434 – 3.443)	(0.766 – 3.392)	(0.415 – 2.680)

[ab] Values within columns within age groups with different superscripts are significantly different (P<0.05).
NA – Not analysed because the outcome occurred before the age at weighing.
† Separation of data points was present in the analysis therefore the results from analysis were not included.

The live weight of the heifers at 6, 9 and 12 months-of-age had an effect the heifers reaching puberty by 12 months of age, with the heifers 1.026 to 1.042 times more likely to have reached puberty by 12 months of age for every extra kilogram of live weight (Table 3.5; Figure 3.1). Similarly, the percentage of individual liveweight targets achieved at 6, 9 and 12 months of age had an effect, with the heifers 1.072 to 1.083 times more likely to have reached puberty by 12 months-of-age for every extra 1 percentage of target they achieved (Table 3.5; Figure 3.2).

Table 3.5. The effect that live weight (Lwt; kg) and the percentage of individual liveweight target (%TAR) achieved by heifers at 6, 9, 12 and 15 months of age had on puberty by 12 (Pub12) and 15 (Pub15) months of age, pregnancy (Preg), pregnancy in the first 3 weeks (Preg3) and pregnancy in the first 6 weeks of mating (Preg6). Values are presented as odds ratios (95% CI). Odds ratios significantly different to one are shown in bold.

Age (months)		Pub12	Pub15	Preg	Preg3	Preg6
6	Lwt (kg)	**1.042**	1.056	1.006	1.000	1.000
		(1.016-1.069)	(1.004-1.111)	(0.997-1.037)	(0.979-1.022)	(0.972-1.028)
	%TAR	**1.072**	1.079	1.003	0.996	0.998
		(1.030-1.117)	(0.997-1.169)	(0.956-1.052)	(0.963-1.031)	(0.955-1.043)
9	Lwt (kg)	**1.035**	1.031	1.001	1.000	0.996
		(1.016-1.054)	(0.997-1.067)	(0.979-1.022)	(0.985-1.015)	(0.976-1.017)
	%TAR	**1.083**	1.060	0.995	0.997	0.991
		(1.040-1.128)	(0.985-1.139)	(0.950-1.041)	(0.965-1.029)	(0.949-1.034)
12	Lwt (kg)	**1.026**	**1.034**	1.005	1.005	1.00
		(1.010-1.041)	**(1.001-1.069)**	(0.986-1.023)	(0.992-1.018)	(0.984-1.018)
	%TAR	**1.077**	1.082	1.005	1.009	0.999
		(1.034-1.122)	(0.997-1.169)	(0.957-1.055)	(0.975-1.044)	(0.955-1.045)
15	Lwt (kg)	NA	**1.040**	1.002	1.007	0.997
			(1.005-1.075)	(0.985-1.019)	(0.994-1.019)	(0.982-1.013)
	%TAR	NA	**1.111**	0.996	1.016	0.989
			(1.005-1.228)	(0.945-1.051)	(0.978-1.055)	(0.942-1.039)

NA – Not analysed because the outcome occurred before the age at weighing.

Live weight of the heifers at 6, 12 and 15 months-of-age had an effect on the likelihood of heifers reaching puberty by 15 months-of-age, with the heifers 1.034 to 1.056 times more likely to reach puberty by 15 months-of-age for every extra kilogram of live weight (Table 3.5; Figure 3.3). Also, the likelihood of a heifer reaching puberty by 15 months of age was 1.111 times greater for every 1% increase in the percentage of individual liveweight target achieved at 15 months of age (Table 3.5; Figure 3.4).

