Nutrition and fertility in dairy cows

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Poor fertility is an important problem for Irish dairy herds and, over the coming months, the *IVJ* will ask experts from across the country to address the issue. This edition features the effects of nutrition.

Introduction

It is now widely recognised that reduced fertility in dairy herds is one of the most important factors affecting producer profitability. Roche (2006) has defined the effect of infertility on profitability as: (i) prolonged calving interval with fewer calves and less milk per cow; (ii) increased replacement costs; (iii) increased labour, semen and veterinary bills; and (iv) an extended low production or dry period which increases BCS (body condition score) at calving and also reduces fertility at the subsequent breeding season. While published targets for fertility parameters are often achieved in research centres and on some commercial dairy farms, there is a tremendous amount of variation in fertility performance between farms and, in general, the fertility performance achieved on commercial Irish farms is often much lower than the quoted targets (Mayne *et al.*, 2002; Mee and Buckley, 2003). Dairy farmers have consequently become more aware that poor dairy herd fertility is costing them large amounts of money. Therefore, the impetus to improve fertility on Irish dairy farms has never been greater. However, it must always be remembered that infertility is a multi-factorial problem and that approaches to solve such problems at herd level must consider a vast range of possible causative factors. This article will deal with nutritional factors that are of importance for dairy cow fertility. It is primarily based on review papers presented at two recent dairy conferences held at University College Dublin: 'Focus on fertility' and 'Production diseases of the transition cow'.

Energy balance and fertility

It is now widely accepted that negative energy balance (NEB) in early lactation is associated with reduced fertility performance (Roche *et al.*, 2000). The physiological basis for this association has been cited as: a reduced LH pulse frequency; reduced circulating concentrations of insulin and IGF-1; reduced production of oestradiol by ovarian follicles during NEB; and possible deleterious effects of the metabolites NEFA and BHB (beta hydroxybutyrate), together with low circulating glucose concentrations on oocyte development (Leroy *et al.*, 2005; Leroy *et al.*, 2006). It has often been demonstrated that where the severity of NEB (as measured by BCS loss) is exacerbated, the resultant fertility performance is reduced (Buckley *et al.*, 2003). Hence an important part of the nutritional management of dairy cows to ensure optimal fertility performance is to limit the extent and duration of NEB in early lactation.

One of the most fundamental aspects of preventing BCS loss in early lactation is to avoid over-conditioning in the dry period and at calving. Several authors have reported that increased BCS at calving causes an increase in BCS loss in the following lactation (Garnsworthy and Webb, 1999; Dechow *et al.*, 2002). Furthermore, Mayne *et al.* (2002) reported that in dairy herds where the dry cow BCS was elevated, fertility performance in the next lactation was significantly reduced. These associations are not surprising given that we have known for 25 years that cows with higher BCS at calving have reduced feed intakes in early lactation (Garnsworthy and Topps, 1982).

It is also important to appreciate that early lactation cows may experience excessive NEB in situations where over-conditioning at calving was not evident. These situations may arise due to under-feeding, poor grazing conditions (soil conditions, grass availability or bad weather), poor silage quality (for indoor diets) or simply because the genetic potential for milk yield in the herd is inconsistent with the chosen feeding-management system and therefore makes excessive NEB virtually unavoidable. As part of a recent dairy herd health investigation, we have recently observed a severe negative energy balance in early lactation dairy cattle turned out to pasture abruptly on calving. The diagnosis of excessive NEB was based primarily on the fact that excessive levels of NEFA were found in the plasma of early lactation dairy cows (**Figure 1**) and the levels of BCS loss in the herd were excessive (**Figure 2**). It is interesting that this herd had a quite a high EBI (economic breeding index) and contained mostly New Zealand Friesian X Holstein Friesian dairy cattle. There was no evidence of over-conditioning pre-calving in this situation.

