Management Guides

E-14
Direct Calving Ease Index
Maternal Calving Process (MCP) Index

▪ Introduction

With respect to AI sires data are collected about the ease of birth of their offspring. The purpose of the birth course registration is to prevent particularly calving problems with heifers by a targeted use of sires whose offspring is born easier. These sires are suitable for use on maiden heifers. In addition, many beef sires are tested on the Calving Ease of their offspring. This is meant to create the possibility to select suitable beef sires for commercial breeding to dairy cattle. Since 1989 indexes for sires have been calculated on the basis of these collected birth data: the Calving Ease index. Since 1997 sires have also received an index for the maternal calving process: the MCP-Index. Research shows that there is a negative correlation between the ease with which a calf is born and the ease with which that same calf gives birth to her offspring later. The MCP-Index shows the calving ease for the daughters of the sires.
Starting in November 2004 the breeding value estimation is a joint evaluation based on data collected in the Netherlands and in Flanders.
In this part the breeding values estimation for Calving Ease and MCP is further explained.

▪ Data collection

‣ CRV

CRV offers bull controllers a service to collect birth process data of a bull's offspring. Until the end of 2006, the possibility existed to collect information through the so-called survey system. However, since the beginning of 2007 birth process data are stored when a farmer reports the birth of a calf through the Voice Response System (VRS) or the Notification System (Dutch: Meldsysteem – MS), which forms a part of 'VeeManager' (CattleManager) from CRV on the website.

Survey system
Shortly before the offspring of the bull is born, the bull controller himself or CRV, on behalf of the bull controller, sends a birth survey to the farmer.
The survey contains questions about calving ease and birth weight. Farmers are asked to complete the survey and return it to the bull controller. The surveys are processed in the CRV-Information System. More information about data collection in the Netherlands can be found in part C-8 of the CRV handbook.

VRS and MS
Reporting the birth of a calf, the farmer indicates the calving ease. The scoring into categories is the same as the classification of the survey system.

Calving Ease
Calving ease is scored in six categories:
1 = easy
2 = normal

3 = hard pull
4 = caesarean
5 = fetonomy
6 = other veterinary aid

Gestation length
The gestation length trait is calculated from the difference between the insemination date and the calving date.

Birth weight of the calf
Survey System
On the survey, the birth weight trait of calves is divided in 12 classes of 5 kg each. The lowest class is for calves of 22 kg and less, the next class is for 23-27 kg, etc. The highest class is for calves of 73 kg or more. The farmer gives therefore a score to the weight class of the calf born. For the breeding value estimation these weight classes are converted into kilograms again.

VRS and MS
The farmer enters the estimated or weighted weight in kilograms.

▸ VRV
VRV collects data about the birth process of their test bulls. Shortly before the offspring of the bull is born VRV sends a birth survey to the farmer.
The survey contains questions about calving ease and birth weight. Farmers are asked to complete the survey and return it to VRV. The surveys are processed by VRV.

Calving Ease
Calving ease is scored in four categories:
1 = no help
2 = slight assistance
3 = hard pull
4 = caesarian of fetonomy

Gestation length
The gestation length trait is calculated from the difference between the insemination date and the calving date.

Birth weight of the calf
Birth weight is estimated or determined by the farmer.

▪ Data

Observation
For the breeding value estimation the number of classes is reduced to 4. This is done by adding score 6 to score 3 and score 5 to score 4. The four classes are similar to the classes used by VRV. As a result, the following division is created:
1 = easy
2 = normal
3 = hard pull and other veterinary aid
4 = caesarian and fetonomy

Observation on calving ease, gestation length and birth weight are used. Calving ease observations are transformed to an underlying normal distribution to account for differences in frequencies. The transformation is stratified through data collection (Survey System, VRS, MS), by region (Flanders and the Netherlands), by parity (first versus higher) and by three-year-period. Definition of the different classes for calving ease is slightly different in Flanders and the Netherlands. The transformation helps to avoid undesirable effects of this difference in definition on breeding values as much as possible.
Characteristics of the transformation: For each stratum (combination of data collection x region x parity x three-year-period) the frequencies are calculated. This frequency is transformed to a number from an underlying normal distribution that matches the frequency. Figure 1 shows an example of this transformation.

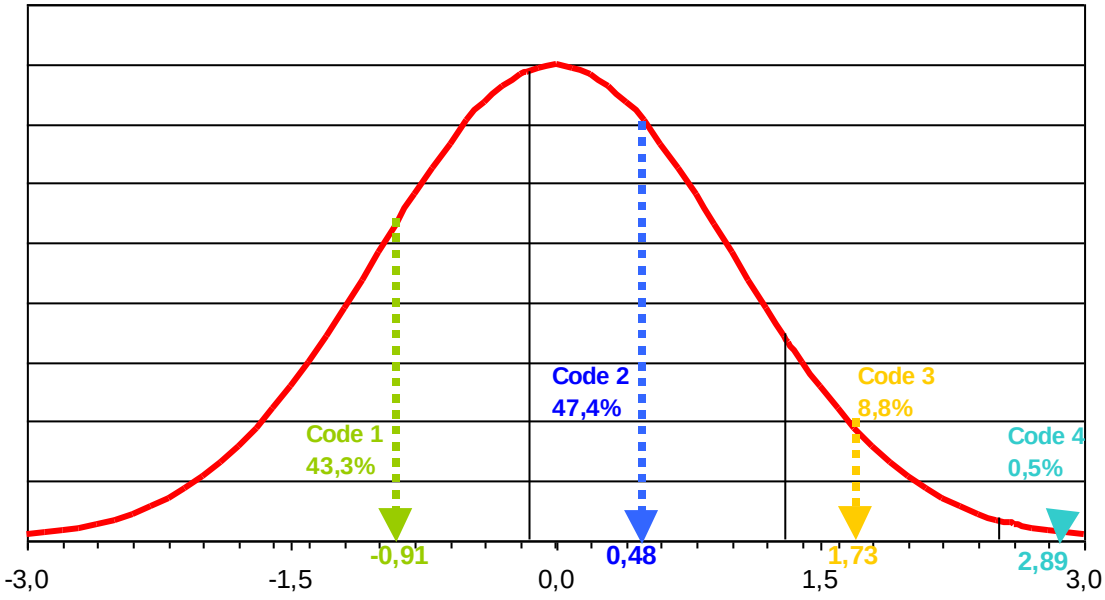

Figure 1. Frequency distribution of calving ease and associated transformation to a normal distribution

In figure 1 class 1 has 43.3% of the observations; class 2 has 47.4% of the observations; class 3 has 8.8% and class 4 has 0.5% of the observations. These percentages are transformed to a normal distribution where class 1 is converted to the number –0.91, class 2 is converted to 0.48, class 3 to 1.73 and class 4 to 2.89. These numbers are the observations that are used in the breeding value estimation instead of the original numbers 1 to 4.