Figure 3.1. The probability of puberty in heifers by 12 months of age (P(Pub12)) in relation to live weight (kg) at 6 (——— , P = 0.001), 9 (······· , P = 0.002) and 12 (----- , P = 0.001) months of age. Probability values are back transformed linear estimates.
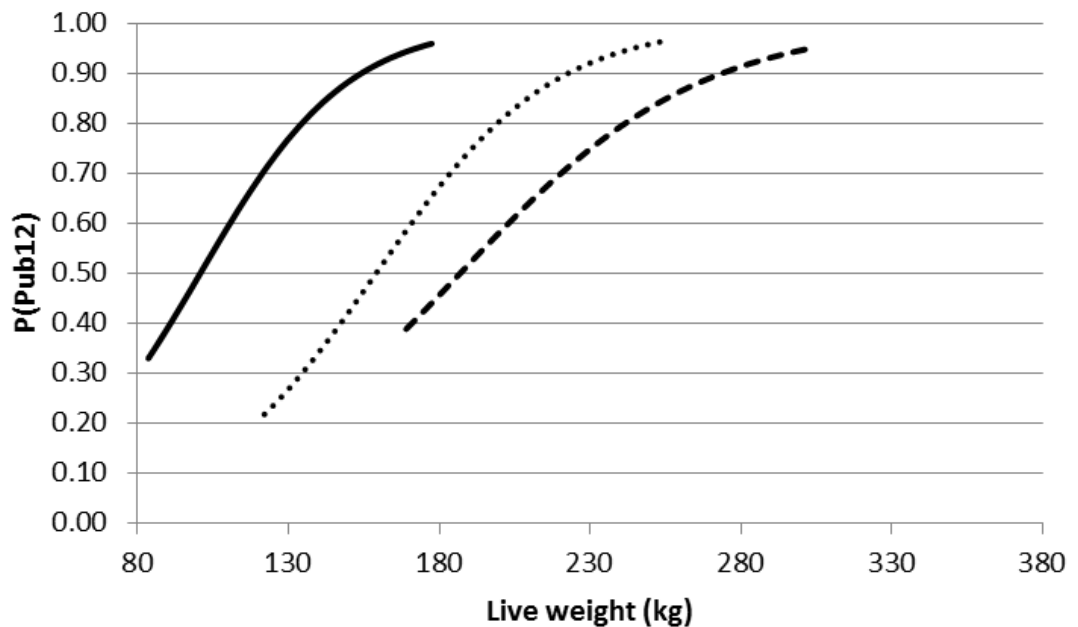
Figure 3.2. The probability of puberty in heifers by 12 months of age (P(Pub12)) in relation to percentage of individual liveweight target achieved at 6 (——, P = 0.001), 9 (·······; P = 0.001) and 12 (----;P = 0.004) months of age. Probability values are back transformed linear estimates.
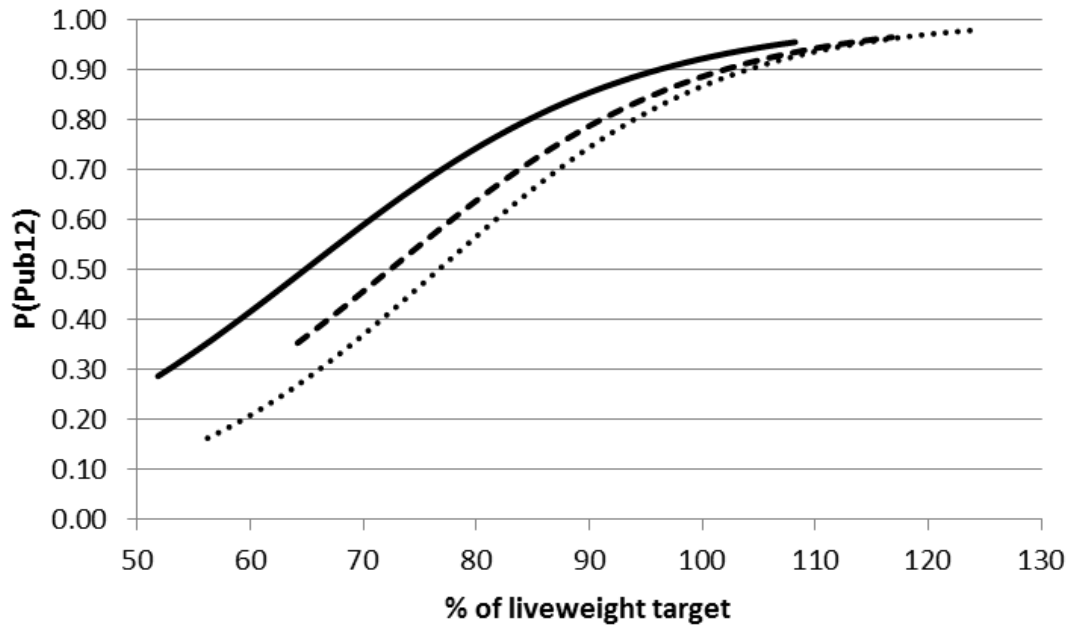
Figure 3.3. The probability of puberty in heifers by 15 months of age (P(Pub15)) in relation to live weight (kg) at 6 (——;P = 0.036), 9 (·······; P = 0.078), 12 (----; P = 0.045) and 15 (— —; P = 0.023) months of age. Probability values are back transformed linear estimates.

54
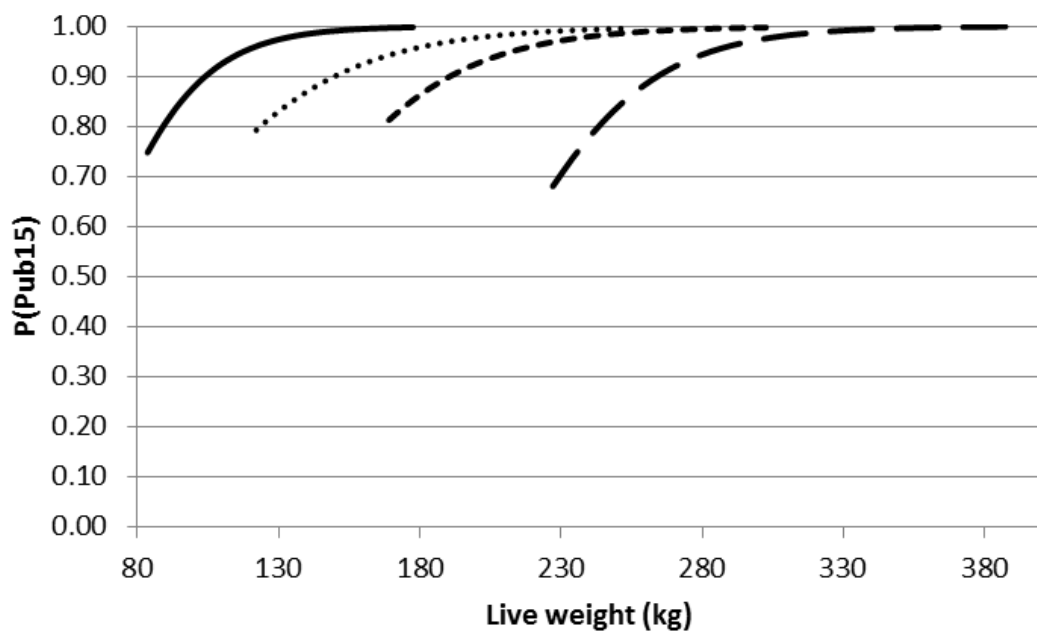
Figure 3.4. The probability of puberty in heifers by 15 months of age (P(Pub15)) in relation to percentage of individual liveweight target achieved at 6 (——, P = 0.060), 9 (·········, P = 0.118), 12 (----; P = 0.071) and 15 (— — , P = 0.040) months of age. Probability values are back transformed linear estimates.
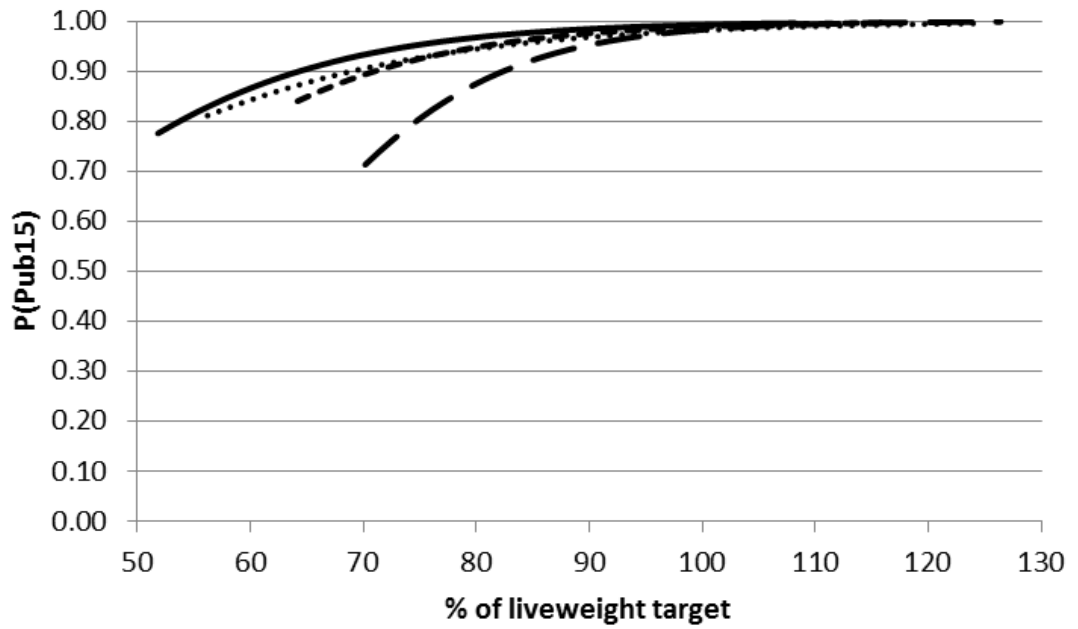
The live weight and percentage of individual liveweight target achieved at 6, 9, 12 and 15 months-of-age did not have an effect on the likelihood of the heifers becoming pregnant (Table 3.5; Figure 3.5 & 3.6).

