The effect of inbreeding on components of dairy cattle fertility as calculated from non-return data, using a multiphasic logistic function

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Abstract

This pilot study demonstrates the use of multiphasic analysis of non-return data to study effects of inbreeding on conception rate, calving rate and calving rate given conception when only non-return data is available. The results indicate that inbreeding of the cow mainly affects late embryonic mortality while inbreeding of the embryo mainly affects foetal mortality. However, interpretation of the results is difficult since inbreeding of the cows is confounded with inbreeding of the embryos. It is concluded that application of multiphasic analysis, as used in this study, is only feasible when extreme large numbers of first insemination are available per bull. Only then will it be possible to include effects of inbreeding of the cow and inbreeding of the embryo simultaneously in order to disentangle effects of inbreeding of cows and embryos.

1. Introduction

Non-return data is used by AI organisations to evaluate the reproductive efficiency of their bulls. However, it can also be used to derive more elementary biological measures for reproductive efficiency (Koops et al., 1995). Based on the initial work by Koops et al. (1995), Grossman et al. (1995) developed a multiphasic logistic function to model the decline in non-return rate over time by estimating, amongst others, conception rate (defined as the presence of a vital embryo by the time of maternal recognition of pregnancy, occurring on Day 15/16 of pregnancy) and calving rate.

We initiated a *pilot study* to investigate the feasibility of using multiphasic analysis of reproductive efficiency of dairy bulls to study effects of inbreeding on conception rate, calving rate and calving given conception when only non-return data is available. The objective of this pilot study was to investigate for a limited number of individual bulls whether non-return rates at 56 days after insemination (NR56) and biological measures as derived from non-return data by multiphasic analysis are affected by (a) the degree of inbreeding of the inseminated cows and (b) the bull's additive genetic relationship with the inseminated cows. As a measure for the additive genetic relationship between a bull and each of the cows inseminated with his semen the inbreeding coefficient (F) of the potential embryo (from here onwards simply referred to as 'embryo') was used. In the following the term 'mates' will be used to refer to all cows inseminated with semen of an individual bull.

2 Material and Methods

2.1 Data

Insemination data for 15 Holstein bulls with on average 17696 first inseminations (range 5630 to 73379) was used. The data were made available by the Royal Dutch Cattle Syndicate. All inseminations were performed in lactating cows that calved in 1995. The average parity of these cows was 3.52 (range between bulls 3.33 to 3.70). For each cow in the data set it was known whether she returned for a second insemination after first insemination. Return intervals of less than 5 days were considered to be re-inseminations during the same oestrus and omitted. Return intervals of more than 300 days were considered to be due to the fact that an insemination in a following parity was registered as a re-insemination in the same parity and also omitted.

Inbreeding coefficients were calculated using 4 generations of pedigree information per sire and mate.

2.2 Multiphasic analysis per bull

Based on the inbreeding coefficients (Fs) of either the mates or the embryos, all inseminations per bull were divided into three groups according to the threshold values as shown in Table 1.

Table 1. Threshold values used to group first inseminations per bull into three inbreeding groups on the basis of the Fs of either mates or embryos

	Threshold values	
Group	F Mates	F Embryos
A	0	<1
B	> 0-1.5	1-2.5
C	> 1.5	> 2.5

Per bull per inbreeding group, daily observations on non-return rate from Day 5 to Day 180 after insemination was used as input for the model. For the calculation of these daily non-return rates all data for cows that returned for insemination between Days 5 and 300 and cows that did not return for insemination, were used. For reliable estimates of the parameters that can be derived by multiphasic analysis, at least 500 returns before Day 180 after insemination should be available. The threshold values in Table 1 were chosen to meet this requirement.

