Changes to the Genetic Evaluation of Fertility in Irish Dairy Cattle

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Abstract

In Ireland, the current genetic evaluation of dairy cattle includes a joint fertility and survival module. It is a multiple trait animal model combining 23 traits. Calving interval is utilized as the primary fertility trait, and this aligns with the definition used in many countries with predominantly all year-round calving systems. It is also widely accepted within the scientific community as providing an accurate measure of genetic merit for fertility. However, around half of the herds in Ireland display seasonal calving patterns, with this trend steadily increasing, and is actively promoted by advocates for a low-cost industry. Calving interval has been found to be an inappropriate selection criterion for fertility in seasonal systems, as early calving and likely more fertile cows often have very long calving intervals, because they are withheld from mating, to avoid them calving too early in the following calving season. The aim of this work was to assess the feasibility and benefits of defining more seasonally orientated phenotypes for the genetic evaluation of fertility for those herds that are classed as seasonal calving. The results from the following steps of work are presented. Firstly, it was necessary to develop a robust set of criteria to differentiate seasonal from non-seasonal herds. This was complicated by the fact that many herds are dynamic across years in the extent to which they restrict calvings to within a season. The approach taken in this study treats a non-seasonal classification as the default for any cow fertility record. Fertility records were classified into the seasonal category if the animal’s contemporary group met certain seasonality criteria. Secondly, the definitions of fertility phenotypes in a seasonal system were investigated and are presented. Based on the results, the following traits are recommended for inclusion in a new fertility evaluation: age at first calving as a heifer fertility trait in both seasonal and non-seasonal herds, timing of conception and calving season day for animals in seasonal calving herds and calving interval and number of services in non-seasonal herds. These traits would be evaluated together in a five-trait repeated record animal model. Thirdly, the variance component estimates for the five-trait model are presented. Lastly, results from a prototype genetic evaluation using the new model with alternative seasonality inclusion thresholds are presented. In summary, based on the obtained results, recommendations are presented for the genetic evaluation of fertility in Ireland.

Key words: dairy, fertility, genetic parameters, genetic evaluation

Introduction

In Ireland, in the current genetic evaluation of dairy cattle fertility and survival traits are evaluated together in a multiple trait animal model which is combining 23 traits (fertility and survival phenotypes as well as milk yield as predictor trait; Olori *et al.*, 2003). Calving interval (CIV) is utilized as the main fertility trait, accompanied by calving to first service, number of services (NS) and age at first calving (AFC). The use of calving interval aligns with the fertility trait definition used in many countries with predominantly all year-round calving systems. It is also widely accepted within the scientific community as providing an accurate measure of genetic merit for fertility. However, around half of the herds in Ireland are displaying seasonal calving patterns, which means that a high proportion of calvings occur within four months at the beginning of the calendar year. This trend is steadily increasing and is actively promoted by advocates for a low-cost industry. Calving interval is not necessarily the optimal selection criterion for fertility in seasonal systems, as the aim in seasonal herds is not to reduce the calving interval, but rather to maintain the optimum of

365 days. Therefore, early calving and likely more fertile cows often have very long calving intervals, because they are withheld from mating, to avoid them calving too early in the following calving season.

The objective of this work was to develop a robust set of criteria to differentiate seasonal from non-seasonal herds and to assess the feasibility and benefits of defining more seasonally orientated phenotypes for the genetic evaluation of fertility for those herds that are classed as seasonal calving. The alternative definitions of fertility phenotypes in a seasonal system were investigated, the variance components were estimated for the five-trait model that combines the fertility phenotypes from seasonal and non-seasonal herds, and lastly, a prototype genetic evaluation using the new model was performed and validated against current genetic evaluation system.

Materials and Methods

Data

The phenotypic records needed for this work were extracted from the Irish Cattle breeding Federation (ICBF) database. The following edits were performed on the data: only cows born after 2001 were included, age at first calving had to fall between 548 and 1240 days, cows with inconsistencies between lactation numbers and calving/mating dates were deleted, and a minimum of two phenotypes were required per contemporary group. Additionally, for variance component estimation only cows with both parents known were used and cows that moved between herds were removed.