Figure 3.5. The probability of pregnancy (P(Preg)) in heifers in relation to live weight (kg) at 6 (——, P = 0.676), 9 (·······; P = 0.956), 12 (-----, P = 0.615) and 15 (— —, P = 0.814) months of age. Probability values are back transformed linear estimates.
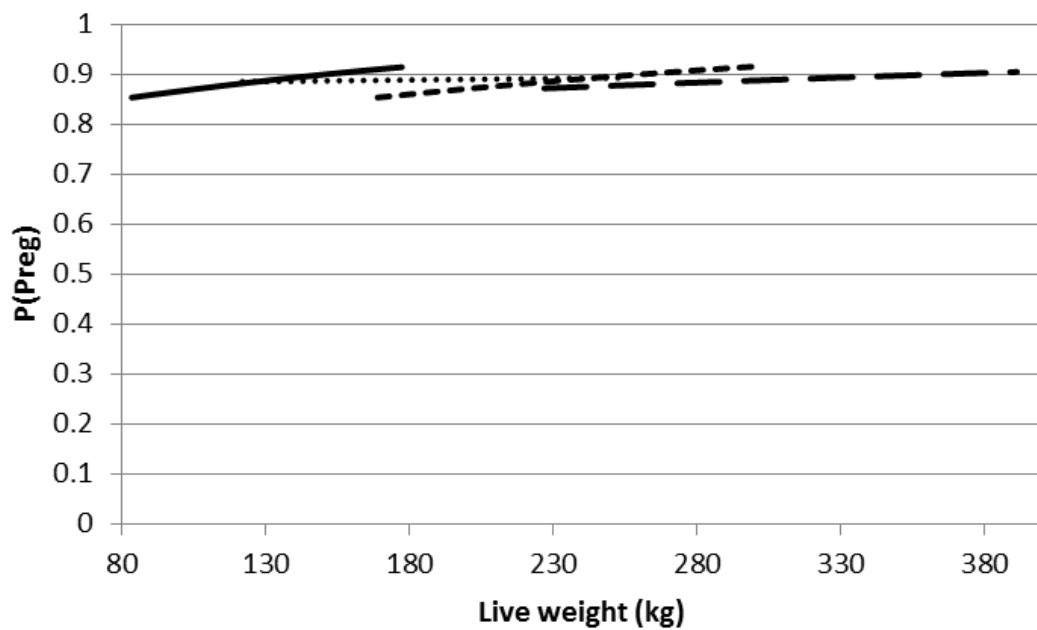
Figure 3.6. The probability of pregnancy (P(Preg)) in heifers in relation to percentage of individual liveweight target achieved at 6 (——, P = 0.893), 9 (⋯⋯⋯; P = 0.817), 12 (----, P = 0.839) and 15 (— — , P = 0.897) months of age. Probability values are back transformed linear estimates.
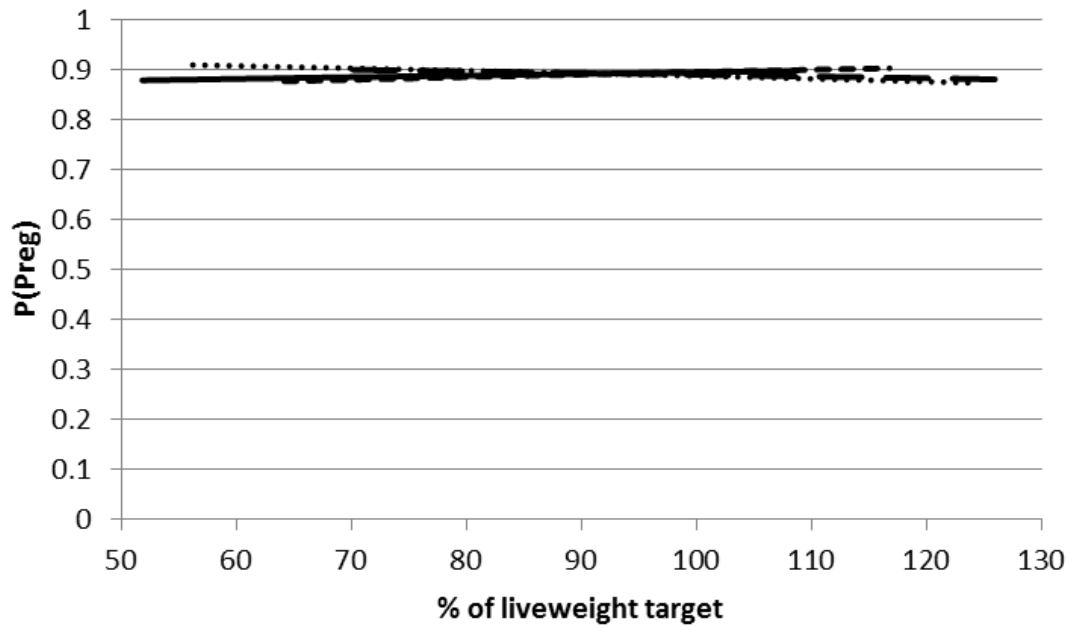
Similarly, the live weight and percentage of individual liveweight target achieved at 6, 9, 12 and 15 months-of-age did not affect the likelihood of the heifers becoming pregnant in the first 3 weeks of mating and the first 6 weeks of mating (Table 3.5; Figure 3.7, 3.8, 3.9 & 3.10).

