Statistical indicators
E-35
Breeding value of AMS traits

▪ Introduction

In the Netherlands and Flanders, the number of cows milked by Automatic Milking Systems (AMS) is increasing. Of all milking parlours that are currently modernised, about half switch to Automatic Milking Systems. The AMS measures and records a lot of data about the milking and the animal to be milked. Part of these data is received every week by CRV and is suitable for creating a breeding value estimation for AMS traits.

It is important to dairy farmers that the AMS is used as efficiently as possible, i.e. that the amount of milk milked per AMS is as large as possible. It is important that the cows are suitable for the system. Cows need to be active and visit the robot frequently, an AMS visit ideally resulting in a successful milking. A high milking speed leads to an increased AMS capacity, resulting in an increased AMS efficiency. But too high a milking speed may lead to a decrease in udder health (Gäde et al., 2007). An optimal milking speed is preferable, in combination with a good udder health.

For heifers, it is important that they get used to the milking system within a short time period after calving. Fetching heifers to the AMS is labour-intensive and time-consuming work. Selecting animals that are suitable for an AMS requires breeding values for bulls based on AMS data. Traits such as AMS efficiency, milking interval and habituation of heifers are potential selection traits to increase the capacity and efficiency of the system.

▪ Trait and breeding goal

For the breeding value estimation of AMS traits, breeding values for the traits AMS efficiency, milking interval and habituation of heifers are estimated, which are defined as follows:

- AMS efficiency: The milk production in kg of milk produced in the total box time, expressed in kg of milk per minute. The total box time is the time the cow enters the milking system until the time the cow leaves the milking system. AMS efficiency indicates how many kg of milk can be produced per minute.
- Milking interval: The time between two consecutive successful milkings.
- Habituation of heifers: The rate at which heifers get used to the AMS. This is determined by comparing the average milking interval in the period immediately after calving (weeks 1 – 3) to the average milking interval in the period later in the lactation (weeks 10 – 12).

AMS efficiency and milking interval are subdivided into parity 1 and parity 2 and higher.

The breeding goal is a more efficient use of the AMS, which means a highest possible AMS efficiency, paying attention to udder health. A short milking interval, leading to frequent AMS visits and heifers that quickly get used to the AMS.

▪ Data

Observations
All available data from automatic milking systems are incorporated in the breeding value estimation for AMS traits.

Data selection
The data need to meet the following requirements to be incorporated in the breeding value estimation:

- An animal must to be female and herdbook registered (S) and the cow's sire needs to be known;
- The age at calving must be at least 610 days;
- Observations must be from an AMS herd*, being designated as AMS the day before the measurement as well;
- Milk yield of the milking must be known, with a minimum milk yield of 1.6 kg and a maximum of 40 kg per milking;
- A cow must have known staying place on the day of the milking.

*A herd is selected as AMS herd if the MPR (milk production registration) shows that the cows on this herd are milked by an AMS.

The following additional requirements specifically apply to AMS efficiency:

- Only observations between 5 and 350 lactation days are used;
- The start and end time of the milking must be known;
- Total box time must be between 1 and 20 minutes;
- The AMS efficiency needs to be at least 0.5 kg / minute and at most 5.0 kg / minute;
- A cow must have at least one observations in the first lactation;
- Milking interval is at least 2 hours.

The following additional requirements specifically apply to milking interval:

- Only observations between 5 and 350 lactation days are used;
- A herd must have at least 30 valid AMS days before the data is used (data from day 1 up to and including day 29 may be considered a start-up period for the herd, when the animals have not attained the final milking interval yet);
- The milking must be identified as valid by the AMS;
- Milking interval is between 4 and 20 hours.
- A cow must have at least one observations in the first lactation.

The following additional requirements specifically apply to habituation of heifers:

- The milking must be identified as valid;
- Milking interval is between 4 and 20 hours;
- Animals must have observations in both time periods, in week 1 – 3 and week 10 – 12.

For the traits AMS efficiency and milking interval, the size of the available data is huge, because each milking of each animal is incorporated in the data. In addition, the number of available observations is rapidly increasing. In order to prevent an overflow of data, for these two traits, week averages are used for determining the breeding values. First of all, all available information of each animal is processed. When all milkings of the animal have been processed, the week averages are used to determine the breeding value for the traits AMS efficiency and milking interval, if there are at least 5 observations in that week.

