

Reproductive management of postpartum cows

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Abstract

High reproductive efficiency in the dairy cow requires a disease-free transition period, high submission rates to AI and high pregnancy rates per service. A key risk factor that causes increased incidence of metabolic disease is low negative energy balance (NEB) in the periparturient and early postpartum periods. Low NEB decreases LH pulse frequency, growth rate and diameter of dominant follicle (DF), IGF-I, glucose, insulin concentrations and increases GH and certain blood metabolites; these effects result in greater loss of body condition score (BCS) and a higher percent of anoestrous cows in the herd. It is important to decrease the incidence of metabolic disease by achieving high dry matter intake (DMI) and minimising the period of NEB after calving. Thus, nutritional management of the cow in the transition period has a crucial role to play in improving reproductive efficiency, because acute nutritional deprivation of heifers has immediate deleterious effects on follicular growth and ovulation. To obtain high submission rates, it is necessary to decrease the incidence of anoestrus and to have good oestrous detection rates. Pregnancy rates per service are affected by a variety of factors. NEB can have deleterious effects on the follicle or the corpus luteum (CL) by decreasing IGF-I concentrations and steroidogenesis. High protein diets fed to postpartum cows leads to increased blood urea and lower fertility. Although the mechanism is not clear, the practical implication of feeding the appropriate level of crude protein in the diet is clear. Thus, a coordinated management approach involving herd managers, nutritionists and veterinarians is required to obtain high reproduction efficiency in dairy cows. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

High reproductive efficiency in the dairy herd requires each cow to calve during a pre-planned calving season, with a calving interval that maximises the economic output

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Table 1

A comparison of postpartum reproduction parameters based on measurement of progesterone in milk twice weekly in two different studies using either moderate yielding Friesians (Fagan and Roche, 1986) or modern high-yielding Holsteins (Opsomer et al., 1998)

	Traditional moderate-yielding Friesian Fagan and Roche, 1986	Modern high-yielding Holsteins Opsomer et al., 1998
<i>Use of progesterone assay</i>		
No. of cycles	463	448
Normal cyclical patterns (%)	78	53*
Prolonged interval to 1st ovulation (%)	7	21*
Temporary cessation of ovulation (%)	3	3
Prolonged luteal phase (%)	3	20
Short cycles (%)	4	0.5
Other irregular patterns (%)	4	2.5

of milk production within the herd. Reproductive efficiency in the dairy cow has been decreasing in the past two decades, in parallel with high increases in milk production per cow. The causes of this decreased reproductive efficiency seem related to the increased incidence of production diseases due to a variable but often prolonged state of negative energy balance (NEB) in dairy cows in the periparturient and early postpartum periods (Van Saun, 1997). A comparison of data on ovarian activity based on measurement of milk progesterone concentrations in moderate yielding (4000–5000 kg milk per lactation) Friesian cows fed mainly grass and conserved grass in Ireland (Fagan and Roche, 1986) versus that in Dutch Holsteins producing 7000 to 9000 kg milk per lactation and fed high amounts of concentrates (Opsomer et al., 1998), shows an increased incidence of postpartum anoestrus, abnormal ovarian cycles and prolonged luteal phases (high progesterone for > 20 days before breeding) in high yielding cows (Table 1).

Recently, Lamming and Darwash (1998) reported similar problems in UK dairy cows, also based on twice weekly progesterone assays. They, furthermore, subsequently showed that cows that had abnormal luteal function before breeding had significantly reduced pregnancy rates to AI, compared to cows with normal pre-breeding cycles. Thus, both submission rates to AI and pregnancy rates per cycle are adversely affected in high yielding cows. The aims of this paper are to review the physiological causes and outline potential management strategies to minimise this low fertility in modern strains of dairy cows.

