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Fertility in High Yielding Dairy Cows

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Introduction

Genetic progress coupled with improved nutritional management has resulted in many more cows that can produce over 8,500 litres per 305 day lactation. This upward trend in production over the past 30 years has been accompanied by a steady decline in fertility, with first service conception rates often falling below 40%. Over the same period, there have been considerable changes to dairy management systems in terms of increased herd size, reduced manpower and altered diets. The important question we need to answer is whether the drop in fertility is an inevitable consequence of increased yield? If not, a better understanding of the underlying causes may enable us to improve the management of modern Holstein cows to enable them to maintain an acceptable level of reproductive performance.

Metabolic changes associated with lactation

Immediately after calving, dairy cows cannot eat enough to meet the demands of lactation. They therefore enter a period of negative energy balance (NEB) during which they mobilise body reserves for milk production and most cows lose body condition at this time. The duration of this NEB varies considerably. In some cows it lasts only a few weeks, but genetic selection for milk yield has resulted in cows with a greater ability to mobilise body tissue and, in such cows, the duration of NEB is extended, possibly up to 20 weeks after calving (Beever *et al*., 2001).

This tissue mobilisation is associated with a number of metabolic changes. Cows in NEB release non-esterifed fatty acids (NEFAs) from their fat as an energy source and ketone bodies including beta-hydroxy butyrate (BHB) are produced by the liver as the fatty acids are metabolised. Circulating concentrations of both NEFA and BHB therefore rise following calving to an extent which is related to the degree of fat mobilisation. There are a number of other important changes going on at this time within the liver. In terms of fertility, one of the most important appears to be that the liver makes less of a metabolic hormone called insulin-like growth factor-I (IGF-I), so IGF-I concentrations drop steeply immediately after calving, taking a number of weeks to recover. This acts as a signal of metabolic status to the reproductive system (brain, ovaries and uterus) which regulates fertility.

Another metabolic parameter with a known link to fertility is urea. Dairy cows' diets typically contain a high crude protein concentration. The rumen degradeable component is broken down during rumen fermentation, releasing ammonia, which is used for microbial protein synthesis, a process requiring energy. If excess effective rumen degradeable protein is fed in relation to the available fermentable metabolisable energy in the diet, then ammonia production will rise. This must be detoxified to urea by the liver, so urea levels increase. The detoxification procedure itself requires energy, thus exacerbating the NEB. The relationship between urea and fertility is, however, somewhat controversial and deserves a separate article, so it will not be considered further here.

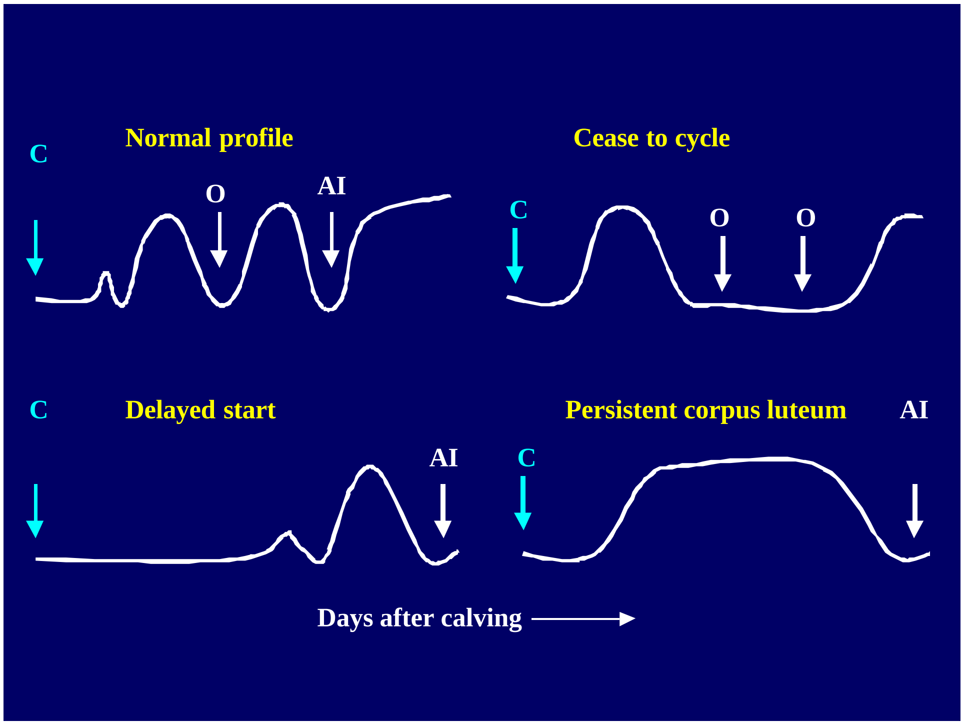
Relationship between infectious disease and the metabolic system