▪ Statistical model

The breeding values described were estimated by using an animal model, according to the BLUP technique (Best Linear Unbiased Prediction). The traits are estimated according to a single trait model, the traits described being treated as individual traits. Different statistical models are used for the different traits:

AMS efficiency – heifers

$Y1_{ijklpqrst}$ = BJM_i + JPDIMj + $LFTD\_K_k$ + JMKl + HET_p + REC_q + INB_r + A_s + $PERM_t$ + $Err1_{ijklpqrst}$

Milking interval – heifers

$Y2_{ijklmpqrst}$ = BJM_i + JPDIMj + $LFTD\_K_k$ + JMKl + JT_m + HET_p + REC_q + INB_r + A_s + $PERM_t$ + $Err2_{ijklmpqrst}$

Habituation of heifers

$Y3_{nklopqrs}$ = BJ_n + $LFTD\_K_k$ + JMKl + MY_o + HET_p + REC_q + INB_r + A_s + $Err3_{nklopqrs}$

AMS efficiency – cows

$Y4_{ijlpqrstu}$ = BJM_i + JPDIMj + JMKl + HET_p + REC_q + INB_r + A_s + $PERM_t$ + $PERMB_u$ + $Err4_{ijlpqrstu}$

Milking interval – cows

$Y5_{ijlmnpqrstu}$ = BJM_i + JPDIMj + JMKl + JT_m + BLJ_n + HET_p + REC_q + INB_r + A_s + $PERM_t$ + $PERMB_u$ + $Err5_{ijlmnpqrstu}$

with:

$Y1_{ijklpqrst}$: Observations for AMS efficiency of heifer s, with farm x year x month of milking i, parity x days in milk upon milking j, age of calving k, month of calving l, with a heterosis effect, recombination effect q and inbreeding coefficient r;

$Y2_{ijklmpqrst}$: Observations for milking interval of heifer s, with farm x year x month of milking i, parity x days in milk upon milking j, age of calving k, month of calving l, with year x time of the milking m; with a heterosis effect p, recombination effect q and inbreeding coefficient r;

$Y3_{nklopqrs}$: Observation for habituation of heifers of heifer s, with farm x year of measurement n, age of calving k, month of calving l, difference in milk yield between the two periods o, with a heterosis effect p, recombination effect q and inbreeding coefficient r;

$Y4_{ijlpqrstu}$: Observation for AMS efficiency or milking interval of cow s, with farm x year x month of milking i, parity x days in milk upon milking j, month of calving l, with a heterosis effect p, recombination effect q and inbreeding coefficient r, permanent environmental effect over lactations *t* and permanent environmental effect within lactations *u*;

$Y5_{ijlmnpqrstu}$: Observation for AMS efficiency or milking interval of cow s, with farm x year x month of milking i, parity x days in milk upon milking j, month of calving l, with year x time of the milking m; with farm x lactation x year of the milking n; with a heterosis effect p, recombination effect q and inbreeding coefficient r, permanent environmental effect over lactations *t* and permanent environmental effect within lactations *u*;

BJMi : Farm – year – month of the milking *i*;

BJ_n : Farm – year of the milking *n*;

JPDIMj : Year - Parity times days in milk at the moment of the milking *j*;

$LFTD\_K_k$: Age of calving of heifers *k* (parity 1) * 3 year;

JMKl : Year - Month of calving *l* * 3 year;

JT_m : Year – time of the milking *m*;

BLJ_n : Farm – lactation – year of the milking *n*;

MY_o : Difference in milk yield weeks 1 – 3 compared to weeks 10 – 12 *o*;

HETp : Heterosis class *p*;

RECq : Recombination class *q*;

INBr : Inbreeding coefficient *r*;

A_s : Additive genetic effect (or breeding value) of animal *s*;

$PERM_t$: Permanent environmental effect over lactations *t* of animal *s*;

PERMBu : Permanent environmental effect within lactations *u* of animal *s*;

$Err1_{ijklpqrst}$: Residual term of $Y1_{ijklpqrst}$ which is not explained by the model;

$Err2_{ijklmpqrst}$: Residual term of $Y2_{ijklpqrst}$ which is not explained by the model;

$Err3_{nklopqrs}$: Residual term of $Y3_{nklopqrs}$ which is not explained by the model;
$Err4_{ijlpqrstu}$: Residual term of $Y4_{ijklpqrstu}$ which is not explained by the model;
$Err5_{ijlmnpqrstu}$: Residual term of $Y5_{ijklmnpqrstu}$ which is not explained by the model;

The effects A, PERM, PERMB and Err are random effects, HET and REC are covariates, and the other effects are fixed effects.