With equation [1], the multiphasic logistic function of Grossman et al. (1995), the conception rate (ConcR) and the calving rate (CalvR) were estimated per bull per inbreeding group by non-linear regression. For this an adaptive non-linear least squares algorithm was used (Sherrod, 1996). A default value of $1.0*10^{-10}$ was used for the tolerance factor, which specifies the convergence criterion for the iterative estimation procedure. From the estimates of ConcR and CalvR, the calving rate given conception (CalvR/c) was calculated as CalvR/ConcR.

$$P_t = P_c + \left[1 - \left(\frac{1}{1+e^{-\frac{t-c}{d}}}\right)\right](P_0 - P_c) + \left[1 - \left(\sum_{i=1}^{n} \frac{h_i}{1+e^{-\frac{t-c_i}{d_i}}}\right)\right](1 - P_0) \quad [1]$$

with:
P_t = probability of non-return by time t after insemination; P_o = probability of conception; P_c = probability of completing gestation after insemination (i.e. calving rate); t = days after insemination; c = days after insemination of maximum decline in non-return for the group of irregular returned cows; d = a measure of the standard deviation with 7.2*d including 95% of the irregular returned cows; e = the base of the natural logarithm; h_i = proportion regular returned cows returning during phase i; c_i = days of maximum decline in non-returns of the group of regular returned cows during phase i; d_i = a measure of the standard deviation for phase i and $7.2*d_i$ includes about 95% of the regular returned cows during phase i.

2.3 Multiphasic analysis on pooled data for all bulls

Based on the Fs of either mates or embryos the pooled data for all bulls were divided into six groups according to the threshold values shown in Table 2. The same calculations as described above were performed for each of these six groups.

Table 2. Threshold values used to group first inseminations in the pooled data set into six inbreeding groups on the basis of the Fs of either mates or embryos

	Threshold values	
Group	F Mates	F Embryos
A	0	0
B	> 0-3	> 0-2
C	> 3-5	> 2-4
D	> 5-7	> 4-8
E	> 7-8	> 8-12
F	> 8	> 12

3. Results

The Fs of the bulls was on average 1.24% (range 0-3.52%). The average F of the mates of the bulls was 0.58 (average of the bull means) with an average maximum F of 24.03. The ranges were 0.46-0.65 and 14.06-27.39, respectively. The average Fs of the embryos was 1.58 (average of the bull means) with an average maximum F of 20.78. The ranges were 0.74-2.49 and 12.70-32.46, respectively.

Table 3 shows the average and maximum Fs for all cows which conceived after insemination as well as for those that were inseminated for a second time between Days 5 and 180 after first insemination. The maximum F, but not the average, is somewhat higher for the cows that returned to oestrus after first insemination in comparison to those which remained pregnant. On average the embryos in cows which returned to oestrus were only slightly more inbred.

Table 3. Comparison of average and maximum Fs of mates that probably conceived (Non-return) and those that returned for insemination between Days 5 and 180 after first insemination (Return). Averages are means of bull means (n=15)

	Non return	Return
Parity mates	3.52	3.53
Mean F mates	0.58	0.58
Fmax mates	20.65	21.64
Mean F embryos	1.56	1.60
Fmax embryos	17.49	18.97

The bull averages for NR56 and biological measures derived from the multiphasic analysis of non-return data are shown in Tables 4 and 5 for the different inbreeding groups based on Fs of mates and embryos, respectively. From both tables it is clear that the effects of inbreeding of the mates (Table 4) and embryos (Table 5) are confounded with parity effects. Furthermore, between the groups based on the Fs of mates, the Fs of the embryos differ (Table 4). Likewise, between the groups based on the Fs of embryos, the average F of the mates differ (Table 5).

Table 4. Average bull fertility measures for inbreeding groups based on inbreeding coefficients of the mates (n=15)

Group	A	B	C
Mean F mates	0	0.63	3.17
Mean F embryos	1.65	1.42	1.41
Parity mates	3.00	4.80	4.77
NR 56	63.0[a]	62.6[a]	61.9[b]
ConcR	70.7	71.1	70.2
CalvR	52.0	51.6	51.4
CalvR/c	73.6	72.6	73.2

a, b: different letters denote significant ($p<0.05$) differences between means.

As far as the reproduction measures are concerned, inbreeding of the mates had a significant effect on NR56 (Table 4), whereas inbreeding of the embryos had a significant effect on CalvR (Table 5). Although CalvR showed a gradual decline with increasing Fs of mates (Table 4) and CalvR/c shows a gradual decline with increasing Fs of embryos (Table 5), differences between groups are not significant.

