UNIVERSITY OF ALBERTA

LONG TERM EFFECTS OF FEED RESTRICTION ON GROWTH AND REPRODUCTIVE PERFORMANCE OF BEEF CATTLE

by

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To my husband and daughter, Boakye and Kwamaa Agyemang Duah.

ABSTRACT

One hundred and thirty six cows in their third trimester of pregnancy, were used to study the long term effects of feed restriction. The study concerned effects on the cows themselves and their new born calves, in particular the effects of feed restriction, both pre and postnatal on the subsequent reproductive performance of the heifer calves. Twenty nine cows were feed restricted in energy intake (48.7 MJ DE/kg) to half of maintenance requirements from January 26, 1990 to calving in April/May (three month restriction; 3MR). Another 29 cows were feed restricted similarly from January 26 to calving, then further until breeding on June 21 (five months restriction; 5MR). The remaining 78 cows (UNR) were ad libitum fed throughout the experiment. On calving the 3MR cows were switched to UNR feeding and their calves were weaned later in October 1990 (3MR-L). Calves of 5MR cows were weaned early in June 1990 onto self feeders (5MR-E). Groups of 26 calves from UNR cows were weaned "early" in August 1990 either to the feedlot (UNR-E), or onto pasture for two months, then into the feedlot (UNR-EP). The final group of 26 calves (UNR-L) were weaned later in October 1990 and then placed directly in the feedlot.

In response to increased feeding, the 3MR and 5MR cows gained liveweights at a faster rate (0.77 and 1.05 kg/day, respectively) than the UNR cows (0.42 kg/day, $P<0.05$). The number of cows calving, calf mortality, and assisted births were not affected ($P>0.05$) by previous nutrition. Birth weight of calves were marginally affected ($P=0.06$) by feed restriction of dams. Feed restriction did not affect ($P>0.05$) the subsequent pregnancy rates of cows, and 5MR cows calved earlier than ($P<0.05$) the other groups. Late-weaned calves (3MR-L and UNR-L) grew significantly faster (1.10 and 1.10 kg/day, respectively) ($P<0.05$) than early-weaned (5MR-E, UNR-E and UNR-EP) calves (0.90, 0.90 and 0.92 kg/day, respectively) before weaning. The early-weaned male calves achieved similar liveweights to the late weaned calves (UNR-L) by April 1991. However UNR-E heifers recovered liveweights by 18 months and 5MR-E, UNR-EP

heifers by 23 months of age.

Preweaning feed restriction affected the age at first estrus ($P<0.05$) but not ($P>0.05$) weight at first estrus in heifer calves. Fertility was however not affected by restriction ($P>0.05$). The number of heifers calving, calving dates, birth weight, calf mortality, udder and body condition scores were not affected ($P>0.05$) by feeding levels; however, four 5MR-E heifers needed calving assistance compared to two from UNR-L and, one from UNR-EP groups. Subsequent pregnancy rates, calfcrop weaned and weaning weights of calves were not different ($P>0.05$) among heifers.

It can be concluded that pre- and early postnatal feed restriction of cows, did not permanently impair the growth of their calves, the subsequent reproductive performance of cows, nor the breeding potential of the heifer calves. Recovery from this feed restriction may however require a longer period in the calves.

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1. GENERAL INTRODUCTION

"Catch-up" growth refers to the recovery of weight-for-age of animals previously subjected to a period of feed restriction, and this is associated with higher growth rates than unrestricted counterparts when returned to an adequate feed supply (Baker et al. 1985; Carstens et al. 1988; Drouillard et al. 1991; Yambayamba and Price 1991). Catch-up growth is a self correcting response restoring previously feed-restricted individuals to their genetically predetermined growth path (Ashworth and Millard 1986). The theory of catch-up growth predicts that underfeeding for a particular period will not necessarily result in stunting, however, the risk of permanent stunting is real if feed restriction in young animals interferes with cell division (Maynard et al. 1979).

Catch-up growth has been extensively studied in cattle (Lofgreen and Kresling 1985; Coleman and Evans 1986; Osoro and Wright 1991), pigs (Mersmann et al. 1987; Pond and Mersmann 1990), sheep (Thornton et al. 1979; Turgeon et al. 1986), poultry (Ponkniak and Cornejo 1982; Calvert et al. 1987) rats, (Harris and Widdowson 1978) and humans (Ashworth and Millward 1986; Dettwyler 1991). In general the results indicate that a period of feed restriction in mammals followed by a sufficient recovery period of unrestricted feeding, results in the same or better efficiency of feed utilization and growth than the continuously fed counterparts.

In regions showing marked seasonality of pasture growth, grazing animals typically suffer extended periods of poor nutrition during the dry or winter seasons. Hence their rate of growth tends to follow a fairly characteristic pattern of summer weight gains and winter losses resulting in a 'saw tooth' pattern of growth (O'Donovan 1984). Catch-up growth follows a period of feed restriction, which may be due to either an intake of limited amounts of good quality feed or free access to feed of lower quality.

1.1 Feed restriction

Wilson and Osbourn (1960) classified nutritional restrictions as mild (when growing animals made small weight gain), moderate (when they maintained weight) and severe (when they lost weight). Experimental findings show that growing animals either losing or maintaining liveweight over a considerable length of time show considerable changes in body composition; this can be largely attributed to a decline in weight and proportion of internal organs, particularly organs associated with assimilation, digestion and absorption such as the liver, gut and intestines (Ledin 1983 and Koong et al. 1985).

Feed restricted animals also tend to have a lower basal metabolic rate (Graham and Searle 1979 and Ferrell et al. 1986), and thus a lower maintenance requirement and feed intake compared to ad libitum fed animals (Ledger and Sayers 1977). Foot and Tulloh (1977) observed that the daily dry matter intake of steers maintained at constant weight declined over time from 5.9 kg to 4.4 kg. Graham and Searle (1979) also found that the energy maintenance needs of lambs decreased by 28% after underfeeding for a few weeks. Other metabolic responses due to feed restriction include a decrease in methane production and urinary nitrogen losses (Thomson et al. 1982). These changes will also have an influence on the animal's hormonal state and the concentration of circulating metabolites in the blood (Ellenberger et al. 1989). Oddy and Holst (1991) observed that feed restriction of single-bearing ewes during mid pregnancy (79, 89 or 95 days post coitus) was associated with higher placental lactogen and progesterone concentration, and lower glucose concentration in plasma than the control group of ewes at the end of the feed restriction. Elevated plasma growth hormone (GH) levels have been reported in animals which are maintaining or loosing liveweight (Blum et al. 1985 and Ellenberger et al. 1989). Ellenberger et al. (1989) reported growth hormone levels ranging from 35.1 to 60.5 ng/ml in steers growing at 0.37 kg/day compared with 20 ng/ml for ad libitum fed controls growing at 1.4

kg/day. In view of all these changes, the physiological state following a period of feed restriction appears to be considerably different from its normal state.

The duration and severity of the feed restriction, the animal's age, weight, stage of maturity and sex will influence the physiological state of the animal at the time ad libitum feeding commences and hence the degree of catch-up growth expressed (Moran and Holmes 1978; O'Donovan 1984; Hogg 1991).

1.2 Realimentation

The realimentation phase involves the repletion of animals on adequate feed following a period of nutritional restriction (O'Donovan 1984). In general, higher liveweight gains (compensatory gains) have been observed in restricted-refed animals during realimentation, apparently compensating for the period of suboptimal growth (Hironaka and Kozub 1973; Park et al. 1987; Drouillard et al. 1991). However, reports by other workers have shown that compensatory gain does not invariably occur following a period of feed restriction. In these studies the restricted animals eventually achieved a similar weight-for-age through an extended period of normal growth as compared to their ad libitum fed counterparts (Thornton et al. 1979; Wright et al. 1987). Hogg (1991) indicated that animals have the potential for compensatory growth until the epiphyses of the long bones fuse, i.e. when ultimate mature size is achieved. He commented however, that animals whose epiphyses have fused, and who have suffered weight loss, may regain weight (homeostasis) when fed ad libitum. This is only a recovery of weight rather than an increase in weight and body size (growth). With metabolic and hormonal responses during realimentation, Parks et al. (1987) reported an elevation in blood urea-nitrogen and triglyceride concentration for heifers during the compensatory phase. Blood glucose increased sharply during the initial stages, and remained unchanged throughout the remainder of the refeeding period. In contrast to normal growth, as growth rate rapidly increases in the early stages of compensatory growth, GH levels are rapidly decreasing and returning to normal levels within 10 to 15 days of starting ad libitum feeding (Hogg 1991). On the other hand, insulin and thyroxin (T4) levels were observed to increase rapidly from the day ad libitum feeding began in previously restricted steers (Blum et al. 1985). They observed that T4 levels peaked around 3 and 4 days after ad libitum feeding, which coincided with the time at which GH level began to fall.

Several studies have also shown a lack of compensatory growth in very young animals (Drennan and Harte 1979; Wright et al. 1987; Berge 1991). Morgan (1972) found that cattle below 16 weeks of age were unable to show compensatory growth. Hogg (1991) concluded that the greatest potential for compensatory response occurs in animals whose weight is near 25-30% of mature weight, and below or above this weight their potential to respond declines.

Several factors were identified by Wilson and Osbourn (1960) which may singly or together influence the animal's ability to exhibit catch-up growth during realimentation:

1) The nature of undernutrition

An animal's growth can be retarded by restriction of any of the components of its diet. Fox et al. (1972) concluded that cattle subjected to temporary energy restriction could recover. On the other hand, Winchester et al. (1957) found that severe protein undernutrition could adversely affect the ability of cattle to compensate especially during preweaning period. This was later confirmed by Drouillard et al. (1991) who found that compensatory gain were higher in energy-restricted animals than protein-restricted animals.

2) The duration of undernutrition

The recovery of the animals from undernutrition depends to a large extent on the duration of the restriction period. Too long a duration coupled with severe restriction can result in failure of recovery. After incurring substantial liveweight losses in underfed lambs, Hight and Barton (1965) observed no subsequent catch-up growth. They attributed the duration and amount of weight loss as likely factors affecting recovery.

3) The severity of undernutrition

This may be measured by the animal's rate of loss in weight. Wilson and Osbourn (1960) suggested that there could be differences in response to realimentation depending on whether the restriction was severe, moderate or mild. Drouillard et al. (1991) recently observed that mildly restricted steers did not exhibit compensatory growth relative to controls. It would appear that the more severe the restriction, the greater the compensatory gain immediately after realimentation (Hironka and Kozub 1973; Saubidet and Verde 1976; Wright et al. 1986). However, this trend has not been demonstrated in the cases of feed restriction in early life or very young animals (Wright et al. 1987; Berge et al. 1991). Severe and prolonged undernutrition resulted in the absence of catch-up growth and in some cases, permanent stunting of animals (Allden 1970).

4) The stage of development at the start of undernutrition

In general, weight compensation is lower in animals restricted at an early age than those at a more advanced age (Everitt and Jury 1977; Drennan and Harte 1979; Osoro and Wright 1991). Morgan (1972) concluded that the younger the animal when underfed, the lower the degree of compensation that can be expected. Bohman (1955) showed that calves on poor nutrition during their first winter were not able to make up their retarded growth rates during the following summer grazing, however, when the same calves were similarly restricted the following winter, they finished their second grazing season with no significant differences between their liveweights and those of unrestricted controls.

5) The relative rate of maturation

The rates of maturation in breeds of cattle have been observed to influence the degree of catch-up growth exhibited during realimentation, with late-maturing breeds compensating more than early-maturing breeds

(Wilson and Osbourn 1960). Joubert (1954) observed this while studying the effects of periodic undernutrition upon the growth of Shorthorn and Afrikander cattle. He found that whereas the difference in liveweight between well fed and poorly fed Shorthorn cattle increased with age, the differences between well fed and poorly fed Afrikander cattle tended to decrease. These differences were attributed to the different maturation rates of the two breeds, the Shorthorn being earlier maturing than the Afrikander cattle.

6) The pattern of realimentation

Several workers have shown that the higher the level of nutrition or feed provided upon realimentation, the more rapid, and greater the recovery in weight in cattle (Bohman 1955; Lawrence and Pearce 1964; Fox et al. 1972). Fox et al. (1972) reported a greater degree of compensation in steers realimented on a diet containing 10.84 MJ ME/kg dry matter (DM) than those fed a diet of 6.28 MJ ME/kg DM. As the level of concentrate in the diet increased, the higher dietary quality allowed compensation to be expressed to a greater degree. Higher compensatory gains have also been reported during recovery on pasture. Tudor and O'Rourke (1980) observed that calves restricted and allowed to recover on pasture grew faster than unrestricted controls, while those allowed to recover in the feedlot exhibited no compensatory gains.

The interrelationship of all the factors affecting the animal's ability to exhibit catch-up growth, makes the responses variable and unpredictable. Hogg (1991) concluded that until more is known of the mechanisms which give rise to compensatory growth, it is not feasible to consider using it as a management tool to produce leaner animals.

1.3 Prenatal and early postnatal feed restriction

The potential risk of permanent stunting exists in undernutrition of very young animals, especially if it occurs so early, as to interfere with cell division (Maynard et al. 1979). Growth of individual organs and the whole body is due initially to increased cell numbers (hyperplasia) with a constant individual cell size. As development continues, growth is due to both hyperplasia and hypertrophy (increased cell size), but later to only hypertrophy (Winick and Noble 1965). Winick and Noble (1966) demonstrated that caloric restriction in the rat during cellular hyperplasia resulted in an irreversible depression of growth, while restriction during cellular hypertrophy was followed by a recovery of growth, and did not retard subsequent growth and development. They concluded that if development is impeded during hyperplasia, growth will be permanently affected leading to stuntedness, but retardation of growth during hypertrophy is reversible. Prior and Laster (1979) also noted that since the relative proportion of growth due to hyperplasia is lower than growth due to hypertrophy, as fetal age increases retardation of fetal growth later in gestation should have less severe effects on subsequent neonatal development. This was later confirmed by Tudor and O'Rourke (1980) when they observed that restricting the nutrition of calves for the first 200 days of post-natal life did not impair the capacity of the calves to resume normal growth when realimented on a high quality diet. Likewise, once the nutritional status of heifers had been restored, no adverse residual effects were observed in terms of lifetime reproduction or lactation performance (Joubert 1963; Allden 1970). Allden (1970) suggested that in order to influence the potential productivity of grazing cattle and sheep in early postnatal life, the nutritional stress has to be so severe that the animal is poised in a precarious balance between death and survival.

The inability of very young (preweaned) animals to exhibit a greater degree of compensatory growth following feed restriction has been documented. Data from Everitt and Jury (1977), Wright et al. (1987) and Berge et al. (1991) on cattle and from Allden (1970) and Thornton et al. (1979) for sheep support this view. One of the reasons for this common occurrence is the fact that individual organs and tissues develop at different rates, because skeletal muscles is one of the more slowly developing tissues in the body (Rattray et al. 1975); a high percentage of the growth due to hyperplasia during the later stages of prenatal and early postnatal development is likely to be muscle growth. Thus growth retardation through nutrition in early life would most likely have its greatest effect on subsequent muscle development (Prior and Laster 1979). Wright et al. (1987) also explained this to be due to the insufficient fat deposition in the first 3 to 4 months of life, which limits the scope of manipulation of body fatness through nutrition, because at this stage the level of nutrition simply determines liveweight, but does not influence body composition at any given liveweight. Later in life when the potential for fat deposition is greater, fat deposition is influenced by level of nutrition, with higher levels of feeding resulting in higher levels of body fat at any given liveweight. They suggested that animals have the ability to compensate following intake restriction only if the restriction is applied at a stage when the level of nutrition can influence fat deposition, i.e. when the potential exists for an appreciable quantity of fat to be deposited. Berge (1991) commented that compensatory growth should however not be considered negligible in very young cattle, but in most cases a significant partial compensation of delayed growth will be obtained at the cost of a long period of recuperation.

1.4 Possible factors responsible for catch-up growth

The nature and physiological basis of catch-up growth is not well understood (Allden 1970; and O'Donovan 1984), but a number of biological mechanisms have been suggested.

A greater voluntary feed intake is generally observed during realimentation in previously restricted cattle compared to their continuously fed counterparts (Graham and Searle 1975; Park et al 1987; Wright et al. 1986). Differences of 10 to 15% were reported by Keane and Drennan (1983). This has been attributed to an increase in appetite which contributes to the increased growth rate. However, Butler-Hogg and Tulloh (1982) found that realimented sheep ate significantly less than the control group for the first 10 kg of liveweight gain, while other workers reported no difference in feed consumption between restricted and control groups during realimentation (Fox et al. 1972; Hironaka and Kozub 1973). These discrepancies can probably be explained in terms of the degree of restriction imposed, the relative lengths of the restriction and realimentation period, the type of feed offered and the amount of variability among animals.

Difference in gut fill weight (Koong et al. 1983; Carstens et al. 1988) has also been identified as a contributing factor to catch-up growth. Keenan et al. (1970) found higher gains during realimentation in sheep and attributed most of the weight difference to extra water in the gut. Likewise part of a 46% greater gain of young sheep undergoing catch-up growth was associated with a rapid accumulation of water in a study reported by Drew and Reid (1975).

Thomson et al.(1982) and Baker et al.(1985) have also attributed changes in composition of tissue gained to catch-up growth. Meyer and Clawson (1964) observed that weight gain during catch-up contained more fat and less protein than did the gain of ad libitum fed rats and sheep. Wright and Russel (1991) however indicated that there is initially an increased proportion of protein and water in the empty body-weight gain and a decrease in fat following realimentation. This is followed by a second phase during realimentation, in which there is an increase in fat deposition and a reduction in protein and water deposition, with the net result that the body composition reaches that of the unrestricted controls.

There is evidence of improved feed conversion efficiency during realimentation (Hironaka and Kozub 1973). Meyer and Clawson (1964) noted that the increased efficiency of feed utilization above the maintenance requirement was largely responsible for catch-up growth. Increased requirement was largely responsible for catch-up growth. Increased efficiency of energy and protein utilization was also explained as the basis of increased growth during realimentation by Fox et al. (1972). Saubidet and Verde (1976); Graham and Searle (1979) also attributed catch-up growth to the lower basal metabolic rate and maintenance requirement of the restricted animals, thus at a similar level of feed intake, a greater fraction of the net energy is available for growth and productive processes in animals exhibiting catch-up growth.

The extent to which each of these mechanisms contributes to catch-up growth remains unclear due to divergence in experimental design, the interdependency of these mechanisms and the fact that few experiments have been conducted to examine the mechanisms simultaneously.

1.5 Nutritional restriction and reproductive performance

Poor reproductive performance in breeding herds reduces profits (Short and Bellows 1971). Delays in the onset of sexual activity and low conception rates are among the most common problems.

The effects of feed restriction on endocrine function has mainly been studied in laboratory rats (Glass et al. 1984; Piacsek 1984 and Sisk and Bronson 1986). In general, feed restriction imposed early in life before spermatogenesis will greatly delay the onset of the process in the rat, once it has begun, feed restriction inhibits the process if it is severe and prolonged. On the other hand steriodogenesis is extremely sensitive to feed restriction through out the male rat's lifetime (Bronson 1989). Sisk and Bronson (1986) also reported a stronger effect of feed restriction on luteinizing hormone (LH) with little effect on the secretion of follicle stimulating hormone (FSH) in the adult rat. They observed that LH pulsing from blood sampling, was completely blocked by restricting a young rat's food intake to a level that allowed maintenance of body weight but not growth. A return to ad libitum feeding then initiated the pusaltile release of LH, but the animals experienced only

14% decline in FSH secretions. Hence the greater sensitivity of steriodogenesis to feed restriction. Growth hormone and thyroid stimulating hormone and prolactin have also been found to be profoundly depressed by feed restriction, which could lead to a general metabolic depression, which in turn could result in an insensitivity to the testes and accessory tissues to LH and testosterone (Bronson 1989). In the female rat, Schenck et al. (1980) reported that chronic feed restriction profoundly depressed gonadotrophin releasing hormone (GnRH) secretion, and hence, LH and gonadal steroid secretion, but it had less effect on FSH secretion, thus folliculogenesis is little affected by feed restriction, while ovulation on the other hand occurs less frequently in response to exogenous gonadotrophins in starved rodents.

In production systems where replacement females are bred within a restricted breeding season, age and weight at puberty will have a considerable effect on the reproductive performance of the heifers. Beef producers for example, want their heifers to reach puberty early so they can be bred, conceive and calve at two years of age. In terms of short term effects of feed restriction on reproduction, it has been recognized that restricted feeding in heifers delays the onset of first estrus, lowers conception rates and results in a relatively high incidence of underdeveloped udders (Joubert 1954; Short and Bellow 1971; and Ferrell 1982). Van Lunen and Aherne (1987) observed that age at puberty was lower for ad libitum fed gilts, however weight and ovulation rates at puberty were not affected by level of feeding, indicating that a weight threshold have to be reached for puberty to occur in gilts.

It is generally believed that adequate feeding is desirable for breeding stock. Overfeeding, however may result in weak estrus, lower conception rates, high embryonic mortality, and decreased milk production (Sorensen et al. 1959; Arnett et al. 1971; and Ferrell et al. 1976). Joubert (1954) found that Afrikander heifers exposed to a better plane of nutrition reached puberty at 440 days compared with 710 days for those on poor nutrition. On the other hand he observed that poor nutrition exerted no influence on conception rates in both the first and second pregnancies. Similar observations were made by Ferrell (1982) when he observed that heifers fed to gain slowly after weaning tended to be older and weigh less at puberty, than those fed to gain at a high rate. However, after breeding pregnancy rates, calf birth weight and mortality were not significantly affected by postweaning growth rate. He suggested that excessively thin or fat heifers perform poorly in terms of breeding and milk production. Sorensen et al. (1959) showed evidence that the mammary glands of Holstein heifers fed to gain at high levels were consistently infiltrated with fat.