The immune system is depressed in early lactation, and dairy cows are therefore particularly susceptible to bacterial infections causing mastitis or endometritis at this time. Such infections are more likely to occur following a difficult calving (eg retained foetal membranes, dystocia, and twins). As part of the cow's response to infection, she will release endotoxins. These have a variety of actions, one of which is to target nutrients preferentially into the immune protection system. This helps the cow to combat the infection, but takes nutrients away from other body functions. Cows with mastitis therefore have lower concentrations of the circulating metabolic hormones IGF-I and insulin, and those with metabolic disorders such as fatty liver have reduced immune competence.

Milk progesterone profiles

The ideal dairy cow resumes regular 21 day oestrous cycles within about 3-4 weeks of calving, shows heat for the first time at about 40 days, and can then be inseminated at observed heat from about 60 days onwards (depending on herd policy). With the development of milk progesterone assays in the 1970s, it soon become apparent that many dairy cows do not follow this desired pattern. The problems can be roughly divided into three categories. Some cows take too long after calving to have their first ovulation, some cows resume cycles but then stop again and some cows have longer than expected luteal phases when progesterone levels remain high (persistent corpus luteum) (Figure 1). All of these irregularities make heat detection much more difficult, as intervals between heat periods may be shorter or longer than the expected "norm" of 18-24 days. Strategic use of milk progesterone assays may assist in detecting the cause of the problem.

Figure 1. Examples of different types of milk progesterone profile. C = calving, O = oestrus, AI = artificial insemination



The incidence of all of these problems has increased over the past 30 years, and is related to yield. Table 1 shows a comparison of the proportion of cows showing some sort of profile abnormality between average and higher yielding cows. Both groups were kept at the same farm and were given nutritional management appropriate to their yield.

Table 1: Increased incidence of abnormal progesterone profiles in high yielding cows. * All values were significantly higher in the HGM cows.

	AGM cows, n = 20	HGM cows, n = 28
Yield (kg)	8047 ? 300	10573 ? 245
Days to first progesterone rise	15 ? 1.6	23 ? 2.3*
% with abnormal progesterone profile	30%	61%*

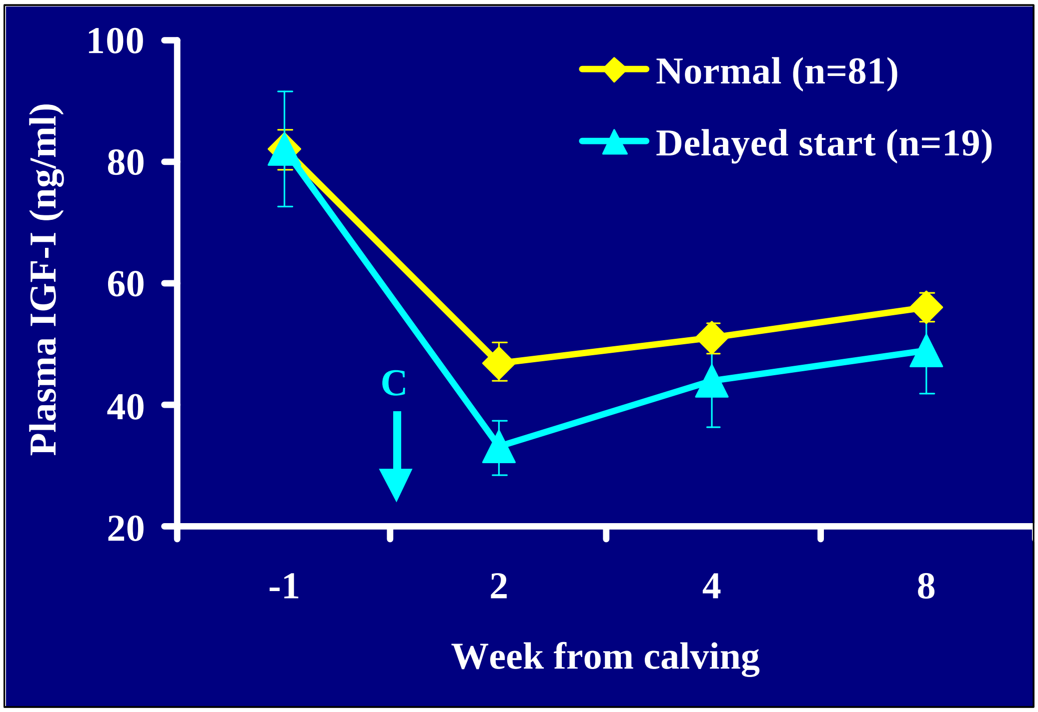
Cows with irregular cycles have poorer conception rates, but in addition to this fertility seems to be lower in higher yielding cows even when they are showing apparently normal cycles. In the past few years we have developed a much better understanding of the factors causing both the cycle irregularities and the poor conception rates. Cycle irregularities are more likely in cows losing excessive body condition, but other factors also come in to play, as described below. In a recent study of 180 multiparous cows, we found that cows with no body condition score (BCS) change in the eight weeks after calving experienced 82% normal progesterone profiles whereas in those losing >1 BCS points only 40% of profiles were normal.