Selection of data for breeding value estimation

The breeding value estimation uses data that meet the following demands:

- the information of a birth recording is complete, i.e. the farm where the calf has been born is known, the sex of the calf is known, the parity number is known, the sire of the calf is known, the calving ease category is known;
- the gestation period is between 260 and 305 days;
- the birth weight of the calf is between 20 and 75 kilograms;
- the calf was not born as part of a multiple birth.
- the dam of the calf has to be herdbook registered;
- if a farm has more than 10 birth notifications per calendar year, the spread of the scores for calving ease within a calendar year should be at least 0.2;

▪ Statistical model

The calculation of the indexes is done with a animal model including a direct and maternal effect, in accordance with the BLUP technique (Best Linear Unbiased Prediction). The following statistical model is used to estimate breeding values for birth traits of bulls:

For heifers:

$$Y1_{ijklmnopqs} = CG_i + YM_j + AGE_k + SEX_l + Hcow_m + Rcow_n + HcalF_o + RcalF_p + COW_q + CALF_r + E_t$$

For cows:

$$Y2_{ijklmnopqrs} = CG_i + YM_j + PAR_k + SEX_l + Hcow_m + Rcow_n + HcalF_o + RcalF_p + COW_q + CALF_r + PERM_s + E_t$$

In which:

$Y1_{ijklmnpqrt}$: Observation during the birth of calf *r* to heifer *q* in management group *i*, born in year x month *j*, with age *k* and sex *l*, where heifer *q* has heterosis *m* and recombination *n*, and where calf *r* has heterosis *o* and recombination *p*;

$Y2_{ijklmnopqrst}$: Observation during the birth of calf *r* to cow *q* in management group *i*, born in year x month *j*, with parity *k* and sex *l* and with permanent environment *s*, where cow *q* has heterosis *m* and recombination *n*, and where calf *r* has heterosis *o* and recombination *p*;

CG_i : Herd or management group *i*;

YM_j : Year x month of birth *j* of the calf;

AGE_k : Age at calving *k* of the calf *p* x 3 year;

PAR_k : Parity *k* of cow *p* x 3 year;

SEX_l : Sex *l* of calf *r* x 3 year;

$Hcow_m$: Heterosis *m* of cow *q*;

$Rcow_n$: Recombination *n* of cow *q*;

$Hcalf_o$: Heterosis *o* off calf *r*;

$Rcalf_p$: Recombination *p* of calf *r*;

COW_q : Additive genetic effect of cow *q* or the maternal effect;

$CALF_r$: Additive genetic effect of calf *r* or the direct effect;

$PERM_s$: Permanent environment effect *s* of cow *q*;

E_t : Residual of Y1 or Y2, which is not explained by the model.

The effects COW_q, $CALF_r$, $PERM_s$ and E_t are random effects, heterosis and recombination are co-variables and the other effects are included in the model as fixed effects.

Effects in the model

The effects in the model are:

1. Herd or management group;
2. Year x month of birth;
3. Age at calving x 3 years for heifers;
4. Parity x 3 years for cows;
5. Sex of the calf x 3 years;
6. Heterosis of the cow;
7. Recombination of the cow;
8. Heterosis of the calf;
9. Recombination of the calf;
10. Additive genetic effect for the cow or the maternal effect;
11. Additive genetic effect for the calf or the direct effect;
12. Permanent environment effect.

Herd or Management Group

Per herd each 10 consecutively sent survey cards form a management group. The observations in this management group are compared with one another. By dividing the observations of a herd in management groups, the possible difference in scoring over time by the farmer is taken care of. Differences may arise as a consequence of a change in the personal definition of calving ease and birth weight of the calf by the farmer, a change of the person completing the survey, a change in the kind of cows or a change of circumstances in the herd. If three years after the return of the first survey the number of 10 has not been reached yet, the group is closed after all.

Month of birth

During the year calving ease, gestation length and birth weight of the calf differs. For heifers at the end of summer there appear to be less difficult births than in the winter and for cows there appear to be less difficult calvings in the summer than in the winter (see Figure 2). For heifers, the biggest difference is found between the months of March and September. Calvings in March produce 4.3 percent more difficult births than calvings in September. The biggest difference for cows is found between the months of February and July. Calvings in February produce 1.7 percent more difficult births than calvings in July.

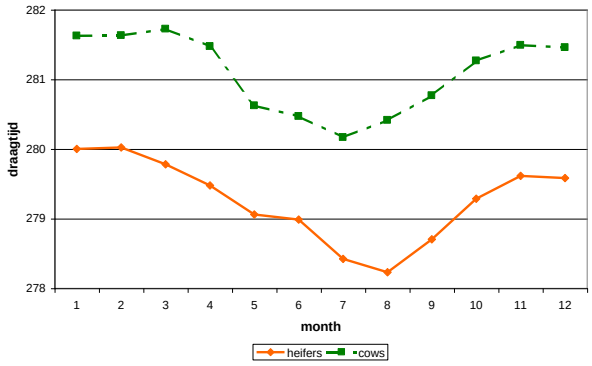

Figure 2. Effect of month on calving ease

Gestation length follows the same pattern as the calving ease trait, with longer gestation length in the winter and spring and shorter gestation length in the summer for both cows and heifers (see Figure 3). Calves born in the autumn to cows have higher birth weights than calves born in the spring (see Figure 4). Calves born to heifers have hardly any difference in birth weight in the different months.

