

Indicators

E-17

Breeding Value Fertility

▪ **Introduction**

The fertility of a sire shows itself in two ways: in the fertilizing capacity of its semen and in the fertility of its daughters. Chapter E-24 treats the fertilizing capacity of a bull's semen. The fertility of the daughters is a trait which a farmer can profitably improve by breeding. This is the subject which will be examined more closely in this part.

▸ **Fertility Traits**

Fertility is a trait which can be measured in many different ways. Definitions which are used frequently are non-return rate at 56 days (NR56), non-return rate at 28 days (NR28), number of days open, calving interval (CI), the interval between calving and first insemination (ICI), the interval between first and last insemination (IFL), conception rate (CR), the number of inseminations per pregnancy, etc.

In addition, fertility traits can be measured on heifers, two-year-olds and older cows. These three physiologically different groups of animals provide information on the fertility of an animal during the rearing period, during lactation while the animal is still growing and during later lactation. Fertility measured on virgin heifers is predicted by the traits conception rate (CR0) and age at first insemination (AFI).

If fertility is to be taken into account when selecting animals for breeding, the question presents itself which fertility trait to use and what the breeding goal is.

▸ **Breeding Goal**

Fertility traits can be divided into two types: traits measuring cycling ability and traits measuring the ability to conceive. For the cycling ability the number of days between two fertility situations is determined. For example: the number of days between calving and the first heat or the number of days between two calvings. The ability to conceive can be expressed by an interval trait or a fertility score. The interval trait can be the number of days between first and last insemination. For the fertility score a percentage of the animals which are in a certain reproductive status is measured. Examples are conception rate (CR), NR56 and NR28. NR56 is a 0/1 trait, which means pregnant or not pregnant at 56 days after insemination. To calculate this figure, a simple check is done whether an animal has been presented for mating (insemination, natural insemination, embryo transfer) within 56 days after the first insemination. If this is the case, the animal will get the status 'not pregnant at day 56 after the first insemination' (0). If this is not the case, the animal will get the status 'pregnant at day 56 after the first insemination' (1). An animal which is presented for a new insemination on day 85 for example, will have a 1 for NR56. The assumption is that it was pregnant on 56 days and only returned to heat after that.

A cow with a good fertility can be defined as a lactating animal that clearly shows its heat on time and conceives after the first insemination. Whenever an animal meets these two requirements, it will automatically achieve a desired calving interval. Moreover, this cow requires little labour and needs one straw of semen to become pregnant.

The breeding goal is: A short calving interval together with as few inseminations as possible per pregnancy.

▪ Data

Visible heats in animals can be deduced from the heat detection by the farmer. However, these data are not registered at national level. Insemination data, however, are available. From these, the interval between calving and first insemination (ICI) can be calculated. This trait has a strong correlation with the trait interval calving to first heat (genetic correlation stronger than 0.90) and has a strong relationship with the calving interval (a genetic correlation of 0.80). In addition, ICI can be determined for more cows than the calving interval (CI); CI can only be determined for 2/3 of the cows for which ICI can be determined. Equally important is the fact that it is necessary to have a next calving date to determine the CI. And especially cows with poor fertility often will not have a next calving date. But often you do have ICI, even if cows have a poor fertility. Therefore, a breeding value which only uses CI will have inaccurate breeding values. A cow without a next calving date will not have data on CI and will therefore not be in the breeding value estimation, even though this is exactly the kind of animal which has a negative effect on fertility. If you want to use CI, you will have to use extra information on fertility, such as ICI. Even cows with poor fertility usually have been inseminated once and will therefore have a ICI. In ICI you will only miss the cows which will never become cyclic again and therefore are never presented again for an insemination.

To conclude, ICI has a somewhat higher heritability than calving interval, therefore a breeding value for ICI is a good and early indicator of calving interval.

Determining whether an animal is pregnant after the first insemination can be expressed with a score or an interval. As score conception rate (CR) can be taken. The disadvantage of this trait is the fact that it is not available until late. It is also not available for all animals, because it can only be determined nine months after the cow has been inseminated. An alternative for CR is NR56. Approximately four out of five animals which can be used to determine the NR56 percentage are also available for the determination of CR. The advantage of CR above NR56 is, that it is used in many countries and can be used better for an international evaluation of breeding values.

An other alternative trait to describe the ability to conceive is the interval between first and last insemination (IFL). This trait will give, together with the interval between calving and first insemination, additional information about the calving interval. IFL has a strong genetic correlation with CR of -0.84 to -0.88, slightly stronger than the genetic correlation between NR56 and CR (0.77-0.79). IFL has a slightly higher heritability than NR56 (see Table 2).

Furthermore, it is important which data are used for the breeding value estimation. For virgin heifers no fertility traits are estimated until present. Since January 2008 Interbull also evaluates the ability of virgin heifers to become pregnant (trait T1). To improve fertility evaluation with other countries, it is important to analyze virgin heifer fertility in the Dutch Flemish breeding value estimation. After evaluating genetic parameters, estimated for The Netherlands and Flanders (de Haer, 2013), it was concluded that for heifers the traits AFI and CR0 should be used in the breeding value estimation.

Data from the Netherlands and Flanders are used for the breeding value estimation. For The Netherlands inseminations since September 1988 are used, calving and lactation data since September 1978. Body condition scores which have been collected in the type classification program are available since 1998. For Flanders insemination data are collected from January 1990, calving and lactation data from September 1975 and body condition scores from June 2003.

To determine IFL a next, valid calving is checked. Research has shown that it is important to include all IFL data, even when there is not a valid next calving. Data without valid next calving are valuable, as a part of the these data belongs to animals with reduced fertility. If there is no valid next calving, IFL is increased by 57 penalty days (De Haer, 2009).

