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THE EFFECTS OF RESTRICTED SUCKLING AND PREPARTUM NUTRITIONAL LEVEL ON REPRODUCTIVE PERFORMANCE OF PRIMIPAROUS CROSSBRED BEEF COWS

A thesis presented in partial fulfilment
of the requirements for the degree
of Master of Agricultural Science
in Animal Science
at Massey University

GUILLERMO de NAVA SILVA

1994

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In memory of my uncle Pardo who used to pose many of the questions addressed in this thesis

ABSTRACT

The objective of this experiment was to study the effect of suckling restriction by fitting nose plates to calves on the reproductive performance of first calving crossbred beef cows managed at two nutritional levels in mid-gestation.

Reproductive activity was recorded in 21 two-year-old Hereford x Friesian and Simmental x Friesian primiparous cows before and after restriction of calf suckling. Cows were allocated two pastures allowances from day 112 to 212 of gestation so that the high nutrition (HN) group gained 0.75 kg/day, whereas the low nutrition (LN) group gained 0.17 kg/day during mid-gestation. Suckling was suppressed for 7 days by fitting nose plates to 46-day-old calves in the restricted suckling (RS) group, whereas the normal suckling (NS) group remained as a control. Ultrasound examinations and blood sampling were carried out at weekly intervals from day 18 and day 25 *post partum*, respectively, to evaluate ovarian activity and serum progesterone concentrations. Calf grazing and suckling activity was observed for 3 h per day on 2, 5 and 3 days before, during and after treatment, respectively.

Dominant follicles (DF) in the ovaries occurred in all cows by day 32 *post partum* and underwent a pattern of growth and atresia before first ovulation. Restricted suckling cows had a mean 18 days shorter interval from calving to conception than NS cows (76.0±5 vs 94.1±6 days, $P<0.05$), whereas genotype and nutritional treatment had no effect on interval to conception. However, the beneficial effect of suckling restriction on reproductive performance was apparent only in those cows fed a high pasture allowance in mid-gestation and consequently calved in better condition than NS cows. Restricted suckling calves spent more time grazing during the period of attachment of nose plates and differences in behaviour remained over a further 5 days after nose plates were removed (62.4±7 vs 38.6±7 minutes spent grazing; $P<0.001$), but were lighter at weaning (146.7 ± 3 vs 162.4 ± 3 kg; $P<0.01$).

Despite the lower calf liveweight at weaning it is concluded that manipulation of suckling through fitting nose plates to calves can be successfully used to shorten the interval from calving to conception in primiparous cows fed higher pastures allowances during mid-gestation and consequently calved in better body condition.

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This thesis is dedicated to the memory of Jose Amalio Silva Gomez, my beloved uncle Pardo who used to pose many of the questions addressed in the objectives of this thesis. At first, his letters encouraged my studies in New Zealand, then it was his soul. Thank you very much tio Pardo...

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LIST OF ABBREVIATIONS

BC	Body condition
CIDR	Controlled internal drug release
CL	Corpus luteum
cm	Centimetre
DF	Dominant follicle
DM	Dry matter
FSH	Follicle-stimulating hormone
GH	Growth hormone
GnRH	Gonadotrophin releasing hormone
h	Hour
ha	Hectare
HN	High nutrition
HxF	Hereford x Friesian
ICC	Interval from calving to conception
IGF1	Insulin-like growth factor 1
IU	International Units
kg	Kilogram
LH	Luteinizing hormone
LN	Low nutrition
LWG	Liveweight gain
ME	Metabolisable energy
MJ	Megajoules
mg	milligram
min	minute
ml	millilitre
mm	millimetre
NEFA	Non esterified fatty acids
ng	nanogram
NS	Normal suckling
PCLI	Interval from calving to occurrence of first corpus luteum
PMSG	Pregnant mare serum gonadotrophin
PPAI	Interval from calving to resumption of ovarian cyclic activity

RS	Restricted suckling
sem	Standard error of the mean
SxF	Simmental x Friesian
vs	Versus
*u*g	microgram

Statistical terms

The following symbols have been used throughout the text to indicate various levels of significance:

SYMBOL	LEVEL OF SIGNIFICANCE
***	$P<0.001$
**	$0.001<P<0.01$
*	$0.01<P<0.05$
†	$0.05<P<0.10$
ns	$0.10<P$

CHAPTER I: INTRODUCTION

Reproductive rates are still low in many beef breeding herds in countries throughout the world including New Zealand despite recent advances in reproductive technology such as production of transgenic animals, *in vitro* fertilization or sexing of sperm (Thatcher *et al*, 1990; McMillan, 1993). These low reproductive rates involve low pregnancy rate, prolonged calving seasons, high calf mortality and low percentage of heifers successfully mated at 15 months. Such poor reproductive performance seriously reduces both the biological and financial efficiency of beef cattle farming systems. At the farm level, this reduces the physical and financial flexibility of the enterprise, while at the national level total meat production is sub-optimal and this reduces potential export earnings (or import savings).

Some of the basic elements of beef cattle breeding herd production under grazing condition are outlined in Figure 1.1. The number and weight of calf weaned per hectare is determined by the amount of feed eaten per hectare and the feed conversion efficiency from pasture to weaned calves. The number of calves weaned per hectare is not only dependent upon the resources of the farm such as its soil, climate and plant populations, but also on management decisions which set farm policy for factors such as stocking rate, feeding priorities between livestock classes and the reproductive management carried out in the farm. These factors have an overriding importance.

The stocking rate selected determines the number of mouths per hectare, and hence the utilization of pasture on the farm (Morley, 1981; Hodgson, 1990). Thus, it has a major impact on the overall level of nutrition provided to the herd. A balance between a high utilization of pasture and animal nutrition must be achieved if returns per hectare are to be maximized (White, 1987).

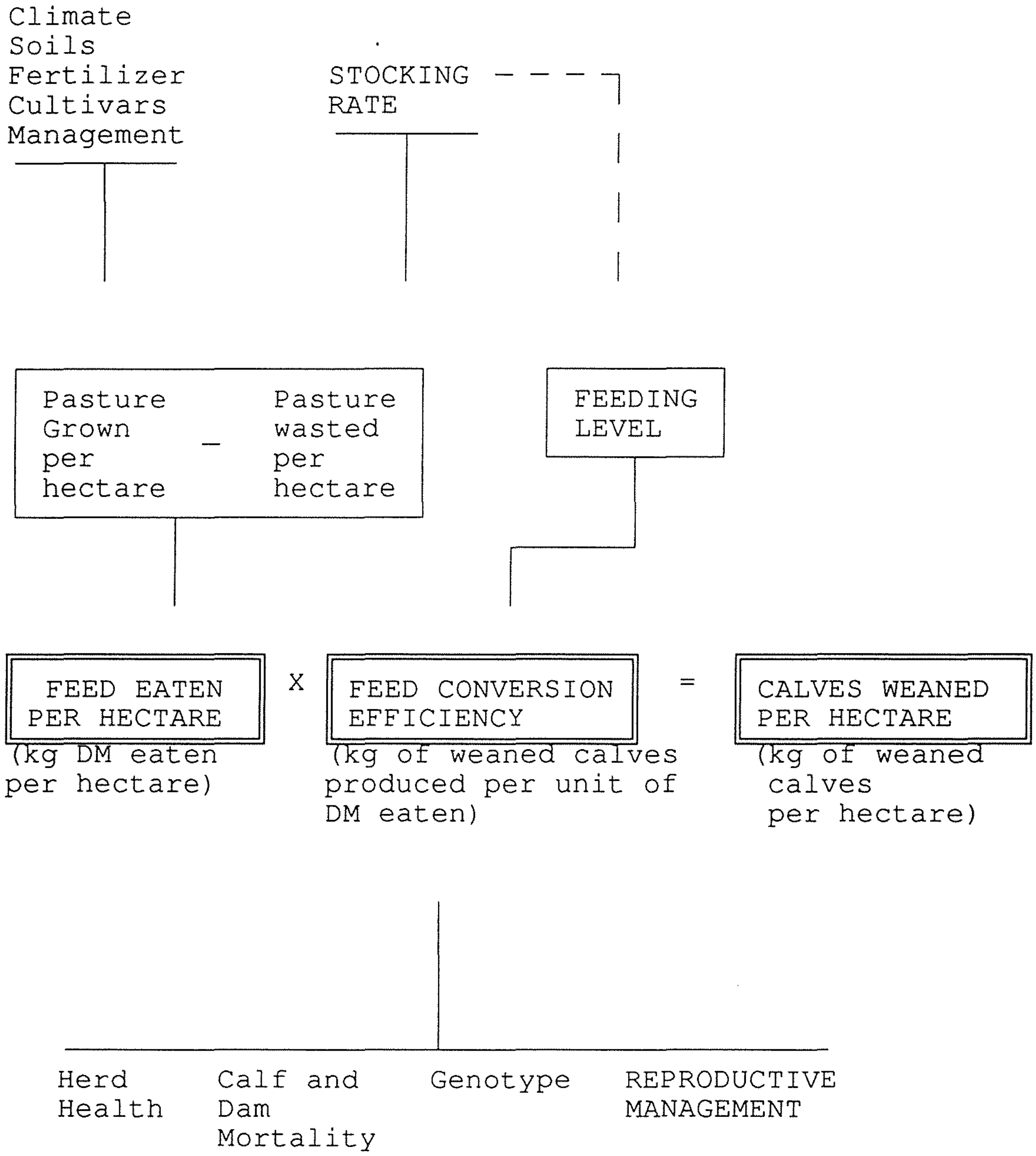

Figure 1.1 An outline of some of the basic elements affecting beef breeding herd production under grazing conditions.

Reproductive management, on the other hand, is also extremely important in defining feed conversion efficiency since it impacts in the amount of animal output achieved per unit of feed consumed (Figure 1.1). High efficiency of feed conversion will be obtained on farms where cows are maintained in a healthy state and sound reproductive management is applied. The objective of the reproductive management must not only be to increase the number and weight of calves weaned per hectare, but also minimize herd replacement rates (i.e. culling for barrenness) and achieve target growth rates for progeny. In addition, the effects of adverse environment can be minimized by management. Once stocking rate is determined for an individual farm, opportunities to improve reproductive management can be identified.

Appreciation of the scope for improvement in reproductive management, and hence of the efficiency of production in the herd, depends on our understanding of the farming systems and management practices which determine cattle reproduction. However, these management practices must be environmentally beneficial, ethically defensible and socially acceptable. In view of this the present study was designed to obtain more information about the effectiveness of a management practice, namely restriction of suckling stimulus, to improve reproductive performance and on the way this may be practically manipulated under farm conditions to increase efficiency of production in beef breeding herds.

CHAPTER II: REVIEW OF LITERATURE

2.1 Setting objectives for commercial breeding herds

Beef cattle efficiency can be defined in terms of biological and economic efficiency (Odde and Field, 1987). Biological efficiency includes factors such as pregnancy rate, calving rate, calf weaning weight and weaning percentage, while economic efficiency is measured by costs of production, net returns, return on investment, etc. Both biological and economic aspects must be taken into account when measuring the efficiency of an animal production system, since partial evaluation can be misleading (Lishman *et al*, 1984). Although biological and economic efficiency are normally closely related, in some circumstances only a limited relationship exists. This fact was illustrated by Odde and Field (1987) who stated that biological efficiency defined as calf weight weaned/cow exposed to bull can be high but economic efficiency may not necessarily be elevated if costs of production are extremely high and/or prices of weaned calves are low.

Despite the above concept, reproductive rate has been reported as having a major influence on production efficiency (Dickerson, 1970; Dziuk and Bellows, 1983) and profitability of the beef cattle enterprise (Smeaton *et al*, 1979; Montgomery and Davis, 1980; McMillan, 1989; McMillan and Macmillan, 1989). The relative importance of reproductive efficiency, growth and carcass composition for profitability of beef breeding herds is in the order of 10:2:1 (Sykes and Stafford, 1984; Prince *et al*, 1987). Therefore, one calf per cow mated per year has been universally aimed for commercial beef breeding herds (Wiltbank, 1970; Smith and Tervit, 1977; Geymonat, 1985; Radostitis and Blood, 1985). The importance of the 365-day calving interval is highlighted by the fact that if the interval between calvings is increased, calves will be raised from parturition to weaning at gradually shorter and later periods. Furthermore, under those circumstances, calving can eventually be missed entirely if the breeding season is limited (Doren *et al*, 1986; Williams, 1990).

However Lishman *et al* (1984) emphasized the need to optimize rather that maximize rates of reproduction because, in some situations, improvements of the biological efficiency is not always profitable. In this sense, though a more complicated formula has been reported (Dickerson, 1970), Spitzer (1986) reported a simplified formula of beef herd economics that seems to relate economic and biological considerations:

Income= (Number of calves weaned x weaning weight x price per kg) - annual costs

Therefore, costs must be taken into account when evaluating the efficiency of production of the enterprise (Harris, 1970; Lishman *et al*, 1984; Lowman, 1985; Spitzer, 1986; Odde and Field, 1987). Large improvements in the economic efficiency of beef production can be obtained by reducing animal costs in beef breeding herds (Trenkle and Willham, 1977; Spitzer, 1986; Odde and Field, 1987) and by implementing cost-effective practices resulting in higher biological efficiency. However, reducing annual herd costs requires knowledge of component costs (Odde and Field, 1987), and implementation of cost-effective practices requires recognition of those practices.

Feed costs have been recognized both from overseas (Lowman 1985, 1988; Odde and Field, 1987) and from New Zealand (Nicoll, 1979; McMillan,1989) as a major part of the total costs of the annual production cycle of the beef breeding cow. This fact has probably led New Zealand authors to set the ultimate objective for beef breeding herds as the minimum weight and condition of the herd through least cost feeding systems consistent with heavy calves at weaning, satisfactory cow and calf survival and unimpaired fertility (Hight, 1968a; Nicoll,1979; Smeaton *et al*, 1979; Mossman, 1984b; Smeaton *et al*, 1984; McMillan, 1989). This objective requires a balance between stock wintered, high pasture utilisation and high reproductive performance needed under pastoral conditions to obtain profitability. Attention must therefore be focused on whether feeding management and feeding levels are limiting reproduction or are decreasing economic efficiency.

Under grazing conditions, stocking rate influences production per animal through its influence on individual herbage intake (Rovira, 1973; Hanly and Mossman, 1977; Morley, 1981; Hodgson, 1990). On the other hand, increases in the stocking rate bring about more herbage consumed/hectare and therefore less wastage of herbage. This increase in herbage utilisation is likely to result in increased efficiency of the grazing systems (Hodgson, 1990). Providing that there is not a great adverse effect on animal health and fertility, increasing stocking rate will favourably affect animal output per hectare.

For instance, Lamond (1970) reported that cows grazing native pastures at a stocking rate of 0.83 cows/ha during 4 years, only 11% of the herd became pregnant every year, whereas 42% of those cows stocked at 0.55 cow/ha became pregnant each year. Rovira (1973), based on the former report, concluded that average calving rates were 71.7% and 84.3% for the herds managed at high and low stocking rates, respectively. However, the herd stocked at 0.83 cows/ha produced 0.59 calves/ha, whereas the herd managed at 0.55 cows/ha produced 0.46 calves/ha. If an average calf weight at weaning of 150 kg is assumed for the high-stocked herd, then the herd managed at the lower rate of stocking would need to produce calves weighing 192 kg, on average, in order to have the same level of biological efficiency. In this last case, an evaluation of the costs of production for those herds will furnish information about which is economically more efficient.

Under New Zealand grazing conditions, reduction in beef breeding cow performance has also been reported as a consequence of increasing stocking rate (Hanly and Mossman, 1977). However, Table 2.1 shows that even though a decrease in the effective calving rate occurred in those farms where cow numbers escalated, increasing stocking rate generally resulted in more calves marked in the farm. Only in herd E (see Table 2.1), was the adverse effects of increasing stocking rate on herd fertility important enough to decrease the calf crop in the farm. Economic analysis will need to take into account the capital costs of the extra livestock required when stocking rate is increased.

Table 2.1 Relationships between herd numbers, calving percentages and number of calves marked over a 5 year period on 7 farms.

	Herd Numbers(*)		Calving %(*)		Difference in calves
Herd	1970	1975	1970	1975	marked/farm
A	800	1000	98	80	+16
B	431	700	94	75	+120
C	800	906	89	80	+13
D	80	156	97	78	+44
E	500	700	94	47	-141
F	480	600	77	68	+38
G	290	538	97	54	+9

(*)Data extracted from Hanly and Mossman (1977)

Nevertheless, available resources must be utilized to best advantages through sound reproductive management practices (Dziuk and Bellows, 1983). If feeding costs are a major input in beef enterprises, management practices must ensure adequate liveweight for high performance, while minimizing costs associated with unnecessary high liveweights or body conditions.

One of those management practices is the achievement of a short calving span and concentrated calving pattern in the herd. This objective can be achieved by restricting the breeding season and by getting the greatest number of cows in calf over as short a time-period as possible (Mossman, 1984a; Chenoweth, 1984). Concentrated calving patterns better utilise resources primarily through improved feed management, but it can also increase chances of higher pregnancy rates, produce heavier and a more even line of calves at weaning (McPhail and Mossman, 1981; Entwistle, 1983; Mossman, 1984c).

Mossman (1984c) also stated that in those herds where there is a prolonged calving spread, feed budgeting is seldom practised and farmers are often unable to select the most appropriate paddocks for calving. This is likely to result in poorer reproductive performance. In this sense, Blockey (1984) pointed out that reproductive parameters such as the pregnancy rate should also be related to the period of time needed to achieve such percentage because this is economically important.

It has been proposed that heifers should be mated preferably over a period of 42-45 days (Hanly and Mossman, 1977; Mossman and Hanly, 1977; Mossman, 1984c). This results in an approximately 84% pregnancy rate, providing heifers are heavier than the critical mating weight (Hanly and Mossman, 1977; Mossman and Hanly, 1977). Once first calvers obtain a concentrated calving pattern, the mixed age cows should be mated over a 63-day period (Mossman, 1984d). Cow in-calf rates of 90-95% (McMillan and Macmillan, 1989) to 98-99% (Mossman, 1984c) and calving rates of 95% (Sykes and

Stafford, 1984) have been reported as possible under Australian and New Zealand pastoral conditions when applying this management.

Other aspects to take into account when evaluating the efficiency and setting objectives for beef breeding herds is the age at first mating. The ratio of calves weaned/total number of females present in the herd accounts for the number of replacement heifers retained and the age at first mating (Nicol, 1984). Increases in this ratio represent a major improvement in the efficiency of beef cow production (Nicol, 1984), but if heifers are mated at a liveweight lighter than the critical minimum weight, then there are likely increases in dystocia and fertility problems as second calvers (Hanly and Mossman, 1977).

In summary, the difference between biological and economic efficiency must be highlighted when evaluating commercial beef breeding herds; even though a high reproductive rate is generally associated with high economic efficiency and profitability. Under grazing conditions, optimum reproductive rate must be based on output/ha, costs of production and resources available within the farm. Optimum reproductive performance relies on the best utilization of available resources, usually achieved through sound and cost-effective management practices. They are likely to comprise a short mating and calving span and all those practices and management techniques that induce a concentrated calving patterns.

2.2 Sources of reproductive wastage in beef breeding herds

Although one weaned calf per cow per year has been established as a theoretical objective in commercial beef breeding herds, it is unlikely to be achieved under most practical conditions (Radostits and Blood, 1985). There are normally losses at different stages in the reproductive process. Those losses are summarized in Table 2.2.

In U.S.A., Wiltbank (1983) analyzed the reasons why cows do not wean a calf in different regions and concluded that while the magnitude of the losses varied from one region to other, the main decrease at all locations occurred because cows did not become pregnant or calves died at or near birth. Similar conclusions can be drawn for those countries represented in Table 2.2.

In Australia, Entwistle (1983) also recognized that a high proportion of barren cows was a major source of loss from beef breeding herds, though in some regions losses due to abortions, starvation, mismothering and predation have also been reported. A pre-natal, peri-natal and post-natal mortality percentage of 10.9% was reported by Entwistle (1983).

Table 2.2 Source of losses affecting reproductive performance in beef breeding herds (%).

Authors (country)	Barren Cows	Fetal Loss	Calf Mortality	Calves Weaned	Other Sources
Hanly & Mossman 1977 (New Zealand)	10	1	7.4	81.6	
Montgomery, 1984 (New Zealand)	10	-	9.0	78.0	3.0(*)
Geymonat, 1985 (Uruguay)	20	2	10.0	68.0	
Dziuk & Bellows (U.S.A.)	17.4	2.3	9.3	71.0	
Wiltbank,1983(**) (U.S.A.)	13.7	3.5	10.6	70.3	
Peters & Ball, 1987 (U.K.)	6.9	1.1	5.3	86.7	
Allen & Lienard, 1992 (France)	6.4	1.1	8.6	83.9	
Carrillo & Schiersman, 1992 (Argentina)	20	2-5	5-7	60-70	

(*)Dam mortality from joining to parturition

(**)Average of different reports

In New Zealand, the reported average calving percentage has varied from 78% to 82% (Hanly and Mossman, 1977; Montgomery, 1978; Montgomery, 1984; Packard, 1984). A high proportion of mated cows fail to rear calves because they are not in-calf at the end of the breeding season or because of high mortality rates (see Table 2.2, Hanly and Mossman, 1977; Montgomery, 1984). The loss to the New Zealand beef industry can be roughly assessed as being 200,000 calves or approximately $ 72 million per annum at current prices for weaners, if a target calf crop of 95% and an average of 180 kg of weaned calf are considered.

Calf mortality in New Zealand beef breeding herds ranges from 7 to 13 per 100 cows mated (Hanly and Mossman, 1977; Montgomery, 1978; 1984). However, the percentage of calves lost at birth was as high as 44% under particular situations (Hanly and Mossman, 1977). Montgomery (1978) reported that dystocia accounts for 64% of calf mortality, but Hanly and Mossman (1977) found dystocia to be a minor contributor to calf loss. According to the last report, less than 2% and 0.2% of dystocia is normally recorded in heifers and adult cows, respectively. Other possible causes of high calf loss include late abortions, calf starvation due to poor udders and bottle neck teats, calves rolling into creeks and holes, death from exposure and starvation, and *E. coli* infections and virus pneumonia (Hanly and Mossman, 1977).

The importance of the postpartum anoestrous interval (PPAI), namely the interval from calving to first oestrus, influencing the likelihood of the beef cow to become pregnant during a restricted breeding season, has been highlighted by many overseas authors (Symington and Hale, 1967; Wiltbank, 1970; 1983; Rovira, 1973; Dunn and Kaltenbach, 1980; Geymonat, 1985; Williams, 1990; Short *et al*, 1990) and from New Zealand (Mossman and Hanly, 1977; Smith and Tervit, 1977; Tervit *et al*, 1977; Knight and Nicoll, 1978; Morris *et al*, 1978; Montgomery *et al*, 1980; Montgomery, 1984; Nicol and Nicoll, 1987; McMillan and Macmillan, 1989; Pleasants and Barton, 1992a; Macmillan and Peterson, 1993). Although Pleasants *et al* (1991) stated that in cows suckling calves the anoestrous period varies between 50 and 80 days, other New Zealand authors have reported substantially longer PPAI (Smith and Tervit, 1977; Tervit *et al*, 1977; Morris *et al*, 1978; Nicoll, 1979; Montgomery *et al*, 1980; Pleasants and Barton, 1992b; Pleasants and McCall, 1993).

The PPAI is particularly longer in primiparous cows (Wiltbank, 1970; Tervit *et al*, 1977; Knight and Nicoll, 1978; Dunn and Kaltenbach, 1980; Dziuk and Bellows, 1983; Short *et al*, 1990; Pleasant and McCall, 1993). For instance, Pleasants and McCall (1993) reported that least square means for the PPAI varied between 56 and 98 days and between 66 and 90 days in 2-year-old and mature cows, respectively. Knight and Nicoll (1978), Morris *et al* (1978), Montgomery *et al* (1980), Montgomery (1984) and Montgomery and Davis (1987) reported that there are cows in New Zealand beef breeding herds that have PPAI longer than 90 days. This fact has probably led Smith and Tervit (1977) and Montgomery (1984) to conclude that the major reason for poor reproductive performance under New Zealand conditions is a long PPAI. Prolonged PPAI has also been reported as the major problem area of beef cow fertility worldwide (Wiltbank *et al*, 1964; Rovira, 1973; Pimentel *et al*, 1979; Dunn and Kaltenbach, 1980; Entwistle, 1983; Wiltbank, 1983; Geymonat, 1985; Bonavera *et al*, 1990; Short *et al*, 1990; Wright *et al*, 1992).