The effects in the model
The effects in the model are:
1. Farm x year x month of milking, for habituation of heifers: Farm x year of milking
2. Year x Parity x days in lactation
3. Age of calving, for parity 1 only * 3 year
4. Year x Month of calving * 3 year
5. Year x time of the milking
6. Farm x lactation x year of the milking
7. Difference in milk yield, the difference between the average milk yield in weeks 1 – 3 and weeks 10 – 12
8. Heterosis
9. Recombination
10. Inbreeding coefficient
11. Cow
12. Permanent environment over lactations
13. Permanent environment within lactations

Herd x year x month of the milking
There are large differences between herds in AMS efficiency, milking interval and habituation of heifers. Also, the level of the AMS traits of a herd may change over time. There are many measurements for efficiency and milking interval in a herd. Herd effects are estimated per year, per month. For habituation of heifers, there is one observation per animal, making the number of observations many times lower. Therefore the herd effect is estimated per year. This means that eventually all animals are compared that have a measurement in the same month (year) in the same herd.

Year x Parity x Lactation stage
In the analysis of AMS efficiency and milking interval, the parity of the animal is taken into account, as well as the lactation stage (number of days that the cow is in production) at the moment of the milking. This is because the milk production differs per parity and also during the lactation. This potentially affects efficiency and milking interval. Table 1 shows the phenotypic differences between parity 1 and parity 2 and higher for efficiency and for milking interval. Due to including year of calving in this effect, the model takes the differences between years into account.

Table 1. Phenotypic differences between parity 1 and parity 2+.

Trait	Parity 1	Parity 2+
AMS efficiency (kg / min)	1.67	1.88
Milking interval (min)	518	520

Age of calving * 3 year
In the analysis of AMS traits, the age at which a heifer has calved is taken into account. 18 age classes for calving are distinguished, class 1 correcting for calving at 20 months of age and younger. Classes 2 – 17 correct for age of calving of 21 – 36 months. Class 18 includes all heifers calving at 37 months of age or older. The model takes into account the effects of age at calving (Figure 1).
The age at calving classes are divided in periods of 3 years. This is to take in account the changing of age of calving in time on the AMS traits.

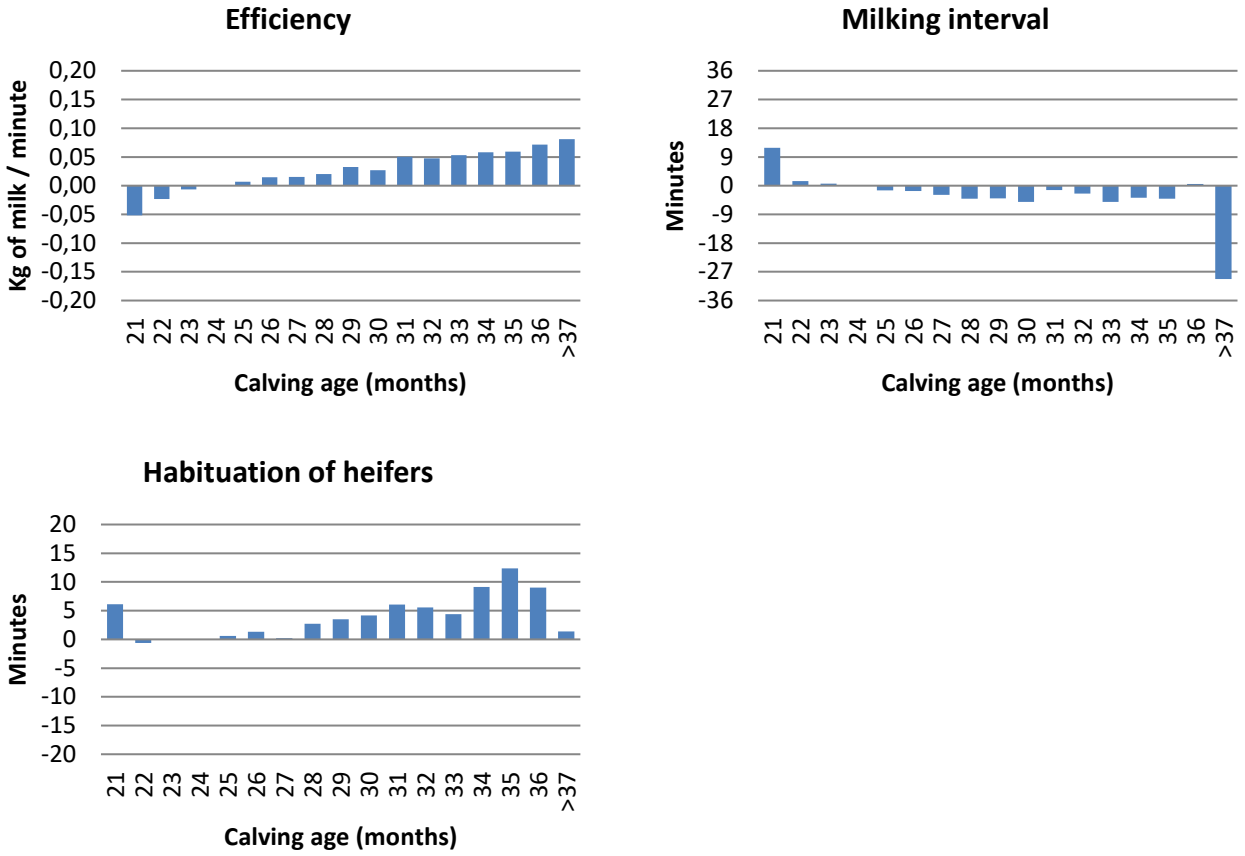
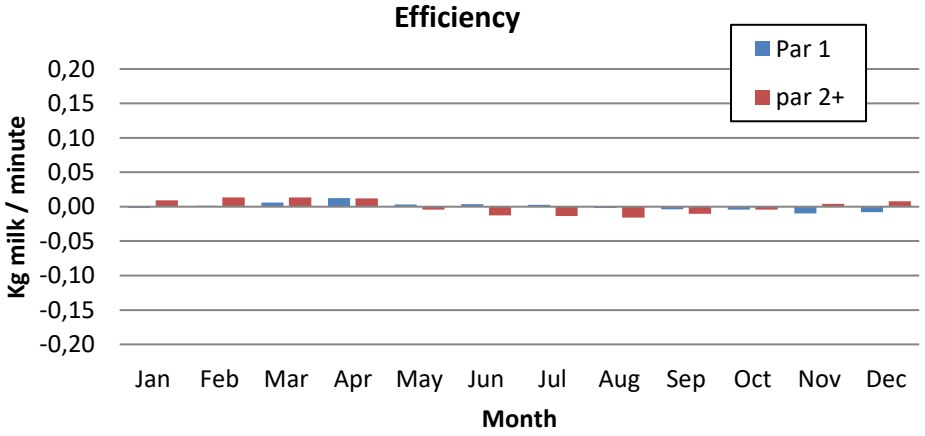


