Temporal trends in reproductive performance in Irish dairy herds and associated risk factors

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Irish dairy herd fertility has been declining since the 1980s. The extent, nature and causes of this decline in fertility and the current status of Irish dairy herd fertility were described. An increase in calving interval of approximately one day per year has been recorded. The principal components of this trend have been an increased incidence of postpartum endocrinopathies, reduced expression of oestrus and a fall in conception rate. Both submission rate and calving-to-service interval have increased slightly over time. Significant risk factors associated with these trends have been strain substitution within the Holstein-Friesian breed and single trait selection for milk production. Critically, these changes have been reflected in loss of body condition. Contributory factors included increased herd size and possibly increased use of DIYAI. The most recent Irish study showed that 48% of cows conceived to first service and 14% of cows were not pregnant at the end of the industry-average 15-week spring breeding season. However, the top quartile of herds achieved a first-service conception rate of 59%, illustrating the wide variation between herds. These phenotypic trends were attributed to both genetic and environmental factors and their interactions. Recent Irish dairy herd fertility performance falls short of the targets set for seasonal compact calving.

Key words
Cattle,
Fertility,
Genetics,
Nutrition,
Management.

Materials and methods
Reproductive performance is defined here by the standard phenotypic indices of herd fertility (O’Farrell, 1992) and culling. The limitations of any one of these indices to adequately describe herd fertility, the influences of both genetic and environmental factors and the biases of management decisions and inadvertent data censoring are recognised. Thus, while calving interval data are readily available from milk records, they are only available for cows that conceive and calve again. The Irish data examined here originated in commercial dairy herds and in An Foras Talúntais and Teagasc research herds. Research herd data came from experimental studies and retrospective analyses of herd fertility databases. Commercial herd data were generated from computerised herd datasets (DairyMIS, a recorder-based computerised data management system, and the National Farm Survey), milk recording schemes, experimental field studies and questionnaire surveys. These sources do not constitute a standardised recording of data from a representative sample of the national herd. Rather,
the fragmented nature of these data sources reflects the absence of a national database on herd fertility. Relationships between variables were examined by least squares regression analysis and the results presented graphically in MS Excel™ (Microsoft Corporation, 1997). The best-fit trend line was chosen from sixth order polynomial regressions as having the highest coefficient of determination (R²).

Results
Extent of the decline in herd fertility
Surveys of Irish dairy cattle showed that herd fertility was high throughout the 1960s and 1970s. The majority of these studies reported calving rates, with a small number reporting conception rates or non-return rates. Calving rates to first service by artificial insemination varied between 60% and 69%, calving intervals between 357 and 380 days and infertile rates between 2% and 10%. These studies collected data on between approximately 2,000 and 8,000 cows per study (O’Farrell et al., 1997).

The first indication of a significant decline in Irish dairy herd fertility was detected in a retrospective analysis of data from Teagasc research herds. The highest conception rate to first service was recorded in 1980 as 67% and it declined to 59% in 1988 (Fair et al., 1991). Subsequent studies in commercial herds in the 1990s confirmed this phenotypic trend (Figure 1) when calving rate to first service declined significantly by 0.7% to 0.9% per year (O’Farrell and Crilly, 2001; Mee et al., 1999). However, the decline in calving rate to all services was smaller (0.5% per year: Mee et al., 1999).

These trends recorded in research herds and DairyMIS herds may or may not be representative of trends in the national dairy cow population. However, they are consistent with fertility data from cows in milk recording herds during the 1990s (Figure 2). These data show an increase in calving interval of 0.9 days per year (1993: 389 days v. 1999: 395 days) and a decrease in reappearance rate between first and second lactation of 1% per year (1993:80.4% v. 1999:73.2%).

Furthermore, the genetic data from Irish progeny test bulls show a similar decline in survival and calving interval proofs in the 1980s and 1990s (ICBF, 2002). Overall, these data suggest that the decline in dairy herd fertility began during the 1980s with a reduction of 0.5% to 0.9% per year in conception rate or calving rate and an increase in calving interval of approximately one day per year.