If twelve monthly calving intervals are the objective then the beef breeding cow has only 80 to 85 days after calving to start cycling and become pregnant (Knight and Nicoll, 1978; Peters and Riley, 1982; Montgomery, 1984; Peters and Lamming, 1990; Dunn and Moss, 1992; Rae, 1992). Since average natural conception rate to a given service are only 0.50 to 0.60 (Peters and Riley, 1982a), the earlier a cow begins to cycle *post partum*, the greater is the chance of successful conception by this time. If she fails to become pregnant in that short period, then the calving interval is longer than 365 days (Morris *et al*, 1978). On the other hand, cows that calve early, wean heavier calves and rebreed earlier in the breeding season (Lesmeister *et al*, 1973). A long PPAI can also be a frequent cause of poor conception rate in beef breeding herds (Bonavera *et al*, 1990). Fertility of beef cows is lower at their first postpartum oestrus than it is at subsequent heats (Smith and Tervit, 1977; Lishman *et* *al*, 1979). Moreover luteal function could be deficient during early oestrous cycles improving only gradually during subsequent cycles(Perkins and Kidder, 1963; Short *et al*, 1972). Thus, expression of multiple oestrous cycles preceding breeding improves conception at first service (Hopkins, 1986; Rae, 1992).

To summarize, prolonged PPAI and high calf mortality are generally regarded as the major sources of reproductive wastage in beef breeding herds. Prolonged PPAI not only decreases the immediate pregnancy rate, but also reduces chances of obtaining a concentrated calving pattern. As a result, calves are likely to be lighter at weaning and pregnancy rate can decrease further in following breeding seasons.

2.3 Physiology in the postpartum cow

After parturition cows are infertile for a variable period of time (Hopkins, 1986; Peters and Ball, 1987; Short *et al*, 1990). The length of this period has a major influence in defining the reproductive performance of beef breeding herds. Therefore, knowledge of the changes occurring after parturition are considered relevant to pinpoint any cause of poor reproductive performance.

The period of infertility that follows parturition can be considered physiological if its duration does not extend past an accepted average (Hopkins, 1986). This average is affected by many factors, which are discussed in the next section of this chapter. In this section, several aspects of postpartum physiology are examined.

2.3.1 Uterine involution

Involution of the uterus after calving is necessary before the cow can conceive again (Peters and Ball, 1987;

Peters and Lamming, 1990). In addition, the non-involuted uterus may be a barrier not only to sperm transport but also to embryo implantation (Short *et al*, 1990). The involutionary process normally starts immediately after calving (Moller, 1970a; Peters and Ball, 1987) when the uterus weighs approximately 9 kg (Gier and Marion, 1968). Involution can be completed between 26-31 days (Moller, 1970b; Rovira, 1973; Spicer *et al*, 1986; Peters and Ball, 1987; Peters and Lamming, 1990; Perry *et al*, 1991) and 50 days (Gier and Marion, 1968; Rovira, 1973; Olson *et al*, 1986).

Dissimilar criteria taken by researchers when considering the involutionary process completed can account for these differences. For instance, Moller (1970b) considered the process finished at the first examination which was followed by two weekly examinations not showing reduction in the size of the cervix or the uterus, but admitted that involution continues long after it is detectable by rectal palpation. In this sense, Gier and Marion (1968) reported that under normal circumstances the weight of the uterus is reduced to 1 kg at 30 days and to 0.75 kg at 50 days after calving in dairy cows. These authors also found that histological changes go on for even longer.

At this stage, the difference between dairy and beef cows must be highlighted. While dairy cows are normally milked twice per day during the lactation, beef cows suckle their calves. This distinction is important because suckling has been reported as a factor modifying the process of uterine involution (Wiltbank and Cook, 1958; Moller, 1970a; Rovira, 1973; Peters and Ball, 1987). Nevertheless, there are contradictory reports about the effect of suckling on the involutionary process. While Peters and Ball (1987) stated that suckling stimulates such a process, Rovira (1973) presented evidence where the involution process lasted longer in Shorthorn suckling cows than in Shorthorn milked cows. In addition, Wiltbank and Cook (1958) found that suckling actually prolonged involution, whereas Moller (1970b) reported that the uterine involution does not differ between multiple-suckled and milked cows.

Another source of variation in the length of the involutionary process is parity. Involution normally takes longer in pluriparous cows than in primiparous cows (Moller, 1970a; Rovira, 1973; Peters and Ball, 1987), although differences were not found in one study (Moller, 1970b). Poor nutritional levels (Rovira, 1973) and periparturient diseases (Moller, 1970a; Rovira, 1973) were also reported as factors prolonging involution. However, the rate of uterine involution was clearly unaffected by very different pre and postpartum energy levels (Perry *et al*, 1991). Therefore, even though these factors can account for differences in uterine involution, the information available is equivocal.

Few beef suckling cows would exhibit heats early enough after calving for uterine involution to interfere with conception under normal conditions (Short *et al*, 1990). For this reason, Short *et al* (1990) concluded that from a practical point of view, uterine involution is not an issue in beef breeding herds because it does not determine the length of the infertility period following parturition. PPAI is normally longer than the involutionary process, as long as disease conditions do not prevent or delay normal involution (Short *et al*, 1990). It must however be acknowledged that the relationship between uterine involution and ovarian activity has received little attention (Peters and Lamming, 1990).

2.3.2 Endocrine pattern

The reproductive activity of a healthy cow cycling normally is regulated by pituitary gonadotrophin secretion, which in turn relies on pulses of GnRH released by the hypothalamus (Peters and Lamming, 1986, 1990). Pituitary gland and hypothalamic function is controlled by the secretion of steroid hormones by the ovaries (Peters and Lamming, 1986; 1990). Thus, reproductive function is physiologically controlled by interactions between the brain, hypothalamus, pituitary gland and the reproductive tract. In theory, the lack of ovarian cycles in the postpartum cow might be due to inability of the ovaries to respond to gonadotrophins, to an inability of the hypophysis to secrete sufficient quantity of gonadotrophins to stimulate follicular growth and ovulation and/or insufficient GnRH secretion that induces inadequate amounts of gonadotrophins.

Braden *et al* (1986) compared follicles from beef cows at various times following parturition and during the oestrus cycles. They concluded that ovarian capacity is not a limiting factor in the PPAI. Other authors have reported that the ovaries appear to be capable of responding to gonadotrophin stimulation very early in the postpartum period, since ovulation could be induced early in that period by injecting gonadotrophins (Peter and Lamming, 1986, 1990; Nett, 1987). There would therefore be enough evidence to reject inability of the ovaries to respond to reproductive hormones as a cause of the suppression of ovarian cycles *post partum*.

Based on that evidence, Nett (1987) concluded that the lack of cyclicity in postpartum cows is due to the lack of gonadotrophin stimulation. Plasma gonadotrophin concentrations are in fact very low immediately after calving (Peters and Lamming, 1984, 1986, 1990; Nett, 1987; Peters and Ball, 1987; Roche *et al*, 1992). Although FSH plasma concentration is reported to increase early after parturition (Peters and Lamming, 1986, 1990; Peters and Ball, 1987) and to change little subsequently (Peters and Ball, 1987), studies have indicated that luteinizing hormone LH plasma concentration rises much more gradually (Peters and Lamming, 1986, 1990; Hopkins, 1986; Nett, 1987; Peters and Ball, 1987). This delay is more dramatic in suckled beef cows than in milked cows (Peters and Lamming, 1990).

The rise in FSH concentration immediately after calving suggests this hormone is not a factor limiting resumption of ovarian cyclicity (Peters and Lamming, 1984; Peters and Ball, 1987). However, Peters and Lamming (1984) reported results where a negative correlation was observed between the length of the acyclic period and the mean plasma concentrations of FSH. Even though it does not seem to be a consistent finding, the occurrence of a FSH plasma concentration threshold below which a lack of FSH can prevent ovarian activity after calving has been hypothesised (Peters and Ball, 1987).

Marked suppression of pulsatile LH release has been the most notable endocrine feature associated with postpartum anoestrum (Haresign *et al*, 1983; Short *et al*, 1990; Williams, 1990; Rice, 1991; Schillo, 1992). Hence, an increase in the frequency of pulsatile LH release is reported as a prerequisite for the resumption of the postpartum fertility (Spicer *et al*, 1986; Williams, 1990; Peters and Lamming, 1990; Rice, 1991; Schillo, 1992; Jolly, 1993). While the episodic release is re-established as soon as 10 to 15 days after calving in non-suckled cows (Haresign *et al*, 1983; Hopkins, 1986; Rice, 1991), suckled cows have a much later and more highly variable onset of episodic release patterns (Haresign *et al*, 1983; Rice, 1991; Roche *et al*, 1992).

The reduction in the concentration of LH in plasma of postpartum cows focuses attention on the components of the hypothalamic-hypophysial axis as responsible for the infertility. According to Nett (1987), the possible limiting components are the amount of LH synthesized and stored in the anterior pituitary gland, the number of receptors for GnRH in the anterior pituitary gland, the amount of GnRH secreted into the hypophyseal portal circulation and the amount of GnRH synthesized and stored in hypothalamus.

Although high oestrogen and progesterone plasma concentrations in late pregnancy induce a reduced pituitary content of gonadotrophins (Nett, 1987; Williams, 1990; Roche *et al*, 1992; Jolly, 1993), the amount of LH in the pituitary gland together with the number of receptors for and the responsiveness to GnRH appear to increase rapidly after calving (Lamming, 1978; Haresign *et al*, 1983; Peters and Lamming, 1984, 1990; Moss *et al*, 1985; Nett, 1987). This recovery appears to be faster in milked cows than in suckled cows. For instance, Canfield and Butler (1990) found that the pituitary function is fully recovered by day 8 to 10 *post partum* in dairy cows. However, Myers *et al* (1989) stated that the recovery of pituitary concentrations of LH and the responsiveness of the gland to exogenous GnRH occurs 10 to 30 days after parturition in suckled beef cows. Such a difference was earlier acknowledged by Lamming (1978), who reported that the pituitary is responsive to GnRH at approximately 20 days *post partum* in suckled beef cows compared to approximately 8 days in milked cows. Despite the delay reported in suckled cows, the amounts of LH in the pituitary gland and its responsiveness to GnRH do not appear to be the cause of the prolonged low plasma concentrations in postpartum suckled cows.

The evidence discussed above suggests that attention must be focused on the quantity of GnRH synthesized and stored in the hypothalamus and its secretion as the mechanisms likely to be responsible of low LH levels in plasma of suckled beef cows. Moss *et al* (1985) reported that the hypothalamic concentration of GnRH in postpartum suckled beef cows is not insufficient at 5 days after calving. Other authors also concluded that the hypothalamic content of GnRH is adequate and cannot be considered a limiting factor to resumption of cyclicity (Nett, 1987; Peters and Lamming, 1990; Rice, 1991).

Although more research is needed to evaluate the secretion of GnRH in the postpartum cow (Nett, 1987), evidence indicates that the inhibition in GnRH release is the ultimate cause of the impaired prolonged low LH levels in suckled cows (Peters and Lamming, 1990; Jolly, 1993). The events discussed in this subsection led Nett (1987) and Myers *et al* (1989) to describe two phases in the establishment of hypothalamic-pituitary-ovarian functions capable of resuming oestrus cycles after calving. An initial phase, which lasts 30 (Myers *et al*, 1989) to 35 days (Nett, 1987), is defined by a reduced amount of LH in the pituitary and by a depressed responsiveness of the pituitary to GnRH. The second phase is characterized by inhibition of GnRH release. Once that inhibition is overcome, LH pulse frequency is sufficient to permit the occurrence of ovulation.

Knowledge about these phases and the way that they are likely to be affected by factors such as genetic, nutritional levels or other environmental influences is of paramount importance when designing treatments or husbandry techniques to optimize reproductive performance in beef breeding herds.

2.3.3 Follicular dynamics

Before the introduction of ultrasonographic techniques, the morphology of the reproductive organs was evaluated by transrectal palpation, at surgery, or at slaughter (Griffin and Ginther, 1992). The recent application of ultrasonography has enabled researchers to study reproductive organs with a noninvasive and nondisruptive methodology. The dynamic aspects of morphology in, usually inaccessible, structures can now be studied and elucidated (Griffin and Ginther, 1992; Fortune, 1993). Follicular development is one of the recent topics studied with this technology (Fortune, 1993). Information about follicular dynamics, namely the process of continual growth and regression of antral follicles that lead to the development of the preovulatory follicle (Lucy *et al*, 1992), in postpartum cows is presented in this subsection. Furthermore, efforts to relate follicular development with the information presented in the previous subsection are also made here.

In the early postpartum period, there is a partial and temporary suppression of follicular growth (Murphy *et al*, 1990; Savio *et al*, 1990a; Roche and Boland, 1991; Roche *et al*, 1992; Jolly, 1993). This period occurs in milked (Savio *et al*, 1990a) as well as suckled (Murphy *et al*, 1990) cows and is characterized by the presence of follicles smaller than 8-9 mm in diameter (Murphy *et al*, 1990; Savio *et al*, 1990; Roche and Boland, 1991; Roche *et al*, 1992). This first phase ends when, from a cohort of smaller follicles, a single one is selected to grow and becomes dominant (Roche *et al*, 1992). This dominant follicle (DF) is defined as a single follicle greater than 10 mm in diameter, which suppresses growth of other follicles (Murphy *et al*, 1990; Savio *et al*, 1990a; Roche *et al*, 1992).

Irish researchers noted that the first DF after calving was detected about 11.5 (Murphy *et al*, 1990) and 10.2 days (Savio *et al*, 1990a) *post partum* for suckled and milked cows, respectively. Although no differences were observed in the timing of occurrence of the first DF *post partum* in milked and suckled cows, differences in the fate of the first DF did occur. While milked cows generally ovulated the first DF, suckled cows had an average of 3.2 DFs before first ovulation after calving (Murphy *et al*, 1990; Savio *et al*, 1990a; Roche and Boland, 1991; Roche *et al*, 1992). Figure 2.1 shows that difference. These findings are in agreement with earlier observations indicating that the appearance of large follicles occurs long before the first postpartum ovulation in suckled beef cows (Wiltbank *et al*, 1964; Spicer *et al*, 1986).

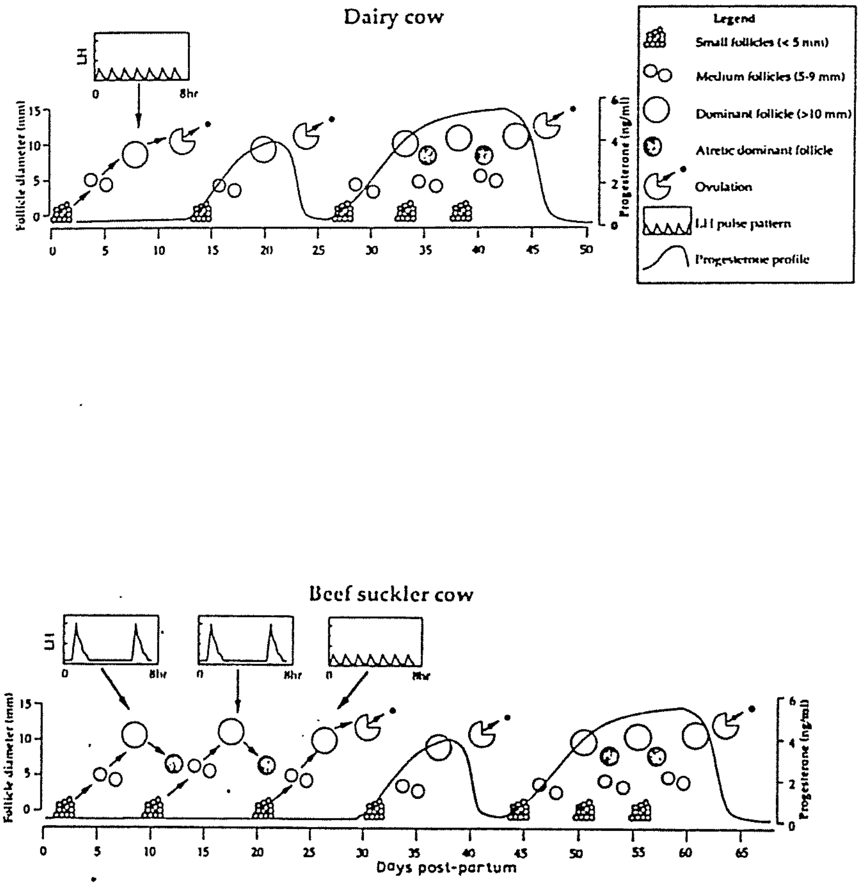

Figure 2.1 A model for the occurrence of dominant follicles and resumption of ovarian cycles during the postpartum period in dairy (milked) and suckled beef cows not nutritionally stressed (extracted from Roche et al, 1992).

These data show that before first ovulation *post partum*, there are recurrent periods of growth and regression of DFs. However, the process of recruitment, selection and dominance is a result of complex interactions at different levels, many of which still remain unknown (Lucy *et al*, 1992). Driancourt (1991) reported that endocrine, as well as autocrine (within tissue) or paracrine (between tissues) regulatory mechanisms are implicated.

There seems to be agreement that the initial state of follicular development, namely up to the recruitment of a cohort of follicles, proceeds in the absence of pituitary gonadotrophin (Godke *et al*, 1990; Driancourt, 1991; Lewis, 1992). The last point is supported by the fact that primary follicle activation occurs even in ovaries of hypophysectomized females (Godke *et al*, 1990). Nevertheless, FSH plays a major role in the process of recruitment and antrum formation (Lishman *et al*, 1979; Godke *et al*, 1990; Driancourt, 1991; Lewis, 1992; Lucy *et al*, 1992; Roche *et al*, 1992; Jolly, 1993). In addition, basal LH levels were also reported to be involved in the recruitment (Driancourt, 1991; Lucy *et al*, 1992).

The mechanism whereby a follicle becomes dominant has not been elucidated, however Driancourt (1991) hypothesized that the largest maturing follicle could reduce FSH plasma concentrations below the threshold necessary to maintain other follicles. The DF in cows produces more oestradiol and inhibin than do other follicles and these hormones suppress pituitary FSH secretion (Peters and Lamming, 1990; Jolly, 1993). While LH concentrations increase very slowly in ovariectomized postpartum cows, FSH concentrations rise much quicker after ovariectomy, which is a reflection of a greater sensibility to a negative influence (Peters and Lamming, 1990).

As mentioned above, paracrine and autocrine factors also intervene in the regulation of follicular dynamics. The maturing follicle can directly inhibit the growth of other follicles by secreting substances that reduce their sensibility to FSH (Driancourt, 1991). Furthermore, the role of insulin-like growth factor (IGF1) must be highlighted since it amplifies the FSH action on aromatization in the DF and increases the number of LH receptors (Driancourt, 1991). Therefore IGF1 would play a key role in the process of dominance.

The life span of DF is controlled by LH secretion (Lucy *et al*, 1992). Atresia can occur because of androgenic substrate for aromatization becomes limiting within the DF (Lucy *et al*, 1992; Jolly, 1993), which can in turn be a consequence of low mean plasma LH levels and LH pulse frequency. When LH levels are not limiting, there is enough androgenic substrate to substantially increase the secretion of oestradiol. This increase in oestradiol is responsible for oestrus, preovulatory gonadotrophin surge and ovulation. Ovulation of the DF would only result when an LH pulse frequency occurs every 40 to 60 minutes to stimulate maximum oestradiol production, positive feedback and ovulatory surge of gonadotrophins (Roche *et al*, 1992).

The pattern of follicular dynamics in suckled beef cows is shown in Figure 2.1, and the mechanism of control outlined above highlights the importance of LH pulse frequency in the restoration of oestrous cycles *post partum*. After calving, basal LH and FSH level is normally sufficient to stimulate recruitment, selection and development of DFs but they undergo atresia due to infrequent LH pulses, insufficient to stimulate the final maturation and ovulation (Murphy *et al*, 1990; Roche and Boland, 1991; Roche *et al*, 1992).

However, a number of secondary endocrine inputs may influence the hypothalamo-pituitary-ovarian axis (Peters and

Lamming, 1990; Schillo, 1992) and therefore the situation described by the Irish researchers (see Figure 2.1) could eventually not apply under other circumstances. For instance, the follicular dynamics described in Figure 2.1 for Irish dairy cows does not apply for New Zealand counterparts. Although DFs were also present approximately 10 days after calving, lactating New Zealand dairy cows had on average 4.2 DFs before first ovulation *post partum* (McDougall and Macmillan, 1993). In addition, Perry *et al* (1991) showed the occurrence of the first DF after calving in suckled beef cows is considerably delayed if energy levels are impaired. Finally, the postpartum interval to detection of the first DF is shorter in autumn calving dairy cows than in spring calving dairy cows, which suggests a seasonal effect on follicular development (Savio *et al*, 1990a). Unfortunately, Irish authors were not specific about the level of nutrition involved in their trials, which prevents any further conclusion to be drawn.

Thus, even though it has been concluded that lack of ovulation of DF (due to suppression of LH pulse frequency) in the postpartum period is primarily responsible for lengthy postpartum anoestrus in suckling beef cows (Roche *et al*, 1992), other causes do occur in practice. In this sense, different 'depth' of postpartum anoestrus has been suggested (Haresign *et al*, 1983; Short *et al*, 1990; Lucy *et al*, 1992) and clinical examinations of cows in postpartum anoestrus often reveal ovaries that range from small and firm with no palpable structures to those that have follicles of considerable size (Hopkins, 1986). Therefore, the information presented and discussed in this paper furnishes enough evidence to divide the PPAI into two clear periods relative to follicular activity. The first phase is defined by the time between calving and development of first DF, whereas the second phase is defined by the period between occurrence of first DF *post partum* and the exposure of a DF to a LH pulse frequency pattern consistent with ovulation. Consequently, the length of both those periods influences the PPAI.

Knowledge about the contribution of those two components to the length of PPAI under a particular set of circumstances is likely to furnish a sounder basis for the implementation of treatments or husbandry practices to improve reproductive performance in beef breeding herds. For instance, those treatments that restore LH pulse frequency would be more likely to be successful if a DF is present in the ovary at that time. A greater understanding of the actual follicular activity in the herd may allow the development of methods to modify the quality and/or quantity of inputs to the hypothalamus in order to restore the endocrine pattern in the postpartum female. Obviously, the achievement of such an understanding would also permit a better utilization of resources in the process of converting pasture into weaned calves.

2.3.4 Summary

The suppression of pulsatile LH release has been the most common and consistent endocrine feature associate with postpartum anoestrum in suckled cows. However, pituitary LH concentrations and pituitary function appears to be fully recovered approximately 30 days after calving in suckled cows. In addition, GnRH hypothalamic concentrations do not seem to be limiting in the postpartum cow. Thus, low LH pulse frequency is likely to be a consequence of an inhibition in GnRH release from the hypothalamus.

Immediately after calving there is a partial suppression of follicular growth. However, the appearance of large DF occurs long before first ovulation in suckled beef cows. Thus lack of ovulation of the DF as a result of low LH pulse frequency is probably the primary cause of long PPAI. Nevertheless, the contribution of the phase from calving to occurrence of first DF *post partum* can be greater under some circumstances and cannot be ruled out as a factor contributing to prolonged PPAI. Despite these particular cases, an increase in the frequency of pulsatile LH is a prerequisite for the resumption of postpartum fertility. All those management practices or treatments restoring LH pulse frequency are likely to result in ovulation, providing a DF has been developed.

2.4 Factors influencing the postpartum anoestrous interval

In this section, those factors likely to affect the length of PPAI are presented. Postpartum anoestrous interval has been defined as the major component in postpartum beef cow infertility because it can affect cattle fertility for a long time after calving. Although other factors such as short oestrous cycles or uterine involution can eventually contribute to infertility, they normally occur a long time before the appearance of first postpartum heat (Short *et al*, 1990). Therefore, under many situations, PPAI is considered the major limiting factor in postpartum rebreeding. Figure 2.2 displays those factors determining postpartum infertility.

2.4.1 Nutritional effects

Evidence of the effects of nutritional levels on reproductive performance of beef breeding herds is overwhelming (Randel, 1990). However, there seems to be some controversy about the relative importance of low and high feeding levels at different stages of the reproductive cycle. The elucidation of that debate is relevant to decisions about the best allocation of the resources in a farm situation.