2. NEB in the postpartum period

Following parturition, dry matter intake (DMI) needs to increase 4- to 6-fold in order to meet the high nutrient demands of milk production. However, the high yielding cow post calving is not able to increase DMI as fast as the increased nutrient demands required for lactation; the cow copes with this nutrient shortage by mobilising body reserves of fat and protein. Energy partitioning in early lactation in one study resulted in mobilisation of 42 kg empty body weight (EBW), 31 kg fat and 5 kg protein (Tamminga

et al., 1997). Cows mobilise an average of 0.7 kg EBW, 0.56 kg fat and 0.04 kg protein per day; however, the largest part of this mobilisation took place in the first week of parturition with 37% of EBW, 12% of total fat and 58% of total protein being mobilised (Tammenga et al., 1997). During this period of declining NEB, LH pulses are suppressed and dominant follicles (DFs) that develop have a decreased chance of producing sufficient oestradiol to induce a pre-ovulatory gonadotrophin surge. Currently, it is proposed that the day of EB nadir is more important than the degree of NEB (Beam and Butler, 1997) in suppressing LH pulse frequency. Delayed resumption of ovulation was related to the degree of NEB; cows in the most severe NEB had higher non-esterified fatty acid (NEFA) and triacyl glycerol levels and a longer interval to first ovulation (Kruip et al., 1998). Thus, achieving high DMI in the early postpartum period of high-yielding dairy cows is crucial to normal resumption of ovulation and development of a corpus luteum (CL) of normal size and progesterone production capability required for high fertility (Vandehaar et al., 1995). Thus, the nutritional management of the dairy cow in the transition period ~ 3 weeks before calving to 3 weeks after calving has significant carry-over effects on reproductive efficiency of high yielding dairy cows.

3. Endocrine cause of anoestrus

It is now clear that anovulatory anoestrus in dairy cows is due to failure of DFs to ovulate rather than to their absence (Roche et al., 1998). Thus, anoestrous cows have recurrent increases in FSH every 7–10 days shortly after calving (7–14 days). Each new FSH increase is responsible for the emergence of a follicle wave, and the decline in FSH results in selection of a single DF. The DF undergoes atresia rather than ovulation due to its failure to produce sufficient concentrations of oestradiol to induce a pre-ovulatory gonadotrophin surge and hence, ovulation (Roche and Diskin, 2000). The inability of the DF in anoestrous cows to produce elevated concentrations of oestradiol is related to the degree of NEB in the early postpartum period (Beam and Butler, 1997; Staggs et al., 1998), which causes the following effects on:

(i) Reproduction

- a decrease in LH pulse frequency,
- decrease in diameter of DF with low oestradiol production,
- decreased systemic IGF-I and perhaps intra-follicular IGF-I availability,
- increased interval to first oestrus;

(ii) Metabolism

- higher GH production and uncoupling between GH receptor and IGF-I production,
- decreased body condition score (BCS),
- lower glucose and insulin concentrations,
- higher NEFA, β hydroxy butyrate and triacyl glycerol concentrations.

The cause of the lower LH pulse frequency is presumed to be due to lower GnRH pulse frequency from the hypothalamus, because of the strong physiological regulation by GnRH on LH release and pulsatile pattern in cattle and sheep. The lower LH pulse

frequency will lead to decreased androgen production by theca cells. This decrease, coupled with lack of maximal stimulation of the aromatase enzyme system by IGF-I within the follicle, leads to low oestradiol production by the DF. Decreased insulin could also play a role in association with low leptin to suppress LH release from the anterior pituitary. The aetiological factors that are involved in the increased incidence of anoestrus have been studied in the Netherlands at farm level (Opsomer, 1999). These data showed that losing body condition was an important risk factor associated with prolonged anovulatory anoestrus in dairy cows, based on multivariate analysis of a number of relevant factors. However, the intricacies and the interactions between low NEB and the reproductive–metabolic axes in postpartum dairy cows are not well understood at present.