These trends are not unique to Irish herds. Similar trends have been reported worldwide: in the UK (Esslemont and Kossaibati, 2002; Royal et al., 2000), France (Boichard et al., 2002; Chevallier and Humblot, 1998), Germany (Gorlach, 1988), Spain (Lopez-Gatius, 2003), the Netherlands (Hoekstra et al., 1994), Scandinavia (Berglund and Philippon, 2001), Israel (Weller and Ezra, 1997), Australia (M. Haile-Mariam, Institute of Land and Food Resources, University of Melbourne, personal communication) and North America (Rajala-Schultz and Fraser, 2003; Washburn et al., 2002; Lucy, 2001). Even in New Zealand, where cow fertility has been assumed to be high, recent survey data indicate conception rates are lower (first AI conception rate of 53%) than in previous years (Xu and Burton, 2000). In addition, in the UK, fertility in maiden heifers selected for milk production declined from 1981 to 1998 (Pryce et al., 2002).

Contrary to this profile of declining herd fertility, Silva et al. (1992) did not find a trend in calving interval in data covering fifty-two years (1923 to 1974) from dairy herds in Florida. Similarly, Whitaker (2002) suggested that declining herd fertility has been happening only on some farms in the UK but not on all farms. These reports may reflect significant regional or herd variation in the occurrence of the risk factors outlined hereunder.

Nature of the decline in herd fertility
The reproductive performance of a herd is determined by the onset of postpartum cyclicity leading to a dominant (ovulatory) follicle, expression/detection of oestrus, conception rate and subsequent loss. While a delay in the onset of puberty has not been documented over time, significant differences now exist between strains of Holstein-Friesians under the same Irish farm management conditions (McGrath et al., 2001).
Postpartum endocrinopathies

There are compelling data from the UK demonstrating significant changes over the last two decades in the pattern, but not the onset, of postpartum luteal activity in dairy cows (Royal et al., 2000). Recent large-scale studies from abroad indicate between 40% and 50% of dairy cows now have abnormal luteal profiles post partum (Mann, 2002; Opsomer et al., 2000). In addition, negative genetic (Veerkamp et al., 2000) and phenotypic relationships have been demonstrated between milk yield and resumption of cyclicity post partum (Taylor et al., 2000). Comparison of recent Irish data (Teagasc, unpublished) with Irish data from 20 years ago (Fagan and Roche, 1986) indicates an increased incidence of both abnormal milk progesterone profiles and delayed onset of luteal activity (Table 1).

Suboestrus

Concern has been expressed over the apparent decline in efficiency of detection of oestrus in recent years (Nebel and Mowrey, 2000). Data from New Zealand (Burton et al., 1999) show a significant decline in 21-day submission rate of 0.5% per year from 1973 (94%) to 1996 (82%). This may reflect a decrease in efficiency of detection of oestrus or an increase in anoestrus. Data from the UK and North America show a slight decline in efficiency of detection of oestrus during the 1980s and 1990s (Esslemont and Kossaibati, 2002) and in 1990s in DairyMIS herds (Mee et al., 1999). Similarly, submission rates increased slightly during the 1990s in DairyMIS herds (Mee et al., 1999), possibly due to increased adoption of pre-breeding-season detection of oestrus and early treatment of anoestrous cows (Mee et al., 2002). Overall, these data suggest that efficiency of detection of oestrus and submission rates have not declined in Irish herds. However, increased awareness of poor fertility and increased veterinary intervention may be masking reduced expression of oestrus.

TABLE 1: Comparison of atypical luteal activity post partum in Irish dairy cows in 1982 (Fagan and Roche, 1986) and in 2002 (Teagasc, unpublished)

| Atypical progesterone profile | 1982 (463 cows) | 2002 (396 cows) |
|-------------------------------|----------------|----------------|
| Delayed onset of ovulation (%) | 7              | 15             |
| Prolonged luteal phase (%)    | 3              | 10             |
| Anovulation following cyclicity (%) | 3          | 1              |
| TOTAL (%)                     | 13             | 26             |

Note: a 1982 (to day 50); 2002 (to day 45), b 1982 (≥20 days); 2002 (≥19 days), c 1982 (≥14 days); 2002 (≥12 days).