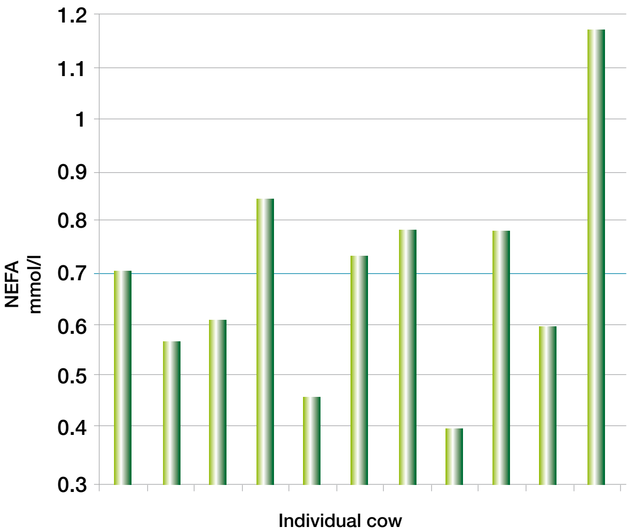

Figure 1: Non-esterified fatty acid concentrations in plasma of early lactation cows indicative of negative energy balance (acceptable threshold below blue line). In this case no over-conditioning existed in the dry period.

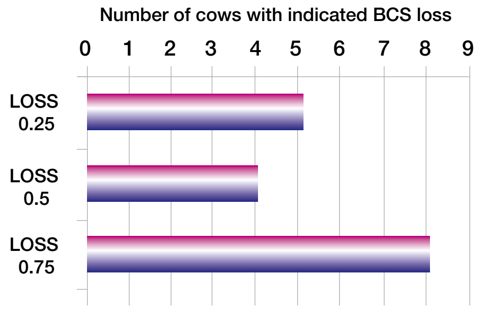

Figure 2: Body condition score loss in early lactation for cows of greater than third lactation indicating excessive negative energy balance (n=17). Many of the cows in this group had a BCS loss of 0.75 units in early lactation.

There are two other points that should be made in relation to NEB. The first is that it is absolutely essential to optimise feed intake in early lactation to avoid excessive NEB and maintain acceptable fertility. Mayne *et al.* (2002) demonstrated this by showing that herds with higher intakes of metabolisable energy and dry matter in the first 100 days after calving had better fertility. The second point is that feeding concentrates to early lactation dairy cattle grazing pasture will almost certainly improve energy balance where that particular herd experienced excessive NEB before concentrate supplementation was introduced or increased. This point is demonstrated in recent data from Teagasc Moorepark where it was shown that cows fed higher levels of concentrate supplementation lost significantly less BCS from calving to nadir BCS for Holstein Friesian and New Zealand Friesian dairy cattle (Horan *et al.*, 2005).

The authors of this article have some concern regarding the fast-becoming accepted wisdom that feeding concentrates to early lactation dairy cows will have no effect on NEB and fertility in absolutely all cases. There is a wide variation in the protein and energy content of concentrates, the type of energy and protein they supply and the inclusion, or not, of appropriate buffers and yeasts when required. Any of these factors could have an important influence on milk yield, NEB and fertility. Furthermore, the pre-supplementation nutritional scenario will vary greatly from farm to farm, making the monitoring of NEB essential before deciding on supplementation or not, as the case may be. In a review of recent Moorepark studies by Diskin *et al.* (2006), it is reported that feeding higher levels of concentrate in early lactation did not improve conception rate to first service, but did improve conception rate to second service for dairy cows. This is an important finding when one considers that 50 to 70% of cows on most dairy farms will be presented for a second service.

The challenge is for veterinarians and others who advise dairy farmers to be better at differentiating between herds that have excessive levels of NEB in early lactation and those that do not. Where cows are under-fed pre-supplementation, a positive response in energy balance is likely to arise on supplementation. However, for herds where the pre-supplementation diets is adequate, for the dairy cattle on that farm, no substantial benefit in terms of energy balance and fertility should be expected after supplementation. One must also appreciate that the type of concentrate fed can have an important influence on this response, and these issues are discussed later in this article. A monitoring strategy for energy balance in early lactation cows that can easily be used by veterinarians and other advisors has recently been published in the *Irish Veterinary Journal* (Mulligan *et al.*, 2006b).