Data edits are:

1. The cow which has been inseminated has to be herdbook-registered;
2. Only first lactation production data and body condition score are used;
3. Insemination data and calving data of the first three lactations of a cow are used;
4. The minimum age of the cow at first calving is 640 days;
5. NR56, ICI and IFL are included if the interval calving to first insemination is between 30 and 250 days;
6. NR56 is included if the insemination is at least 4 months before the last insemination date in the selected data set;
7. ICI is included if the calving date is at least 3 months before the last calving date in the selected data set;
8. IFL is included if the calving date is at least 12 months before the last calving date in the selected data set;
9. CI is included if the calving date is at least 18 months before the last calving date in the selected data set and is less than 800 days. All CIs between 800 and 550 days are changed to 550;
10. IFL is 0 when there is only 1 registered insemination, or when re-insemination takes place within 4 days.
11. The maximum interval length for IFL is 220 days (without penalty days).
12. IFL will receive 57 penalty days when CI is more than 800 days.
13. NR56, ICI, IFL and CI are not included if there has been a flushing or a transplantation during lactation;
14. IFL based on insemination data is set to missing when running with the bull has taken place during lactation.
15. NR56 is not included if running with the bull has taken place before the animal has been mated at least two times (artificial insemination or natural service);
16. ICI is not included if running with the bull has taken place before the animal has been mated at least one time (artificial insemination or natural service);
17. If there is a period of 150 days or more between successive matings or the CI is less than 210 days (both indications of an abortion), then NR56 and ICI are included in the breeding value estimation but CI is not; IFL will be derived from the interval between first and last insemination, occurring before the 150 days interval, increased with 57 penalty days.
18. If the number of days between the last insemination and the next calving date is greater than 400 days, the calving interval is not included;
19. IFL will receive 57 penalty days if the gestation length is not within 265 and 300 days and there is a next calving date. If the gestation length is more than 300 days and a valid next calving is present (and therefore valid CI), then IFL is calculated as $CI - ICI - 280$ days (280 being the average gestation length). The long gestation length may be due to unregistered inseminations or natural services.
20. IFL will receive 57 penalty days if a next calving date is missing and a minimum period of 300 days is present between the last insemination date of the cow and the last calving date in the data set. If the next calving date is missing but the period between the last insemination date of the cow and the last calving date in the data set is less than 300 days, IFL is missing.
21. AFI was calculated as the age of first insemination of virgin heifers. AFI was missing when date of first insemination or birthdate was unknown.
22. In general, CR was calculated as 100 divided by number of inseminations before calving. CR was missing when gestation length was less than 45 days and CR was 0 when gestation length was more than 300 days (a gestation between 45-300 days was considered as a pregnancy or a pregnancy followed by an abortion). CR was 0 when next calving date was missing. If a virgin heifer was exported CR was set to 100 divided by number of inseminations (pregnancy was assumed).
23. For cows with calving data first inseminations had to occur within 30 to 250 days after calving, otherwise CR was set to missing.
24. When CI was more than 800 days, CR was missing.

25. Based on the number of first inseminations in a period of 1 year and on the national average of 65%, a threshold for NR56 is calculated (see table 1). This threshold is an indication as to whether the farmer in question is reporting only the successful mating's. If a herd-year exceeds the threshold, NR56, ICI, IFL and CR data of that herd-year are not used in the breeding value estimation.

The threshold is determined as follows:

$$\text{Threshold} = p + 2.57 \times \sqrt{(p \times q / n)}$$

$p = 0.65$, probability that an animal is not presented for insemination again within 56 days

$q = 1 - p = 0.35$, probability that an animal is presented for insemination again within 56 days

n = number of observations in a herd within one year

26. Extreme measurements of production traits are set to a maximum or minimum. The maximum and minimum are determined by the average production of a herd plus or minus 3 times the phenotypic standard deviation respectively. The used standard deviations are 950, 37 and 29 for kg milk, kg fat and kg protein respectively. The productions are standardised to an age at calving of 24 months.

Table 1. NR56 thresholds, depending on the number of inseminations

Number of Inseminations	Limiting Value NR56
20	92.4
30	87.4
40	84.4
50	82.3
60	80.8
70	79.7
80	78.7
90	77.9
100	77.3
125	76.0
150	75.0
175	74.3
200	73.7

▪ Statistical Model

The breeding values for fertility traits are estimated with an animal model, using the BLUP-technique (Best Linear Unbiased Prediction). At the same time, milk, fat and protein yields as well as the body condition score from the first lactation are analysed. Correlations between all traits are used in this process. Therefore, the breeding value estimation is a so-called multiple trait breeding value estimation. The reason to include these last four traits in the breeding value estimation is the fact that these traits are good predictors of fertility. By including these four predictors the reliability of the fertility breeding values will eventually increase, especially for the youngest sires, of which the daughters do not have much fertility information yet (no calving interval). When estimating breeding values, it is theoretically also more correct to take into account a correlated trait (milk production) for which a lot of selection has taken place during the past years. Production traits are not included anymore for the second and third lactation. They don't add any value, because the fertility information of the first lactation is already available.

Different statistical models are used for different traits:

$$\begin{aligned}
 Y1_{ijklm} &= HIYS_i + IYP_j + HET_k + REC_l + A_m + Res_{ijklm} \\
 Y2_{ijklm} &= HCYS_i + CYP_j + HET_k + REC_l + A_m + Res_{ijklm} \\
 Y3_{ijklmno} &= HSD_i + HET_k + REC_l + AGE_n + LACT_o + A_m + Res_{ijklmno} \\
 Y4_{iklm} &= HBY_i + BM_j + HET_k + REC_l + A_m + Res_{iklm}
 \end{aligned}$$

in which:

- $Y1_{ijklm}$: Observation for NR56, IFL, CR (all measured in lactating cows), CR0 (measured in virgin heifers), on cow m, in herd-insemination year-season i and in insemination year-period j, with heterosis effect k and recombination effect l;
 $Y2_{ijklm}$: Observation for ICI, CI, Milk, Fat, Protein on cow m, in herd-calving year-season i and in calving year-period j, with heterosis effect k and recombination effect l;
 $Y3_{ijklm}$: Observation for Body Condition Score on cow m, with herd-scoring date i, heterosis effect k and recombination effect l, age at condition score n and stage of lactation at scoring o;
 $Y4_{iklm}$: Observation for AFI (virgin heifers) on heifer m, with herd-birth year i, heterosis effect k and recombination effect l;