Poor quality of oocyte or embryo

The most recent data from high-yielding Holstein-Friesian cows indicate that fertilisation rate (90%) has not declined (Sartori et al., 2002). Thus, it is assumed that the major components of the decline in conception rate are compromised developmental competence of oocyte and/or of embryo leading to early embryonic mortality. It is not clear what are the underlying mechanisms. Working physiological models include greater hepatic metabolism of steroid hormones in high-yielding cows with consequent asynchrony between the onset of oestrus and ovulation (Bloch et al., 2001), increased ovulation rate (Wiltbank et al., 2000), and compromised development of early oocytes (Snijders et al., 2000) and of embryos (Mann et al., 1999). Severe negative energy balance (NEB) immediately post partum may alter gene expression in the pre-antral follicle resulting in a dysfunctional mature follicle with resultant poor oocyte quality and a subfunctional corpus luteum during the subsequent breeding season (Britt, 1994). Metabolic non-adaptation in early lactation, as evidenced in the circulation by elevated concentrations of ammonia, urea and NEFAs and lower concentrations of IGF-I, may detrimentally affect the quality of oocyte and corpus luteum (Jorritsma et al., 2003a,b). Underlying these models may be alteration of the somatotropic-gonadotrophic axis in favour of increased somatotropin and reduced insulin secretion resulting from increased milk production and reduced fat deposition through single trait selection.

Fertility of sires

It is unknown whether a concomitant decline in male fertility occurred over the last two decades but this trend has been reported in humans, partially attributed to endocrine disrupting compounds (EDC). Inbreeding has also been implicated in declining dairy cow fertility in North America.

Causes of the decline in herd fertility

Putative risk factors may be classified as genetic (strain substitution, selection for milk yield, inbreeding), nutritional (NEB), managemental (calving pattern, herd size, detection of oestrus, feeding management, synchronisation of oestrus, do-it-
yourself artificial insemination (DIYAI), fixed-time AI (FTAI),
milking frequency, bovine somatotropin (bST), environmental
(reproductive diseases, housing conditions, EDCs, global
warming) and their interactions. Some of these factors are of
limited relevance in Irish dairy herds (FTAI, milking frequency,
bST, confinement, global warming), whereas others are of
unknown relevance (inbreeding, EDCs) and the remainder are
most relevant.

Strain substitution
Prior to the 1960s, the dairy Shorthorn was the predominant
breed in Irish dairy herds (Figure 3). Shorthorns were gradually
replaced by British Friesians, which predominated in the
national herd during the 1970s and 1980s. In 1974, the
Department of Agriculture licensed the first importation of
semen from Holstein bulls. By the 1980s the British Friesian
was rapidly being replaced through the importation of
European and North American Holstein-Friesian (NAHF)
cows, semen and embryos. This trend was accelerated following
the introduction of the single European market in 1992. Thus,
the proportion of NAHF genetics increased from less than 10%
in 1977 to 80% in 1998 in the British Isles (Figure 4). This
compares with 24% and almost 100% in the New Zealand and
Dutch national dairy herds, respectively (Dillon and Veerkamp,
2001).

As this was occurring, it was concluded that the available data
did not support or refute the contention that “holsteinisation”
would reduce Irish herd fertility (More O’Ferrall, 1984).
However, Irish experiments in the 1990s showed poorer
reproductive performance in imported Holstein-Friesians of
high genetic merit than in those of medium genetic merit
(Snijders et al., 2001). The introduction of NAHF genetics to
dairy cow populations worldwide has been associated with
reduced herd fertility, particularly in seasonal-calving dairy
industries (Harris et al., 2001; Royal et al., 2000; Hockstra et
al., 1994). This impact has been greatest in dairy industries
where Holstein-Friesians comprise over 90% of the dairy cow
population, such as North America, the Netherlands, the UK
and Ireland. There are, nonetheless, reports of no adverse
relationship between genetic merit for milk production and
dairy herd fertility (Mayne et al., 2002; Morton et al., 2000).