4. The effect of acute nutritional restriction on ovulation

Although it is well known that nutrition plays a key role in regulation of reproductive function in cattle, the relative effects of chronic and acute nutritional effects are not well understood. Chronic nutritional effects are seen in beef cows, where there is a negative correlation between level of prepartum nutrition and length of postpartum anoestrus (Richards et al., 1991; Wright et al., 1982). Long-term studies in heifers show that chronic nutritional deprivation decreases growth rate and maximum diameter of the DF, but heifers had to lose 17–23% of their body weight before ovulation was suppressed (Rhodes et al., 1995; Stagg et al., 1995; Bossis et al., 1999). LH pulse frequency was only suppressed during the oestrous cycle before the onset of anovulation, while FSH recurrent increases responsible for new follicle wave emergence every 7–10 days were not affected (Stagg et al., 1995). However, nutritional changes pre- and postpartum are more acute in dairy cows due to the massive increased nutrient demands for milk production after calving. Thus, to establish the effects of acute nutrition on follicular dynamics in cattle, a cyclic heifer model was developed by Mackey et al. (1999a) where heifers being fed on 1.2 maintenance (M) were reduced to 0.4 M day before the end of a progesterone synchronisation regimen. Exposing cyclic heifers to an acute nutritional restriction from 1.2 to 0.4 M beginning 1 day before the removal of a progesterone intravaginal device (CIDR, InterAg, New Zealand) caused a decrease in both growth rate and maximum size of the DF that developed during the first wave of the subsequent synchronised cycle (Table 2). These follicular effects occurred in the absence of measurable effects on LH and nadir FSH concentrations during this time. This suggests effects on local cytokines within the follicle possibly involving the IGF system. They agree also with the chronic effects of nutrition on follicular growth and show that cattle are very sensitive to acute nutritional deprivation, which began within 3–5 days of their initiation. In the above study, two of eight heifers assigned to the 0.4 M diet failed to ovulate; hence, the experiment was repeated to see if acute nutritional restriction from 1.2 to 0.4 M could not only detrimentally affect DF growth, but also prevent its ovulation (Mackey et al., 1999b). The results showed that 12/20 heifers assigned to acute nutritional restriction from 1.2 to 0.4 M did not ovulate the DF present either at progesterone device withdrawal (2/20) or during the first follicle wave of the synchro-

Table 2

The effect of diets supplying 0.4 M or 1.2 M on follicle wave dynamics in beef heifers when applied from one day before removal (day 0) of a progesterone synchronising device (CIDR). Heifers received prostaglandin F2 α 6 days after detected ovulation to induce luteolysis and allow ovulation of first DF of the new oestrous cycle to occur

	Nutrition Level		<i>P</i>
	0.4 M	1.2 M	
No. of heifers	20	21	
<i>Synchronized DF</i>			
Diameter at day 0 (mm)	8.0 \pm 0.5	7.8 \pm 0.5	NS
Maximum diameter attained (mm)	11.7 \pm 0.2	12.6 \pm 0.2	**
Day of ovulation	4.4 \pm 0.1	4.5 \pm 0.1	NS
Interval: CIDR withdrawal to ovulation (days)	3.4 \pm 0.1	3.5 \pm 0.1	NS
No. anovulatory heifers	2/20	0/21	NS
<i>First new follicular wave</i>			
No. follicles emerging	10.1 \pm 0.7	10.4 \pm 0.6	NS
Diameter at PG injection (mm)	9.6 \pm 0.2	11.2 \pm 0.3	***
Growth rate of DF (mm/day)	0.96 \pm 0.05	1.28 \pm 0.08	**
Maximum diameter of DF (mm)	10.6 \pm 0.3	13.8 \pm 0.3	***
No. anovulatory heifers	10/18	0/21	***
<i>Incidence of anovulation</i>			
Total no. anoestrous heifers	12/20	0/21	***

nised cycle following induced luteolysis 6 days after ovulation (10/18 heifers). Failure of ovulation was always associated with the absence of a preovulatory LH and FSH surge, based on collection of blood samples every 4 h. However, the absence of an LH and FSH surge was not always associated with absence of a pro-oestrous increase in oestradiol concentrations. This points to two potential mechanisms being involved in anovulation as a result of acute nutritional restriction in cattle, viz. (i) failure of oestradiol induced positive feedback, (ii) failure to obtain a pro-oestrus increase in oestradiol to induce positive feedback. Thus, these results highlight, for the first time, the rapid detrimental effects of acute nutritional restriction on DF growth and ovulatory ability in cattle. Furthermore they have significant implications for the acute effects of NEB on follicular growth and ovulatory ability of early postpartum DFs in dairy cows.