The long term effects of undernutrition early in the growth period on breeding stock is considerable. Allden (1970) noted that the onset of puberty in relation to retarded size becomes important, since it determines the potential capacity of animals to reproduce. In general, studies tend to show that growth restriction in early life will not influence reproductive performance permanently once an adequate diet has been restored. Joubert (1954) remarked that once estrus is restored upon favourable nutritional conditions, there should be little difficulty in getting the heifer in calf. Penzhorn (1974) found that heifers which were feed restricted during the first and second winter, achieved puberty about seven months later than ad libitum controls, However, reproductive capacity of these heifers were not permanently impaired, with 100% calving rates and higher milk production than ad libitum fed heifers during the second season. Park et al. (1987) reported a 10% increase in milk production of restricted-refed heifers over ad libitum fed controls (21.3 vs. 23.4 kg/d). Preliminary analyses revealed that mammary tissues of heifers undergoing compensatory growth contained more parenchyma and less fat than the controls. Quirke (1979) also observed no effects of nutritional treatment of ewes on conception rates, litter size, birth weight and growth rate of lamb progeny.

It could therefore be concluded that nutritional deprivation could delay sexual maturity and reproductive performance in the short term. Detrimental effects are not carried on into later life, if adequate feed is provided to enable the feed restricted animals to reach a threshold weight or body composition which is associated with the onset of satisfactory reproductive function and performance.

1.6 Background and objectives of research

Most of the studies in cattle have established catch-up growth during the postweaning phase of growth, especially in steers and entire males. Catch-up growth in very young animals (preweaned) has not received much attention, and less information is also available on the long term effects of feed restriction in early life on subsequent growth and reproductive performance. This is due to the fact that existing studies, mostly on males, were terminated when slaughter weight was reached.
Little attention has been paid to heifers, especially those destined to join the breeding herd. The risk of permanent stunting is however real, if feed restriction is applied to young heifers either too early in their development or for too long a time. More work is needed on the consequences of early feed restriction on the growth and subsequent reproductive performance of breeding females.

Studies to verify the limitations to such early restrictions, and to determine the period suitable when to fully exploit compensatory gains would enable livestock producers to minimize feed cost (Morrison et al. 1989) without jeopardizing the reproductive potential of their replacement heifers.

The objectives of this study were therefore:

1. To establish the pattern and degree of compensation in beef calves subjected to undernutrition at different stages (pre and postnatal) and for different durations during the growth period.
2. To investigate the subsequent effects of this early feed restriction on puberty, fertility and reproductive performance of the heifer calves.

1.7 LITERATURE CITED

Allden, W.G. 1970. The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutr. Abstr. Rev. 40:1167-1184.

Arnett, D.W., Holland, G.L. and Totusek, R. 1971. Some effects of obesity in beef females. J. Anim. Sci. 33: 1129-1134.

Ashworth, A. and Millward, D.J. 1986. Catch-up growth in children. Nutr. Rev.44:157-163.

Baker, R.D., Young, N.E. and Laws, J.A. 1985. Changes in the body composition of cattle exhibiting compensatory growth and the modifying effects of grazing management. Anim. Prod. 41:309-321.

Berge, P. 1991. Long term effects of feeding during calfhood on subsequent performance in beef cattle (a review) Livest. Prod. Sci. 28:179-201.

Berge, P., Geay, Y. and Micol, D. 1991. Effects of feeds and growth rate during the fattening period and carcass composition in young dairy breed bulls. Livest. Prod. Sci. 28:203-222.

Bohman, V.R. 1955. Compensatory growth of beef cattle: The effect of hay maturity. J. Anim. Sci. 145:249-255.

Blum, J.W., Schnyder, W., Kunz, P.L., Blom, A.K., Bickel, H. and Schurch, A. 1985. Reduced and compensatory growth: Endocrine and metabolic changes during food restriction and refeeding in steers. J. Nutr. 115:417-421.

Bronson, F.H. 1989. Food as a proximate factor: Neuroendocrine pathways. In: Mammalian Reproduction Biology. pp 60-89. The University of Chicago Press Ltd. Chicago.

Butler-Hogg, B.W. and Tulloh, N.M. 1982. Growth pattern in sheep: The effect of weight losses on compensatory growth and feed intake in Corriedale sheep. J. Agric. Sci. (Camb). 99:641-649.

Calvert, C.C., McMurty, J.P., Rosebrough, R.W. and Campbell, R.G. 1987. Effect of energy level on the compensatory growth response of broilers following early feed restriction. Poult. Sci (Suppl.1) 66:75.

Carstens, G.E., Johnson, D.E. and Ellenberger, M.A. 1988. Energy metabolism and composition of gain in beef steers exhibiting normal and compensatory growth. In: Energy metabolism of farm animals EAAP publication No 43. pp. 131-134 Lunteren Netherlands.

Coleman, S.W. and Evans, B.C. 1986. Effects of nutrition, age, and size on compensatory growth in two breeds of steers. J. Anim. Sci. 63:1968-1982.

Dettwyler, K.A. 1991. Growth status of children in rural Mali: Implications for nutrition education programs. American J. Human Bio. 3:447-462.

Drennan, M.J. and Harte, F.J. 1979. Compensatory growth in cattle. 2. Influence of growth rate in the calf stage (birth to 8 months) and during the first winter (8 to 13 months) on the subsequent performance and carcass composition. Ir. J. Agric. 18:145-156.

Drew, K.R. and Reid, J.T. 1975. The effects of weight loss and realimentation on whole body composition. J. Agric. Sci. (Camb). 85:193-204.

Drouillard, J.S., Ferrell, C.L., Klopfenstein, T.J. and Britton, R.A. 1991. Compensatory growth following metabolizable protein or energy restrictions in beef steers. J. Anim. Sci. 69:811-818.

Ellenberger, M.A., Johnson, D.E., Carstens, G.E., Hossner, K.L., Holland, M.D., Nett, T.M. and Nockels, C.F. 1989. Endocrine and metabolic changes during altered growth rates in beef cattle. J. Anim. Sci. 67:1446

Everitt, G.C. and Jury, K.E. 1977. Growth of cattle in relation to nutrition in early life. N.Z.J. Agric. Res. 20:129-137.

Ferrell, C.L., Garrett, W.N. and Hinman N. 1976. Growth , development and composition of the udder and gravid uterus of beef heifers during pregnancy. J. Anim. Sci. 42:1477-1483.

Ferrell, C.L. 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. J. Anim. Sci. 55:1272-1283.

Ferrell, C.L., Koong, L.J. and Nienaber, J.A. 1986. Effects of previous nutrition on body composition and maintenance energy cost of growing lambs. Bri. J. Nutr. 56:595-605.

Foot, J.Z. and Tulloh, N.M. 1977. Effect of two paths of liveweight changes on the efficiency of feed use and on body composition of Angus steers. J. Agric. Sci. (Camb). 88:135-142.

Fox, D.G., Johnson, R.R., Preston, R.L., Dockerty, T.R. and Klosterman, E.W. 1972. Protein and energy utilization during compensatory growth in beef cattle J. Anim. Sci. 34:310-318.

Glass, A.R., Anderson, J. Herbert, D. and Vigersky R.A. 1984. Relationship between pubertal timing and body size in underfed male rat. Endocrinology 115:19-24.

Graham, N. Mc C. and Searle T.W. 1975. Studies of weaner sheep during and after a period of weight stasis I. Energy and nitrogen utilization. Aust. J. Agric. Res. 26:343-353.

Graham, N. Mc C. and Searle T.W. 1979. Studies of weaned lambs before, during and after a period of weight loss I.Energy and nitrogen utilization. Aust. J. Agric. Res. 30:513-523.

Harris, P.M. and Widdowson, E.M. 1978. Deposition of fat in the body of the rat during rehabilitation after early undernutrition. Bri. J. Nutr. 39:201-207.

Hogg B.W. 1991. Compensatory growth in ruminants. In: Growth regulation in farm animals. Advances in Meat Research Vol.7 Eds. A.M. Pearson and T.R Dutson Elsevier Appl. Sci. London and New York.

Hight, G.K. and Barton, R.A. 1965. The effects of undernutrition and realimentation on the Romney ewe. J. Agric. Sci. (Camb) 64:413-424.

Hironaka, R. and Kozub, G.C. 1973. Compensatory growth of beef cattle restricted at two energy levels for two periods. Can. J. Anim. Sci. 53:709-715.

Joubert, D.M. 1954. The influence of winter nutritional depressions on the growth, reproduction and production of cattle. J. Agric. Sci. (Camb) 44:5-66.

Joubert, D.M. 1963. Puberty in female farm animals. Anim. Breed. Abstr. 31:295-306.

Keenan, D.M. McManus, W.R. and Freer, M. 1970. Voluntary intake of food by mature sheep following restricted feeding. J. Agric. Sci. (Camb) 74:477-485.

Keane, M.G.and Drennan, M.J. 1983. Supplementation of grass fed calves. 3. Effects of concentrate level and protein content, and subsequent performance to slaughter. Ir. J. Agric. Res. 22:113-125.

Koong, L.J. Nienaber, J.A. and Mersmann, H.J. 1983. Effect of plane of nutrition on organ size and fasting heat of production in genetically obese and lean pigs. J. Nutr. 113:1626-1632.

Koong, L.J., Ferrell, C.L. and Nienaber, J.A. 1985. Assessment of interrelationships among levels of intake and production, organ size and fasting heat production in growing animals. J.Nutr. 115:1383-1392.

Lawrence, T.L.J. and Pearce, J. 1964. Some effects of wintering yearling beef cattle on different plane of nutrition I. Liveweight gain, food consumption and body measurement changes during winter period and subsequent grazing period. J. Agric. Sci. (Camb). 63:5-21.

Ledger, H.P. and Sayers, A.R. 1977. Utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation. 1. The effects of time on the maintenance requirement of steers held at constant liveweight. J. Agric. Sci. (Camb). 88:11-26.

Ledin, I. 1983. Effect of restricted feeding and realimentation on compensatory growth, carcass composition and organ growth in lambs. Swed. J. Agric. Res. 13:175

Lofgreen C.P. and Kresling H.E. 1985. Effects of receiving and growing diets on compensatory gains of stressed calves. J. Anim. Sci. 61:320-328.

Maynard, L.A., Loosli, J.K., Hintz, H.F. and Warner, R.G. 1979. Retardation of growth. In: Animal Nutrition. pp 422-424 Tata McGraw Hill New Delhi.

Mersmann, H.J., MacNeil, M.D., Seiderman, S.C. and Pond, W.G. 1987. Compensatory growth in finishing pigs after feed restriction. J. Anim. Sci. 64:752-764.

Meyer, J.H. and Clawson, W.J. 1964. Undernutrition and subsequent realimentation in rats and sheep. J. Anim. Sci. 23:214-224.

Moran, J.B. and Holmes, W. 1978. The application of compensatory in grass/cereal beef production systems in the United Kingdom. Wd. Rev. Anim. Prod. 14:65-73.

Morgan, J.H.L. 1972. Effect of plane of nutrition in early life on subsequent liveweight gain, carcass and muscle characteristics and eating quality of meat in cattle. J. Agric. Sci. (Camb) 78:417-423.

Morrison D.G., Bagley, C.P., Feazel, J.I. and Moose G.D. 1989. Influence of first winter roughage sources on subsequent growth, reproduction and maternal performance of replacement beef heifers. J. Prod. Agric. 2:74-78.

Oddy, V.H and Holst, P.J. 1991. Maternal foetal adaptation to mid pregnancy feed restriction in single - bearing ewes. Aust. J. Agric. Res. 42:969-978.

O'Donovan, P.B. 1984. Compensatory gain in sheep and cattle. Nutr. Abstr. Rev.-Series B 54:389-410.

Osoro, K. and Wright, I.A. 1991. A note on the post-weaning performance of autumn-born suckled calves. Anim. Prod. 52:551-553.

Park, C.S., Erickson, G.M., Choi, Y.J. and Marx, G.D. 1987. Effect of compensatory growth on regulation of growth and lactation: Response of dairy heifers to a stair-step growth pattern. J. Anim. Sci. 64:1751-1758.

Penzhorn, E.J. 1974. Wintering levels and reproduction in Afrikaner heifers. S. Afr. J. Anim. Sci. 13:49-57.

Piacsek, B.E. 1984. Reduced caloric intake alters the feedback response to testosterone in prepubertal male rats. Biol. Reprod. 30:163-168.

Pond, W.G. and Mersmann, H.J. 1990. Differential compensatory growth in swine following control of feed intake by a high alfalfa diet fed ad libitum or by limited feed. J. Anim. Sci. 68:352-362.

Ponkniak, J.A. and Cornejo, S.B. 1982. Effects of energy and protein undernutrition on productive performance and carcass liver and digestive tract composition of broiler males. Nutr. Rep. Int. 26:319-327.

Prior, R.L. and Laster, D.B. 1979. Development of the bovine fetus. J. Anim. Sci. 48:1546-1553.

Quirke, J.F 1979. Effects of body weight on the attainment of puberty and reproductive performance of Galway and Fingalway female lambs. Anim. Prod. 28:297-307.

Rattray, P.V., Robinson, D.V., Garrett, W.N. and Ashmore, R.C. 1975. Cellular changes in the tissues of lambs during fetal growth. J. Anim. Sci. 40:783- 787.

Saubidet, C.L. and Verde, L.S. 1976. Relationship between liveweight, age and dry matter intake for beef cattle after different levels 6 food restriction. Anim. Prod. 22:61-69.

Schenck, P.E., Koos Slob, A., Uilenbroek J. Th., and Bosch, van der Werff ten J.J. 1980. Effect of neonatal undernutrition on serum follicle stimulating hormone levels and ovarian development in female rat. Br. J. Nutr. 44:179-182.

Short, R.E. and Bellows, R.A. 1971. Relationships among weight gains, age at puberty and reproductive performance in heifers. J. Anim. Sci. 32:127-131.

Sick, C. and Bronson F.H. 1986. Effects of food restriction and restoration on gonadotropin and growth hormone secretion in immature male rats. Biol. Reprod. 35:554-561.

Sorensen, A.M., Hansel, W., Hough, W.A., Armstrong, D.T., McEntee, K. and Bratton R.W. 1959. Causes and prevention of reproductive failure in dairy cattle I. Influence of underfeeding and overfeeding on growth and development of Holstein heifers. Cornell Univ. Agr. Exp. Sta. Bull. No.936 pp 1-51.

Thomson, E.F., Bickel, H. and Schuch, A. 1982. Growth performance and metabolic changes in lambs and steers after mild nutritional restriction. J. Agric. Sci.(Camb). 98:183-194.

Thorton, F., Hood, R.L., Jones, P.N. and Re, V.M. 1979. Compensatory growth in sheep. Aust. J. Agric. Res. 30:135-151.

Tudor, G.D. and O'Rourke, P.K. 1980. The effect of pre- and post-natal nutrition on the growth of beef cattle II. The effect of severe restriction in early post-natal life on growth and feed efficiency during recovery. Aust. J. Agric. Res. 31:179-189.

Turgeon, O.A.Jr., Brink, D.R., Bartle, S.J., Klopfenstein, T.J. and Ferrell, C.L. 1986. Effects of growth rates and compensatory growth on body composition in lambs. J. Anim. Sci. 63:770-780.

Van Lunen, T.A. and Aherne F.X. 1987. Effect of long-term feed restriction on age at puberty of gilts. Can. J. Anim. Sci. 67:797-801.

Wilson, T.N. and Osbourn, D.F. 1960. Compensatory gain in sheep and cattle Bio. Rev. 50:324-363.

Winchester, C.F., Hiner, R.L. and Scarborough V.C. 1957. Some effects on beef cattle of protein and energy restriction. J. Anim. Sci. 16:426-431.

Winick, M. and Noble, A. 1965. Quantitative changes in DNA, RNA, and protein during prenatal and postnatal growth in the rat. Dev. Biol. 12:451-459.

Winick, M. and Noble, A. 1966. Cellular response in rats during malnutrition at various ages. J. Nutr. 89:300-308.

Wright, I.A., Russel, A.J.F. and Hunter, E.A. 1986. The effect of winter food level on compensatory growth of weaned, suckled calves grazed at two sward heights. Anim. Prod. 43:211-223.

Wright, I.A., Russel, A.J.F. and Hunter, E.A. 1987. The effects of genotype and post-weaning nutrition on compensatory growth in cattle reared as single or twins. Anim. Prod. 45:423-432.

Wright, I.A., Russel, A.J.F. 1991. Changes in the body composition of beef cattle during compensatory growth. Anim. Prod. 52:105-113.

Yambayamba, E. and Price, M.A. 1991. Growth performance and carcass composition in beef heifers undergoing catch-up (compensatory) growth. Can. J. Anim. Sci. 71:1021-1029.

2. CATCH-UP GROWTH FOLLOWING PREWEANING FEED RESTRICTION IN BEEF CALVES.

2.1 INTRODUCTION

It has been demonstrated by several workers that cattle of at least 6 months of age can overcome periods of feed restriction varying in both severity and duration, with no long term reduction in either growth or efficiency of production (Fox et al. 1972; Thomson et al. 1982; Drouillard et al. 1991; Yambayamba and Price 1991). However, information pertaining to the effects of feed restriction in younger (preweaned) animals on subsequent growth and development have been varied. Burt and Bell (1962) found that calves that gained only 0.5 lb per day during the first month of life showed no signs of recovery at three months, suggesting perhaps permanent stunting caused by restriction of growth at a very early age. Similarly Everitt and Jury (1977) restricting one member of a set of twins from birth to grow at 0.34 kg per day up to weaning, showed that the mature body weight of cattle could be modified by underfeeding during the first 16 weeks after birth.

On the contrary, Stuedemann (1968) observed that calves feed restricted from birth to eight months of age were able to recover from their nutritional restriction and attain desired market weight, carcass grade, dressing percent, and marbling score at slaughter, even though their average daily gains were not greater than their continuously fed counterparts during refeeding. Tudor and O'Rourke (1980) and Tudor et al. (1980) also found that severe nutritional restriction in Hereford calves prenatally through feed restriction of their dams, and during the first 200 days of post natal life (mean gain 0.05 kg/day) did not impair the capacity of the calves to resume normal growth, when grazing on pasture or when fed a high quality diet later. Restricted calves allowed to recover on pasture grew faster (0.50 kg/day) than unrestricted controls (0.36 kg/day), and restricted heifers finished on pasture attained an acceptable weight of 275 kg at breeding about 150 days after the control heifers. They also observed that intensively realimented calves did attain a marketable slaughter weight without exhibiting compensatory gains, within a period equivalent to the length of the restriction period.

The degree of catch-up growth was found to be very low in preweaned calves (Drennan and Harte 1979; Wright et al. 1987 and Osoro and Wright 1991). Morgan (1972) underfed steer calves from birth to 16 weeks and from 16 weeks to 32 weeks of age and observed that only the latter expressed catch-up growth. Wright et al. (1985) found that calves reared as twins and subjected to lower levels of nutrition by early weaning, showed no evidence of compensation, as they gained weight at similar rates as single calves. Berge et al. (1991) concluded that calves have only a limited capacity to compensate for delayed growth. However, the minimum age below which the calf's compensation capacity is definitively altered is still unknown. Differences in findings may be attributed to not only the age at which feed restriction occurs, but the severity, duration, pattern and time allowed for realimentation may also influence the degree of catch-up growth. A more complete or longer study is needed to further clarify "too early" or "too long" feed restriction to allow catch-up growth in very young cattle subjected to feed restrictions imposed during early life.

The main objective of this study was to investigate the effects of undernutrition imposed in both pre and postnatal stages of growth, and for varying lengths of time, on subsequent growth in beef calves.

2.2 MATERIALS AND METHODS

2.2.1 Animals and experimental design

One hundred and thirty six Beef Synthetic (SY) cows (Berg et al. 1986) in their third trimester of pregnancy were used to study the effects of prenatal feed restriction on growth of calves. The SY population used was a synthesis of approximately 60% Hereford; 11% Angus; 10% Charolais; 8% Galloway and small amounts of other breeds. The experiment was conducted at the University of Alberta Ranch at Kinsella, 150 km SE of Edmonton.

On January 26, 1990, cows of four age groups (3; 4; 5 and 6' yr) which had been bred in the previous June, were weighed and condition scored according to the East of Scotland College of Agriculture condition scoring system (Lowman et al. 1973) on a scale of 0 (emaciated) to 5 (grossly fat) in half point increments and then assigned to three winter feeding treatments shown in Table 2.1.

2.2.2 Feeding and management

To loose body condition, 29 cows were restricted on a group-fed basis to half of energy maintenance requirements (48.7 MJ DE/kg) from January 26, 1990 until calving in April/May of 1990 (three months restriction; 3MR). Another group of 29 cows was also feed restricted similarly in energy intake from January 26, 1990 to calving and then restricted further until breeding in June 1990 (five months restriction; 5MR); (Table 2.2). The third group consisted of 78 cows received ad libitum feeding throughout (unrestricted; UNR) (see Figure 2.1).

Table 2.1 Liveweights and condition scores of cows by age group and nutritional treatments on January 26, 1990.