Figure 3.7. The probability of pregnancy in the first 3 weeks of mating (P(Preg3)) for heifers in relation to live weight (kg) at 6 (——, P = 0.966), 9 (········, P = 0.999), 12 (----, P = 0.474) and 15 (— —, P = 0.287) months of age. Probability values are back transformed linear estimates.
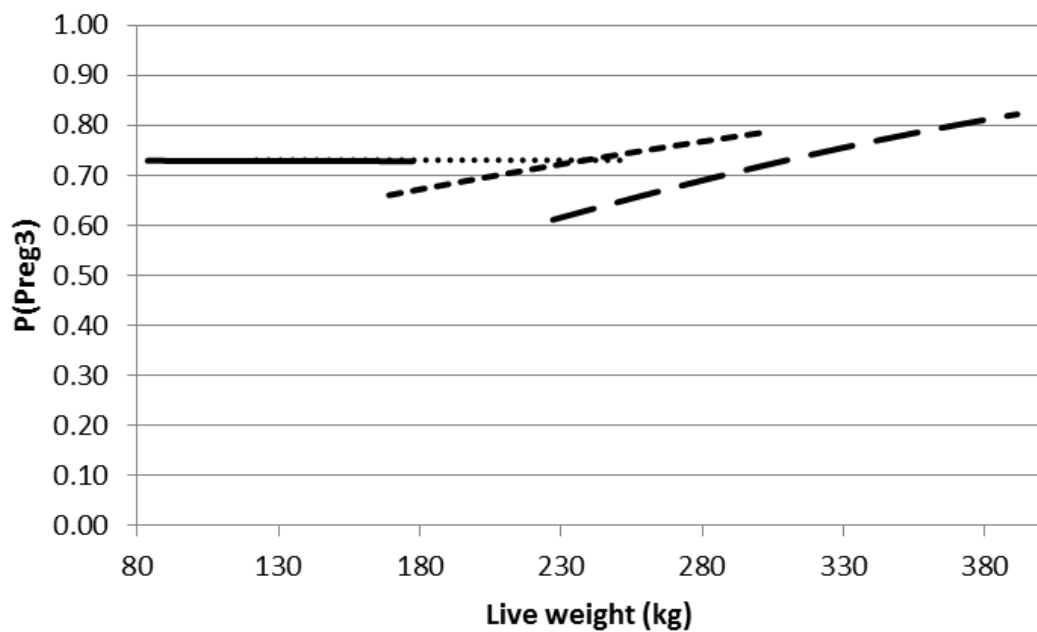
Figure 3.8. The probability of pregnancy in the first 3 weeks of mating (P(Preg3)) for heifers in relation to percentage of individual liveweight target achieved at 6 (—— , P = 0.837), 9 (⋯⋯⋯; P = 0.842), 12 (----, P = 0.618) and 15 (— —, P = 0.421) months of age. Probability values are back transformed linear estimates.
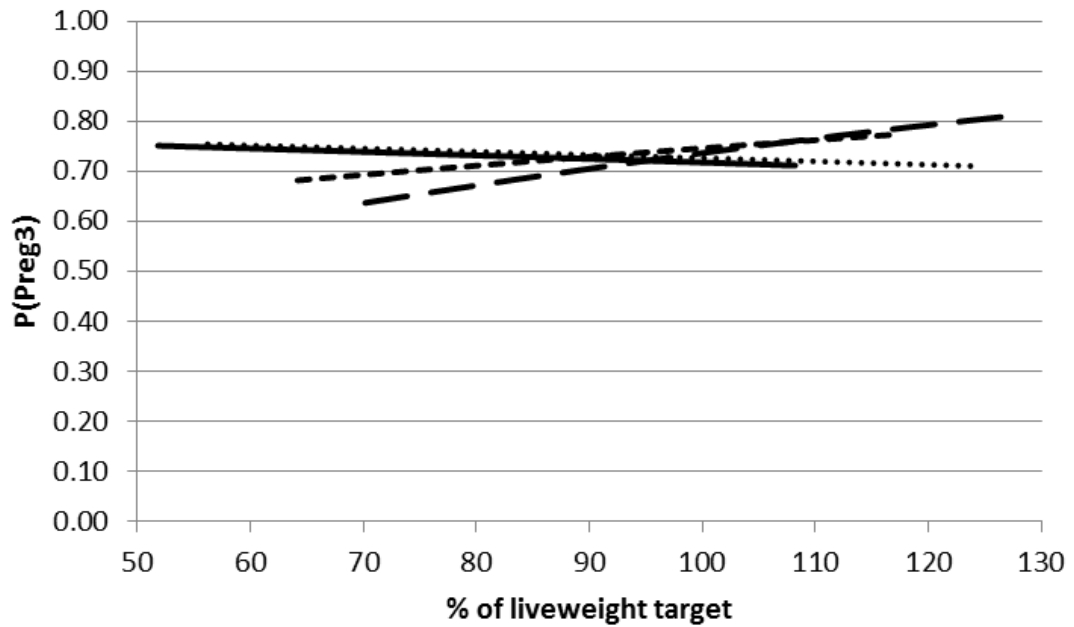
Figure 3.9. The probability of pregnancy in the first 6 weeks (P(Preg6)) for heifers of mating in relation to live weight (kg) at 6 (——, P = 0.986), 9 (⋯⋯⋯; P = 0.719), 12 (----- , P = 0.954) and 15 (— — , P = 0.746) months of age. Probability values are back transformed linear estimates.
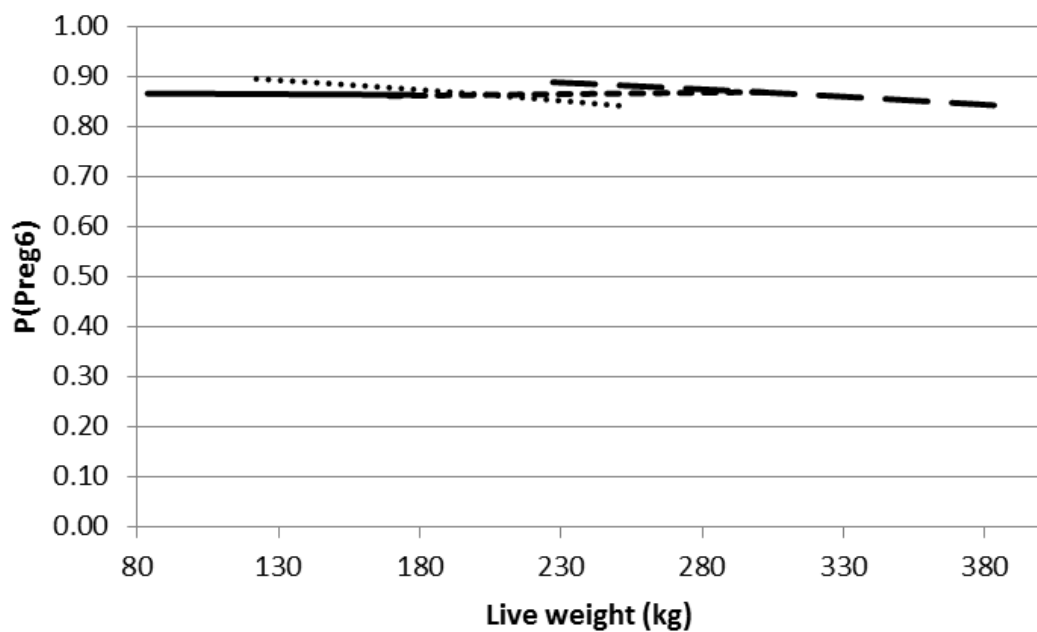
Figure 3.10. The probability of pregnancy in the first 6 weeks of mating (P(Preg6)) for heifers in relation to percentage of individual liveweight target achieved at 6 (——, P = 0.922), 9 (⋯⋯; P = 0.663), 12 (----, P = 0.978) and 15 (— —, P = 0.670) months of age. Probability values are back transformed linear estimates.
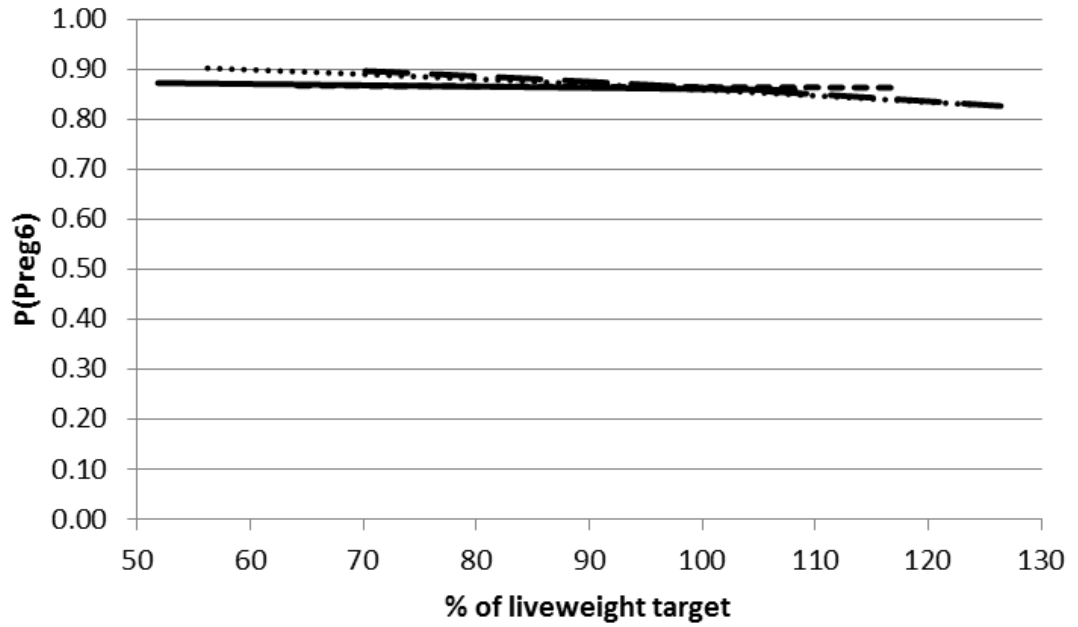
There was no effect seen on the pregnancy parameters measured from the heifers reaching or not reaching puberty by 12 and 15 months of age, as well as achieving or not achieving individual liveweight targets at 12 and 15 months of age (Table 3.6 & 3.7).