Figure 1. Effect of age at calving on AMS efficiency, milking interval and habituation of heifers. Effects are expressed in relation to the effect of calving at 24 months.

Year x Month of calving * 3 years

In the analysis of AMS traits, the year and month in which an animal calves is taken into account. The month of calving affects the AMS traits (Figure 2). By including the month of calving as an effect in the model, the season in which an animal is milked for the first time is taken into account. By including the year of calving difference in time are taken into account as well.
The year x month calving classes are divided in periods of 3 years. This is to take in account the changing of year x month of calving in time on the AMS traits.



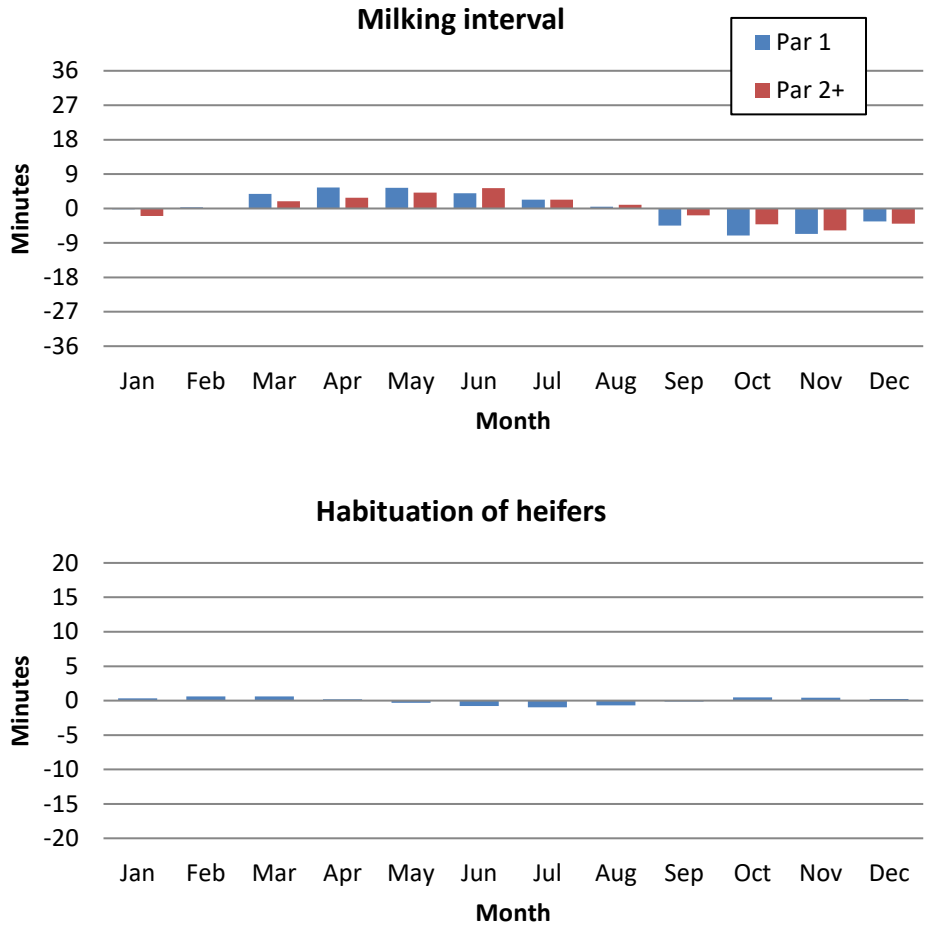


Figure 2. The effect of month of calving on AMS efficiency, milking interval and habituation of heifers. Effects are expressed in relation to the average month effect.

Year x time of the milking

For the milking interval trait, the time of the milking is taken into account. This is done to take into account the visiting pattern caused by the time of day. The effects of the time of day are shown in Figure 3 for milking interval in parity 1 and parity 2+.

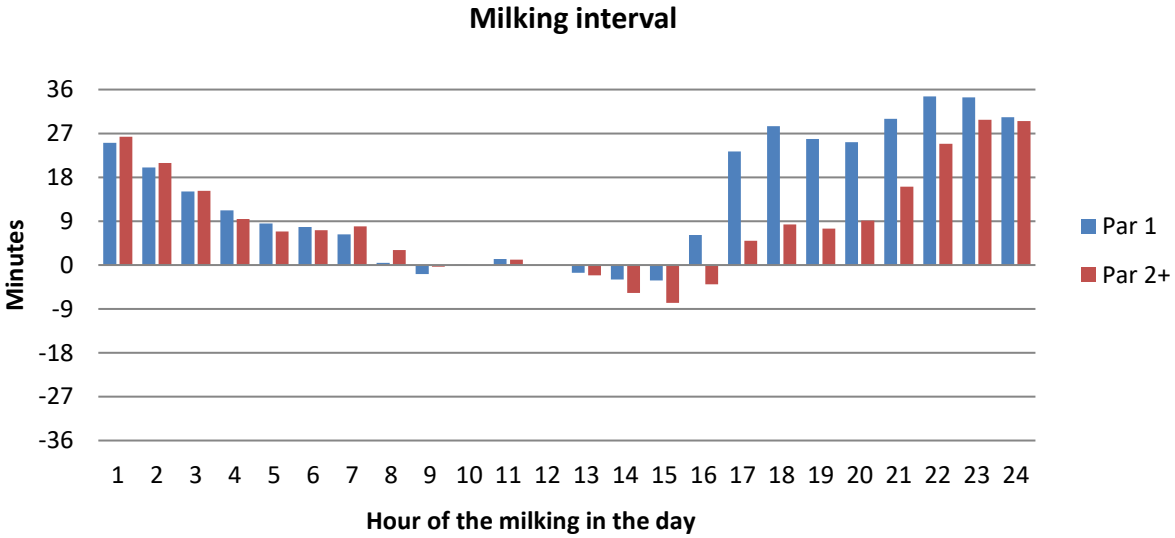


Figure 3. The effect of the time of the milking on milking interval for parity 1 and parity 2+. Effects are expressed in relation to a milking at 12 o'clock.

Farm x lactation x year of the milking
For the milking interval trait selection within herd, between cows in different parities over time is taken into account. On farm level the selection between cows is different over years.

Difference in milk yield
In the analysis of habituation of heifers, the difference in milk yield between the two periods to be analysed is taken into account. Generally a higher milk yield results in a shorter milking interval.

Heterosis and recombination effect
Heterosis and recombination effects play a role in cross-breeding. These are genetic effects that are not passed on to the descendants. Research has shown that these effects need to be adjusted for. The magnitude of heterosis is defined as the difference between the level of the trait in the cross-breed and the average of the parent breeds. Recombination is the loss of the usually positive effect of heterosis and occurs when the earlier obtained crossbred product is backcrossed with one of the parent breeds. This is also described in E-chapter 7.