	Treatment groups[1]		
	3MR	5MR	UNR
3 year old			
No.	8	9	33
Liveweight (kg)	503.7±18.3	471.0±14.2	482.4±7.9
Condition score	3.3±0.11	3.3±0.08	3.3 ±0.05
4 year old			
No.	7	6	6
Liveweight (kg)	529.0±16.9	504.5±18.3	493.2±18.3
Condition score	3.2±0.11	3.3±0.11	3.4±0.11
5 year old			
No.	5	6	6
Liveweight	524.2±20.0	570.3±18.3	582.8±18.3
Condition score	3.4±0.12	3.5±0.11	3.6±0.11
6⁺ year old			
No.	9	8	33
Liveweight	609.6±14.9	637.0±15.8	600.5±7.9
Condiiton score	3.6±0.09	3.6±0.10	3.7±0.05

[1] 3MR = three months restriction (Jan 26 to calving); 5MR= five months restriction (Jan 26 to breeding); and UNR= unrestricted.

A 10-day adjustment period was allowed before starting 3MR and 5MR cows on their restricted diet. They started off with their previous ration of 2.3 kg of rolled barley + 2.3 kg alfalfa/brome hay + straw to appetite daily. From the fifth day, feeding hay was discontinued and barley was increased by 0.2 kg/hd/day till the start of the experiment. They were group fed once daily in pens of 42.7 m x 35.9 m, and straw and water were provided freely. Liveweights and body condition scores were recorded periodically until April/May 1991. Cows had been pregnancy tested by rectal palpation in November 1990.

Table 2.2 Composition of diet as fed to cows from January 26 to June21, 1990.

	Restricted				Ad libitum	
	3MR[a]		5MR[a]		UNR[a]	
Ingredient	1[b]	2[b]	1[b]	2[b]	1[b]	2[b]
Composition (g/kg)						
Barley grain	752.0	347.8	752.0	417.7	135.5	347.8
Alfalfa/brome hay	248.0	652.2	248.0	582.3	763.2	652.2
Greenfeed(oats)	-	-	-	-	101.3	-
Dry matter[c] (kg)	3.4	8.2	3.4	7.0	12.5	8.2
Digestible energy[c] (MJ/kg DM)	48.7	97.5	48.7	86.0	137.0	97.5

[a]3MR = three months restriction (Jan 26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 1990); UNR = unrestricted.
[b]1 = Precalving; 2 = Postcalving.
[c] Nutrient composition based upon book values (NRC 1984).

Figure 2.1 Schematic plan of Cow treatment

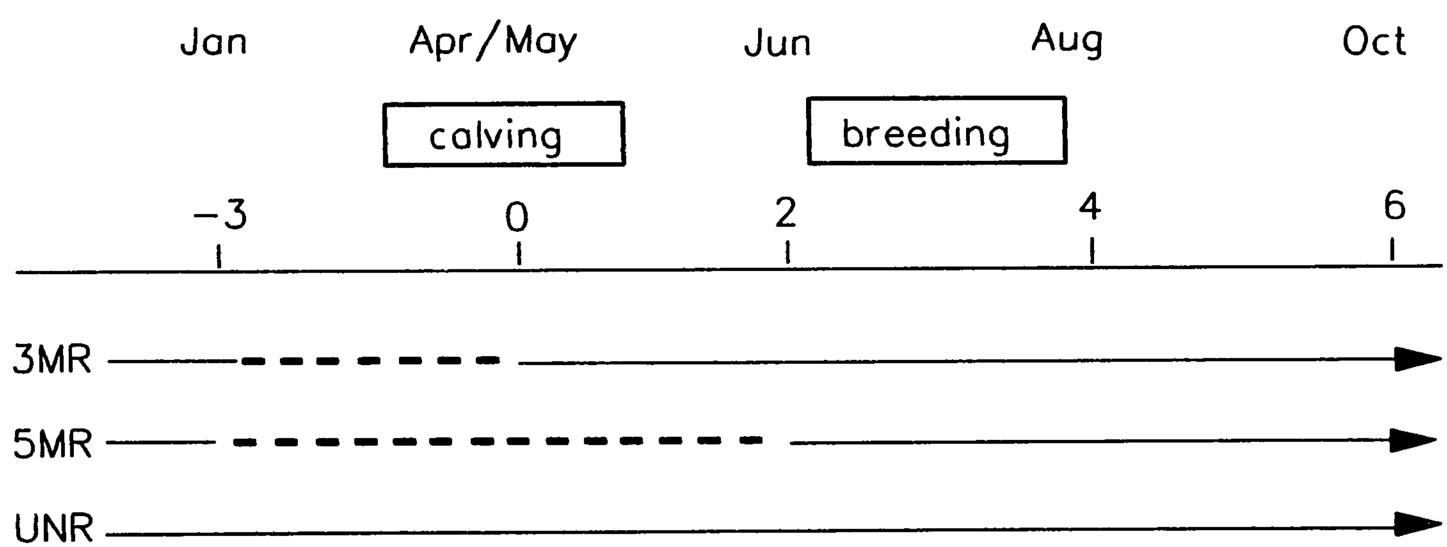

Figure 2.1 Schematic plan of cow treatment.
3MR = three months restriction (Jan 26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 21 1990); UNR = unrestricted.

Calves were identified and weighed within 24 hr after birth and periodically during the preweaning period. Cows were also weighed, body condition scored and scored for the ease of calving on a scale of 0 to 5 (0 = no assistance, 1 = slight assistance, 2 = a puller used easily, 3 = a puller used with difficulty, 4 = veterinarian required and 5 = caesarean birth). Udders were scored (1 = small ideal teats; 2 = ideal teats, 3 = large teats, 4 = very large (bottle) teats; 5 = pendulous udder; 6 = one or two blind teats, 7 = mastitis) within 24 hr after calving.

Cows were moved onto pasture for calving on April 2. The 3MR cows were switched to the ration of the unrestricted cows as they calved, supplementing alfalfa (*Medicago sativa*), brome (*Bromus spp.*) and fescue (*Festuca spp.*) pasture until May 23, 1990 when they only grazed the pasture. Their calves were weaned in October 1990 and placed in the feedlot (3MR-L). The 5MR cows continued their restricted feeding after calving but their diet was adjusted by increasing the alfalfa/brome hay content to 4.6 kg/hd/day. This was to match the energy drain of lactation. They were then limited to pasture grazing starting June 21, 1990. Their calves were early weaned in June 1990 (5MR-E) and had access to a calf ration from self feeders (see Appendix 1) before going into the feedlot in October 1990.

UNR calves were allocated to three types of weaning treatment as follows (see figure 2.2):

1) 26 calves were weaned in August 1990 into the feedlot (UNR-E).

2) 26 were also weaned in August 1990 but stayed on unsupplemented pasture of alfalfa (*Medicago sativa*), brome (*Bromus spp.*) and fescue (*Festuca spp.*) for two more months before being placed in the feedlot in October 1990 (UNR-EP).

3) 26 calves were weaned in October 1990 to the feedlot (UNR-L)

Male and female calves were treated differently following weaning. Bull calves received 4.54 kg of alfalfa/brome hay for ten days and were then given 0.45 kg of bull mix concentrate on day 11 (21.3% oats + 63.7% rolled barley + 5% concentrate + 10% hay pellet) raised by 0.23 kg/head/day till they reached ad libitum feeding on bull mix concentrate. Females on the other hand were weaned initially onto 10 days of ad libitum hay, then limited to 2.3 kg of rolled barley grain and 2.3 kg of alfalfa/brome hay/head per day with straw available as bedding. Monthly liveweights were taken until the bull calves were one year of age (April/May 1991), and the heifers reached puberty and were bred (July/Aug 1991). One 3MR cow calved twins, and was removed from the experiment. Through a communication error, another 3MR cow was not refed at the time the others were being fed, and was therefore switched to the 5MR group. Cows and calves which died were not replaced.

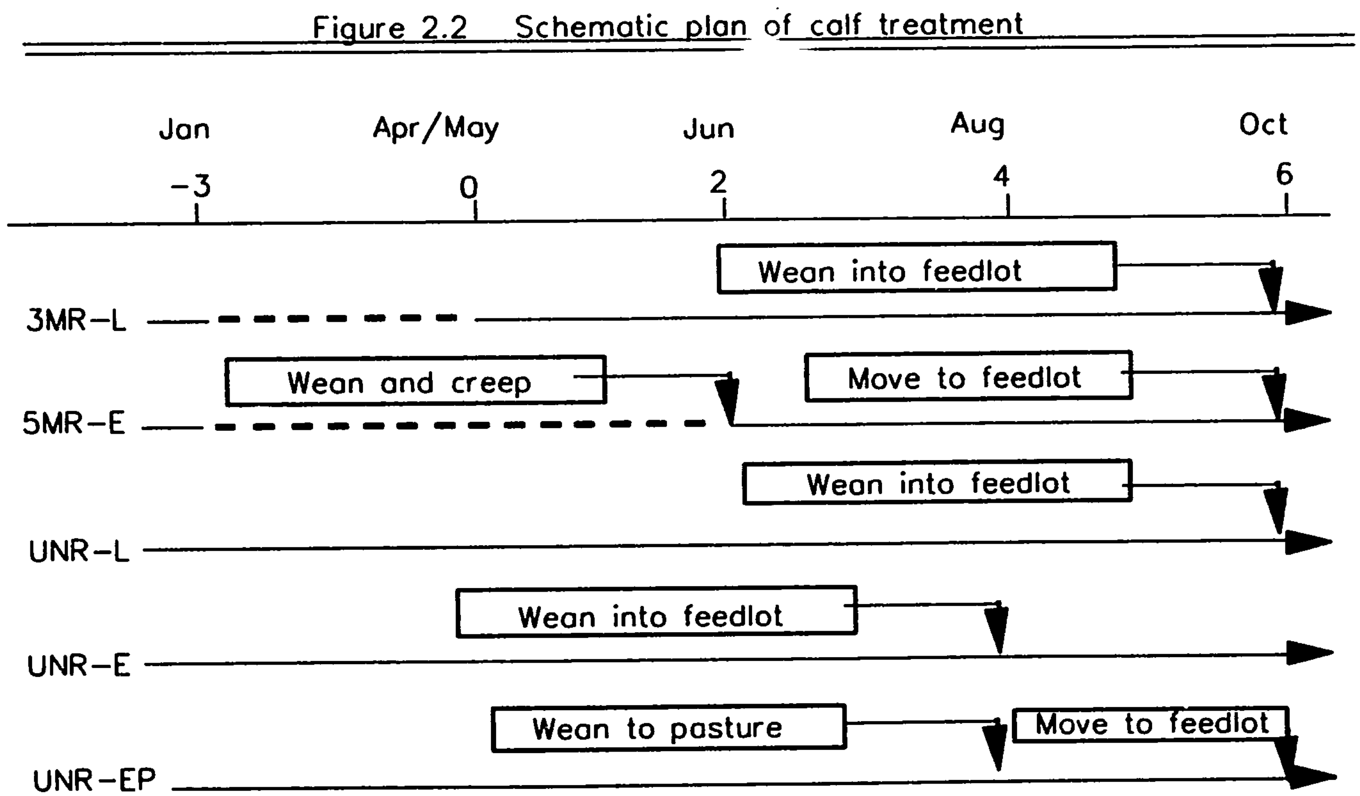

Figure 2.2 Schematic plan of calf treatment. 3MR-L = late-weaned calves of three months restricted cows; 5MR-E = early-weaned calves of five months restricted cows; UNR-L = late-weaned calves of unrestricted cows; UNR-E = early-weaned calves of unrestricted cows; UNR-EP = early-weaned calves onto pasture of unrestricted cows.

2.2.3 Statistical Analysis

Liveweights of individual cows and calves were regressed on days within each period to estimate the rates of gain and then used least squares analysis of variance to compare the effects of the various feed restrictions on growth traits.

Liveweight, liveweight changes, body condition score of cows and calves, and reproduction data within the different periods were subjected to least squares analysis of variance to study the effects of preweaning feed restriction on growth of calves and subsequent rebreeding performance of restricted and refed cows using the General Linear Model (Type III) procedure (SAS 1989).

The models : $Y_{ijk} = \mu + T_i + A_j + TA_{ij} + E_{k(ij)}$ (cows)

$Y_{ijkl} = \mu + T_i + A_j + TA_{ij} + S_k + TS_{ik} + AS_{jk} + E_{l(ijk)}$ (calves)

where Y_{ijk}/Y_{ijkl} = trait under consideration

μ = overall mean

T_i = treatment with (i=1...3) for cows and (i=1...5) for calves.

A_j = age of cows with (j=1...4) i.e. 3yr = 1; 4yr = 2; 5yr = 3; 6+yr = 4.

S_k = sex with k =1,2

$E_{k(ij)}/E_{l(ijk)}$ = error term

Significant differences among means were tested by pairwise t-test comparisons for the unequal treatment and age group numbers (Steel and Torrie 1980).

Comparison of the percentage of cows calving, calf mortality, assisted births and pregnancy rates were made using a Chi- square test (Steel and Torrie 1980). Significance was assessed at the 0.05 level.

2.3 RESULTS

2.3.1 Liveweight changes in cows

Liveweights and body condition scores of 3MR and 5MR cows recorded 24 hr after calving, were significantly lower than those of UNR cows (P<0.05), with 3MR and 5MR cows losing about twice as much body weight (77.2 kg and 75.5 kg, respectively) as UNR cows (33 kg) from January 26 1990 to calving in April/May 1990 (Figure 2.3 and Figure 2.4). As expected, liveweight and body condition scores among the age groups after calving followed a similar trend as at the start of the experiment i.e older cows (5 yr and 6+ yr) being significantly (P<0.05) heavier and fatter than younger cows (3 yr and 4 yr); (Figure 2.5 and Figure 2.6).

Following refeeding of 3MR cows after calving, liveweights were not significantly different (P>0.05) from the UNR cows by June 19, (Figure 2.3). The 3MR cows exhibited significantly higher (P<0.05) daily gains than UNR cows from calving to June of 1990 (Figure 2.7). Recovery of liveweight of 5MR cows was achieved by higher daily gains (P<0.05) than UNR cows and restricted-refed 3MR cows during June to August 1990; However their body condition scores were still lower (P<0.05) than the other groups by September 24 (Figure 2.4). During realimentation, 3MR cows gained more (1.03 kg/day) in the initial refeeding period compared to 0.54 kg/day and 0.75 kg/day in the later stages (June to August and August to September 1990, respectively; Figure 2.7). On the other hand 5MR cows recovered more slowly (0.91 kg/day) in their initial refeeding period (June to August) with higher rates of gain (1.31 kg/day) in the latter stages (August to September). The 5MR cows gained liveweight at a faster rate than 3MR cows (1.05 vs. 0.77 kg/day; P<0.05) during the periods allowed for realimentation i.e June to September and calving to September, respectively. Daily gains were not different (P>0.05) among age groups from calving to June (Figure 2.8). From June to August, 5yr old cows gained less (P<0.05) than the other three group of cows, and in the later stages (August to September) they gained as fast as the 3 yr old cows,

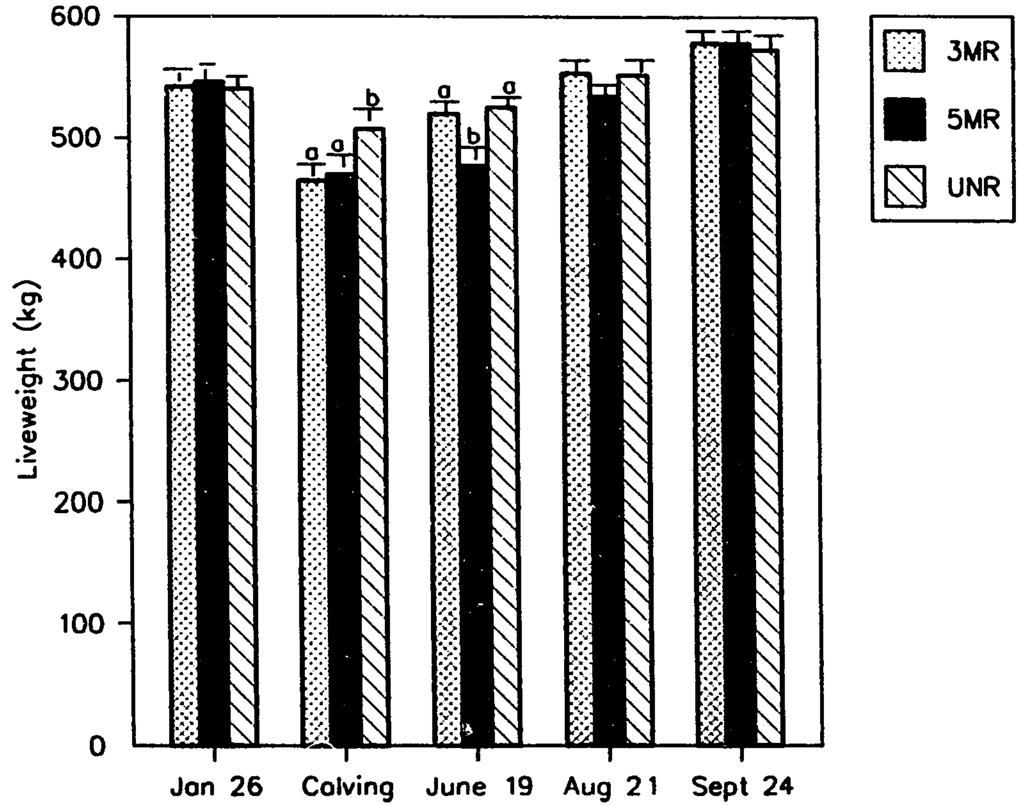

Figure 2.3 Effects of feed restriction and refeeding on liveweights of cows. 3MR = three months restriction (Jan 26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 21 1990); UNR = unrestricted. Means within times with different letters are significantly different at $P<0.05$.

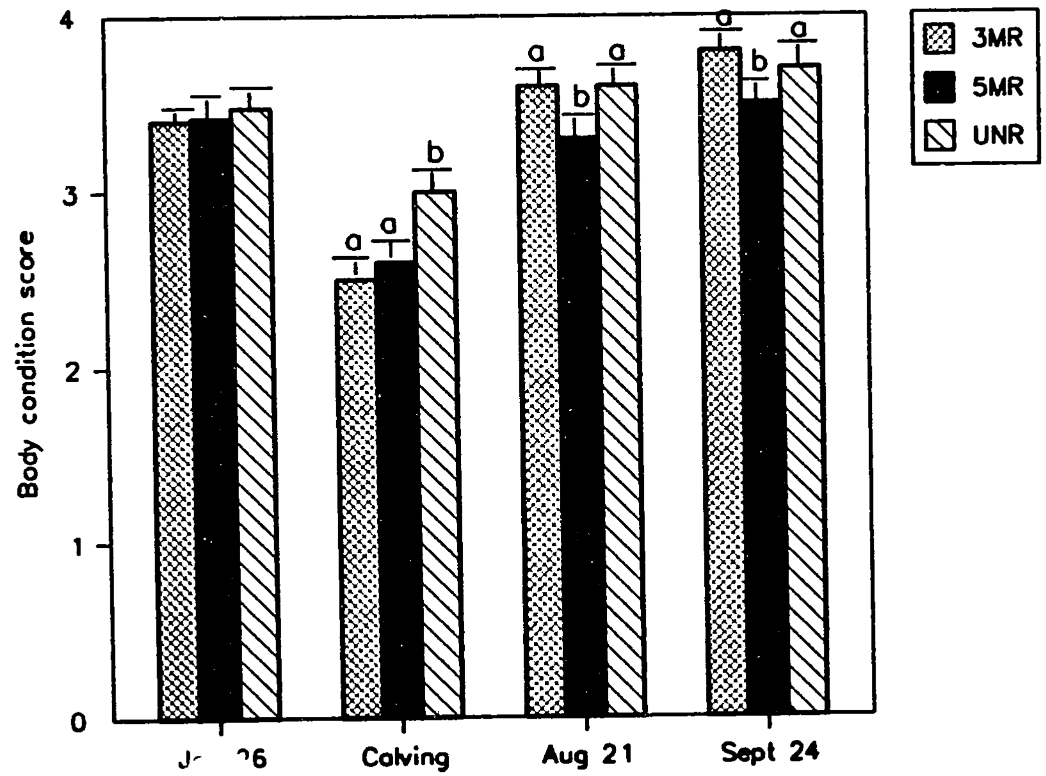

Figure 2.4 Effects of feed restriction and refeeding on body condition scores of cows. 3MR = three months restriction (Jan 26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 21 1990); UNR = unrestricted. Means within times are different letters are significantly different at P<0.05.

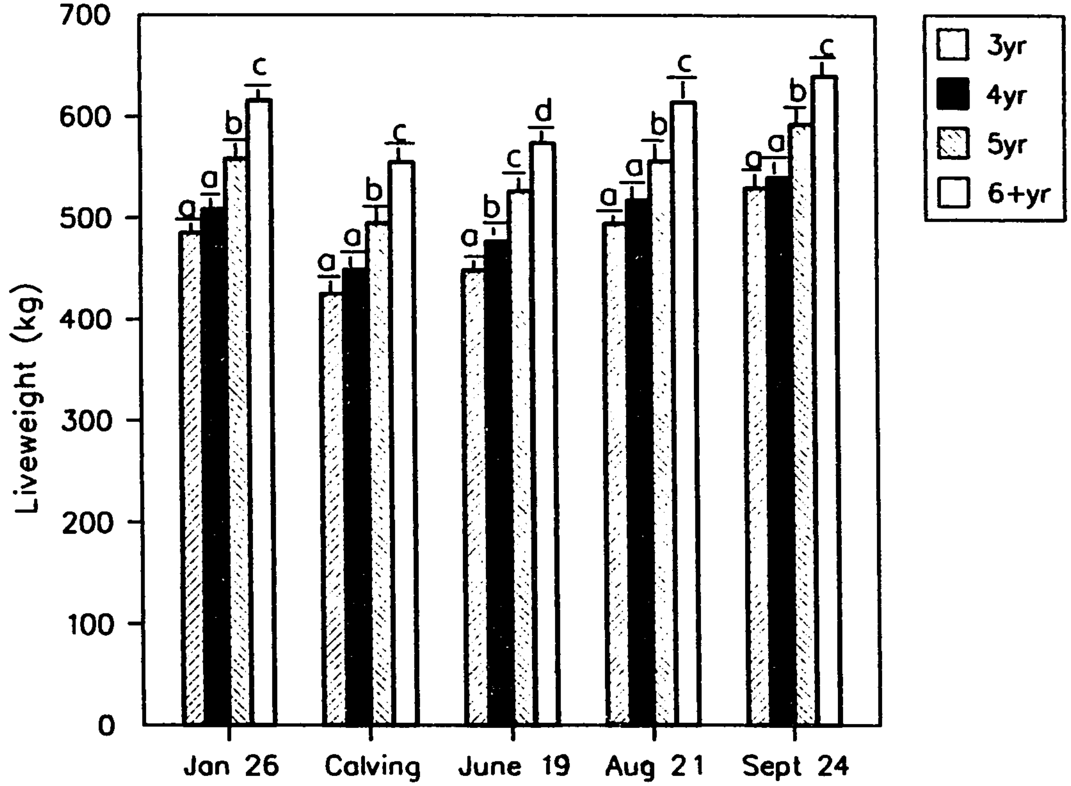

Figure 2.5 Effect of cows' age on liveweights during refeeding. Means within times with different letters are significantly different at $P<0.05$.