Table 3.6. The effects of puberty in heifers by 12 months of age (Pub12) on pregnancy (Preg), pregnancy in the first 3 weeks of mating (Preg3) and pregnancy in the first 6 weeks of mating (Preg6). Values are presented as probabilities (95% CI) (back transformed) and odds ratios (95% CI).

	Achieved	n	Preg	Preg3	Preg6
	Yes	126	0.897 (0.742 – 0.963)	0.746 (0.570 – 0.867)	0.873 (0.713 – 0.950)
Pub12	No	37	0.882 (0.811 – 0.928)	0.712 (0.624 – 0.787)	0.856 (0.782 – 0.908)
	Odds Ratio (Y vs N)		1.358 (0.451 – 4.095)	1.410 (0.636 – 3.128)	1.331 (0.480 – 3.688)

Table 3.7. The effects of puberty in heifers by 15 months of age (Pub15) on pregnancy (Preg), pregnancy in the first 3 weeks of mating (Preg3) and pregnancy in the first 6 weeks of mating (Preg6). Values are presented as probabilities (95% CI) (back transformed) and odds ratios (95% CI).

	Achieved	n	Preg	Preg3	Preg6
	Yes	158	†	0.734 (0.308 – 0.945)	†
Pub15	No	5	†	0.671 (0.450 – 0.835)	†
	Odds Ratio (Y vs N)		†	1.842 (0.297 – 11.410)	†

† Separation of data points was present in the analysis therefore the results from analysis were not included.

3.4 Discussion

The aim of this experiment was to determine the effect that live weight, percentage of individual liveweight target achieved, and achieving or not achieving individual liveweight targets at 6, 9, 12 and 15 months of age had on 5 reproductive parameters (reaching puberty at 12 and 15 months of age, becoming pregnant and becoming pregnant in the first 3 or 6 weeks of mating).

At 6, 9, 12 and 15 months of age, less than 40% of the heifers had achieved their individual liveweight targets. The fact that the heifers were not meeting individual liveweight targets is in agreement with McNaughton & Lopdell (2012), with the exception that less heifers achieved liveweight targets in this experiment than what was reported by McNaughton & Lopdell (2012). McNaughton & Lopdell (2012) reported that at 6 months of age 47% of heifers achieved individual liveweight targets compared to the 7.3% observed in this experiment. The percentage of heifers that achieved individual liveweight targets at 15 months of age was 36.4% which is more consistent with what McNaughton & Lopdell (2012) reported of 39%.

Growth rates of the heifers in the 9-to-12 months-of-age period were lower than the growth rates in the 6-to-9 and 12-to-15 months-of-age periods. As a result of the lower growth rates in the 9-to-12 months of age period, a decrease in the percentage of heifers that achieved individual liveweight targets was seen from 9 to 12 months of age. This was consistent with what McNaughton and Lopdell (2012) reported, which was that heifer growth rates reduced during the 9-to-12 months of age period to 0.32 kg/day (target growth rate = 0.58 kg/day), with the growth rates achieved being only approximately 55% of the target growth rates. The 9 to 12 months of age period (for spring born heifers) coincides with the winter months when herbage growth rates are reduced (Holmes & Roche, 2007). It can be assumed that the DMI and the amount of herbage offered during the 9 to 12 months of age period were not adequate. As a result of these not being adequate, fewer heifers achieved individual liveweight targets.

Live weight had an effect on the percentage of heifers that achieved puberty by 12 and 15 months of age. This was consistent with numerous other experiments which have observed that live weight (and/or pre-pubertal growth rates) affected the proportion of heifers achieving puberty (Crichton et al., 1959; Foldager et al., 1988; Macdonald et al.,

2005; Krpálkova et al., 2014). To the author's knowledge the relationship between the percentage of individual liveweight target achieved, as per the equation described earlier (3.3.4; Burke et al., 2007), and heifers achieving puberty has not been observed. In this experiment, the effect that the percentage of individual liveweight target achieved had on the heifers achieving puberty by 12 and 15 months of age was the same as the effect that live weight had on the heifers achieving puberty by 12 and 15 months of age. Based on the results of this experiment, increasing the live weight and/or the percentage of individual liveweight target achieved for lighter heifers or heifers that are only achieving a low percentage of individual liveweight targets, in comparison to heavier heifers that are achieving a greater percentage of individual liveweight target, will result in an increased chance of the heifers reaching puberty by 12 and 15 months of age.

The effects that achieving or not achieving individual liveweight targets had on the heifers achieving puberty by 12 and 15 months of age were similar to that of the effects that live weight and the percentage of individual liveweight target achieved had. The effect that achieving or not achieving individual liveweight targets has on puberty by 12 and 15 months of age has not been reported in previous studies, however McNaughton and Lopdell (2012) suggested that heifers that were pre-pubertal 13 days prior to mating in an experiment (McDougall et al., 2013) were most likely pre-pubertal due to the fact that they had failed to achieve liveweight targets.