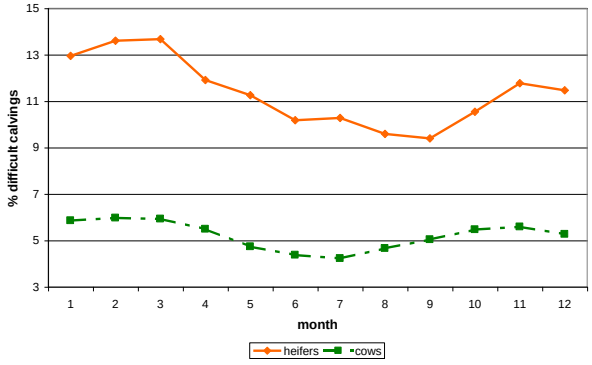

Figure 3. Effect of month on gestation length

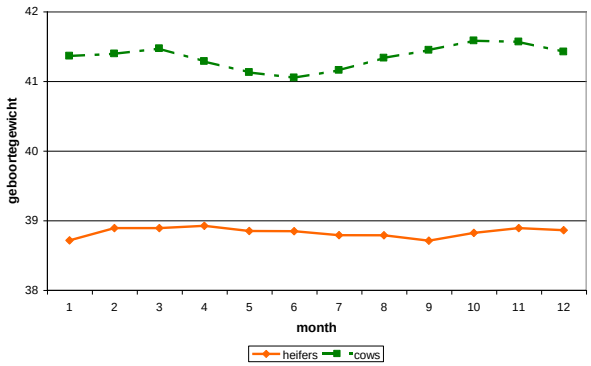

Figure 4. Effect of month on birth weight

The fact that cows have more trouble calving in November is mainly caused by the higher birth weight of the calf. In the spring period the birth weight drops, due to which also the percentage of difficult births goes down. In the January-April period, at the end of the stable season, the percentage of difficult births increases again. This is probably caused by the bad physical condition of the cow, whereas the birth weight remains equal to the period prior to it. During the grazing period the percentage of difficult births drops and the birth weight remains the same. The cows are then in a better physical condition, which eases the birth process. To take account of changes over time, the month effect is included in the model as year x month.

Correction for the month in which the calves are born is important for test bulls because most of the inseminations are done within two months. Should this correction not be applied, then the results of a sire could easily be affected by the period in which his calves are born.

Calving age x 3 years
In analysing the birth traits, age at calving is taken into account for heifers. Age has an effect on calving ease, gestation length and birth weight. Heifers that calve young, when they are 21 months old, have less difficult births than heifers who are older when they calve, over the age of 32 months (see Figure 5). Young heifers have 2.6 percent less difficult births than old heifers.

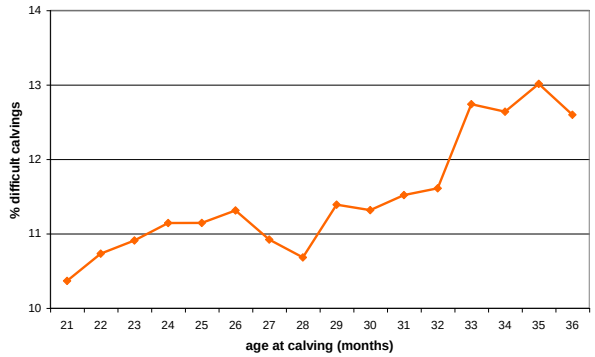

Figure 5. Effect of calving age on calving ease

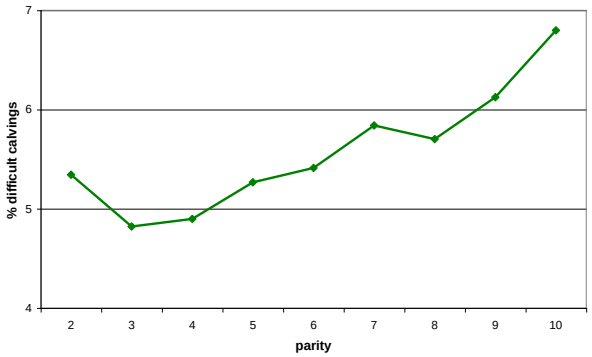

Figure 6. Effect of parity on calving ease

18 age classes are differentiated, with class 1 correcting for calving age of 20 months or younger. Class 2 to 17 corrects for calving age of 21 to 36 months. Class 18 contains all heifers that are 37 months or older at calving. The age classes are divided into 3-year periods. Working back from the earliest calving date in the breeding value estimation, 3-year periods are formed. If the last period is shorter than 2 years, it is combined with the next period. The division into 3-year periods has been carried out in order to take account of changes in the way in which farmers report births over time.

Parity x 3 years for cows
In analysing the birth traits, parity at calving is taken into account for cows. Parity has an effect on calving ease, gestation length and birth weight (see Figure 6). Third and fourth parity cows have the least difficult births; after that the percentage of difficult births increases again. The biggest difference is between fourth and tenth parity cows, and that difference is 2.0 percent.

9 parity classes are distinguished. Class 1 to 8 corrects for parity 2 to 9. Class 9 contains all cows with a parity of 10 or higher. The parity classes are divided into 3-year periods. Working back from the earliest calving date in the breeding value estimation, 3-year periods are formed. If the last

period is shorter than 2 years, it is combined with the next period. The division into 3-year periods has been carried out in order to take account of changes in the way in which farmers report births over time.

Sex of the calf x 3 years
In analysing the birth traits, account is taken of the sex of the calf. Bull calves have considerably more difficult births and are heavier than heifer calves (see Figure 7). In heifers, 15.6% of bull calves have difficult births, compared with 6.9% difficult births for heifer calves. In cows, 7.3% of bull calves have difficult births, compared with 2.9% difficult births for heifer calves.