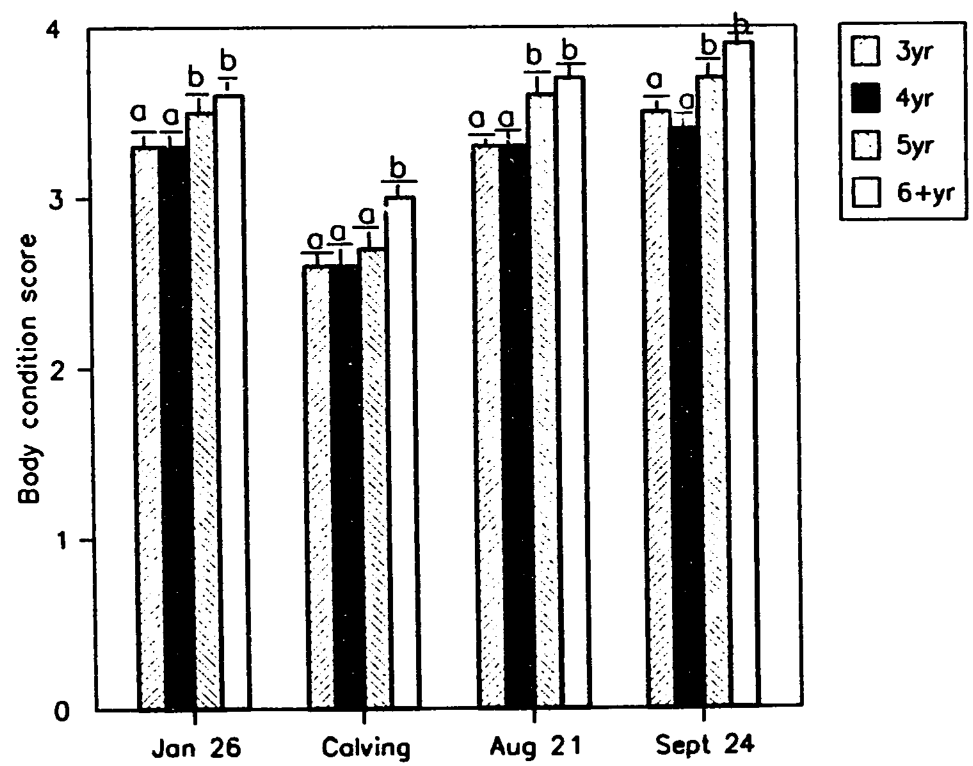

Figure 2.6 Effect of cows' age on body condition scores during refeeding. Means within times with different letters are significantly different at $P<0.05$.

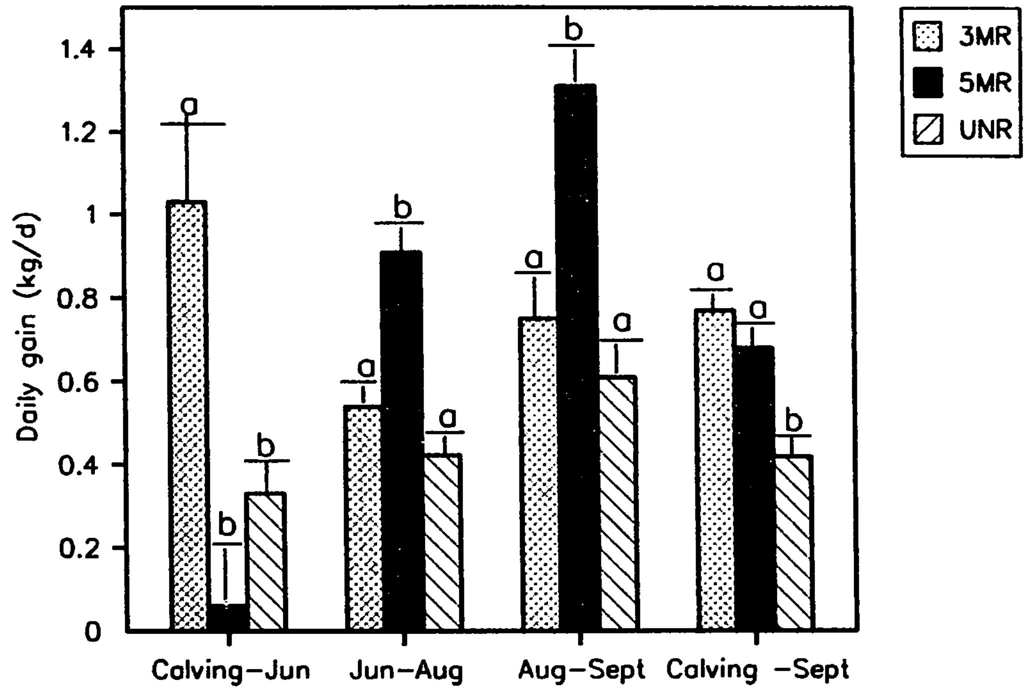

Figure 2.7 Liveweight gains of cows during refeeding.
3MR = three months restriction (Jan 26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 21 1990); UNR = unrestricted. Means within times with different letter are significantly different at $P<0.05$.

while the 4 yr and 6⁺yr cows gained slower (P<0.05) than the 3yr and 5yr old cows. Over the whole period (Calving to September) there were no differences in gains (P<0.05) among the age groups.

2.3.2 Calving performance

Feed restriction during the third trimester of pregnancy had a marginal effect on birth weights of calves (P=0.06) among the treatment groups with UNR calves being slightly heavier (Table 2.3), there was the trend of heavier calves with increasing age of cows as expected (P<0.05). The percentage of cows calving, calving dates and udder condition scores were not significantly (P>0.05) affected by the three feeding treatments, and the oldest group of cows (6⁺ yr) tended to calve later (P<0.05) than the other group ot cows. Calf mortality within 24 h of birth and incidence of calving difficulty were not affected by treatment or age (P>0.05). A significant treatment by age of cows interaction was found for birth weight of calves (Table 2.4). The younger (3 yr and 4 yr) UNR cows had comparable birth weight of calves as the UNR 5 yr and 6⁺ yr old.

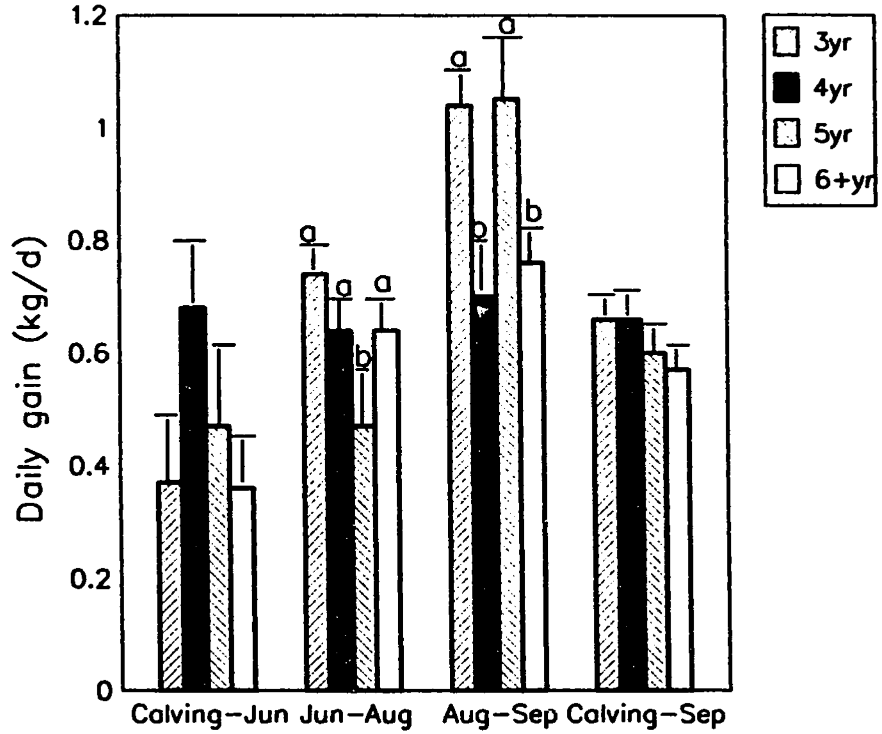

Figure 2.8 Effect of cows' age on liveweight gains during refeeding. Means within times with different letters are significantly different at P<0.05.

Table 2.3 Calving performance of restricted and refed cows.

	Treatment groups[1]				Age groups				
Tra	3MR	5MR	UNR	Prob.	3yr	4yr	5yr	6⁺yr	Prob.
No. of cows	27	30	78		49	19	17	50	
No. calving	27 (100%)	29 (96.7%)	77 (98.7%)	0.57	49 (100%)	18 (94.7%)	17 (100%)	49 (98%)	0.40
Calving[2] date	111.5 ±2.8	109.0 ±2.7	111.4 ±2.0	0.84	108.7[a] ±2.6	107.0[a] ±3.4	107.8[a] ±3.5	120.0[b] ±2.5	0.002
Birth wt. calves (kg)	34.1 ±0.9	34.7 ±0.9	36.7 ±0.7	0.06	33.6[a] ±0.8	35.2[ab] ±1.1	34.8[ab] ±1.1	37.0[b] ±0.8	0.03
Udder [3] score	2.3 ±0.2	2.1 ±0.2	2.4 ±0.1	0.38	2.2 ±0.2	2.1 ±0.2	2.4 ±0.2	2.3 ±0.1	0.82
Calf[4] mortality	1 (3.7%)	0 (0.0%)	1 (1.3%)	0.51	1 (2.0%)	1 (5.3%)	0 (0.0%)	0 (0.0%)	0.40
Assisted births	1 (3.7%)	1 (3.5%)	0 (0.0%)	0.25	1 (2.0%)	1 (5.3%)	0 (0.0%)	0 (0.0%)	0.40

[1]3MR= three months restriction (Jan 26 to April/May 1990); 5MR= five months restriction (Jan 26 to June 21 1990) UNR= unrestricted.
[2]Day of the year (eg. day 1= January 1).
[3]see section 2.2.2.
[4]Deaths within 24 hr after birth.
[ab]Means within rows with different superscripts are significantly different at $P<0.05$.

Table 2.4 Age of cow x treatment interaction on birth weight(kg) of calves

	Treatment groups [1]		
Age groups	3MR	5MR	UNR
3yr	30.5±1.9	34.9±1.5	35.4±0.8
4yr	33.3±1.7	32.2±2.0	40.0±1.9
5yr	35.2±2.0	33.8±1.9	35.3±1.9
6+ yr	37.3±1.5	37.8±1.6	36.0±0.8

[1]3MR = three months restriction (Jan26 to April/May 1990); 5MR = five months restriction (Jan 26 to June 21 1990); UNR = unrestricted.

The percentage of pregnant cows tested in November 1990 did not differ significantly ($P<0.05$) among treatment and age groups (Table 2.5). Birth weights of calves during the second calving were not affected by previous nutritional treatment or age of dam ($P>0.05$). Male calves were heavier at birth ($P<0.05$) than females (41.4 vs 37.9 kg, respectively). There were no differences in cows' liveweight, body condition or udder scores measured within 24 hr postnatally among all feeding groups of cows. The younger cows (3 yr and 4 yr) weighed significantly less ($P<0.05$) than the older cows, and 3 yr-old cows had body condition scores lower ($P<0.05$) than the other three age groups. The 5MR cows calved earlier ($P<0.05$) than 3MR and UNR cows while there were no differences ($P<0.05$) in calving dates among age groups. There were no incidents of calving difficulty.

2.3.3 Preweaning growth pattern of calves

Liveweights of 3MR-L calves were comparable to UNR-L throughout the period, upon refeeding of their dams after calving (Figure 2.9). On the other hand, 5MR-E calves following refeeding of their dams on June 21, continued to show significantly lower ($P<0.05$) liveweights than UNR-L calves throughout the period, such that at the end they were 29 kg lighter. Early weaned calves (UNR-E and UNR-EP) of unrestricted dams were 26.3 and 29.3 kg respectively lighter ($P<0.05$) than UNR-L calves by September 24. There were however no differences in liveweights ($P>0.05$) among UNR-E, UNR-EP and 5MR-E calves by the end of the preweaning period.

Table 2.5 Effects of feed restriction and refeeding on subsequent reproductive performance of cows.

	Treatment Groups[1]				Age groups				
Trait	3MR	5MR	UNR	Prob.	3yr	4yr	5yr	6+yr	Prob.
No. of cows	24	23	69		43	15	14	44	
No. pregnant	21 (87.5%)	20 (86.9%)	64 (92.7%)	0.61	39 (90.7%)	13 (86.7%)	14 (100%)	39 (88.6%)	0.59
Calving[2] date	109.3[a] ±2.0	101.1[b] ±2.4	107.2[a] ±1.5	0.03	106.4 ±1.8	106.0 ±2.9	105.5 ±2.5	105.0 ±1.9	0.97
Birth weight calves (kg)	39.2 ±1.1	40.3 ±1.2	39.5 ±0.8	0.80	40.4 ±1.0	36.9 ±1.6	39.8 ±1.4	41.5 ±1.0	0.11
Calf mortality	0 (0.0%)	2 (1.9%)	0 (0.0)	0.10	2 (5.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0.33
Calving wt. cows (kg)[4]	536.6 ±10.4	561.6 ±12.0	539.0 ±7.5	0.22	496.0[a] ±9.0	517.6[ab] ±14.5	553.3[b] ±12.7	617.2[c] ±9.6	0.001
Calving condn score[4]	2.6 ±0.1	2.9 ±0.1	2.8 ±0.1	0.11	2.4±[a] ±0.1	2.8[b] ±0.1	2.9[b] ±0.1	3.0[b] ±0.1	0.001
Udder score	2.3 ±0.2	2.2 ±0.2	2.1 ±0.1	0.69	2.1 ±0.2	2.2 ±0.3	2.3 ±0.2	2.3 ±0.2	0.92

[1]3MR = three months restriction (Jan 26, to April/May 1990); 5MR = five months restriction (Jan 26 to June 1990); UNR= unrestricted.
[2]Day in the year (day 1= January 1).
[3]Deaths within 24 hr of birth.
[4]Calving weight and condition score within 24 hr post calving.
[abc] Means within rows with different superscripts are significantly different at P<0.05.

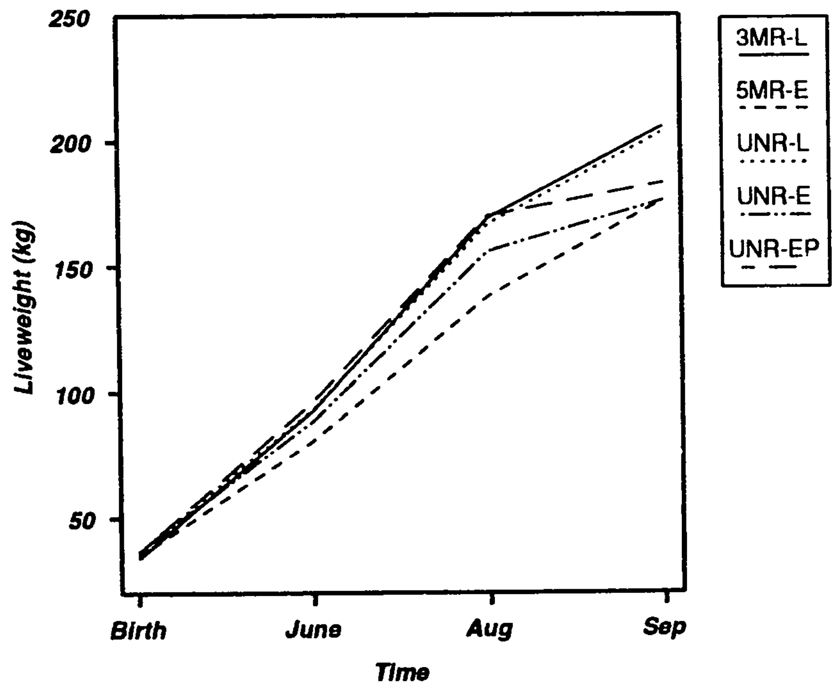

Figure 2.9 Growth pattern of calves during the preweaning period. 3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR-L = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams.

There were no significant differences (P>0.05) in liveweight among the calves of the different age group of dams throughout the whole period (Figure 2.10). Liveweights of male and female calves were similar (P>0.05) at birth (35.9 vs 34.9 kg, respectively) and June (91.5 vs 89.8 kg, respectively), however, the males were heavier (P<0.05) than the females by August (164.2 vs 155.7 kg, respectively) and September (193.7 vs 183.6 kg, respectively). There was a significant treatment x age group interaction for August liveweights (Figure 2.11). There was a decreasing trend of liveweights for the UNR-L and UNR-EP calves of 5yr-old dams, while this was true for 3MR-L and UNR-E calves of 4yr-old dams.

In terms of growth rates during the period, 3MR-L calves grew at a similar rate to UNR-L calves (Figure 2.12) during the initial stages (birth to June). Daily gains of 3MR-L calves from June to August were not different from those of UNR-L, UNR-E, UNR-EP calves (P>0.05). The 5MR-E calves grew significantly slower (0.90 kg/day) than all the other treatment groups in the initial period of realimentation (June to August). Although they exhibited daily gains of 1.12 kg/day in the later stages (August to September), this was not sufficient to achieve comparable weights with the other groups at the end of the period. Thus catch-up growth was not complete in 5MR-E calves by September 1990. Early weaned UNR-E and UNR-EP calves grew slower (P<0.05) than UNR-L calves from August to September. Calves weaned onto pasture (UNR-EP) showed a lower (P<0.05) gain than calves weaned directly into the feedlot (UNR-E). On the whole (birth to September), late weaned calves (3MR-L, UNR-L) grew significantly faster (P<0.05) than early weaned calves (5MR-E, UNR-E and UNR-EP).

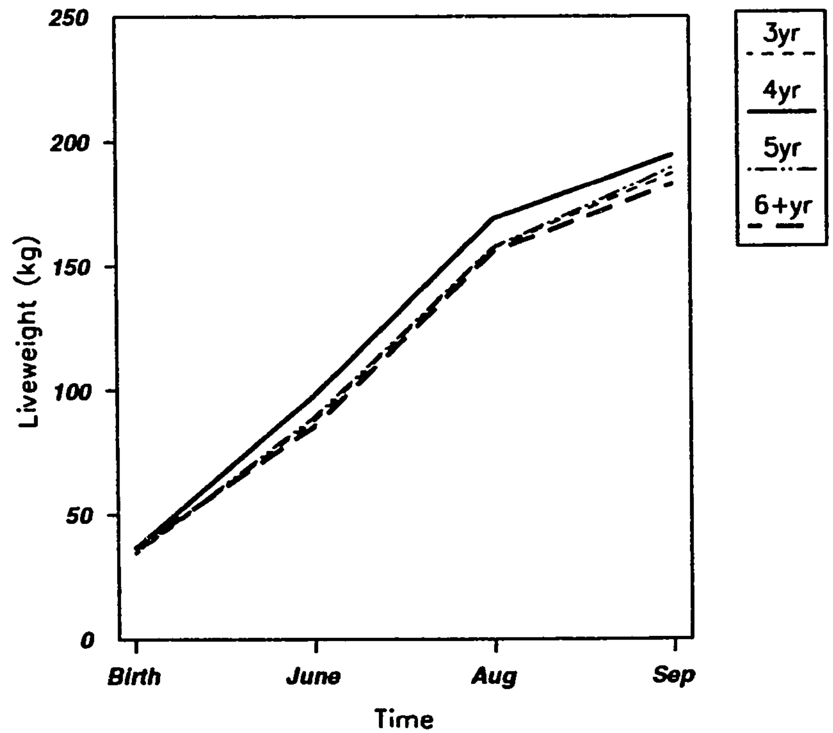

Figure 2.10 Effect of dams' age on preweaning growth pattern of calves.