The earliest work demonstrated that onset of postpartum oestrous cycles is delayed when energy intake is limited either before or after calving (Wiltbank *et al*, 1962; 1964;

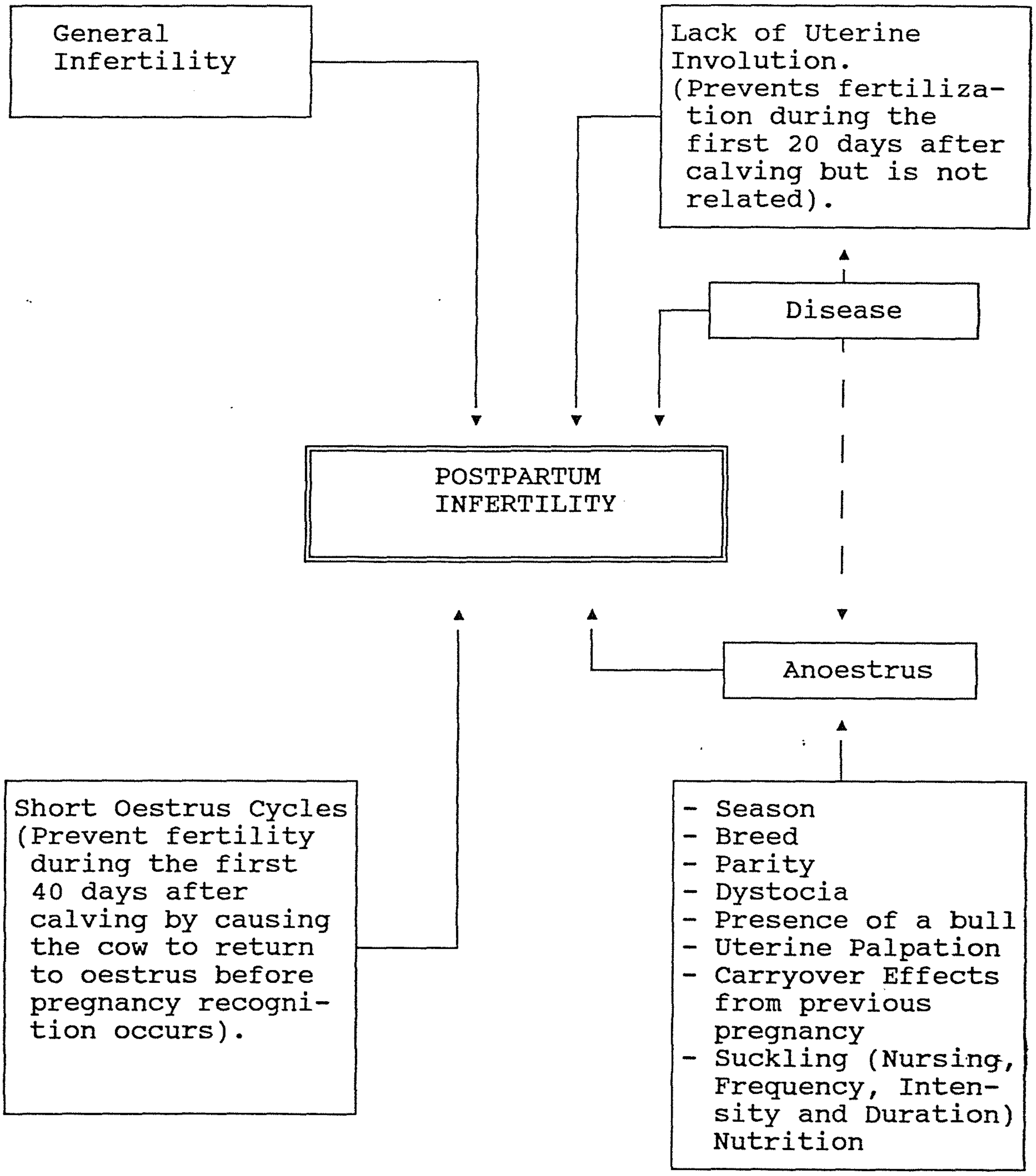

Figure 2.2 Factors affecting postpartum infertility

Dunn *et al*, 1969). These early trials also indicated that low pregnancy rates caused by low prepartum nutritional levels could be, to some extent, compensated by high feeding levels *post partum*. For example, the pregnancy rate of Hereford cows fed 30.7 or 61.5 Megajoules (MJ) of metabolizable energy (ME) during 4 to 6 weeks before calving and then fed 109.7 MJ of ME after parturition was 95% for both groups (Wiltbank *et al*, 1962).

These trends were later confirmed for New Zealand pastoral conditions where researchers reported that cows on low allowances before calving recovered both liveweight and condition after parturition when grazing high pasture allowances (Hight, 1968a, 1968b; Reardon *et al*, 1978; Nicoll, 1979). Cows with the greatest postpartum liveweight gain had shorter PPAI (Nicoll, 1979) and the highest pregnancy rates (Hight, 1968a), even though they were fed on low prepartum nutritional levels. Based on these results, Smeaton *et al* (1979) stated that poor nutrition from calving until mating has a greater detrimental effect on postpartum rebreeding than poor nutrition before calving. This concept suggests that, in spring calving herds, winter feed costs can be reduced without depressing subsequent reproductive performance. This could eventually mean higher stocking rates, better pasture utilization and improved herd profitability.

Nicoll (1979) found that PPAI was not influenced by prepartum feeding levels, while Reardon *et al* (1978) reported that the interval from calving to first oestrus was 1.2 days shorter for each kg increase in pasture allowance *pre partum*. Prepartum pasture allowance can also influence PPAI in yearling-mated heifers (Nicoll *et al*, 1984). Overseas, many reports have highlighted the importance of body condition at calving, since higher body condition scores are associated with shorter PPAI (Whitman *et al*, 1975; Dunn and Kaltenbach, 1980; Graham, 1982; Dziuk and Bellows, 1983; Richards *et al*, 1986; Wright *et al*, 1987; Houghton *et al*, 1989; Short *et al*, 1990; Randel, 1990; Osoro and Wright, 1992; Wright *et al*, 1992; Schillo, 1992; Patterson *et al*, 1992; Laflamme and Connor, 1992) and more concentrated calving patterns (Osoro and Wright, 1992). This effect of body condition at calving on postpartum reproduction in the beef cow led some reviewers to conclude that prepartum nutrition is more important than postpartum nutrition in determining the length of the PPAI (Dunn and Kaltenbach, 1980; Dziuk and Bellows, 1983; Short *et al*, 1990).

The effect of body condition at calving on PPAI appears to be non-linear (Short *et al*, 1990). This concept is displayed in Figure 2.3. This effect helps explain the differences found by researchers between pre and postpartum nutrition. According to Short *et al* (1990), the influence of body condition at calving is greatest at very low scores (<4, scores described by Spitzer, 1986). Figure 2.3 shows that the effect of body condition at calving (and hence the prepartum nutritional level) on PPAI becomes less important as body condition increases.

Postpartum nutritional level can also modify the effect of body condition at calving on PPAI, with postcalving nutrition having its main effect when cows calve with scores of ≤ 6 (Figure 2.3). This concept is supported by Richards *et al* (1986) and Wright *et al* (1992) who found that postpartum nutritional level does not have any effect on PPAI if cows calve with body conditions of ≥ 5 (1-9 system of body condition score, Spitzer, 1986) and ≥ 2.25 (1-5 system of body condition, Lowman *et al*, 1976), respectively. In addition, the modification in PPAI carried out by different postpartum feeding levels is greater when the feed intake is low vs adequate rather that adequate vs high (see Figure 2.3). This may partially explain some of the contradictory reports about the relative importance of pre and postpartum nutrition on PPAI in beef breeding herds.

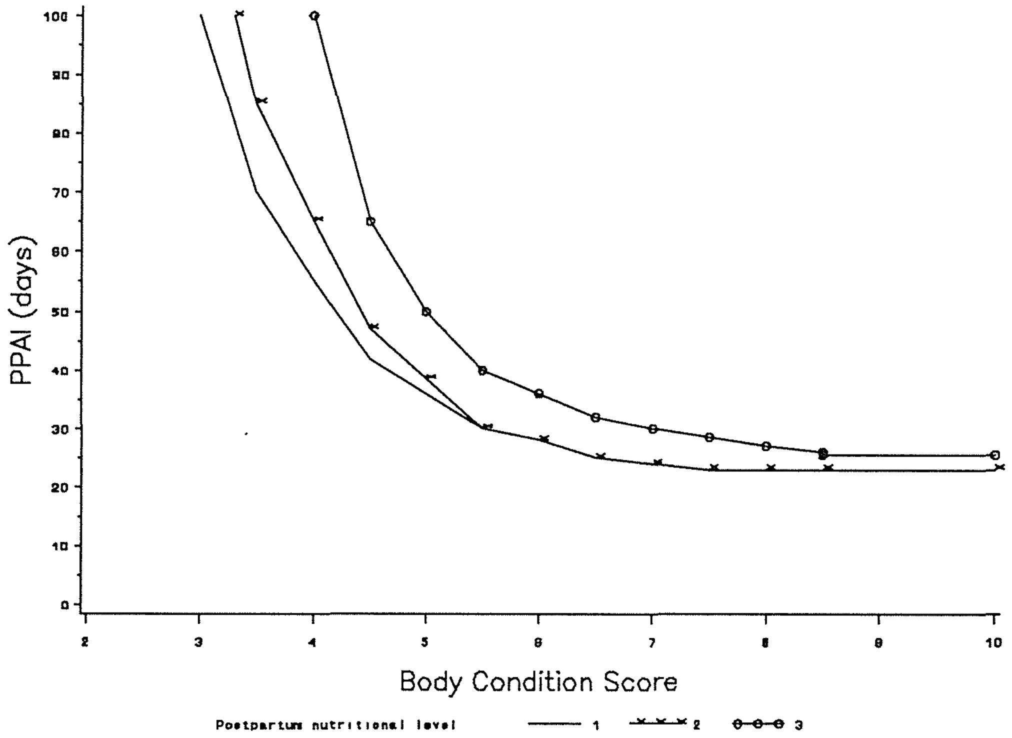

Figure 2.3 Effect of postpartum nutrition level (1= high; 2= moderate; 3= low) and body condition score at calving on PPAI (from Short *et al*, 1990).

Rutter and Randel (1984) and Rakestraw *et al* (1986) reported that those cows that maintain liveweight after calving have a shorter PPAI than those that lose liveweight. Therefore the later authors concluded that body condition at calving will not itself ensure adequate rebreeding *post partum*. Nevertheless, Osoro and Wright (1992) found that liveweight changes after calving did not have any significant effect on reproductive performance. Despite those disagreements, there seems to be consensus about a high percentage of cows that lost weight prior to calving not showing oestrus following calving unless they gained liveweight after calving (Wiltbank *et al*, 1962, 1964; Dunn *et al*, 1969; Dunn and Kaltenbach, 1980; Richards *et al*, 1986; Houghton *et al*, 1989; Short *et al*, 1990).

Since variables like body condition and PPAI are only physiological responses in the animal, they can be co-generated rather than owing to a cause and effect (Short *et al*, 1990). Therefore caution must be exercised when interpreting correlation and regression analysis among variables. This does not decrease the importance of body condition scores as a way to monitor nutritional levels in reproductive management of beef breeding herds, but it highlights how relevant is the knowledge about the physiological mechanisms that mediate those effects.

Little is known about those mechanisms by which nutrition effects on reproduction are mediated (Rutter *et al*, 1989; Peters and Lamming, 1990; Richards *et al*, 1991; Schillo, 1992; Dunn and Moss, 1992). A number of studies have shown that body condition is related to mean LH plasma concentrations, with poor body condition being associated with lower LH plasma concentrations (Rutter and Randel, 1984; Wright *et al*, 1987; Wright *et al*, 1990; Perry *et al*, 1991; Wright *et al*, 1992). Prepartum and postpartum levels of dietary energy influence concentrations and pulse frequency of LH (Whisnant *et al*, 1985; Perry *et al*, 1991). Therefore, effects on the neuroendocrine control of LH secretion can possibly be one of the mechanisms whereby nutrition influences reproductive activity.

Low FSH levels caused by low dietary intake have also been associated with low LH plasma concentrations and promote a profound suppression of the hypothalamic-pituitary-axis (Terqui, 1985; Jolly, 1993). In the last case, the result would be a deep anoestrus. Nevertheless, FSH plasma concentrations were not decreased in poorly fed postpartum beef cows (Perry *et al*, 1991). Therefore, more consistent evidence is needed to draw further conclusions about the role of FSH in nutritionally deficient postpartum cows.

Impaired ovarian response to gonadotrophin was also suggested by Schillo (1992) as one of those mechanisms whereby low nutrition prolongs PPAI. However, there is evidence that the decreased LH release caused by impaired nutrition may be independent to the ovary (Richards *et al*, 1991) and undernutrition may directly influence hypothalamic and/or pituitary regulation of LH. The relation between nutrition and hypothalamic function is supported by the fact that hypothalamic response to oestradiol is altered by nutritional levels (Randel, 1990; Richards *et al*, 1991). Furthermore, the pituitary of underfed animals can be capable of responding to GnRH (Entwistle and Oga, 1977; Whisnant *et al*, 1985; Wright *et al*, 1990; Dunn and Moss, 1992). In addition, the hypothalamic content of GnRH is greater in those underfed animals than in adequately fed animals (Wright *et al*, 1990; Dunn and Moss, 1992). Therefore, inadequate nutrition probably inhibits reproduction by actions exerted on the hypothalamus causing a decrease in GnRH release rate (Dunn and Moss, 1992).

Impaired function of the hypothalamus-pituitary-ovarian axis in cows with poor body condition results in a smaller population of follicles at 5 weeks *post partum* (Prado *et al*, 1990), the occurrence of the first DF *post partum* delayed up to 90 days (Perry *et al*, 1991), the steroidogenic activity of follicles often impaired (Prado *et al*, 1990) and the size of those follicles diminished (Godke *et al*, 1990; Murphy *et al*, 1991; Thatcher *et al*, 1992) in comparison with good body condition animals.

Several theories and different metabolic signals and hormones have been proposed as physiological mechanisms whereby the female informs the central nervous system about its nutritional status. During negative energy balance Growth Hormone (GH) pulses increases (Rutter *et al*, 1989; Schillo, 1992) and serum concentrations of IGF1 (Rutter *et al*, 1989; Richards *et al*, 1991; Spicer *et al*, 1991; Schillo, 1992; Thatcher *et al*, 1992) and Insulin (Rutter *at al*, 1989; Schillo, 1992) decrease. All of these hormones were proposed as substances involved in the mechanism linking reproductive performance to nutritional status.

Serum concentrations of IGF1 change in relation to physiological status and nutrient availability (Rutter *et al*, 1989). Thus, increased glucose availability elevated IGF1 serum concentration (Rutter *et al*, 1989). Insulin-like growth factor 1 was suggested to be inversely related to PPAI in cattle (Schillo, 1992). In this sense, Nugent *et al* (1993) reported that serum concentrations of IGF1 at 3 weeks *post partum* is negatively related to PPAI in beef suckling cows only when feed supply in the non-lactational period is 0.71 MJ of ME/kg of liveweight$^{0.75}$ or less. Recently, other reports have also linked IGF1 with ovarian function (Spicer *et al*, 1991; Thatcher *et al*, 1992) since that hormone was considered critical to the development of ovarian follicles (Thatcher *et al*, 1992) and in the process of dominance, as mentioned in subsection 3.3. Glucose (Short and Adams, 1988) and Insulin (Schillo, 1992) have both been involved as nutritional signals influencing LH release. In addition, non esterified fatty acids (NEFA) and tyrosine serum levels were suggested to inhibit and to enhance LH secretion, respectively (Schillo, 1992).

The complexity of the neuroendocrine mechanisms makes it unlikely that only one of the substances acts as the factor responsible to mediate the nutritional effects on reproduction (Dunn and Moss, 1992). Thus, it is likely that the final release of LH is dependent on the cumulative effects of the balance between negative and positive stimuli on the hypothalamus.

Finally, it must be pointed out that the information presented in this subsection concerns dietary energy nutrition. However, successful reproduction is also dependent on other macro and micronutrients (Dunn and Moss, 1992). For instance, primiparous cows fed isocaloric diets (100% of National Research Council requirements) containing only 33% of the recommended crude protein during 150 days *pre partum* and 40 days *post partum* had longer PPAI and interval from calving to conception than those cows fed an adequate protein level (Sasser *et al*, 1988). Nolan *et al* (1988) studied the effects of low crude protein intake on the hypothalamic-pituitary-ovarian axis. These authors suggested that longer PPAI in cows deficient in crude protein was due to reduced gonadotrophin release and decreased pituitary responsiveness to GnRH. The LH pulse frequency by day 60 after calving in the adequately fed cows was twice that in crude protein deficient cows (Nolan *et al*, 1988).

2.4.2 Suckling

Suckling has an inhibitory effect on return to oestrus *post partum* (Short *et al*, 1972; Wetteman *et al*, 1978; Carruthers and Hafs, 1980; Egerton, 1980; LaVoie *et al*, 1981; Peters and Ball, 1987; Short *et al*, 1990; Williams, 1990). Removing calves at birth shortened the PPAI, even though nutrient intake was adjusted for lactation status (Short *et* *al*, 1972; LaVoie *et al*, 1981). Early work reported that postpartum suckling cows come into heat later than postpartum milked cows (Clapp, 1937; Wiltbank and Cook, 1958). PPAI was approximately 30 days longer in Shorthorn suckled cows than in Shorthorn milked cows (Wiltbank and Cook, 1958). Furthermore, considerably greater variation in the length of PPAI is observed in suckling cows than in milked cows (Peters and Ball, 1987).

Increasing the suckling intensity of beef breeding cows increases PPAI and spreads out calving patterns since cows rearing their calves had a PPAI of 67 days, while the first postpartum oestrus did not occur until 95 days after calving in those cows that suckled two calves (Wetteman *et al*, 1978). Thus, suckling is considered a major factor determining the length of PPAI and reproductive performance in beef breeding herds (Short *et al*, 1990).

The effect of suckling on PPAI is mediated by lower LH plasma concentration since suckling inhibits the release of that hormone in postpartum cows (Short *et al*, 1972; Carruthers and Hafs, 1980; Walters *et al*, 1982; Edwards, 1985; Peters and Lamming, 1990). This reduction in pulsatile release of LH cannot be achieved by mechanical stimulation of the teat (Williams *et al*, 1984). However, the specific exteroceptive stimuli required to produce such suppression are not well-defined (Williams *et al*, 1984, 1987; Vicker *at al*, 1993).

Presence of the udder in postpartum non-suckled cows itself extends the PPAI (Short *et al*, 1972). In addition, the presence of the calf itself can prolong PPAI in non-suckled cows (Macmillan, 1983; Vicker *et al*, 1993). Mastectomized cows with unrestricted calves had longer PPAI than those mastectomized cows with calves removed or restricted in such a way that the inguinal region was not stimulated (Vicker *et al*, 1993). In addition, the PPAI of milked cows with muzzled calves was 22 days longer than for their twin mates, which had calves removed 72 h after calving (Macmillan, 1983). Although the specific area of the cow that transduces the suckling signal is unknown (Vicker *et al*, 1993), these data suggest that the calves somehow stimulate the inguinal region, which is enough to trigger the mechanism whereby suckling extends PPAI.

Suckling suppresses the hypothalamic GnRH secretion (Peters and Lamming, 1990). This suppression is supported by reports suggesting that suckling inhibits the neural elements responsible for the release of GnRH (Parfet *et al*, 1986; Malven *et al*, 1986). Naloxone, an opioid antagonist, administrated to postpartum suckled cows increased mean plasma concentrations of LH (Whisnant *et al*, 1986; Gregg *et al*, 1986; Myers *et al*, 1989). Therefore, there is strong evidence indicating that suckling suppresses the release of LH through the endogenous opioid peptides mechanism (Whisnant *et al*, 1986; Gregg *et al*, 1986; Myers *et al*, 1989; Williams, 1990; Cosgrove *et al*, 1993).

The role of endogenous opioid peptides in the PPAI appears to vary with time post partum (Whisnant *et al*, 1986; Cosgrove *et al*, 1993). Endogenous opioid peptides concentrations in the nervous system may be higher during the early postpartum period (Whisnant *et al*, 1986). This finding can explain the different phases of PPAI mentioned in previous the section.

Calf removal increases mean plasma concentrations of LH and (or) LH pulse frequency 24 to 48 h after separation (Troxel *et al*, 1980; Walter *et al*, 1982; Edwards, 1985; Whisnant *et al*, 1985; 1986; Williams *et al*, 1987; Wright *et al*, 1987; Myers *et al*, 1989) and decreases concentrations of propiomelanocortin, a precursor of B-endorphin, 72 h after removal (Byerley *et al*, 1993). B-endorphin has been identified as the primary opioid peptide regulating LH secretion (Byerley *et al*, 1993).

Therefore, suppression of suckling in postpartum cows is a management approach consistent with the apparent physiological mechanism inhibiting postpartum rebreeding. Suppression of suckling can be carried out and be permanent, partial or temporary. Permanent suppression involves early weaning. Weaning of calves before the planned start of mating (34 to 76 days-old) decreased PPAI and interval from calving to conception (Laster *et al*, 1973). However, this management practice has high cost and intensive labour because calves have to be artificially fed (Williams, 1990), and therefore can be considered unpractical under many farm conditions.

Suckling can also be manipulated by partial or temporary weaning. Partial weaning consists of a restriction in suckling activity to once or twice per day. This management practice has been reported to be effective to decrease PPAI (Randel, 1981; Montgomery, 1982; Bastidas *et al*, 1984; Hill and Godke, 1987; Bluntzer *et al*, 1989; Tegegne *et al*, 1992) and to increase pregnancy rate in postpartum beef cows (Odde *et al*, 1986; Bluntzer *et al*, 1989; Tegegne *et al*, 1992). The effects of partial weaning on reproductive performance of beef breeding cows are showed in Table 2.3. Partial weaning can increase labour on the farm and once or twice daily suckled calves can also be lighter at weaning (Montgomery, 1982; Hill and Godke, 1987).

Temporary weaning, on the other hand, comprises 48 or 72 h calf removal or temporary restriction of suckling by fitting muzzles or nose plates to calves. It has been reported that temporary weaning reduces PPAI (Holness *et al*, 1978; Leimester and Drake, 1978; Smith *et al*, 1979; Tervit *et al*, 1982; Dunn *et al*, 1985; Odde *et al*, 1986), increases pregnancy rate (Geymonat, 1985; Odde *et al*, 1986; Orscasberro, 1991) and concentrates calving patterns

Table 2.3 Effect of once- or twice-daily suckling on reproductive performance in cattle

Authors (country)	Treatments[1]	Number of Animals	Parameter[2]			Comments
			PPAI	ICC	% Preg.	
Carruthers and Hafs, 1980 (U.S.A.)	Non-suckled and milked at 12 h intervals (since 2 dpp)	5	39			Multiparous Holstein cows
	Non-suckled and milked at 6 h intervals (since 2 dpp)	5	45			
	Suckled and milked at 12 h intervals (since 2 d pp)	6	50			
Randel, 1981 (U.S.A.)	30 min once daily suckling (since 30 d pp)	19	69			Primiparous Brahaman x Hereford cows
	Control Group	16	168			
Montgomery, 1982 (New Zealand)	60 min once daily suckling (since calving)	37	64			Adult Angus and Friesian x Angus cows
	60 min twice daily suckling (since calving)	39	67			
	Control Group	38	75			

Bastidas *et al*, 1984 (Venezuela)	Twice daily suckling (since 30 dpp)	42	58			Adult first-calvers Brahaman
	Control Group	34	77			
Odde *et al*, 1986 (U.S.A.)	Once daily suckling during 24 days (since 11 days before PSM)	57	52	77	93	Polled Hereford and Simmental crossbreeds
	Twice daily suckling during 24 days (since 11 days before PSM)	56	53	81	93	
	Control Group	56	55	78	82	
Hill and Godke, 1987 (U.S.A.)	90 min once daily suckling (from 21 to 28 dpp)	12		46	58	Primiparous cows
	Control Group	14		54	50	
	90 min once daily suckling (from 21 to 28 dpp)	12		28	100	Adult cows
	Control Group	11		39	91	

(1) dpp = days post partum; PSM = planned start of mating.

(2) PPAI = postpartun anoestrum interval; ICC = interval from calving to conception.