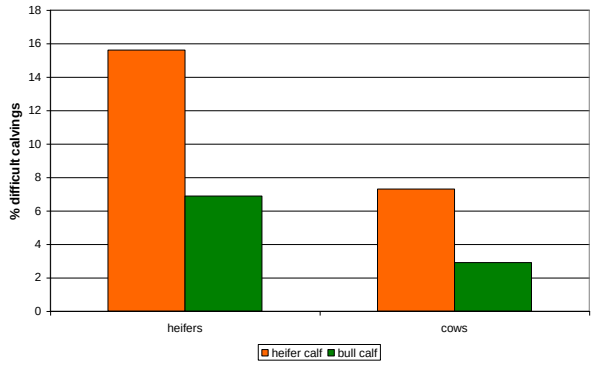

Figure 7. Effect of sex of calf on calving ease

The sex classes are divided into 3-year periods. Working back from the earliest calving date in the breeding values estimation, 3-year periods are formed. If the last period is shorter than 2 years, it is combined with the next period. The division into 3-year periods has been carried out in order to take account of changes in the way in which farmers report births over time.

Heterosis and recombination of cow and calf
Heterosis and recombination effects play a role in the combining of breeds. These are genetic effects that are not transmitted to the offspring. Research has shown that a correction must be made to these effects.
The amount of the heterosis is defined as the difference in level or the trait in the crossing with the average of the parent breeds. Recombination is the loss of the usually positive effect of heterosis and occurs when the earlier achieved crossing product is crossed back with one of the parent breeds.

Additive genetic effect for the cow or maternal effect
The additive genetic effect of the cow is the maternal breeding value, the effect that matters in the end. The variable cow contains the (genetic) contribution of a cow to the observation and determines the maternal breeding value of an animal. All of the information concerning ancestors and progeny is also used in determining the breeding value. The heritabilities used are shown in Table 1.

Additive genetic effect for the calf or direct effect
The additive genetic effect of the calf is the direct breeding value, the effect that matters in the end. The variable calf contains the (genetic) contribution of a calf to the observation and determines the direct breeding value of an animal. All of the information concerning ancestors and progeny is also used in determining the breeding value. The heritabilities used are shown in Table 1.

Permanent environment effect
A cow can calve several times in her life. The observations within a cow have more in common than genetics. This additional agreement is called permanent environment effect, an effect of the constant conditions in which a cow is kept. By using a permanent environment effect in the model, several observations on an animal can be used in order to obtain a better estimate of breeding value. The heritabilities used are shown in Table 1.

▪ Parameters

A total of 6 traits are analysed in the breeding values estimation: 3 for heifers and 3 for cows. These are the three traits of calving ease, gestation length and birth weight. These traits are analysed as separate correlated traits for heifers and cows. Because both cow and calf are involved in the birth, an additive genetic effect is estimated for both animals. As a result, two breeding values are obtained for each trait: the direct effect for the calf and the maternal effect for the cow. In the end, breeding values are estimated for 12 traits. Table 1 shows the heritability, repeatability and genetic standard deviation. Heritability is a measure of the fraction that is explained by genetics. Repeatability indicates the part of the observation on an animal that corresponds with a subsequent observation on the same animal. Table 2 shows the genetic correlations.

Table 1. Heritability (h^2), repeatability and genetic standard deviation for the birth traits (1 = heifers, 2+ = cows)

trait	h^2	repeatability	genetic standard deviation	unit
maternal calving ease 1	0.048		0.170	
maternal gestation length 1	0.062		1.223	days
maternal birth weight 1	0.035		0.625	kg
maternal calving ease 2+	0.034	0.078	0.132	
maternal gestation length 2+	0.048	0.093	1.101	days
maternal birth weight 2+	0.036	0.094	0.698	kg
direct calving ease 1	0.068		0.203	
direct gestation length 1	0.391		3.066	days
direct birth weight 1	0.095		1.027	kg
direct calving ease 2+	0.052	0.096	0.164	
direct gestation length 2+	0.405	0.451	3.208	days
direct birth weight 2+	0.115	0.173	1.244	kg

Table 2. Genetic correlations calving traits on the biologic scale (1=heifers, 2+ =cows)

	maternal calving ease 1	maternal gestation length 1	maternal birth weight 1	maternal calving ease 2+	maternal gestation length 2+	maternal birth weight 2+	direct calving ease 1	direct gestation length 1	direct birth weight 1	direct calving ease 2+	direct gestation length 2+	direct birth weight 2+
maternal calving ease 1												
maternal gestation length 1	0.194											
maternal birth weight 1	0.238	0.369										
maternal calving ease 2+	0.713	0.187	0.608									
maternal gestation length 2+	0.609	0.741	0.272	0.456								
maternal birth weight 2+	0.216	0.366	0.803	0.651	0.372							
direct calving ease 1	0.194	0.014	-0.011	-0.276	-0.082	-0.223						
direct gestation length 1	0.327	0.075	0.139	0.052	0.255	0.066	0.272					
direct birth weight 1	0.216	0.088	0.092	-0.222	-0.030	-0.148	0.942	0.371				
direct calving ease 2+	0.186	0.226	0.013	-0.314	0.128	-0.123	0.918	0.404	0.932			
direct gestation length 2+	0.084	0.075	0.134	-0.138	0.123	0.046	0.295	0.908	0.397	0.439		
direct birth weight 2+	0.284	0.180	0.137	-0.117	0.055	-0.100	0.900	0.402	0.941	0.905	0.408	

▪ Publication

Sire breeding values for Calving Ease and MCP (and also for Gestation Length and Birth Weight) are presented as relative breeding values with an average of 100 and a standard deviation of 4. Breeding values based on heifer calvings are published, because most problems occur around calvings of heifers. The effect on the offspring of a 104 breeding value of a bull mated to an average cow is shown in table 3. The transmitting ability is calculated as half the breeding value and indicates the effect on the offspring.