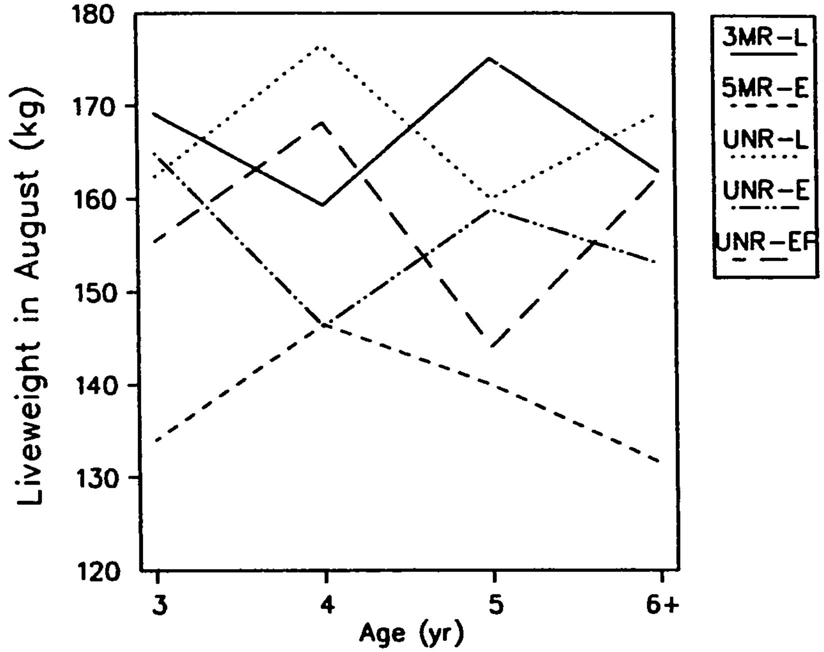

Figure 2.11 Age of dam x treatment interaction on August liveweights of calves. 3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR-L = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams.

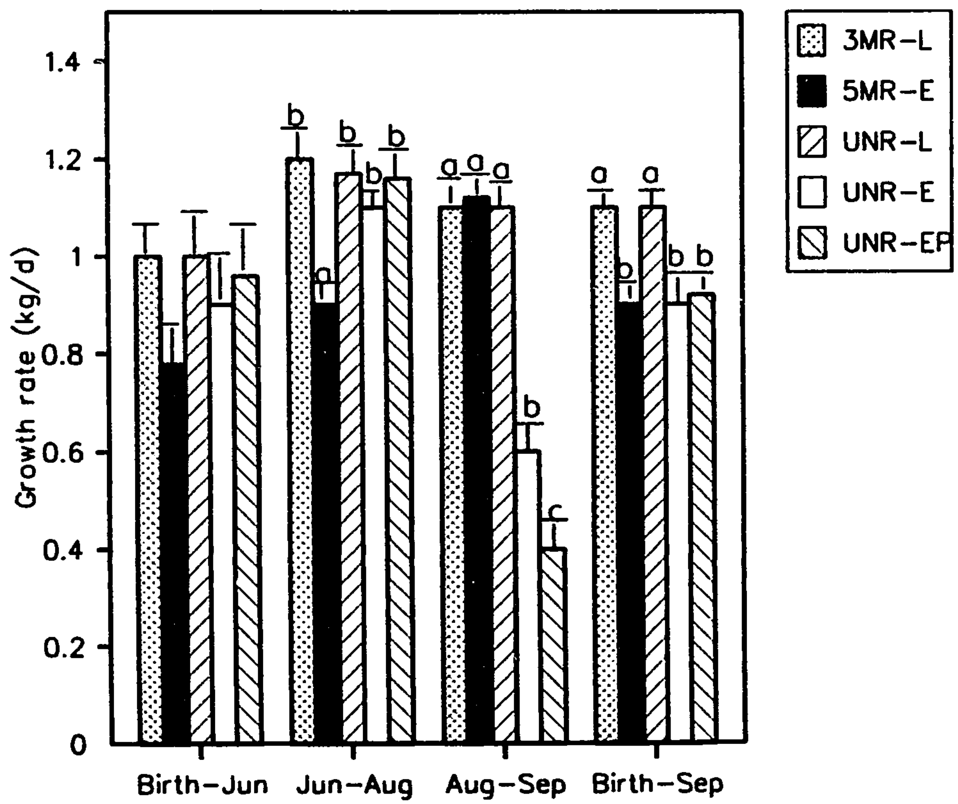

Figure 2.12 Growth rate of calves during the preweaning period. 3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR-L = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams. Means within times with different letters are significantly different at $P<0.05$.

There were no differences (P>0.05) in growth rates of calves categorized by the age of their dams from birth to June and from June to August periods (Figure 2.13); however, calves of 3 yr and 5 yr old dams tended to grow (0.89 and 0.94 kg/day, respectively) significantly faster (P<0.05) than calves of 4 yr and 6⁺ yr old dams (0.75 and 0.80 kg/day respectively) during August to September. From birth to September there were no differences (P>0.05) in gains of calves by the age groups, however, males calves grew (1.02 kg/day) significantly faster (P<0.05) than females (0.94 kg/day) during this period. There was a significant treatment x age group interaction for daily gains from August to September (Figure 2.14). There was a decreasing trend of liveweight gains in 5MR-E calves of 5yr-old dams, with little or no change in gains among the 3MR-L calves in all the age group of cows. On the other hand, UNR-L, UNR-E and UNR-EP calves of 4yr-old dams showed decreasing gains.

2.3.4 Feedlot growth performance

Bull calves

The UNR-E bull calves that were weaned in August and received full feed in the feedlot, recovered from the early postnatal period by November 1990 were significantly (P<0.05) heavier (289.1 kg) than the UNR-L calves (258.7 kg), (Figure 2.15). The 5MR-E and UNR-EP calves continued to weigh significantly less than those from other three treatment groups. However by April 1991, their weights were not significantly (P>0.05) different from UNR-L, 3MR-L and UNR-E groups (491, 493 and 505 kg, respectively). Liveweight gains during feedlot recovery were not significantly different (P>0.05) among the groups (3MR-L = 1.61, 5MR-E = 1.50, UNR-L = 1.61, UNR-E = 1.60 and UNR-EP = 1.69kg/day).

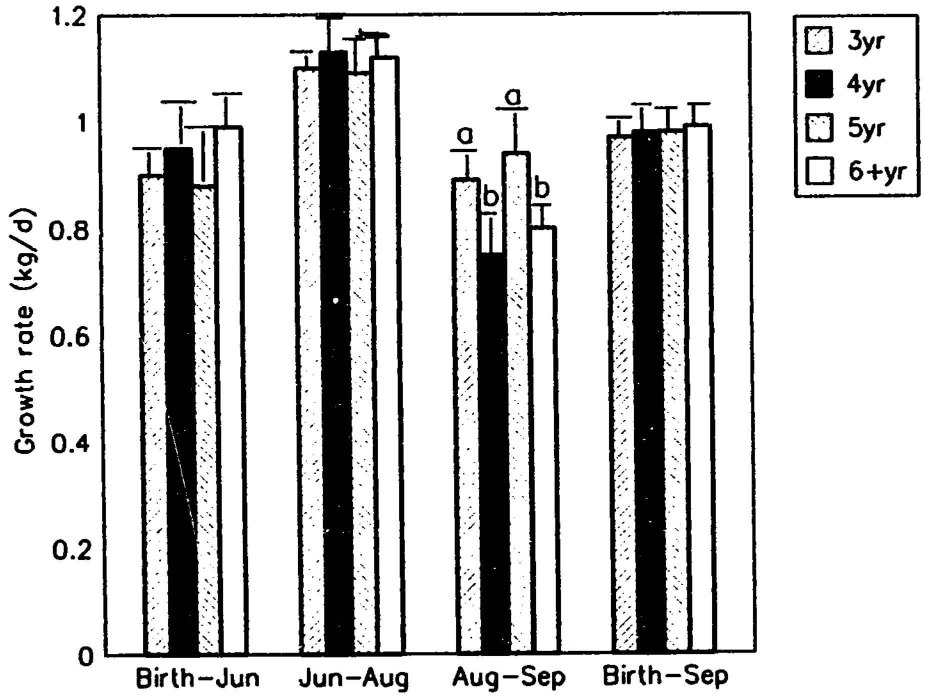

Figure 2.13 Effect of dams' age on growth rate of their calves. Means within times with different letters are significantly different at $P<0.05$.

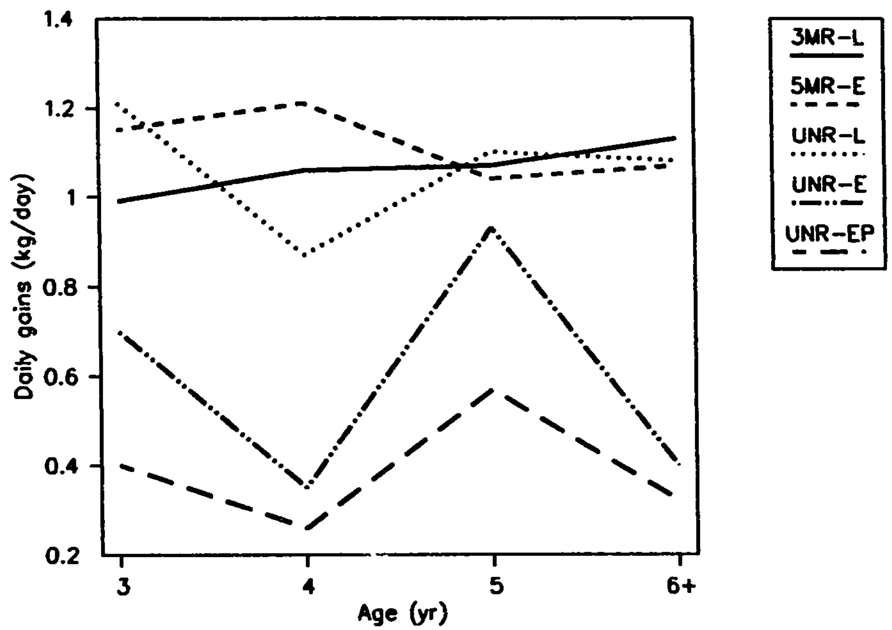

Figure 2.14 Age of dam x treatment interaction on daily gains of calves from August to September. 3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR-L = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams.

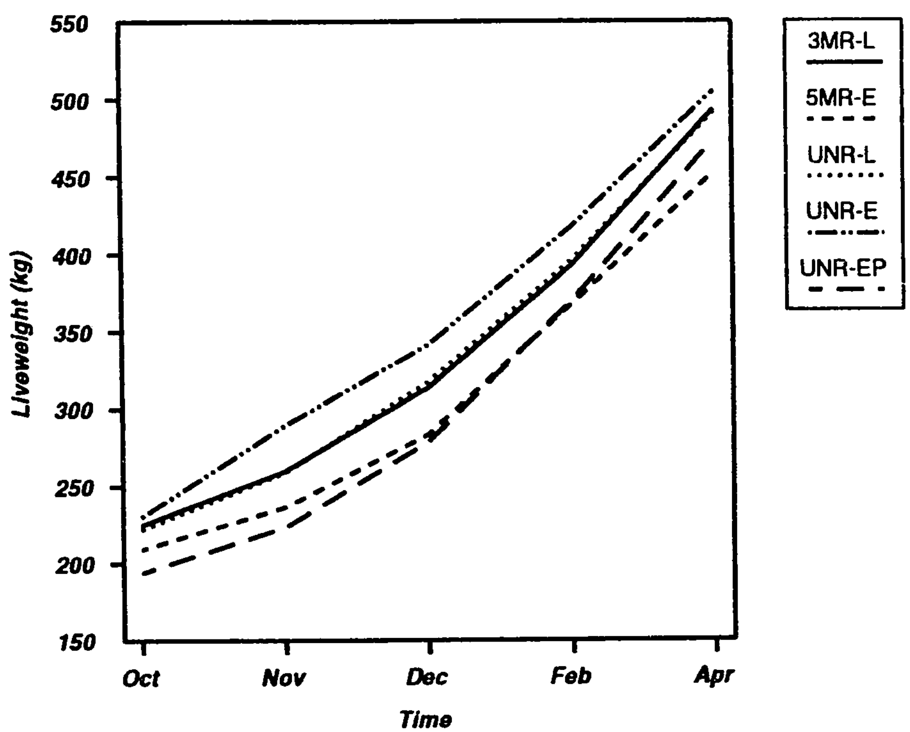

Figure 2.15 Feedlot growth pattern of bull calves.
3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR-L = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams.

Thus the bull calves recovered their liveweights in the feedlot, by growing at the same rate as unrestricted calves.

Heifers

Throughout the period, 5MR-E, UNR-E, and UNR-EP calves weighed significantly less (P<0.05) than UNR-L and 3MR-L calves (Figure 2.16). By June 1991, they still had not caught up to the controls and were 49.8 kg, 24.3 kg and 28.1 kg, respectively lighter (P<0.05) than UNR-L calves. Early-weaned calves of UNR-E and UNR-EP exhibited high liveweight gains over the period (0.40 and 0.39 kg/day, respectively), but this was not significantly higher than the controls (0.37 kg/day), nor was it sufficient to recover all their liveweight. The 5MR-E calves on the other hand grew significantly more slowly (0.31 kg/day) than the controls even though not different (P>0.05) from the 3MR-L calves (0.33 kg/day; P>0.05). Catch-up growth of liveweight was not complete for heifer calves by the end of the feedlot period.

2.3.5 Health

One UNR cow died of bloat on March 20, 1990 and was not replaced. One 5MR cow experienced difficulty during calving and could not continue on the restriction, she was removed with her calf from the experiment. A calf from each group (3MR-L and UNR-L) died at birth, one calf which died on May 14 from 5MR-E, had a hairball in its digestive tract. Two calves, one each from 3MR-L and 5MR-E were missing and presumed dead in June 1990. Incidence of scours in the first few weeks of life were one from UNR-E, two from UNR-L and one from 5MR-E. Dead calves were not replaced in the experiment. All sick cows and calves were treated (see Appendix 2).

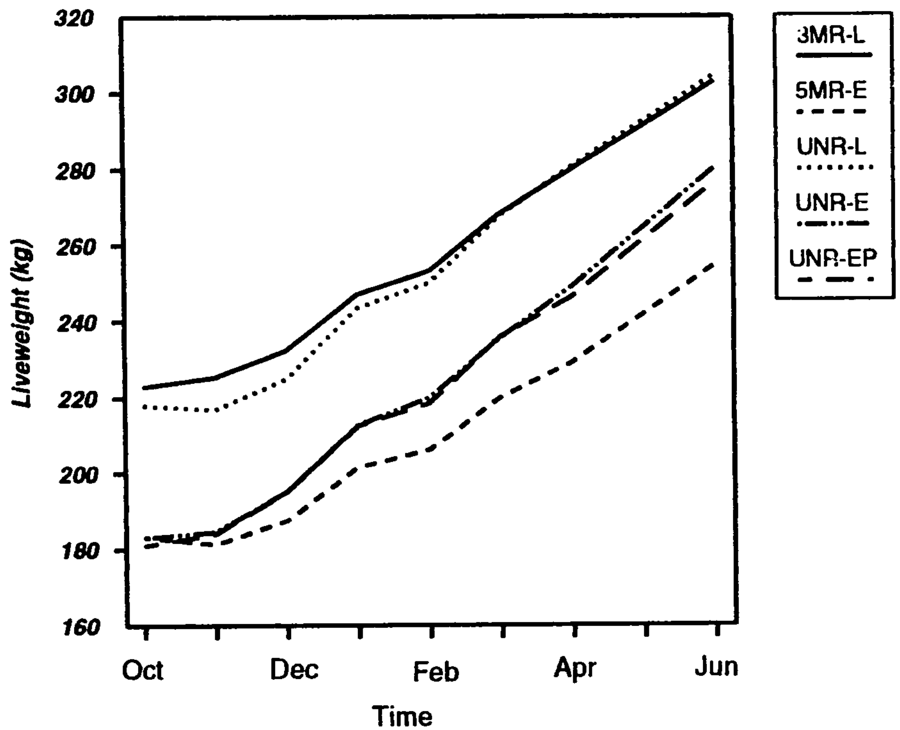

Figure 2.16 Feedlot growth pattern of heifers.
3MR-L = late-weaned calves of three months restricted dams; 5MR-E = early-weaned calves of five months restricted dams; UNR = late-weaned calves of unrestricted dams; UNR-E = early-weaned calves of unrestricted dams; UNR-EP = early-weaned calves to pasture of unrestricted dams.

2.4 DISCUSSION

2.4.1 Liveweight changes in cows

The results of this study indicated that feed restriction of cows in the third trimester of pregnancy was followed by a rapid regain of liveweight during refeeding. During re-feeding 3MR and 5MR cows exhibited greater gains than the continuously fed cows and thereby recovered their liveweights. These results are consistent with those of Butler-Hogg and Tulloh (1982), Parks et al. (1987), Drouillard et al. (1991) and Wright and Russel (1991).

It was further noted that the cows restricted for a longer duration (5MR) exhibited higher growth rates during the time allowed for realimentation (June to September) than 3MR cows which were restricted for a shorter duration and refed from April to September. Earlier work by Yambayamba and Price (1991) support this finding as they also observed that during realimentation, growth rates of severely restricted heifers were greater than those mildly restricted (1.91 vs. 1.18 kg/day, respectively). Butler-Hogg and Tulloh (1982) working with sheep suggested that when animals are realimented, those which have lost a greater proportion of their initial body weight are likely to make a more rapid recovery. Saubidet and Verde (1976) and Ledger and Sayers (1977) have attributed this general trend in restricted-refed animals to the higher voluntary feed intake per unit live weight or metabolic body size during realimentation and also to much lower maintenance requirements of severely restricted animals, making a greater fraction of energy intake available for growth. The relative contribution of these factors in this present experiment however cannot be determined since they were not measured.

Wright and Russel (1991) have also shown that restricted-refed cattle initially show a greater proportion of protein and water in tissue gained and a greater portion of fat in the later stages of refeeding. This might explain the lack of recovery of all body condition in 5MR cows by September 1990, as a result of their shorter realimentation period (June to September) compared to their 3MR counterparts (birth to September). Cows showed a trend of increasing body weight and condition score with age during refeeding, as a result of the significant differences existing between age groups at the start of the experiment.

2.4.2 Calving performance

Feed restriction in the third trimester of pregnancy did not have a significant effect on birth weight of calves. This may be explained in part to the significant treatment x age of cows interaction. Similar observations were reported by Whittier et al. (1988) with heifers. However, contrary to these findings Tudor (1972) observed that a submaintenance ration over the last third of the gestation period significantly reduced birth weight of calves as well as the length of gestation period compared to an above maintenance ration. Differences in observations may also be due to the severity and duration of restriction. Tudor reported a 36.8 kg loss of body weight from 180 days of pregnancy to parturition with dams on a ration of 3.5 kg/head Rhodes grass chaff, whilst the loss in weight of cows in the present study averaged 2 kg in the 80 days before parturition. Hight (1966) commented that the effects of a period of suboptimal nutrition on the dam and the birth weight of the calf is dependent on the severity of the restriction imposed.

Prior and Laster (1979) in studying the development of the bovine fetus found higher placental weights for low and medium than for high maternal dietary energy levels. They suggested that development of the fetal membranes increased on the lower maternal energy level to compensate for the lower level of nutrients available to the placenta from the maternal circulation. This might explain the greater loss of maternal weight after calving of the 3MR and 5MR cows despite the comparable birth weight of their calves with the UNR controls.

Older and heavier cows tended to calve late and have heavier calves at birth. The influences of dam's age and gestation length on birth weight has been reported by other workers (Anderson and Plum 1965; Koonce and Dillard 1967), with older and heavier dams tending to have larger offspring than younger ones. The competition of the younger growing cows and their fetuses for nutrients for maintenance of the pregnancy would reduce the total nutrients available for fetal growth and as such smaller birth weights than older cows (Tudor 1972). Thus in the presence of unrestricted feeding of cows, the younger cows are able to produce comparably heavy weight of calves at birth. This may explain the significant interaction of the age of cows x feeding treatments (Table 2.4). Furthermore, the bigger size of the placenta of older cows may influence absorption of more nutrients to their offsprings. Later parities and the longer gestational length in the older cows would also influence the birth weight of their calves. Tudor (1972) found a positive correlation of length of gestation with birth weight of calves. The size of the cow is also important in determining the growth of the fetus and its weight at birth, with older, bigger cows having bigger calves (Widdowson and Lister 1991).

Subsequent pregnancy rates showed no effects of previous feeding treatments because restricted-refed cows regained their liveweights. Increase in age and parity of the 3 yr and 4 yr old cows may have increased the birth weight of their calves (Anderson and Plum 1965). This may explain the absence of significant differences in the birth weight of the calves during the second calving season. The reason for the shorter calving interval observed in the 5MR cows may be attributed largely to the earlier weaning of their calves, which could enable them to be bred early. Laster et al. (1973) noted that suckling has an inhibitory effect on the return to ovarian cyclicity in cattle. Calf mortality occurring in the youngest cows were to due malpresentation at calving. However on the whole, the capacity of restricted-refed cows to calve satisfactorily and to reproduce subsequently was not impaired. Those findings agree with works done by Tudor (1972), Parks et al. (1987) and Whittier et al.(1988).

On the other hand, other workers have reported poor subsequent reproductive performance with restricted feeding pre-partum (Dunn and Kaltenbach 1980, Richard et al. 1986). Variations in results may be affected by the degree of restriction, type and pattern of feeding upon realimentation.

2.4.3 Preweaning growth of calves

Prenatal restriction per se did not have any effect on brith weight of calves, and changes in liveweight and gain can be attributed directly to nutritional treatments imposed from birth. This may explain the lack of a compensatory gain in calves whose dams were refed at calving (3MR-L). They grew at similar rates as the continuously fed UNR-L calves.

The absence of catch-up growth in 5MR-E, UNR-E and UNR-EP calves restricted during the nursing stages agrees with the general observation in catch-up growth studies done on younger calves (Everitt and Jury 1977; Wright et al. 1987; Osoro and Wright 1990 and Berge et al. 1991). Morgan (1972) found that during refeeding, the liveweight gain of calves reared from birth to 16 weeks on a low plane of nutrition was at no time higher than that of the continually well-fed calves. However calves underfed from 16 to 32 weeks expressed some degree of compensatory growth during refeeding. Wright et al. (1987) suggested that animals have the ability to compensate only if restriction is applied at a stage when the potential exists for an appreciable quantity of fat to be deposited.