Seasonal vs non-seasonal herds

It was necessary to develop a robust set of criteria to differentiate seasonal from non-seasonal herds. This was complicated by the fact that many herds are dynamic across years in the extent to which they restrict calvings to within a season. Seasonal calvings are defined as those taking place in four-month window, either from the beginning of January to the end of April, or from the beginning of February to the end of May. The approach taken in this study treats a non-seasonal classification as the default for any contemporary group or cow fertility record. Contemporary groups with less than ten cows were considered non-seasonal. Herd-year calving patterns were classified into the seasonal category if they met certain seasonality criteria, for example: at least 80% of calvings needed to occur within the season (four-month window), there was a requirement for the herd to have records and a seasonal calving pattern in at least two years prior to the current one. There was also a two year "allowance" of a 10% lower seasonality threshold before a previously seasonally classified herd could be reclassified as non-seasonal. Those rules were designed in such a way that would minimize the chance of herds frequently moving in and out of the seasonal category between years.

Once contemporary groups were assigned to a seasonal or non-seasonal category each cow was assessed individually. If a cows first calving took place in a non-seasonal herd all her records were included as non-seasonal. If first calving was in a seasonal herd, then the second calving was evaluated. If that second calving was non-seasonal then non-seasonal records were used, if seasonal then seasonal phenotypes were used. If herd classification changed later in cow's life from this point onwards all further records were set to missing.

For the purposes of validation and considering final results, bulls were classified as seasonal if at least 75% of their daughters were in seasonal herds, and as non-seasonal if at least 75% of their daughters were in non-seasonal herds.

Trait definitions

For all cows meeting the criteria to be included in the evaluation, an AFC phenotype was used. For non-seasonal cows, CINT and NS phenotypes were used. Their definitions are as in the current ICBF fertility and survival evaluation (Olori *et al.*, 2003). For seasonal cows, calving season day (CSD) and time of conception day (TCD) were used.

CSD is defined as the number of days to calving from the planned start of calving (PSC) date for a given contemporary group (herd-year). It is a continuous trait expressed in days. TCD is the difference in days between planned start of mating (PSM) for a contemporary group and the last recorded mating that resulted in the pregnancy.

For each herd-year, the planned start of mating (PSM) is calculated using the definition proposed by Creagh *et al.* (2013) – 4 of 7 days, with 2 consecutive days – that is, the first date of a mating period where there are four mating dates within a 7-day window, where the first two dates are on consecutive days. The first of these two consecutive days is set as the PSM. If PSM does not get assigned using this approach, then PSM is calculated using the method proposed by Bowley *et al.* (2015) – the average mating date of the first 10% of matings observed within herd and year, minus 1 day.

For each herd-year, the planned start of calving (PSC) is calculated using the definition proposed by Bowley *et al.* (2015) – the average calving date of the first 3-10% of calvings observed within herd and season, minus 3 days. If PSC does not get assigned using this approach, then PSC is calculated by the method described by Burke *et al.* (2007):

a. PSC=3rd day of 1st week, when the number of calvings in the 1st week is greater than that in the 2nd week,

b. or PSC=1st day of 2nd week, when the number of calvings in the 2nd week is greater than that in the 1st week.

The statistics of the data used for genetic evaluation are presented in Table 1.