5. Causes of abnormal ovarian cycles

Once ovulation resumes in the early postpartum period, the most common ovarian abnormality to occur, based on two to three times weekly progesterone samples, is prolongation of the luteal phase (Lamming and Darwash, 1998; Opsomer et al., 1998). The cause of this is most likely to be delayed luteolysis, which suggests problems with the timing of the luteolytic cascade of oestradiol induction of oxytocin receptors in the uterine endometrium, necessary to induce prostaglandin F2 α release and luteolysis. Thus, an increase in subclinical uterine infection or other uterine pathological problems

may be involved. In fact, Opsomer (1999) has shown that factors that adversely affect uterine function such as dystocia, retained foetal membranes or uterine infection are all key risk factors involved in the incidence of abnormal ovarian and progesterone profiles in the postpartum cow.

A second factor that may be important in determining pregnancy rate is the functional capacity of the CL formed during the period of improving NEB, once nadir values have been reached. The diameter of the DFs may be reduced, leading to the formation of a CL of smaller size, whose ability to produce maximal progesterone output may be compromised. Furthermore, decreased IGF-I concentrations at this time of continued NEB could also lead to a reduction in progesterone synthesis, because it has already been shown that the GH–IGF-I axis is important in determining steroidogenesis in luteal tissue in ewes (Juengel et al., 1997). Indeed, it has been shown that cows with a retarded increase in progesterone elevation during the early luteal phase have lower pregnancy rates (Larson et al., 1997). In support, recent work (Mann et al., 1998) from the UK suggests that embryos obtained from cows with a delayed elevation in progesterone concentrations between days 4 and 8 of the cycle, produce significantly decreased interferon tau levels, and thus, such cows are more prone to have higher levels of early embryo loss around the time of maternal recognition of pregnancy in cattle. Higher metabolic clearance rate of progesterone in high yielding cows could also be involved.

6. Reproductive management of the cow

High reproductive efficiency in the dairy herd requires: (i) a disease-free transition period, (ii) high submission rates to AI, (iii) high pregnancy rates per service.

6.1. Transition period

As milk production per cow continues to increase due to improved management and genetic gain, there is increased need to decrease production and clinical reproductive diseases, because they cause not only short-term problems and production losses, but also they have long-term detrimental effects on fertility. Cows that succumb to one periparturient disease are more susceptible to develop other diseases, viz. cows with retained placenta are 16.4 times more likely to become ketotic than those with normal expulsion of the placenta (Curtis et al., 1985). The preparation for and the actual process of parturition and the onset of lactation are major physiological challenges to the cows. These result in decreased DMI before calving, decreased absorptive capacity of volatile fatty acids from shrinking rumen papillae, increased risk of rumen acidosis unless the rumen bacterial population is allowed sufficient time to adapt to the post-calving dietary constituents pre-calving, and decreased immuno-competency due to increased cortisol and oestrogens before parturition (Goff and Horst, 1997). Thus, a healthy and safe passage through the transition period is crucial to proper health, welfare and reproductive efficiency of the cow. The key management factors are to have cows entering the dry period in good BCS (3.5–3.8), and to maintain this score during the dry period. Excessive BCS at calving results in increased incidence of fatty liver, decreased feed

intake due to poor appetite post-calving and increased level of anoestrus and reduced pregnancy rates to service (Grummer, 1993). The pre-calving ration should be introduced 3–4 weeks before calving to allow proper rumen flora adaptation to the post-calving diet (Goff and Horst, 1997; Van Saun, 1997). It is also crucial to minimise the degree of reduced DMI before and after calving. High DMI requires the use of highly palatable feeds, proper feed management, sufficient trough space for each cow and adequate frequency of feeding (Grant and Albright, 1995). The minimisation of stress and immunosuppression by proper management and adequate feeding of vitamin E and selenium and proper cation–anion balance to decrease metabolic diseases are also important (Kehrli et al., 1998).

