Preliminary Genetic Evaluation of Female Fertility in Ireland

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1. Introduction

The only fertility traits currently genetically evaluated in Ireland are calving interval and survival (Olori *et al.*, 2002) and these are only evaluated in lactating animals up to and including parity three. However, both traits are lowly heritable (Olori *et al.*, 2002) and take a long time to measure. Service and pregnancy diagnosis data are now being collected and stored by the Irish Cattle Breeding Federation.

The objective of this study was to undertake a preliminary analysis of the insemination data to decide on new fertility trait definitions, models of analysis and finally to quantify the genetic variation in these traits.

2. Materials and Methods

2.1 Data

A total of 790,452 artificial insemination records, 85,500 natural mating records as well as 128,141 pregnancy diagnosis events were extracted from 1st January 2005 to 7th July 2007. An equal number of records were available in 2005 (n=307,401), 2006 (n=338,532) and 2007 (n=358,160). A total of 618,119 lactations (including maiden heifers as a separate parity) from 453,550 cows and heifers were represented in the dataset. Calving dates for 2006 and 2007 (where available) were also extracted and merged by cow to the 2005 and 2006 data, respectively.

Only cows of at least 75% Holstein-Friesian were retained; remaining breed fraction, if present, was coded as a single breed. Heterosis and recombination loss of the served cow as well as that resulting from the ensued mating were calculated; 801,234 service and pregnancy diagnosis records remained. Only meaningful service dates (i.e., animals served less than 1 year of age or in the periparturient period were deleted) were retained. Only service data from herd-years with at least 20 mating records were retained. Where mating events for the same cow occurred within 5 days of each other only the second record was retained. Contemporary group of herd-year-season of calving and birth were generated using the algorithms of Crump *et al.* (1997). Only contemporary groups with at least 5 records were retained.

In Ireland, breeding of lactating dairy cows in spring calving production systems (the predominant production system in Ireland) usually commences around mid-April for a period of approximately 15 weeks. On average Irish farmers use AI for the first 6 weeks, after which natural mating is generally used. The end of the AI breeding season in the present study was defined as the last AI service record to a lactating cow in a herd-year where at least 10 matings in lactating animals occurred. Only herd-years where the breeding season commenced between March and June were retained; this is to avoid herds that operate a split calving pattern where conscious breeding decisions taken by the farmer may bias the results. Start of the breeding season was defined as the first date in the year where at least 3 services to lactating animals occurred within 10 days of each other. Sire status was coded as 1=natural mating sire, 2= test sires (i.e., sire <5 years of age at the time of service) and 3 = proven AI sire (i.e., sire ≥5 years of age at service or sire date of birth missing). Limited information was available on the AI technician responsible and the batch number of the semen.

Fertility variables were generated separately for both cows and heifers. Data from only the first three parities as well as maiden heifers were retained, consistent with the data currently used in the genetic evaluation of calving interval and survival in Ireland. Records on a potential 47,450 heifers/cows were available for inclusion in the analyses.

A separate dataset was used to estimate genetic parameters for age at first calving. Data used for genetic evaluations of calving interval and survival were merged with data for age at first calving. Contemporary groups of birth with less than 5 records were removed as were records from paternal half-sib groups of <10. A total of 100,585 records were included in this analysis