- $HIYS_i$: Herd-insemination year-season i. Season is defined as a period of one year in a herd;
 $HCYS_i$: Herd-calving year-season i. Season is defined as a period of one year in a herd;
 HSD_i : Herd-date of scoring i;
 IYP_j : Insemination year-period j, in which the cow was inseminated. For every year 36 new classes are defined, each consisting of 10 days;
 CYP_j : Calving year-period j, in which the cow has calved. For every year 36 new classes are defined, each consisting of 10 days;
 HBY_i : Herd-birth year i;
 BM_j : Month of birth;
 HET_k : Heterosis class k;
 REC_l : Recombination class l;
 AGE_n : Age class at scoring n;
 $LACT_o$: Stage of lactation o;
 A_m : Additive genetic effect (or breeding value) of cow m;
 Res_{ijklm} : Residual term of $Y1_{ijklm}$, $Y2_{ijklm}$ and $Y4_{ijklm}$ which is not explained by the model;
 $Res_{ijklmno}$: Residual term of $Y3_{ijklmno}$ which is not explained by the model;

The effects A and Res are random effects, the other effects are fixed.

The observations for milk, fat and protein yield have been standardized to 24 months at calving. With the above model, breeding values for both cows and bulls are estimated.

► The Effects in the Model

The effects in the model are:

1. herd-insemination year-season;
2. herd-calving year-season;
3. herd-date of scoring;
4. insemination year-period
5. calving year-period;
6. herd-birth year;
7. month of birth;
8. heterosis and recombination;
9. age at scoring;
10. stage of lactation at scoring;
11. cow.

Herd-insemination year-season/Herd-calving year-season.

Between farms, large differences in fertility management exist. At the same time, the level of fertility in a herd may change over time. This is taken into account by comparing the cows within a herd and a season of one year. The definition of a season is from the 1st of September last year up to and including the 31st of August this year. For NR56 and IFL season is defined by date and herd of insemination. For the other traits season is defined by the calving date and the insemination farm. If the insemination farm is not known (cows without NR56 and ICI data), then the farm on which the first Milk Production Recording took place is used.

Herd-date of scoring

For the analysis of body condition score, data are compared of heifers that are scored at the same herd and date.

Insemination year-period/Calving year-period

As it turns out, animals which are inseminated in the period of March up to and including July, return less often than animals which are inseminated in the other months of the year (see Figure 1). At the same time, animals which calve in August/September are inseminated for the first time at an earlier stage than those that calve in April (see Figure 2). The interval between calving and first insemination is influenced by the month of calving. The difference in ICI between the calving months September and April is somewhat over 10 days.

For the trait calving interval figure 3 shows that cows which calve between June and October realize a shorter calving interval on average than cows that calve in other months. The average difference between those two periods is 10 days with a maximum of almost 20 days between March and August (see Figure 3).

The year of calving is also taken into account, because the changes from month to month differ per year.

Herd-birth year

For the analysis of AFI, data are compared of virgin heifers that are at the same herd and birth year.

Month of birth

For the analysis of AFI data are corrected for month of birth (24 periods of half a month per year).

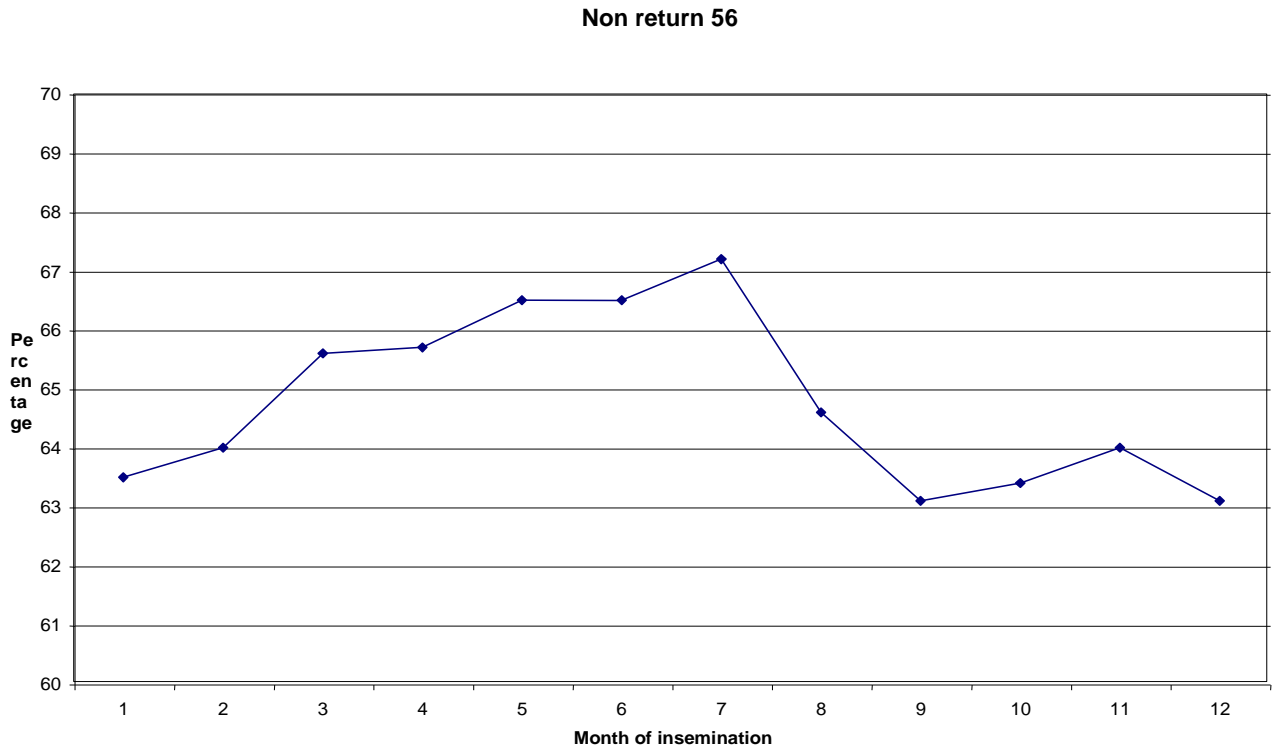


Figure 1. Non-Return Percentage after 56 days per insemination month (1=Jan., 12 = Dec.)