Variance components

Variance components were estimated using ASReml software (Gilmour *et al*., 2015) and the following models:

AFC = julday + cg + breed + het + rec + animal

NS = agec + agec2 + cg + fmating_type + lmating_type + breed + het + rec + animal + pe

CIV = agec + agec2 + camonth + cg + breed + het + rec + animal + pe

CSD = agec + agec2 + cg + breed + het + rec + animal + pe

TCD = agec + agec2 + cg + fmating_type + lmating_type + breed + het + rec + animal + pe

where, the fixed effects and covariates are: Julian day of the year the cow was born (*julday*); herd-year for seasonal herds and herd-year-calving season (2 seasons per year) for non-seasonal herds (*cg*); breed is a categorical fixed effect with 6 levels - Friesian, Holstein, Cross between Friesian and Holstein, Other Dairy, Beef and Beef x Dairy; heterosis (*het*); recombination (*rec*); *agec* is the age at the corresponding calving; *camonth* is the calving month of the first calving in the calving interval trait; *fmating_type* and *lmating_type* are mating type for first and last mating respectively, and are either natural or artificial insemination; finally, *animal* is the random animal genetic effect and *pe* is the permanent environmental effect.

A five-trait animal model with repeated records for all traits except AFC was implemented. Residual covariances between seasonal and non-seasonal phenotypes were fixed as zeros.

To reduce the time needed for variance component estimation ten independent data sets were created by randomly sampling herds. Each of the samples had around 15 000 cows with at least AFC phenotype. Pedigree size of each sample was around 60 000 animals.

Genetic evaluation

Genetic evaluation was performed using Mix99 software (Stranden 2016) and the same model as described above. Reliabilities were also calculated using Mix99 using the method described by (Jamrozik *et al.*, 2000). The runs were performed using parallel processing option in Mix99, utilizing 6 cores, on a Windows 7 operating workstation. There were nine million records included in the evaluation dataset with 3.6 million cows and almost five million animals in the pedigree.

Validation

In order to validate the new evaluation approach, the records from the 2017 year were removed from the dataset, while keeping the pedigree unchanged, and analysis was repeated with Mix99. The average daughter performance was calculated for each bull using both the full dataset and separately using the 2017 records that were removed. As the results of the validation could be sometimes difficult to interpret for low heritability phenotypes the correlations between average daughter performance and EBVs resulting from the full run were calculated as a baseline (maximum possible values) for validation. The correlations between average daughter performance in 2017 and EBVs resulting from validation runs were calculated for bulls born after 2010 that have a relatively low number of daughters in the reduced (2017 records excluded) dataset and their number of daughters increased in 2017. These bulls typically had a substantial change in accuracy of evaluation between full and validation runs. Correlations between phenotypes and EBVs from the current official survival evaluation were also calculated.

Results & Discussion

Seasonal vs non-seasonal herds

Based on the criteria described above used to assign herd-years to seasonal and non-seasonal categories, 53% of herd-years in the dataset were seasonal. There were 52% of cows that were classified as seasonal.

This approach to herd classification was also helpful in reducing the number of herds changing their status between years (results not presented), which should help assure that genetic evaluation would be more stable between runs. The number of seasonal records that were set to missing when a cow's herd changed status from seasonal to non-seasonal was also reduced comparing with a test situation where herd-year categories based only on percentage of seasonal calvings. 2.9% (instead of 5.3%) of CSD phenotypes and 1.7% (instead of 2.5%) of TCD phenotypes were set to missing.

Out of all the bulls considered with large numbers of daughters (>300), 41% and 22% were classified as seasonal and non-seasonal respectively. This left 36% of bulls with between 25-75% of their daughters in seasonal herds. Thus, there was a tendency for the majority of bulls to be used predominantly in one type of herd only.

Genetic parameters

The results for genetic parameters presented here are means of individual results obtained from ten subsample analyses (Table 2). Heritabilities ranged from 0.02 to 0.05 which is typical for fertility traits.

The residual correlations between AFC and other fertility phenotypes for non-seasonal herds were almost zero, while they were around 0.5 for seasonal traits. This reflects the definitions of the traits, where CSD and TCC effectively have an age at first calving component in them for the remainder of the cow's life. For example, a cow that is old at first calving is also more likely to be mated and calve later in the season, and because this is hard to catch up, tends to remain throughout the life of the cow. Quite a strong residual correlation (0.89) was found between CSD and TCD, which was expected as the only point of difference between CSD and TCD is the length of gestation, which is a trait with very high heritability and very low phenotypic variation (Amer *et al.*, 2016).