Single trait selection
Although selection for milk production alone had traditionally
been practised in Irish dairy herds, the rate of genetic gain was
low (0.5% per year) up to the mid-1980s. However, since 1985,
with accelerated strain substitution, this has increased markedly
to over 1% per year (Evans et al., 2002). There is a qualified
genetic relationship between increasing genetic merit for higher
milk yield (Figure 5) and reducing fertility whereby
management and environment affect the relationship. For
example, relatively higher-producing cows tend to be
inseminated later than their lower-producing herdmates
(Ouweltjes et al., 1996). In Ireland, this relationship is affected
not merely by genetic merit for milk production but also by
concurrent strain substitution. Hence, the decline in fertility
cannot solely be attributed to the increase in yield (Figure 6).
In Ireland, the introduction of the milk quota resulted in excess
dairy cows being retained in herds with consequent lower
phenotypic milk yields per cow than their genetic potential
might indicate as reflected in the temporal trend in genetic and

FIGURE 3: Breed composition (%) of the Irish national dairy cow
population between 1960 and 1990.
(Sources: Cunningham, 1976; EEC, 1989; Drennan and Power, 1993).

FIGURE 4: Percentage of Holstein genes in cows registered by Holstein
UK and Ireland (HUKI) between 1977 and 1998.
(Sources: Simm, 1998; Dillon and Veerkamp, 2001).

FIGURE 5: Genetic merit for milk yield in Irish dairy cows
between 1989 and 1999.
(Source: ICBF, 2002).
phenotypic yield during the 1980s (Figures 5 and 6). Introduction of the milk quota also resulted in a low culling rate (15%) by international standards but infertility is the most common reason for culling (24%) and has increased significantly over time (Mee et al., 1999; O’Farrell et al., 1997). Selection for milk production alone has consistently been accompanied by reduced herd fertility due to the negative genetic correlations at cow level between these variables (Evans et al., 2002; Pryce and Vercamp, 2001).

Negative energy balance

In early lactation milk output increases faster than dry matter intake. With selection on milk production alone, the correlated increase in dry matter intake is insufficient to balance the increased nutrient requirements; hence, the extent and duration of NEB is exacerbated. In Ireland, the introduction of milk quotas in 1984 led to the practices of drying off early and restricting feeding prior to the spring breeding season to avoid supplying over quota as most farmers retained excess cows for their quota. These practices resulted in excess body condition score (BCS) at calving and increased subsequent BCS loss. High BCS during the dry period is often associated with a more severe and longer-lasting NEB in early lactation (Jorritsma et al., 1999). Selection for milk production alone has consistently been accompanied by reduced herd fertility due to the negative genetic correlations at cow level between these variables (Evans et al., 2002; Pryce and Vercamp, 2001).

Breeding pattern

Throughout the 1990s the farming media highlighted the decline in fertility in Irish dairy herds. This could have influenced dairy farmers to prolong the calving-to-first service interval in the hope that this would improve conception rate but with a possible increase in the calving interval. Data from France indicate this policy was adopted there when conception rates declined and calving interval increased (Chevallier and Humblot, 1998). Irish data show a small increase in calving-to-service interval (68 ± 71 days) between herd surveys in 1969-70 (Langley, 1986) and in 1999 (Buckley et al., 2000). However, the proportion of cows first served more than three months postpartum increased from the 1980s (12%, Fair et al., 1991) to the 1990s (21%, O’Farrell et al., 2001). The other component of calving interval, gestation length, has increased by approximately one day in Friesian cows mated to Friesian sires since records began (1979: 281 days; 2001: 282 days - Department of Agriculture, Food and Rural Development, 1979 - 2001). Consequently, it is suggested that a lower conception rate (and, hence, longer calving-to-conception interval) is the primary component of a longer calving interval but there may also be a contribution from an increased calving-to-service interval.