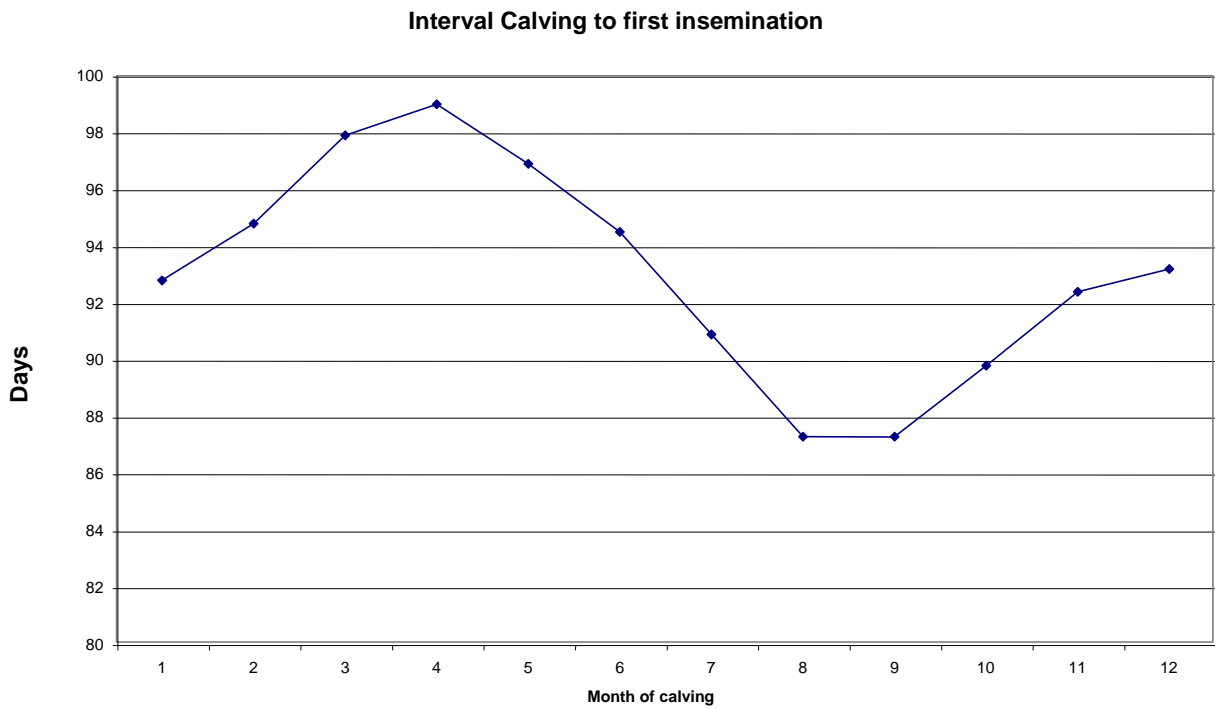


Figure 2. Interval between Calving and First Insemination (ICI), depending on the month of calving (1=Jan., 12 = Dec.)

Calving Interval

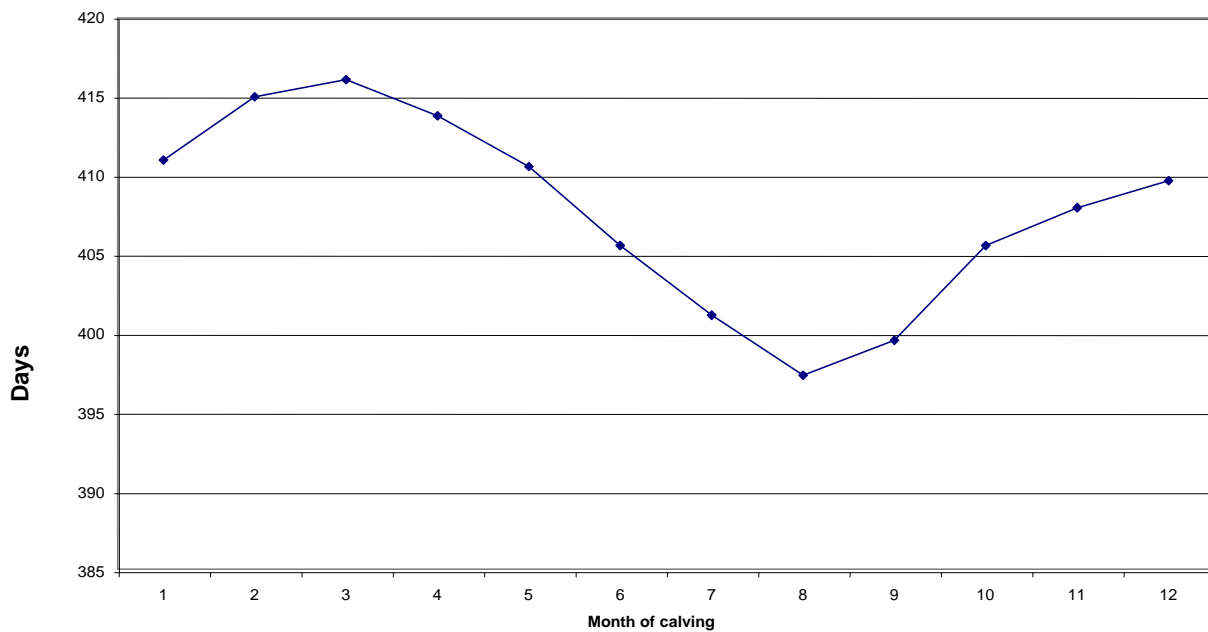


Figure 3. Calving Interval (CI), depending on the month of calving (1=Jan., 12 = Dec.)

Heterosis and recombination effect

Heterosis and recombination effects play a role in crossbreeding. They are genetic effects, which are not passed on to the offspring. Research has shown that corrections must be made for these effects.