Table 3. Effect of relative breeding values for calving ease, gestation length and birth weight at first and higher parities (1 = heifers, 2+ = cows)

trait	Relative breeding value	Transmitting ability (effect on offspring)	unit
maternal calving ease 1	104	-1.7	%
maternal gestation length 1	104	0.55	days
maternal birth weight 1	104	0.28	kg
maternal calving ease 2+	104	-0.7	%
maternal gestation length 2+	104	0.49	days
maternal birth weight 2+	104	0.31	kg
direct calving ease 1	104	-1.8	%
direct gestation length 1	104	1.37	days
direct birth weight 1	104	0.46	kg
direct calving ease 2+	104	-0.9	%
direct gestation length 2+	104	1.43	days
direct birth weight 2+	104	0.56	kg

There is a difference between the effect at birth for heifers and for higher parities. The unit of half breeding value for the trait of calving ease and MCP is percentage: for gestation length it is day, and for birth weight, kilogram. A breeding value for calving ease and MCP over 100 means greater ease, so fewer problems. A breeding value for calving ease of 104 means that around 1.8% less difficult births will occur in heifers and the combination of the same bull with the older cows will produce around 0.9% less difficult births. For gestation length as a direct effect, a breeding value of 104 means a gestation length 1.37 days longer for heifers and 1.43 days longer for cows. For birth weight as a direct effect, a breeding value of 104 means that a calf born to a heifer is 0.46 kg heavier, and 0.56 kg heavier for a calf born to a cow. For breeding values under 100, the opposite applies: namely more difficult births, shorter gestation length and lower birth weight.

The breeding value of calving ease in bulls is published for AI bulls if the reliability of the breeding value is at least 30%. MCP is published for AI bulls if the reliability of the breeding value is at least 30%. For tested AI bulls, the breeding value must be based on at least one offspring. For untested AI bulls, there is a minimum requirement of 10 offspring. See chapter E-26 for further information on publication rules.

▪ Calving-index

The two breeding values for direct calving ease and maternal calving ease are used to compute the calving index. The calving index is:

Calving index = 0.08 x (breeding value direct calving ease –100)
+ 0.08 x (breeding value maternal calving ease –100)
+ 0.55 x (breeding value direct vitality –100)
+ 0.83 x (breeding value maternal vitality –100)
+ 100

▪ Base

Breeding values for calving ease traits are presented on three different bases: a Black&White base, a Red&White base and a Local base.

Black&White base (Z)
Pedigree cows born in 2005 with at least 87.5% HF blood and 12.5% or less FH blood, with black&white colour and with at least one observation in the breeding values estimation.

Red&White base (R)
Pedigree cows born in 2005 with at least 87.5% HF blood and up to 12.5% MRIJ blood, with red&white colour and with at least one observation in the breeding values estimation.

Local base (Y)
Pedigree cows born in 2005 with at least 87.5% MRIJ blood and 12.5% or less HF blood, with at least one observation in the breeding values estimation.

An observation is a calf's birth notification.

The distribution of breeding values is determined by the Black&White base animals. The distribution in breeding values is calculated and standardised to a reliability of 80 percent. This means that 4 points of distribution is equivalent to 0.9 x genetic distribution. The advantage of a single distribution for all bases is that there is only a difference in level between the bases, and no difference in distribution.

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

The base differences are shown in Table 4.

Table 4. Base differences for calving ease traits (1 = heifers, 2+ = cows)

	Z → R	*Z → Y*	*R → Y*
maternal calving ease 1	0	0	0
maternal gestation length 1	-2	-1	1
maternal birth weight 1	1	1	0
maternal calving ease 2+	0	-1	-1
maternal gestation length 2+	-1	0	1
maternal birth weight 2+	1	1	0
direct calving ease 1	1	-2	-3
direct gestation length 1	-2	2	4
direct birth weight 1	-1	2	3
direct calving ease 2+	1	0	-1
direct gestation length 2+	-1	1	2
direct birth weight 2+	-1	0	1

▪ Breed differences and genetic trends

‣ Breed differences

The average breeding values of the birth traits for a number of breeds are shown in Table 5. Bulls were used that had at least 70% reliability for the breeding value in question, and only breeds with more than 10 bulls per breeding value are included in the table. In addition, the breeding values are presented on the Black&White base.

Table 5. Average breeding value for birth traits for various breeds. The breed averages are based on bulls born after 1985 with at least 70% reliability per breeding value. Breeds with at least 10 bulls are included in the table. Breeding values are on the Black&White base.

Breed	maternal calving ease 1	maternal gestation length 1	maternal birth weight 1	maternal calving ease 2+	maternal gestation length 2+	maternal birth weight 2+	direct calving ease 1	direct gestation length 1	direct birth weight 1	d direct calving ease 2+	direct gestation length 2+	direct birth weight 2+
BA							86.8	125.3	117.2	81.1	124.9	122.5
BBL	65.7	92.1	113.7	47.5	91.1	103.1	71.5	103.2	126.2	76.7	104.1	124.5
BS				112.9	102.1	88.7	101.0	111.0	102.2	96.9	112.4	105.9
BWR	98.7	95.8	106	98.4	93.3	100.2	92.3	104.9	112.9	93.1	105.9	114.3
FH				89.7	100.5		103.8	98.9	96.1	103.1	98.3	96.3
FLV		90.1					94.2	110.4	112.0	90.2	112.3	113.9
G				105.7	92.6	90.8	105.0	95.5	93.0	103.3	97.7	96.0
HF	99.5	99.9	100.3	99.6	100.6	99.7	100.2	100.9	99.9	99.3	101.3	100.8
RHF	99.2	101.6	98.9	99.5	101.3	99.2	99.7	101.8	100.6	98.4	102.3	101.7
JER					96.3		121.7	105.6	64.8	115.0	105.1	64.6
MON	111.8	94.2		112.5	89.1	85.7	93.5	111.0	110.6	90.1	110.9	113.5
MRIJ	100.2	99.6	99.4	99.7	99.8	99.8	100.5	100.0	99.5	99.9	100.6	100.2
PIM							90.1	123.4	112.6	86.6	120.6	114.2

BA – Blonde d'Aquitaine; BBL – Belgian Blue; BWR – East Flemish White-Red; FH – Fries Hollands; FLV – Fleckvieh; G – Blaarkop; HF – Holstein Friesian; RHF – Red Holstein Friesian; JER – Jersey; MON – Montbéliarde; MRIJ – Maas Rijn IJssel; PIM – Piemontese.