Calving pattern

After the introduction of milk quotas (1984), there was a move away from winter/early spring-calving towards late spring-calving, to maximise utilisation of grazed grass (Dillon et al., 1995). This may have contributed to higher culling for ‘infertility’ (Mee et al., 1999) as farmers had to adopt a more compact breeding season to have cows milking from the first day of April, the start of the new milk quota year. It is not known whether these changes in calving and breeding patterns accentuated any possible detrimental effect on dairy cow fertility exerted by the stress of turnout onto highly fertilised, low dry matter pasture. In beef heifer models, acute nutritional stress around AI has significantly reduced embryo survival (Dunne et al., 2001) but intake of high crude protein pasture has not (Kenny et al., 2001). The reproductive needs of a seasonal dairy industry with a compact breeding season may not be compatible with NAHF genetics, which originated in an all-year-round-calving dairy industry.

Herd size

Increased herd size and greater numbers of cows per labour unit have frequently been cited as contributory factors to declining herd fertility (Lacy, 2001). The average Irish dairy herd size increased by 34% (Figure 7) in the 1990s (ICBF, 2002).
However, a shortage of skilled labour has emerged as a more critical issue with a 17% drop in the farm labour force during the same decade (O'Donovan et al., 2000). In addition, part-time farming emerged as a significant trend in herd management on Irish farms during the 1990s. Reduced efficiency of detection of oestrus in large herds has been associated with inadequate attention to individual cows, insufficient time spent observing cows for oestrus, over-reliance on tail paint, and poor record keeping (Lucy, 2001). A factor analysis of data from Irish dairy herds from 1991 to 1998 showed a significant relationship between large herd size (and associated characteristics) and reduced calving rate (Fahey et al., 2002). Expanding and large herds are also more likely to maintain infectious agents that may cause reduced calving rates, such as bovine viral diarrhoea virus (Mee et al., 2002), *Leptospira interrogans* serovar hardjo (Leonard et al., 2002) and *Salmonella* spp (Mee et al., 2002). This infectious challenge may have been exacerbated by increased use (22%) of bulls for breeding throughout the 1990s, possibly in order to reduce time spent detecting oestrus. Furthermore, with increases in herd size has come a move away from tie-up byre and straw-bedded housing to cubicle housing, which may contribute towards a reduction in the expression of oestrus and in the productive lives of the cows.

Do-it-yourself artificial insemination (DIYAI) The Department of Agriculture issued the first licences for herdowners or their whole-time employees to perform DIYAI in 1984. In 1991, approximately one third of inseminations in DairyMIS herds were conducted by DIYAI. By 1996, this had increased to almost half of all inseminations (O’Farrell and Crilly, 2001). This trend was confirmed nationally by the doubling in the number of DIYAI licences issued from 1992 to 2001 (ICBF, 2002). There has also been increased usage of DIYAI internationally (Washburn et al., 2002). In an Australian study (Morton, 2000) where professional and DIYAI technicians were compared in the same herds, the latter had no differences in conception rates between commercial and DIY operators in DairyMIS herds (Buckley et al., 2003b). Furthermore, the impact of DIYAI on herd fertility nationally is likely to be much less than that in DairyMIS herds as the proportion of farmers nationally using DIYAI is substantially lower (2,923 dairy and beef farmers licensed in 2001; ICBF, 2002).

Current fertility in Irish dairy herds Given these trends in herd fertility, Teagasc embarked on a large-scale longitudinal study in 1999 to benchmark the reproductive performance of Irish commercial dairy herds. This ongoing study of 77 spring-calving herds has collected data on approximately 6,500 cows per year. Data were collected on management, nutrition, genetics, health and fertility with all herds enrolled in DairyMIS (Buckley et al., 2000). Results for fertility traits are shown in Table 2. Estimated 305-day milk yield averaged 6,570kg/cow in cows having 50% Holstein-Friesian genes. On average, herd fertility was below that required to achieve compact calving. However, the top quartile of herds on conception rate to first service achieved good herd fertility (conception rate to first service 59%, infertile rate 11%, calving rate to DIYAI (48%) was significantly lower than that of commercial AI (55%) and overall first service calving rate declined over time. The decline in herd fertility in these herds was partially attributed to the increased use of DIYAI and the associated lower fertility (O’Farrell and Crilly, 2001). However, calving rates following DIYAI may be attributed to DIYAI per se or herd characteristics such as calving pattern, herd size and milk yield (Mee et al., 1999). Recent data (1999-2000) indicate no differences in conception rates between commercial and DIY operators in DairyMIS herds (Buckley et al., 2003b).