(Lesmeister and Drake, 1978; McCarthey *et al*, 1990) in beef breeding cows. Although results varied in different trials, temporary weaning increased pregnancy rates by on average 14% in several trials (Orscasberro, 1991). Tables 2.4 and 2.5 show the effects of short-term calf removal and fitting nose plates on reproductive performance, respectively. As can be seen, there are some trials which showed no improvements in reproductive performance after temporary weaning of calves (Lishman and Harwin, 1985; Wright *et al*, 1987; Warren *et al*, 1988; Makarechian and Arthur, 1990).

Although negative effects of temporary weaning on mothering up (Lesmeister and Drake, 1978), health of calves (Leimester and Drake, 1978; Dunn *et al*, 1983; Makarechian and Arthur, 1990) or weaning liveweight of calves (Beck *et al*, 1979; Galloway *et al*, 1979; Dunn *et al*, 1985; Wetterman *et al*, 1986, Warren *et al*, 1988; Makarechian and Arthur, 1990) were not observed in many trials, a reduction in weaning liveweight of calves has been reported in others (Tervit *et al*, 1982; McCarthey *et al*, 1990). The reduction in liveweight gain of calves can offset any advantage in reproductive performance in the cows achieved by temporary weaning.

The conflicting reports in the improvement of reproductive performance and the effect on calf performance caused by suckling manipulation have prevented a wider use of these techniques. Length of period of suckling removal, timing of removal (days *post partum*), optimum nutritional level at which suckling manipulation is effective, class of livestock (e.g. age and parity) and genotype of the cow (e.g. high or low potential for milk production) are some of the factors accounting for these conflicting results. These factors need to be more precisely defined in order to efficiently apply alternative management systems to optimize reproductive performance in beef breeding herds.

Table 2.4 Effect of temporary calf removal (CR) on reproductive performance in cattle.

Authors (country)	Treatments(1)	Number of Animals	Parameter(2)			Comments(3)
			PPAI	ICC	% Preg.	
Leal and Borba(*), 1978 (Brazil)	72 h CR at PSM	40	88		68	Hereford cows
	Control Group	38	73		53	
Beck *et al*, 1979 (U.S.A.)	48 h CR (50-80 dpp)				40	Hereford cows %preg at 10 d after CR
	Control Group				27	
Pampillo *et al*(*), 1982 (Argentina)	72 h CR at PSM (48 dpp)	34			21	%preg at 45 d after A.I.
	Control Group	34			6	
Pampillo *et al*(*), 1982 (Argentina)	72 h CR at PSM (68 dpp)	31			90	%preg at 45 d after A.I.
	Control Group	31			71	
Tervit *et al*, 1982 (New Zealand)	48 CR (35 dpp)	94	56	72		Mixed breed and age cows & heifer
	48 CR (42 dpp)	93	59	76		
	Control Group	91	62	78		
Tervit *et al*, 1982 (New Zealand)	48 CR (44 dpp)	209	77	81		Mixed breed and age cows & heifer
	Control Group	214	82	83		

Dunn *et al*, 1983 (U.S.A.)	72 h CR (30-32 dpp)		60			Angus, Simmental & Charolais cross bred cows
	Control Group		77			
Sawyer & Carrick, 1984, (Australia)	48 h CR (55-60 dpp)	15	78			First calvers Wokalups cows
	Control Group	20	56			
Sawyer & Carrick, 1984, (Australia)	48 h CR (35 dpp)	200	46			Mature crossbred cows
	Control Group	200	52			
Dunn *et al*, 1985 (U.S.A.)	72 h CR (30-32 dpp)	13	55			Angus, Simmental & Charolais cross breed mixed age cows
	Control Group	9	77			
Fogwell *et al*, 1986 (U.S.A.)	48 h CR (after PGF2)	221			60	Mixed age & crossbred cows
	Control Group (after PGF2)	256			57	
Wettemann *et al*, 1986 (U.S.A.)	48 h CR (58 dpp)	60-90		90	78	Different breeds & locations
	Idem + flushing	60-90		89	73	
	Control Group	60-90		92	77	
Warren *et al*, 1988 (U.S.A.)	48 h CR (2 d before PSM)		47		82	Multiparous Angus & cross
	Control Group		42		81	

(Continue)

Table 2.4 Effect of temporary calf removal (CR) on reproductive performance in cattle (Continued).

Authors (country)	Treatments(1)	Number of Animals	Parameter(2)			Comments
			PPAI	ICC	% Preg.	
Makarechian & Arthur, 1990 (Canada)	48 h CR at PSM	160	76		84	very good BC Crossbred cows
	Control Group	163	75		79	
McCartney *et al*, 1990 (Canada)	48 CR at PSM	120		72		Angus x Heref & Simm x Heref
	Control Group	122		74		
McCartney *et al*, 1990 (Canada)	48 CR at PSM	119		75		Angus x Heref & Simm x Heref
	Control Group	107		80		
Andrade *et al*, 1991 (Brazil)	26 h CR every 30 d		92			Nelore Cows
	Control Group		96			

(*) Extracted from Geymonat, 1985.
(1) PSM = planned start of mating.
(2) PPAI = postpartum anoestrus interval; ICC = interval from calving to conception.
(3) BC= body condition.

Table 2.5 Effect of suckling manipulation by fitting nose plates (NP) to calves on reproductive performance in beef herds

Authors (country)	Treatments(1)	Number of Animals	Parameter(2)			Comments
			PPAI	ICC	% Preg.	
Leal & Borba(*), 1978 (Brazil)	6 d NP at onset of PSM & 3 d NP 30 d after	36			75	Hereford cows
	Control Group	38			53	
Da Rosa & Leal(*) 1979 (Brazil)	7 d NP	30			70	
	10 d NP	30			62	
	13 d NP	30			82	
	Control Group	30			33	
Geymonat, 1986 (Uruguay)	3 d NP at onset of PSM	54			80	Hereford mixed age cows
	Control Group	54			30	
Orscasberro *et al*, 1990 (Uruguay)	11 d NP at onset of PSM	11			82	
	Control Group	11			45	calvers

(*)Extracted from Geymonat, 1985.
(1)PSM = planned start of mating.
(2) PPAI = postpartum anoestrum interval; ICC = interval from calving to conception.

The duration of suckling suppression is a critical factor since it affects the extension and magnitude of the LH response in the cow (Williams *et al*, 1987) as well as the degree of stress caused by this practice. A linear increase in LH pulse frequency was observed between day 0 and 4 after suckling removal (Williams *et al*, 1987). Thus, short-term calf removal (e.g. 48 h) may not be sufficient to cause increases in LH release and/or the LH response to temporary weaning may not be high enough as to promote ovulation. Stressful conditions as consequence of applying techniques of suckling manipulation could weaken responses. The LH response to naloxone injections was impaired in cows that had elevated serum cortisol (Whisnant *et al*, 1986; Gregg *et al*, 1986). Elevated cortisol concentrations could also impair responses to temporary weaning. Long suckling removal periods can be more stressful for calves and impair calf liveweight gains and calf weaning weights. Therefore, there must be a compromise between the time of suckling removal needed to cause a LH response consistent with ovulatory activity and the period of time at which calves are exposed to irrecoverable liveweight loss.

The fitting of nose plates to calves could reduce stress caused by suckling removal because the dam-calf bond is not broken. However, as was mentioned above, the presence of the calf can itself prolong PPAI in cows, which would therefore reduce the effectiveness of the temporary weaning. Nevertheless, the increase in LH pulse frequency was also elicited in postpartum beef cows by fitting muzzles to their calves (Williams et al, 1987). More research is needed to estimate the relative importance of these conflicting results when trying to apply those management practices to farm conditions.

A more precise definition of the timing of suckling removal is important. Little advantage would be obtained if cows were in the first phase of PPAI, when pituitary LH concentrations are low and/or there is no DF in the ovary. Little information is available on the effect of temporary weaning on reproductive performance and ovarian follicles. Furthermore, timing of suckling removal can also be important in determining the impact of that management practice on liveweight gain of calves. If calves are too young, they are likely to be more dependent on milk as a main source of feed and therefore calves would not be able to greatly compensate through a more intense grazing activity or eating any other source of feed on offer.

Temporary weaning was reported to be effective in Mashona but not in Africander cows (Holness *et al*, 1978). In addition, it was reported that temporary weaning in first-calving heifers does not have as much beneficial effects as in older cows (Tervit *et al*, 1982; Geymonat, 1985). Whether those effects are only results of particular environmental factors further affecting a particular genotype or class of livestock or there are actual differences in the responses given by intrinsic physiological mechanisms is unknown.

Finally, the effects of suckling and nutrition seldom act independently (Williams, 1990). Calf removal reduced PPAI in those cows with good body condition but not in those with poor corporal condition (Dunn *et al*, 1983; Geymonat, 1985). Therefore, the beneficial effects of suckling manipulation can depend upon minimum body energy reserves in postpartum beef cows. However, reproductive performance was not affected by temporary calf removal in cows with very good body condition (Warren *et al*, 1988). In addition, suckling also interacts with season. The negative influence of suckling on PPAI was not as great among summer-calving cows than among winter-calving cows (Hauser, 1984). Therefore, the environmental conditions at which the beneficial effects of suckling manipulation are more likely to be obtained also needs to be more accurately defined.

2.4.3 Season

Season has an important effect on the length of the PPAI and reproductive performance of beef suckling herds. It has been reported that beef breeding cows that calve later in the calving season have shorter PPAI (Bellows and Short, 1978; Morris *et al*, 1978; Knight and Nicoll, 1978; Montgomery et al, 1980; Short et al, 1990). For each day later in the season that a cow calved, the PPAI was reduced between 0.4 (Knight and Nicoll, 1978) and 1.05 (Morris *et al*, 1978) days in adult cows and 0.7 days in primiparous cows (Knight and Nicoll, 1978) calving in spring. This effect was not found in autumn-calving herds (Montgomery et al, 1980).

In the Northern Hemisphere, PPAI of cows calving between November 1 and April 30 was longer (70.8 days) than PPAI of those calving between May 1 and October 31 (35.9 days) (Peters and Riley, 1982b). PPAI is longer in spring-calving herds than in autumn-calving herds (Montgomery et al, 1980; Montgomery, 1985; Montgomery and Davis, 1987). As a consequence, calving patterns are likely to be naturally more concentrated in autumn than in spring (Montgomery and Davis, 1987). In those herds calving all year around the longest PPAI is likely to occur in winter and the shortest in summer (Hauser, 1984; Montgomery, 1985).

Peters and Riley (1982b) found a highly significant negative correlation between the photoperiod one month before calving and the length of the PPAI. It has been suggested that the effect of photoperiod are mediated via the pineal gland since injection of melatonin increases PPAI (Short et al, 1990). In addition, the first DF after calving occurred 7 days *post partum* in autumn-calving milked cows compared to 20 days in spring-calving milked cows (Savio et al, 1990).

The effect of calving date on PPAI appears to be more important in primiparous than in mature cows (Knight and

Nicoll, 1978). Season also interacts with other environmental factors to influence the length of the PPAI (Hauser, 1984; Montgomery, 1985). Thus, the nutritional effects on PPAI are much greater in early compared with late calving cows (Montgomery, 1985). As was mentioned in the previous subsection, suckling will negatively suppress resumption of oestrous activity *post partum* more consistently in late winter-early spring calving cows than in cows calving in other seasons such as summer. Furthermore, season is more likely to influence PPAI in high milk producing than in low milk producing dams (Hauser, 1984).

It must be pointed out that under pastoral farming systems in temperate regions, those beef breeding herds calving in late winter-early spring are also likely to be subject to low feed supply since seasonal increase in pasture growth does not occur until later in the season. This particular low nutritional level combines with the seasonal effect to lengthen the PPAI in suckled beef cows.

2.4.4 Genotype

Differences in the length of PPAI are also likely to be influenced by breed and genotype (Short *et al*, 1990). When dairy cows are suckled they normally have longer PPAI than suckled beef cows (Short *et al*, 1990). However, Knight and Nicoll (1978) reported that mature Friesian and Friesian crossbred cows have shorter PPAI than Angus cows under New Zealand hill country conditions. This situation is reversed for primiparous cows.

Nugent *et al* (1993) studied the effects of biological type and nutritional environment on length of PPAI. The authors found a significant interaction between energy availability x biological type. Increased energy availability decreased PPAI in all biological types, but the effect was greater in high potential growth biological genotype cows. In addition, lower energy dietary intakes were less detrimental for PPAI in genotypes with high genetic potential for milk as well as growth than in those breeds only selected for growth (Nugent *et al*, 1993). However, the intrinsic mechanism whereby genotype affects the length of PPAI remains unknown (Short *et al*, 1990).

Finally, there is some evidence that the genotype of the calf can also affect PPAI. Short *et al* (1990) stated that fast-growing, larger calves and those calves consuming more milk have dams with longer PPAI.

2.4.5 Parity

Primiparous cows have longer PPAI than multiparous cows (Tervit *et al*, 1977; Knight and Nicoll, 1978; Short *et al*, 1990). Younger cows have longer PPAI than older cows (Wiltbank *et al*, 1962; Wiltbank, 1970; Short *et al*, 1990). Dziuk and Bellows (1983) indicated that young cows suckling their first calf have a PPAI 15 to 25 days longer than in adult dams.

First-calving heifers have additional nutritional demand for maternal growth, which results in greater feed requirement compared with mature cows (Sawyer and Carrick, 1984; Lowman, 1985), but they are often managed together with adult cows. As a consequence, the pregnancy rate of primiparous cows is lower than that in multiparous cows (Bellows *et al*, 1982; Doonorbos *et al*, 1984; Bellows *et al*, 1988). The effect of prepartum nutrition on PPAI and overall reproductive performance is also likely to be more relevant in primiparous than multiparous cows (Bellows *et al*, 1982).

2.4.6 Dystocia

Dystocia is associated with longer PPAI and delayed postpartum conception (Laster *et al*, 1973; Peters and Ball, 1987; Short *et al*, 1990). Moreover, those dams having shorter duration of stage II of parturition (Roberts, 1986) had higher pregnancy rates and more concentrated calving patterns (Doornbos *et al*, 1984; Bellows *et al*, 1988). Thus, cows that received early obstetrical assistance at calving had improved reproductive performance in the subsequent breeding season (Bellows *et al*, 1988).

Cows nursing male calves have longer PPAI (Bellows *et al*, 1982; Doornbos *et al*, 1984; Bellows *et al*, 1988) and lower pregnancy rate than those dams nursing female (Bellows *et al*, 1982; Doornbos *et al*, 1984). Cows nursing males calves had a PPAI of 78 days, compared with cows nursing female calves which had intervals from calving to oestrus of 70 days (Bellows *et al*, 1982). This effect of sex of the calf can possibly be a consequence of greater calving difficulty with males calves (Bellows *et al*, 1971; Rovira 1973) or higher milk production obtained from their dams by males calves (Reynolds *et al*, 1978) and hence increased suckling activity.

The physiological mechanism whereby the effect of length of stage II of parturition on PPAI is mediated is not clear. Doornbos *et al* (1984) hypothesized that prolonged labour at calving can result in exhaustion of the dam at calving. This exhaustion would somehow impair the subsequent reproductive performance of the cow. Assistance at calving could be profitably implemented in those countries where labour is not too expensive. Extra supervision at calving also reduces the percentage of calf and dam mortality under grazing conditions (Hodge *et al*, 1982). All those factors should be taken into account when evaluating the economic feasibility of implementing assistance at calving in commercial beef breeding herds.

2.4.7 Biostimulation

Presence of mature teaser bulls (Macmillan *et al*, 1979; Zalesky *et al*, 1984; Naasz and Miller, 1990; Stumpf *et al*; 1992; Burns and Spitzer, 1992; Cupp *et al*, 1993; Fernandez *et al*, 1993), yearling bulls (Cupp *et al*, 1993) or androgenized cows (Burns and Spitzer, 1992) can stimulate the resumption of ovarian cyclicity *post partum* in suckled beef cows. Biostimulation shortened PPAI by 9 to 21 days in mature beef cows (Burns and Spitzer, 1992; Zalesky *et al*, 1984; Stumpf *et al*, 1992; Cupp *et al*, 1993). In addition, biostimulation is elicited not only in multiparous but also in primiparous suckling cows (Gifford *et al*, 1989; Custer *et al*, 1990; Fernandez *et al*, 1993). In this class of livestock, the PPAI was shortened 16 to 18 days and subsequent calving pattern is concentrated (Gifford *et al*, 1989; Fernandez *et al*, 1993). The effect of biostimulation on the length PPAI can be seen in Table 2.6.

Research into biostimulation has largely been conducted under grazing conditions but most authors were unspecific about the size of the paddocks where the male effect was exerted. The bull:cow ratio has varied from 1:10 (Monje *et al*, 1985; Alberio *et al*, 1987) to 1:29 (Burns and Spizer, 1992), although some authors did not specify any ratio (Gifford *et al*, 1989; Naasz and Miller, 1990). No authors mentioned libido or servicing capacity differences between bulls and its relationship with the effect on PPAI. However, the presence of testosterone-treated cows induced a mean PPAI which was not different to that elicited by epididymectomized bulls (Burns and Spitzer, 1992).

The technique to sterilize males varied from vasectomy (Macmillan *et al*, 1979; Alberio *et al*, 1987; Gifford *et al*, 1989), epididymectomy (Cupp *et al*, 1993; Stumpf *et al*, 1992; Naasz and Miller, 1990; Fernandez *et al*, 1993) or epididymectomy and deviation of penile (Burns and Spitzer,

Table 2.6 Effect of biostimulation on postpartum anoestrous interval (PPAI) in suckled beef cows.

Authors	Treatments[1]	No	PPAI	Comments[2]
Alberio *et al*, 1987 (Argentina)	Exposed to bulls 10 d pp	10	56	Angus crossbred cows. R 1:10 BC non-specified Grazing conditions
	Control Group	9	67	
Burns & Spitzer, 1992 (U.S.A.)	Exposed to bulls within 72 h pp	54	44	Brangus, Angus and crossbred cows. R less than 1:29 BC > 5 (1-9 score)
	Control Group	54	52	
	Exposed to testosterone-treated cows within 72h pp	39	41	
	Control Group	39	52	
Cupp *et al*, 1993 (U.S.A.)	Exposed to mature bulls from 7 d pp	154	60	Mixed age crossbred cows. R 1:17 BC non-specified Grazing conditions
	Exposed to 1-year old bulls from 7 d pp	152	62	
	Control Group	158	72	
Fernandez *et al*, 1993 (U.S.A.)	Exposed to bulls continuously from 72 h pp	18	47	Angus x Hereford first-calving cows. R 1:19 BC 5.5 (1-9 score) Grazing conditions
	Exposed to bulls for the first 30 d pp	17	51	
	Exposed to bulls after the first 30 d pp	16	51	
	Control Group	18	65	
Gifford *et al*, 1989 (Australia)	Exposed to bulls from 3 to 85 d pp	62	31	Hereford and crossbreds adult cows. R and BC non-specified Grazing conditions
	Control Group (cows exposed to bulls from 55 to 85 d pp)	55	32	

(Continue)

Table 2.6 Effect of biostimulation on postpartum anoestrous interval (PPAI) in suckled beef cows (Continued).

Authors	Treatments[1]	No	PPAI	Comments[2]
Gifford *et al*, 1989 (Australia)	Exposed to bulls from 3 to 120 d pp	48	46	Angus primiparous cows. R and BC non-specified Grazing conditions
	Control Group (exposed to bulls 58 to 120 d pp)	50	62	
Monje *et al*, 1985 (Argentina)	Low pp nutrition exposed to bulls 30 d pp	10	146	Multiparous Angus and crossbreds R 1:10
	High pp nutrition exposed to bulls 30 d pp	10	65	
	Low pp nut control	10	132	
	High pp nut control	10	85	
Naasz & Miller, 1990 (U.S.A.)	Exposed to bulls within first week pp to PSM. Year 1	37	42	Angus, Simmental, Hereford. BC 6 (1-9 score) R non-specified
	Control Group	35	58	
	Exposed to bulls within first week pp to PSM. Year 2	20	46	
	Control group	21	56	
Stumpf *et al*, 1992 (U.S.A.)	Moderate BC cows exposed to bulls	44	44	Crossbred adult cows. Moderate BC 4.9. Good BC 5.9 (1-10 score). R 1:20 Grazing conditions
	Control Group	44	58	
	Good BC cows exposed to bulls	42	44	
	Control Group	42	50	

(Continue)

Table 2.6 Effect of biostimulation on postpartum anoestrous interval (PPAI) in suckled beef cows (Continued).

Authors	Treatments(1)	No	PPAI	Comments(2)
Zaleski *et al*, 1984 (U.S.A.)	Exposed to bulls from 3 to 85 d pp Year 1	45	43	Mature Hereford and Hereford x Angus. R 1:20 BC non-specified
	Control Group	39	63	
	Exposed to bulls from 3 to 85 d pp Year 2	35	39	
	Control Group	36	61	

(1) d pp = days *post partum;* PSM = Planned start of mating.
(2) R = bull:cow ratio; BC = body condition; nut = nutrition.

1992), and does not appear to elicit any difference in results.

As can be seen from Table 2.6 the timing of exposure to biostimulation post partum does not seem to be important. Although in most trials the biostimulation was exerted within a few days after calving (Zalesky *et al*, 1984; Gifford *et al*, 1989; Naasz and Miller, 1990; Burns and Spitzer, 1992; Stumpf *et al*, 1992). Macmillan *et al* (1979) reported that the presence of the bull for 18 to 21 days before the start of the breeding season was associated with a significant increase in the amount of suckled beef cows subsequently detected in heat. Therefore, control groups used by some researchers to study the effect of biostimulation on PPAI may have also been exposed to the stimulus (Table 2.6). Note also that any research on PPAI and postpartum rebreeding that uses teaser bulls as an aid to heat detection is also exposing cows to biostimulation and therefore PPAI would be underestimated in those conditions.

The physiological explanation and mechanism involved in biostimulation remain unknown (Burns and Spitzer, 1992; Fernandez *et al*, 1993). Pheromones from the male were suggested as substances mediating this effect (Zaleski *et al*, 1984; Burns and Spitzer, 1992; Stumpf *et al*, 1992; Cupp *et al*, 1993). They would act on the vomeronasal organ in the female to provoke endocrine responses. However, the possibility of other auditory, visual or tactile stimuli can not be ruled out (Zaleski *et al*, 1984; Burns and Spitzer, 1992; Cupp *et al*, 1993). Stumpf *et al* (1992) suggested that the presence of bulls possibly elicited GnRH release. These authors also found that cows in lesser body condition are more responsive to biostimulation than are cows with higher body condition score. However, the presence of bulls failed to shorten the PPAI in postpartum cows in very poor body condition (Monje *et al*, 1985). Therefore, there exists an interaction between the bull effect and nutritional status

(Monje *et al*, 1985; Stumpf *et al*, 1992) but the extension of this interaction needs to be better defined.

Furthermore, the bull effect was found in a spring-calving herd but not in an autumn-calving herd (Macmillan *et al*, 1979), and in one year but not in another (Naasz and Miller, 1990). Even though it has been hypothesized that presence of the bull can have a stimulatory effect on PPAI when the interval to resumption of cyclicity is influenced by seasonal factors (Macmillan *et al*, 1979), the interaction between body condition and bull-effect cannot be ruled out in those cases.

As mentioned in other subsections for other management practices, a better definition of the environmental factors limiting the effectiveness of biostimulation is needed. Particularly, it is necessary to more precisely define the body condition at which the bull effect is likely to have the greatest response. Even though many authors were unspecific on the nutritional levels and body condition involved in their trials, data from Table 2.6 roughly suggest that responses can be obtained with cows calving in body condition varying between 4 to 5.5 (1-9 scale). More research is needed to confirm this suggestion and to evaluate the extension at which body condition can be decreased without impairing subsequent reproductive performance when cows are exposed to bulls.

2.4.8 Miscellaneous

PPAI can also be influenced by factors such as uterine palpation (Short *et al*, 1990) and feeding supplements such as monensin (Mason and Randel, 1982). This gives some support to field observations indicating that those postpartum cows submitted to veterinary rectal inspection are likely to come into heat sooner than herdmates which were not examined, even though treatment was not implemented. However, it is acknowledged that this effect is more subtle than those presented in former .subsections (Short *et al*, 1990). The addition of monensin to the diet shortened the mean interval PPAI by 46 days in Brangus cows (Mason and Randel, 1982). This effect would be mediated by changes in ruminal proportions of volatile fatty acids.