Reasons why some cows don't start to cycle

Cows in poor energy status generally have a delayed start to cycles (Figure 1). In these cows, a succession of follicles grow on the ovary, but they regress without ovulating so the egg is not released and no corpus luteum forms. This occurs in cows that show a high rate of BCS loss following calving, or in cows that calve in poor condition. In both cases, the metabolic changes generated send signals to the reproductive system which prevent the follicle from maturing. There is also a seasonal effect, with a longer interval to first ovulation in UK cows calving in March – May. This is probably related to altered nutrition at different times of the year, in particular spring turn out to grass.

We have measured a variety of metabolites in the early *post partum* period that could be acting as signals. These included NEFA, BHB, insulin, glucose and IGF-I. We then linked their concentrations in the month immediately following calving to the time taken to resume cycles. Of these, IGF-I was the best predictor (Figure 2) although BHB and NEFA concentrations were raised in some cows with a delayed start to cycles and in the first lactation, insulin concentrations also tended to be lower. We will come back to differences between first lactation and more mature cows later on.

Figure 2. IGF-I concentrations in the blood before and after calving in cows with normal progesterone profiles and those which had a delayed start to cycles. Values were significantly lower 2 weeks after calving in the latter group.



There are many reasons why an individual cow may experience a high rate of BCS loss. Apart from genetic selection for cows which are able to ‘milk off their backs’, a variety of management factors come in to play, mainly related to a reduced dry matter intake (DMI) or an inappropriate dietary management.

?? Excess protein:energy ratio in lactational diet

?? Poor quality of feed

?? Poor transition management

?? Too little fibre causing acidosis

?? Difficult calving

?? Low DMI due to illness, lameness, bullying by herd mates, hot environmental temperature etc

?? Over conditioned at calving, resulting in reduced appetite and a higher incidence of fatty liver.

Reasons why other cows stop cycling

A cow normally comes into heat 2-3 days after the end of a luteal phase, when progesterone production by the corpus luteum has declined. If the ovaries are monitored at this time, there should be one follicle that grows rapidly to an adequate size before it ovulates. During this growth period the follicle produces increasing amounts of oestrogen which should bring the cow into heat. The process of ovulation requires the ovary to receive a specific hormonal signal from the brain, and it is now apparent that this signal can be blocked by stress. The follicle then either regresses without releasing the egg or else it develops into a cyst that can persist for a number of days. The stress can be caused by a variety of metabolic and disease factors, for example transporting the cow, a sudden change in diet or the onset of an infection such as mastitis or endometritis. In addition, cows that cease to cycle often have metabolic parameters indicating that they are in poor energy balance. As soon as the original follicle stops producing oestrogen another one will start to grow. If the stress has passed, this one may go on to ovulate. If not, the process will repeat itself leading to a longer delay before the cow resumes normal cycles.

Long luteal phases

The incidence of long luteal phases (raised progesterone for >19 days) has increased over the past 30 years (Royal *et al.*, 2000). The main risk factors for this condition are an abnormal calving, retained placenta and endometritis, although many cows with persistent corpora lutea show no obvious signs of uterine infection. The incidence also increases with age (>4 lactations) and during heat stress, but it does not seem to be associated with any major changes in metabolic hormone profiles suggestive of a prolonged NEB. It is higher in US Holsteins than New Zealand Friesians. This suggests that there may be a genetic component, and that some of the factors that have been selected for in increasing yield may also influence the lifespan of the corpus luteum.

Carry over effects of poor condition on fertility

Our studies of over 500 cows that we have monitored in detail have shown that fertility is more profoundly influenced by the events around calving and during the initial period of NEB than during the actual service period, by which time metabolic parameters have often apparently improved. This carry over effect may be attributable to a number of possible factors.