The type of energy fed and fertility

There are many different reports which indicate that the type of energy fed has a significant influence on dairy cow fertility. It has been reported that feeding diets which result in a relatively high supply of glucogenic nutrients (mostly ruminal propionate and glucose) results in less mobilisation of adipose tissue as measured by blood metabolites (Rizos *et al.*, 2004). In addition, there are some reports that such diets improve fertility in dairy cattle (Gong *et al.*, 2002). Similarly, Beever (2006) concluded that cows fed glucogenic (in this case, starch-based) diets mobilised less adipose tissue than those fed on high protein or high fat diets.

In Ireland, dairy cattle in early lactation are often fed grass-based diets. In this scenario, the potential to alter the supply of glucogenic nutrients is limited, especially as feeding high starch supplements at pasture may lead to lower than desired rumen pH (although this impact may be reduced if the correct type of starch, effective fibre and appropriate buffers are used). The use of supplements such as propylene glycol have been shown to alter indices of body lipid mobilisation for grazing cows at UCD Lyons research farm (**Table 1**). Furthermore, easily supplemented forms of the product are becoming available as a dry supplement for inclusion in compound feeds. However, although these diet types often increase circulating levels of insulin and IGF-1 and reduce indices of body fat mobilisation, they do not always increase fertility.

Table 1: Effect of propylene glycol supplementation on indices of negative energy balance in grazing cows at 15 days in milk. The BHB and NEFA concentrations observed for the control cows are indicative of excessive NEB

Plasma metabolite	Propylene glycol	Control
Glucose (mmol/l)	4.0	3.0
BHB (mmol/l)	0.5	1.5
NEFA (mmol/l)	0.55	0.95

Many experiments have reported beneficial effects of supplemental fat on fertility indices in dairy cattle (Staples *et al.*, 1998). However, in some cases detrimental effects on dairy cow fertility were realised (Gardener *et al.*, 1999). The most relevant of these studies for Irish conditions is likely that of McNamara *et al.* (2003) where fat supplements based on calcium salts of palm fatty acids improved first service conception rates, in comparison to controls, for grazing dairy cows. However, no effect of treatment on overall pregnancy rate was observed in this experiment.

There are several potential mechanisms by which polyunsaturated fatty acid (PUFA) supplements may improve fertility in dairy cattle (Staples *et al.*, 1998). These include: i) a glucose sparing effect at the mammary gland which may improve circulating concentrations of glucose, with a positive effect on LH release pattern; ii) increased circulating concentrations of cholesterol, a precursor of progesterone; and iii) inhibition of PGF2α and oestradiol-17β in order to improve the lifespan of the corpus luteum and potentially improve the survival of the embryo. The potential effect of PUFAs in reducing embryo mortality is interesting because Diskin *et al.* (2006) indicated that the main reason for reduced fertility in modern-day Irish dairy cattle is increased early embryonic mortality. In support of this hypothesis, Petit and Twagiramungu (2006) have demonstrated that supplementation with flax seed (a rich source of linolenic acid, an omega-3 PUFA) significantly reduced embryo mortality in comparison to other fat-supplemented groups. This is consistent with other reports, which indicate that fatty acids from the omega-3 family reduce ovarian and endometrial synthesis of PGF2α and may result in reduced embryo mortality (Mattos *et al.*, 2004). There are currently several supplemental fat or PUFA products for sale in Ireland that claim to enhance dairy cow fertility.

Protein feeding and fertility

When discussing the effect of dietary protein on fertility in dairy cows it is first necessary to differentiate between rumen degradable protein (RDP), which is essentially ingested feed protein that is degraded to ammonia (and other non-protein nitrogen products) in the rumen, and metabolisable protein (MP), which is essentially the amino acids absorbed from the small intestine. Metabolisable protein has two origins: the truly digestible amino acids in microbes from the rumen (microbial protein) and the truly digestible amino acids in feed protein that has bypassed the rumen, or rumen undegraded protein (RUP). It is necessary to make this distinction as the balance (dietary supply relative to requirement) of these different protein fractions may have different effects on fertility.