The extent of the heterosis is defined as the difference in level of the trait in the crossbreeding with the average of the parent breeds. Recombination occurs when at least one crossbred animal is used for breeding. The heterosis effect (het) of two breeds can be calculated using this formula:

$$\text{het} = [p_s(1-p_d) + p_d(1-p_s)]$$

in which:

p_s = breed blood portion sire
 p_d = breed blood portion dam

The formula for recombination (rec) is as follows:

$$\text{rec} = [p_s(1-p_s) + p_d(1-p_d)]$$

If an animal comes from three different breeds, the number of heterosis and recombination effects also increases.

The effect of heterosis is a 0.8 percent higher NR56, a 2.6% higher CR, a 0.6 day shorter ICI, 2.0 days shorter IFL and a 2.8 days shorter calving interval respectively, for animals with 100 percent heterosis.

Age at scoring

If body condition score is analysed, a correction is made for age at scoring, as it influences the condition score. 18 Age classes are determined. Class 1 accounts for an age of 24 months or younger. Class 2 till 17 accounts for age at scoring of 25 till 40 months. Class 18 accounts for an age of 41 months or more.

Stage of lactation

As stage of lactation influences body condition score, the stage of lactation (months) is corrected for. 13 Lactation stages are determined, one for each month of lactation. Class 13 accounts for a stage of lactation at scoring of 13 months or more.

Cow

To estimate the effect of the cow all ancestors of the animal are considered. In this way, genetic relations between animals are taken into account and sires will have a breeding value for fertility traits based on the data of their daughters.

▪ **Traits**

In all, 34 fertility traits are analysed in the breeding value estimation: four for virgin heifers and 30 for lactating cows.. For virgin heifers AFI and CR0 in two regions (The Netherlands and Flanders) are analysed. For lactating cows there are five fertility traits (NR56, ICI, CI, IFL and CR) in three lactations and 2 regions, which is $3 \times 5 \times 2 = 30$ fertility traits. The heritabilities for the various traits are in Table 2 and the genetic correlations are in Table 3. Dutch and Flemish fertility traits are analysed as separate traits, as genetic variations and heritabilities of Flemish traits are different from Dutch traits (generally lower) (see Table 2).

Besides the 34 fertility traits, information from milk production and body condition score is used. This information is available at an early stage and provides better fertility breeding values (see paragraph Importance of the Use of Predictors).

The genetic correlations between identical Dutch and Flemish traits are 1.00 (Table 3). This means that breeding values of each animal for the Dutch and Flemish trait are identical. Genetic correlations between the different traits are used in the breeding value estimation. Therefore, the breeding value estimation for fertility traits is a so-called multiple trait breeding value estimation, which means that all available information regarding fertility is used to estimate breeding values as accurately as possible.

We can therefore also use the information on CI, even though this information is not available for all animals (a cow might be in the middle of a lactation or it doesn't have a next calving date anymore).

Milk production and body condition score are also adding value to cows with a fertility which is so bad they are never presented for mating. These cows don't have NR56, ICI, CI, IFL or CR, whereas they are the cows with the biggest fertility problems. In that case, you can still use the information on milk production and body condition score, and so these animals also take part in the fertility breeding value estimation.

Table 2. Heritabilities (h^2) and genetic standard deviations of traits.

Trait	Lactation	Region	h^2	Genetic deviation	unit
AFI	0	NL	0.045	7.9	day
CR0	0	NL	0.018	4.1	%
AFI	0	FL	0.026	7.9	day
CR0	0	FL	0.015	4.4	%
NR56	1	NL	0.016	6.2	%
ICI	1	NL	0.081	9.9	day
CI	1	NL	0.062	14.7	day
IFL	1	NL	0.033	13.4	day
CR	1	NL	0.025	5.1	%
NR56	1	FL	0.012	5.2	%
ICI	1	FL	0.068	9.4	day
CI	1	FL	0.056	13.8	day
IFL	1	FL	0.033	11.7	day
CR	1	FL	0.027	6.5	%
NR56	2	NL	0.02	6.9	%
ICI	2	NL	0.099	11.0	day
CI	2	NL	0.075	15.6	day
IFL	2	NL	0.033	12.7	day
CR	2	NL	0.026	5.2	%
NR56	2	FL	0.016	6.0	%
ICI	2	FL	0.074	10.0	day
CI	2	FL	0.053	13.2	day
IFL	2	FL	0.034	11.9	day
CR	2	FL	0.027	6.7	%
NR56	3	NL	0.021	6.9	%
ICI	3	NL	0.097	11.0	day
CI	3	NL	0.078	15.8	day
IFL	3	NL	0.033	12.6	day
CR	3	NL	0.027	5.3	%
NR56	3	FL	0.022	7.1	%
ICI	3	FL	0.064	9.3	day
CI	3	FL	0.049	12.6	day
IFL	3	FL	0.036	12.5	day
CR	3	FL	0.034	7.6	%
Milk	1	NL/FL	0.342	624.8	kg
Fat	1	NL/FL	0.264	21.3	kg
Protein	1	VL/FL	0.276	17.5	kg
Body condition	1	NL/FL	0.207	0.51	pt

► Derived Breeding Values

The 30 cow fertility traits (NR56, ICI, CI, IFL and CR in three lactations and 2 regions) are combined into five overall breeding values and one fertility index. The five overall breeding values are calculated from the breeding value for the three different lactations as follows:

$$BV_{overall} = 0.41 \times BV_1 + 0.33 \times BV_2 + 0.26 \times BV_3$$

in which:

BV_i : breeding value for a fertility trait in lactation i .

The derivation of the factors (0.41, 0.33 and 0.26) is described in chapter E7.

Next, the overall breeding values for IFL and CI are combined in the fertility index (see below for the derivation).

All these derived traits also have their own heritability and genetic standard deviation, see Table 4. The genetic correlations between the derived traits are in Table 5 and those between the derived and underlying traits are in Table 6.