?? If cows have experienced a high rate of BCS loss, their condition tends to be lower during the service period
?? It takes about 150 days for a follicle to develop up to ovulatory size in the cow. The metabolic changes outlined above which occur during the period of NEB may adversely affect the eggs which are present in the growing follicles.
?? If the follicles are poorly developed, they also tend to turn into inadequate corpora lutea. Several studies have shown that good fertility requires the corpus luteum to increase its progesterone production within

4-5 days of ovulation (Mann *et al.* 2001). If this increase is delayed, the embryo grows too slowly, and may be lost.

?? Cows with a high BCS loss are more susceptible to infection, and this can have an adverse effect on both the ovary and uterus.

Effects of age and yield

These are considered together as their effects are inter-related in terms of fertility. There are major differences in the ways in which cows react to lactation as they mature, which leads to altered relationships between milk production, energy balance and fertility. These differences are most noticeable between the first and subsequent lactations, although they will clearly be influenced by the age and state of maturity at which cows calve for the first time. In general, first lactation cows are still growing. They therefore tend to target extra nutrients into growth rather than milk. Older cows, however, have higher yields and put extra feed into milk production. Probably because they are having to cope with growth as well as milk production, first lactation cows take longer to conceive (Table 2).

Table 2: Effect of lactation number on yield and fertility. * Indicates significantly different values between the two age groups.

Parameter	Primiparous cows	Multiparous cows
n	185	166
Peak yield kg/day	31.6 ? 0.4*	43.5 ? 0.6
Days to first service	81 ? 1.9*	73 ? 1.8
Days to conception	115 ? 3.9*	101 ? 3.5
Services per conception	2.0 ? 0.1	2.0 ? 0.1
% culled for infertility	12%	9%

In multiparous cows we have found a strong relationship between yield and fertility and calving to conception intervals increased as peak yields increased. In our recent studies of high yielding herds, we found that a peak yield of about 42 kg/day seemed to be the point above which fertility was adversely affected (Wathes *et al*., 2001) with the mean open period increasing from 82 to 114 days above this production level. This is illustrated in more detail in Figure 3, which shows the individual points for each cow in the study. All of the cows producing less than 42 kg had conceived within 150 days, and most took less than 100 days to get back in-calf. In contrast, only half the higher yielding cows were back in-calf by 100 days, and about a quarter of them took more than 150 days. This shows that it is not impossible to combine high yields with good fertility, but it becomes increasingly more difficult as yield goes up. During the early *post partum* period (first seven weeks) there was a greater fall in IGF-I, a larger rise in urea levels and a greater loss of body condition in higher yielding cows, all indicative of a worse energy balance at this time. Multiparous cows calving with a low BCS (<2) also took longer to conceive. The risk factors for poor fertility are summarised in Table 3.

Figure 3. Relationship between peak yield and days open in multiparous cows. Each symbol represents one animal.