It was also found that though UNR-EP calves were early weaned onto pasture for 2 months and grew slower than UNR-E calves in the feedlot (August to September), there were no differences in their liveweights at the end of the period (Figure 2.11). Furthermore early weaning in June (5MR-E) or in August (UNR-E and UNR-EP) did not have any effect on the degree of catch-up growth exhibited to the end of September, as was indicated by the absence of significant differences in liveweights (September) and growth rates (birth to September) of the early weaned (5MR-E, UNR-E and UNR-EP) calves, i.e the severity and duration of feed restriction (early weaning) did not influence catch-up growth. Berge (1991) in his review on long-term effects of feeding during calfhood commented that weight compensation in calves restricted before weaning was low and practically independent of the severity of restriction, while in cattle restricted at a later stage of development it was greater and increased with the severity of restriction. The reason for age of dam x treatment group interaction observed for August liveweight and gains from August to September is unknown.

2.4.4 Feedlot growth performance

Bulls

This phase allowed a longer realimentation period from the feed restriction imposed earlier on the calves in the nursing phase. Results indicated that the ability of bulls to recover and attain comparable slaughter weights was not impaired by previous nutrition. There were no statistically significant differences in liveweight at 1 year old. These findings agree with studies done by Tudor and O'Rourke (1980) and Tudor et al. (1980) who showed that severe nutritional restriction for the first 200 days after birth did not influence the ability of calves to attain the desired slaughter weights of 400 kg. The time taken was however equivalent to the length of the restriction period. Berge et al. (1991) restricted the feed of young dairy bulls from 5 to 11 months of age and observed that they showed little compensatory growth during the fattening period, they concluded that feed restriction imposed before one year of age only affected the duration of the fattening period required (14 to 40 days longer) to reach a fixed carcass weight of 568 kg. Voluntary feed intake, feed efficiency, daily gains and carcass composition (though not measured in this study) have been shown by several workers to be little affected by previous feed restriction during realimentation of calves (Stuedemann et al. 1968; Drennan and Harte 1978; Berge et al. 1991). This may explain the lack of significant differences in daily gains exhibited by the bulls in the feedlot.

Heifers

While the males recovered liveweight during refeeding in the feedlot, the restricted heifers had not recovered all their liveweights at the start of the breeding season in June 1991. This was due to the type and amount of feed offered during realimentation. Males were fed a very high energy diet while the heifers were fed lower energy diet (see chapter 2.2.2), which would have restricted their opportunity to compensate. The ability to recover all their liveweight differences however cannot be ruled out altogether, although they may require a longer period to do so. The third chapter of this thesis examines this potential.

The lack of any significant catch-up growth exhibited by all the restricted-refed heifers is in agreement with the general observation made in calves restricted early in life (Drennan and Harte 1979; Wright et al. 1987; and Berge et al. 1991).

2.4.5 Health

There were no indications of influence of pre-calving nutrition of cows on the incidence of scours during the first few weeks of life. This is contrary to the view of Yaremcio (1993) who indicated that cows that are underfed before calving and are below a condition score of 2.5 to 3.0 would not be able to produce the colostrum required by the calf, thus making them susceptible to diseases. This indicates that there may be other factors such as sanitation, age of dams, calving difficulty of dams that may predispose the calf to scours.

2.5 CONCLUSION

Cows feed restricted during the third trimester of pregnancy fully regained their liveweight, body condition scores and reproduce satisfactorily with adequate feed upon realimentation. Furthermore, liveweight gains in cows during refeeding tends to increase with the severity or duration of the restriction previously applied.

Prenatal feed restriction did not affect birth weight of calves. Restricted feeding in the cow did not necessarily result in growth restriction of the calf. The pregnant cows tended to buffer the adverse effects of undernutrition on their developing fetus by utilizing their body reserves. Feed restriction of calves during early life (0 to 4 months of age) is not fully compensated for during recovery over a short period, independent of the duration of the restriction. Full recovery of calves to either attain a marketable slaughter weight or a suitable liveweight for breeding may however be achieved at the cost of a long period of recuperation.

2.6 LITERATURE CITED

Anderson, H. and Plum, M. 1965. Gestation length and birth weight in cattle and buffaloes (a review). J.Dairy Sci. 48:1224-1235.

Berg, R.T., Goonewardene L.A. and Makarechian M. 1986. The University of Alberta beef breeding project - 1986 update. 65th Annual Feeders Day Report pp. 3-6. University of Alberta, Agriculture and Forestry Bulletin.

Berge, P. 1991. Long term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci. 28:179-201.

Berge, P., Geay, Y. and Micol, D. 1991. Effects of feeds and growth rate during the growing phase on subsequent performance during the fattening period and carcass composition in young dairy breed bulls. Livest. Prod. Sci. 28:203-222.

Burt, A.W.A. and Bell, E.O. (1962). Effect of the level and concentration of liquid milk substitutes fed to early weaned calves. J. Agric. Sci. 58:131-136.

Butler-Hogg, B.W. and Tulloh, N.M. 1982. Growth patterns in sheep: the effects of weight losses on compensatory growth and feed intake in Corriedale sheep. J. Agric. Sci. (Camb) 99:641-649.

Drennan, M.J. and Harte, F.J. 1979. Compensatory growth in cattle. 2.Influence of growth rate in the calf stage (birth to 8 months) and during the first winter (8 to 13 months) on the subsequent performance and carcass composition. Ir. J. Agric. Res. 18:145-156.

Drouillard, J.S., Ferrell, C.L., Klopfenstein, T.J. and Britton, R.A. 1991. Compensatory growth following metabolizable protein or energy restrictions on beef steers. J.Anim. Sci. 69:811-818.

Dunn, T.C. and Kaltenbach, C.C. 1980. Nutrition and the postpartum interval of the ewe, sow, and cow. J. Anim. Sci. (Suppl. 2) pp 29-39.

Everitt, G.C. and Jury, K.E. 1977. Growth of cattle in relation to nutrition in early life. N. Z. J. Agric. Res. 20:129-137.

Fox, D. G., Johnson, R.R., Preston, R.L., Dockerty, T.R. and Klosterman, E.W. 1972. Protein and energy utilization during compensatory growth in beef cattle. J. Anim. Sci. 34:310-318.

Hight, G.K. 1966. The effects of undernutrition in late pregnancy on beef cattle production. N. Z. J. Agric. 9:479-485.

Koonce, K.L. and Dillard E.H. 1967. Some environmental effects on birth weight and gestation length in Hereford cattle. J. Anim. Sci. (Abst) 26:205.

Laster, D.B., Glimp, H.A. and Gregory, K.E. 1973. Effects of early weaning on post-partum reproduction of cows. J. Anim. Sci. 36:734-740.

Ledger, H.P. and Sayers, A.R. 1977. The utilization of dietary energy by steers during periods of restricted food intake and subsequent realimentation. 1. The effect of time on the maintenance requirements of steers held at constant live weights. J. Agric. Sci. (Camb) 88:11-26.

Lowman, B.G., Scott, N. and Sommerville, S. 1973. Condition scoring of cattle. East of Scotland College of Agriculture, Bulletin. No. 6.

Morgan, J.H.L. 1972. Effect of plane of nutrition in early life on subsequent liveweight gain, carcass and muscle characteristics and eating quality of meat in cattle. J. Agric. Sci. (Camb) 78:417-423.

NRC 1984. Nutrient Requirement of Beef Cattle. (6th Rev. Edition) National Academy Press. Washington, D.C.

Osoro, K. and Wright, I.A. 1991. A note on the post-weaning performance of autumn-born suckled calves. Anim. Prod. 52:551-553.

Park, C.S., Erickson, G.M., Choi, Y.J. and Marx, G.D. 1987. Effects of compensatory growth on regulation of growth and lactation: Response of dairy heifers to a stair-step growth pattern. J. Anim. Sci.

64:1751-1758.

Prior, R.L. and Laster, D.B. 1979. Development of bovine fetus. J. Anim. Sci. 48:1546-1553.

Richards, M.W., Spitzer, J.C. and Warner, M.B. 1986. Effects of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J. Anim. Sci. 62:300-306.

SAS 1989. SAS/STAT User's Guide. Version 6, 4th edition, Vol. 2, Cary, N.C. SAS Institute Inc., 1989. pp 846.

Saubidet, C.L. and Verde, L.S. 1976. Relationship between liveweight, age and dry-matter intake for beef cattle after different levels 6 food restriction. Anim. Prod. 22:61-69.

Steel, R.G.D and Torrie, J.H. 1980. Principles and procedure of statistics. McGraw Hill, New York NY.

Stuedemann, J.A., Guenther, J.J., Ewing, S.A. Morrison, R.D., and Odell, G.V. 1968. Effect of nutritional level imposed from birth to eight months of age on subsequent growth and development patterns of full-fed beef calves. J. Anim. Sci. 27:234-241.

Thomson, E.F., Bickel, H. and Schuch, A. 1982. Growth performance and metabolic changes in lambs and steers after mild nutritional restriction. J. Agric. Sci. (Camb) 98:183-194.

Tudor, G.D. 1972. The effect of pre- and post-natal nutrition on the growth of beef cattle. 1. The effect of nutrition and parity of the dam on calf birth weight. Aust. J. Agric. Res. 23:389-395.

Tudor, G.D. and O'Rourke, P.K. 1980. The effect of pre- and post-natal nutrition on the growth of beef cattle. II.The effect of severe restriction in early post-natal life on growth and feed efficiency during recovery. Aust. J. Agric. Res. 31:179-189.

Tudor, G.D., Utting, D.W. and O'Rourke P.K. 1980. The effect of pre- and post-natal nutrition on the growth of beef cattle. III.The effect of severe restriction in early post-natal life on the development of the body components and chemical composition. Aust. J. Agric. Res. 31:191-204.

Whittier, J.C., Clanton, D.C. and Deutscher G.H. 1988. Effect of varying weight gain during the last trimester of gestation on productivity of beef heifers. Anim. Prod. 47:53-57.

Widdowson, E.M. and Lister, D. 1991. Nutritional control of growth. In: Growth regulation in farm animals. Advances in Meat Research Vol. 7 Eds. A.M. Pearson and T.R. Dutson Elsevier Appl. Sci. London and New York.

Wright, I.A. 1985. Compensatory growth in beef cattle. In: Emerging technology and management for ruminants. pp 195-201. Livestock seminars, International Stockmen's school. F. H. Baker and M.E. Miller (Eds). Winrock International.

Wright, I.A., Russel, A.J.F. and Hunter, E.A. 1986. The effect of winter food level on compensatory growth of weaned, suckled calves grazed at two sward heights. Anim. Prod. 43:211-223.

Wright, I.A., Russel, A.J.F. and Hunter, E.A. 1987. The effects of genotype and post-weaning nutrition on compensatory growth in cattle reared as singles or twins. Anim. Prod. 45:423-432.

Wright, I.A. and Russel, A.J.F. 1991. Changes in the body composition of beef cattle during compensatory growth. Anim. Prod. 52:105-113.

Yambayamba E. and Price, M.A. 1991. Growth performance and carcass composition in beef heifers undergoing catch-up (compensatory) growth. Can. J. Anim. Sci. 71:1021-1029.

Yaremcio, B. 1993. Pre-calving nutrition affects colostrum quality. In: Agric News. Alberta Agriculture, Print Media Branch pp 1.

3. EFFECT OF PRENATAL AND EARLY POSTNATAL FEED RESTRICTION ON PUBERTY, FERTILITY AND REPRODUCTIVE PERFORMANCE OF BEEF HEIFERS.

3.1 INTRODUCTION

The potential for increased lifetime productivity, makes age at first estrus of replacement heifers important under current production systems where heifers are bred at 15 months of age in order to calve as two year olds (Chapman et al. 1978 and DeRouen et al. 1989). Age at first ovulatory estrus in the bovine is markedly influenced by breed and level of nutrition (Laster et al. 1972; Morgan 1981 and Fajersson et al. 1991). Joubert (1963) explained weight as an important factor affecting puberty, thus any delay in reaching a certain target body weight through feed restriction will increase the age at puberty. It has long been recognized that restricted feeding of heifers delays the onset of first estrus (Short and Bellows 1971; Fleck et al. 1980 and Newman and Deland 1991).

Ferrell (1982) observed that heifers fed to achieve 0.4 kg/day during a postweaning period of 184 days tended to be older (387 days) and weighed less (301 kg) at first estrus than those fed to gain at a high rate of 0.8 g/day (372 days and 322 kg for age and weight at first estrus, respectively). Wiltbank et al. (1969) and Dufour (1975) reported that age and weight at puberty were highly associated with postweaning rate of gain. The former observed that heifers reached puberty at 483 and 600 days of age and 279 and 257 kg when postweaning rate of gain was 0.33 and 0.27 kg/day, respectively.

Ferrell (1982) found that pregnancy rates were not affected by postweaning rate of gain (93.3% vs 93.8% for high and low feeding levels, respectively). Similarly, Joubert (1955) observed that the number of services required per conception for heifers on a low nutritional plane (1.43) was similar to that of heifers on a high nutritional plane (1.57). Joubert (1963) commented that once estrus is restored upon favourable nutritional conditions, there should be little difficulty in getting the heifer in calf. Undernutrition has also been reported to result in high incidence of underdeveloped udders and poor weaning weights (Dufour 1975 and Quirke 1979). On the other hand overfeeding was found to result in weak estrus signs, lower conception rates, high mortality rates and decreased milk production (Arnett et al. 1971 and Ferrell et al. 1976; Fleck et al. 1980). Sorensen et al. (1959) showed evidence that the mammary glands of Holstein heifers fed to gain at a high level were consistently infiltrated with fat. Thus improper nutrition during the growing period may have both short and long term effects on heifer productivity.

Much of the research referred to above has involved postweaning nutritional effects on heifers, but few have studied the effect of feed restriction in early life (preweaning) on the subsequent reproductive performance of heifers once a normal diet has been restored. Allden (1970) in his review on long term effects of nutritional deprivation noted that there was no detrimental effect on reproduction performance of cattle once a normal diet has been restored. Makarechian et al. (1988) observed that the reproductive performance of early weaned heifer calves were not different from late weaned calves in terms of percent calf crop, incidence of calving difficulty, birth weights, birth dates and weaning weights of calves. Fleck et al. (1980) on the other hand reported lower birth and weaning weight of calves and a higher incidence of calving difficulty for heifers with low gains during their first winter. The severity of the early feed restriction would influence results. More information is needed about feed restriction in early life on reproduction of heifers. The objective of this study was therefore to determine the short and long term effects of pre and early postnatal feed restriction on puberty, fertility and reproductive performance of heifers.

3.2 MATERIALS AND METHODS

3.2.1 Animals and feeding

Fifty-four beef synthetic (SY) weaned heifers from Experiment 1 were used to study the effects of pre and early postnatal feed restriction on puberty, fertility and subsequent reproductive performance. The heifers had a previous history of being subjected to different weaning treatment during their first winter (see chapter 2.2.1 for description). The distribution, weight and age of heifers used from the five feed restriction treatments imposed during preweaning in Experiment 1 at the end of the period (October 1990), were as shown in Table 3.1.

Table 3.1 Distribution of heifers by preweaning nutritional groups.

	Treatment groups[1]				
Item	3MR-L	5MR-E	UNR-L	UNR-E	UNR-EP
No. of heifers	12	11	11	10	10
Liveweight(kg)	222.8±5.8	183.3±6.0	218.0±6.0	182.6±6.3	181.0±6.3
Age (days)	194.9±3.9	193.0±4.1	190.0±4.1	184.5±4.3	195.6±4.3

[1] 3MR-L = late weaned heifers of three months restricted dams; 5MR-E = early weaned heifers of five months restricted dams; UNR-L = late weaned heifers of unrestricted dams; UNR-E = early weaned heifers of unrestricted dams; UNR-EP = early weaned heifers to pasture of unrestricted dams.

All heifers received the same winter diet of 2.3 kg rolled barley + 2.3 kg alfalfa/brome hay per head/day from October 1990 in the feedlot during the recovery period (see chapter 2.2.2). Heifers grazed alfalfa (Medicago sativa); brome (Bromus spp.) and fescue (Festuca spp.) pasture from May 1991. Liveweights were recorded monthly till heifers were bred in June 1991.

3.2.2 Blood sampling

From January 17, the heifers were bled twice weekly until June 3 1991, to determine cyclicity and age at first estrus through plasma progesterone (P_4) concentrations. Blood samples from each heifer were taken by jugular venipuncture and collected into 10 ml heparinized evacuated glass tubes between 9 am and 11 am on every sampling day. The samples were centrifugated at 2500 rpm for 15 min at 4°C. Plasma samples were portioned into two sterile plastic vials and stored at -20°C for later radioimmunoassay. During this period, heifers were also checked for cycling by rectal palpation periodically by a veterinarian. Observations included condition of the vulva, (swollenness and redness of area) nature of discharge, (thickness of mucous) as well as size and location of follicles and corpus luteum.

On June 12, 1991, heifers were weighed and put back on pasture for breeding. They were multiple sired (20 heifers to 1 bull) in a 58-day breeding season from June 18 to August 15 1991. Pregnancy was verified from plasma P_4 concentration by sampling blood twice a week for a month (September 17 to October 11, 1991) after the end of the breeding season. Blood samples were collected by jugular venipuncture into 10 ml heparinized evacuated glass tubes and plasma collected as described previously. Pregnancy was further checked by rectally palpating all heifers on October 11, 1991. All non pregnant heifers were removed from the experiment. During palpation one pregnant heifer from UNR-E had its rectum torn and was also removed from the experiment.

3.2.3 Hormone assays

Plasma samples were assayed for progesterone by a double antibody radioimmunoassay (RIA) as described by Rawlings et al. (1980). Plasma (200, 100 and 50µl in duplicate) was extracted with 4 ml of petroleum ether for 5 min, and the extracts assayed using an anti-serum raised in rabbit against 4-pregnen-11x-ol-3,20-dione hemisuccinate, and goat anti-rabbit gamma-globulin as the second antibody.

Progesterone samples were analyzed in 10 assays using the duplicate extracts of 200µl,100µl and 50µl of plasma. Each assay contained plasma of heifers from all five treatment groups. Within assays, extraction efficiency as determined by recovery of [1,2-'H(N)] -progesterone was used to correct the progesterone concentration determined for each sample. The mean recovery of titrated progesterone across all assays was 72±10.1% (mean±s.e.m, n=10). Standard curves ranged from 0.003313 to 1.6 ng/tube. Sensitivity of the assays (defined as mean of Bmaximum dose - (2 x SD of Bmaximum dose)/mean of Bmaximum dose) was 91.3±4.1% (mean±s.e.m, n=10) equivalent to 0.97 ng/tube. The intra-and inter-assay coefficients of variation were 5.76% and 10.54% respectively.

3.2.4 Age at first estrus

Plots of plasma P_4 conc. (ng/ml) over time were used to estimate age at first estrus. The age at first estrus was defined as the first day that plasma P_4 concentration indicated the presence of a corpus luteum that was functional for the duration of a normal estrous cycle of 20-21 days. The criterion for identification of the first estrus or ovulation was that plasma P_4 concentrations had to be above 1 ng/ml and be elevated ≥4 ng/ml for at least seven days.

This criterion thus eliminated short luteal phases of P_4 concentration from the calculation of age at first estrus, which frequently preceded the first normal estrus. Twenty-one heifers had not begun cycling when sampling ended, but their date of first estrus could be estimated from their calving dates, if the last date of sampling to predicted conception dates (taking a mean gestation length of 285 days) were within a cycle of 19 to 21 days then the last date of sampling was taken as the date of first estrus. eg. The last date of sampling was 154 and a 5MR-E heifer calved on day 457, its estimated conception date is (457 -285)= 172, since the last date of sampling to the latter date is 18 days (within a normal cycle) the day 154 was taken as date of estrus. Age at first estrus could be estimated by this method for four heifers (2 from 5MR-E, 1 from UNR-E and 1 from UNR-EP groups). A shift of the sampling period later would have enabled first estrus to be determined in a greater proportion of the heifers.

3.2.5 Fertility

The criterion used for pregnancy determinations over the sampling period was that P_4 concentration should be ≥4 ng/ml and elevated throughout the sampling period. Heifers with P_4 concentration lower than 1 ng/ml at any stage in the sampling period were considered non-pregnant, and these were later checked by rectal palpation. Liveweight at first estrus was estimated by interpolation between the nearest weights taken before a: after the first estrus dates (Short and Bellow 1971, Ferrell 1982).

3.2.6 Measurement of reproductive performance

Liveweights and body condition scores according to the East of Scotland College of Agriculture condition scoring system (Lowman et al. 1973) on a scale of 0 (emaciated) to 5 (grossly fat) were taken periodically throughout gestation. Abortions were recorded when known. At the onset of calving in March 1992, heifers were moved to a new calving area. Within 24 hr after birth, calves were identified and weighed. Mortality of calves recorded included stillbirth and deaths within 24 hr after birth. Heifers were weighed, body condition scored in this period, and their udders were scored (1 = small ideal teats, 2 = ideal teats, 3 =

large teat, 4 = very large (bottle) teats, 5 = pendulous udder, 6 = 1 or 2 blind teats, 7 = mastitis). Heifers were scored for ease of calving on a scale of 0 to 5 (0 = no assistance, 1 = slight assistance, 2 = a puller used easily, 3 = a puller used with difficulty, 4 = veterinarian required, and 5 = caesarean birth). Liveweights and condition scores of heifers and their calves were recorded periodically until weaning in October 1992, when the experiment ended.