Inbreeding coefficient
The amount of inbreeding can effect the behaviour and performance of an animal, also the automatic milking system traits. The higher the inbreeding coefficient the larger the negative effect, this is called inbreeding depression. By including the inbreeding coefficient as an effect in the model, the negative effects of inbreeding on automatic milking system traits are taken into account.

Cow
This is the additive genetic effect or breeding value, the effect that ultimately counts. The *animal* variable contains the (genetic) contribution of an animal to the observation and determines the breeding value of an animal. In addition, all information of ancestors and descendants is also used to determine the breeding value.

Permanent environment over lactations
AMS efficiency and milking interval are measured during the complete lactation. Therefore an animal may have many observations. Observations on a cow have more in common than genetics. This additional common ground is called permanent environmental effect, an effect of the common environment of a cow. By using a permanent environmental effect in the model, multiple observations of an animal may be used to achieve a better estimation of the breeding value. The permanent environmental effect over lactations is taken into account with the constant condition a cow is in throughout all lactations. For example: a cow with teat damage in lactation two, which will affect the AMS efficiency in a negative way, will be corrected for this permanent condition in all later lactations.

Permanent environment within lactations
If the teat damage just described only affects the observations during the lactation in which the teat damage takes place, there is no need to correct for this permanent effect in later lactations. Therefore, the permanent environmental effect is split into over lactations as well as within lactations. The permanent environmental effect within lactations takes into account the constant condition of a cow during one lactation.

▪ Parameters

Overall, 5 traits are analysed in the breeding value estimation for Automatic Milking Systems, being AMS efficiency (parity 1 and 2+), milking interval (parity 1 and 2+) and habituation of heifers.

Heritability, repeatability and genetic variance of the 5 AMS traits are given in Table 2.
In the breeding value estimation, the genetic correlations between parities are taken into account. The genetic correlations are presented in table 3.

Table 2. Heritability (h^2), repeatability and genetic variance (σ) for the AMS traits.

Trait	h^2	Repeatability	Genetic variance
AMS efficiency 1	0.29	0.83	0.20 kg / minute
Milking interval 1	0.10	0.64	29.3 minutes
Habituation of heifers	0.15		18.5 minutes
AMS efficiency 2+	0.30	0.82	0.23 kg / minute
Milking interval+	0.07	0.69	30.6 minutes

Table 3. Heritability (h^2) of the AMS traits on the diagonal and *genetic correlations* between the AMS traits under the diagonal.

	AMS efficiency 1	Milking interval 1	Habituation of heifers	AMS efficiency 2+	Milking interval 2+
AMS efficiency 1	0.29				
Milking interval 1	*-0.05*	0.10			
Habituation of heifers	*0.38*	*-0.52*	0.15		
AMS efficiency 2+	*0.95*	*0.12*	*0.35*	0.30	
Milking interval 2+	*0.05*	*0.95*	*-0.48*	*0.12*	0.07

▪ Breeding value for publication

The breeding values intended for publication are the overall breeding values for AMS efficiency and milking interval, as well as the breeding value for habituation of heifers. The overall breeding values AMS efficiency and milking interval are calculated from the breeding values for parity 1 and parity 2 and higher:

$$FW_i = 0.41 \times FW_{i1} + 0.59 \times FW_{i2+}$$

With:
FW_i : breeding value for AMS efficiency or for milking interval.

The derivation of the factors (0.41; 0.59) is described in E-chapter 7 Milk production. Here the weighting factors for parity 1 and parity 2 and higher are determined.

Table 4 shows the heritabilities and genetic variances for the overall traits.

Table 4. Heritability (h^2) and genetic variance (σ) for the overall traits.

Trait	h^2	Genetic variance
Overall AMS efficiency	0.44	0.22 kg / minute
Overall milking interval	0.14	29.5 minutes

This relative breeding value or index has an average of 100 and a variance of 4.

▪ AMS efficiency in INET (Dutch production index)

The breeding value AMS efficiency reflects the amount of milk produced in the total box. Because the AMS registers the amount of milk in kg and the box time in minutes, the breeding value is based on kg of milk per minute box time. However the payment of the milk is based on kg fat,

protein and lactose delivered. Therefor the breeding value AMS efficiency is converted to an economic based breeding value. The economic value for milk is based on the Dutch production index, called INET. The formula is given in E-chapter 9 ‘Dutch production index (INET)’.

Because the original breeding value AMS efficiency is expressed in kg milk per minute, the combination with the INET formula results in an economic value. This value is called AE€; AMS efficiency expressed in INET. The value is expressed as a relative breeding value, based on the variance of the absolute breeding value (euro’s per minute).