Even though only 17.6% of the heifers achieved individual liveweight targets at 12 months of age, 77.3% of the heifers were pubertal by 12 months of age. This may be explained by the fact that heifers, beef and dairy, have been observed to achieve puberty at 45-50% of the estimated mature live weight (Garćia-Muñiz, 1998; McNaughton, 2003) and that individual liveweight targets at 12 months of age are equal to 50% of the estimated mature liveweight (Troccon, 1993). The average percentage of individual liveweight targets achieved at 12 months of age in this experiment was 90.71% which equates to approximately 45% of the estimated mature liveweight target, which falls within the range that heifers have been observed to achieve puberty (Garćia-Muñiz, 1998; McNaughton, 2003). However, 47.2% of the heifers were below 45% of their estimated mature live weight which leads to the possibility that the estimated mature live weights used for the heifers, on an individual heifers basis, may have been too high.

Live weight had no effect on the pregnancy parameters that were measured. This is in agreement with Troccon (1993) and Macdonald et al. (2005), who observed that live weight had no effect on pregnancy rate. It is acknowledged in the experiment presented here, that the number of heifers (n=163) was a low number for detecting difference in the binomial outcome traits. In addition to the fact that live weight had no effect on the pregnancy parameters measured, the pubertal status of the heifers also did not have an effect on the pregnancy parameters measured. This is contrast to Byerley et al. (1987) and Staigmiller et al. (1993), who both reported that beef heifers that were in their third oestrous cycle post-puberty had increased conception rates compared with beef heifers that were in their first oestrous cycle post-puberty.

One factor that may have led to the results of this experiment not agreeing with those of Byerley et al. (1987) and Staigmiller et al. (1993) is differences in the design of the experiments. For example Byerley et al. (1987) mated the beef heifers once they had completed their second oestrus whilst they were in their third oestrus. In comparison, the heifers in this experiment were mated when they were approaching 15 months of age, when the 77.3% of heifers that had reached puberty by 12 months-of-age would have completed at least their fourth oestrus prior to being mated. The majority of the heifers would have completed more than three oestrus cycles prior to mating and very few heifers would have been in their first cycle. Additionally, the number of heifers that had not reached puberty by 12 months of age was too low to detect differences in pregnancy, a binomial trait.

Given that live weight was not observed to have any effect on pregnancy in this experiment, it is still important that heifers achieve liveweight targets as increased milk production has been associated with increases in the percentage of individual liveweight target achieved. McNaughton & Lopdell (2013) demonstrated that every 1% increase in liveweight target achieved increased milk production by approximately 26.8-30.0 L in the first lactation. Therefore it is valuable to understand where heifers are in relation to liveweight targets as increased milk production can be achieved from ensuring heifers are meeting liveweight targets.

Using individual heifer liveweight targets instead of using a mob average liveweight target allows for mobs that consist of heifers from a range of breeds that have different mature liveweight targets to be assessed on an even scale. For example a Jersey heifer

may weigh 150 kg and a Friesian heifer may weigh 175 kg at the same age so a 25 kg difference exists. If these are compared to mature liveweight targets suitable for their respective breeds (Jersey approx. 450 kg & Friesian approx. 500 kg) then they are 33% and 35% of their mature liveweight targets, respectively, a difference of only 2%. In contrast, it is recommended that individual liveweight targets are not used due to the low accuracy on individual breeding values based on parental records due to the effects of Mendelian sampling and random environmental effects with the accuracy of a group average breeding value is greater and therefore the recommended option.

Furthermore, using a percentage of individual heifer liveweight target achieved versus a simple yes or no the heifer has reached individual liveweight target provides more information to the farmer. By knowing exactly how far heifers are either below or above liveweight targets allows for adjustments to the feed offered to the heifers. Adjustments such as increases in the amount of feed (kg DM) offered or an increase in the nutritive value of the feed offered. Drafting a mob of heifers into respective sub-groups based on the percentage of individual heifer liveweight target achieved and then altering the feed offered to increase live weight gains of those heifers further from liveweight targets is possible. The results of this experiment imply that there is perhaps a value of looking after lighter heifers or heifers that are only achieving a low percentage of individual liveweight targets, based on figures, although more data is needed to confirm this. There would most likely be an increased amount of work when using individual heifer liveweight targets and creating sub-groups but it would ensure that all the heifers have the greatest chance to achieve liveweight targets and fulfil their potential.

3.5 Conclusion

Heifers that were heavier at 6, 9 and 12 months of age were more likely to reach puberty by 12 and 15 months of age but there were limited effect of live weight, percentage of individual liveweight target achieved and achieving individual liveweight targets observed on the pregnancy parameters measured. Farmers wishing to maximise the pregnancy rate of heifers should focus on lighter heifers or heifers that are only achieving a low percentage of individual liveweight targets, as results of this experiment imply that greater gains in heifers reaching puberty can be achieved in these heifers compared to heavier heifers or heifers that are achieving a high percentage of individual liveweight targets. Although the results of this experiment did not observe any effects from reaching puberty by 12 or 15 months of age on pregnancy parameters measured, previous research has indicated that when puberty is obtained may effect when heifers become pregnant. The benefits from increasing live weight at these ages may be seen in future milk yields so farmers should aim to grow heifers for future milk yields rather than to increase pregnancy rates as live weight has little effect on pregnancy within the range of live weights observed in this experiment.