2.2 Fertility variables for cows

1. Calving to first service (CFS): records between 10 and 250 days retained.
2. Days open (DO): days between calving and last service. If pregnancy diagnosed as not pregnant then days open was set to missing. Records also set to missing in herd-years that recorded service dates for <10 weeks.
3. Number of services (NS): calculated as the number of services recorded for a cow. Set to missing in herd-years that recorded services for <10 weeks.
4. Submission rate in the first 21 days (SR21) of the breeding season was coded as 1 if an animal was mating in the first 21 days of the breeding season, irrespective of calving date. Animals served prior to the start of the breeding season were coded as missing. A further definition of submission rate (SR21_35) was animals calved less than 35 days prior to the start of the breeding season were coded as missing.
5. Pregnancy rate to first service (PRFS) was coded 1=pregnant or 0=not pregnant. Animals with more than one service were immediately coded as not pregnant as were animals diagnosed not in calf. Animals culled or dead within 30 days post first mating were given a missing value as were animals that were served for the first time within 30 days of the last AI record within that herd-year. An alteration on PRFS was generated (PRFS_valid) using the same criteria previously outlined but coded as 1 if the subsequent gestation length was within 273 to 293 days. If gestation length was less than 273 days then PRFS was set to missing and the animal was assumed not to have held to first service if the subsequent gestation length was greater than 293 days (if inseminated with Holstein-Friesian semen) otherwise greater than 300 days.
6. 56-day non-return rate to first service ($NR56_{COW}$) was coded as 1 if the animal was deemed not to have returned to service within 56 days of 1st mating (i.e., became pregnant to the first service) and otherwise zero. Animals served within 56 days of first service were coded as zero. A missing value was given to animals that were served for the first time less than 56 days prior to the last recorded AI within herd-year or less than 56 days prior to culling or death. An alteration of $NR56_{COW}$ using subsequent calving dates (NR56_valid) was generated as previously outlined for PRFS_valid.

2.3 Fertility variables for heifers

1. Age at first calving (AFC): restricted to between 600 and 1,260 days
2. Age at first service (AFS): restricted to between 365 and 500 days
3. 56-day non-return to first service ($NR56_{HEIFER}$) was coded as zero if an animal received a second service within 56 days of the first service, otherwise it received a value of 1. Animals were coded as missing if their first service was within 56 days of the last service to maiden heifers within herd-year.
4. Pregnancy rate to first service ($PRFS_{HEIFER}$) was coded as outlined for pregnancy rate in cows whereby the end of the breeding season was denoted by the last AI within herd-year to maiden heifers

2.4 Analysis

A series of single-trait analyses using an animal linear model were undertaken in ASREML (Gilmour *et al.,* 2007) to estimate variance components. Fixed effects included in the model for AFC were, contemporary group of birth, cow Friesian, Jersey, Montbeliarde and “other breed” proportion, as well as heterosis and recombination loss effects between breed combinations. Fixed effects included all models for cow fertility traits were contemporary group of calving, age at calving, cow Friesian and "other" breed fraction, and a general effect for cow heterosis and cow recombination loss. For the binary traits year-month of service, service sire status, CFS, and heterosis and recombination loss of the resultant mating were also included as fixed effects; sire-year was included as a random effect. For the heifer fertility traits contemporary group of birth and heterosis and recombination loss of the heifer were included as a fixed effect while for $NR56_{HEIFER}$ and $PRFS_{HEIFER}$ year-month of service, sire status, and heterosis and recombination loss of the resultant mating were included as fixed effects.

3. Results and Discussion

3.1 Age at first calving

Mean age at first calving in the dataset was 840 days (28 months); median age at first calving was 793 days. Montbeliardes and Friesians were older at first calving compared to Holsteins while Jerseys and "other breeds" were younger. Standard errors associated with the heterosis and recombination loss estimates were large and all estimates were not significantly different from zero with the exception of the heterosis between a Holstein and Monbeliarde cross which was -12 days (SE=4.5) for a F_1 cross. Heritability for AFC in the present study was 0.24 (SE= 0.0094). The coefficient of genetic variation was 5.3%. It was not computationally possibly to estimate genetic correlations with calving interval, survival, milk yield and a select number of type traits using an animal model on all data and hence a sire model was used. Correlations from the sire model were similar to those estimated using an animal model on a subset of the data. Estimated genetic correlations between age at first calving and the traits currently included in a multi-trait evaluation of fertility in Ireland are summarized in Table 1.

Table 1. Genetic correlations (standard errors in parenthesis) between age at first calving and milk yield, calving interval (CIV), survival, body condition score (BCS), angularity (ANG), foot angle (FA), udder depth (UD) and lifespan.