All genetic correlations obtained were positive and favourable. Again, a stronger relationship was observed between AFC and seasonal fertility phenotypes than non-seasonal ones. Genetic correlations between mating and calving traits from seasonal and non-seasonal herds were around 0.5. The strongest genetic correlation was observed between CSD and TCD (0.72) probably for the same reasons as explained above for the residual correlation between the two traits.

Genetic evaluation

The running time for the Mix99 pre-processor was 15 minutes, around one hour for the solver and 20 minutes for the reliability calculation. The relatively strict convergence criteria of 1.0E-10 was used.

The results of the prototype evaluation were compared with the current official fertility EBVs (results not shown). Figure 1 depicts the genetic trend for CIV for high reliability bulls. Averages for each year of birth were calculated separately for bulls classified as seasonal and non-seasonal. The trends resulting from the new model are very similar to those from the current official evaluation. The favourable downward trend was observed for non-seasonal bulls, while trends for seasonal bulls were more stable over time. A very clear difference was observed between the trend lines for seasonal and non-seasonal bulls. This shows that the current evaluation and breeding program resulted in favourable genetic change for fertility in the non-seasonal portion of the dairy population. However, it confirms that CIV as a selection criterion is not an optimal tool for improving fertility in seasonal herds.

Validation

Tables 3 and 4 present results of the validation. In Table 3 the correlations between average daughter performance and EBVs resulting from the full run are presented. They could be interpreted as the maximum values that could be obtained using validation datasets with 2017 records dropped. The tested prototype model resulted in higher correlations between phenotypes and EBVs for CIV (0.36) than the current model (0.26), which shows that excluding CIV phenotypes of seasonal cows is increasing the predictive abilities of the model.

Table 4 presents the correlations between average daughter performance in 2017 and EBVs resulting from the reduced dataset run. For CIV there was almost no difference in the predictive abilities of the models, although the current genetic evaluation models resulted in the highest correlations. For CSD (the seasonal fertility phenotype) there was a clear advantage observed for the CSD EBVs from the prototype model (0.20) compared with CIV EBVs from both the current and the new model (0.15). This shows that CIV EBVs are always inferior when predicting the seasonal fertility phenotypes.

Conclusions

Strict seasonality of calving is increasing, and it is a key driver for low cost dairy production in Ireland. Use of calving interval has already delivered strong favourable genetic trends for fertility in Irish dairy cattle. For seasonal herds, the introduction of calving rate and conception rate traits offers an opportunity to further enhance the fertility evaluation by better extracting information from calving and mating date phenotypes in seasonal calving herds. The validation results indicate that the prototype model is improving predictions of genetic merit of fertility for seasonal calving herds while at the same time maintaining the quality of evaluation for non-seasonal herds.

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Table 1. Mean descriptive statistics for phenotypic records.

	N	Mean	SD	Min	Max
AFC	3 628 665	787	87	550	1233
CIV	3 535 387	407	94.5	290	800
NC	1 194 012	1.72	1.09	1	10
CSD	4 388 885	42.7	39.2	-50	221
TCD	2 008 663	44.0	77.6	-48	521

Table 2. Heritabilities (diagonal) residual correlations (below diagonal) and genetic correlations (above diagonal)[a].

	AFC	CIV	NS	CSD	TCD
AFC	0.05	0.22	0.17	0.58	0.57
CIV	-0.01	0.04	0.43	0.49	0.29
NS	-0.00	0.76	0.04	0.62	0.52
CSD	0.51	0	0	0.03	0.72
TCD	0.52	0	0	0.89	0.02

[a]Values are mean estimates from 10 replicate analyses

Table 3. Correlations between average daughter performance and EBVs form current and new evaluations calculated using all the data and full genetic evaluation run.

	Current CIV EBVs	New CIV EBVs	New CSD EBVs
Average CIV phenotypes	0.26	0.36	0.25
Average CSD phenotypes	0.29	0.30	0.33

Table 4. Correlations between average daughter performance in 2017 and EBVs form current and new validation evaluation runs.