For the maternal effects, not all breeds have sufficient bulls for all breeding values to determine a breed average. Both breeds are therefore around the average. For the direct effects, all breeds have a breed average for all breeding values. For calving ease, Belgian Blue is the breed with the lowest average breeding value, followed by Blonde d'Aquitaine, Piemontese, Montbéliarde and Fleckvieh. These breeds score clearly below average. The direct gestation length in the breeds Piemontese and Blonde d'Aquitaine is markedly longer than average. And for direct birth weight, Belgian Blue has the highest breed average and Jersey the lowest breed average.

Genetic trends

Figures 8 to 13 show the genetic trends for Holstein bulls born after 1985 with at least 70% reliability.

For MCP, there is a slight positive trend for the breeding value based on heifer data. For calving ease, the average breeding value from birth year 2000 is around 2 points higher for both breeding values. The average breeding value for maternal gestation length is fairly constant, with an increase from birth year 2000 for the breeding value based on heifer data. Maternal gestation length shows a decline of 5 breeding value points. Maternal birth weight is constant over time. Direct birth weight shows a decline after birth year 2000 and has been fairly constant since 2004.

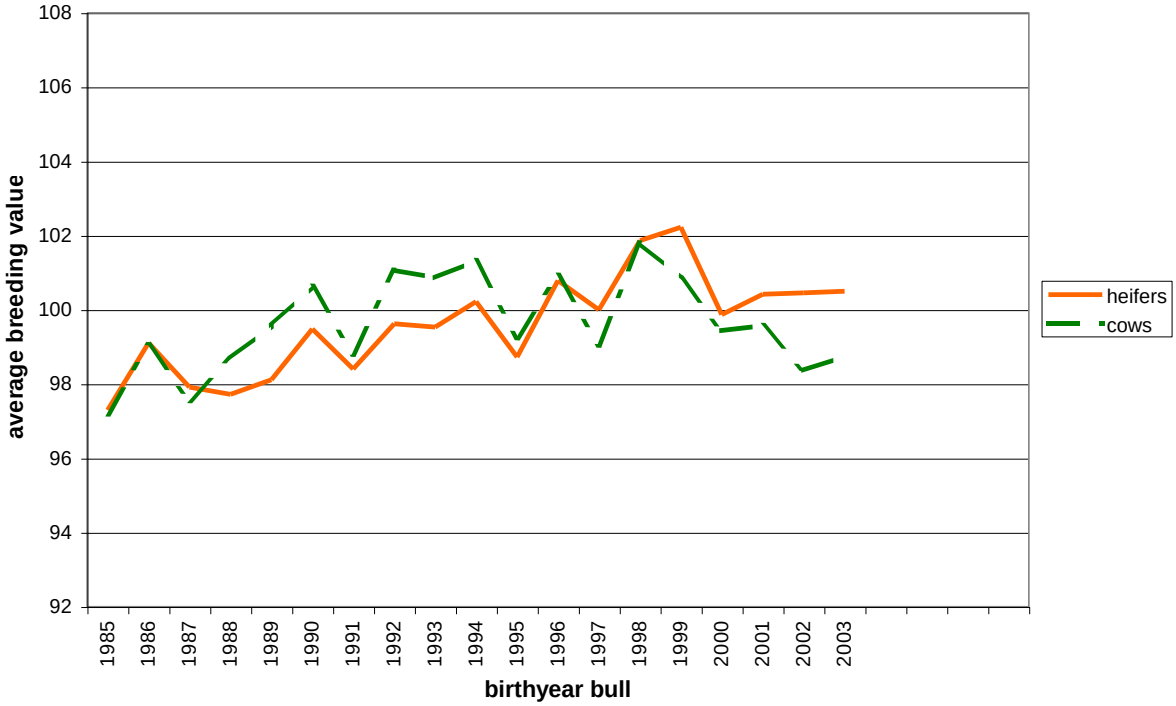

Figure 8. Average breeding value for MCP (calving ease maternal) based on heifer and cow data for Holstein bulls born after 1985.

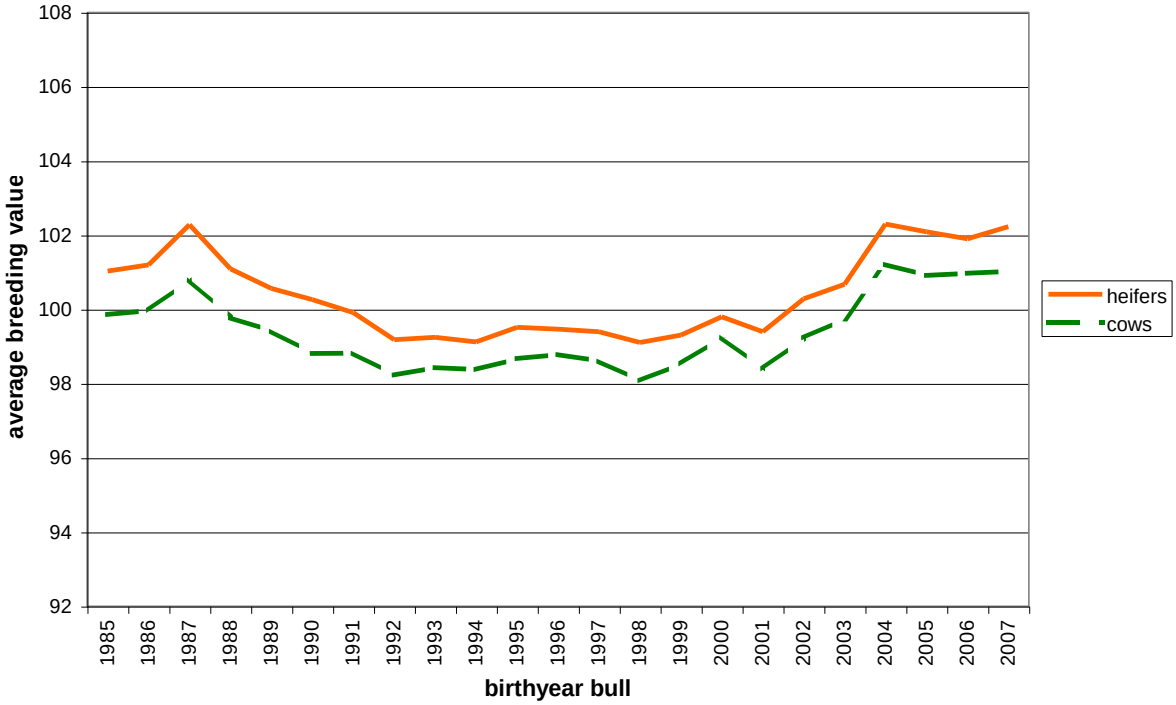

Figure 9. Average breeding value for direct calving ease based on heifer and cow data for Holstein bulls born after 1985.