CHAPTER FOUR

GENERAL DISCUSSION, IMPLICATIONS & FUTURE RESEARCH

4.1 General discussion

The primary aim of this thesis was to measure the effect of grazing alternative forages on ADG, wither height, girth & crown to rump length, and to determine the effect that liveweight and reaching liveweight targets at 6, 9, 12 & 15 months of age has on the reproductive performance on heifers.

The live weights of the heifers that were used in both of these experiments reflect the current situation within New Zealand, with many heifers failing to reach liveweight targets (McNaughton & Lopdell, 2012). During the treatment period, a greater proportion of L heifers were on or above liveweight target compared with P and C heifers. The increased ADG achieved in L heifers showed that alternative forages have the potential to increase ADG and provide the opportunity for heifers to reach liveweight targets. These increased ADG achieved from grazing lucerne and supplementary meal would come at a greater cost than that of heifers grazing only pasture. Therefore there would need to be an advantage gained from the use of alternative forages and supplementary meal. From the puberty status and pregnancy status of the heifers, there was an increase in the likelihood of a heifer achieving puberty by 12 months of age with an increase in liveweight. There was no benefit from increased live weight, percentage of individual liveweight target achieved and achieving liveweight target on the pregnancy status of heifers. This would suggest that for the heifers in these experiments, the increased ADG in L heifers, which came at an increased cost, was of limited benefit and no additional financial return would be received from the greater capital invested in feeding the heifers under the circumstances experienced during these experiments. Although, benefits may be observed in L heifers outside of the timeframe that was observed in these experiments, such as increased milk production or increased chance of becoming pregnant.

Currently, it is recommended that heifers within the New Zealand dairy industry should meet certain liveweight targets. The liveweight targets of 30%, 60% and 90% of mature live weight at 6, 15 and 22 months of age, respectively, were suggested by Troccon (1993) and have been further supported by Penno (1997). The recommend liveweight targets at 3, 9, 12, 18 and 21 months of age (DairyNZ, 2014) have not been generated as the result of animal studies. It appears that these recommended liveweight targets have

been produced as a result of linear interpolation between the recommend liveweight targets at 6, 15 and 22 months of age. This would equate to a growth curve that would appear to be a straight line, which is not an accurate representation of the typical growth curve of cattle (Perotto et al., 1992).

One of the main observations made by Troccon (1993) was that the lifetime longevity was greater in those heifers that had a high ADG. So it should be acknowledged that even though there were limited benefits for the reproductive performance of the heifers from increased growth rates, other benefits may occur later in the lifetime of the heifers.

4.2 Limitations of experiments

It should be acknowledged that the observations which were made in these experiments may not be the same if these experiments were to be repeated as there were a number of limitations to these experiments. There are a number of limitations to the two experiments completed in this thesis. During the first experiment (Chapter 2), the timeframe over which the experiment was completed may have limited the results that were observed and therefore a repetition of this experiment, but over a greater timeframe, may produce different results to those that were observed. The second limitation is that the mixed herb crop used in the C treatment was removed from the treatment after a short period of time (D_0–D_{11}). The mixed herb crop was removed as a result of minimal/reduced herbage growth rates due to the crop succumbing to the drought conditions experienced. A repetition of this experiment in which a mixed-herb crop is used throughout the whole of the experiment may produce different results to those that were observed in the C heifers. Similarly, heifers grazing pasture might produce different results under non-drought conditions.

There are two limitations for the second experiment (Chapter 3). The first limitation is the number of heifers (n=163) that were used in the experiment. This is a low number for detecting difference in the binomial outcome traits. Another limitation is that the majority (63% to 92%) of the heifers that were used did not achieve individual liveweight targets from 6 to 15 months of age. Given that the majority of heifers were not achieving individual liveweight targets, it means that the spread of live weights, in relation to liveweight targets, was skewed to below the liveweight targets. This may

have influenced the effects that were observed in this experiment, and there may be the potential to observe different effects with a more even spread, of live weights below and above the liveweight targets.

4.3 Future research

Future research could be focused on repetition of both of these experiments with a number of differences. For the first experiment (Chapter 2), the timeframe over which the experiment would be completed over would be longer (i.e. 6 months), and the experiment could be completed over a number of years to ensure the variation in climatic conditions are account for (i.e. one experiment every year for 3 years). In addition, the location of where the experiment is completed could vary across different regions within New Zealand to observe any difference that may occur as a result of being in different regions (i.e. climatic/seasonal differences). A further point that future research may be based around for an experiment similar to this is the inclusion of other alternative forages as bull calves have shown acceptable ADG whilst grazing a brassica crop (Muir, 2009).

For the second experiment (Chapter 3), the scale of this experiment would be on a larger scale. An increase in the number of heifers would be required as the number of heifers used in this experiment may have limited the differences observed in the binomial outcome traits. In addition to an increased number of heifers, a wider spread of live weights below and above the individual liveweight targets may result in different observations compared to those in this experiment. A key point that needs to be mentioned is that the time frame that has been observed in this experiment is only a small proportion of the heifer's/cow's lifespan. That is, reaching puberty and getting pregnant for the first time is only the start of a heifer's/cow's lifespan. Therefore future research may not just investigate the time frame that has been observed in this experiment but from rearing as a calf to the end of the cow's lifespan.

4.4 Conclusion

Increased growth rates, as a result of grazing lucerne with supplementary meal also fed, allowed a greater proportion of heifers to achieve liveweight targets. For those heifers that achieved increased growth rates, there was limited benefit from these increased growth rates on the pregnancy rates of the heifers during their first mating. Benefits from these increased growth rates may occur at a later stage in the heifer's lifetime than that which was observed in these experiments completed. From the observation made in these experiments, it is implied that the allocation of feed towards heifers that are not achieving liveweight targets will provide an increase in the likelihood of these heifers reaching puberty by 12 months of age, compared to those heifers that are closer to achieving liveweight targets.

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