Figure 4 show the relation between the breeding value AMS efficiency in milk and AMS efficiency in INET. The figure shows that not all bulls with a breeding value 100 for AMS efficiency in milk also have a breeding value of 100 for AMS efficiency in INET. The difference comes from the fat, protein and lactose content in milk.

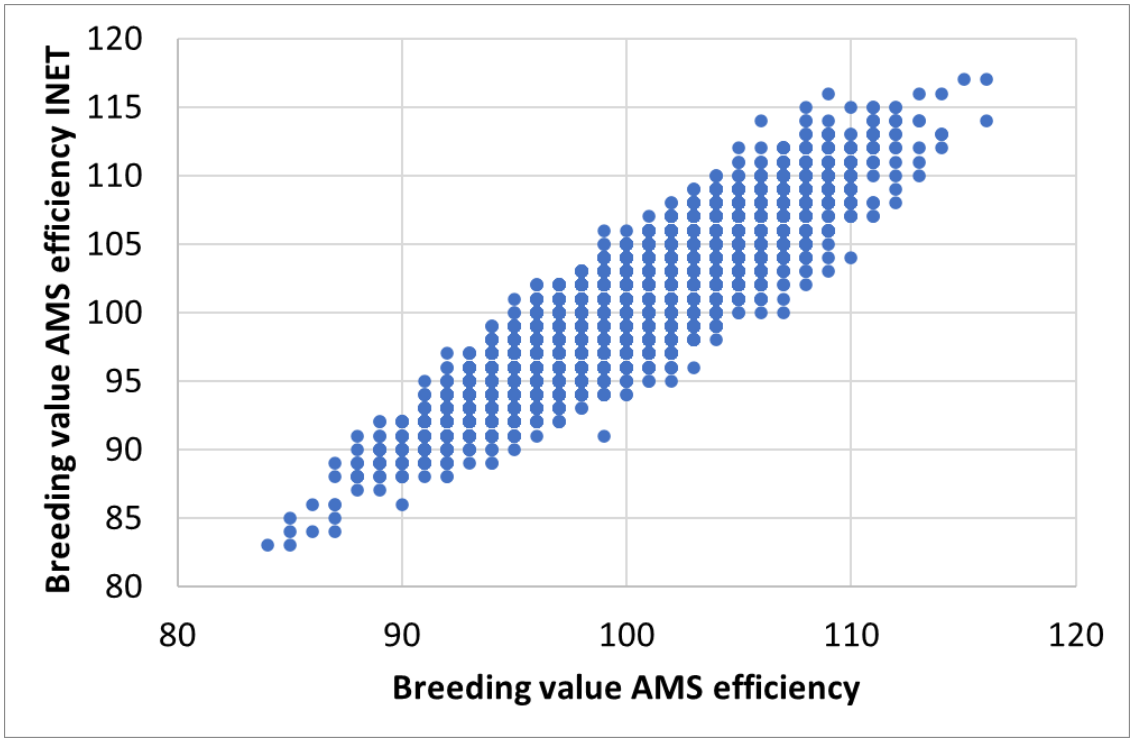


Figure 4. Relationship between breeding value AMS efficiency in milk and breeding value AMS efficiency INET.
[1]Figure is based on HF bulls with a minimum reliability of 50% for the breeding value AMS efficiency INET.

▪ AMS-index

The goal of an AMS-index is to breed cows that are suitable for the AMS system, by improving the AMS traits, without negative effects on udder health. The reach this goal the AMS-index is based on the breeding values AMS efficiency in INET, milking interval, habituation of heifers and the udder health index. The formula to calculate the AMS-index is as follows:

AMS-index = 0.86 * (BV AMS efficiency INET – 100)
+ 0.86 * (BV milking interval – 100)
+ 0.97 * (BV habituation of heifers – 100)
+ 0.16 * (Udder Health index – 100)
+ 100

▪ Base

See chapter ‘Bases for breeding values and base differences’.

▪ Publication

In publications the overall breeding values AMS efficiency and milking interval are used, parity 1 and parity 2 and higher being combined into one breeding value. The parities were weighted according to the ratios 0.41 and 0.59 for parity 1 and parity 2 and higher, respectively. The breeding value habituation of heifers is also used in publications, being based on the first parity only.