Finally, it must be always taken into account that organic dysfunction in the postpartum cows that cause long PPAI can be a consequence of a primary reproductive tract disease or secondary systemic problems (Hopkins, 1986; Peters and Ball, 1987). For instance, diseases such as placental retention, metritis or hydrops are related to longer PPAI (Hopkins, 1986). In addition, any other uterine disease can prolong that interval (Hopkins, 1986; Peters and Ball, 1987). Chronical debilitating disease affecting the herd is also likely to be associated with longer PPAI (Hopkins, 1986). Therefore, an evaluation of the health status of the herd is important under practical conditions when trying to improve reproductive performance of beef breeding herds.

2.4.9 Clinical treatments

An infrequent GnRH pulse frequency and, consequently, low LH plasma concentrations were pointed out in section 3 as the most important mechanism mediating long PPAI in suckled beef cows. Therefore, therapy with GnRH and gonadotrophins has been attempted to overcome long PPAI. Different treatments reported by the literature are briefly discussed in this subsection.

GnRH was acknowledged as a drug that can regulate ovarian function in a manner that improves postpartum reproductive efficiency (Thatcher *et al*, 1993). As mentioned above, the number of receptors to GnRH and the pituitary responsiveness to GnRH is delayed in suckled compared to milked cows but it restored by 20 to 30 days after calving.

Therefore, maximum response to exogenous GnRH is elicited after 20 to 30 days *post partum* (Hopkins, 1986; Peters and Ball, 1987). Although therapy with this hormone has been used extensively (Hopkins, 1986; Roche *et al*, 1992), GnRH injection in postpartum cows brings about variable results (Peters and Ball, 1987; Roche *et al*, 1992; Thatcher *et al*, 1993). Failures in restoring oestrous cycles have been reported with GnRH therapy (Peters and Ball, 1987; Roche *et al*, 1992), though Hopkins (1986) indicated that single intramuscular injections of 250 *u*g result in a 50% ovulation rate in suckled beef cows that have palpable follicular structures at the time of treatment (Hopkins, 1986). In addition, a microencapsulated GnRH agonist administrated at day 5 *post partum* and releasing 15 *u*g of the drug per day for 30 days shortened PPAI 12 days but it was not effective in reducing the interval from calving to conception (Roberge *et al*, 1992).

The positive effects of GnRH therapy would be more obvious in those herds experiencing periparturient disorders (Thatcher *et al*, 1993). However, Roche *et al* (1992) suggested that body condition of cows and follicular structures at the time of treatment have been major factors affecting the response to GnRH supplementation. The importance of follicular status is highlighted in a trial where the injection of 20 *u*g of GnRH to suckled beef cows during the growing phase of the first DF resulted in 100% of ovulatory response (Roche *et al*, 1992). While the control cows had a mean interval to first ovulation of 27 days, the treated cows had an interval of 16 days. Although, there were more cows having short cycles after first ovulation in the treated than in the control group, these data suggest that GnRH does ovulate a DF as identified by ultrasound (Roche *et al*, 1992).

Those authors suggested that progesterone therapy can overcome lack of expression of oestrus and occurrence of short cycles following first ovulation. This hormone suppresses the release of LH and once progesterone therapy is withdrawn, plasma LH concentration increases culminating in a pre-ovulatory LH surge in those animals that respond (Peters and Ball, 1987). Progesterone or progestagen therapy would mimic the first progesterone rise *post partum* (Hopkins, 1986; Peters and Ball, 1987). The treatment with Syncro-Mate B, which comprises a 6 mg norgestomet ear implant with injection of 3 mg of norgestomet plus 5 mg oestradiol valerate is used in beef cows (Geymonat, 1985; Hopkins, 1986). Oestradiol is used to initiate luteolysis in case a corpus luteum is present (Hopkins, 1986; McMillan and Macmillan, 1989). The implant is removed 9 days later and the best results are obtained when it is combined with 48 h calf-removal (Geymonat, 1985; Hopkins, 1986). The response to this treatment is also considered dependent on the nutritional status of the dams (Hopkins, 1986).

Others forms of progesterone treatment have also been reported. For instance a progesterone releasing intravaginal device (PRID) and a controlled internal drug release device (CIDR^{TM}) containing progesterone have both been reported to be effective in overcoming anoestrus in cattle (Peters and Ball, 1987; McMillan and Macmillan, 1989; Macmillan and Peterson, 1993). The currently recommended treatment for the form of postpartum anestrus commonly diagnosed in New Zealand dairy cows is to insert a CIDR device for 7 days and then inject 400 to 600 IU of pregnant mares serum gonadotrophin (PMSG) at CIDR removal (Macmillan and Peterson, 1993).

In suckled beef cows, treatment intervals of 14 to 21 days were recommended with CIDR devices (McMillan and Macmillan, 1989). It has been reported that the use of a gonadotrophin may not be essential in beef cows if the anoestrous condition, as a consequence of suckling, is not confounded by under-nutrition (Macmillan and Peterson, 1993). This observation is based on results reported by McMillan and Macmillan (1989) where pregnancy rates in treated animals to a 4 day mating following CIDR withdrawal were similar in the 0 to 400 IU PMSG group (55% vs 56%). In this trial, CIDR treatment was effective at concentrating subsequent calving patterns. Caution must however be focused when interpreting these data, since the percentage of anoestrous cows before the onset of treatment was not specified. Twelve-day treatment with PRID resulted in ovulation in about half of the beef cows (Peters and Ball, 1987). These authors indicated that the best success in induction of ovulation in beef cows can be achieved by injecting 750 IU of PMSG at the time of progesterone withdrawal.

In conclusion, equivocal results have been found in the literature about the effectiveness of a particular hormonal treatment for postpartum anoestrum in suckled beef cows. As in many of the management practices discussed earlier, variability among studies relative to the efficiency of treatments are related to unknown factors, However, chances of positive results after applying any treatment seems to be enhanced if cows are healthy, their nutritional level is adequate and follicular structures (particularly DF) are identified. Thus, therapy with drugs cannot profitably correct poor reproductive and nutritional management.

2.5 Purpose and scope of the investigation

Prolonged PPAI and ICC are major constraints to the achievement of high pregnancy rates and short and concentrated calving seasons. Primiparous cattle often show longer intervals than mature animals. Reduction of these intervals increases the reproductive performance in beef breeding herds.

The aims of the present experiment was to study the resumption of reproductive activity *post partum* in first-calving beef cows that had calved at either of two widely different liveweights and to make observations on the practical application of using nose plates to nursing calves to temporarily inhibit suckling and promote early resumption of ovarian cyclic activity and conception. The main observations made were:

1) The pattern of ovarian changes during the postpartum period using ultrasonography.

2) Determination of resumption of ovarian function and conception in heifers with and without temporary suckling removal.

3) The practical application and management benefit of nose plate devices to achieve inhibition of calf suckling and improvement of reproductive performance of first-calving heifers.

CHAPTER III: MATERIALS AND METHODS

3.1 Animals and Treatments

The experiment was conducted at Massey University's Sheep and Beef Cattle Research Unit, New Zealand, from August 1992 to January 1993. Twenty-three 2-year old Hereford x Friesian (HxF) and Simmental x Friesian (SxF) in-calf heifers were selected from a herd in August 1992. Data from two cow-calf pairs were excluded from the analysis due to calf death at different stages of the experiment for reasons unrelated to the treatments. The heifers had been inseminated with Angus semen in November 1991 after oestrus synchronization using Controlled Internal Drug Release (CIDR-B) devices plus oestrogen (Jellie, 1991).

Heifers were randomly allocated two pastures allowances, from day 120 to 210 of gestation. In the high nutritional (HN) treatment, heifers were managed for daily liveweight gains of 0.5 kg, whereas in the low nutritional (LN) treatment animals were at a maintenance feeding level. The HN group grazed a pre-grazing herbage mass of 2000 kg of DM/hectare down to 1000 kg of DM/hectare. The LN group was always grazed the paddock previously grazed by the HN animals. This management was continued until the end of the nutritional treatment, at approximately day 210 of gestation. Unfasted liveweights of heifers were recorded at 21 day intervals during the period from March to June. For the last 70 days of gestation, heifers were fed at maintenance levels, approximately 5 to 6 kg of DM/day.

Heifers started calving on 18 August. Dams were weighed immediately before and after calving. Calving assistance was scored according to Table 3.1. Calf birth weight and calf birth date were also recorded. Body condition score was recorded at the end of the nutritional treatment, at calving and fortnightly from calving to weaning. A body condition score was assessed on a scale of 1= emaciated to 5= extremely fat (Lowman *et al*, 1976).

Table 3.1 Observations (score) made on assistance given at calving.

Degree of Assistance when calving	Score
No Assistance	1
Minor Pulling (just pulling the calf if considered necessary)	2
Easy Pulling (with obstetric machine)	3
Hard Pulling (manual assistance and pulling the calf)	4
Substantial Assistance (Veterinary assistance, not Caesarean)	5
Caesarean Surgery	6

At 45 days *post partum*, heifers were randomly assigned within breed and nutritional treatment to either a restricted suckling (RS) or normal suckling (NS) group. Suckling was suppressed for 7 days by fitting nose plates[1] to calves in the RS group, whereas NS calves could suckle their mothers freely. Figures 3.1 illustrates the nose plate design. The nose plates consisted of plastic devices with points on its external and lower surface, which when calves attempt suckling causes discomfort to dams. When it is on, calves can graze but they are not able to suckle their mothers.

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[1] Walmur. Uruguay

Figure 3.1 Nose plates (Walmur, Uruguay) used on restricted suckling calves to temporarily inhibit the suckling activity.

During the restricted suckling period, RS and NS groups grazed in adjacent paddocks of similar botanical composition and herbage allowances. At the end of that period, RS and NS groups were managed together as one group again. Because there were heifers that calved later than the main herd, fitting of nose plates was carried out in two stages. The first one involved 9 calves, whereas the second stage involved 4 calves. Table 3.2 shows the different treatment groups in this experiment.

Table 3.2 Number of heifers allocated to treatment groups[1].

Crossbred Type[2]	Nutritional Level[3]	Restricted Suckling Treatment[4]	
		RS	NS
H x F	HN	3	4
	LN	2	2
S x F	HN	3	0
	LN	4	3
Total		12	9

1 Two heifers were removed from the experiment
2 HxF = Hereford x Friesian; SxF = Simmental x Friesian
3 HN = High nutrition; LN = Low nutrition
4 RS = Restricted suckling; NS = Normal suckling

3.2 Observations on Behaviour and Liveweight of Calves

Three hour observations of calf suckling behaviour were carried out before, during and after fitting nose plates in the older calves of both RS and NS groups (19 animals) (Table 3.3). Suckling or attempt to suckle (if calves had nose plates), idling and grazing activity were recorded at 10 minute intervals, from 6 to 9 a.m.. Comparisons between RS and NS calves' behaviour were then made. Observations were carried on for longer during the restricted suckling treatment period to detect any sign of distress or sickness in calves and heifers.

Table 3.3 Periods when observations of calves' behaviour were recorded.

Time	Date	Period
Pre-treatment	Oct 7	1
	Oct 9	2
During treatment	Oct 10	3
	Oct 11	4
	Oct 12	5
	Oct 13	6
	Oct 14	7
Post-treatment	Oct 17	8
	Oct 19	9
	Oct 21	10

Calves were weighed at approximately 15 days intervals from birth to weaning (December 14). Liveweight was also recorded immediately before and at the end of the restricted suckling treatment.

3.3 Ultrasonography

Ovarian structures were monitored by ultrasonography at weekly intervals from d 20 to approximately d 115 *post partum*. During the period of restricted suckling, two extra examinations were carried out two days after the start and three days before the end of the treatment. Only the 19 earliest calving heifers were included in these extra examinations.

To monitor ovarian follicular development the ultrasonic transducer was inserted rectally, moved along the dorsal surface of the reproductive tract for orientation and then moved laterally to scan each ovary. All ovarian images were recorded on video. Images were frozen and measurements of the largest follicle ≥ to 5 mm in each ovary were taken. The number of follicles ≥ 5 mm were recorded. When a corpus luteum (CL) was identified its size was also measured.

The ultrasonography was carried out with a transrectal real time ultrasound (Aloka, Echo Camera, Multicristal Scanner, Model SSD-210-DA, Japan) with a 5.0 megahertz probe.

3.4 Blood Sampling and Progesterone Assay

Blood samples were collected by tail venipuncture at weekly intervals from approximately d 18 until d 115 *post partum*. After this date, three extra samplings were taken at 10 day intervals. Blood samples in heparinized tubes were kept on ice until centrifugation, which was performed at 3000 r.p.m. and -4°C during 20 minutes within 3 to 4 hours after collection. Serum was stored at -20°C until hormone assay was performed.

Serum progesterone concentrations were determined using the radioimmunoassay validated by Kirkwood *et al* (1984). Assay sensitivity was 0.05 ng ml^{-1} and intra and inter-assay coefficients of variation were 11.98% and 13.45%, respectively. The assays were continued on individual basis until at least four consecutive samples were > than 1 ng/ml.

3.5 Reproductive Performance

Two entire Friesian bulls were introduced to the cows from d 20 *post partum*. Bulls were considered satisfactory for mating after breeding soundness examination. Heifers were tail painted (Macmillan and Curnow, 1977) and daily observations were carried out to detect oestrus. Bulls were removed from the herd on 5 January.

Uterine involution was studied following the procedure used by Moller (1970b). Thus, involution was considered complete when no further reduction in uterine size was observed in the subsequent weekly examination. Resumption of oestrous cycles of normal length was determined based on either of the two criteria: serum progesterone concentrations of above 1 ng ml^{-1} for two consecutive weeks or serum progesterone concentrations $\geq$ 2 ng ml^{-1} in a single sample, as used by Zalesky *et al* (1984) and Naasz and Miller (1990). The postpartum anoestrus interval (PPAI) was considered the period from calving to resumption of oestrus cycles.

Heifers were killed on March 8, 1993. At slaughter, the uterus was removed from the animal and identified. Once in the adjacent room, the gravid uterine horn was incised and the foetus removed. Crown-rump measurements were then taken as indicated in Figure 3.2. Conception dates were estimated based on the regression equation reported by Harris *et al* (1983), namely

$$Y = 54.6 + 2.46 (X)$$

where Y is fetal age in days for any given crown-rump length (X) in cm. The interval from calving to conception (ICC) was calculated as the difference between conception date and calving date.

3.6 Statistical Analysis

Main effects in the model were suckling (restricted and normal), prepartum nutrition (high and low) and dam crossbred (Hereford x Friesian and Simmental x Friesian). Data were analyzed by least-squares analysis of variance using the general lineal model procedure of the Statistical Analysis System (SAS, 1985).

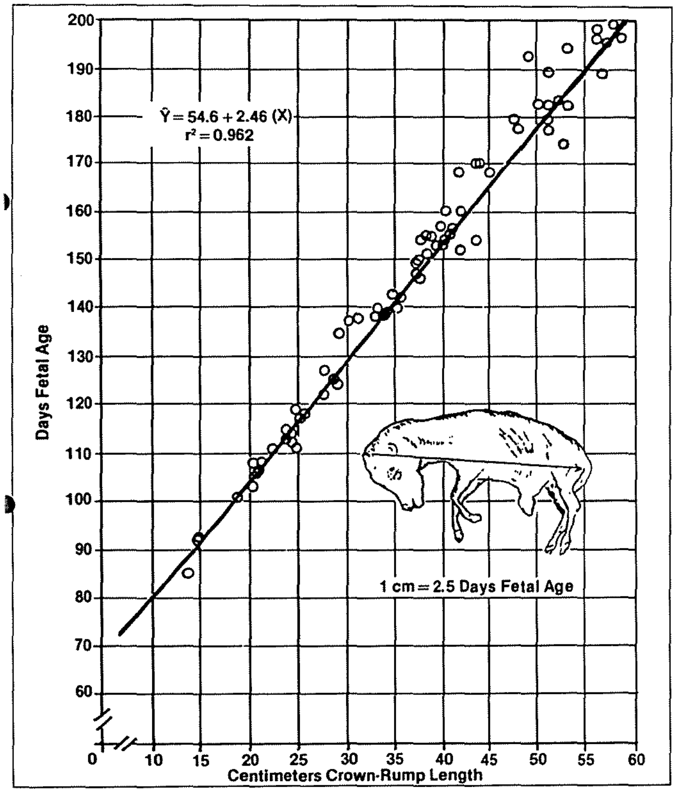

Fig. 2 — The linear relationships of fetal age to crown-rump measurements are shown.

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Figure 3.2 Crown-rump measurement and equation used in the present trial to estimate fetal age and conception date (extracted from Harris *et al*, 1983).

3.6.1 Postpartum intervals

Interactions that were not significant were deleted from the model and the model refitted. Postpartum anoestrus interval, PCLI and ICC data were analyzed using calving date as a covariate to adjust for differences in calving date. The model fitted for postpartum reproductive intervals was:

$$Y_{ijkl} = \mu+S_i+N_j+G_k+(SN)_{ij}+(SG)_{jk}+(NG)_{jk}+(SNG)_{ijk}+\beta_1\ CD_{ijkl}+e_{ijkl}$$

where:

Y_{ijkl} = an observation on the lth heifer belonging to the ith suckling treatment, jth nutritional level and the kth genotype;

μ = population mean;

S_i = the ith suckling treatment effect (i = 1,2);

N_j = the jth nutritional treatment effect (j = 1,2);

G_k = the kth genotype effect (k = 1,2);

$(SN)_{ij}$ = the interaction between the ith suckling treatment with the jth nutritional treatment;

$(SG)_{ik}$ = the interaction of the ith suckling treatment with the kth genotype;

$(NG)_{jk}$ = the interaction between the jth nutritional treatment with the kth genotype;

$(SNG)_{ijk}$ = the interaction between the ith suckling treatment, the jth nutritional treatment and the kth genotype;

β_1 = regression coefficient for calving date;

CD_{ijkl} = calving date of the lth heifer in the ith suckling treatment, jth nutritional level and kth genotype;

e_{ijkl} = the error term associated with the individual heifer.

3.6.2 Calf behaviour data

Data from the calf behaviour study was analyzed with the following model:

$$Y_{ijklm} = \mu+P_i+S_j+N_k+G_l+(PS)_{ij}+e_{ijklm}$$

where:

Y_{ijklm} = an observation on the mth calf belonging to the ith period, the jth suckling treatment, kth nutrition level and the lth genotype;

μ = population mean;

P_i = the ith period effect (i=1...10);

S_j = the jth suckling treatment effect (j = 1,2);

N_k = the kth nutritional treatment effect (k = 1,2);

G_l = the lth genotype effect (l = 1,2);

$(PS)_{ij}$ = the interaction between the ith period with the jth suckling treatment;

e_{ijkl} = the error term associated with the individual calf.

3.6.3 Size of Follicular Structures

Size of the largest follicle and CL were analyzed with the following model:

$$Y_{ijkl} = \mu+S_i+N_j+G_k+(SN)_{ij}+e_{ijkl}$$

where:

Y_{ijkl} = an observation on the lth heifer belonging to the ith suckling treatment, jth nutrition level and the kth genotype;

μ = population mean;

S_i = the ith suckling treatment effect (i = 1,2);

N_j = the jth nutritional treatment effect (j = 1,2);

G_k = the kth genotype effect (k = 1,2);

$(SN)_{ij}$ = the interaction between the ith suckling treatment with the jth nutrition treatment;

e_{ijkl} = the error term associated with the individual heifer.

CHAPTER IV: RESULTS

4.1 Liveweight Changes

4.1.1 Cows

The mean liveweight of cows on the nutritional treatments are presented in Table 4.1 and illustrated in Figure 4.1. At the end of the differential feeding period, the high plane cows were significantly ($P<0.001$) heavier than the low plane cows. Differences in liveweight between both groups remained significant ($P<0.05$) until weaning. Body condition score was also influenced by nutrition in June and at calving but not at weaning (Table 4.1). Body condition at the end of the nutritional treatment was positively correlated with body condition at calving ($r=0.59$; $P<0.01$). There was no correlation between dam liveweight at calving and liveweight gain from calving to weaning. However, daily liveweight gain of cows from calving to weaning was correlated to dam liveweight at weaning ($r=0.46$; $P<0.05$).

The later cows calved, the heavier they were immediately before calving ($r=0.64$; $P<0.01$), immediately after calving ($r=0.66$; $P<0.01$) and at weaning ($r=0.59$; $P<0.01$). Prepartum liveweight was highly correlated to postpartum liveweight ($r=0.97$; $P<0.001$) and to liveweight at weaning ($r=0.91$; $P<0.001$). The liveweight difference between pre and postpartum measurements was correlated to prepartum liveweight ($r=0.56$; $P<0.05$), but not to postpartum liveweight.

There was no effect of genotype on dam liveweight gain at any stage of the experiment. Furthermore, daily liveweight gain of cows from calving to weaning was influenced neither by nutrition (0.614 ± 0.10 vs 0.680 ± 0.06 kg/day, HN and LN, respectively) nor suckling treatment (0.663 ± 0.07 vs 0.631 ± 0.06 kg/day, RS and NS, respectively). Thus, the mean liveweight at weaning of those cows in the restricted

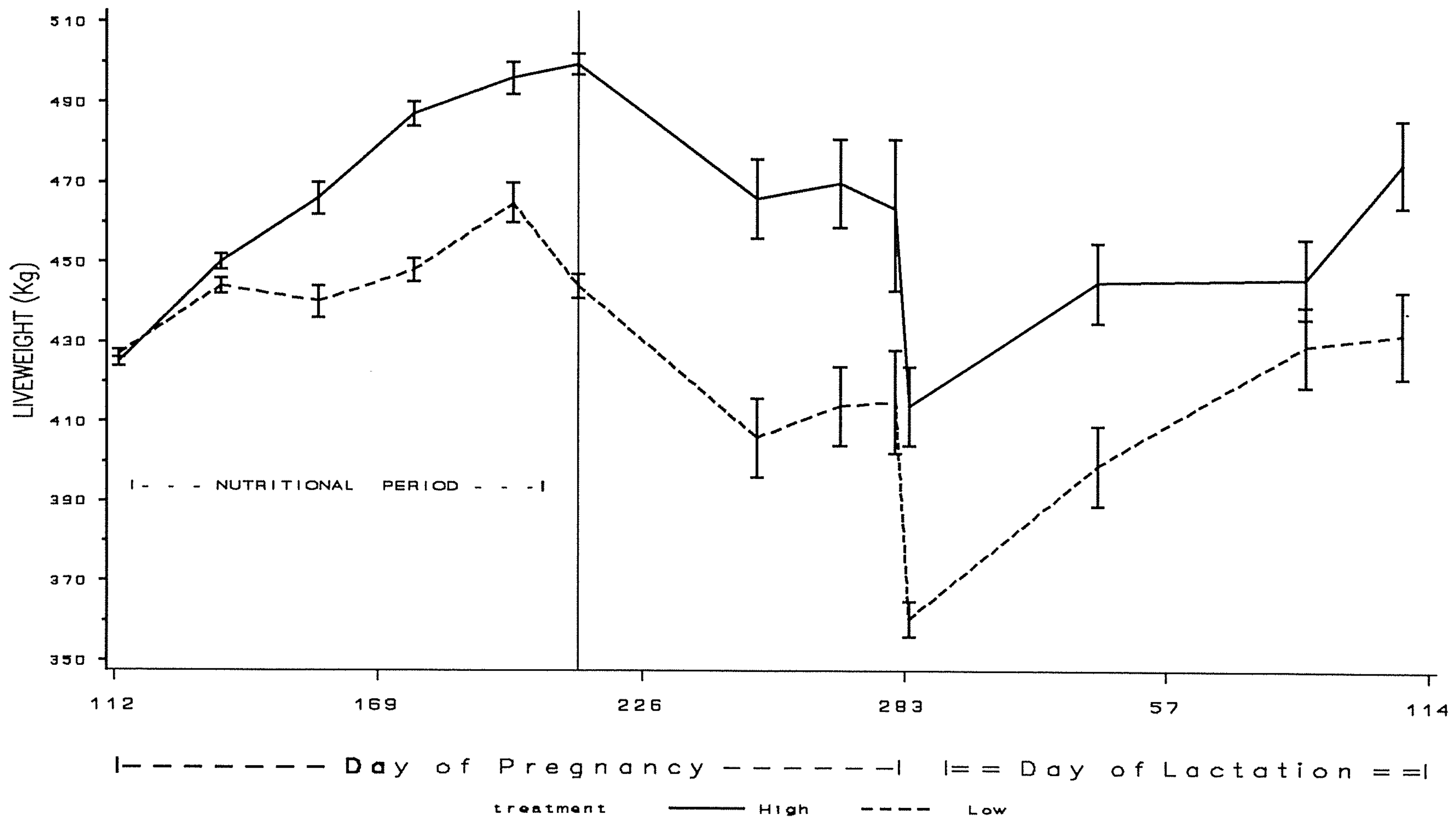


Figure 4.1 Effect of level of nutrition (High ——; Low ----) from day 112 to 212 of pregnancy on prepartum and postpartum liveweight of cows.

suckling treatment did not differ from the control group (455±10 vs 454±12 kg, RS and NS cows, respectively).