| Table 2: Fertility traits in the Teagasc Farm Fertility Study (Source: Buckley et al., 2000) |
|-----------------------------------------------|
| Fertility trait                  | Herd mean | Herd range |
|-----------------------------------------------|
| **Pre-breeding**                  |           |            |
| Anovulation (%)                  | 10        | 0 - 21     |
| Cystic ovaries (%)               | 3         | 0 - 10     |
| Subclinical endometritis (%)     | 24        | 8 - 38     |
| Pyometra (%)                     | 2         | 0 - 8      |
| **Breeding season**              |           |            |
| Calving-to-first service (days)   | 71        | 59 - 92    |
| Calving-to-conception (days)     | 88        | 73 - 103   |
| Submission rate (21-days) (%)    | 70        | 25 - 96    |
| Conception rate to first service (%) | 48        | 29 - 71    |
| Infertile rate (%)               | 14        | 2 - 40     |
| Breeding season (weeks)          | 15        | 9 - 25     |

* Determined by ultrasonography approximately one week before the date set for the start of mating.

\[
y = 2E - 07x^6 - 0.0021x^5 + 10.314x^4 - 27218x^3 + 4E + 07x^2 - 3E +10x + 1E + 13 (R^2 = 0.999)
\]

**FIGURE 7:** Average Irish dairy herd size between 1960 and 2001.
(Source: ICBF, 2002; EEC, 1977-2001.)
14-week breeding season). In a questionnaire survey, the majority of farmers replied that they followed recommended fertility management practices (Mee et al., 2002b). One of the primary risk factors associated with poor fertility was BCS loss (Buckley et al., 2003a). The conception rate described here (48%) is consistent with recent reports from other dairy industries (Australia, 49%, Morton, 2000; New Zealand, 53%, Xu and Burton, 2000; Northern Ireland, 37%, Mayne et al., 2002; North America, 45%, Lucy, 2001; United Kingdom, 44%, Esslemont and Kossaibati, 2002).

These trends were confirmed by an analysis of National Farm Survey data, which showed that in the year 2000 less than 10% of farmers calved 90% or more of their cows over a nine-week period (Donnellan et al., 2002). In conjunction with these studies, a recent large-scale study of Irish dairy herds showed an embryonic loss rate of 7% in pregnant heifers and cows between 28 and 84 of gestation (Silke et al., 2002). The primary risk factor was BCS loss; cows that lost 0.5 of a BCS unit had a probability of 0.12 of embryonic mortality compared to a probability of 0.04 for cows which gained 0.5 of a BCS unit. This incidence of late embryonic mortality is considerably lower than that of early embryonic mortality (30%) or late embryonic mortality reported in North America (20%, Vasconcelos et al., 1997) but similar to that reported in New Zealand (4.5%, Clark, 2001). Data from a recent longitudinal survey of twelve European countries comprising 143 dairy herds showed that, although both mean calving interval (394 days) and mean culling rate (28%) were high, the Irish herds had below average calving interval, culling rate and milk yield (EDF, 2002).

Strategies are required to improve or halt the decline in reproductive performance as production systems are continually evolving. These approaches must include feeding systems to reduce negative energy balance and maintain body condition, automated management systems to improve detection of oestrus with less labour, and adoption of a total merit breeding index to select for genetically more fertile cattle. In the absence of research and progress in these areas, the response to traditional veterinary therapies may become increasingly diminished.

Conclusions

In Ireland, dairy herd fertility has declined over the past twenty years. The primary components of this decline have been a lower conception rate and an increased calving interval. These phenotypic trends can be attributed to both genetic and environmental factors and their interactions. Currently, dairy herd fertility falls short of the targets set for seasonal compact calving.

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Erratum

In the March issue of the *Irish Veterinary Journal*, there was an error in Figure 3 in the peer-reviewed article “Temporal trends in reproductive performance in Irish dairy herds and associated risk factors” (57: p161). The upwardly mobile line, which refers to Friesian, should be red, including the diamonds. The plunging graph, which refers to Shorthorn, should be blue, including the squares.