There is quite a large volume of published research, which indicates that feeding excess RDP has a negative effect on fertility (Tamminga, 2006). Tamminga (2006) clearly states that feeding high levels of RDP delays the first ovulation or oestrus, reduces the conception rate to first insemination, increases the number of days open and lowers the overall conception rate. There are several proposed mechanisms for this effect including an exacerbated NEB for cows fed diets high in RDP in comparison to diets high in RUP (Westwood *et al.*, 2000) and proven deleterious effects of both ammonia and urea on both oocyte and embryo development (Ocon and Hansen, 2003; Rhoads *et al.*, 2006). However, this deleterious effect of excess RDP ingestion may be absent in beef heifers, which are normally in positive energy balance at breeding (Diskin *et al.*, 2006).

When we apply some of the more up-to-date ruminant protein rationing models to Irish dairy cow diets based on perennial rye-grass or grass silage, it becomes clear that dairy cattle are often fed 140 to 150% of RDP requirements. Unfortunately, the supplements used for grazing Irish dairy cows often exacerbate this problem by feeding diets that further accentuate the excessive RDP in Irish pasture. This problem is not readily discernible where dairy cow diets are formulated using the outdated crude protein measure for rationing purposes.

Although dietary excesses of MP are thought to be of lesser consequence than excesses of RDP in terms of dairy cow fertility, excess MP supply relative to requirement will often increase milk yield and exacerbate NEB. Because of this, there has been some interest by farmers in feeding diets that supply relatively low amounts of MP, in order to reduce milk yield response to energy supplementation and thus improve energy balance. It is interesting to note that some UK and US research has shown that BCS loss in early lactation was reduced by using a similar feeding strategy (Orskov *et al.*, 1987; Chappa *et al.*, 2001). However, there has been little or no research conducted with typical Irish diets, which are normally very high in RDP, to investigate this feeding strategy.

Dry and transition cow feeding and management

There are numerous consequences of a poorly managed dry and/or transition cow period that may reduce dairy cow fertility. The greatest severity of NEB experienced by early lactation dairy cows is in weeks one and two after calving. Therefore it is important that poor husbandry practices, which may limit feed intake in early lactation dairy cows, are eliminated. For example, abrupt dietary change from the dry to lactating cow diet is very common and may have very little effect on early lactation cow milk yield. However, this practice has been shown to cause sub-clinical laminitis in some situations (Donovan *et al.*, 2004) and because the microbial population of the rumen have not been acclimatised to the lactating cow diet, it may restrict rumen fermentation and therefore feed intake. The Dairy Herd Health Group at UCD have recently come across a serious problem with displaced abomasums in a dairy herd where abrupt introduction to pasture (day and night grazing strictly introduced on the day of calving) was practised. While the rumen pH values for this herd (assessed by rumenocentesis) indicated that sub-acute ruminal acidosis (SARA) was not involved, and there was no clinical milk fever on the farm, the rumen fill of the cows was noticeably poor. We suspect that the abrupt introduction to pasture was one causative factor of the displaced abomasums observed in this case. While it is easy to appreciate how lame cows, or cows with a displaced abomasum, will have a low feed intake and lose excessive levels of BCS in early lactation, we often forget that several of the cytokines released as a component of an immune response will also reduce feed intake in early lactation (Ingvartsen and Andersen, 2000). In other words, infectious conditions such as mastitis or metritis have the potential to reduce feed intake for transition cows.

It is also well known that milk fever and subclinical hypocalcaemia significantly reduce fertility in dairy cows, while most will readily appreciate that complications of the reproductive tract, such as dystocia, retained foetal membranes, uterine torsion etc., will most likely reduce fertility in the subsequent breeding season.