Table 4.1 Effect of nutritional treatment on liveweights (kg), body condition score (BC) of cows and calf birth weight (kg).

	Groups[1]		
	HN	LN	Significance Level
Initial LW (March 10)	425±1	427±1	ns
Final LW (June 18)	499±3	444±3	***
LW Gain (kg/day)	0.75±.03	0.17±.03	***
BC in June[2]	3.9±0.2	3.2±0.2	*
Prepartum LW	467±14	415±13	*
Postpartum LW	414±10	356±9	***
BC at calving	2.6±0.1	2.1±0.1	*
Calf birth weight	34.3±0.9	33.7±0.8	ns
LW at weaning	476±11	432±11	*
BC at weaning	3.2±0.1	3.1±0.8	ns

1 HN= High Nutrition; LN= Low Nutrition.

2 Body condition score at the end of the nutritional treatment

4.1.2 Calves

Table 4.1 shows that calf birth weight was not affected by nutritional treatment of their dams. Furthermore, there was no influence of calf sex or of genotype of the dam on birth weight of calves. It should however be pointed out that only 14.3% (n=3) of calves were males.

Calf liveweight gain during the first 45 days of lactation was not affected by the nutritional treatment of cows (0.968±0.04 vs 0.972±0.03 kg/day, HN and LN respectively), however calves born from LN gained more liveweight in the period from 45 days after calving until weaning. Daily calf liveweight gain during the month before weaning and the calf weaning liveweight were 1.596±0.07 kg/day and 160.5±2.8 kg in the LN group compared to 1.368±0.08 kg/day and 149.8±3.1 kg in the HN group ($P<0.06$ and $P<0.05$, respectively). As a consequence, overall calf liveweight gain from birth to weaning was also significantly affected by level of dam nutrition in mid-gestation (1.046±0.03 vs 1.138±0.03, HN and LN respectively; $P<0.05$).

Liveweight or liveweight gain of calves was not affected by dam genotype at any stage of the experiment. Restricted suckling resulted in a 13 kg difference ($P<0.001$) between NS and RS calves after adjusting liveweight at the end of the treatment for liveweight at the beginning (Table 4.2, Figure 4.2). At weaning, RS calves were lighter than NS calves (146±7 vs 162±3 kg, respectively; $P<0.01$). Despite this lower liveweight, fitting nose plates to calves did not affect their subsequent liveweight gain once the devices were taken off. However, the daily liveweight gain from calving to weaning was influenced by suckling treatment due to liveweight losses experienced by calves when the nose plates were fitted (see Table 4.2). No interactions were observed between the main effects on liveweight of calves in this experiment. Calf liveweight gain was not correlated to either dam liveweight at calving or dam liveweight gain from calving to weaning.

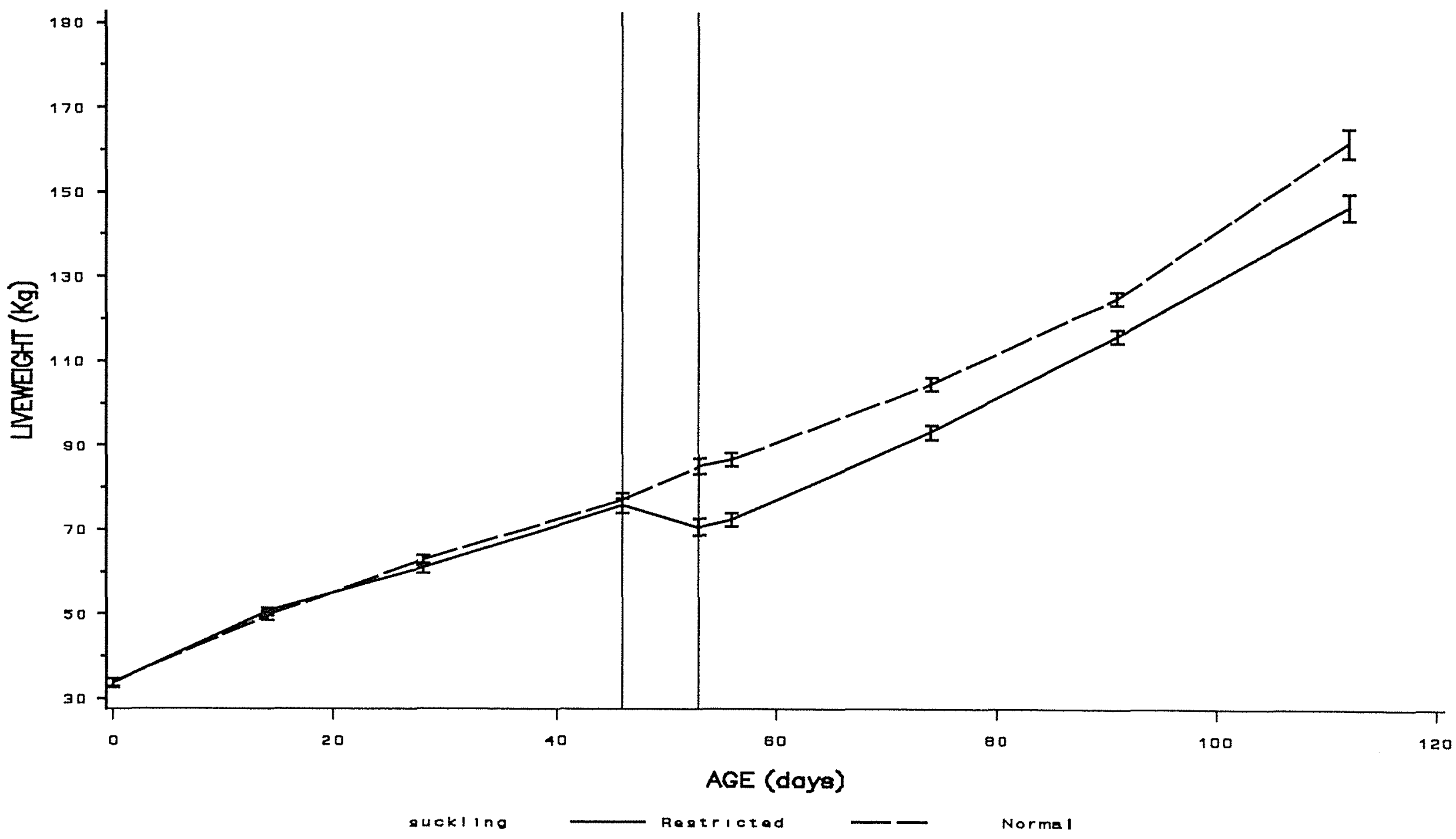


Figure 4.2 Effect of restricted suckling (—) vs normal suckling (---) from day 46 to day 53 of lactation on liveweight of calves.

Table 4.2 Effect of suckling treatment on liveweight and liveweight gain (LWG) of calves (kg and kg/day).

	Groups[1]		Significance Level
	NS	RS	
LWG from calving to treatment	0.962±.04	0.922±.03	ns
LW at onset of treatment	77.1±1.6	75.7±1.7	ns
LW at end of treatment	85.0±1.9	70.5±2.0	***
LWG during treatment	1.121±.10	-0.750±.10	***
LW 3 days after end of treatment	86.6±1.6	72.3±1.7	***
LW at weaning	162.4±2.9	146.7±3.1	**
LWG from end of treatment to weaning	1.316±.05	1.309±.06	ns
Overall LWG from calving to weaning	1.161±.03	1.022±.03	**

1 RS = Restricted suckling; NS= Normal suckling.

4.2 Calf and Cow Behaviour

Observations made during and after the period of nose plate attachment suggested no signs of distress in the calves. However, there was some distention of the udders in the cows. No mastitis or any other disease was observed as a consequence of suckling restriction. One calf lost its nose plate during the night of the second day, but it was replaced early next morning. No problems were encountered with mothering up following the restricted suckling treatment.

Before fitting nose plates, there was no difference in behaviour between NS and RS calves (see Figure 4.3 and Table

4.3). Approximately 20 hours after the beginning of suckling restrictions, there was no difference between groups in time spent grazing and idling, although RS calves made unsuccessful but repeated attempts to suckle their mothers. Differences in calf behaviour were apparent 48 hours after fitting nose plates. Figure 4.3 and Table 4.3 show that RS calves spent less time idling and more time grazing than NS calves (85±7 vs 124±7 min and 71±7 vs 22±7 min, respectively, $P<0.001$).

Figure 4.3 and Table 4.3 show that the time spent grazing was longer once nose plates were removed for RS calves than NS calves at approximately 24, 72 and 120 hours after nose plates removal (44 vs 25 min, 57 vs 15 min and 62 vs 39 min, respectively; $P<0.05$; $P<0.001$; $P<0.05$). Restricted suckling calves also spent more time sucking than the control group (27±3 vs 11±3; 19±3 vs 12±3 and 16±3 vs 5±3, for periods 8, 9 and 10 respectively, $P<0.001$; $P<0.10$; $P<0.05$).

When the data from all periods were pooled, suckling treatment had no effect on the time spent suckling (11±1 vs 12±1 min, RS and NS, respectively) but exerted a highly significant effect on time spent idling (99±2 vs 135±2 min, RS and NS, respectively; $P<0.001$) and grazing (58±2 vs 27±2 min, $P<0.001$). In addition, calves from HxF dams spent more time idling (120±2 vs 114±3 min, calves born to HxF and SxF, respectively, $P<0.05$) and tended to spend less time grazing (41±1 vs 44±1 min) and suckling (11±1 vs 13±1 min). Calves born to HxF dams also tended to make less attempts to suckle their mothers when nose plates were attached, though the effect was not statistically significant (3±0.5 vs 4±1.0 min). Furthermore males calves attempted suckling more frequently than females (8±2.0 vs 2±1.0 min, $P<0.05$).

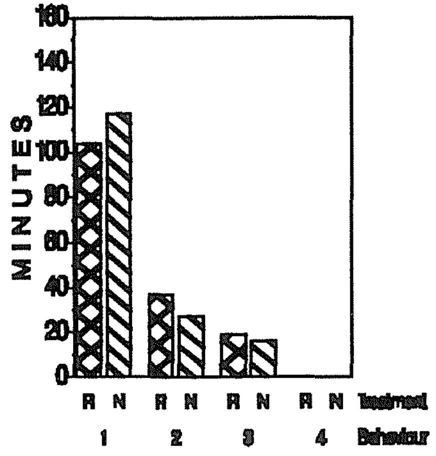
Table 4.3 Effect of suckling restriction by fitting nose plates to calves on time (min) spent idling, grazing, suckling and attemting to suckle from 06.00-09.00 h on selected days.

	CALF BEHAVIOUR						
	Idling[1]		Grazing[1]		Suckling[1]		Attempts[1]
HOURS[2]	RS	NS	RS	NS	RS	NS	RS
Prior to Treatment							
-72	104 ± 7^{b}	117 ± 7^{bc}	37 ± 6^{abfg}	27 ± 6^{adfg}	19 ± 3^{abc}	16 ± 3^{acd}	-
-24	129 ± 7^{cde}	134 ± 7^{cdef}	20 ± 6^{ad}	22 ± 6^{adf}	31 ± 3^{bf}	24 ± 3^{abf}	-
During Treatment							
24	93 ± 7^{b}	108 ± 7^{b}	47 ± 6^{bfg}	49 ± 6^{bfg}	-	13 ± 3^{cdg}	30 ± 2^{a}
48	85 ± 7^{ab}	129 ± 7^{cde}	71 ± 6^{c}	22 ± 6^{adf}	-	17 ± 3^{dg}	12 ± 2^{b}
72	67 ± 7^{a}	142 ± 7^{cdef}	86 ± 6^{c}	17 ± 6^{d}	-	10 ± 3^{dg}	20 ± 2^{c}
96	107 ± 7^{b}	136 ± 7^{cdef}	69 ± 6^{c}	34 ± 6^{adfg}	-	10 ± 3^{dg}	3 ± 2^{d}
120	92 ± 7^{b}	146 ± 7^{ef}	84 ± 6	24 ± 6^{adf}	-	10 ± 3^{dg}	3 ± 2^{d}
After Treatment							
+24	110 ± 7^{b}	143 ± 7^{ef}	44 ± 6^{g}	25 ± 6^{adf}	27 ± 3^{f}	11 ± 3^{dg}	-
+72	104 ± 7^{b}	154 ± 7^{f}	57 ± 6^{cg}	14 ± 6^{d}	19 ± 3^{df}	12 ± 3^{dg}	
+120	102 ± 7^{b}	138 ± 7^{def}	62 ± 6^{c}	38 ± 6^{fg}	16 ± 3^{df}	5 ± 3^{g}	-

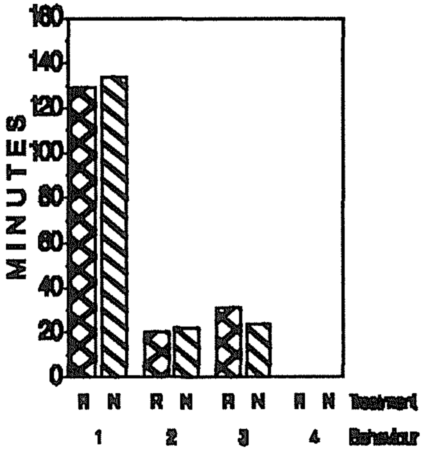
[1] RS= Restricted Suckling; NS= Normal Suckling.

[2] hours before the biginning of (-), during or after (+) suckling treatment.

abcdfg Means within behaviour classes which have superscripts with letters in common are not significantly different ($P>0.05$).



PERIOD 1



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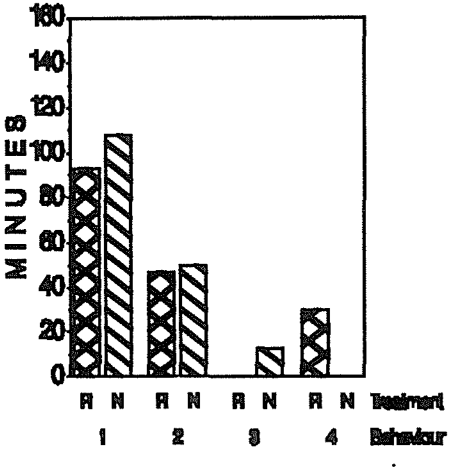

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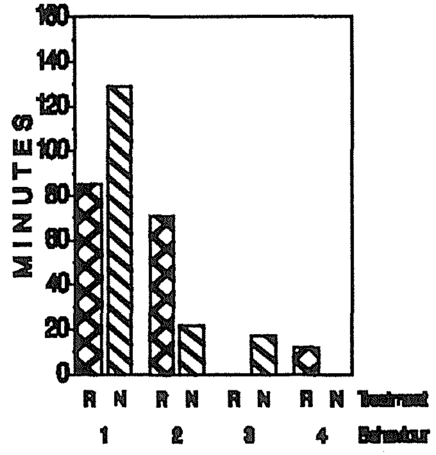

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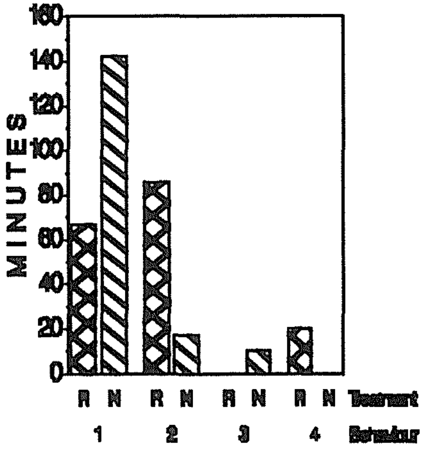

PERIOD 5

TREATMENT :

R : Restricted Suckling
N : Normal Suckling

BEHAVIOUR :

1 : Idling
2 : Grazing
3 : Suckling
4 : Attempt to Suckle

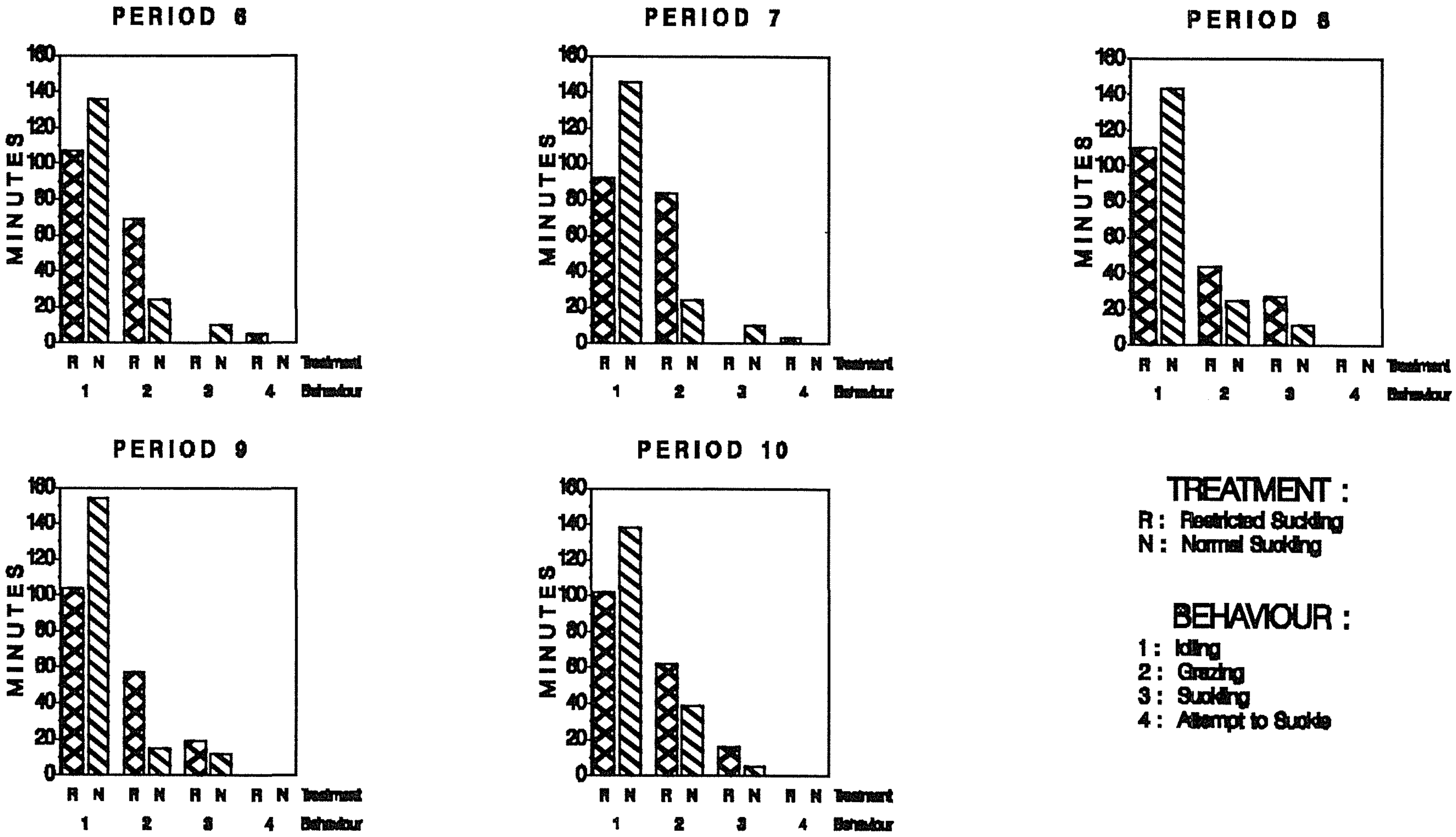

Figure 4.3 Effect of suckling treatment on calf behaviour before (periods 1 and 2), during (periods 3 to 7) and after (periods 8 to 10) fitting nose plates to calves.

4.3 Reproductive Performance

The mean calving date of the herd was 28 August, with the earliest calving on 18 August and the latest on 23 September. The mean postpartum interval to resumption of ovarian cyclic activity (PPAI), to occurrence of first CL (PCLI) and to conception (ICC) were 81.9±18.0, 82.7±15.0 and 83.1±21.0 days, respectively. Calving date significantly influenced these intervals. Postpartum interval to resumption of ovarian cyclic activity, PCLI and ICC decreased 0.96±0.40 ($P<0.05$), 0.96±0.30 ($P<0.01$) and 1.05±0.50 ($P<0.05$) days for every day later the cows calved.

Nutritional levels in mid-gestation did not affect any of the postpartum intervals studied. Least squares means for PPAI, PCLI and ICC were 79.8±7.0 and 85.4±4.0 days, 81.8±5.0 and 84.6±4.0 days, 84.6±7.0 and 85.5±6.0 days, in HN and LN groups, respectively. Body condition at calving was negatively correlated with PPAI ($r=-0.45$; $P<0.05$). No correlations were found between PCLI or ICC and body condition score at the end of the nutritional treatment or at calving. Body condition at calving was not correlated to any other reproductive variable.

Liveweights immediately before and after calving were negatively correlated to PPAI ($r=-0.61$ and $r=-0.69$; $P<0.01$), PCLI ($r=-0.66$ and $r=-0.67$; $P<0.01$) and ICC ($r=-0.60$ and $r=-0.55$; $P<0.01$ and $P<0.05$, respectively). In addition, liveweight of cows at weaning was also negatively correlated to PPAI ($r=-0.45$; $P<0.05$), PCLI ($r=-0.54$; $P<0.05$) and ICC ($r=-0.55$; $P<0.05$).

Genotype of the dam did not significantly affect any of the postpartum intervals, however there was a tendency for HxF cows to experience shorter intervals than SxF crossbred (79.8±6.0 vs 85.4±7.0 days for PPAI; 80.1±4.0 vs 86.3±3.0 days for PCLI; 78.5±6.0 vs 91.6±7.0 days for ICC).

No cow was detected in heat or experienced a CL or a rise in progesterone concentrations prior to restricted suckling at d 46 *post partum*. Restricted suckling did not affect the PPAI (78.7±5.0 vs 86.5±6.0 days, RS and NS respectively) or PCLI (81.8±3.0 vs 84.6±6.0, RS and NS, respectively) but influenced the ICC. Those cows that experienced restricted suckling had on average an 18 days shorter interval from parturition to pregnancy than the control group of cows (76.0±5.0 vs 94.1±6.0 days; $P<0.05$). As a consequence, pregnancy was more concentrated in the RS group. At day 85 post partum the percentage of pregnant cows tended to be higher ($P<0.10$) in the RS cows than in the NS cows (see Figure 4.4).

There was no interaction between nutritional level in mid-gestation and suckling restriction on PPAI, but the interaction of these effects on PCLI and ICC approached significance ($P<0.10$; see Table 4.4). There was a beneficial effect of suckling restriction on reproductive performance in those cows fed high pasture allowances in mid-gestation. However, the postpartum interval observed in those cows fed low pasture allowances during mid-gestation that had restricted suckling was greatly influenced by the long postpartum intervals observed in one cow (Nº32). If the data for this cow was removed from the analysis, then mean ICC for this subgroup was reduced to approximately 75 days from 85 days. Surprisingly, the calf from this Nº32 did not lose liveweight during the period of temporary weaning. This would presumably suggest that this calf was still able to suckle its mother. If this was the case, then cow Nº32 would not have had a complete removal of the suckling stimulus.