The fertility measures, calculated per inbreeding group in pooled data of the 15 bulls, are shown in Table 6 for the groups based on Fs of mates and in Table 7 for the groups based on Fs of embryos. ConcR and CalvR show a tendency to decrease as Fs of mates increase (Table 6). The high value for CalvR/c in Table 6 is mainly due to the relatively low value for ConcR in the group with the highest Fs. No consistent changes in fertility measures with increasing Fs are seen when groups are based on Fs of embryos (Table 7).

Table 5. Average bull fertility measures for the inbreeding groups based on inbreeding coefficients of the embryos (n=15)

Group	A	B	C
Mean F embryos	0.50	1.62	4.21
Mean F mates	0.68	0.53	0.48
Parity mates	4.02	3.32	3.02
NR 56	62.9	62.2	62.7
ConcR	70.7	69.6	70.0
CalvR	52.2[a]	51.1[b]	50.8[b]
CalvR/c	73.8	73.5	72.5

a, b: different letters denote significant ($p<0.05$) differences between means.

Table 6. Fertility measures for inbreeding groups based on inbreeding coefficients of mates, calculated in the pooled data for 15 bulls

Group	NR56	ConcR	CalvR	CalvR/c
A	62.5	70.0	51.9	74.1
B	61.3	68.6	50.0	72.9
C	61.5	68.3	49.3	72.2
D	60.4	69.1	48.1	69.6
E	61.5	67.6	49.3	72.9
F	62.6	57.0	48.8	85.6

Table 7. Fertility measures for inbreeding groups based on inbreeding coefficients of embryos, calculated in the pooled data for 15 bulls

Group	NR56	ConcR	CalvR	CalvR/c
A	62.5	70.0	51.9	74.1
B	61.3	68.7	50.0	72.8
C	61.3	68.9	49.6	72.0
D	61.0	68.4	48.7	71.2
E	63.4	73.3	49.7	67.8
F	61.4	64.6	46.8	72.4

4. Discussion

Although the present study indicates some effects of inbreeding on fertility, the effects are relatively small and difficult to interpret. The former can be due to the fact that the differences in average inbreeding of the groups investigated per bull were also very small. There are two reasons for this. Firstly, although the range of Fs was large (up to 35%), the average was very low due to very few mates and embryos with an F of more than 5%. Secondly, for reliable estimates of the derived variables (ConcR, CalvR) the model that was used for the multiphasic analysis of the non-return data requires at least 500 returns between Days 5 and 180. To meet this requirement, given the frequency distribution of Fs, only three groups could be made. Although the group with the highest average inbreeding (be it on the basis of the Fs of mates or embryos) contained the highly inbred individuals, the average inbreeding was still low.

Cows in the group with the highest average inbreeding carried embryos that were on average less inbred than the embryos carried by the group of cows with the lowest average inbreeding. The other way round, embryos in the group with the highest average inbreeding were carried by cows which were on average less inbred than the cows which carried the embryos from the group with the lowest inbreeding. This confounding of effects of inbreeding of mates and inbreeding of embryos adds much to the difficulty to interpret the current results. Unfortunately, with the available data set and the requirements of the multiphasic model regarding the number of returns needed for reliable results, no cross-classification on the basis of inbreeding of the bull's mates and embryos could be made.

Although the results of this pilot study must be interpreted with much care, the results based on analyses per bull seem to indicate that inbreeding of the cow mainly affects late embryonic mortality (see Table 4: ConcR and CalvR/c unaffected, NR56 and to some extent CalvR affected). Inbreeding of the embryo seems to affect mainly foetal mortality (Table 5: NR56 and ConcR unaffected, CalvR and to some extent CalvR/c affected). This is in contrast to the generally accepted belief that inbreeding of the embryo leads to early embryonic loss and inbreeding of the dam to (late) foetal loss.

In conclusion, this pilot study demonstrates the use of multiphasic analysis of non-return data to enable investigation of the effects of inbreeding on biological measures for fertility as derived from the non-return data. It is clear that the application of multiphasic analysis is only feasible when extreme large numbers of first inseminations are available per bull. Only then will it be possible to generate inbreeding groups with substantial differences in average inbreeding and to disentangle effects of inbreeding of mates and embryos.

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