Table 4. Heritabilities (h^2) and genetic standard deviation for the derived traits

Trait	h^2	Genetic Standard Deviation	unit
NR overall	0.046	6.4	%
ICI overall	0.176	10.3	days
CI overall	0.141	14.9	days
IFL overall	0.073	12.4	days
CR overall	0.059	5.0	%
FER index	0.101	4.1	pt

As is shown in Table 4, the heritability of the overall traits NR56, ICI, CI, IFL and CR is higher than the heritabilities of the corresponding traits in Table 2. NR56, for example, has a heritability in Table 2, which is 0.02 or lower. In Table 4 overall NR56 (a combination of NR56 in lactation 1, 2 and 3) has a heritability of 0.046. This may seem strange, because this is higher than the heritability in one of the three lactations. The reason for this is the fact that the genetic correlations between NR56 are much higher than the environmental correlations. The consequence is that with a NR56 observation in lactation 1, 2 and 3 you are better able to eliminate the effect of the environment on the observation, and therefore you will realize a higher heritability.

Table 5. Genetic correlations of breeding values between derived traits

Trait	FER index	NR56 overall	ICI overall	CI overall	IFL overall	CR overall
FER index						
NR56 overall	0.35					
ICI overall	0.73	-0.33				
CI overall	0.96	0.13	0.87			
IFL overall	0.96	0.56	0.53	0.85		
CR overall	0.84	0.75	0.29	0.69	0.93	

Table 5 shows correlations between breeding values of sires, as a measure for genetic correlations of overall traits. The interval traits (ICI, IFL and CI) have a scale opposite to the biological meaning, indicating that a higher breeding value represents a shorter interval length. Genetic correlations are comparable to or a little stronger than genetic correlations of the underlying traits in Table 3. Furthermore, the fertility index is correlated very strongly with IFL overall, CI overall and to a lesser extent, CR overall. As CI is represented by ICI and IFL, it is shown that IFL has the largest influence on the fertility index. A shorter interval between first and last insemination and therefore a higher breeding value for IFL, will result in a higher breeding value for the fertility index.

Table 6. Genetic correlations between the derived traits and the underlying traits

Trait	NR56 overall	ICI overall	CI overall	IFL overall	CR overall
Lactation 1	0.98	0.98	0.98	0.98	0.97
Lactation 2	0.98	0.98	0.98	0.99	0.98
Lactation 3	0.98	0.98	0.98	0.97	0.97

Table 6 shows that the overall traits are correlated very strongly with the underlying traits. The reason is that the underlying traits themselves also have very high genetic correlations between lactations.

▪ Fertility Index

In the fertility index, interval first-last insemination (IFL) and calving interval (CI) have equal weighing factors. The index is calculated as:

$$\text{Fertility index} = 0,52 * (\text{breeding value IFL} - 100) + 0,52 * (\text{breeding value CI} - 100) + 100$$

▪ The Importance of the Use of Predictors

In order to get an impression of the effect or importance of the use of predictors such as body condition score and milk production in the breeding value estimation, a number of selection index calculations have been completed for the situation that a sire receives 100 daughters in production as two-year-olds. This means that for calving interval a sire will receive approximately 80 daughters with a known (or calculated) calving interval, about 90 daughters with IFL and 64 animals with a score for body condition. Parameters are used as explained in Table 2 and 3. The breeding goal is the same as the current breeding goal: the improvement of NR56 and calving interval. The results are found in Table 8.

In the given standard situation, an index based exclusively on the fertility traits NR56 and ICI provides a reliability of the fertility index of 42 percent. Adding IFL as a source of information increases the reliability to 63 percent and when CI is added the reliability increases to 76 percent. Therefore, using IFL and calving interval in the breeding value estimation clearly seems to provide additional information about the breeding goal.

The moment of availability for IFL and CI is later than for other traits. Animals without known IFL and CI, but with NR56 and ICI known, will have an increase in the reliability of the fertility index from 42 to 47 percent by including milk production traits and condition score as predictor traits. When IFL is added too, the reliability will increase to 63 percent. When also CI is added subsequently, the predictor traits and condition score will only have a small effect on the reliability: 76 percent without and 77 percent with predictor traits included.

If a bull has 100 daughters from the test period with milk production and with inseminations known and if he has 64 daughters with a body condition score, he will have a fertility index with a reliability of 77 percent. Of these daughters next calving dates have to be known, so the calving interval and IFL can be calculated.

Table 8. Accuracies of various indexes with a breeding goal formed by NR56 and CI in lactation 1. A bull has 100 daughters in production. The bull has a sire which has information on 1000 daughters for the same traits as the bull.

number of daughters								
100	100	90	80	64	100	100	100	
traits in the index								Reliability Fertility Index
NR56	ICI	IFL	CI	BCS	Milk	Fat	Protein	
X								0.03
	X							0.30
		X						0.49
			X					0.58
				X	X	X	X	0.18
X	X							0.42
X	X	X						0.63
X	X	X	X					0.76
X	X			X	X	X	X	0.47
X	X	X		X	X	X	X	0.66
X	X	X	X	X	X	X	X	0.77

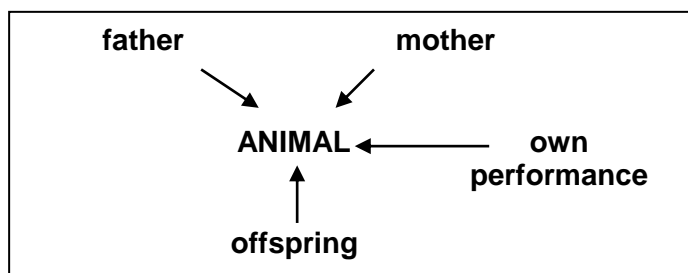
▪ Reliability

Breeding values are estimations of genetic value. The word ‘estimation’ means that there is a certain amount of inaccuracy in a breeding value. The reliability of a breeding value indicates how much difference there might be between the estimated breeding value and the real genetic value.

Reliability depends on the amount of available information for an animal. There are three sources of information:

1. own performance
2. offspring
3. parents

Information on the fertility of (half)sisters, grandparents, etc. is included through the parents; information on granddaughters, etc. is included through the offspring.