3.2.7 Analysis of data

Liveweights, gains, body condition scores (prior to calving) age and weight at first estrus were subjected to least squares analysis of variance using the General Linear Model (Type III) procedure (SAS 1989) to compare the effects of preweaned feed restriction on first estrus of heifers in a model: $Y_{ik} = \mu + T_i + E_j(_i)$; where Y_{ij} = trait under consideration; μ = overall mean; T_i = treatment groups with (i = 1,..5) and $E_j(_i)$ = the error term. Pre- and postweaning daily gains (prior breeding) were related to age and weight at first estrus by covariance and correlations computed within treatments using GLM in SAS. Calving and weaning data were analyzed by least squares analyses of variance using GLM in SAS to find the effects of early feed restriction on reproductive performance in a model: $Y_{ijk} = \mu + T_i + S_j + TS_{ij} + E_k(_{ij})$ where Y_{ijk} = trait under consideration; μ = overall mean; T_i = treatment with (i = 1...5); S_j = sex of calf with (j = 1,2); and $E_k(_{ij})$ = error term. Differences among means were tested for significance by paired t-test comparisons for unequal treatment groups (Steel and Torrie 1980).

Chi-square tests were used to test for significance of treatment on percentage of heifers cycling, pregnant, calf mortality and assisted births (Steel and Torrie 1980). Significance was assessed at the 0.05 level.

3.3 RESULTS

3.3.1 First estrus

Feed restriction during preweaning affected the age at first estrus (Table 3.2). The 5MR-E and UNR-EP heifers were older (P<0.05) at puberty. From the results only 10%, 20% and 40% of 5MR-E, UNR-E and UNR-EP heifers, respectively cycled before June 3, (the end of blood sampling), thus a greater proportion of the heifers in these groups came into puberty at a later age. On the other hand a greater proportion (P<0.05) of heifers which were not restricted in early postnatal life (3MR-L and UNR-L) had cycled before June 3, 1991. Differences in age at first estrus among the groups would therefore have been greater if age at first estrus in all heifers could be determined with an extended sampling period.

On the other hand weight at puberty was not significantly different (P>0.05) among the feed treatment groups. However, late weaned heifers (3MR-L and UNR-L) were slightly heavier than 5MR-E and UNR-EP heifers at first estrus. Heifers whose dams were unrestricted during the last trimester of pregnancy and weaned early into the feedlot (UNR-E) were of similar weights (294.3 kg) to UNR-L heifers of unrestricted dams (290.9 kg). The average number cycles of heifers that had cycled before June 3, were independent of previous dietary treatment.

Age at first estrus was not affected (P>0.05) by pre and postweaning daily gains. Preweaning daily gains influenced (P<0.05) weight at first estrus (r = 0.54). A strong correlation of 0.70 was found between daily gains from weaning to breeding and weight at first estrus (P<0.05).

3.3.2 Fertility

There were no significant differences in pregnancy rates (P>0.05) among the treatment groups (Table 3.2). Two 3MR-L and one UNR-E heifers that had cycled before June 3, were not found to be pregnant on October 11.

3.3.3 Liveweight changes in heifers (breeding to calving)

By breeding (June 12), 5MR-E, UNR-E and UNR-EP heifers weighed 49.8, 24.3 and 28.1 kg, respectively less ($P<0.05$) than UNR-L heifers (Table 3.3). Liveweights of heifers which were early weaned into the feedlot (UNR-E) were not significantly different ($P>0.05$) from 3MR-L and UNR-L heifers by September 17. On October 11, 5MR-E and UNR-EP still weighed less ($P<0.05$) than the other treatment groups, however there were no significant differences ($P>0.05$) in body condition scores among the treatment groups.

Liveweights and body condition score just prior to calving (Feb 26) were not significantly different ($P<0.05$) among the feeding groups. Thus 5MR-E and UNR-EP had recovered their weight for age by about 23 months of age. This was achieved by gaining weights at similar rates to the unrestricted UNR-L heifers, but sustaining the gain for a longer period.

Table 3.2 Effects of pre and early postnatal feed restriction on cyclicity, first estrus and fertility of beef heifers.

Trait	Treatment groups[1]					Prob.
	3MR-L	5MR-E	UNR-L	UNR-E	UNR-EP	
No. of heifers	12	11	11	10	10	
Oct. 30 wt.(kg)	222.8[a] ±5.8	183.3[b] ±6.0	218.0[a] ±6.0	182.6[b] ±6.3	181.0[b] ±6.3	0.001
Number cycling before June 3[2]	9 (75%)	1 (9.1%)	7 (63.6%)	2 (20%)	4 (40%)	0.006
Number of cycles before June 3	2.8 ±0.36	2.0 ±1.07	1.7 ±0.40	3.5 ±0.75	1.5 ±0.53	0.11
Age at first[3] estrus (days)	(n=9) 388.8[a] ±3.9	(n=3) 426.3[c] ±6.5	(n=7) 397.0[ab] ±4.2	(n=3) 412.7[bc] ±6.5	(n=5) 407.8[b] ±5.0	0.005
Weight at first estrus (kg)	(n=9) 279.6 ±8.2	(n=3) 269.1 ±13.4	(n=7) 290.9 ±8.7	(n=3) 294.3 ±13.4	(n=5) 269.1 ±10.3	0.38
Breeding weight (kg)	302.8[ab] ±7.7	254.6[d] ±8.5	304.4[a] ±8.1	280.1[bc] ±8.5	276.3[cd] ±8.5	0.002
No. pregnant in October	9 (75%)	9 (81.8%)	11 (100%)	8 (80%)	8 (80%)	0.56

[1]3MR-L = late-weaned heifers of three months restricted dams; 5MR-E = early weaned heifers of five months restricted dams; UNR-L = late-weaned heifers of unrestricted dams; UNR-E = early-weaned heifers of unrestricted dams; UNR-EP = early-weaned heifers to pasture of unrestricted dams.
[2]End of blood sampling.
[3]Estimated if not determined prior June 3.
[abcd]Means within rows with different superscripts are significantly different at $P<0.05$.

Table 3.3 Least squares means and standard errors of liveweights and body condition score of heifers from breeding to calving.

Trait	Treatment groups[1]					
	3MR-L	5MR-E	UNR-L	UNR-E	UNR-EP	Prob.
No. of heifers	12	11	11	10	10	
Liveweight (kg)						
June 12 '91[2]	302.5^{ab} ±7.7	254.6^{d} ±8.1	304.4^{a} ±8.1	280.1^{bc} ±8.5	276.3^{cd} ±8.5	0.003
Sept 17 '91	380.[illegible] ±8.5	336.0^{b} ±9.0	379.2^{a} ±9.0	357.0^{ab} ±9.4	346.8^{b} ±9.4	0.002
Oct. 11 '91	400.5^{a} ±10.6	349.7^{b} ±11.0	397.4^{a} ±11.0	372.1^{ab} ±12.2	368.0^{b} ±11.6	0.009
No. of heifers	9	9	11	7	8	
Feb. 26 '92	413.8 ±11.2	408.1 ±11.0	438.1 ±9.6	442.2 ±13.2	405.6 ±12.1	0.29
ADG (kg/day)[3]	0.47 ±0.02	0.55 ±0.02	0.51 ±0.02	0.53 ±0.03	0.48 ±0.[illegible]	0.17
Body condition score[4]						
Oct. 11 '91	2.7 ±0.1	2.5 ±0.1	2.7 ±0.1	2.4 ±0.1	[illegible] ±0.1	0.34
No. of heifers	9	9	11	7	8	
Feb. 26 '92	2.9 ±0.1	2.9 ±0.1	2.9 ±0.1	3.1 ±0.1	3.0 ±0.1	0.62

[1]3MR = late-weaned heifers of three months restricted dams; 5MR-E = early-weaned heifers of five months restricted dams; UNR-L = late-weaned heifers of unrestricted dams UNR-E = early-weaned heifers of unrestricted dams; UNR-EP = early-weaned heifers to pasture of unrestricted dams.
[2]Weight at the beginning of the breeding period.
[3]June 12 1991 to Feb 26 1992.
[abcd]Means within rows with different superscripts are significantly different at $P<0.05$.
[4]Scale 0 (emaciated) to 5 (grossly fat)

3.3.4 Calving performance

One heifer from UNR-EP aborted her calf during the winter. Birth weight of calves were not affected (P>0.05) by previous nutrition of heifers (Table 3.4) and male calves (33.2 kg) were not significantly heavier than (P>0.05) female calves (33.0 kg). Calving dates among treatment groups and sex of calves (males = 101.2; females = 99.5) were not significantly different (P>0.05). A greater percentage (71.7%) of UNR-EP heifers calved in the first 21 days of the calving season compared to 55.5, 44.4, 54.5 and 57.1% of 3MR-L, 5MR-E, UNR-L and UNR-E respectively.

Liveweights, body condition and udder scores of heifers within 24 hr after calving were not significantly affected (P>0.05) by feeding treatment. There was a significant interaction (P<0.05) between feeding treatment and sex of calf for heifers weight at calving (Table 3.5). The number of heifers requiring assistance at birth was marginally influenced (P=0.08) by the preweaning nutritional treatment of the heifers. About half of 5MR-E heifers required assistance, and a long delivery of one heifer in the group resulted in the death of the calf.

Table 3.4 Effects of pre and early postnatal feed restriction on calving performance of heifers.

	Treatment groups[1]					
Trait	3MR-L	5MR-E	UNR-L	UNR-E	UNR-EP	Prob.
No. of heifers	9	9	11	7	8	
Number calving	9 (100%)	9 (100%)	11 (100%	7 (100%)	7 (87.5%)	0.33
Calving date[2]	100.3 ±3.8	103.0 ±3.8	100.3 ±3.3	99.6 ±4.5	98.3 ±4.0	0.94
Calf birth weight (kg)	33.3 ±1.4	33.3 ±1.4	34.8 ±1.2	32.3 ±1.6	31.8 ±1.5	0.57
Calving weight[3] of heifers (kg)	389.0 ±13.6	379.4 ±13.6	411.3 ±11.6	409.3 ±16.0	377.8 ±14.6	0.25
Calving condition[3] score of heifers	2.3 ±0.1	2.2 ±0.1	2.3 ±0.1	2.3 ±0.2	2.1 ±0.1	0.86
Udder score	1.5 ±0.3	1.9 ±0.3	2.0 ±0.3	2.0 ±0.3	1.5 ±0.3	0.53
Calf mortality	0 (0.0%)	1 (11.1%)	1 (9.1%)	0 (0.0%)	0 (0.0%)	0.65
Assisted births	0 (0.0%)	4 (44.4%)	2 (18.2%)	0 (0.0%)	1 (14.3%)	0.08

[1]3MR-L = late-weaned heifers of three months restricted dams; 5MR-E = early-weaned of five months restricted dams; UNR-L = late-weaned heifers of unrestricted dams; UNR-E = early-weaned heifers of unrestricted dams; UNR-EP = early-weaned heifers to pasture of unrestricted dams.
[2]Day of the year (day 1 = January 1).
[3]Calving weight and condition score (0 = emaciated to 5 grossly fat) of heifers 24 hr post calving

Table 3.5 Treatment group x sex of calf interaction means for heifers weight (kg) at calving.

	Treatment groups[1]				
Sex of calf	3MR-L	5MR-E	UNR-L	UNR-E	UNR-EP
Male	398.7±22.1	379.0±19.2	435.0±17.1	358.0±17.1	369.5±19.2
Female	379.3±15.6	379.8±19.2	387.5±15.7	460.5±27.1	386.0±22.1

[1]3MR-L = late-weaned heifers of three months restricted dams; 5MR-E = early-weaned heifers of five months restricted dams; UNR-L = late weaned heifers of unrestricted dams; UNR-E = early-weaned heifers of unrestricted dams; UNR-EP = early-weaned heifers to pasture of unrestricted dams.

3.3.5. Weaning performance

Heifers liveweights and body condition scores were not significantly different (P<0.05) at weaning, though 5MR-E and UNR-EP heifers were slightly lighter (Table 3.6). Successful pregnancy rates of heifers (89, 100, 100, 100 and 100% for 3MR-L, 5MR-E, UNR-L, UNR-E and UNR-EP, respectively) to pregnancy testing in October 1992, were not influenced (P>0.05) by feeding treatments.

There was no effect (P>0.05) of heifer's preweaning nutrition on liveweight of calves and percentage of calf crop weaned. Daily gains of calves from birth to weaning were not significantly different (P>0.05) among treatment group of heifers. Male calves did not weigh (208.3 kg) significantly different (P>0.05) from females (201.9 kg) at weaning. Although males grew (0.92 kg/day) faster than females (0.88 kg/day) from birth to weaning, the differences were not significant (P>0.05).

Table 3.5 Effects of pre and early postnatal feed restriction on heifers and their calves at weaning in October 1992.

	Treatment groups[1]					
Trait	3MR-L	5MR-E	UNR-L	UNR-[illegible]	[illegible] EP	Prob.
No. of heifers at breeding	12	11	11	[illegible]	10	
No. of heifers at weaning	9	8	8	6	6	
Wt. of heifers at weaning (kg)	447.0 ±12.9	430.8 ±12.9	461.0 ±12.9	475.4 ±15.8	422.3 ±14.9	0.096
Body condition score	3.0 ±0.15	3.1 ±0.15	3.1 ±0.15	3.1 ±0.18	2.8 ±0.18	0.81
Calf crop born	9 (75%)	9 (81.8%)	11 (100%)	7 (70%)	7 (70%)	0.39
Calf crop wea[illegible]	[illegible])	8 (72.7%)	10 (90.9%)	7 (70%)	7 (70%)	0.77
Age of calves at weaning(d)	1[illegible].8 ±3.8	188.0 ±3.8	189.6 ±3.4	191.4 ±4.5	192.7 ±4.1	0.93
ADG (kg/d)[2]	0.89 ±0.04	0.88 ±0.04	0.90 ±0.03	0.91 ±0.04	0.94 ±0.04	0.84
Calves weaning weight (kg)	202.5 ±8.3	199.0 ±8.3	205.0 ±7.4	206.5 ±9.7	212.4 ±8.9	0.85

[1]3MR-L = late-weaned heifers of three months restricted dams; 5MR-E = early-weaned heifers of five months restricted dams; UNR-L = late-weaned heifers of unrestricted dams UNR-E = early-weaned heifers of unrestricted dams; UNR-EP = early-weaned heifers to pasture of unrestricted dams.
[2]Birth to weaning.

3.4 DISCUSSION

3.4.1 First estrus

As could be expected, the preweaning feed restriction of heifers delayed age at first estrus and reduced the number of heifers cycling by the end of the sampling period (June 3). Heifers which were early weaned (5MR-E, UNR-E, and UNR-EP) were 29, 14 and 19 days, respectively, older than UNR-L calves at first estrus. This agrees with the general findings that feed restriction delays the onset of sexual maturity (Topps 1977; Morrison et al. 1989; Newman and Deland 1991). The early weaned heifers would have been much more older at first estrus if age at first estrus could be estimated for all the heifers, since a greater proportion of heifers in these groups cycled after the end of the sampling period.

Gordon (1983) indicated that first estrus was chiefly a function of body weight, but will vary with breed, nutrition and season of birth. As at the start of the experiment in October, the early weaned heifers had not recovered all their liveweight-for-age, i.e they were still lighter and had not caught-up to their late weaned counterpart, it would be expected that they reach a certain target body weight before attaining first estrus. This may explain the delay in age at first estrus and a smaller proportion were in estrus by June 3 (about 14 months of age).

On the other hand, irrespective of the different preweaning feed restrictions, heifers manifested first estrus at about the same average body weight, with some indication however of a slightly lower weight for 5MR-E and UNR-EP heifers. Similar results were reported by Penzhorn (1974). Joubert (1963) indicated that first estrus will occur when animals have reached the degree of physiological development (expressed as liveweight) which at that stage is typical of their kind. Other workers have reported higher body weight at first estrus with higher growth rates (Arije and Wiltbank 1971; Short and Bellows 1971 and Ferrell 1882) whereas Dufour (1975); Fajersson et al. (1991) reported a lower body weight at first estrus on a higher nutritional plane of heifers. This discrepancy may in part be due to the various techniques and criteria employed by different workers in determining first estrus, the breed, nutrition and rate of maturing of the heifers used, also silent or unobserved estrus may come into the picture (Wiltbank et al. 1969 and Gordon 1983).

The strong correlation between pre and postweaning daily gains and weight at first estrus (r = 0.54 and r = 0.70) indicates that heifers (late weaned) gaining at faster rates (see chapter 3.3.3) during pre and early postweaning tended to be heavier at puberty. Similarily, Arije and Wiltbank (1971) observed that heifers which grew faster preweaning tended to reach puberty at an earlier age and at a heavier weight (r = -.36 and r= 0.32 respectively), while heifers that grew rapidly after weaning to puberty tended to be heavier but not necessarily younger at puberty (r= 0.65 and r = 0.63 respectively).

Allden (1970) indicated that once puberty has been reached, estrus cycles occur with equal regularity whether they are growing rapidly or slowly. This may explain the absence of differences in the number of cycles exhibited among the feeding groups prior breeding.

3.4.2 Fertility

Pregnancy rates were not affected by preweaning nutrition even though first estrus was delayed in the heifers that were early weaned (5MR-E, UNR-E and UNR-EP), and a majority of these heifers had not cycled before June 3. Similar observations were also reported by Quirke (1979), Ferrell (1982) and Morrison et al. (1989). This indicates that a majority of the early-weaned heifers cycled and conceived from June to August. The availability of sufficient pasture around this time might have influenced most of the early-weaned heifers to increase daily gains, attain heavier weights to reach puberty rapidly and be bred. The influence of the bull in this season may also be another factor. Joubert (1955) noted that once estrus is restored by favourable conditions, there should be little difficulty in getting the heifer in calf. The fact that not all the heifers of 3MR-L that had cycled before June 3 got pregnant, suggests that some may be over fat, causing difficulty in getting them pregnant (Fleck et al. 1980).

Short and Bellows (1971) and Penzhorn (1974) on the other hand observed that heifers fed to gain at a lower rate had lower pregnancy rates. The former workers explained this as due to an accumulation of fewer heifers being bred; fewer becoming pregnant that were bred and fewer maintaining pregnancies between an August and October palpation.

3.4.3 Liveweight changes in heifers

Liveweights and condition scores of heifers from breeding to calving indicated that UNR-E heifers caught up to the UNR-L heifers by two months after breeding. Thus heifers which were early weaned into the feedlot finally caught up to the unrestricted heifers (UNR-L) by 18 months of age, while 5MR-E and UNR-EP recovered their weight-for age by about 23 months of age even though they had recovered body condition four months earlier. The available feed supply during the summer might have affected the daily gains of the early-weaned heifers to catch-up with their counterparts even though they did not grow significantly faster than the unrestricted counterparts in this period (Hogg 1991). This finding agrees with studies done on feed restriction during preweaning, that the degree of compensation is low in calves restricted during the nursing phase (Berge et al. 1991). Bond et al. (1972); Keane and Drennan (1983) restricted calves at less than seven months and observed they required 14 to 18 months to compensate 70 to 80% of their growth delay. Berge (1991) noted that a compensation growth delay during the nursing period will be obtained at the cost of a long period of recuperation. The recovery of body condition earlier than liveweight in the 5MR-E and UNR-EP may be due to the faster recovery of fat than other tissues. Yambayamba and Price (1991) similarly found that over a longer period of restriction, a higher proportion of fat was recovered in the carcass tissues following refeeding, while muscle showed a greater impetus for growth over a shorter period of restriction.

3.4.4 Calving performance

The absence of any effect of preweaning feeding on the calving traits measured was expected, as all feeding treatment groups had attained similar weights and body condition scores just prior to calving (Table 3.4). Richardson et al. (1978) and Ferrell (1982) had earlier reported similar findings. Makarechian et al. (1988) also found no significant differences in the percent calf crop born, birth weight and birth date of calves born to either early weaned or late weaned heifers. Reid (1960) and Fleck et al. (1980) on the other hand reported a significantly lower birth weight of calves and higher incidence of dystocia in heifers with lowest first winter gains.

The similar calving dates among the treatment groups shows that though the late weaned heifers (3MR-L and UNR-L) achieved first estrus at an earlier age they did not calve earlier than the early-weaned calves (5MR-E, UNR-E and UNR-EP) in fact, a greater percentage of UNR-EP heifers calved in the first 21 days of the calving season. thus calving dates was not influenced by age at first estrus. The reason for the significant feeding treatment x sex of calf for heifers liveweight at calving is unknown.

Preweaning feeding regimem did not influence calf mortality, but tended to affect the incidence of calving difficulty as the effect approached a significant level (P=0.08). Reynolds et al. (1971) and Richardson et al. (1978) reported that early-weaned heifers had a lower perinatal calf mortality compared with the late-weaned heifers. The 45% assisted births occurring in the 5MR-E heifers may be partially due to pelvic incompatibility; these heifers weighed about 40 kg less than the UNR-L heifers, but had comparable birth weight of calves as the latter, and hence the dystocia. On the other hand, Makarechian et al. (1988) reported no significant differences in the incidence of calving difficulty between early-weaned (30%) and late-weaned (29.8%) heifers.

3.4.5 Weaning performance

The successful rebreeding performance of the heifers by October 1992, indicates that the preweaning nutritional regime had no detrimental effects on the reproductive efficiency of the heifers. They were all in similar body condition scores and liveweights at calving, and at weaning of their calves, thus the absence of significant differences in pregnancy rates would be expected. Similarly, Fleck et al. (1980) observed that first winter gains of heifers did not affect first-service conception at rebreeding, however conception dates were earlier for heifers with higher first winter gains.