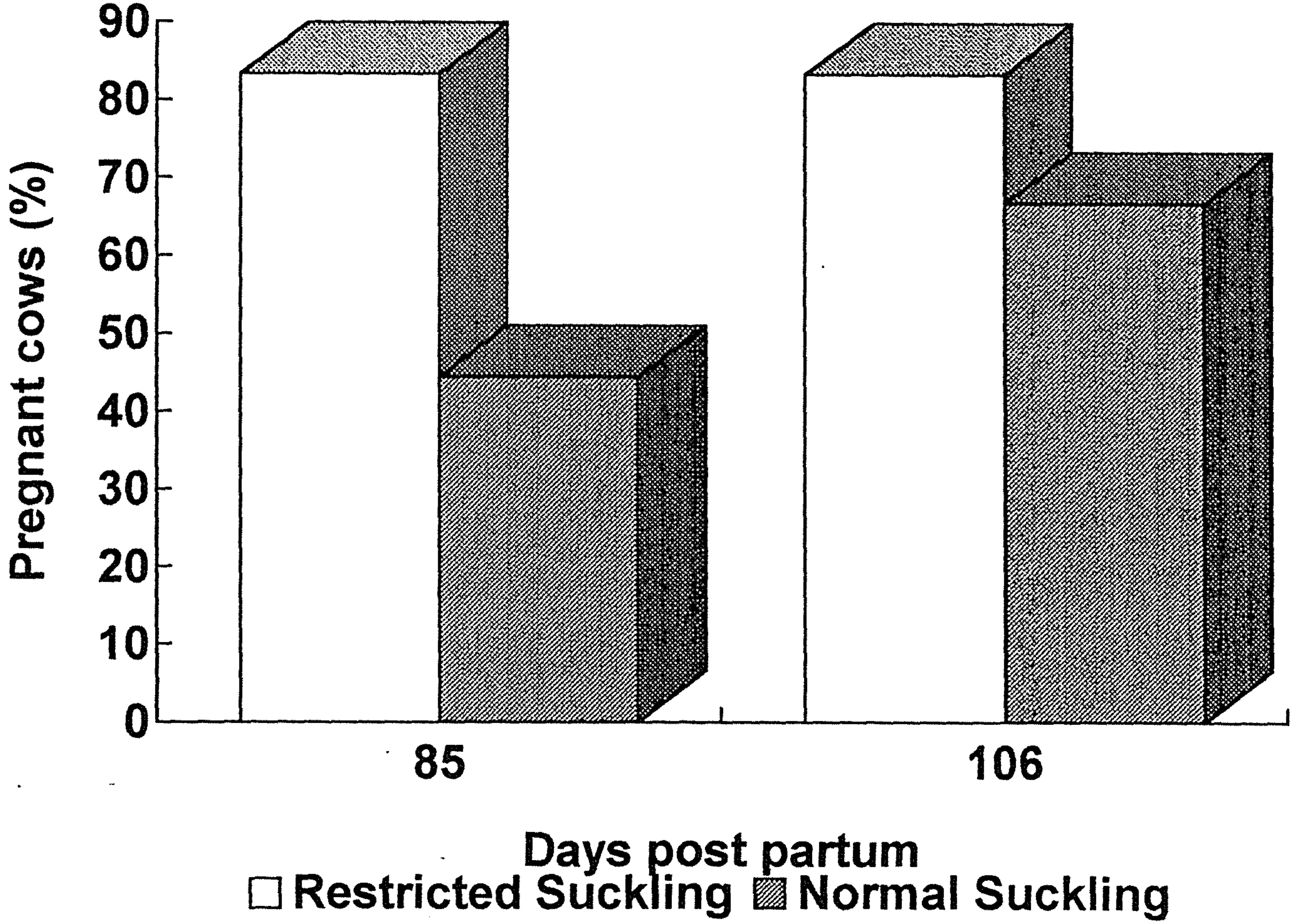

Figure 4.4 Effect of suckling treatment on percentage of pregnant cows at day 85 post partum and one cycle later.

Table 4.4 Interaction between suckling and nutritional treatments on reproductive performance (least squares mean ± sem).

Groups^{1}		No	Reproductive Performance (days)		
			PPAI	PCLI	ICC
RS	HN	6	72.3±8	75.5±6	67.3±8^{a}
RS	LN	4	85.1±8	88.2±5	84.8±8^{ab}
NS	HN	6	87.3±9	88.2±7	102.0±9^{b}
NS	LS	5	85.8±8	81.1±5	86.3±8^{ab}

1 RS= Restricted Suckling; NS= Normal Suckling; HN= High Nutrition; LN= Low Nutrition.

ab Means within columns which have superscripts with letters in common are not significantly different ($P>0.05$).

The degree of liveweight loss of RS calves during treatment was negatively correlated to PPAI ($r=-0.71$; $P<0.05$) and PCLI ($r=-0.65$; $P<0.06$), but ICC was not correlated to the calf liveweight loss during restricted suckling treatment. There was a tendency of total liveweight gain in the calves to be positively correlated to ICC ($P<0.10$). Total liveweight gain from calving to weaning, on the other hand, was not correlated either to PPAI or PCLI.

The mean calving difficulty score was 2.09±1.40. Calving difficulty was not affected either by nutrition or genotype, nor was it correlated with any of the postpartum intervals studied. Uterine involution took on average 31.5±4.9 days. It was not influenced by any of the effects studied in this experiment. Furthermore, uterine involution was not correlated with any of the variables measured.

Finally, there was a positive correlation between ICC and PPAI ($r=0.61$; $P<0.01$) and between ICC and PCLI ($r=0.69$;

P<0.001), while PPAI was also positively correlated to PCLI (r=0.83; P<0.001).

4.4 Ovarian Structures

Technical problems prevented the measurement of one weekly ultrasound observation (d 67 *post partum*). Therefore, there was fourteen days between consecutive ultrasound examinations from day 60 to 74 after calving.

Follicles larger than 1 cm were observed in 90.5 % of the herd (n=19) at 25 days *post partum*. Only two cows did not have large follicles (> 1 cm) at that first examination after calving. However, both cows developed large follicles at the second observation one week later. The mean (± sem) size of the largest follicle at 25 days *post partum* was 1.22±0.34 for the whole herd.

Simmental x Friesian cows had larger follicles at first examination after calving than HxF cows (1.44±0.13 vs 1.05±0.10 cm; P<0.05). A similar tendency was observed in subsequent observations, but the differences were not significant. The size of the largest follicle was unaffected by nutritional treatments. In addition, restriction of suckling did not significantly affect the largest follicle diameter when it was applied at day 46 *post partum*. The greatest difference in size of follicles between RS and NS cows was observed two days after fitting nose plates to the calves when the RS group had a mean largest follicle of 1.35±0.10 cm, while the NS group had a largest follicle of 1.13±0.09 cm (P=0.12). There was an interaction between nutrition in mid-gestation and suckling treatment on size of the largest follicle (see Table 4.5).

The largest follicle was located in the right ovary in 57.7% of the observations, while 55% of the pregnancy CL were observed in the left ovary.

Table 4.5 Size of largest ovarian follicle (cm) at different stages of the experiment (Mean±sem).

	PERIOD							
	Pre-treatment[1]			During treatment[1]				Post-treatment[1]
Group[2]	25dpp[3]	32dpp	39dpp	onset[4]	2dafter	4dafter	end[4]	60dpp
RS HN	1.45±.13	1.44±.11	1.04±.20	1.35±.12	1.55±.17[a]	1.66±.22	1.30±.18	1.31±.23
RS LN	1.12±.13	1.53±.10	1.15±.13	1.25±.10	1.15±.11[ab]	1.35±.14	1.30±.18	1.31±.15
NS HN	1.23±.20	1.29±.14	1.26±.18	1.17±.15	1.05±.16[b]	1.32±.20	1.56±.24	1.68±.23
NS LN	1.18±.16	1.39±.11	1.27±.14	1.09±.12	1.21±.12[ab]	1.28±.15	1.50±.19	1.32±.16

1 Suckling restriction treatment.
2 RS= Restricted Suckling; NS= Normal Suckling; HN= High Nutrition LN= Low Nutrition.
3 25dpp= 25 days *post partum*.
4 onset= fitting of nose plates devices; end= removal of devices.
ab Means within colummns which have superscripts with letter in common are not significantly different (P>0.05).

A pattern of development and atresia of large ovarian follicles was clearly observed in the herd before first ovulation *post partum.*

Mean (± sem) CL diameter observed throughout the trial was 2.13±0.36 cm. Size of CL was not affected by genotype, suckling treatment or period after calving (see Table 4.6). Although nutritional treatment did not itself affect the size of the CL, there was an interaction between period after calving and nutrition on CL size. The effect is shown in Table 4.7.

Table 4.6 Effect of suckling treatment and days after calving on size (cm) of the corpus luteum (least squares mean ± sem).

Days *post partum*	Suckling Treatment[1] RS	Suckling Treatment[1] NS	Mean CL size in the herd
77	1.95±0.16 (6)	2.04±0.17 (6)	2.00±0.11
84	2.12±0.15 (7)	2.16±0.17 (6)	2.14±0.14
91	2.15±0.14 (9)	2.11±0.14 (7)	2.13±0.10
98	2.14±0.14 (9)	1.95±0.14 (8)	2.04±0.10
105	2.11±0.14 (9)	2.25±0.13 (9)	2.18±0.10

1 RS = Restricted Suckling; NS= Normal Suckling. Numbers between brackets indicate number of observations.

Table 4.7 Effect of nutritional treatment in mid-gestation and days after calving on size (cm) of corpus luteum (least squares ± sem).

Days *post partum*	Nutritional Treatment[1] HN	Nutritional Treatment[1] LN
77	2.06 ± 0.19^{a} (6)	1.93 ± 0.17^{a} (6)
84	2.20 ± 0.22^{ab} (6)	2.09 ± 0.14^{a} (8)
91	1.72 ± 0.20^{a} (6)	2.55 ± 0.13^{b} (10)
98	2.02 ± 0.19^{a} (6)	2.07 ± 0.12^{a} (11)
105	2.23 ± 0.18^{ab} (7)	2.13 ± 0.12^{a} (11)

1 HN= High Nutrition; LN= Low Nutrition. Numbers between brackets indicate number of observations.
ab Means which have superscripts with letter in common are not significantly different (P>0.05).

Corpus luteum size was correlated with serum progesterone levels (r=0.33; P<0.01). However, the correlation between those two variables was not consistent throughout the trial, as shown in Table 4.8. Fifteen percent of the CL had a hole in the middle of their structure. Although holes were observed to be up to 1 cm in diameter, this finding was not related to lower serum progesterone levels.

Table 4.8 Correlation coefficients between size of the corpus luteum (cm) and serum progesterone (ng/ml) on different days *post partum*.

Days *post partum*	Correlation Coefficient	Significance Level
56	0.99	†
63	0.91	ns
70	0.65	ns
77	0.48	ns
91	0.41	ns
98	0.17	ns
105	0.62	*
Total	0.33	**

4.5 Progesterone

Serum progesterone levels increased ($P<0.001$) with interval after calving (see Table 4.9). High nutrition cows had higher overall mean progesterone levels than LN cows (3.21 ± 0.16 vs 2.69 ± 0.17 ng/ml, $P<0.05$), but the nutritional effect on progesterone levels was not significant when only high (> 1 ng/ml) or basal (< 1 ng/ml) progesterone levels were considered. Genotype and suckling treatment did not significantly influence progesterone levels.

When only basal levels of progesterone were considered in the statistical analysis, the period after calving did not affect progesterone concentrations. Mean basal serum

Table 4.9 Effect of genotype, nutrition and suckling treatment on serum progesterone levels (ng/ml) *post partum* (least squares means ± sem).

Days post partum	Mean Herd Values	Genotype[1]		Nutritional Treatment[2]		Suckling Treatment[3]	
		HxF	SxF	HN	LN	RS	NS
18	$0.25\pm.41^{a}$	$0.21\pm.57^{a}$	$0.28\pm.60^{a}$	$0.44\pm.62^{a}$	$0.04\pm.55^{a}$	$0.24\pm.55^{a}$	$0.36\pm.64^{a}$
25	$0.34\pm.41^{a}$	$0.18\pm.57^{a}$	$0.50\pm.60^{a}$	$0.44\pm.62^{a}$	$0.17\pm.54^{a}$	$0.35\pm.55^{a}$	$0.41\pm.64^{a}$
32	$0.13\pm.41^{a}$	$0.01\pm.57^{a}$	$0.26\pm.60^{a}$	$0.15\pm.62^{a}$	$0.03\pm.54^{a}$	$0.15\pm.55^{a}$	$0.18\pm.64^{a}$
39	$0.38\pm.43^{a}$	$0.08\pm.60^{a}$	$0.69\pm.63^{ab}$	$0.22\pm.66^{a}$	$0.40\pm.56^{a}$	$0.54\pm.60^{a}$	$0.23\pm.64^{a}$
46	$0.20\pm.41^{a}$	$0.01\pm.57^{a}$	$0.38\pm.60^{a}$	$0.33\pm.62^{a}$	$0.02\pm.54^{a}$	$0.23\pm.55^{a}$	$0.23\pm.64^{a}$
50	$0.24\pm.46^{a}$	$0.03\pm.57^{a}$	$0.45\pm.72^{ab}$	$0.38\pm.71^{a}$	$0.02\pm.56^{a}$	$0.22\pm.64^{a}$	$0.27\pm.64^{a}$
53	$0.22\pm.41^{a}$	$0.12\pm.57^{a}$	$0.32\pm.60^{a}$	$0.37\pm.59^{a}$	$0.06\pm.56^{a}$	$0.27\pm.55^{a}$	$0.24\pm.64^{a}$
60	$0.46\pm.41^{a}$	$0.02\pm.57^{a}$	$0.90\pm.60^{ab}$	$0.93\pm.59^{a}$	$0.01\pm.56^{a}$	$0.67\pm.55^{a}$	$0.22\pm.64^{a}$
67	$0.82\pm.41^{ab}$	$0.46\pm.57^{a}$	$1.17\pm.60^{abc}$	$1.37\pm.56^{a}$	$0.24\pm.59^{a}$	$1.35\pm.55^{ab}$	$0.15\pm.64^{a}$
77	$1.70\pm.41^{bc}$	$1.11\pm.57^{abc}$	$2.28\pm.60^{bcd}$	$3.13\pm.59^{bc}$	$0.33\pm.56^{a}$	$2.27\pm.55^{bc}$	$0.96\pm.64^{ab}$
84	$2.83\pm.41^{cd}$	$2.62\pm.67^{cde}$	$3.04\pm.60^{def}$	$4.20\pm.62^{cde}$	$1.72\pm.53^{ab}$	$2.64\pm.55^{cd}$	$3.16\pm.64^{cd}$
91	$3.52\pm.51^{de}$	$2.64\pm.57^{cde}$	$4.41\pm.60^{f}$	$3.57\pm.62^{cd}$	$3.34\pm.54^{cd}$	$4.01\pm.55^{cd}$	$2.87\pm.64^{cd}$
98	$4.27\pm.42^{ef}$	$4.20\pm.63^{ef}$	$4.35\pm.57^{f}$	$4.52\pm.66^{cde}$	$3.97\pm.54^{cd}$	$4.33\pm.58^{defg}$	$4.24\pm.64^{cdef}$
105	$4.74\pm.45^{fg}$	$4.69\pm.60^{f}$	4.78 ± 68^{efg}	$4.99\pm.71^{def}$	$4.48\pm.56^{cde}$	$5.28\pm.60^{efgh}$	$4.16\pm.68^{def}$
112	$5.81\pm.53^{gh}$	$6.65\pm.72^{ghif}$	$4.97\pm.78^{fg}$	$7.11\pm.84^{fgh}$	$4.99\pm.66^{de}$	$6.16\pm.78^{fgh}$	$5.64\pm.72^{fgh}$
119	$6.95\pm.60^{hi}$	$7.73\pm.85^{ij}$	$6.17\pm.85^{ghi}$	$8.21\pm.94^{hi}$	$5.98\pm.72^{efg}$	$7.04\pm.95^{ghi}$	$6.83\pm.78^{ghi}$

126	$5.68\pm.63^{fgh}$	$6.32\pm.95^{fghi}$	$5.05\pm.85^{fgh}$	$5.93\pm.1.1^{efgh}$	$5.23\pm.76^{ef}$	6.01 ± 1.1^{fgh}	$5.31\pm.78^{efgh}$
137	$6.87\pm.72^{hi}$	6.20 ± 1.1^{fghij}	$7.53\pm.95^{hij}$	4.96 ± 1.3^{defg}	$7.51\pm.83^{gh}$	7.50 ± 1.1^{ghi}	$6.49\pm.95^{ghi}$
147	9.41 ± 1.1^{i}	9.22 ± 1.9^{j}	9.60 ± 1.3^{ij}	9.74 ± 1.9^{hi}	9.10 ± 1.3^{hi}	9.65 ± 1.4^{hi}	9.17 ± 1.9^{hi}

[1] HxF= Hereford x Friesian; SxF= Simmental x Friesian.

[2] HN= High Nutrition; LN= Low Nutrition.

[3] RS= Restricted Suckling; NS= Normal Suckling. Figures from day 18 to 46 *post partum* correspond to pretreatment values.

[abcdfghij] Means within main effects which have superscripts with letters in common are not significantly different (P>0.05).

progesterone was 0.13±0.18 ng/ml. Basal concentrations of progesterone were not affected by any of the other main effects studied in the trial.

The postpartum progesterone profiles found in this trial are illustrated in Figure 4.5. No progesterone elevations before conception were found in 66.6% of the herd (n=14) while 28.5% of the cows (n=5) experienced one or two progesterone rises before conception. A long luteal phase was observed in one cow (Nº 36) (see Figure 4.5).

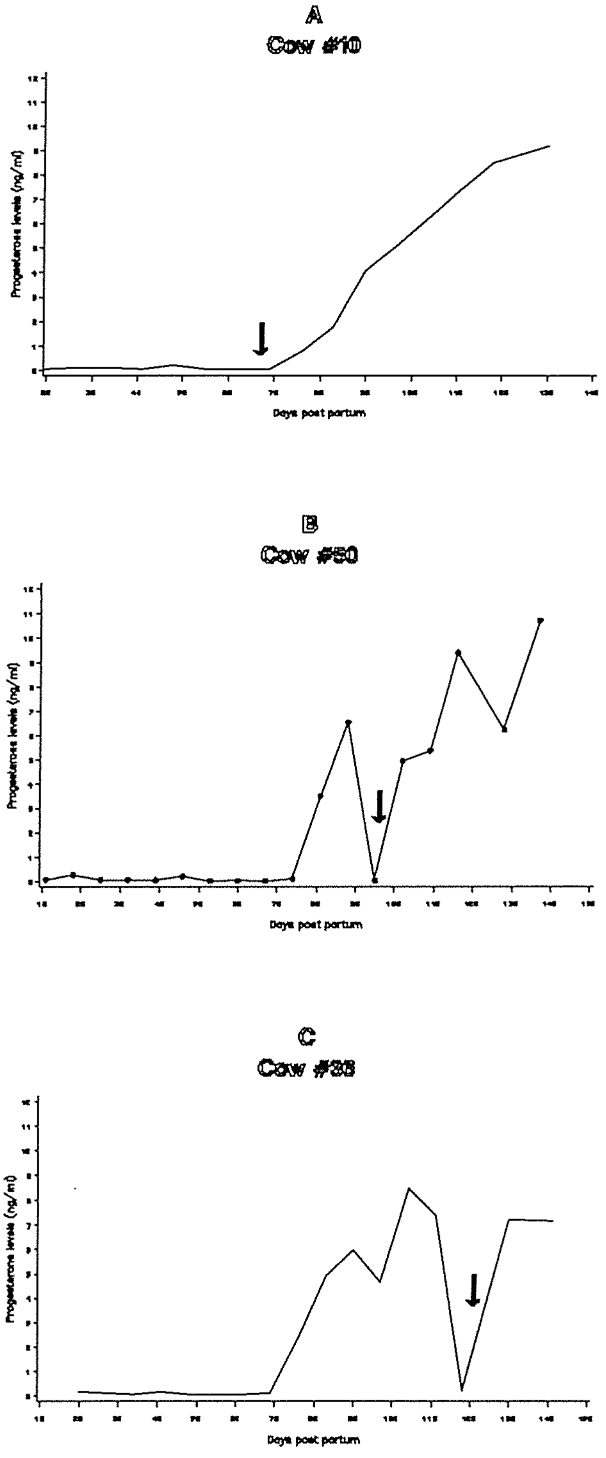

Figure 4.5 Serum progesterone profiles found in the postpartum cows: One progesterone elevation corresponding to pregnancy as found in cow #10 (A), at least one progesterone peak before conception as cow #50 (B), a long luteal phase as found in cow #36 (C). Arrows indicate conception date.

CHAPTER V: DISCUSSION

The aims of the present experiment was to study the resumption of reproductive activity *post partum* in first-calving beef cows that had calved at either of two widely different liveweights and to make observations on the practical application of using nose plates to nursing calves to temporarily inhibit suckling and promote early resumption to breeding. In addition, the study aimed to discuss the management implications of the use of a restricted suckling procedure in first-calving cows. A discussion of the results of this experiment and its objectives is carried out in the following sections.

5.1 Pattern of Ovarian Changes

At first ultrasound examination (day 25 *post partum*), most cows (90.5%) had follicles larger than 1 cm. The two cows which had smaller follicles at first examination both developed follicles larger than 1 cm at second examination *post partum*. Whether the follicles of those two animals were in the first growing phase or they were DF in a stage of regression at the first examination remains unknown.

Despite these particular cases, ovarian follicular activity must have resumed earlier than day 25 after calving, with the development of DF. However, first ovulation after calving did not occur until later in the postpartum period. A pattern of growth and regression of DF was identified in the herd as soon as the examinations started at approximately day 25 *post partum*. Thus, prolonged resumption of ovarian cyclic activity was due to lack of ovulation rather than delayed development of DF. These findings are in agreement with those reported by other authors such as Spicer *et al* (1986) who found that follicles of 0.8 cm and greater were present on ovaries by day 7 *post partum* in primiparous suckled cows. Furthermore, there is agreement with the findings reported by Murphy *et al* (1990) for adult suckled beef cows and with the model for resumption of ovarian cycles *post partum* proposed by Roche *et al* (1992). These authors indicated that the majority of suckled beef cows develop the first DF within 14 days after calving but this DF is likely to undergo atresia. The present findings are also consistent with the pattern of ovarian activity reported for lactating New Zealand dairy cows of mixed age and breed type (McDougall and Macmillan, 1993) and in single- and twin-suckled HxF adult cows (W.H. McMillan, personal communication).

The nutritional levels imposed on heifers in mid-gestation did not affect either the occurrence of DF after day 25 *post partum* or the size of the largest follicle. Perry *et al* (1991) found, however, that adult cows receiving restricted levels of energy four months before calving did not develop DF up to 46 days after calving. This interval from parturition to the observation of the first DF can be further delayed if cows received low nutritional levels after calving (Perry *et al*, 1991). Nevertheless, the cows calved with poorer body condition in that trial (3.2, 1-9 scores) than in the present study where cows calved with body condition of 2.09 and 2.55 (1-5 scores) in the LN and HN groups, respectively. Unfortunately, the authors have not been specific about the actual level of nutrition and body condition involved in other trials (Spicer *et al*, 1986; Murphy *et al*, 1990) and further comparisons cannot be made.

The size of the largest follicle in HxF cows (1.05±0.10 cm) was significantly smaller than the size of the largest follicles in SxF cows (1.44±0.13 cm) at day 25 *post partum* ($P<0.05$). A similar diameter was found in Hereford crossbreed primiparous cows (1.09±0.03 cm) between day 7 and 56 after calving, when cows were still anovulatory (Spicer *et al*, 1986). Murphy *et al* (1990) reported, on the other hand, that maximum diameter in anovulatory DF as measured by daily ultrasound examinations varied from 1.35 to 1.63 cm in adult

Limousin x Friesian cows. The difference in the size of the largest follicle found between HxF and SxF in the present experiment cannot be explained by differences in liveweight or body condition between both genotypes since those variables did not differ in HxF and SxF cows throughout the trial.

The effect of genotype on size of DF was not found to be significant in subsequent observations, even though SxF cows developed larger DF than HxF cows. Larger DF for SxF cows did not mean better reproductive performance. In fact, HxF cows tended to have shorter PPAI, PCLI and ICC, though the effect was not significant. There was no effect of genotype on size of CL, but SxF cows tended to have higher serum progesterone levels (see Table 4.8).

The pattern of follicular growth and atresia found in the ovaries of primiparous cows prior to first ovulation, even in those cows calving with moderate to good body condition, suggests that the lack of ovulation of DF is a result of low LH pulse frequency as reported by other authors (Murphy *et al*, 1990; Lucy *et al*, 1992; Roche *et al*, 1992).

5.2 Reproductive Performance

The lengths of the interval to resumption of ovarian activity found in the two crossbreeds in this experiment are similar to those reported by Knight and Nicoll (1978) for primiparous cows of mixed breeds, but shorter than those reported by Pleasant and Barton (1992b) in primiparous Angus cows. However, these authors measured the interval from calving to first oestrus *post partum*, whereas the resumption of ovarian cyclic activity was estimated in the present trial based on serum progesterone concentrations. Increases in serum progesterone levels were taken as a reference point to indicate ovulation had occurred. Serum progesterone concentrations are elevated some days after oestrus (Manns *et* *al*, 1983; Peters and Ball, 1987). Therefore, the actual interval from calving to first oestrus would be a few days shorter than the interval to resumption of ovarian cyclic activity as estimated in this experiment.