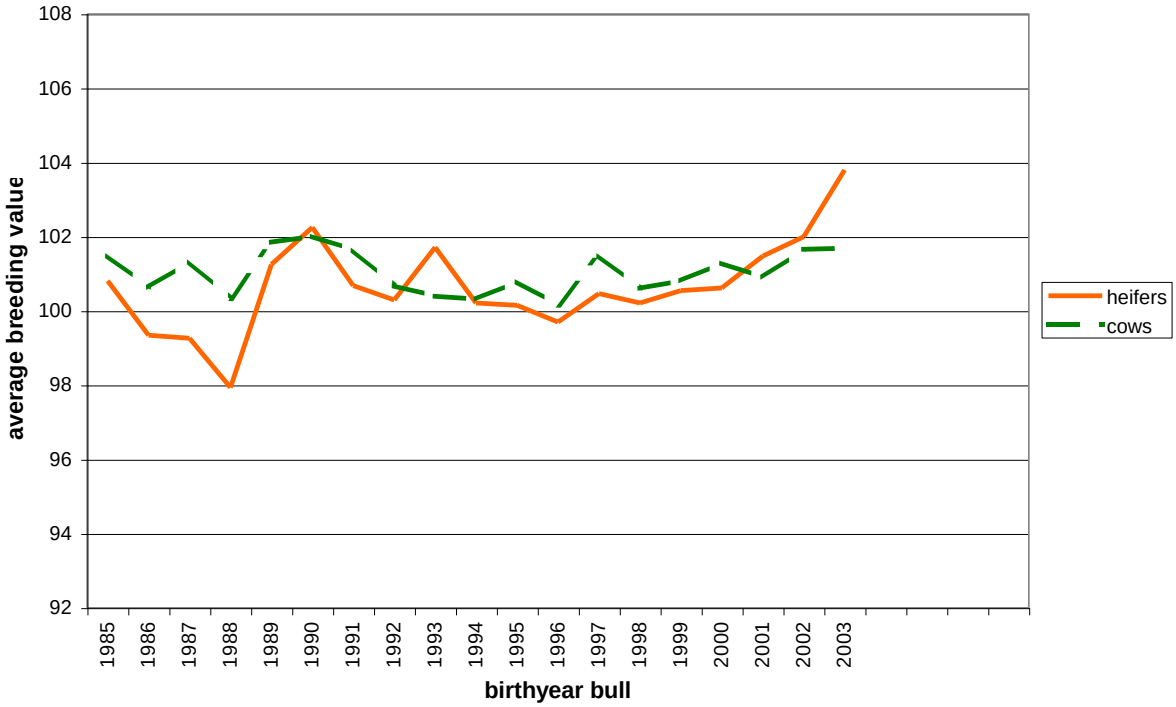

Figure 10. Average breeding value for maternal effect for gestation length based on heifer and cow data for Holstein bulls born after 1985.

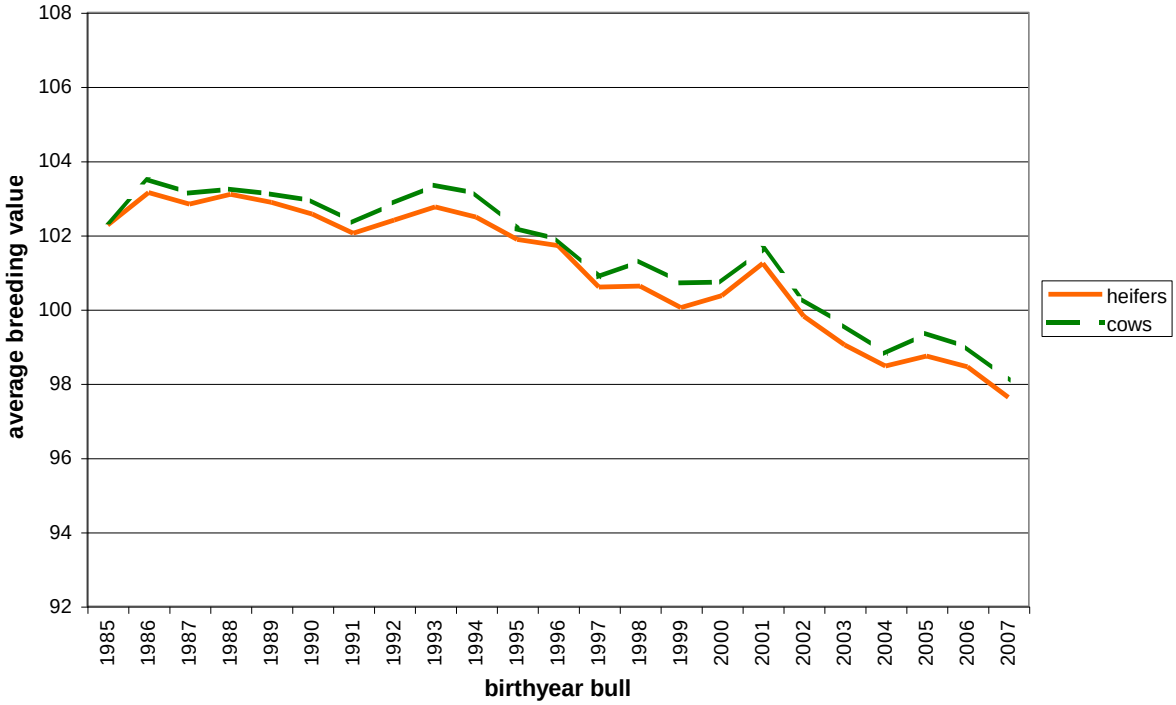

Figure 11. Average breeding value for direct effect for gestation length based on heifer and cow data for Holstein bulls born after 1985.