Presentation

The breeding values for overall AMS efficiency, overall milking interval and habituation of heifers are presented as relative breeding values with an average of 100 and a variance of 4. It is important to remember that values higher than 100 are desirable. A breeding value for overall AMS efficiency of more than 100 indicates that the animals in the daughter group are more efficient than average for AMS use. The production per minute of AMS time is *higher* for these animals. A breeding value for overall milking interval of more than 100 indicates that the animals in the daughter group visit the AMS *more* frequently. A breeding value for habituation of heifers of more than 100 indicates that the animals in the daughter group attain the final milking interval *faster*.

Table 5 shows the effect of a breeding value of 104 on the descendants of a bull mated to an average cow. The bull breeding value is calculated as half a breeding value, showing the actual effect on the descendants. This is because sire and dam pass on half of their breeding value to their descendants.

Table 5. Effect of relative breeding values for AMS traits on descendants

Trait	*Relative breeding value*	*Half breeding value (effect on descendants)*
Overall efficiency	104	0.11 kg / minute
Overall milking interval	104	14.8 minutes
Habituation of heifers	104	9.2 minutes

An overall breeding value of 104 for AMS efficiency means that the descendants of the respective bull produce an additional 0.11 kg of milk per minute. With an average visiting time of 6 – 7 minutes, this means an additional 0.66 kg – 0.77 kg of milk per visit. An overall breeding value of 104 for milking interval means that the descendants of the respective bull visit the AMS 15 minutes earlier. A breeding value of 104 for habituation of heifers means that the descendants of the respective bull have 9 minutes less difference between the milking interval shortly after calving and the milking interval later in the lactation.

Figure 5 shows the relationship between the relative breeding value and the percentage of descendants that has attained the final interval level early. It can be concluded that, with a breeding value of more than 100, over 50% of the descendants have attained the final milking interval in week 3 (milking interval weeks 10 – 12). While of descendants of a bull with a breeding value of 92, only 30% have attained the final milking interval in week 3.

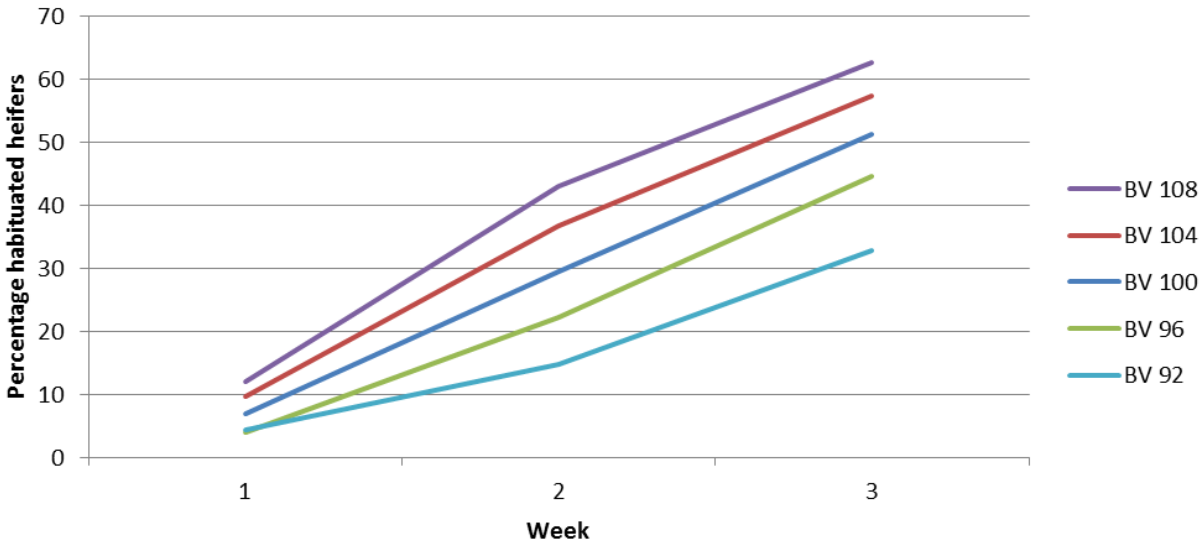


Figure 5. Relationship between the relative breeding value and the percentage of descendants having attained the final milking interval.

Requirements for publication

See chapter 'Publication rules sires'.

▪ Literature

E-chapter 7, Breeding value estimation of milk production traits with test-day model. Quality Handbook.

Gäde, S., Stamer, E., Bennewitz, J., Junge, W., Kalm, E. 2007. Genetic parameters for serial, automatically recorded milkability and its relationship to udder health in dairy cattle. Animal 1: 787-96.

Vosman, J.J., De Jong, G., Eding, H. 2014. Breeding of cows suitable for an automatic milking system. Paper Interbull Berlin 2014.