6.2. *High submission rates*

In order to achieve high submission rates, it is necessary that the cow resumes normal oestrous cycles within 30–45 days after calving and that the efficiency of oestrous detection is high. The factors that affect the level of anoestrus and hormonal treatments to be used to induce oestrus have been recently reviewed (McDougall and Rhodes 1998; Roche and Diskin, 2000). The solution to the problem of inadequate detection of oestrus relate to consideration of three options: (i) increase frequency of daily checks, (ii) use of an acceptable aid for detection, viz. tail paint, pedometers or pressure transducers on the tail head of the cow or (iii) judicious use of hormones to synchronise oestrus in groups of cows.

6.3. *High pregnancy rates*

Once cows have been correctly detected to be in oestrus, it is vital to obtain high pregnancy rates per service to achieve high reproductive efficiency in the herd. Low pregnancy rates to AI are multifactorial complex problems that are difficult to solve. They can be caused by nutritional or management problems of a chronic or acute nature. There are two key questions regarding the effect of nutrition on pregnancy rates in dairy cows. The first question is the possibility of the long-term deleterious carry-over effects of low NEB in the periparturient period on subsequent oocyte quality once cows have resumed ovulation 30–60 days later (Britt, 1992). Kruip et al. (1998) have reported that oocyte developmental competence in over-conditioned cows that had a greater decline in NEB in the first 2 weeks of calving and a slower recovery to energy balance, was poorer than in controls up to 100 days postpartum. However, O'Callaghan et al. (2000) found that oocyte competency based on *in vitro* blastocyst production was poor in oocytes recovered during the first 50 days postpartum. Thus, it is not yet clear whether there is deleterious carry-over effects of low NEB on oocyte quality or if oocytes produced from follicles that develop in the early postpartum period are inherently less competent to produce blastocysts *in vitro*. The second question is the role of excess protein in the diet on fertility, leading to high production of ammonia in the rumen, which in turn is converted to urea leading to increased blood urea levels (Canfield et al., 1990; O'Callaghan et al., 2000), and lower fertility (reviewed in O'Callaghan and Boland, 1999). Butler and Gilbert (1998) have reported that high plasma urea concentrations post

AI are associated with lower fertility by causing alterations in uterine pH with consequent deleterious effects on embryo survival. However, it is not clear if high urea per se causes lower embryo survival in ruminants, because transferring embryos to recipient heifers with different blood urea concentrations did not affect embryo survival rates (O'Callaghan and Boland, 1999). Thus, O'Callaghan and Boland (1999) suggest if urea adversely affects fertility, the effect is more likely to be at the level of the oocyte/follicle or in the oviduct environment rather than at the uterine level. Thus, while high protein diets fed to cows in NEB cause lower fertility, the mechanism of this effect is not clear but the practical implication of not feeding excess crude protein diets to dairy cows during the breeding season is clear.

7. Conclusion

Effective reproductive management requires that cows have a disease- and stress-free transition period; that cows resume normal oestrous cycles in the early postpartum period in association with high efficiency of detection of oestrus during the designated breeding season; and finally, that pregnancy rates per service are high. It is becoming increasingly clear that nutritional management of the cows is crucial to achieve the above targets. The role of high DMI of palatable feeds to minimise the extent and duration of the inevitable period NEB that the cow undergoes in the periparturient period is crucial. The prevention of metabolic and gynaecological disease is also important. Thus, high reproductive efficiency requires long-term planning, the implementation of good preventative measures to decrease periparturient diseases, and the interaction of herd managers, nutritionists and veterinarians in a coherent but coordinated fashion working together to achieve the above goals.

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