The number of calves weaned as well as their weaning weights were expected, as there were no significant differences in calving weights, body and udder scores of dams as well as in gains of calves, thus resulting in comparable liveweights at weaning. This indicates that the preweaning feed regimem of the heifers did not affect their ability to successfully wean a calf of acceptable liveweight. The high positive correlation between daily gains and weaning weights of calves showed that weaning weights increased with an increase in daily gains as shown in Table 3.4. These findings agree with those of Richardson et al. (1978); and Makarechian et al. (1988). Fleck et al. (1980) on the other hand reported that first winter gains of heifers that calved initially as two year-olds had a positive effect on calf performance, with those having the highest first winter gains producing heavier calves at weaning, however calf performance did not reflect milk production level which was higher for heifers with low first winter gains.

3.5 CONCLUSION

Feed restriction during preweaning did not result in permanent stunting of heifers, catch-up growth was complete in restricted heifers, however this was achieved at about 23 months of age, and compensatory gains were not exhibited in the recovery. The subsequent reproductive performance of heifers was not impaired by the feed restriction, but would probably delay first estrus if heifers are destined to calve as two year olds. A higher incidence of calving difficulty may also be encountered if the duration of the feed restriction is too long. Calf performance was not affected by feeding regimem of their heifer dams.

3.6 LITERATURE CITED

Allden, W.G. 1970. the effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutr. Abstr. Rev. 40:1167-1184.

Arije, G.F. and Wiltbank, J. N 1971. Age and weight at puberty in Hereford heifers. J. Anim. Sci. 33:401-406.

Arnett, D.W., Holland, G.L. and Totusek, R. 1971. Some effects of obesity in beef females. J. Anim. Sci. 33:1129-1134.

Berge, P. 1991. Long term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci. 28:179-201.

Berge, P., Geay, Y. and Micol, D. 1991. Effects of feeds and growth rate during the fattening period and carcass composition in young dairy breed bulls. Livest. Prod. Sci. 145:249-255.

Bond, J., Hooven, N.W., Warwick, E.J., Hiner, R.L. and Richardson, G.V. 1972. Influence of breed and plane of nutrition on performance of dairy, dual-purpose and beef steers II. from 180 days of age to slaughter. J. Anim. Sci. 34:1046-1053.

Chapman, H.D., Young, J.M., Morrison, E.G. and Edwards, N.C. Jr. 1978. Differences in lifetime productivity of Herefords calving first at 2 and 3 years age. J. Anim. Sci. 46:1159-1164.

DeRouen, S.M., Franke, D.E., Chapman, H.D. and McRae, T.O. 1989. Reproductive performance of beef cattle heifers first exposed to calve at 24, 30, or 36 months. La. Agric. Exp. Stn. Bulletin. 818: pp 3-19.

Dufour, J.J. 1975. Influence of post-weaning growth rate on puberty and ovarian activity in heifers. Can. J. Anim. Sci. 55:93-100.

Fajersson, P. Barradas, H.V. Roman-Ponce H. and Cook, R.M. 1991. The effect of dietary protein on age and weight at puberty in Brown Swiss and Zebu heifers in the tropics. Theriogenology 35:845-855.

Ferrell, C.L., Garrett, W.N. and Hinman N. 1976. Growth, development and composition of udder and gravid uterus of beef heifers during pregnancy. J. Anim. Sci. 42:1477-1483.

Ferrell, C.L. 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. J. Anim. Sci. 55:1272-1283.

Fleck, A.T., Schalles, R.R. and Kiracofe, G.H. 1980. Effect of growth rate through 30 months on reproductive performance of beef heifers. J. Anim. Sci. 51:816-821.

Gordon, I. 1983. In: Controlled Breeding in Farm Animals. Pergamon Press: Oxford, UK. As cited by Newman and Deland 1991.

Hogg, B.W. 1991. Compensatory growth in ruminants. In: Growth regulation in farm animals. Advances in Meat Research Vol.7 Eds. A.M. Pearson and T.R. Dutson Elsevier Appl. Sci. London.

Joubert, D.M. 1955. The influence of high and low nutritional planes on the oestrus cycle and conception rate of heifers. J. Agric. Sci. (Camb) 45:164-172.

Joubert, D.M. 1963. Puberty in female farm animals. Anim. Breed. Abstr. 31:295-306.

Keane, M.G. and Drennan, M.J. 1983. Supplementation of grassfed calves. 3.Effect of concentrate level and protein content, and subsequent performance to slaughter. Ir. J. Agric. Res. 22:113-125.

Laster, D.B., Glimp, H.A. and Gregory, K.E. 1972. Age and weight at puberty and conception in different breeds and breed-crosses of beef heifers. J.Anim. Sci. 34:1031-1035.

Lowman, B.G. Scott, N. and Sommerville, S. 1973. Condition scoring of cattle. East of Scotland College of Agriculture. Bulletin. No. 6.

Makarechian M., Kubisch, H.-M. and Price M.A. 1988. Effects of date of weaning on subsequent performance of beef cows and their female calves. Can. J. Anim. Sci. 68:1035-1040.

Morgan, J.H.L. 1981. A comparison of breeds and their crosses for beef production. II. Growth and puberty of heifers. Aust. J. Agric.

Res. 32:399-406.

Morrison D.G., Bagley, C.P., Feazel, J.I. and Moose G.D. 1989. Influence of first winter roughage source on subsequent growth, reproduction and maternal performance of replacement beef heifers. J. Prod. Agric. 2:74-78.

Newman, S. and Deland, M.P. 1991. Lifetime productivity of crossbred cows 2. Age and weight at first oestrus, calf birth weight assisted calvings, calving interval and reproduction rate. Aust. J. Exp. Agric. 31:293-300.

Penzhorn, E.J. 1974. Wintering levels and reproduction in Afrikaner heifers. S. Afr. J. Anim. Sci. 13:49-57.

Quirke, J.F. 1979. Effects of body weight on the attainment of puberty and reproductive performance of Galway and Fingalway female lambs. Anim. Prod. 28:297-307.

Rawlings, N.C., Weir, L., Todd, B., Manns, J. and Hyland, J.H. 1980. Some endocrine changes associated with the post-partum period of the suckling beef cow. J. Reprod. Fert. 60:301-308.

Reid, J.T. 1960. Effect of energy intake upon reproduction in farm animals. J. Dairy Sci. 43:103 (Suppl.)

Reynolds, W.L., De Rouen, T.M., Meyerhoff, D.C. and Bellows, R.A. 1971. Effects of percentage Zebu breeding, inbreeding and weight at different ages on calving percent of Brangus and Africander-Angus heifers. J. Anim. Sci. 32:500-507.

Richardson, A.T.,. Martin, T.G. and Hunsley, R.E. 1978. Weaning age of Angus calves as a factor influencing calf and cow performance. J. Anim. Sci. 47:6-14.

Short, R.E. and Bellows, R.A. 1971. Relationships among weight gains, age at puberty and reproductive performance in heifers. J. Anim. Sci. 32:127-131.

Sorensen, A.M., Hansel, W., Hough, W.A., Armstrong, D.T., McEntee, K. and Bratton R.W. 1959. Causes and prevention of reproductive failure in dairy cattle. I. Influence of underfeeding and overfeeding on growth and development of Holstein heifers. Cornell Univ. Agr. Exp. Sta. Bull. No. 936 pp 1-51.

Steel, R.G.D. and Torrie, J.H. 1980. Principles and procedures of statistics. McGraw Hill, New York, N.Y.

Topps, J.H. 1977. The relationship between reproduction and undernutrition in beef cattle. World Rev. Anim. Prod. XIII:43-48.

Wiltbank, J.N., Kasson, C.W. and Ingalls, J.E. 1969. Puberty in crossbred and straightbred beef heifers on two levels of feed. J. Anim. Sci. 29:602-606.

Yambayamba, E. and Price, M.A. 1991. Growth performance and carcass composition in beef heifers undergoing catch-up (compensatory) growth. Can. J. Anim. Sci. 71:1021-1029.

4. GENERAL DISCUSSION AND CONCLUSION

Feed restriction of cows during the third trimester of pregnancy in the study, did not reduce the birth weight of the calves. The pregnant cow tended to buffer the adverse effects of undernutrition on her developing fetus by utilizing her body reserves (Topps 1977), resulting in weight loss during pregnancy. The significant interaction effect of age of cows and the feeding treatments may also have influenced the absence of the feed restriction on the birth weight of their calves. Liveweights in restricted cows were regained at faster rates than the unrestricted counterparts upon realimentation, with the 5MR cows gaining faster than 3MR cows. However compensatory gains were not exhibited by calves following feed restriction. The 3MR-L calves grew at similar rates as the unrestricted calves (UNR-L) throughout the experiment, and 5MR-E, UNR-E UNR-EP calves grew slower than the ad libitum fed calves during preweaning and caught up by 12 months for the males and about 23 months for the females. It is concluded that compensation is lower in preweaned calves irrespective of the duration or the severity, than with cattle restricted at a more advanced age (Drouillard et al. 1991, Yambayamba and Price 1991). Recovery of weight-for-age would also be achieved over a long period of recuperation (Wright et al. 1987, Osoro and Wright 1991). Berge (1991) noted that the compensatory growth exhibited by calves following restriction before weaning is low and practically independent on the severity or duration of the restriction. He concluded that the growth delay imposed before weaning is actually the least likely to be subsequently compensated.

The most important effect of underfeeding during pregnancy on the cow is frequently the reduced body weight and consequently low condition postpartum, resulting in its connection with longer postpartum anoestrus and poor fertility (Richards et al. 1986, and Wright et al. 1992). On the contrary, subsequent pregnancy rate and calving performance of the cows in this experiment were not different among the different feeding groups

(Tudor 1972, Park et al. 1987). The restricted-refed 5MR cows calved earlier than the other groups, this was influenced more by the earlier weaning of their calves, than the restriction (Laster et al. 1973). Birth weight of their calves was not influenced by previous nutrition of dams. It is concluded that upon adequate nutrition, cows feed restricted during the third trimester can fully regain their liveweights and subsequently reproduce satisfactorily.

The early-weaned heifer calves (5MR-E, UNR-E) attained first estrus at an older age than the late-weaned heifers, with a greater proportion of the former cycling after breeding, Thus the differences between the two groups in age at first estrus would be greater if the sampling period occurred at a latter stage, so as to determine first estrus for a greater proportion of early-weaned heifers. As a result of the heavier weight of the late-weaned heifers during the growing phase. It would be expected they reach a target body weight for ovarian activity earlier (Joubert 1963) than the early-weaned group of heifers. It is concluded that pre-and early postnatal feed restriction delayed first estrus in heifers destined to calve as two year olds. When the restricted heifers caught up and attained acceptable liveweights during the summer, the pregnancy rates were independent of previous feeding regimen, it would thus be expected that the preweaning restriction would have no effects on the calving performance (Park et al. 1987, Whittier et al. 1988).

Subsequent pregnancy rates, percent calf crop born and weaned were not different among the treatment groups of heifers and the liveweights, gains of their calves were not affected by the previous nutrition of dams (Makarechian et al. 1988). It can be concluded that heifers can tolerate some form of feed restriction during preweaning with no detrimental effects on their rebreeding performance and the performance of their calves provided they are allowed to compensate on adequate feed. This would however be achieved at a longer period, thus delaying the onset of sexual maturity.

4.1 Practical implications

An understanding of the long term effects of feed restriction at different stages of life on the growth and productivity of cattle is of great economic importance in the development of feeding strategies especially during feed shortage (particularly in winter or dry season). With the increasing prices of cereals, purchased conserved fodders and seasonal poor pastures from droughts or floods, producers may be faced with the management decision of not only to feed restrict or not, but more importantly at what age, and to what extent of restriction to allow so as to minimize losses. In view of this study, the cow herd (if bred in the summer) with body condition score of about 3.0 gained in the previous summer can be fed less through the winter, (which mostly coincides with the third trimester of gestation) without reducing their capacity to regain their weight loss and adequately nurse their calves, in the following summer when feed is cheaper. This would not impair their subsequent reproductive performance or the growth of their calves once weight loss is recovered upon adequate feeding. Savings in feed cost can be realized and more cows can be kept when feed is cheaper.

Priority feeding should however be given to the calves if they are below the age of four months since feed restriction below this age is not fully compensated for over a short period, even though it does not result in stunting of the calves. Hogg (1991) indicated that true compensatory growth probably occurs for only a very limited time following realimentation, and its occurrence may be highly unpredictable, given the many factors such as degree of stress, stage of maturity, age, type of feed, animals and pattern of realimentation which can all influence the degree of recovery. The cost of recovery over a longer period should be weighed against the economic benefits of the feed restriction. I therefore concur with Allden (1970) who remarked that; "In pastoral environments where low cost inputs are important to profitability, the decision to accept periods of undernutrition of grazing livestock in preference to sustained productivity must rest on economic analysis rather than biological considerations".

It has generally been accepted that heifers should be fed much to enable them grow rapidly to be bred at 15 months, and in some cases heifers receive more feed as calves than is necessary. From this study, heifers can tolerate some form of feed restriction during early postnatal life, to be bred and calve as two year olds with no permanent detrimental effects on the calving, rebreeding and calf performance. In the presence of adequate feeding, although heifers restricted during early postnatal may delay attaining first estrus (this may not be a problem if calving is destined at 30 or 36 months) their potential to breed and calve successfully is not impaired. The growth of their calves is not restricted as they are able to attain comparable weights with those whose dams were not restricted.

Many factors still need to be investigated if a wide practical application is to given to early feed restriction. The following factors need consideration: 1) The effects of the types of feeds used, a better knowledge will help in understanding between the growth level and the subsequent voluntary feed intake during realimentation. 2) Variations in the weight of the digestive tract content is also an important point. Differences can in fact explain part of the liveweight variations in cattle especially during the major alimentary transitions such as weaning, turnout to pasture and housing in the fall (Lawrence and Pearce 1964; Carstens et al. 1988). 3) Breed differences as well as the economic analysis of savings in feed costs should also be looked at.

By utilizing the knowledge on how to fully exploit catch-up growth, considerable cost saving and benefits can arise from restricting animals at strategic times during their growth and development.

4.2 LITERATURE CITED

Allden, W.G. 1970. The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutr. Abstr. Rev. 40:1167-1184.

Berge, P. 1991. Long term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci. 28:179-201.

Carstens, G.E., Johnson, D.E., Ellenberger, M.A. and Tatum, J.D. 1988. Composition of carcass and non-carcass tissues in beef steers exhibiting normal and compensatory growth. J. Anim. Sci. 66 (Suppl. 1) 491-492.

Drouillard, J.S., Ferrell, C.L., Klopfenstein, T.J. and Britton, R.A. 1991. Compensatory growth following metabolizable protein or energy restrictions on beef steers. J. Anim. Sci. 69:811-818.

Joubert, D.M. 1963. Puberty in female farm animals. Anim. Breed. Abstr. 31:295-306.

Laster, D.B., Glimp, H.A. and Gregory, K.E. 1973. Effects of early weaning on post-partum reproduction of cows. J. Anim. Sci. 36:734-740.

Lawrence, T.L.J. and Pearce, J. 1964. Some effects of wintering yearling beef cattle on different planes of nutrition. 1. Liveweight gain, feed consumption and body measurement changes during the winter period and subsequent grazing period. J. Agric. Sci. (Camb) 63:5-21.

Makarechian, M., Kubisch, H.-M. and Price, M.A. 1988. Effects of date of weaning on subsequent performance of beef cattle and their female calves. Can. J. Anim. Sci. 68:1035-1040.

Osoro, K. and Wright, I.A. 1991. A note on the post-weaning performance of autumn-born suckled calves. Anim. Prod. 52:551-553.

Parks, C.S., Erickson, G.M., Choi, Y.J. and Marx, G.D. 1987. Effect of compensatory growth on regulation of growth and lactation: Response of dairy heifers to a stair-step growth pattern. J. Anim. Sci. 64:1751-1758.

Richards, M.W., Spitzer, J.C. and Warner, M.B. 1986. Effects of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J. Anim. Sci. 62:300-306.

Topps, J.H. 1977. The relationship between reproduction and undernutrition in beef cattle. World Rev. Anim. Prod. XIII:43-48.

Tudor, G.D. 1972. The effect of pre-and post-natal nutrition on the growth of beef cattle. 1. The effect of nutrition and parity of the dam on calf birth weight. Aust. J. Agric. Res. 23:389-395.

Whittier, J.C., Clanton, D.C. and Deutscher G.H. 1988. Effects of varying weight gain during the last trimester of gestation on productivity of beef heifers. Anim. Prod. 47:53-57.

Wright, I.A., Russel, A.J.F. and Hunter, E.A. 1987. The effects of genotype and post-weaning nutrition on compensatory growth in cattle reared as single or twins. Anim. Prod. 45:423-432.

Wright, I.A., Rhind, S.M., Whyte, T.K. and Smith, A.J. 1992. Effects of body condition at calving and feeding level after calving on LH profiles and the duration of the post-partum anoestrus period in beef cows. Anim. Prod. 55:41-46.

Yambayamba, E. and Price, M.A. 1991. Growth performance and carcass composition in beef heifers undergoing catch-up (compensatory) growth. Can. J. Anim. Sci. 71:1021-1029.

APPENDICES

Appendix 1.

Composition of creep feed fed to 5MR-E calves weaned on June 21, 1990.

Period	Ingredient	Amount (kg/head/day)
June 22 and 23	Alfalfa/brome hay	4.54
	Oats	0.45
June 24 - July 11	Alfalfa/brome hay	2.72
	[a]Complete calf ration 1	0.66
	Oats	0.66
July 12- July 28	[a]Complete calf ration 1	1.36
	Oats	2.45
July 29 - October 14	Oats	3.88

[a] All pelleted complete calf ration 1, consisting of ground barley, oats, wheat mill, beet pulp bran, sun cured alfalfa, canola mill, sprouts, corn distillers grain and vitamins and minerals in a premix.

Appendix 2. Health records of cows and calves

Date	Animal No.	Treatment gp.	Cause	Medication
Cows				
May 12, 1990	82770	5MR	Injury (lame)	30cc long penicillin + 30cc ethacilin
Aug 1	85105	UNR	"	15cc long penicillin + 25cc short penicillin
Aug 1	85064	5MR	"	15cc long penicillin + 25cc short penicillin
July 12, 1991	87709	UNR	"	35cc pendure + 35cc ethacilin
July 12,	85039	UNR	"	35cc pendure+ 35cc ethacilin
Sept 13	87127	5MR	"	30cc penicillin + 30cc pendure neat
Oct 7	84729	UNR	"	30cc penicillin+ 30cc pendure neat
Jan 31, 1992	85105	UNR	"	30cc pendure neat
Feb. 4	85105	UNR	"	40cc pendure neat
Calves				
May 12, 1990	90018	UNR-EP	scours	2cc oral + 2 I.M of gentocin + 1000 mls oral electrolite
May 14	90050	UNR-L	"	2cc oral gentocin + 2cc gentocin I.M
May 14	90030	UNR-L	. "	2cc oral gentociin + 2cc gentocin I.M
May 14	90084	5MR-E	"	2cc oral gentocin + 2cc gentocin IM + 10 cc oxymycine
Sept 2	90020	UNR-E	high temp.	15cc oxymycine LP I.V+ 15cc oxyvet I.M
Sept 3	90020	UNR-E	"	15cc oxyvet I.M
Sept 22	90047	UNR-E	Bloat	6oz diactol I.M
Oct 1	90053	UNR-E	high temp	15cc oxymycine LP I.V

Oct 2	90053	UNR-E	"	20cc oxymycine LP I.M
Oct 15	90053	UNR-E	worms	3cc A.D.E + 1/2 Lavasole pill
Nov 13	90130	UNR-E	high temp	25cc oxyvet LA
Nov 13	90110	5MR-E	"	25cc oxymycine LP I.V
Nov 15	90111	3MR-L	"	30cc oxymycine LP I.M
Nov 15	90040	UNR-EP	breathing problems	33cc oxymycine LP I.M
Nov 18	90110	5MR-E	high temp	30cc oxyvet LP I.V
Nov 19	90110	5MR-E	"	30cc oxyvet LP I.M
Nov 20	90110	5MR-E	"	30cc Oxyvet LA I.M
Nov 28	90076	3MR-L	bloat	15oz of dioctal
Dec 10	90106	3MR-L	fracture right humerus and radial paralysis	
Dec 27	90035	UNR-L	swollen jaw	20cc penicillin
Jan 3, 1991	90035	UNR-L	lump on jaw	flushed out + 25 cc penicillin
Jan 19	90124	5MR-E	bloat	hosed off
Jan 20	90133	UNR-L	"	hosed off
Jan 21	90110	5MR-E	infected left eye	injected 1.5 ml deratort
Jan 21	90035	UNR-L	lumpy jaw abscess on left maxilla	lanced and flushed
Feb 4	90133	UNR-L	bloat	hosed off
Feb 11	90133	UNR-L	"	hosed off
Feb 11	90120	UNR-E	"	hosed off
Feb 14	90133	UNR-L	bloat	250 ml dioctol, hosed off
March 22	90133	UNR-L	"	hosed off
June 24	90007	UNR-L	injury (lame)	35cc ethacilin + 35cc pendure neat
July 18	90097	3MR-L	"	25cc pendure + 25cc penicillin
July 18	90032	UNR-EP	"	25cc pendure + 25cc penicillin
July 18	90080	3MR-L	"	25cc pendure + 25cc

				pencillin
July 18	90090	5MR-E	"	25cc pendure + 25 cc penicillin
Oct 11	90130	UNR-E	"	25cc penicillin + 25cc pendure neat
Nov 29	90076	3MR-L	bleeding from prepuce, warts on penis	
June 17 1992	90040	UNR-EP	injury (lame)	50cc penicillin