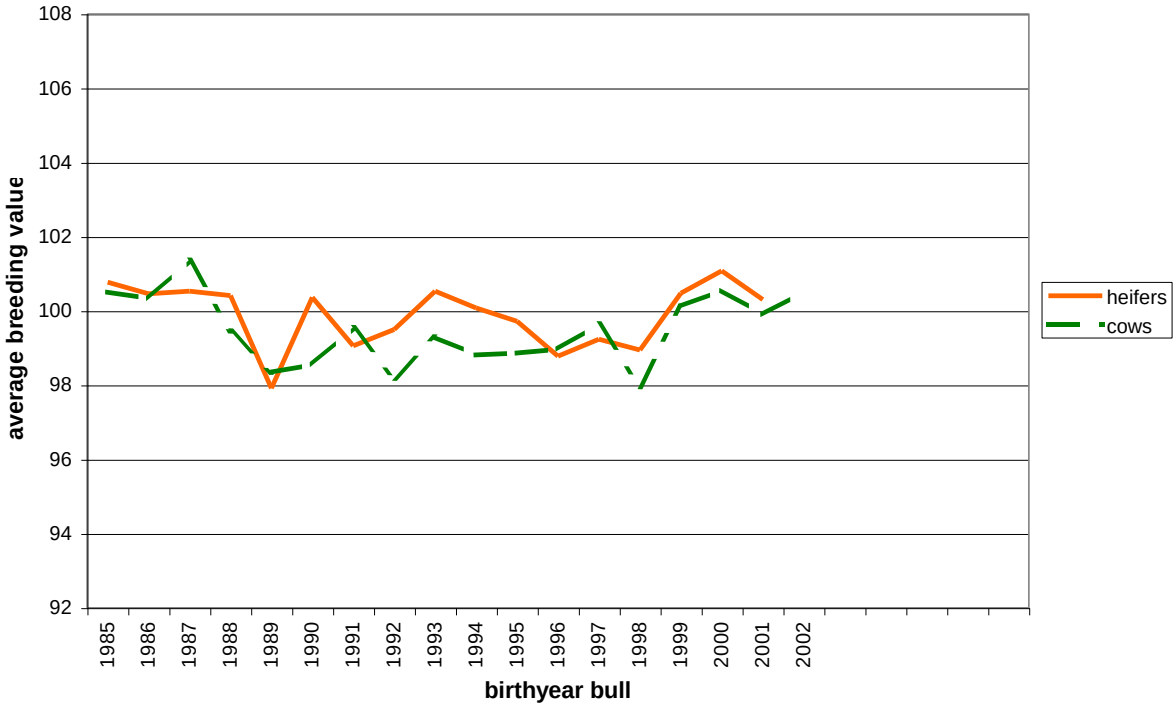

Figure 12. Average breeding value for maternal effect for birth weight based on heifer and cow data for Holstein bulls born after 1985.

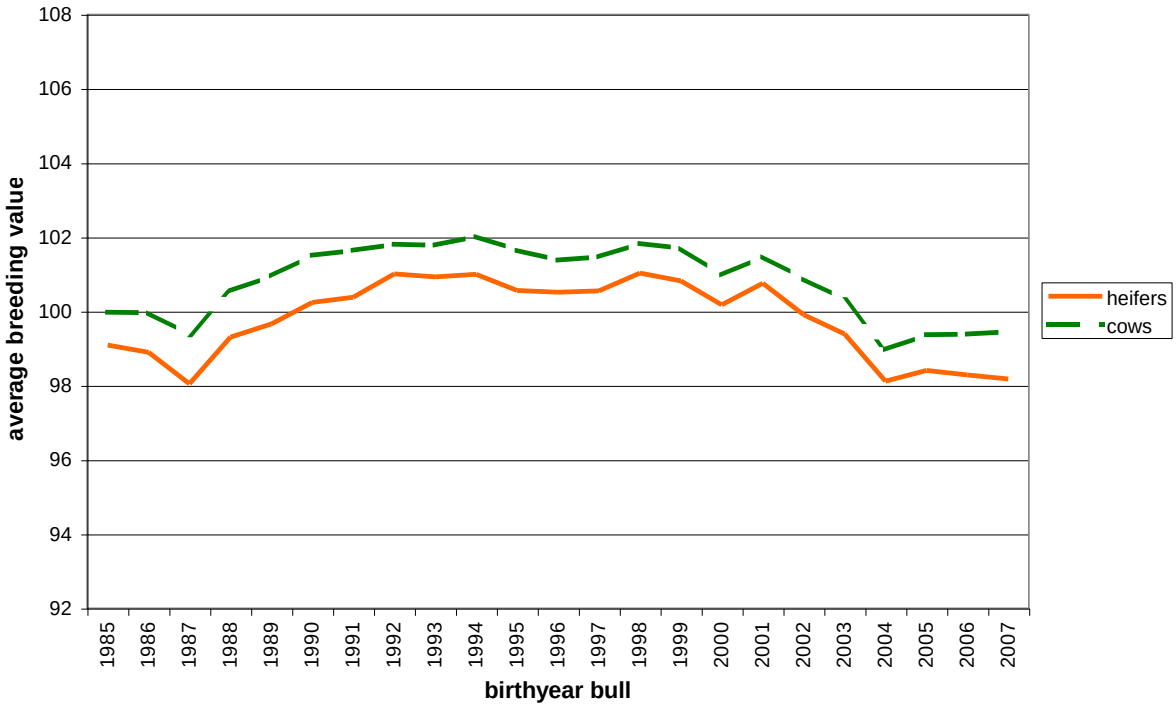

Figure 13. Average breeding value for direct effect for birth weight based on heifer and cow data for Holstein bulls born after 1985.