Since there are 38 traits and six derived breeding values, there are 44 reliabilities in total. For instance, the breeding value for NR56 in lactation 1 may have a different reliability than the breeding value for NR56 in lactation 3. If a sire still only has first calf daughters, the reliability for traits in lactation 3 will be lower than for those in lactation 1. The breeding value for traits in lactation 3 will then have a smaller deviation from the parent average than the breeding value for lactation 1. This doesn't mean that the breeding value for traits is exactly equal to the parent average. The first calf daughters of the bull are already showing whether the bull is better than its parent average in lactation 1. This also gives us information on the deviation of the parent average in lactation 3, because breeding values of lactation 1 and 3 are correlated (see Table 3).

To give an impression of the reliabilities of the fertility index at different publication moments, there is an outline in Figure 4. In this figure, the reliability of the fertility index is outlined in relation to the

number of publications which a bull has. The first official publication is the moment on which there are at least 15 daughters in production for 120 days. At that moment, the bull has information on NR56 and ICI in lactation 1 for a number of its daughters and for production and body condition score. The figure shows that the reliability of the fertility index at that moment is between 70% and 75%. As the daughters are progressing in their first lactation, the reliability increases until 78% at the most. To further increase the reliability, it is necessary that the daughters enter their second lactation. The reason for this is, that at that moment it is possible to calculate the calving interval and IFL of lactation 1. You also have information on NR56 and ICI in lactation 2. The addition of this information increases reliability to 82%. With the beginning of lactation 3, there is another increase of reliability. Ultimately, the maximum reliability of the fertility index based on test bull daughters is 88%. This reliability is only reached when the test bull daughters are in their 4th lactation, because you are able to calculate the calving interval and IFL of lactation 3 only at that moment.

Second-crop bulls have hundreds to many thousands of daughters. These bulls will eventually reach a reliability of 99%.

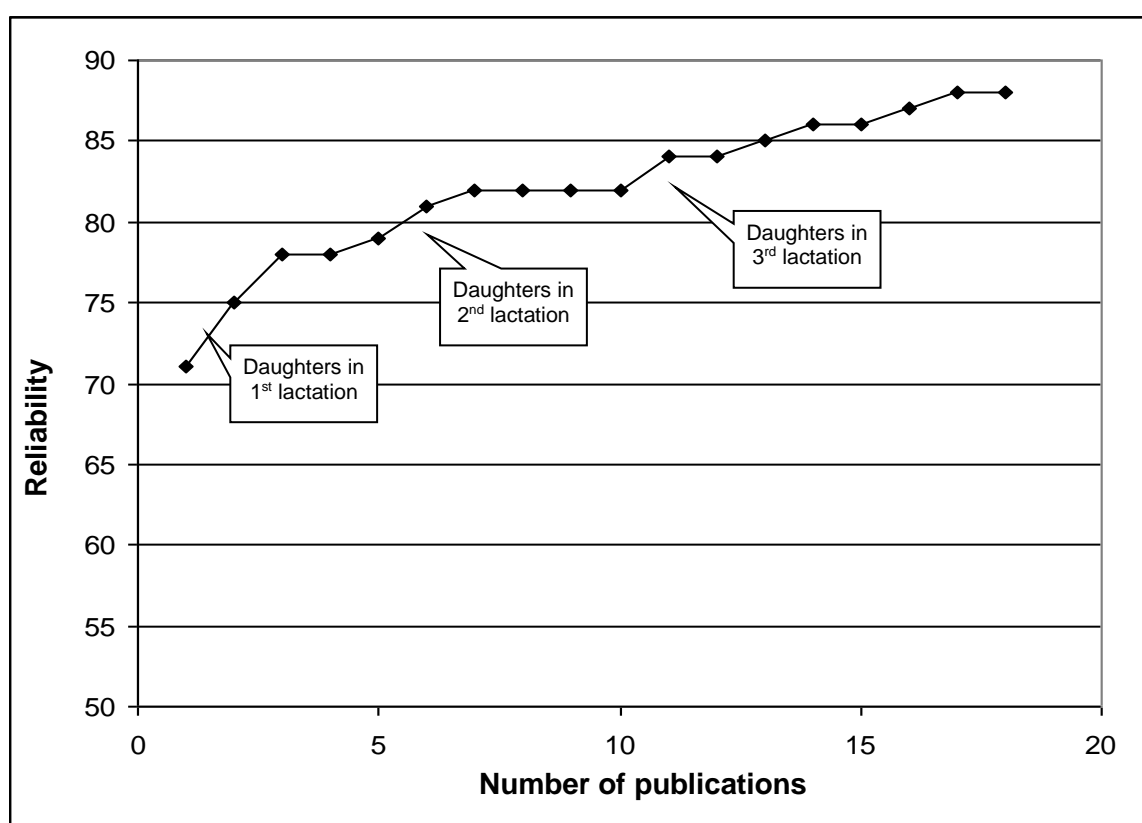


Figure 4. Development of reliability of the fertility index at various publication moments

▪ Base definitions

Breeding values for fertility traits of sires are published on the 2015 base. This base is determined by the cows that were born in 2010. Breeding values for fertility traits are presented on four different bases: Milk goal Black, Milk goal Red, Dual purpose and Belgian Blue.

Milk goal Black (Z)

Herdbook-registered cows born in 2010 with at least 87.5% HF-blood and up to 12.5% FH-blood and hair colour black pied, with at least one observation in the genetic evaluation.

Milk goal Red (R)

Herdbook-registered cows born in 2010 with at least 87.5% HF-blood and up to 12.5% MRY-blood and hair colour red pied, with at least one observation in the genetic evaluation.

Dual purpose (D)

Herdbook-registered cows born in 2010 with at least 75% MRIJ-blood and 25% or less HF blood, with at least one observation in the genetic evaluation.

Belgian Blue (B)

Herdbook-registered cows born in 2010 with at least 87.5% Belgian Blue-blood, with at least one observation in the genetic evaluation.

An observation is defined as at least a score for one of the fertility traits.

Every 5 years, in a year divisible by 5, the reference year for the base is moved 5 years.