	Current CIV EBVs	New CIV EBVs	New CSD EBVs
Average CIV phenotypes	0.22	0.20	0.21
Average CSD phenotypes	0.15	0.15	0.20

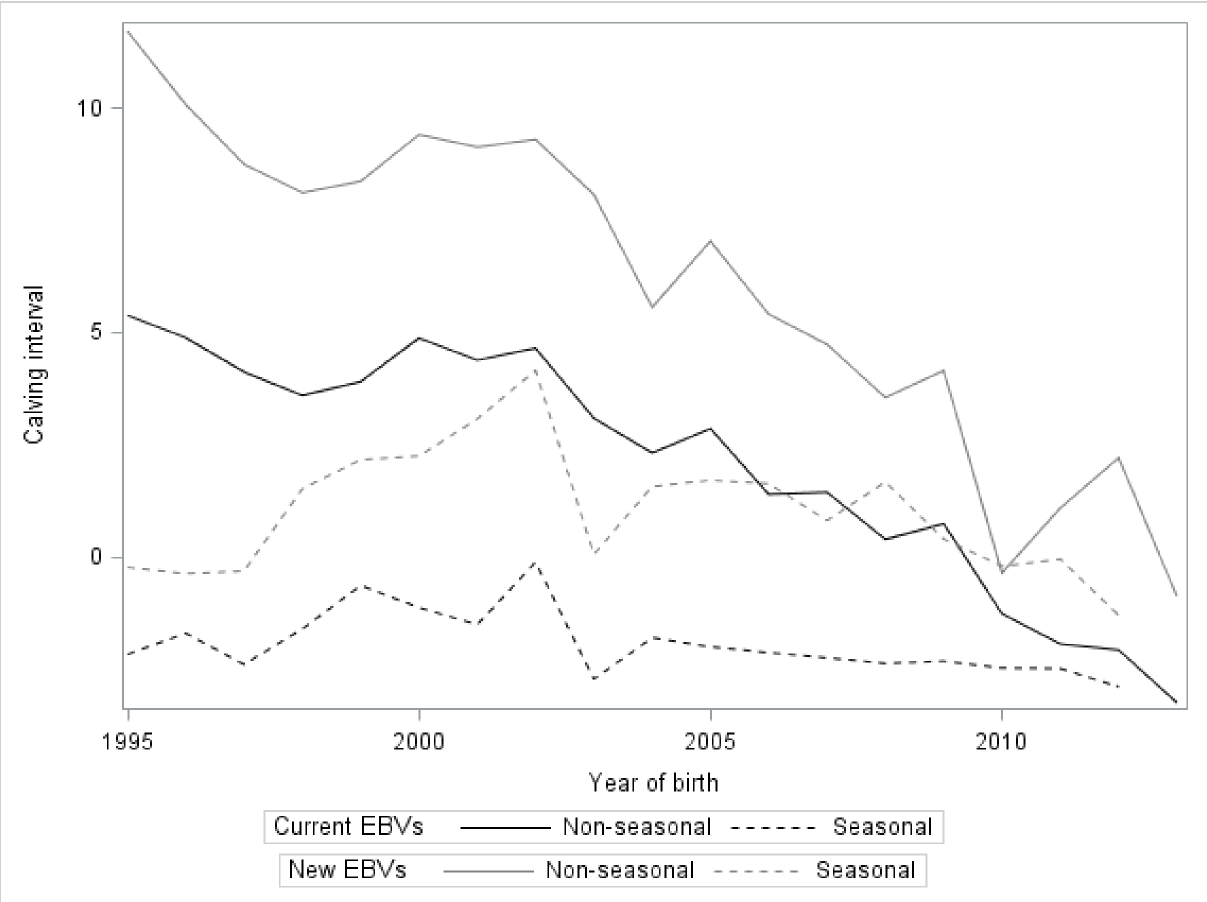

Figure 1. Genetic trends for calving interval for bulls classified as seasonal and non-seasonal obtained from this work and current official genetic evaluation.