Trait	Parity		
	1	2	3
Milk yield	0.16	0.10	-0.14
	(0.048)	(0.054)	(0.059)
CIV	-0.10	0.11	0.57
	(0.122)	(0.118)	(0.175)
Survival	-0.67	-0.27	-0.37
	(0.111)	(0.144)	(0.129)
BCS	0.39	(0.072)	
ANG	-0.48	(0.066)	
FA	-0.19	(0.082)	
UD	-0.28	(0.060)	
Lifespan	-0.48	(0.066)	

3.2 Fertility traits from insemination data

Neither heterosis nor recombination loss effects of the cow or the resultant mating were significantly different from zero for most traits although the sign of the effects for heterosis were generally consistent with expectations (i.e., CFS and DO decreased as level of heterosis increased and PRFS, SR21 and NR56 improved with heterosis). However, 100% heterosis equalled a 6.2 day (SE=0.462) delay to first service; the recombination loss effect was 18.4 days (SE=1.26). Solutions for recombination loss were not always consistent across parities although there were mostly opposite in sign to the heterosis effects. NR56 increased with CFS up to 70 to 100 days after which it decreased; maximum PRFS was observed at CFS of 100 to 130 days.

Number of records, mean and heritability estimates for the fertility traits are summarised in Table 2. Validated NR56 and PRFS were always lower, albeit not by much, than the raw figures indicating some level of under-recording of repeat inseminations. Heritability estimates were low for most of the fertility traits varying from no genetic variance ($NR56_{HEIFER}$ & $PRFS_{HEIFER}$) to 0.022 (SR21 in parity 3) the exception being AFS (h^2=0.16). The NR56 and PRFS traits had the lowest heritability estimates. However, the standard errors of the estimates were relatively large rendering some of the heritability estimates not significantly different from zero.

Table 2. Mean and heritability estimates for the fertility traits evaluated.

Trait	Parity	Mean	h^2	SE
AFS		447	0.159	0.023
CFS	1	75	0.019	0.006
	2	73	0.012	0.006
	3	71	0.021	0.010
DO	1	90	0.008	0.004
	2	87	0.010	0.005
	3	84	0.012	0.017
NS	1	1.4	0.004	0.003
	2	1.5	0.008	0.005
	3	1.4	0.007	0.005
NR56	0	0.36	0.000	0.000
	1	0.43	0.004	0.004
	2	0.39	0.006	0.006
	3	0.40	0.000	0.000
NR56_valid	0	0.36	0.000	0.000
	1	0.39	0.003	0.004
	2	0.37	0.004	0.005
	3	0.37	0.006	0.006
PRFS	0	0.55	0.007	0.007
	1	0.57	0.001	0.002
	2	0.55	0.012	0.007
	3	0.56	0.009	0.008
PRFS_valid	0	0.56	0.000	0.000
	1	0.57	0.001	0.002
	2	0.55	0.011	0.006
	3	0.55	0.005	0.006
SR21	1	0.75	0.008	0.004
	2	0.75	0.014	0.006
	3	0.74	0.021	0.010
SR21_35	1	0.82	0.008	0.004
	2	0.83	0.020	0.008
	3	0.84	0.022	0.012

For most of the traits the genetic covariance matrix within trait, between parities was not positive definite, the exceptions being CFS and DO where the genetic correlations between parities varied from 0.43 to 0.72 and from 0.18 to 0.54, respectively. Furthermore, it was not possible to estimate genetic correlations between some of the fertility traits and calving interval, within parity. However, genetic correlations between CFS and calving interval in first, second and third parity was 0.71, 0.87 and 0.77, respectively.

4. Conclusions

Significant genetic variation in AFC exists which in itself is an economically important trait and should therefore be included in the Irish total merit index (i.e., the economic breeding index) but is also genetic correlated with survival and will therefore act as a predictor of survival in a multi-trait evaluation. Low heritability estimates (albeit with large standard errors) were estimated for fertility traits derived from insemination data but some were moderately correlated with calving interval and survival and therefore may be used as predictor traits.

5. Acknowledgements

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6. References

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