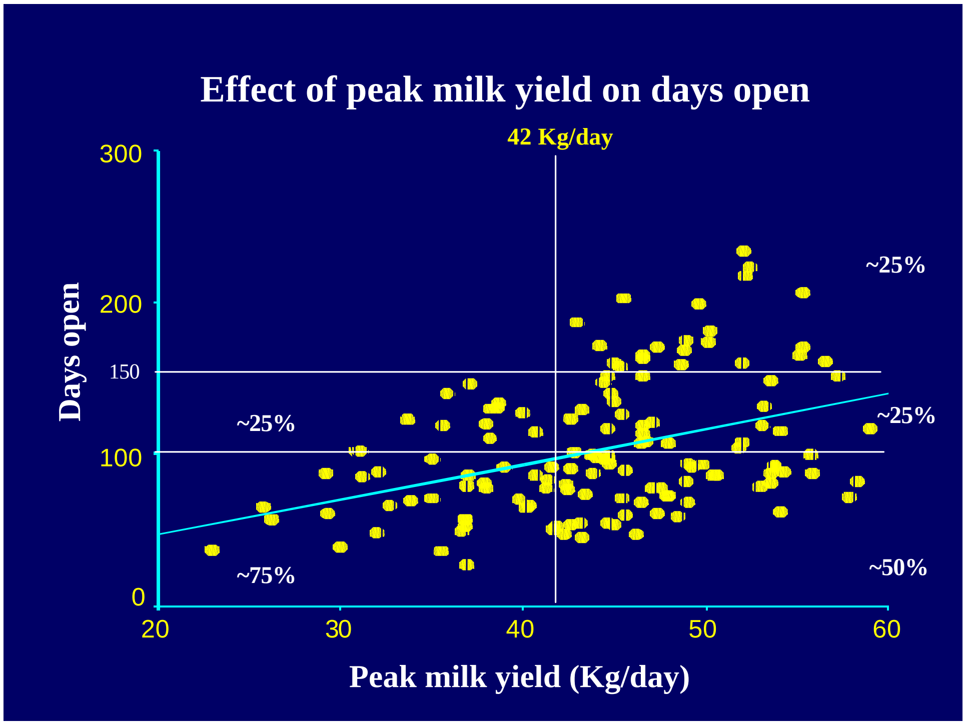


Table 3: The main risk factors for poor fertility

Multiparous Cows	**Primiparous cows**
High yield (peak yields > 42 kg/day)	
Loss of > 0.5 BCS points in the first 7 weeks *post partum* or BCS < 2 at calving	High *pre-partum* BCS (> 3)
Low IGF-I values (< 50 ng/ml) after calving	High *pre-partum* IGF-I (> 140 ng/ml)
Increasing urea values (to > 6.5 mmol/l) after calving	High *pre-partum* urea (> 6 mmol/l)

The relationship between yield and fertility was much less pronounced in primiparous cows. The main problem we encountered in terms of fertility in the first lactation was over condition at calving. Heifers with a BCS > 3 at calving took three weeks longer to conceive than those in the BCS range 2-3, with open periods of 124 ? 7 and 103 ? 8 days respectively, although milk yields were similar in the two groups. Furthermore, heifers that failed to conceive at all had the highest IGF-I values pre-calving, whereas those with the shortest open periods had the lowest IGF-I. The main points relating to poor fertility in the first lactation are summarised in Table 3 and are all related to over condition in late pregnant heifers.

It is important to note that both the absolute values, the pattern of change of many metabolic hormones and metabolites and their relationship to fertility all differ in the first lactation. In our study, IGF-I, insulin and BCS values were all higher in primiparous cows, whereas BHB and urea levels were lower pre-calving, but then increased more in the first eight weeks *post partum.* When these metabolites are used diagnostically for poor fertility, it is essential to subdivide the younger animals in order to be able to interpret the results.

Effect of diet

There is no space here to go into this subject in any detail, but we just want to make a few simple observations.

?? It is clearly essential that the diet supplied meets the protein, energy and mineral requirements of the cow according to her stage of lactation and that she receives sufficient quantity. However, it is hard to improve fertility in high genetic merit cows by feeding more. They tend to put the extra feed into more milk, and this can make the energy status and fertility worse rather than better.

?? Careful dry cow management will help to get the cow into an appropriate body condition to calve and will avoid the problems outlined above, which are associated with either over condition or under condition at calving.

?? When we have compared either transition or lactation diets that were designed to fulfil these criteria (ie which met the estimated protein, energy and mineral requirements) but which differed in their individual constituents, we found that the differences in the ways in which individual cows responded to the same diet in terms of fertility were almost always greater than any differences between diets. This is because individual cows behave differently in the way in which they mobilise their body reserves during lactation, according to their genetic make up, metabolic condition and disease status as discussed above.

?? In order to maximise fertility, it is therefore necessary to feed each cow to her individual requirements at each stage of her lactational cycle. This becomes increasingly more challenging as yields increase, as there is more scope to get it wrong and to put the cow into energy deficit.

?? In our view, very little infertility is due to a mineral deficit and fertility problems are unlikely to be cured with mineral supplements.

Conclusions

Dairy cow fertility in the UK and elsewhere is continuing to decline and this is intimately linked to increasing milk yields. Genetic selection to optimise yield has resulted in cows with enhanced abilities to mobilise body reserves for milk production. In cows producing peak yields of > 42 kg/day, it is always going to be difficult to achieve a 365 day calving interval, as such cows may not return to a positive energy balance until 15-20 weeks *post partum* and fertility is likely to be impaired. However it is possible to achieve acceptable levels of fertility with excellent management. The most critical periods are during the dry period and in the first few weeks of lactation. It is important to try to ensure a trouble-free calving and a high dry matter intake immediately after. If cows do lose >1 BCS point in early lactation, then the chances of conception are significantly reduced and it may be advisable to delay first service until after 100 days to allow animals to return to positive energy balance before trying to establish a pregnancy. Both metabolic and infectious diseases experienced by the cows can impact on fertility, even if the animal has apparently recovered by the time of service.

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