In spite of the significant differences in liveweight and body condition score at calving as influenced by nutritional levels in mid gestation, nutritional treatment did not affect the length of the reproductive intervals studied in this trial. The lack of effect of nutritional treatment on reproductive performance could have been a consequence of liveweight losses experienced by both HN and LN groups during the last period of gestation. The resumption of ovarian cyclic activity *post partum* is delayed in primiparous cows receiving low levels of energy before calving (Dunn *et al*, 1969). However, cows in better body condition at calving tended to resume ovarian activity earlier in the present experiment, an effect widely reported by other researchers (Dunn and Kaltenbach, 1980; Dziuk and Bellows, 1983; Richards *et al*, 1986; Short *et al*, 1990).

In the present trial, RS cows did not have significantly shorter PPAI and PCLI than NS cows, but RS cows conceived 18 days sooner and their pregnancy was thus more concentrated than in the control group ($P<0.05$). Only those cows that had restricted suckling could have had a calving interval of 365 days or less in this trial (ICC= 76.0±5 vs 94.1±6 days, RS and NS cows, respectively; $P<0.05$). The lack of significant effect of suckling removal on PPAI could have been a consequence of the frequency at which blood samples were taken. Samples to determine progesterone levels, and hence PPAI, were collected at weekly intervals, however conception date was estimated on a daily basis. Therefore greater differences in PPAI could have been masked by the intervals between blood samples. This is supported by the positive correlation found between PPAI and ICC whereby those cows that resumed cyclic activity sooner tended to conceive earlier. Other authors have also taken blood samples weekly (e.g. Montgomery *et al*, 1982; Zalesky *et al*, 1984; Naasz and Miller, 1990; Fernandez *et al*, 1993) or more often (Stumpf *et al*, 1992; Cupp *et al*, 1993) to determine serum progesterone levels and thus estimate resumption of ovarian cyclic activity.

The ovulatory response to suckling treatment occurred many days after the end of the treatment. This is consistent with the observation made by other researchers who recorded that positive responses to calf removal occurred 5 to 10 days after separation (Dunn *et al*, 1985; Anderson *et al*, 1986). The shorter ICC obtained in RS cows could have been a consequence of increased LH pulse frequency influenced by restriction of suckling (Walters *et al*, 1982; Williams *et al*, 1987). This increase in the frequency of pulsatile LH release is reported as a prerequisite for the resumption of ovarian cyclic activity in the postpartum cow (Williams, 1990; Peters and Lamming, 1990; Schillo, 1992).

Suckling manipulation in postpartum suckled cows has altered reproductive performance in many studies (Tervit *et al*, 1982; Dunn *et al*, 1985; Geymonat, 1985; Odde *et al*, 1986; McCartney *et al*, 1990) but not in others (Lishman and Harwin, 1985; Wright *et al*, 1987; Warren *et al*, 1988; Makarechian and Arthur, 1990). These trials have involved cows with different body condition score, age, parity and genotype. Furthermore, the length of the suckling restriction and the timing *post partum* at which the suckling treatment was implemented have also varied.

The nutritional level in mid-gestation tended to influence the restricted suckling treatment effect, an effect consistent with that found by other authors (Holness *et al*, 1978; Dunn *et al*, 1983; Geymonat, 1985). These authors reported that better responses in reproductive performance are obtained when cows are in moderate to high body condition rather than a low condition. The reasons for this interaction are not very clear. Lesmeister and Drake (1978) working with Hereford calves of similar weight (75 kg) but older (68 days) than calves in the present trial found that 48 h calf removal had a greater effect on reproductive performance of cows suckling the faster growing calves than on cows suckling slower growing calves. The authors suggested that the first group presumably stimulated greater milk production. Thus, it can be hypothesized that HN cows produced more milk than the LN animals and restriction of suckling was thus more beneficial in the former group. Nevertheless, there is no evidence that this would be the case because calf liveweight gains were similar for both nutritional groups in the first 45 days *post partum* and LN cows had calves with better daily liveweight gain than HN calves from day 45 onwards.

If it is assumed that the improved response to restricted suckling on reproductive performance in the present experiment was mediated by increased LH pulse frequency elicited by suckling treatment, then the LH response in LN cows could have been impaired due to lower liveweight and body condition throughout the trial. This is supported by Whisnant *et al* (1985), who found that primiparous cows fed low dietary energy levels delay the LH response to calf removal. While serum LH concentrations increased by 24 h after suckling restriction in cows fed high nutritional levels, a similar increase was not observed in cows fed low nutritional levels until 48 h after calf removal (Whisnant *et al*, 1985). Table 4.4 shows that there was an increase in average follicular size from the onset to day 2 of suckling treatment and from day 2 to day 4 in RS HN cows but not in RS LN cows. This increase in the mean size of the largest follicle after suckling restriction probably suggests that a higher LH pulse frequency occurred in the RS HN group than in the RS LN cows. However, these follicles did not ovulate in either of those groups because ovulation occurred later in the postpartum period. The reasons for that interaction between suckling manipulation and nutritional levels are thus unknown and more evidence is needed before a firm conclusion can be made.

Some authors have tried to explain the variable responses to temporary weaning by indicating that responses might be related to the amount of follicular development at the time of suckling restriction (Dunn *et al*, 1985). However, this explanation is not consistent with the observation in this trial that there was no difference among groups in the occurrence of DF or size of largest follicle prior to the imposition of restricted suckling (see Table 4.4). In spite of responses to restricted suckling treatment on reproductive performance being evident only in HN cows, the development of follicular structures did not differ in the HN and LN cows. Although the possible lack of DF at the time of temporary weaning implementation could still explain the lack of responses obtained in herds with poor body conditions, the presence of DF itself does not imply improvements in reproductive performance induced by restriction of suckling through fitting nose plates to calves, according to the present trial.

Results from the present study differ from some other reports where it is suggested that primiparous cows do not respond to temporary weaning (Geymonat, 1985). In New Zealand, Tervit *et al* (1982) reported that mature cows respond better to 48 h calf removal than young cows. Primiparous cows on a relatively high plane of nutrition are able to favourably respond to that management practice according to this trial. Poor responses obtained with this class of livestock in other trials (e.g. Tervit *et al*, 1982) can be a consequence of mixed age cows run together in one single herd. In these circumstances, the feeding of the younger cows may be impaired because they are more likely to be under nutritional stress than the adult cows. Therefore, primiparous cows are likely to be in poorer body condition than mature pluriparous cows. This could eventually explain the limited responses to temporary weaning recorded in primiparous cows.

No interaction between genotype and suckling treatment on reproductive performance was observed in the present trial, however suckling restriction by fitting nose plates to calves can be effective in some breeds but not in others (Holness *at al*, 1978).

Restriction of suckling activity in the herd can be carried out by different methods, namely by once or twice daily suckling (Montgomery, 1982; Bastidas *et al*, 1984; Odde *et al*, 1986), 48 or 72 h calf separation (Tervit *et al*, 1982; Dunn *et al*, 1985) and by fitting nose plates (Holness *et al*, 1978; Geymonat, 1985) or muzzles to calves (Macmillan, 1983). These different methods whereby suckling is restricted can be important in defining the responses to this management practice. First of all, the various methods are likely to differ in the degree of stress caused in the animals by the restriction of suckling. Stressful environmental situations can induce high serum cortisol levels and this is associated with failures to respond to treatments or practices that increase LH secretion (Li and Wagner, 1983; Whisnant *et al*, 1986; Gregg *et al*, 1986). Serum cortisol levels were not measured in the present trial and there was therefore no way to estimate whether RS-LN cows experienced more stress than RS-HN cows. However, that is unlikely since both groups were managed together.

In addition, the effectiveness whereby LH elevations are elicited after suckling restrictions can greatly vary within the different methods. The increase in LH pulse frequency after restriction of suckling was observed to be linear from day 0 to 4 after the onset of treatment (Williams *et al*, 1987). Thus, suckling manipulations of shorter duration (42 or 72 h) can bring about LH levels which are still not high enough to result in an ovulatory response in the cows. As mentioned before, that delay can be even more important if cows are not with a good body condition. Cow-calf bond was not temporarily broken by fitting nose plates to calves. Cows with calves fitted with nose plates had contact through nuzzling and licking. This particular feature might reduce some of the stress as a consequence of calf and cow separation. As well it would also avoid other problems such as the difficulty in mothering up after temporary weaning reported by other researchers (Tervit *et al*, 1982).

However, the presence of the calf itself was reported to prolong the PPAI and ovulation in milked cows with muzzled calves (Macmillan, 1983) and mastectomized cows (Vicker *et al*, 1993). Cow-calf bonding was indicated as responsible for delays in post partum ovulation (Macmillan, 1983), while Vicker *et al* (1993) found that cow-calf bonding alone is not enough to prolong PPAI but that the cow must receive stimuli from the calf resembling a normal suckling event. Those stimuli involved cow-calf nursing orientation with tactile stimuli in the inguinal area (Vicker *et al*, 1993). Restricted suckling calves could effectively exert that sort of stimuli in their mothers in the present trial. The calf behaviour study showed that calves fitted with nose plates had frequent suckling attempts, even though they spent progressively less time attempting to suckle from the onset to the end of the suckling restriction period. Restriction of suckling by fitting muzzles to calves for 4 days can also be effective in eliciting increases in LH pulse frequency and hence improvement in reproductive performance in cows (Williams *et al*, 1987). Therefore, despite the presence of those negative stimuli to resumption of ovarian cyclic activity during the restricted suckling treatment in the present trial, marked rises in LH could have been achieved in the cows over several days after calves had been fitted with nose plates.

The feed requirements of RS cows decreased during the period of nose plates attachment because milk production dramatically dropped during the restricted suckling treatment. If an efficiency of conversion from milk to calf liveweight of 6:1 (Barton, 1970) and a nutritional requirement of 4.8 MJ of ME for every kg of milk produced (Geenty and Rattray, 1987) are assumed, then NS cows had approximately 30 MJ of ME/day higher feeding requirements during the restricted suckling period than RS cows. Therefore, the extra energy available for the last group of cows might have also mediated the better reproductive performance achieved by RS cows.

In the present the trial, suckling treatment was implemented by day 46 *post partum*. The timing of suckling restrictions in the cow seems to be very important in determining the effectiveness of temporary weaning. No response to 48 hour calf removal was obtained when the treatment was applied at day 34 *post partum* (Wright *et al*, 1987), which may presumably be a consequence of higher endogenous opioid peptide tone early after calving (Whisnant *et al*, 1986).

The results of the present study also confirmed the observation reported by many authors that cows which calve later in the calving season have shorter PPAI (Morris *et al*, 1978; Knight and Nicoll, 1978; Montgomery *et al*, 1980). In primiparous cows calving in spring, Knight and Nicoll (1978) found that PPAI decreased 0.7 days for each day later the cows calved whereas this value was 0.96 days in the present experiment. Differences in the actual calving date, length of calving season, breed and milk production as well as nutritional levels (Hauser, 1984) involved in the trials may explain the greater effect of day of calving on PPAI found in this study. This effect has been indicated to be a consequence of the photoperiod (Peter and Riley, 1982b; Hauser, 1984; Montgomery, 1985). However, this can also be related to liveweight at calving because there was a positive correlation between day of calving and liveweight at calving and liveweight at calving was, in turn, negatively correlated to PPAI. Although Osoro and Wright (1992) did not find a significant effect of liveweight on PPAI in adult cows, liveweight at first calving was reported to affect PPAI (Rovira, 1973). Therefore, it is likely that liveweight could have also contributed to decrease PPAI as the cows calve later.

As expected, serum progesterone concentrations remained basal for a variable period of time after parturition. This period was highly correlated to PCLI. In spite of this high correlation, there were few cases were the occurrence of a CL was not accompanied by high serum progesterone levels and *vice versa*. Manns *et al* (1983) observed CL in postpartum cows that appeared to be functional but they were not producing progesterone. In the present trial, that finding was associated with the first observed CL after ovulation. Therefore, it could have been a consequence of CL still not fully functional immediately after ovulation. Other authors have also suggested that early serum progesterone elevations in postpartum cows can be a consequence of luteinized follicles (Webb *et al*, 1980; Manns *et al*, 1983). Basal progesterone level was slightly lower in the present trial than that reported by Montgomery (1982). However, the criteria to determine resumption of ovarian activity was also slightly different. Montgomery (1982) considered that cyclic ovarian activity for an individual cow was resumed when the serum progesterone was greater than 1.7 ng/ml.

In the present trial, 66.6% of cows were observed to conceive before any rise in serum progesterone concentration was determined. This finding has also been reported for both dairy and suckled beef cows (Peters and Ball, 1987). The high percentage of cows conceiving in the present experiment before rises in progesterone levels might suggest a high conception rate at first oestrous *post partum*. A short luteal phase and oestrous cycle is often reported in postpartum cows (Ramirez-Gordinez *et al*, 1981; Manns *et al*, 1983), however its identification was difficult in the present trial as the blood samples were taken only at weekly intervals and luteal phases can be as short as 3-4 days (Manns *et al*, 1983).

5.3 Effectiveness of the nose plate to prevent suckling

In contrast to suckling inhibition where cows and calves are separated, the use of nose plates allows that cow-calf pairs to be maintained. The question arises as whether suckling is completely inhibited when the nose plates are attached. No actual suckling was observed during the calf behaviour study when the nose plates were on. Such a study comprised not only the first three hours from sunrise onwards, but it went on to sunset on many days during the suckling treatment. One calf which lost its nose plate probably suckled its mother during the treatment period before its replacement.

There was a negative correlation found between calf liveweight loss during the period of suckling restriction and the PPAI of RS cows. This indicates that the higher the liveweight loss experienced by calves with nose plates, the shorter the PPAI experienced by their mothers. This observation is not in agreement with the finding of no suckling activity in the RS cow-calf pairs during treatment. Thus, one can be led to think that nose plates were not always 100% effective in preventing suckling if the degree of calf liveweight loss is interpreted as an indication of the milk consumption during treatment. However, liveweight loss during suckling treatment would not only be determined by reduced milk consumption, but also by pasture intake and physical activity which occurred in the period. However, there was a wide range of losses. While the average daily liveweight loss in the RS calves was 0.75 kg/day, that loss ranged from 0 to 1.14 kg/day.

These figures can be compared to the liveweight loss experienced by the calf that lost the nose plate. This calf lost 0.93 kg/day, even though it could have suckled during a limited period of a few hours. Therefore, despite the lack of suckling activity observed in the RS cow-calf pairs during treatment, some calves could have consumed some milk from their mothers in that period. Even in those circumstances, suckling activity must have been very limited. This is supported by the daily liveweight gains made by the control NS calves during treatment. NS calves had a liveweight gain of 1.12 kg/day during the week the RS calves had nose plates on.

A more complete calf behaviour study than was conducted is needed to confirm the degree of suckling activity achieved by calves fitted with nose plates. If this activity was confirmed, the study itself could furnish information that could be used to design more effective devices. One alternative would be using muzzles such as those utilized by Macmillan (1983). Two disadvantages are however identified, even though they can probably be more effective in avoiding suckling activity than the nose plates used in the present trial. First of all, muzzles prevent grazing. Therefore, muzzled calves must be fed, which increases the workload. Secondly, muzzles would presumably be more expensive than the simple nose plates used in this study.

Calves with nose plates on were able to graze. Restricted suckling calves spent almost 40% of their time from 6 to 9 a.m. grazing, while NS calves only grazed 16% of their time during the suckling restriction period ($P<0.001$). Five days after the removal of nose plates, RS calves still grazed for 34% of the observational time in comparison to the 10% for the NS calves ($P<0.05$). The effects of this increased grazing activity on the development of the digestive tract are unknown. Calves normally begin to eat small quantities of pasture when they are a few days old but they cannot eat sufficient pasture to satisfy their total feed requirements until they are eight to ten week old (Holmes and Wilson, 1987).

Increased grazing activity was clearly insufficient to maintain liveweight during treatment in the RS calves. Furthermore, the expanded grazing activity observed in calves after the removal of nose plates did not mean higher liveweight gains. However, daily liveweight gain after treatment was not affected by suckling restriction, even though RS calves were significantly lighter at weaning. This would presumably indicate that milk production of RS cows was not dramatically affected by restricted suckling treatment. Other researchers did not find any negative effect of restricted suckling on milk production of cows after the treatment (Beck *et al*, 1979; Dunn *et al*, 1983; Dunn *et al*, 1985), although daily liveweight gains after 48 h calf removal was impaired in one experiment (McCartney *et al*, 1990). Unfortunately milk production was not measured in the present trial, which would have given an idea whether increased grazing activity after treatment had a quantitative effect on the maintenance of daily liveweight gains in the RS calves or dam milk production was in fact unimpaired after restricted suckling treatment.

Daily liveweight loss in RS calves during treatment was smaller than that reported in another trial where calves lost 1.3 kg/day during 48 h calf separation, even though calves were fed hay and concentrates (Lesmeister and Drake, 1978). The negative effect of suckling restriction on calf liveweight at weaning found in the present trial is in disagreement with some reports (Dowling *et al*, 1977; Beck *et al*, 1979; Dunn *et al*, 1985; Odde *et al*, 1986; Wright *et al*, 1987; Warren *et al*, 1988; Makarechian and Arthur, 1990) but in agreement with others (Tervit *et al*, 1982; McCartney *et al*, 1990). The reasons for such variation probably is associated with the conditions and environment surrounding the temporary weaning system, genotypes involved and age of calves at weaning.

In some trials, calves were fed concentrates during temporary weaning (Holness *et al*, 1978; Odde *et al*, 1985; Wright *et al*, 1987). In some reports calves were locked inside a shed during suckling treatment (Wright *et al*, 1987; McCartney *et al*, 1990), while in others calves were placed in a paddock adjacent to the cows where they could move freely (Tervit *et al*, 1982). Tervit *et al* (1982) also reported that bad weather during calf removal could have influenced the liveweight losses. Thus, conditions and environment varied during the period of suckling restriction and any reference to the effect on liveweight of calves should be related to the conditions involved in the trial.

Despite lower liveweights at weaning, results from the present trial are in agreement with the lack of an effect of suckling restriction on calf health (Lesmeister and Drake, 1978; Dunn *et al*, 1983; Makarechian and Arthur, 1990) and the lack of problems in mothering up (Lesmeister and Drake, 1978).

5.4 Management benefits and Practical Application

The effect of temporary weaning on calf liveweight at weaning is very important since the output from the breeding cow herd is the product of weaning percentage and weaning liveweight (Nicol, 1984; Spitzer, 1986). It also challenges the concept that management practices which enhance cow reproduction also enhance progeny growth rate (Nicol, 1984; McMillan, 1989). Although an increase in total weight of calf weaned is generally observed when weaning percentage increases, the use of temporary weaning can be, at least in the short term, an exception to that concept. This highlights the importance of calculations to estimate the economic benefits of using restriction of suckling as a management practice to increase the economic efficiency of the breeding suckling herd.

A feed budget for the period of nutritional treatment can be made based on those figures reported by Geenty and Rattray (1987). High nutrition cows had to eat approximately 99 MJ of ME/day to gain 0.75 kg/day, while LN cows only require 63 MJ of ME/day to gain 0.17 kg/day during the nutritional treatment. Thus, HN cows ate 3600 MJ of ME/cow or 327 kg of DM/cow (assuming a M/D value of 11) more than LN cows during the 100 days of nutritional treatment. However, this extra feed in mid-gestation did not improve the reproductive performance or calf liveweight gains. On the contrary, it increased the maintenance requirements of HN cows since they were always heavier than LN counterparts. Therefore, the higher feeding level gain to the HN cows might be considered a wastage of resources in a common farm situation.

Only when higher nutritional levels were combined with temporary restriction of suckling were the benefits apparent. Restricted suckling cows had shorter interval from calving to conception. However, this group also had lower calf liveweight at weaning. A partial budget would give the economic benefits of fitting nose plates to primiparous cows. In this case, the advantages received from this practice would be that cows become pregnant 18 days sooner than the control group. As a consequence, calves would have had 18 extra days for growth in the next season. Theoretically, greater calf liveweight gains can be obtained when cows are in their second parity than when they are primiparous. However, if just the same average calf liveweight gains obtained this year is assumed for the next season, then calves born from RS dams would be more than 20 kg heavier at weaning than those born from NS cows (18 days x 1.16 kg/day). That extra gain would mean a positive balance of 5 kg per animal if it is subtracted by the lower weaning liveweight experienced in the current year. As the cost of nose plates is minimal and they can be used for many years this management practice does not have any increased cost. Although compensatory growth did not occur in the RS calves after removal of nose plates, the difference in liveweight between HN and LN calves was likely to be reduced if a more traditional weaning was made (i.e. at 200 days).

There are also extra advantages that might be noted: longer time from calving to the planned start of mating and the increased chance to become pregnant early in the subsequent calving season. Therefore the calculations indicate that temporary weaning may be a cost-effective management practice since the lower calf liveweight at weaning can be offset by older and heavier calves following the next calving. In addition, in those farm situations where there are naturally low pregnancy rates this management practice may increase the reproductive performance if combined with adequate nutritional management. This increase in performance is likely to be achieved more efficiently than by increasing nutritional levels alone.

This management practice does not use artificial hormones. Restriction of suckling by fitting nose plates to calves causes only minimal distress to cows or calves. Therefore it should not raise any animal welfare issues. Finally, it has a very reduced cost and workload and therefore farmers would not have major constraints to adopt this technology.

5.5 Further Studies

It is apparent that more studies are needed to increase understanding about the practical applications of temporary weaning of beef calves on the farm. More studies are needed to evaluate the interactions between the responses to suckling restrictions and different nutritional levels, and between those responses and age or parity of the cow. In addition, the combined effects of suckling restrictions and other practices such as biostimulation need to be evaluated. Information resulting from this research is likely to be utilized when designing management practices to increase biological and economic efficiency of beef breeding herds.

There is also a need to evaluate different methods of suckling restriction. Forty-eight and 72 h calf removal can be compared to fitting nose plates to calves. The effectiveness of those methods needs to be monitored by daily ultrasonography of follicular structures. The treatments must be implemented after 40 days *post partum*, when the chance to elicit a response in the LH pulse frequency increases. Cows would be allocated to treatment groups when a DF increasing in size is identified. Then treatments would be implemented and the ovarian follicular activity monitored daily.

The effectiveness of other treatments to accelerate ovulation and their effect on follicular dynamics and reproductive performance can be simultaneously studied. Results may be compared with those obtained with different methods of suckling restriction. Any liveweight loss caused by restricted suckling in the calves can be considered with the extra cost of those treatments (i.e. CIDR) . Thus, the economic and biological soundness of different treatments are compared.

Daily ultrasound examinations of ovaries to monitor follicular activity plus determination of LH serum concentrations influenced by temporary weaning in cows fed different nutritional levels can help to define the minimum feeding status of cows consistent with a favourable response in reproductive performance. These studies would provide better information for the concept of management of follicles to shorten postpartum intervals. The use of Ultrasonography to observe the actual effects of treatments or management practices on follicular dynamics of cows is valuable.

Finally, studies to decrease the liveweight loss of calves during suckling restrictions would greatly increase the advantages of this management practice.

5.6 Conclusions

In primiparous cows a pattern of growth and atresia of DF was observed. Dominant follicles were observed from as early as day 25 *post partum*. Prolonged PPAI and ICC occurred as a consequence of the DF not ovulating, rather than the lack of DF. Thus, any management practice that might lead to ovulation of DF must be regarded as potentially useful for beef breeding herds.

Restriction of suckling by fitting nose plates can reduce ICC in primiparous cows and concentrate subsequent calving pattern. First calving cows must be calved in a moderate to good body condition for the restriction of suckling by fitting nose plates to be effective in improving reproductive performance. This is particularly important in primiparous cows, since this class of livestock has often been identified as having longer postpartum and calving intervals. The low cost and workload associated with the nose plates make this technique a potentially very useful management practice to be implemented to increase both the economic and biological efficiency of New Zealand beef breeding herds.

Weaning liveweight of calves is reduced in restricted suckling calves, but daily liveweight gain after treatment is not compromised. Calculations indicate that the potential economic losses as a result of lighter weaning weight in the present season can be offset by older and heavier calves in the following season. This is a consequence of a more concentrated calving pattern achieved when restricted suckling treatment has been practised. More studies are, however, needed to increase the understanding about the practical applications of restriction of suckling under farm situations.

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