In summary, any nutritional or management factor that causes production diseases for transition cows will likely reduce fertility in the subsequent lactation. The UCD Dairy Herd Health Group recently published a prevention and monitoring strategy for production diseases in transition cows (Mulligan *et al.*, 2006a). The key principles of this approach are: correct BCS at drying-off and at calving; elimination of NEB in the dry cow and as much as possible in the milking cow; the prevention of milk fever and subclinical hypocalcaemia; the maintenance of rumen health; and the maintenance of optimal trace element status.

Trace elements and fertility

Trace element deficiency may be linked to problems such as retained foetal membranes (Gupta *et al.*, 2005), abortion (Mee, 2004) and weak calf syndrome (Logan *et al.*, 1990). Furthermore, Husband (2006) has recently reported combined selenium and iodine deficiency in a dairy herd with a high incidence of retained foetal membranes, milk fever and vulval discharge. In other cases, differences in the reproductive performance of cattle and sheep have been reported when comparing trace element supplementation strategies (Hemmingway, 2003; Black and French, 2004). Since many of the proposed reasons that trace element status reduces dairy cow fertility involve transition cow health and immunity, the trace element status of dry cows is very important for fertility in the following lactation. In Ireland, the trace elements likely to be of most practical significance are copper (Cu), selenium (Se) and iodine (I) (Rice, 1994).

When dealing with suspected trace element problems, begin by enquiring about both the supplementation given and the history of trace element deficiencies on that particular farm or in that locality. If the health problems in question are occurring in transition cows (e.g., retained placenta) then blood or liver samples from dry cows are required to diagnose trace element deficiency. If there are no health problems in transition cows, and trace elements are still suspected of causing infertility, then the sampling of cows calved four to six weeks is more appropriate. For an accurate diagnosis of Cu status, liver Cu samples obtained by biopsy are preferred to blood values. Although liver biopsy is not widely practised in Ireland, it is common in other countries and is frequently used in UCD Lyons research farm, without any negative consequences in the vast majority of animals. For Se status, blood, milk or liver Se concentration, as well as glutathione peroxidase (GSPx), give an accurate indication. For the assessment of I status, blood samples should be assessed for plasma inorganic iodine (PII) and not thyroxine (T4). Unfortunately, the unavailability of a PII test in Irish laboratories means that we often send samples out of the country for analysis. **Figure 3** shows plasma inorganic iodine concentrations for 12 grazing milking cows, indicating iodine deficiency in the milking cows in that herd. Interestingly, there was no iodine deficiency in dry cows on this farm. After the diagnosis of a trace element deficiency based on blood or liver analysis, often the only way to confirm the diagnosis is by assessment of the response to treatment.

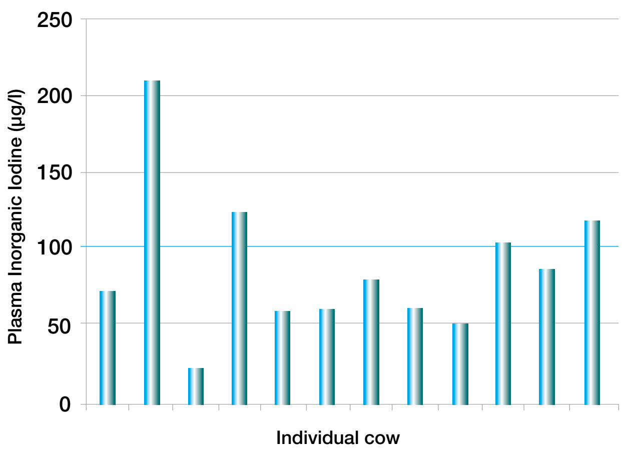

Figure 3: Plasma inorganic iodine (PII) concentrations for grazing milking cows indicating iodine deficiency (acceptable threshold above blue line).

Summary

The nutrition of early lactation cows has an important influence on their fertility performance. In particular, the energy and protein balance of early lactation dairy cows are factors, which are likely to be implicated in poor fertility for Irish herds quite often. Furthermore, when dairy cattle do not have a healthy transition period, this may directly or indirectly (via NEB) reduce fertility performance.

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