The bulls from the Milk goal Black base are used to determine the standard deviation of the breeding values for all bases. The standard deviation of the breeding values from the base animals is calculated followed by standardization of this standard deviation to an average reliability of 80% for the breeding values. Because of this 4 points breeding value corresponds to 0.9 x genetic standard deviation of the concerning trait. Using one standard deviation for the 4 bases has as advantage that only the level differs between the bases and no difference exists between the standard deviations. Table 9 shows the base differences for the fertility traits.

Table 9. Base differences for the fertility traits

Trait	Kind of base ⁽¹⁾	Base differences ⁽²⁾					
		Z=>R	Z=>D	Z=>B	R=>D	R=>B	D=>B
Overall							
FER index(3)	K	-1	-7	-1	-6	0	6
NR56	K	-2	-4	2	-2	4	6
ICI	K	0	-5	-4	-5	-4	1
CI	K	-1	-7	-2	-6	-1	5
IFL	K	-1	-7	0	-6	1	7
CR	K	-1	-3	5	-2	6	8
CR0 (heifers)	K	-1	2	9	3	10	7
AFI (heifers)	K	0	9	36	9	36	27
Lactation 1							
NR56	K	-1	-4	1	-3	2	5
ICI	K	-1	-6	-1	-5	0	5
CI	K	-1	-7	0	-6	1	7
IFL	K	-1	-6	0	-5	1	6
CR	K	-1	-3	5	-2	6	8
Lactation 2							
NR56	K	-2	-3	4	-1	6	7
ICI	K	0	-5	-5	-5	-5	0
CI	K	-1	-7	-3	-6	-2	4
IFL	K	-2	-8	-1	-6	1	7
CR	K	-1	-3	6	-2	7	9
Lactation 3							
NR56	K	-2	-4	3	-2	5	7
ICI	K	0	-5	-7	-5	-7	-2
CI	K	-1	-7	-4	-6	-3	3
IFL	K	-2	-7	-1	-5	1	6
CR	K	-1	-3	4	-2	5	7

(1) C=cow base, S=sire base

(2) Z= Milk goal Black, R= Milk goal Red, D= Dual purpose, B= Belgian Blue

- (3) *For calculation of these traits the underlying traits are calculated on the right base and with these values the overall trait or index is calculated with the index formula. The base differences for overall traits or index are indicative and are applicable to a whole population.*

▪ Publication

Presentation

The breeding values for fertility are presented as relative breeding values with an average of 100 and a standard deviation of 4. The average is determined by a group of animals which forms the base of the breeding value. The standard deviation of all bases is determined by the bulls from the Black&White base (see above at Base definitions).

A breeding value above 100 means that the daughters of the bull have an above average fertility. Note that the scale of the breeding values for interval traits (ICI, IFL, CI) is opposite to the biological scale: a shorter interval will result in a higher breeding value.

The sire passes half of its breeding value on to its daughters. A sire with a breeding value for calving interval of 104 has daughters with a calving interval which is on average 6.7 days shorter. A breeding value of 104 for NR56 means that those daughters have a 2.9% better non-return on 56 days than on average. For the interval calving to first insemination, the daughters from a sire with a breeding value of 104 have a 4.6 days shorter interval than daughters from a sire with a breeding value of 100.

The standard deviation for IFL is 12.4 and CR has a genetic standard deviation of 5.1%. The genetic correlation between these traits is -0.93 . A sire with a breeding value of 104 for IFL will have daughters with a shorter interval first-last insemination of on average 5.6 days and also a higher conception rate of on average 2.3%.

When selecting a sire with a fertility index of 101, the daughters can be expected to have an IFL of 1.4 days shorter and a calving interval which is on average 1.7 days shorter in comparison with daughters from a sire with a fertility index of 100.

Publication Requirements

The Fertility Index (in Dutch the VRU-index) for bulls is published when the reliability is at least 25% and the index contains information of at least one offspring. This means that sires with a first publishable NVI will also have an official breeding value for the fertility index. This first fertility index will contain information about NR56 and ICI, but not yet about IFL and CI. It will take at least half a year before the first information about IFL is included and at least one year before CR and CI data are included. At the moment the first fertility index is published, also breeding values about underlying fertility traits are published (calculated through correlations between relatives and traits).

The publication requirement for Dutch breeding values for import bulls with an Interbull breeding value and daughters with milk yield in The Netherlands, is at least 90% reliability for the fertility index based on Dutch data.

When reliability of the fertility index based on Dutch data is less than 90%, the Interbull breeding values will be published. However, in these breeding values national information can be included. The national breeding value of import bulls is used by Interbull when the breeding value is based on at least 15 daughters on 10 herds for a trait and when there is also information from the country where the bull is tested.

The publication requirement for import bulls without Interbull breeding value is at least 25% reliability for the fertility index and use of information of at least one daughter in the national fertility breeding value estimation. So, for these bulls requirements are identical as for the nationally tested bulls.

For all bulls from countries with Interbull evaluations, breeding values for fertility traits without Interbull conversions are calculated from the parent average for that trait, the genetic correlations with and mendelian sampling of other fertility and production traits.

When this is applied to bulls of different countries, the following situations may occur:

1. Country is not taking part in the international fertility breeding value estimation

Bulls of these countries always have a breeding value that is based on the parent average for NR56, ICI, CI, IFL and CR and the mendelian sampling for milk production traits. Possibly available breeding values from the original country of the bull are not included in the national breeding value estimation.

2. Country is participating in the international breeding value estimation with fertility traits

Bulls from these countries will always have a breeding value that is based on the international breeding value estimation. Breeding values for fertility traits of the original country are included in the national breeding value estimation.

3. Country is participating in the international breeding value estimation with some fertility traits

The breeding value for the missing trait(s) is based on parent average for the missing trait(s) and mendelian sampling for the available fertility and production traits. Therefore, breeding values for fertility traits of the original country are partly used for the national breeding value estimation.

▪ Literature

Haer, L.C.M. de, 2009. Estimation of genetic parameters of fertility traits for dairy cattle in The Netherlands and Flanders. CRV Report.

Haer, L.C.M. de, 2013. Estimation of genetic parameters of fertility traits for virgin heifers and lactating cows in The Netherlands and Flanders. CRV Report, Arnhem, The Netherlands.